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Sustainable Agriculture Development Project
Important Role of Government in Conservation Tillage Extension and Development

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Abstract: Extension of conservation tillage is quite a nonprofit commonwealth work and the government is obligated to this. Attributed to its special position and authority, the government can promote conservation tillage with many kinds of effective measures. In recent years, Chinese Ministry of Agriculture (MOA) has been devoted to organizing researchers, manufactures, extension stations and other organizations to enhance the application of conservation tillage in China by means of introducing foreign technology, making innovations in accordance with Chinese situations and testing different conservation tillage modes for the corresponding individual regions.

Key words: role, government, conservation tillage

Conservation tillage is now becoming a hot issue in world agriculture. It suggests to stop the traditional over-explore tillage system and to produce the food while improving soil fertility, reducing soil erosion and ensuring sustainable use of land resources. As a nonprofit commonwealth activity, the development of conservation tillage needs the government to play an important role.

Developing conservation tillage is the obligation of the government

Government, as the representative and manager of public interests, should take building a harmonious society as its basic functions. For a long time, our human being has been trying best to produce more food by over tillage at the cost of soil desertification, soil erosion and non sustainable use of land. As a result, farmland becomes one of the main sources of sand and dust storms and contributes much to the sediment in rivers and oceans, which seriously affect the sustainable development of agriculture. The environment where we live was damaged and the harmonious development of economy was ruined. To solve this problem, government no doubt has the duties.

In China, farmland is owned by farmers collective instead of privately owned, thus the farmers may prefer getting short term high yields and profits from the collective land instead of paying much attention to keep the soil in better condition for their future sustainable use. In addition, farms are quite small and separated in China which may limit the extension of new technology, especially environmental technology. It needs some time for the farmers to accept the ideas that they should stop the traditional ways of farming in order to control soil erosion. Thus the government should work out an effective solution, which can satisfy the long term public interests and the short term interests of farmers in the mean time. From the overseas and domestic experiences, conservation tillage is a proper choice to meet this requirement.

Started from early 1990s with international joint research projects and technology exchanges, Chinese government introduced the conservation tillage technology and extension experiences from overseas countries and launched the campaign of conservation tillage study, demonstration and extension in China. Conservation tillage was proved to provide social, economical and ecological benefits.

Controlling sand and dust storms, protecting the environment

Wind erosion data collected from Field test and wind tunnel simulation in Fengning (Hebei province), Wuchuan and Songshan (Inner Mongolia) showed that conservation tillage can reduce sand and dust from farmland by 60%, 54.4% and 48% and large areas application of conservation tillage in these
areas would be effective for controlling dust storms.

Reducing soil erosion and protecting the farmland soil from depletion

Soil water and wind erosion, carrying away fertile top soil and ruining the environment, is the main reason of soil deterioration in North China. According to the data reported in Inner Mongolia, Hebei and Beijing, every year about 10–20 tons of top soil is blown away by strong wind which is common in winter and early spring of North China. Conservation tillage, which can reduce runoff and water erosion by 60% and 80%, is a better solution to this problem.

Conserving soil water and improving soil fertility

Conservation tillage can increase soil water content by 16%~19% and raise water use efficiency by 12%~16%. For the irrigated double cropping areas, when conservation tillage was applied all around the year, the irrigation water can be reduced once for each crop which means that totally about 1050~1200 m$^3$/ha water can be saved. Taking Beijing as an example, if conservation tillage is applied in all the 6.7 million hectares farmland, about 100 million m$^3$ of irrigation water would be saved every year, which is close to the total amount Huairou Dam can hold. In addition, the residue left in the field can improve soil fertility. The soil Organic Matter in Wheat field can increase by 0.01%~0.03% per year and soil Organic Matter in maize field can increase by 0.02%~0.06% per year.

Reducing production cost and improving profits

Conservation tillage can reduce the 2~5 field operations each year thus to reduce the cost by 20%. In addition, conservation tillage has some clear benefits of increasing the yield. From the results of the 14 crops growing in the 10 demonstration sites set up by MOA, 13 crops produce higher yield with conservation tillage, among which maize yield was increased by 4.1%, wheat yield increased by 7.3%, millets yield increased by 11.2% and soybean yield increased by 32%. The total annual profits increase will be around 101 Yuan/Mu for the double cropping areas and 43.5 Yuan/Mu for the one crop a year region. Taking 50 Yuan/Mu as the average annual profit increase, if conservation tillage can be applied on 60% of all the 1 billion Mus farmland in the 13 provinces of North China, in other words in the area of 600 million Mu, the total profits increase would be 30 billion RMB, which means that the per capita profit for the farmers in the areas would increase 90 RMB. Conservation tillage can also reduce the emission of Greenhouse gas like Carbon Dioxide by sequestration more Carbon into the soil.

It can be clearly seen that extension of conservation tillage is a nonprofit common wealth activity toward the long term public interest and sustainable development. Thus it should be the obligation of the government to promote conservation tillage development.

The role of government in conservation tillage extension

The extension of conservation tillage is not just a technology issue; it also involves changes of the traditional concepts in people’s minds and reforming of the traditional farming systems, thus promoting conservation tillage can also be called another revolution movement in agriculture. Government and other nonprofit common wealth extension institutes should make use of their special positions and authorities to develop conservation tillage with many kinds of effective measures like administration, laws, economics, etc.

According to social economy development situation and the characteristics of conservation tillage, the roles of government can be summarized into 4 aspects:

Making decisions

To well manage the reformation of tillage methods, government agencies need to make clear decisions on objectives and tasks, the programs, steps and methods to achieve the objectives which are closely in accordance with the local situations climatic, soil and economic etc.. All through the procedure of making decisions on conservation tillage development, the government should follow the scientific concept of development, choose realistic measures and consider economy development and environmental protection together.
Organizing
During the procedure of extension conservation tillage, the tasks should be well organized into different classifications and allocated to the corresponding agencies or institutes; the objectives should be divided into different levels or steps and designated to the proper institutes or person accordingly.

Coordination
Conservation tillage is a package of multi technologies disciplines, which involving many agencies and areas. The government should play an important role in coordinating the kinds of agencies in research, production, extension, test and evaluation, thus to combine machinery, agronomy, biotechnology and engineering techniques toward the same goal.

Effects control
This means taking control measures to insure accomplishment of the objectives and tasks in high quality and high efficiency. The control methods can be many kinds, for example, unifying ideas and changing traditional tillage concepts by training; setting up the organization systems with clear tasks, making the procedures and technical standards; collecting enough information to control the work development; setting up evaluation standards and system of rewards and penalties, correcting the mistakes in time, etc.

The main measures Ministry of Agriculture took to develop conservation tillage
In promoting conservation tillage, the government mainly applied the measures like publicizing conservation tillage related information, training farmers, making development plan, experiment and demonstration, publishing special policies and legislations, research and development on key technologies. Since 2002, Chinese government started to set up special funds for conservation tillage and the National Conservation Tillage Extension Project was launched. Chinese Ministry of Agriculture (MOA) has been devoted to promoting the application of conservation tillage in China by means in accordance with Chinese situations. What have been done till now can be summarized into following aspects:

Making extension specifications and improving management of projects
MOA has been absorbing more experiences and improving management of the conservation tillage projects with the scientific, standardized and regulated ways. Several technical documents and management regulations were proposed and formulated, which are “Key technological points for conservation tillage application”, “Regulations of conservation tillage projects management”, “Specifications for monitoring the effects of conservation tillage in different regions”, “Evaluation specifications of conservation tillage projects”, etc. Some training and publicity materials were compiled which are “conservation tillage technology training textbook”, “conservation tillage Q & A”, “ conservation tillage machinery Catalogue”, “Conservation tillage introduction video”, “Chinese conservation tillage brochure”. All the above documents and regulations have provided powerful support for improve the management and effects of conservation tillage projects.

Exploring more technical modes and enhancing technical innovation
It is very important to exploring more technical modes and enhancing technical innovations in accordance with various situations in different areas. New conditions, new problems and new technologies are coming up continually in the procedure of conservation tillage development. There seems no end for the new technology and machinery development. Thus MOA set up more than 20 technology innovation projects to develop new technical modes and to find solutions to the problems like disease, pest, weed control and adaptability of machinery, coming up in the application of conservation tillage, etc. Through these projects, agronomy, machinery and biotechnology were integrated and new technology package for various regions and situations were developed consequently.

Publicizing conservation tillage information and organizing well training
Technology publicizing is an important way to raise public attention and get to a common view; and training and technical service is the necessary part to insure the right effects achieved from
conservation tillage application. In recent years, MOA has put much effort on the publicity through kinds of media to get the public acceptance of the conservation tillage concepts and to transfer the traditional tillage ideas among farmers into new scientific ways of farming with conservation tillage. Whether successful results can be got from conservation tillage is directly related to the knowledge of conservation tillage for farmers and machinery operators. Thus, MOA pay much attention to the training and technical service to them all the time. The technicians went down the fields to conduct on site advising and to show them the key points of technology and operation specifications.

Consolidating the achievements and sustaining long term development

Whether the conservation tillage extension is successful, setting up long term running mechanism on the basis on the achievements will be the key issue. In China, without the support from central governmental funding, the areas of conservation tillage application in some demonstration sties may decrease because of the low enthusiasm of farmers and less support from local governments and agencies. This case showed that there is no long term running mechanism for sustaining the achievements of extension projects. Firmly setting up conservation tillage systems in agriculture should not only rely on government input for long time. It is necessary to develop the power source or motives for farmers to stay on conservation tillage, which may include economical profits and enthusiasm of farmers and machinery contractors. Socialized, organized and commercialized service mechanism may be set up on the aid of governmental authority, funding appeal, technical support from extension stations and profit triggered farmers’ acts. This is one of the key jobs that Chinese government is exploring to do.

International collaboration and exchanges

Conservation tillage research and application in China was started on the basis of overseas experiences and some foreign experts had made great contributions to Chinese conservation tillage development. Conservation tillage machinery is advanced and technology is mature in some developed countries whose experiences are valuable for China to learn. MOA will organize more technical and management personnel to visit overseas countries possessing advanced conservation tillage technology and also will invite more foreign experts to China to share their knowledge and experiences. By international collaboration and exchanges, we hope to develop Chinese way of conservation agriculture and promote the all-round development of conservation agriculture in China.

Basic technical contents and modes of conservation tillage in China

Chinese Ministry of Agriculture has defined Conservation tillage consisting four basic aspects of technology. 1. Straw mulching. After harvest, farmland is covered by straw or residue. Sometimes other operations like straw chopping, harrowing and shallow tillage are taken, if necessary. 2. Direct seeding. A no-till planter can finish furrow opening, planting, fertilizing, soil covering and firming in one pass in straw mulched field. 3. Pest and weed control. To control pest and weed, such methods like spraying chemicals, mechanical surface tillage, manual weeding and crop rotation are used. 4. Subsoiling. According to the specific condition, subsoil is used to break the hard plow pan to raise soil water holding capacity for crop.

Specific agricultural conditions should be taken into consideration when applying the above aspects of technology in different areas. The conditions for conservation tillage extension vary in different areas, such as natural conditions, limitations and problems, etc., Thus the specific technical system and modes need to be developed according to the requirements of the areas.

The Conservation Tillage Demonstration areas in Northern China were classified into five geographical regions, which are:

**North China Plain**--- The areas across Yellow river, Huai River and Hai River basins. This region includes the irrigated double cropping areas in Hebei, Henan, Shandong, Beijing, Tianjin, etc., where large area of irrigation and high yield cause the serious overuse of groundwater, high production cost and further more, straw burning contributes a lot to air pollution. The main objectives for conservation
tillage are to reduce ground water exertion, reduce production cost, control air pollution from burning the stubble and improve soil fertility.

**Main technical modes in this region**

1. Whole-course straw mulch and no-till seeding. Harvesting wheat in summer, straw mulch, no till seeding corn; Harvesting corn in fall, straw chopping(standing stubble mulch), and no till seeding wheat.

2. Straw mulch and minimum till seeding. Harvesting wheat in summer, straw mulch, subsoil if necessary, no till seeding corn (or combining corn no-till seeding and subsoil together); Harvesting corn in fall, straw chopping(standing stubble mulch), and no till seeding wheat (or strip-rotary-till direct seeding wheat). Permanent raised beds combined with conservation tillage are also used in some areas of this region.

**Inter cross areas of agricultural and pastoral region**

This region includes most part of Inner Mongolia, North of Hebei and Shanxi, Northwestern part of Liaoning, etc. The cultivation system is one crop a year planting at spring. In this region the land surface is bare and loose in the fallow period of winter and early Spring when wind is very strong causing land degradation, desertification, wind erosion and drought. Farmers’ income here is very low and crop stubble is used as fuels or for feeding the animals. The main objectives for conservation tillage are to control wind erosion and soil desertification, to increase yield and to improve soil productivity.

**Main technical modes in this region**

1. Straw mulch and no-till plant: Harvest in summer (or autumn), straw mulch with undisturbed soil in the fallow period of winter, No-till planting in spring.

2. Residue-mulch and no-till plant. Harvest in summer (or autumn), leaving stubble more than 20cm high in field to hold the topsoil and moving away the rest part, winter fallow, then no till planting.

3. Straw mulch and minimum tillage planting. Harvest in summer (or autumn), straw(or roots) cover, subsoil if necessary, winter fallow, no till planting in spring.

4. Pasture no-till(minimum till) direct seeding using conservation tillage principle and no-till planter.

**Loess plateau region**

Main cropping system is one crop a year and some areas have two crops a year. Main crop are winter wheat, spring wheat, spring corn and small cereals. Lack of irrigation water and less rainfall easily causes drought in the region especially in spring and winter. Most part of annual rainfall concentrates in summer, which causes serious runoff and soil loss. Wind erosion in spring and winter cause land degradation. The main objectives for conservation tillage are to control soil water erosion and to improve soil productivity for sustainable development.

**Main technical modes in this region:**

1. Straw mulch and no-till planting. Harvest in summer (or autumn), straw mulch, no till, fallow, no till plant in autumn or next spring, harvest in summer (or autumn).

2. Straw mulch and subsoil. Harvest in summer, straw mulch, and subsoil, summer fallow, no till plant in autumn or next spring.
(3) conservation tillage for small cereals. Harvest in summer, straw(or roots) cover, no till, winter fallow, no till plant in spring.

(4) whole-course straw mulch and no till planting in two crops a year area. Wheat harvest in summer, straw covers, no till plant corn, corn harvest in autumn, straw chopping or standing cover, no till plant wheat.

**Cold Ridge Farming Areas in Northeastern China**

This region includes Heilongjiang, Jilin, and parts of Liaoning and Innermongolia, where the main issues are lack of water, low temperature and wind erosion in winter and spring. Cropping system is one crop a year. The main objectives for conservation tillage are to reduce water and wind erosion, to improve soil fertility and soil moisture content.

Main technical modes in this region:

(1) straw (roots) mulch and minimal tillage plant. Autumn harvest, straw(roots) covers, winter fallow, spring minimum tillage (subsoil, sweep or harrow), direct seeding.

(2) ridge farming with conservation tillage. It can take both advantages of ridge tillage in increasing soil temperature and conservation tillage in conserving soil and water, improving soil fertility and increasing profits.

**Northwest oasis agricultural area**

Cropping system is one crop a year in this region. Limited rainfall, high evaporation rate, serious drought are the main problems and agriculture completely relies on irrigation water. The main objectives for conservation tillage are to increase water use efficiency, to save the irrigation water, AND to reduce cost.

Main technical modes in this region:

(1) Permanent raised beds. Permanent irrigation furrows as wheel tracks are established in between the crop beds in field. All wheels are limited to the track to keep the crop beds out of compaction. Furrow irrigation rather than flood irrigation can save water. The procedure: Harvest in summer, straw covers, no till, then fallow, plant in next spring.

(2) Straw mulch and no-till planting. Harvest in summer, straw covers, no till, then fallow, no till plant in autumn or next spring.

(3) Crop rotation under conservation tillage. To solve the disease and weeds problems, crop rotation systems under conservation tillage are demonstrated. Different straw mulch and no-till pattern are still used in the rotation crops.

**The guidelines of Chinese MOA to develop conservation tillage**

Based on our practices in conservation tillage demonstration and promotion, we developed our guidelines for conservation tillage.

1. We must follow China’s own way for conservation tillage development to suit Chinese conditions and develop specific technical modes in accordance with local situations. Although conservation tillage has developed in North America and Australia for decades, it is still new in China. As to the big terrain and various climate conditions in China, differences among areas in cultivation customs, soil and water conditions and crop species are huge. Based on the introduced experiences from other countries, we have to develop specific technical methods, different management modes and specific machinery to suit the requirements of different areas.

2. Agronomy, machinery and other related disciplines should be integrated and collaborated together
in the research, demonstration and extension of conservation tillage. Conservation tillage development is a systematic progress involving various subjects. Thus, it is essential to integrate agronomy and machinery, engineering and biology, and to mobilize the initiatives of specialists and different departments to work on this. It is necessary to strengthen the basic research on soil, environment and crop dynamic changes with conservation tillage so as to provide theoretical support for large area promotion of the technology. Agricultural, biological, chemical and mechanical methods should be integrated together to optimize the technologies of breeding, cultivating, rational fertilizing, rotation and intercropping, and water saving irrigation, then they can be integrated into a new technical mode with high efficiency and low cost, the optimal benefits.

3. The well planned schedule, like the procedure of “experiment- demonstration- extension”, should be followed step by step for the demonstration and extension. To persuade farmers to change their traditional ideas and fully accept conservation tillage need a time and a process. Thus, we can’t just push the extension in short period. We need to establish a practical plan to clarify the key points, to make adjustments in accordance with the real conditions and to precede conservation tillage step by step in accordance with natural and economic rules. While in the process of implementing the plan, we must respect farmer’s will and no compelling means should be used to push them. As long as we establish rational operation mechanism and build up well managed typical demonstration areas, farmers will see the real benefits from the technology by themselves and then adopt conservation tillage initiative.

4. Keep scientific research and machinery development appropriately ahead. As we all know, sciences and technology is the first productive forces or engine for social development. Scientific R&D, especially machinery development, is the priority prerequisite for conservation tillage development to follow a right way. In R&D, the whole procedures from Study, Research and Production should be combined and coordinated together to jointly explore the solutions to the key problems and bottle-neck techniques.

5. Making full use of the publicity media and technical training to increase the understanding of conservation tillage. Conservation tillage is a revolutionary change for conventional tillage system. More publicity and direct technical service are needed in order to effectively extending this technology, to change farmers traditional ideas, to improve their understanding of conservation tillage, and to encourage them accepting conservation tillage,. Mass media publicity is also helpful for raising the whole society public attention, attracting more financial support and creating an active atmosphere for conservation tillage development. Technical training is an important step of demonstration and extension, which can help farmers and machinery operators have a good command of technical specifications and truly find out the benefits of conservation tillage.

6. Focusing on both ecological and economical benefits of conservation tillage. Conservation tillage is an advanced technology which can promote agricultural production and protect the environment at the mean time. In implementing the conservation tillage projects, emphasis should not only be put on controlling soil erosion and dust storms. More importantly we need to develop technical modes and matched machinery system which can also improve economic benefits thus to increase farmers’ income. This should be the right way for the long-term acceptation of conservation tillage in China, where large populations need to be fed.

In conclusion, conservation tillage is an important technology for the sustainable development of agriculture. Conservation tillage enjoys remarkable ecological benefits which makes it an important nonprofit commonwealth work for the whole society. Thus government should play a more initiative role in conservation tillage development.
Weed Dynamics in Direct-Seeding Systems

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Weeds challenge farmers, extension personnel and researchers in all major agricultural cropping systems. Specific weed communities assemble according to the specific selection pressures that they are exposed to. Tillage, or the lack of tillage, influences weed community composition and density (Blackshaw 2005). Direct seeding no-tillage systems, like other systems, will continue to face challenges with weeds, but these challenges have been, and will likely continue to be, manageable.

Weed populations can readily adapt to new environments because of their diversity (Harker 2004). There always seems to be a weed species or biotype that can adapt to and thrive in the agricultural environments we create. Unfortunately, our first and often only response to weed infestations is to treat them with herbicides. We seldom examine the causes of the perpetual presence of weeds (Buhler 1999). Over the last few decades there is good evidence on the Canadian Prairies to suggest that we have reduced weed density and species numbers via the management practices that have been employed (Leeson et al. 2005). However, because our dominant weed management tool has been herbicides, we now deal with significant herbicide resistance problems with major weeds such as wild oat (Avena fatua L.) (Beckie et al. 1999).

The high level of “disturbance” that accompanies crop production facilitates the success of weed communities. Froud-Williams et al. 1988 state that: “Arable land is characterized by regular, recurrent, and often highly predictable disturbance. The consequence of this disturbance is that weeds of cultivated land represent the most ephemeral of plant communities, completing their life cycles within a relatively short time and producing copious quantities of dormant seed of potentially long life span.” Indeed, the three habitat traits that favour weed invasion in natural environments are almost always present in modern agroecosystems; they are: disturbance (tillage), low species richness (crop monocultures), and high resource availability (bare soil/crop stubble, sunlight, fertilizer, etc.) (Booth et al. 2003). Rapid response to high resource availability is a physiological attribute of most early succession plants, including weeds (Bazzaz 1979).

Weeds do have vulnerabilities. Weeds are relatively susceptible to the negative effects of shade (Mohler 2001). Astute managers are aware of this vulnerability and strive to promote rapid, uniform crop emergence and ground cover to preempt resources potentially available to weeds. One of the most effective management tools to ensure that crop canopies develop quickly is to plant crops at a relatively high density. Weed species that require a “light” signal for germination are actually inhibited when red-light depleted radiation is filtered through crop leaves. Weeds also suffer greater relative declines in growth than crops when nutrients are limited. Accordingly, wise crop producers place nutrients where crops have better access to those nutrients than weeds.
Over the years, the widespread use of tillage in agricultural systems has selected for weeds that thrive in tilled soils (Mohler 2001). Many weed seeds are relatively small and can only thrive after tillage has removed other species and improved the light, nutrient, and temperature environment for seedling establishment. In direct-seeding systems where crop residues are left on the soil surface, many small weed seeds are disadvantaged. Liebman and Mohler (2001) state that: “...detrimental effects of crop residue are greater for small-seeded species that larger-seeded species. Because seeds of most major crops are one to three orders of magnitude larger than the weeds with which they regularly compete, residue management offers important opportunities for weed suppression.”

In direct-seeding and no-till cropping systems weed seeds are left on the soil surface where they are more susceptible to mortality (Mohler 2001). Vertebrate and invertebrate seed predators have easier access to weed seeds left on the soil surface. In addition, weed seed predators occur in much greater numbers in no-till fields than in conventional tillage or organic fields (Menalled et al. 2000). Some insects, bacteria and fungi that serve as weed seed predators survive best in undisturbed plant residues that are common in direct-seeding and no-till systems (Derksen et al. 1996). Holmes and Froud-Williams (2005) determined that for weeds such as wild oat (Avena fatua), common lambsquarters (Chenopodium album), and Canada thistle (Cirsium arvense), non-avian seed predators removed more seeds than avians (birds). Weed seeds left on the soil surface also experience greater mortality for at least two additional reasons: physiological aging and exhaustion of reserves through respiration and germination at soil positions and times of year that are not suitable for seedling emergence or survival.

Although, tillage intensity influences weed community density and composition, it is difficult to consistently categorize weeds in functional groups that respond similarly to varying levels of tillage intensity (Blackshaw 2005). Variables such as weed adaptation to specific soil zones, and numerous environmental conditions probably have greater influences on weeds communities than tillage. “Farmers should not be deterred from adopting zero tillage production practices because of concerns of increased weed control problems but rather be aware of potential changes in weed communities and how they may be effectively managed” (Blackshaw 2005).

Some have suggested that volunteer canola, and more specifically volunteer glyphosate-resistant canola, is over-running western Canadian cropland and will soon be our most important weed species in direct-seeding systems. Post-management weed surveys (Leeson et al. 2005), and crop producer experience do not generally support this supposition. Careful volunteer canola management in the year after a canola crop helps preclude additional glyphosate-resistant canola management concerns in subsequent years (Harker et al. 2006). Pekrun et al. (1998) showed that volunteer canola is less prone to develop secondary dormancy and persist in soil seedbanks if tillage is delayed for several weeks after harvest or not employed at all.

The most effective and sustainable form of weed management involves diversified cropping systems. Weeds fortunate enough to grow in simple, repeated cropping systems will continue to have little difficulty adapting and thriving in those systems (Harker and Clayton 2003). Buhler (1999) suggests that the majority of all current cropping systems are highly simplified, allowing the best adapted weed species to proliferate.

The weed seed population of the soil is greatly influenced by the type of crop grown. “Soil conditions being similar, the composition of the flora under continuous wheat and barley is very much
the same, but the relative composition of the constituent species varies greatly, some being favoured by the wheat crop and others by the barley” (Brenchley and Warington 1933). “Continuous production of a single crop and short sequences of crops with similar management practices promote the increase of weed species adapted to conditions similar to those used for producing the crops….In contrast,…employing crops with different planting and harvest dates, different growth habits and residue characteristics, and different tillage and weed management practices, weeds can be challenged with a wide range of stresses and mortality risks, and given few consistent opportunities for unchecked growth and reproduction” (Liebman and Staver 2001).

Two things govern the successful utilization of crop diversity in weed management systems: the life cycle of the most dominant weed(s) and the life cycle of the rotational crops. Many crop rotations involve substantial crop species diversity but lack crop life cycle diversity. For example, if wild oat is the dominant weed species, crop producers must employ something other than just summer-annual crops in their rotation. Accordingly, in winter wheat, winter-annual downy brome is easily managed when the crop rotation involves a summer-annual canola crop (Blackshaw 1994).

Using crop rotations with varying crop life cycles is not the only way of introducing diversity into a cropping system. Diversity can also be introduced by varying crop seeding date (Clayton et al. 2004), or by varying the date of crop harvest (Harker et al. 2003). Almost any other method that introduces diversity into cropping systems can reduce the impact of dominant weed species.

It is important to recognize that any singular practice will not be adequate for long-term weed management. Successful crop managers combine a variety of weed management practices. For example, combining early herbicide application with a competitive canola cultivar and higher than normal seeding rate not only reduced weed biomass and variability; but also improved crop yield (Harker et al. 2003). When combining several optimal practices, a major goal should be the promotion of crop health. Healthy crop canopies limit weed invasion (Harker et al. 2005) since they exploit weed vulnerability to low light and altered light quality (Mohler 2001) and pre-empt nutrient and soil moisture resources. Overall, weed management in direct-seeding systems will be successful when two cropping principles are promoted: rotational diversity and crop health.

References


Crop Production Equipment for Conservation Farming and Direct Seeding

in Western Canada

David Hundeby

Introduction

Crop Production Equipment for Conservation Farming: I wish to thank the China-Canada Agricultural Development Program for the opportunity to speak on Conservation Agriculture and Direct Seeding. Also thank you for the use of some previous slides. Other slides were supplied by equipment manufacturers, Seed Hawk, Redekop and Riteway. My father Robert Hundeby, as well as Jody Hundeby and my wife Annette Hundeby also took pictures to help with this presentation.

Hundeby Consulting Ltd.: Hundeby Consulting Ltd. is a small engineering design company specializing in crop production equipment. I love to design farm equipment and have worked with various companies in Canada, Europe and USA. In addition, I have been farming since the mid 1970’s. Many of the machines that are used on my farm were designed by me or have modifications that have “personalized” the machine.

Crop Production Equipment for Conservation Farming Outline: In this presentation, we will look at some history of the farming methods and equipment from the time Western Canada was settled until now. We will see the close ties between agronomic principles and machine design over this time period. In addition, we will look at the farming practices of my brothers and my farms, located in three different locations in Western Canada, better known as “the prairies”.

Canadian Prairies: The Canadian prairies have five different soil zones; brown, dark brown, black, dark grey and gray. My brothers at Elbow are on the boundary between the brown and dark brown soil zones, my brother at Wetaskwin is in the heart of the black soil zone, while my farm is located just north of Saskatoon, on the boundary between the dark brown and black soil zone.

Hundeby Farm ~ 1970: Dad started farming in 1946 when he was able to purchase 400 acres (162 ha). In 1947 he moved to the farm shown on the slide and was able to purchase that land in 1959. Farming practice at that time was to seed half the land and summerfallow the other half. Dad had six sons and we all wanted to farm!

History, 1900 to 1940

Rumly Oilpull 1911: My grandfather, George Hundeby operated a Rumly Oilpull tractor and did plowing for farmers. This practice inverted the soil and buried the crop residue.

Threshing Wheat 1923: Grandpa also owned a threshing machine and did harvesting for farmers in the area. This harvest system removed straw, chaff and grain from field.

Hoosier Drills 1911: Settlers came to the prairies from Europe and the USA, and brought farming practices from these higher rainfall areas. Drills were commonly used for seeding, and required the burial of most of the crop residue to operate.

Western Canadian Farmers Learn Results of these Farming Practices: The 1930’s brought drought,
blowing dust and soil drifts! Plowing was abandoned and many farms were abandoned as well, as many farmers moved from the brown and dark brown soil zones north to the black and grey soil zones.

Wind Erosion versus Soil Type: Research has shown that it takes a certain percentage of crop residue as soil cover to prevent erosion. Lighter land requires more soil cover and even heavy clay is prone to wind erosion if left with insufficient soil cover.

**History, 1940 to mid 1980’s**

One-way seeder 1940’s: A John Deere D tractor with a one-way was the seeding tool Dad used when he started farming in 1946.

Straight Combining 1955: In the mid 1950’s Dad used a Massey Harris Super 27 to straight combine the wheat. This left standing stubble, straw and chaff on field and improved organic matter. It also helped to trap snow for additional moisture stored in the soil

Chisel Plows 1960’s: In the 1960’s my brother Art drove a John Deere R and I drove an International Harvester WD9. We each pulled a 16’ (6.5 m) chisel plow with sweeps in the summerfallow year, keeping residue on the surface, controlling weeds and saving moisture for next year’s crop

One Way Discer Seeder 1957: In the dryer areas of the prairies the one-way discer provided a simple, one-pass operation to kill weeds, seed and pack. The seed was sown in a furrow and the soil was turned over. Later fertilizer attachments were added and fertilizer was applied with the seed

Press Drill 1950’s: In the wetter growing areas of the prairies, press drills were very common in the 1950’s. The use of press drills required pre-seeding tillage and elimination of most of residue to get good seeding job.

Rod Weeder 1970’s: The rod weeder became a popular summerfallowing machine in the drier areas in the 1970’s. It was used in alternating operations with chisel plows for keeping residue on top and killing weeds in summerfallow year. A rod rotated under the soil, and pulled the roots of the weeds out of the soil.

Friggstad 80’ (24.4 m) Chisel Plow: As farms grew larger, machines became larger. In about 1980, Terry Friggstad and I designed the Friggstad 80’ (24.4 m) chisel plow and at the time, it was the largest production chisel plow.

Friggstad 80’ Chisel Plow, transport position: Transporting large equipment was a real challenge. Lots of hydraulic cylinders were used and wide roads were needed to move these machines.

**Air seeder and air drill development**

Nitrogen Application, Various Soil Zones and Irrigation: Saskatchewan Agriculture published a bulletin in 1986, “Nitrogen Fertilization of Spring Annual Crops” with a lot of information on nitrogen fertilizer. This bulletin showed there was more potential for nitrogen response in black soil zone and less in brown soil zone.

Banding Fertilizer & Broadcasting Fertilizer: The 1986 bulletin also illustrated various applications of banding and broadcasting fertilizers. Fertilizer can be banded with the seed or side-banded to the side and below the seed. Fertilizer can also be deep banded into the soil in a separate operation before seeding. Fertilizer can be broadcast on the surface of the soil and then incorporated into the soil before
Relative Effectiveness of Methods and Times of Nitrogen Application: Research showed the benefits of banding the nitrogen fertilizer. Compared to spring broadcasting, there was a 15% increase in yield if the nitrogen was banded, either spring or fall.

Nitrogen Banding, Effectiveness of Various Application Methods, Times and Moisture Conditions: The lower the rainfall in the early growing season, the more effective banding of the nitrogen. With a dry, early growing season, there was a 66% yield advantage of banding over broadcasting. With this nitrogen banding information, the machine manufacturers quickly brought along the development of the air seeder as a fast, efficient way to band fertilizer.

Standing Stubble Traps Snow and Prevents Soil Erosion: In addition to the fertilizer banding information, research was also showing that lack of moisture was usually the most yield-limiting factor in southern Saskatchewan and southern Alberta, and that trapping snow in the stubble was an effective means of mitigating this problem.

Air Seeder 1985, Flexi-coil 1100 Air Cart: In the late 1970's and early 1980's, many manufacturers started building air carts and in the winter of 1984-85, I designed the Flexi-coil 1100 air cart. Most air carts had two compartments that each had a meter. Product was metered from the tanks into an airstream and the airstream delivered the products to the application tool. Air carts coupled with chisel plows were commonly used for banding fertilizer and were called air seeders.

Air Seeder Unit, Flexi-coil 800 Cultivator & 1610 Air Cart & System 75 Packer: Air seeders needing packing systems that could easily be transported and in 1988 I designed the System 75 wing-up packer. Air seeders were capable of operating in high residue conditions as well as low residue conditions.

Trip Mechanisms: Various trip mechanisms were developed for the chisel plows and cultivators, with varying trip force capabilities, depending on application (soil type, depth, type of opener, etc.). I was involved with the development of various trip mechanisms at Flexi-coil.

Loading the Air Cart: The air carts were easily loaded using an auger attached to the air cart. Typically, the farmer loaded seed in one compartment and fertilizer in the other.

Unloading the Air Cart: The air cart auger can be easily swung around and used to unload the left-over products back into the truck. This feature was first introduced on the Flexi-coil 1100 air cart.

Air Hoe Drill, Flexi-coil 5000 with 2320 TBH: Air carts were also used to supply seed and fertilizer to hoe drills and disc drills.

Air Hoe Drill: The air hoe drill is the most common seeding and fertilizing tool used on the prairies today. There are many manufacturers and many variations of these machines.

Single Shoot, Double Shoot & Triple Shoot: The air cart technology developed as new design criteria were added. Today, air carts are typically capable of single shooting, double shooting and even triple shooting. The slide shows a typical 340 bushel air cart with three tanks and a number of different combinations of seed and fertilizer to be delivered to the openers. With “single shoot”, the products from all three tanks are delivered through a single distribution system. In “double shoot” mode, two of the products (typically seed and starter fertilizer) are combined into one distribution system and the product from the other tank (typically the nitrogen fertilizer) is metered into the other distribution...
Knife Opener Types: Single shoot air drills (fertilizer and seed in the same distribution system) typically use knife tip or spread tip openers. Often, carbide inserts are added to high-wear areas on tips.

Harrow Leveler: Harrow levelers are used to level soil between rows on air hoe drills.

Disc Leveler: Disc Levelers are used to prevent soil from being thrown from one row to another, and allow higher operating speeds with air hoe drills.

Single Disc Opener: The single disc, no-till opener is not too popular in Western Canada. Compared to knife openers, the disc openers have higher initial cost, higher maintenance costs and hair pinning problems in heavy, damp straw conditions. Air hoe drills do a better job of getting good seed-to-soil contact in most applications of direct seeding.

Soil Warming: One additional reason why no-till disc openers have not become popular is the effect of the zero till opener on soil warming. Often it is desired to seed crops when the soil is still cold. The hoe opener does a much better job of warming the soil to a 1” depth than the disc opener.

Seed Placed Urea: The amount of seed placed urea (46-0-0) depends on:

a. Seed Bed Utilization (SBU). SBU = W x 100 / S
   i. Width of seed/fertilizer spread (W)
   ii. Row Spacing (S)

b. On my farm I use a 3” (75 mm) spread and a 9” (230 mm) row spacing for a Seedbed Utilization of 33%. On my loam soil, this lets me apply 40 lb/acre of actual nitrogen with the seed.

38. Seed Placed Phosphate: Maximum safe rates of actual seed placed phosphate (P2O5) fertilizer vary with crop type. Cereals are much more tolerant to seed placed phosphate than oil seeds and pulse crops.

Fertilizer Placement – Canola: The best results when placing phosphate fertilizer at the same time as seeding canola, are obtained when the fertilizer is placed below and to the side of the seed.

Fertilizer Placement – Peas: The best results when placing phosphate fertilizer at the same time as seeding peas, are obtained when the fertilizer is placed below and to the side of the seed.

Opener with Separate Seed and Fertilizer Placement: Many manufacturers offer openers that are capable of placing the fertilizer separate from the seed.

Fertilizer and Seed Placed Separately with Knife-style openers: Double shoot air delivery systems are required to supply fertilizer and seed in the separate distribution systems, to single side band or paired row openers.

Mid-Row Banding: Other companies offer mid-row banding options where a separate fertilizer opener is used between pairs of seed openers.

Canola Seed Depth: Canola seedling emergence is very sensitive to seeding depth. Many of the air drills struggle to get uniform, accurate, shallow seeding depth for canola. The latest technology
addresses this issue.

Accurate Depth Control Critical for Establishing Canola: Some companies, like Seed Hawk, now offer individual depth control for each seed opener as well as adjustable packing pressure to allow fine-tuning for various soil conditions. On the slide we can see each opener following the soil independent of frame height and the hydraulic cylinder used to apply pressure downward as the opener follows the ground.

Large Air Carts with Multiple Compartments: The Seed Hawk 777 Air Cart is the largest production air cart in the world with a total volume capacity of 777 bushels (27.5 cu meters). It has three compartments, each with its own meter and can combine any combination of the products.

Anhydrous Ammonia Option: Anhydrous ammonia (NH3) is the cheapest and most concentrated form of nitrogen. Provided there is adequate and consistent separation between the seed and the fertilizer, NH3 can be used as the nitrogen source of fertilizer at seeding time.

Earliest Pneumatic Applicator: It is interesting to note that the development of the air carts was thought to be new technology in the 1970’s. In actual fact, there were pneumatic applicators long before the advent of the air seeders we know today. I came across the Leggett Cotton Duster on a plantation in Louisiana. It was a horse-drawn, ground-driven pneumatic applicator that required one person to drive the horses, and others carrying hoses & nozzles for dusting the cotton crops.

Pneumatic Cotton Duster: On the Leggett Cotton Duster, one wheel had a chain drive to the fan or blower and the other had a chain drive to the meter. Powdered insecticide was metered into the inlet of the fan and then delivered through the splitter to the hoses and nozzles.

**Harvesting & Spraying technologies**

Tandem Swather 1983, MacDon 50’ (15.2 m): Swathers came into common usage in the 1960’s in Western Canada. Swathing allowed a quick, uniform dry-down of the crop so that combining could be done before winter weather set in. Swathers increased in size and in the early 1980’s, I patented the design of two swathers that were pulled behind one tractor. The slide shows two 25’ (7.6 meters) units being pulled behind one tractor for a total cutting width of 50’ (15.2 meters).

High Clearance Self Propelled Sprayer: Sprayers are used for many operations on modern farms in Western Canada:

a. Chemical Fallow (Chemfallow)
b. Spring burnoff
c. In-crop pest control during the growing season
d. In-crop pre-harvest perennial weed control
e. Desiccation of crops in the fall

GPS Guidance Systems: Global Positioning System (GPS) guidance systems are quite common on the farms, both the light bars and auto-steer units. These systems help to minimize misses and overlaps and are used on sprayers as well as seeding and fertilizing equipment.

Aeration Bins: In the 1980’s aeration bins started to be commonly used by farmers. This allowed combining the grain when it was 5% or more above the moisture levels required for safe storage. The grain was then aerated to bring the moisture content down by forcing ambient air through the grain.
This system allowed the return of straight combining as the most common form of harvesting on the prairies and the use of swathers declined substantially.

Straight Combining: Large self-propelled combines with straight cut headers and the latest technology in choppers, like the Redekop MAV Chopper are used to harvest crops. Chopping and spreading the straw the full width of the header is desired. It is also best to spread the chaff full width as well. Cutting as high as possible will help to trap snow and the only limitation on stubble height is that the seeding and fertilizing tool must be able to operate in the stubble.

Swathing Oats and Canola: Swathing is recommended for oats and canola to minimize shelling in windy conditions. It is recommended to cut the canola as high as practical and use a swath roller on the canola to minimize wind damage to the swaths.

Combining Canola: It is important to spread the canola chaff to provide uniform growing conditions for the following crop.

Canola Augered into Bin: Grain is typically hauled to the farm yard and stored in grain bins until the appropriate time to market the grain. These bins have temperature sensors located through the middle of the bin so that the temperature of the stored grain can easily be monitored.

Combining Oats: If the straw is to be dropped and baled, the chaff should still be properly spread.

Baling Oat Straw: Cereal straw is sometimes baled for use in cattle operations.

Chaff Harvesting: Sometimes, it is desired to harvest the chaff to be used in cattle feed. Even if the chaff is to be harvested, the straw should be chopped and uniformly spread.

Chaff Piles: Chaff piles may be left in the field and fed to the cattle there or picked up and transported to the cattle feeding location. Standing stubble is always left in the fall to catch snow and protect soil.

Feeding Chaff Piles: Cattle can feed on the chaff piles in winter in the field.

Disc Opener in Corn Residue: If the farmer is growing corn or sunflowers, the stalk residue from these crops is difficult for knife openers to work through. In these residue conditions, disc openers might be a good option for the farmer.

**Minimum tillage systems at Hundeby farm**

Hundeby Family Farms, Elbow, Saskatchewan: There are three separate farm operations at Elbow Saskatchewan located at the boundary of the Brown and Dark Brown soil zones. Total size of the farms is 12,480 acres (5050 hectares). No fall tillage is done and stubble is cut as high as possible to catch snow, while still allowing fertilizing and seeding operations to be performed without difficulty. The standard crop rotation is durum-peas-durum-lentils.

Heavy Harrow: A heavy harrow with a granular herbicide attachment is used to apply granular herbicide on the cereal stubble. The heavy harrow also helps to break up and spread the straw. This land will be seeded to a pulse crop the following spring.

Chisel Plow with Granular Attachment: Chisel plows with sweeps and 3 bar harrows as well as a Vallmar pneumatic applicator can be used for spring or fall herbicide application and incorporation of granular herbicides. If used in the fall, narrow sweeps are used so that a percentage of the stubble remains anchored and standing for the winter. The unit is also sometimes used in the early spring to kill winter annuals and seal the soil to conserve moisture.
67. Air Hoe Drill: Three 57'(17.4 meter) Flexi-coil 5000 air drills are used to seed and fertilize the crops. Two of the 5000’s have 180 mm spacings and one has 230 mm spacing and they all use Flexi-coil Stealth openers. In some cases more than one air cart is used with one air hoe drill for added product carrying capacity and metering combinations.

Land Roller: Land is rolled after seeding pulse crops, typically after the crop is a few inches high, to flatten the soil and push small stones into the ground. This operation makes combining the short crops possible without damaging the combines.

Straight Combining Pulse Crop: Peas and lentils are typically harvested with 9 meter straight cut flex-headers. Pulse crops must be cut very short in order to harvest all the seeds.

Don Hundeby Farm, Wetaskwin, Alberta: My brother Don farms at Wetaskwin, Alberta in the black soil zone. His farm size is 1270 acres (514 hectares) and the standard crop rotation is canola-wheat-barley on a black loam soil. This area typically has adequate rainfall and has excellent soils, the combination results in high-yielding crops. No fall tillage is done other than perhaps an operation with a heavy harrow. Stubble is cut as high as possible to catch snow.

Chisel plow with mounted harrows, air cart and coil packers: Don uses a chisel plow with 300 mm spacing, 180 mm sweeps and a spreader boot that provides 50% seed bed utilization. His soil has a low pH (5.8 to 6.2), high organic matter (11%), high clay content, and typically high moisture levels. With this combination, he is able to put on all of the fertilizer requirements in a single shoot system with no apparent damage to canola seedlings.

Combining at Night: Because the crop remains dry enough to combine well into the night, equipment must be well lit to allow safe operation in the dark.

Dave Hundeby Farm, Saskatoon, Saskatchewan: My farm at Saskatoon is on the line between dark brown and black soil zones. Crops that are grown are canola and oats on some very rocky loam soil. No fall tillage is done and stubble is cut as high as possible to catch snow.

Tractor cab Monitors: The same tractor is used to pull the air seeder unit, the sprayer, the swather, and the combine. Air cart, sprayer and combine monitors are all located in the cab. In a new tractor equipped with the ISO 11783 serial control and communications data network, all the monitors would be replaced with one “smart monitor” in the tractor. This computer system senses what implement is attached to the tractor and provides the appropriate monitor screen.

Air Seeder with 230 mm Spacing and 280 mm Sweeps: An air seeder with harrows and double packing (on-row packers and coil packers) was used in 2006: The unit was used early in April to band urea, kill winter annuals, seal the soil by preventing soil cracking, and double packing to encourage weed seed germination while at the same time keeping moisture close to the surface for seed germination later. In May, the same unit was used to seed and place the recommended phosphate, potash and sulfur blend with the seed in a single shoot operation.

Air Seeder with on-row packing with liquid fertilizer system: An air seeder with harrows and on-row packing as well as a liquid fertilizer system was used in 2004 and 2005: The unit performed well in a single pass operation at the desired seeding time in May. The operations that were done in one pass by this machine were killing winter annuals, placing the seed and starter fertilizer (phosphate, potash and sulfur) in a 75 mm wide band, placing the liquid nitrogen (28-0-0) in a band beside the seed, leveling the soil with the harrows, and packing on the individual seed rows.
Sweep with seed tube and liquid fertilizer tube: With the 2005 seeding rig the liquid fertilizer was dropped to the side of the seed and granular fertilizer band.

Seedlings in Stubble: With the air seeding unit properly set traveling at speeds less than 4.5 mph (7.2 kph), the unit leaves considerable standing stubble and in the picture, ~ 300 mm high. This provides very good erosion protect and an excellent micro-climate in which the seedlings can develop.

Suspended Boom Sprayer, Field Position: I put together a very simple suspended boom sprayer:

a. Booms are mid-mounted between the tractor drawbar and the sprayer tires
b. Simple steel cable vertical suspension system and polyethylene rope horizontal suspension system hold the booms in place.

c. Typically spray at speeds up to 19 kph
d. Sprayer width is 20.6 meters (twice the width of the air seeding unit)

Suspended Boom Sprayer, Transport Position: The sprayer is quickly and easily converted from field position to transport position.

Hauling Grain to Market: Grain is hauled to market with large truck and trailer units, capable of hauling 43,500 kg per load.

Rock Digger and Picker: My land has excessive rocks and a number of days are spent each year picking rocks. The unit I use is a tractor with a rock digger unit on the front end loader, followed by the rock picker. Rocks are hauled to a storage location on the field.

Conclusions

Increased Production 1969 to 1999: For the time period from 1969 to 1999, the production of wheat, barley, oats and durum all held steady or slightly increased. At the same time, there were huge increases in production of canola, flax, dry peas, sunflowers, lentils and dry beans. This shows clearly what has happened in the Canadian prairies over that period of time to increase production, and in my opinion, most of the increased production is directly related to advances in technology and agronomy along with high residue farming practices.

a. Always leave stubble standing in the fall and over the winter
b. Minimize number of passes through field and accomplish multiple tasks with each pass
c. Always keep maximum surface residue to control erosion and conserve moisture
d. Place fertilizer in the most economic, agronomically beneficial location relative to the seed
e. Only till very shallow to conserve moisture
Coservation Tillage in California

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Abstract: Current estimates indicate that conservation tillage (CT) practices are used on less than 2% of annual crop acreage in California’s Central Valley. Tillage management systems have changed relatively little since irrigation and cropping intensification began throughout this region more than 60 years ago. The University of California (UC) and the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) CT Workgroup is a diverse group of UC, NRCS, farmer, private sector, environmental group and other public agency people that has provided wide-ranging services aimed at developing information on reduced tillage alternatives for California’s production valleys. In a short span of seven years, the Workgroup has grown to over 650 members and has conducted over 60 demonstration evaluations of CT systems. While CT is still quite new in California, a growing number of farmers has become increasingly interested in it for both economic and environmental reasons and are now pursuing a wide range of activities and approaches aimed at accelerating its adoption. Two crop production systems in which CT has been growing are dairy forage crop and tomato systems.

Keywords: strip-tillage, no-tillage

Why conservation tillage?

The importance of minimizing soil erosion and conserving soil resources first came to national attention in the United States during the “Dust Bowl” period in the early 1930’s when the combination of intensive tillage, drought, crop failure and wind-driven erosion of millions of acres of farmland occurred in the Great Plains region of the US (Coughenour and Chamala, 2004). In the decades following, a number of reduced soil disturbance or conservation tillage (CT) production systems emerged in the Midwest and the southeast US to address soil loss concerns. Because of the important role that surface cover or roughness has in mitigating soil erosion losses, the concept of CT during this time eventually became linked with the specific management goal of maintaining at least 30% crop residue on the soil surface after planting and this has been the primary characteristic used in
USDA definitions of CT. Reduced soil disturbance, however, is a key element in these definitions. Most CT systems are based on one of three reduced soil disturbance planting systems: no-till, ridge-till, or strip-till. In no-till, or zero-till, the only tillage that is used is the soil disturbance in a narrow slot created by coulters or seed openers (MWPS – 45, page 6). The soil surface is thus generally left undisturbed except at the time of planting. Ridge-till is a reduced disturbance planting system in which crops are planted and grown on ridges formed during the previous growing season and by shallow, in-season cultivation equipment. Ridge-till planters sweep away or shear off residues and soil in the seed line but do not disturb much of the inter-row soil surface. In strip-till, coulters cut residues ahead of subsoiling shanks that loosen the soil from a few to as many as 14 inches ahead of a planter. In each of these CT systems, only a small percentage of the soil surface is disturbed unlike the “broadcast” tillage, or land preparation operations that are typically used in conventional tillage systems.

In California, however, where use of the term “conservation tillage” is much more recent, a broader paradigm has developed that focuses more on reducing the overall number of tillage passes rather than on strictly preserving surface residues in part, to reduce fuel use and dust emissions. Thus, CT in California currently refers to a wide range of production practices that deliberately reduce primary, intercrop tillage operations such as plowing, diskng, ripping and chiseling. Under this definition, residues are managed in a variety of ways to permit efficient planting, harvesting and pest control. From this perspective, any production system that significantly reduces tillage operations and conserves resources (generally by more than 40% relative to what was done in the year 2000) is defined as “conservation tillage” in California.

Benefits of CT

The success of CT in maintaining yields while reducing soil erosion has added to its popularity. Equipment innovations, herbicides and herbicide-tolerant crops, as well as widespread farmer and researcher experience have contributed to the success of CT. In addition to reducing soil loss by erosion and runoff, CT systems have a number of other attributes that add to their appeal to producers. Because they aim at reducing primary, intercrop tillage operations such as plowing, diskng, ripping and chiseling, fewer tractor operations are used. The consequent reduced fuel use often improves farm profitability. In addition, NOx and dust generation are reduced (Baker et al., 2005) and CO2 losses may be decreased (Reicosky, 1997). CT systems may also conserve soil water by reducing evaporative and surface runoff losses, thereby enabling the intensification and diversification of cropping systems (Beck, 1990; Freebairn et al., 1993). Possible benefits of CT are summarized in Table 1.

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<tr>
<th>Table 1</th>
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<td>- saves fuel</td>
<td>- saves machinery</td>
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<td>- increases soil moisture</td>
<td>- increases soil organic matter</td>
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<td>- saves soil</td>
<td>- sequesters carbon</td>
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<td>- saves time</td>
<td>- reduces dust emissions</td>
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<td>- saves labor</td>
<td>- reduced surface water (sediment, nutrient and pesticide) runoff</td>
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</table>

Governmental incentives for adopting CT
The 2002 US Farm Bill provides incentives for farmers to voluntarily address environmental resource concerns using production practices such as CT. Such practices are approved through Local Work Group initiatives in county United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) offices. The NRCS Environmental Quality Incentives Program (EQIP), for example, provides technical assistance and cost-share incentive payments to assist producers with environmental conservation improvements such as the use of CT on their farms, and in 2003, for the first time in California, CT was approved as a statewide “cost-share” EQIP practice. In the past two years, a number of EQIP CT contracts have been implemented in the San Joaquin Valley aimed primarily at air quality improvement.

Adoption of CT in California

Since 1997, more cropland acres have been farmed nationwide using CT practices than standard tillage practices (CTIC, 2004). However, despite the apparent attractiveness of reduced tillage or CT systems, the NRCS estimates that less than one percent of row crop production acreage in California’s Central Valley is currently farmed using CT practices (CTIC, 2004). Reasons for this low rate of CT adoption in California are generally thought to result from a lack of CT equipment being available locally, inexperience with CT techniques, the predominance of surface, or gravity irrigation systems in California, and the fact that tillage-intensive systems have been developed here for several decades and are generally quite productive.

The CT Workgroup

To respond to needs for information on reduced tillage production alternatives in California, the UC Division of Agriculture and Natural Resources and the USDA NRCS Conservation Tillage Workgroup was established in 1998. The goals of the CT Workgroup are to develop knowledge, exchange information and coordinate research and extension education programs related to CT production alternatives in California. From a handful of academics, the Workgroup has grown to over 650 UC, USDA ARS and NRCS, farmer, public agency, private industry and non-governmental group members and has been active at more than 60 research and demonstration sites throughout the State. The growing body of experience that Workgroup members have acquired during this time includes CT production systems evaluations for cotton, wheat, tomatoes, melons, corn, beans, lettuce, and cover crops. The CT Workgroup currently has a Technical Service Provider agreement with the NRCS to provide support and education related to CT systems and has partnered with more than 30 farmers in a variety of CT evaluations throughout the Central Valley.

CT Workgroup research and education activities

Workgroup-sponsored CT conferences have been held annually in Five Points and Davis, CA beginning in 1998 with sessions focusing on relationships between soil organic matter, tillage, and soil quality. The 2000 conference highlighted CT success stories from around the US. Our 2001 conferences focused on CT equipment demonstrations, our 2002 events dealt with researcher and farmer innovation, the 2003 sessions dealt with the current state of CT in the Valley, CT2004 again highlighted CT equipment and CT2005 was organized as tours to innovative CT tomato, cotton and dairy forage farms. Participant feedback reveals increasing interest in CT alternatives and indicates an expectation that CT will become more widely used throughout the State once successful examples are demonstrated (Table 2). Recent informal polling of the Workgroup’s farmer members suggests that unlike other regions where CT systems have been adopted, primary motivations for these
alternatives in California include cutting production costs, storing carbon in the soil to improve soil quality, weed management using dense crop residues or over-the-top herbicides for organic and growers using herbicide tolerant crop, respectively, and generally conserving society’s “common assets” - our soil, water and air resources. Examples of the types of CT studies currently being conducted by the Workgroup are briefly described below.

Table 2  
Participant responses to post-CT1998, 2000 and 2003 conference questionnaire question “What do you think about the future adoption of the various conservation tillage practices in California presented at this Conference?”  Numbers in parentheses are the percentages of respondents.

<table>
<thead>
<tr>
<th></th>
<th>1998 (n = 54)*</th>
<th>2000 (n = 79)</th>
<th>2003 (n = 48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT practices will not be widely adopted in California</td>
<td>3 (4)</td>
<td>11 (14)</td>
<td>3 (6)</td>
</tr>
<tr>
<td>Adoption of CT will likely be on a very limited scale</td>
<td>11 (20)</td>
<td>45 (57)</td>
<td>21 (44)</td>
</tr>
<tr>
<td>CT may become more widely adopted if successful examples are demonstrated</td>
<td>36 (67)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is inevitable that CT will have a far wider role in California</td>
<td>7 (13)</td>
<td>20 (25)</td>
<td>23 (48)</td>
</tr>
</tbody>
</table>

*Number of responses

A variety of evaluation activities have been initiated to develop information on reduced tillage production options. These studies have focused on different aspects of CT systems including 1) opportunities and issues related to integrating cover crops in CT production systems, 2) developing and refining the ability to produce single crops using reduced till approaches, and finally, 3) integrating CT principles throughout various sequences or rotations of crops. Much of this early research was done in standard research and extension center small plot work (Herrero et al., 2002a, Herrero et al, 2002b). This preliminary work was essential for subsequent larger-scale trials that have been done in conjunction with farmers. Figure 1 indicates the crops and locations where CT practices have been evaluated.

Following these initial small-scale studies, and as the CT Workgroup acquired more reduced till equipment, several larger-scale demonstrations of CT systems were initiated with partner farmers. Farmers actually initiated a number of these trials asking for implementation support and offering land, facilities and labor to Workgroup partners. Several of these farmer demonstrations have been developed into case studies documented in the CT Workgroup 2003 conference proceedings and on the CT Workgroup website (http://groups.ucanr.org/ucct/), and others have been prepared as peer-reviewed publications (Mitchell et al. 2006).

The CT Workgroup, in conjunction with the California NRCS State Agronomist, also initiated a survey to track trends in reduced tillage practices throughout the Central Valley. Local CT Workgroup members conducted this survey for the first time in 2004. Data on CT acreage for major Central Valley crops were collected from local NRCS staff, UC Advisors and private sector CT Workgroup members, and will be provided every two years to the Conservation Technology Information Center in Lafayette, IN for compilation in their national database on CT. In this survey, a new CT category, “≥40% reduction in overall tillage relative to standard tillage practices for a given crop in the year 2000,” was used in addition to the more conventional CT classifications of no-till,
strip-till / ridge-till and mulch-till. The rationale for including this category was to track “reduced pass” practices that may achieve conservation and economic goals, but that do not necessarily conform to the “30% or more residue” requirement of the classic USDA CT definition. Results of this 2004 survey are presented in Table 3. In general, both the classic CT and the minimum till (≥40% reduction in tillage passes) systems currently represent about 2% of the total acreage for the crops and counties surveyed, with more acreage under minimum tillage than under CT.

The CT Workgroup has also instituted an annual CT Farmer Innovator Award Program to acknowledge and honor pioneering leaders in the development of CT systems in California. Workgroup

Table 3 2004 California Conservation Tillage Acreage Survey for tomatoes, cotton, edible dry beans, silage corn, grain corn, and small grains for grain, hay and silage.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Conservation Tillage</th>
<th>Minimum Tillage</th>
<th>Conventional Tillage</th>
<th>Total Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 30% Residue Cover after Planting</td>
<td>&gt;40% reduction in total passes</td>
<td>&lt; 30% Residue Cover after Planting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Till</td>
<td>RT/ST</td>
<td>Mulch Till</td>
<td>Subtotal</td>
</tr>
<tr>
<td>Fresno County</td>
<td>2,250</td>
<td>260</td>
<td>150</td>
<td>2,660</td>
</tr>
<tr>
<td>Kern County</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kings County</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Madera County</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Merced County</td>
<td>485</td>
<td>0</td>
<td>0</td>
<td>485</td>
</tr>
<tr>
<td>Sacramento</td>
<td>650</td>
<td>0</td>
<td>0</td>
<td>650</td>
</tr>
<tr>
<td>San Joaquin</td>
<td>505</td>
<td>0</td>
<td>0</td>
<td>505</td>
</tr>
<tr>
<td>Tulare County</td>
<td>1,375</td>
<td>430</td>
<td>0</td>
<td>1,805</td>
</tr>
<tr>
<td>Yolo County</td>
<td>0</td>
<td>0</td>
<td>51,000</td>
<td>51,000</td>
</tr>
<tr>
<td>Total</td>
<td>5,265</td>
<td>690</td>
<td>52,150</td>
<td>57,105</td>
</tr>
</tbody>
</table>

1Ridge-till/Strip-till

2Mulch-till is defined by the CRIC as “full-width” tillage usually requiring only one to three tillage passes. After planting, at least one-third of the surface remains covered with residue.
members have visited farmers and researchers in Alabama, South Dakota, Iowa, South Carolina, Texas, Oregon and Arizona in an effort to learn about successful CT systems.

**Future of CT in California**

The development of successful CT systems in California, as in other regions, requires a “systems” orientation and will not result from the introduction of a single technology or practice (Coughenour and Chamala, 2004). New paradigms for rotations, planting, fertility, irrigation and pest management systems are needed and are currently beginning to be developed and shared through connections between farmers, the private sector, non-governmental organizations (NGO’s) and “information flow” people from the University of California and the USDA NRCS. Several “local networks” of CT cropping innovation (Coughenour and Chamala, 2004) have been established and are currently being facilitated by the CT Workgroup. Many questions remain to be answered, however, with respect to the extent to which CT will be pursued in California: How might CT practices be developed for California’s very diverse cropping systems? Can CT contribute to water conservation in California? Will CT improve soil, water and air resource quality? and What will be the long-term impacts of CT on labor and farm economies? To date, the CT Workgroup has been pivotal in initiating research aimed at answering these questions. Its success has resulted from several factors including its timeliness in responding to the need for information on reduced tillage options within California’s current production systems and economic environment, the encouragement of the University DANR and the USDA NRCS, and perhaps most importantly the recognition that public-private partnerships result in diversified teams that are an effective means for innovative program development and a dynamic organizational structure for the integration of research and education leading toward improved cropping systems.
Refining CT tomato production

An example of the development of information on CT systems in California is seen in our work with tomatoes. Since 1999, we evaluated CT and cover cropping (CC) practices for tomato production in an 8 acre field in Five Points, CA. The objective of this work has been to compare standard till (ST) with and without (NO) winter cover crops and conservation tillage with and without cover crops in terms of economics, productivity, soil properties and dust emissions through a tomato – cotton rotation. The study field was divided in half to allow both crops to be grown in each year. A summary of the first five years of this work is presented here.

The standard tillage systems have been managed as customarily done in the West Side San Joaquin Valley region. Beds are disked and reformed following harvest of each crop. Prior to tomatoes, the beds are also shaped with a power incorporator. The standard till cover crop system uses a triticale/rye/vetch “green manure” approach with the cover crop disked each spring before reshaping beds and establishing the summer crops.

The CT systems use about 50% of the overall tillage, or soil disturbance operations as the ST systems. Tomatoes are “no-till” transplanted and cotton is no-till seeded into beds that haven’t been worked or moved since the beginning of the study, except for a shallow root undercutting following cotton harvest for Pink Bollworm management compliance. Tomato beds have been quite “rough” following the one-pass fall cotton stalk management operation and are “re-readied” using furrow sweeps at the time of transplanting and during in-season cultivations. In the CT cover crop systems, the cover crop is sprayed with glyphosate, chopped and left on the soil surface as a mulch before transplanting tomatoes or planting cotton. A summary of pre-tomato tillage operations used in each system is shown in Table 4.

<table>
<thead>
<tr>
<th>Standard tillage</th>
<th>Conservation tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>undercut cotton</td>
<td>undercut cotton</td>
</tr>
<tr>
<td>disk</td>
<td>transplant tomatoes</td>
</tr>
<tr>
<td>disk</td>
<td></td>
</tr>
<tr>
<td>rip</td>
<td></td>
</tr>
<tr>
<td>disk</td>
<td></td>
</tr>
<tr>
<td>list beds</td>
<td></td>
</tr>
<tr>
<td>power incorporate beds</td>
<td></td>
</tr>
<tr>
<td>transplant tomatoes</td>
<td></td>
</tr>
</tbody>
</table>

CT equipment

A few equipment modifications have been made in the CT system. A three-row transplanter sled
fitted with 20” diameter coulters ahead of each transplanter shoe, residue-slicing disks in front of each sled, and additional press wheels behind the transplanter drive wheels to seal seedlings into the soil, was used. A Sukup high residue corn cultivator (Sheffield, IA) was converted to a 3 row 60” configuration and bed-top L-sweep blades were added for tomato bed cultivation. Sidedress fertilizer was applied using Yetter Mfg. (Colchester, IL) high residue liquid or dry fertilizer applicators that had coulters fitted in front of the shanks.

Yields

Processing tomato yields (cv Heinz ‘8892’) are shown in Table 5 for 2000 - 2004. CTNO yields matched or exceeded those of either ST system in all five years of this research. Yields of the CTCC system were lower than the other systems in 2000 and were lower than the CTNO in each of the next two years of the project as well. We observed that tomato plants often grow more slowly early in the season in the high residue CT cover crop mulches. The slower growth is perhaps due to lower measured temperatures above and below the mulch layer. We also observed more surface “trash” entering the harvester in the CT systems. However, virtually all of this mulch was typically removed by the harvester’s suction cleaning mechanism.

Table 5  Tomato yields 2000 – 2004 (tons/acre) from field comparison of standard and conservation tillage production in Five Points, CA

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard till no cover</td>
<td>58 a</td>
<td>61 b</td>
<td>46 b</td>
<td>42 c</td>
<td>46 bc</td>
</tr>
<tr>
<td>Standard till cover crop</td>
<td>53 b</td>
<td>63 a</td>
<td>43 b</td>
<td>45 b</td>
<td>42 c</td>
</tr>
<tr>
<td>Conservation till no cover</td>
<td>56 a</td>
<td>64 a</td>
<td>56 a</td>
<td>54 a</td>
<td>52 a</td>
</tr>
<tr>
<td>Conservation till cover crop</td>
<td>51 b</td>
<td>61 b</td>
<td>43 b</td>
<td>52 a</td>
<td>48 ab</td>
</tr>
</tbody>
</table>

These results indicate at least the short-term potential to produce tomatoes following cotton with considerably less tillage than is currently done in most production fields. The tillage management approach that has been pursued in this study seeks to reduce primary, intercrop tillage and depends on subsequent, early-season bed “reconditioning” with the transplanter and cultivator operations. By doing this, beds have been left quite rough during the winter and into the spring and this may be a management strategy that today’s growers may not be comfortable with because early-season beds are rather degraded and may not be well shaped. In this study, however, we have found that it is possible to establish tomato transplants into these beds, to rebuild beds using the transplanter and cultivator that are both fitted with “riding wings,” or furrowing tools and to successfully mechanically harvest fruit with this management system. With this approach, early cultivation is needed to recreate furrows and to clean residues out of furrows to enable surface irrigation.

Within this CT tomato system, the largest challenge has been to consistently manage weeds during the entire production season. The strategy we have pursued involves cultivation, - generally two to three times per season, - and hand weeding. However, because herbicides have not been incorporated into the soil, the CT systems have consistently had many late-season weeds grow in the furrow and they have not been effectively managed because the tomato plants are by then too big to allow topical herbicide spraying or cultivation. There is thus a need to improve the CT systems, particularly late in the season.
Developing CT dairy forage production systems

California’s dairy industry is a huge contributor to the State’s economy. Dairy products have been California’s top agricultural commodity for a number of years (CDFA, 2004). They account for over 5 billion in cash receipts which is about 17% of the State’s overall agricultural output in recent times. California dairies require year-round availability of inexpensive, locally-produced forage materials. Common dairy forage production systems consist of winter small grains seeded either individually or in mixes in November and December. These winter forages are then harvested as “green chop” the following March through May. In conventional production systems, fields may be disked a number of times following the harvest of these winter forages, relisted or bedded and then preirrigated for spring corn planting. Turnaround time between winter small grain forage harvest and spring corn planting routinely takes about two weeks. Spring silage corn is then produced for late-summer harvest. Occasionally, corn or another forage crop such as milo or sorghum sudan, may be double-cropped after an early planted corn crop with the second crop coming off sometime in early fall. In most current production systems, intercrop tillage and seedbed preparation is done ahead of each successive crop. Such production systems, however, lend themselves quite well to a variety of conservation tillage approaches that have been developed in other production regions, and in recent years, a number of California dairy forage producers have begun experimenting with these reduced till forage production alternatives.

The primary motivation for CT in dairy forage systems is to save time, labor and fuel. This is accomplished by reducing primary, intercrop tillage or soil preparation operations such as diskling, plowing, chiseling and ripping to the greatest extent possible while still achieving adequate productivity. In general, the earlier that a crop such as corn is planted, the higher the yield. Corn stunt disease is also less severe in early corn than in later-planted corn. Minimizing or eliminating intercrop tillage can reduce the time between winter forage harvest and corn seeding from 2 – 3 weeks under conventional practices, down to 7 to 10 days or even less due to reduced time for tillage operations, and less water applied as preirrigation.

There are currently three general types of conservation tillage that are being used in Central Valley dairy forage production fields: Complete no-till, strip-till and a one-pass operation in which several implements such as a light disk and a harrow are pulled in tandem to create seedbed conditions quite similar to conventional tillage. In no-till or zero-till, the only tillage that is used is the soil disturbance in a narrow slot created by coulters or seed openers during planting. The soil surface is thus generally left undisturbed except at the time of planting. In strip-till, coulters cut residues ahead of subsoiling shanks that loosen the soil from a few to as many as 14 inches deep ahead of a planter. A strip-till implement can also be connected to a planter to enable a one-pass planting operation. Finally, strip-till is sometimes referred to as “vertical till” because tillage is done in a vertical fashion in the soil profile, thereby preserving much of the residues on the soil surface. A variety of implements including basic disk harrow and other recently-introduced and more specialized “all-in-one” type tillers can also be used to accomplish the reduced pass approach. This latter CT system reduces the number of overall tillage operations while tilling the surface soil sufficiently to mix residues with the soil, thus providing seedbed conditions relatively comparable to standard tillage procedures. Specific examples of CT that have recently been used in Central Valley dairies are listed in Table 6.
Table 6  Conservation tillage dairy forage production evaluations conducted in the Central Valley  2002 – 2005

- no-till corn planted into winter small grain forage
- strip-till corn planted into winter small grain forage
- strip-till corn planted into burned down alfalfa
- no-till sorghum sudan drilled into corn stubble
- no-till corn planted into corn stubble
- no-till triticale drilled into sorghum sudan
- one-disk corn planted into winter small grain forage
- no-till oats drilled into alfalfa
- no-till wheat drilled into corn stubble

Summary

Conservation tillage production systems have the potential to significantly transform major sectors of California agriculture in the coming years. In their many and varied forms, CT systems eliminate traditional soil preparation operations such as plowing, diskng and ripping, thereby reducing fuel use, production costs and dust emissions. While soil tillage practices in California have changed little during the past 60 years and estimates of the use of CT in California are currently quite low, projections of UC’s CT Workgroup indicate huge and as yet largely unexplored potential for CT in the State. In order for conservation tillage production systems to be realized and sustained in California, however, many fundamental and applied research questions remain to be addressed and resolved.

References


Conservation Agriculture in Europe: History, Current Situation and Challenges

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Introduction

Conservation Agriculture in Europe started as in many other places with the attempt to reduce plough tillage, which for many centuries was the most effective way to guarantee satisfactory weed control, nutrient mineralization and seed bed preparation. Conservation tillage, including the different forms and terminologies of reduced tillage, minimum tillage, strip tillage, non-inversion tillage, zero or no-tillage, direct drilling and others, however, is only part of the concept of Conservation Agriculture, although one of its main pillars. The practice of the replacement of soil tillage, partly or entirely, both for crop establishment and for pasture renovation started in the end of the first half of the last century, but only the availability of chemicals such as plant growth regulators and herbicides initiated a wider application of conservation tillage and the consequent research in reduced and no-tillage (Phillips and Phillips, 1984).

The initial adoption of conservation tillage was driven by different motives in the regions where these techniques are widely applied today. In the US it was mainly the concern of the degradation of the highly erodible soils subject to both wind and water erosion. Soon, the economical benefits of reduced and no-tillage crop production systems became as relevant as the concern of soil conservation for the massive adhesion of farmers to the new technology for crop establishment and grassland renovation. Despite the occurrence of severe soil erosion in many regions of Brazil, there it was mainly the economic aspect that led farmers to initially adopt no-tillage in the early 70s (IAPAR, 1981).

In Europe, although intensive research on the different aspects of conservation tillage was carried out after the invention of Paraquat in 1955 and its commercial release in 1961, no-tillage and even reduced tillage were applied at a very small scale until the end of the last century. The only exception was UK where in the early 80s almost 300,000 ha were sown under no-tillage. However, the straw burn ban caused farmers to abandon this technique due to increasing problems of weed control and volunteer cereals (Christian, 1994).

Nevertheless, it appears that a “renaissance” of conservation tillage has occurred during the last few years in a number of countries throughout Europe. In addition to conservation tillage practices the two other main principles of Conservation Agriculture are becoming more and more important amongst European farmers: permanent soil cover both in annual and perennial crops and the utilization of balanced but market-oriented crop rotations to reduce the input of agro-chemicals and to overcome a potential increase of problem weeds, pests and diseases. Still, Europe lags far behind in the uptake of Conservation Agriculture when compared with the Americas, where in some countries the area only under no-till achieves around 50% of the total arable land. In the member countries of ECAF this percentage reaches only around 1%.
Table 1

<table>
<thead>
<tr>
<th>Country</th>
<th>Minimum tillage (1000 ha)</th>
<th>No-till (1000 ha)</th>
<th>Cover crops in perennial woody crops (1000 ha)</th>
<th>Total surface CA (1000 ha)</th>
<th>% NT/arable land</th>
<th>% CA/arable land</th>
</tr>
</thead>
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<tr>
<td>Belgium</td>
<td>140</td>
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<td>n.d.</td>
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<td></td>
</tr>
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<td>n.d.</td>
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</tr>
<tr>
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</tr>
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<td>7,0</td>
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<td>n.d.</td>
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<td>7</td>
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<td>12,6</td>
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<td>2400</td>
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<td>12</td>
<td>10</td>
<td>102</td>
<td>2,9</td>
<td>25,4</td>
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<td>United Kingdom</td>
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<td>180</td>
<td>n.d.</td>
<td>2680</td>
<td>3,1</td>
<td>45,6</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>27959</strong></td>
<td><strong>2249</strong></td>
<td></td>
<td><strong>30726</strong></td>
<td><strong>1,1</strong></td>
<td><strong>15,5</strong></td>
</tr>
</tbody>
</table>

**Reasons for the poor adoption of Conservation Agriculture in Europe**

- **Cultural entrenchment of traditional tillage methods**

Traditional tillage in modern agriculture is based on the mouldboard plough, which replaced the ancient Roman plough in the 18th century. The perfect inversion of the upper soil layer that controlled effectively perennial grass weeds and provided a clean seed bed turned the mouldboard plough the preferred tillage implement ever since and the symbol of modern agriculture used by many agricultural institutions worldwide. Knowing the history of this implement, it is comprehensible why Europeans are the strongest defenders of the plough.

- **Favourable natural conditions in many regions**

Under certain conditions the benefits of Conservation Agriculture are so evident that its uptake is almost immediate once its interaction with the soil-plant-water environment is understood and thus the benefits felt and associated with the practice of Conservation Agriculture.

However, in the most important agricultural regions of Europe with the biggest influence on the definition of agricultural policies and on technological development, conditions are rather favourable regarding these aspects or at least there is/was not enough perception of the existence of such conditions.

- **Agriculture guided by common agricultural policy**

For almost 50 years farming in Europe has been subject to the strong influence of the Common Agricultural Policy. The objectives of these policies changed substantially over this period but there was always a strong financial support for most of the farming activities. Until a few years ago subsidies were mostly production oriented favouring high productivity levels, obtained with massive external inputs, instead of an overall long-term sustainability.
- **Low economic pressure**

The constant transfer of welfare from the consumer to the producer in form of subsidies prevented the necessary adaptation of European agriculture to the changes and the new realities of a global agrarian market. Thus European farmers did not perceive the imperative necessity of lowering productions costs in order to be able to compete and their farming systems to become economically sustainable.

- **Crop residue management**

Within Europe there exist tremendous differences in terms of agro-ecological conditions with extremely high productivity levels and high input farming systems in the centre and northern parts whereas in the southern parts around the Mediterranean rainfed agriculture is very extensive. This reflects on the amount of crop residues produced under intensive and extensive farming, respectively. Therefore there are regions with extreme amounts of crop residues (i.e. ten or more tons of cereal straw) and others with very low quantities. Both situations represent obstacles for an easy uptake of Conservation Agriculture, especially no-tillage, as excess of residues causes technical problems in terms of drilling equipment and seed placement and low residue levels due to low productivities and animal competition prevent the rapid improvement of soil and water conditions.

- **Lack of condition specific drilling equipment**

The reduced need to cut down production costs through reduced tillage intensity and especially direct drilling, and thus the low demand for adapted and specific drilling equipment made European manufactures stay behind the machinery development in this specific area when compared to other regions where manifold solutions and options are available to cope with very different conditions and crop requirements.

- **Lack of problem oriented research**

Although intensive and long-term research in the area of reduced and no-tillage had been carried out over almost 40 years, the uptake of Conservation Tillage systems was very reduced. However, it seems that all this research was primarily driven by academic interest in order not to stay behind the international research development and thus it was focussed mainly on the potential impacts and benefits of Conservation Tillage techniques. The lack of uptake and the demand for problem-oriented research made investigation in this area continue to be rather an academic exercise than a practical solution oriented effort.

Besides these general reasons for the poor uptake of Conservation Agriculture there are certainly many others that on a regional level contribute to the resistance for the implementation of Conservation Agriculture practises, as for example the very small farm size and the split up of the land.

**Why insisting in the uptake of Conservation Agriculture in Europe?**

The potential benefits of Conservation Agriculture have been proven under many conditions and are widely documented in numerous scientific studies and practice oriented reports (Holland, 2004). The question regarding the consequent uptake of Conservation Agriculture is whether the benefits are really perceived and strong enough to outweigh any known and unknown constraints of the change and whether the application of Conservation Agriculture is considered feasible under specific, individual conditions.
The conditions under which the benefits of Conservation Agriculture are most likely understood are:
- severe soil erosion
- farming under marginal economic conditions
- high production risk

The perception of reduced surface runoff and erosion of a minimum disturbed soil surface covered with crop residues or a growing crop is rather easy as it is also, where a significant reduction of production costs contributes to make farming economically sustainable.

Some deeper insight into the functioning of Conservation Agriculture seems to be required to regard this concept as the preferred option under the following conditions:
- low soil fertility (low soil organic matter)
- dry conditions and unfavourable rainfall distribution (water conservation)
- poor soil structure

The overcoming of these three constraints through the application of Conservation Agriculture principles seems much more difficult to be understood as the effects on these parameters are not visually perceptible and as soil organic matter and structure build-up and the improvement of the soil’s water holding are long-term processes.

Regarding the applicability of Conservation Agriculture under European conditions, especially soil conditions, an inquiry amongst experts in several European countries estimates 34% of the arable land suitable for no-tillage (table 2). Additionally Tebrügge and Basch (2002) consider another 40% of European arable land as suitable for the application Conservation Agriculture practices (except no-tillage).

Table 2  Arable Land Considered Suitable for the Application of No-tillage in Several European Countries (Tebrügge and Böhrensen, 1997)

<table>
<thead>
<tr>
<th>Country</th>
<th>Arable land (AL) *(1000 ha)</th>
<th>AL suitable for no-tillage (1000 ha)</th>
<th>AL suitable for no-tillage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switzerland</td>
<td>409</td>
<td>201</td>
<td>49.1</td>
</tr>
<tr>
<td>Germany</td>
<td>11791</td>
<td>4374</td>
<td>37.1</td>
</tr>
<tr>
<td>Denmark</td>
<td>2276</td>
<td>1001</td>
<td>44.0</td>
</tr>
<tr>
<td>Spain</td>
<td>13738</td>
<td>6251</td>
<td>45.5</td>
</tr>
<tr>
<td>France</td>
<td>18449</td>
<td>5867</td>
<td>31.8</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5753</td>
<td>1024</td>
<td>17.8</td>
</tr>
<tr>
<td>Greece</td>
<td>2717</td>
<td>1005</td>
<td>37.0</td>
</tr>
<tr>
<td>Italy</td>
<td>8287</td>
<td>1865</td>
<td>22.5</td>
</tr>
<tr>
<td>Netherlands</td>
<td>899</td>
<td>236</td>
<td>26.3</td>
</tr>
<tr>
<td>Portugal</td>
<td>1990</td>
<td>896</td>
<td>45.0</td>
</tr>
<tr>
<td>Total/Average</td>
<td>66309</td>
<td>22720</td>
<td>34.1</td>
</tr>
</tbody>
</table>

* Source: FAO

Despite the favourable natural conditions mainly in Central Europe, a high percentage of European
arable land is prone to conditions (erosion, water shortage, low to very low soil organic matter, a.s.o.) where the use of Conservation Agriculture practices should be considered as a must. Having a look to the main agro-climatic conditions throughout Europe, it is possible to identify regions where land use planers and agricultural and environmental authorities should insist in or at least be incentive to the application of Conservation Agriculture:

- all regions with some or serious concern of soil erosion
- regions with low annual rainfall (<500 mm) or those with a very irregular seasonal rainfall distribution
- regions with low to very low soil organic matter contents
- regions with large extensions of perennial crops on undulated and hilly areas
- regions where low yields and a high production risk due to high climatic variability make the reduction of production costs imperative for an ongoing farming activity

Several of these conditions can be found to a large extent in the Mediterranean countries with high rainfall concentration during winter, very low soil organic matter contents and over 7 Mha of olives, grapes and almonds, part of it grown on erosion prone, hilly land. Thus, it is mainly the South of Europe that requires the application of the principles of Conservation Agriculture. But also in many eastern countries, where huge areas suffer from water shortage, annual crop production could decisively benefit from the increase of the water holding capacity and a reduced evaporation if soils were cultivated according Conservation Agriculture principles. Nevertheless, despite the apparent favourable conditions in Central and Northern Europe providing high and very high yields, those are achieved with very high inputs, questioning the economic and environmental sustainability of farming. Again, the consequent use of minimum soil disturbance for crop establishment, soil cover through crop residues and cover crops and market-oriented but diversified crop rotations, could contribute in these regions to a reduction of inputs, mainly machinery, labour, fuel and fertilizers, and to a higher competitiveness of farming combined with a reduced environmental impact. Some countries in this region already succeeded to increase their acreage under Conservation Agriculture, especially Finland, UK, France and Germany, although the area under no-tillage is still very low.

The adhesion of many eastern European countries to the European Union represents an enormous challenge for the Common Agricultural Policy. The still poorly developed agricultural production systems in many of these countries, however, and the necessary modernisation of agriculture in these regions provide a great opportunity to introduce Conservation Agriculture and to take immediate advantage of its benefits, skipping the step of a modern but conventional agriculture with all its drawbacks. Depending on the predominant farm size, different strategies and structures will have to be adopted to enable this step forward. Russian and Ukrainian agriculture, for example, would benefit incredibly from a widespread implementation of Conservation Agriculture, as large areas are not cultivated due to the lack of necessary machinery.

Besides the necessities, different agri-environmental measures are already in place to reward the adoption of Conservation Agriculture. Carbon sequestration through the increase of soil organic matter and an emerging carbon trading is another aspect that Conservation Farmers should be aware of.

The revision of the Common Agricultural Policy will oblige farmers further to an environmentally
sustainable way of farming. Both the single farm payment and any additional agri-environmental measure payments will be based on the environmental compliance of all farming activities.

The preparation of a soil framework directive based on the perception of the major soil threats could also be decisive for a large-scale adoption of Conservation Agriculture in Europe. Five of the main eight soil threats (erosion, decline in soil organic matter, decline in biodiversity, soil compaction, floods and landslides), identified by the European Commission can be successfully tackled by applying the principles of Conservation Agriculture. However, it is up farmers, scientists, technicians, extension services to proof and convince politicians, decision-makers and other stakeholders, but also consumers and the overall society, that the primary sector is willing to comply with the new demands of farming and that Conservation Agriculture is the most straightforward way to achieve these demands in a large scale.

Conclusions and future challenges for the adoption of Conservation Agriculture in Europe

Although a considerable change in the discussion around Conservation Agriculture and an initial uptake of Conservation Agriculture methods took place in Europe during the past 5-10 years, Europe still lags far behind the uptake of Conservation Agriculture in South or North America. It seems however, that conditions became and become more and more favourable towards a widespread adoption of Conservation Agriculture systems both in annual and in perennial crops.

The reliance of Conservation Agriculture on the use of herbicides and the alleged increased input of herbicides and other chemicals for disease and pest control are the main constraint for the full acceptance of Conservation Agriculture as sustainable crop production concept in Europe. Thus, a strong effort has to be undertaken in order to show that Conservation Agriculture does not require increased pesticide input if compared to conventional farming, and that there is a change towards the use of less aggressive and non-persistent herbicides instead (Nalewaja, 2001). The implementation of balanced, nonetheless market-oriented crop rotations would further contribute to reduce external inputs (including herbicides) and should be one of the priorities of problem-oriented research.

A second and as important challenge is crop residue management. Both excessive and scarce amounts of crop residues, mainly cereal straw, hamper the successful uptake of no-tillage. The development of drilling equipment capable to handle 8 or more tons of straw per hectare and incentives to leave ssity to improve economic competitiveness, European Agriculture will have to comply with increased standards of environmental sustainability. Conservation Agriculture can provide both. However, European and national administrations are still not fully convinced that the concept of Conservation Agriculture is the most promising one to meet the requirements of an environmentally friendly farming capable to meet the needs of the farmers to lower production costs and increase farm income, and to meet the consumer demands for enough and affordable quality food with a minimum impact on natural, non-renewable resources. The trend to reward farmers for adopting environmentally beneficial technologies or, in the future, of establishing penalties for environmental damage occurring off-farm, is likely to promote the uptake of Conservation Agriculture practices, if duly recognized as environmentally fiendly production technology. In several European cou crop residues under extensive production conditions could transform an enormous acreage into successful no-tillage areas. A further decrease of tillage intensity must be accomplished and quality standards within Conservation Agriculture established.

Another important constraint to be overcome is knowledge transfer and the training of an adequate
number of technicians and advisors to attend the increasing demand of expertise required by farmers willing to change. The application of Conservation Agriculture means the break with traditional/conventional cultivation methods, a considerable change in attitudes and convictions and an open-minded and insisting effort to overcome constraints and problems that certainly will arise and for which there are no recipes to offer. Conditions in Europe vary a lot both over time and over space. Only the rapid exchange of experience and knowledge transfer based on practical experience that integrates farmers, technicians, extensionists and researchers will ensure the adaptation of farming to the challenges agriculture will face during the 21st century.

References


Controlled Traffic Farming Takes Conservation Agriculture into China

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Introduction

Conservation agriculture

The practice of conservation agriculture (CA) on a large scale emerged out of Brazil, Argentina and Mexico in the 80’s and has been practiced gradually in more than 70 countries on about 169Mha. Conservation agriculture is based on the principles of rebuilding the soil, optimising crop production inputs, including labour and optimising profits (Dumanski, et al., 2006). CA promotes these principles to achieve conservation objectives, which institute an incremental approach to sustainable farming, focussed on producing healthy soils. The principles of CA according to Dumanski, et al., (2006) are: a). Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through zero tillage systems. b). Crop rotations, cover crops and the use of integrated pest management technologies. c). Balance application of fertilisers, pesticides, herbicides, and fungicides with crop requirements. d). Precision placement of inputs (including permanent placement of wheel tracks). e). Legume fallows, composting and the use of manures and other organic soil amendments. f). Agroforestry for fibre, fruit and medicines.

Control traffic farming systems

In Australia and Mexico the contention is that without permanent wheel placement to stop random compaction, you can not truly move toward sustainable farming or conservation agriculture. The strategic bed planting research activities at CIMMYT over the past 15 years in Mexico, has successfully extended CA using zero till permanent bed planting as the platform and adequately demonstrates that zero tillage is not possible without permanent wheel tracks, in fact CTF systems enable zero tillage. In terms of soil amelioration, people have only thought of tillage effects, and not traffic removal and its effects on soils and processes, hence minimum/zero tillage farming concepts.

Soil compaction is widespread in cropping lands and occurs largely as a result of random field wheelings and land preparation from agricultural machinery. According to Whalley, et al. (1995), the processes of machinery and tillage are often disruptive and harmful to soil ecosystems. The use of tillage to remove compaction can be expensive in terms of the increased power requirement and fuel usage (Tullberg, 1998). Compaction is also cyclic and persistent under conventional farming systems (Alakukku, 1998). However, very few studies had looked closely at what happens to a degraded soil
environment when traffic and tillage is removed. But since the mid 90’s and more recently others such as Wang et al., (2005), have demonstrated that soil compaction significantly influences soil hydraulic and infiltration properties reducing the saturated hydraulic conductivity and alters the shape of the soil water retention curves, which are all indicative of soil health (Zhang, 2006), bearing in mind that this is only true if cyclic compaction from random traffic is removed. The technical basis of controlled traffic farming has been known for many years. Its adoption in the USA and Europe has met with little success and more widely ignored as the underlying basis for CA. Controlled traffic farming was originally trialled in Australia to combat soil compaction, but its rapid uptake was also due to a number of other benefits, such as facilitating zero tillage, stubble management, improved irrigation management and reducing farming inputs. Farmers increasingly frustrated with minimum and zero till recognised, under the stewardship of Dr Don Yule and the future CTF Solutions Group, that random traffic systems were failing to take full advantage of the benefits of permanent traffic lanes and uncompromised soil. Therefore from the mid 90’s controlled traffic farming systems have been widely adopted in Australia and about 2Mha of grains are now under the system.

**Chinese conservation agriculture**

Traditional farming systems in China are characterised by routine cultivation and removal or burning of crop residues. Pressure on the farming lands to maintain productivity has been increasing at a phenomenal rate to support the population of 1300 million. This pressure, in association with the harsh cultivation and residue removal regime, has led to severe land degradation, contributing to China’s unenviable status of having “among the most severe (environmental) problems of any major country. Especially affected are the dryland areas, which occupy 52% of the nation’s total area and 43% of the population. These lands are inherently fragile due to a combination of harsh seasonal variations in climate, inherently low soil fertility and annual rainfall of less than 500 mm.

Although China’s water resources total about 280 Mm$^3$, it is less than 500 m$^3$ per capita in northern China. Therefore water shortage is becoming the most limiting factor for Chinese development. Wheat is the main crop in northern China. More than 23 Mha of wheat was planted in 2004 with an output of 90 Mt. Traditionally, almost all of the wheat has been conventionally planted on intensively tilled, flat, flood irrigated land with corresponding low water use efficiency. However vegetables, peanut, cotton, tobacco, water melon, sweet potato, etc are planted on raised beds with furrow irrigation in order to get higher net return. Raised beds with furrow irrigation are recognised as beneficial for water management, but they do not extend to irrigated wheat production.

The Chinese government is very aware of the growing land degradation and water issues and have been actively creating several farm-based approaches to combat natural resource degradation, desertification and erosion. A vital approach is CA, which is a further development of the practices commonly termed Conservation Tillage (CT). CT is defined as “farm practices that leave a minimum of 30% of (crop) organic residues in the field”. In contrast, the key elements of CA, described previously, are applied as a package, because the power of CA comes from the synergy (interplay) of the various elements.

Chinese agriculture is experiencing an important transition phase after 15 years of research, experimentation and extension of CT. The government has issued national policies to encourage farmers to practice CA, because it is fully committed to the reduction of farming inputs, yield maintenance, reduction in land degradation and reduction in environmental pollution, but the on farm
adoption rate in poor rural area appears slow or non existent. To Australian and Mexican researchers and farmers, CA would seem like a natural choice for subsistence farmers of north western China. If there are so many advantages to the system why do farmers not adopt it right away? The major reasons are: a). Lack of technology, b). Lack of technology transfer, c). Lack of institutional support, d). Immediate benefits vary depending on environmental and economic situation and, e). Less need to take risks.

Research objectives

The aim of research in Queensland was to assess changes in soil following the implementation of a controlled traffic-zero till farming system (CTFS) after 50 years of conventional farming. In subsequent years the intention was to transfer that knowledge to high altitude, arid farming regions of north western China. The technology transfer commenced in 1992 with an ACIAR project based in CT dryland systems over 10 years. In 2005, a new ACIAR project introduced and commenced extending CA, by using practises such as zero tillage and permanent raised beds (PRB), to reduce irrigation water use, maintain farm yields and improve farmer incomes in irrigated wheat systems.

Australian methodology

The Australian study was conducted on structurally degraded black cracking clay, which had been cropped conventionally since 1945 in the Lockyer Valley, Queensland, to demonstrate the natural regeneration of soils and the impact of traffic removal. A CTFS was established on 3m wheel centres and after each planting, over four seasons, soil measurements and observations were made in track and cropping zones. Rate and depth of soil amelioration from biological activity of previous cropping seasons was assessed by changes in hydraulic conductivity ($K_s$) plant available water capacity (PAWC) and bulk density.

Conclusions and discussion

At the start of the study $K_s$ was very low in comparison to other well structured soils. However, after 7 months of nil traffic $K_s$ increased by 60%. At the end of the study $K_s$ had increased to 125 mm.h⁻¹, at 100 mm below planting depth and at 200 and 300 mm depths it had increased by 50 mm.h⁻¹ on initial values. Track zone $K_s$ remained constant (~22 mm.h⁻¹) over the four cropping seasons (Figure 1).

Under conventional tillage conditions, field capacity was measured at 0.36 g.g⁻¹ and after 22 months of nil traffic it increased by 7% to ~0.39 g.g⁻¹. Moisture content at wilting point improved by 6.5% after 22 months of nil traffic, changing on average over the 0.3m depth from 0.29 g.g⁻¹ to 0.267 g.g⁻¹. Under conventional tillage conditions PAWC was less than 10 mm per 100 mm depth of active rooting zone. However, after 22 months of nil traffic, PAWC increased by 63% to >15.9 mm per 100 mm depth of active rooting zone. Track zone PAWC remained constant at <10 mm per 100 mm in the top 400 mm of soil (Figure 2).
Figure 1. The average unsaturated hydraulic conductivity of the soil matrix ($K_{\text{matrix}}$ mm.l$^{-1}$) grouped by depths and position for months after nil traffic (after implementation of CTF) through four seasons.

Figure 2. The change in PAWC (mm) in 0.3m of active root zone for the cropping and wheeled zone after 22 months of controlled traffic farming on an area previously cropped conventionally (random traffic).

The bulk density values measured at time zero of \textasciitilde1.4g.cm$^{-3}$ appeared consistent with soils observed under continuous conventional cotton and wheat production. In comparison, bulk densities of 1.1-1.2g.cm$^{-3}$ have been measured in virgin soils for depths of 0.1–0.3m. Bulk density in tracks at 100mm depth remained constant, indicating the effect of cyclic compaction, by comparison, bed and adjacent position bulk density declined. The largest changes in bulk density occurred in the upper layers that are predominantly influenced by weather conditions. The reduction of bulk density through natural amelioration over time was significant, reducing by 0.23% per month of CT and increasing in rate during the latter part of the study. Root growth as a percentage of maximum root growth at the beginning of the study would have been close to zero, but 22 months after implementation of CTF in the 100-200mm soil layer, it was less than 50%, and at depth, less than 30%. This change in bulk density equates to a probable increase in root growth of \textasciitilde15%.

Over the period of the study changes in hydraulic conductivity, PAWC and bulk density indicated movement away from a soil profile with a predominance of micropores (<30 m diameter) to a profile that included a range of larger transmission pores up to 350 m in diameter. Development of micro cracks, larger planar voids and biopores formed by drying processes persist in non-wheeled soil,
increasing pore interconnectivity and pore size distribution. These seasonal improvements in soil structure accrued and expanded down through the profile. However the rate of change was very dependent on cropping zone soil ageing processes since the last tillage/traffic event. Initially, any changes in structure due to reduction or absence of tillage and traffic were small, because it remained difficult for roots to penetrate the soil. Once a few roots penetrated and the effects of drying accrued, the natural cycle of amelioration proceeded. The better the drying, the better the structural improvements, the better the root environment and quickly the entire biological and physical systems interact, moving toward the soils natural structure. However, based on this studies data, to naturally ameliorate the soil from a degraded state to a condition, that is, halfway toward a non-degraded clay soil, could take 5-9 years. But even over the short study period the transitory nature of tillage was demonstrated and even the soil moisture characteristic can be affected by agronomic management.

![Figure 3. Change in average bulk density (g.cm$^{-3}$) in cropping and track zones at 3 depths. Grouped by depth for months after CTF implementation.](image)

**Summary**

Under conventional (random traffic) farming operations, amelioration may be achieved at considerable cost by soil amendments and intensive tillage, but the results are often transitory and are inadequate for a self-sustaining cropping system. Soil amelioration in the cropping zone was evident after 3 years of isolation from wheel traffic. This was demonstrated by:

a. Hydraulic conductivity increased by 65% (all layers 0-400mm).

b. PAWC increased from 9-16mm per 100mm of active root zone in top 400mm.

c. Bulk density decreased by 9% in the cropping zone from soil surface to 400mm.

**Conservation agriculture in China**

Gansu is a north western Chinese province in the Yellow River upper drainage basin and between Gansu and neighbouring Inner Mongolia lies a distinct valley, the Hexi (Her She) Corridor with an annual rainfall <200 mm. Zhangye City (Pop. 800,000) is centrally located in the corridor.
Over the past 2000 years, reliable snowmelt water from the adjacent Qialian (chilian) mountains has sustained irrigated agricultural along the length of the valley. In more recent times (last 30 years), reduced snowmelt water has led to significant reductions in arable land, reduced surface water, and decreased recharge of groundwater levels. As a consequence, farmers are facing severe water restrictions (50% reduction in allocations). Other crop production issues such as small farms, low levels of mechanisation, high inputs, conventional tillage, high wind erosion, soil degradation and low incomes are placing further pressure on farmer livelihoods. Therefore the aim of this project was to introduce and develop CA using PRB, to reduce irrigation water use and wind erosion, maintain farm yields and improve farmer incomes.

**Chinese methodology**

Experiments were conducted at the Zhangye research station, on eight 400m$^2$ plots and on three 1700m$^2$ demonstration fields in Shandan County, 60km to the east of Zhangye City. This was a comparative study between district conventional practices (CT), PRB, permanent flat beds (ZT) and Fresh Raised beds (FRB) (Table 1.)

**Conclusions and discussion**

The different cultivation methods had considerable effect on a number of agronomic parameters, selected results are shown in Table 1. CT yield was the highest, followed by PRB at 8% less and then ZT. However, these yields were not significantly different at $P<0.05$. Interestingly, PRB was planted after CT at much lower planting density, planted area and with resultant poorer emergence (65%), (attributed to prototype planter, frozen subsoil and fertiliser burn), yet yields were similar, and both crops were ready for harvest at the same time. This suggested if basic agronomy under the new system is perfected and soil amelioration by freezing and thawing continues, PRB could have significantly higher potential than CT farming to improve yields and farmer incomes. Total NPK and available NPK were the highest in PRB treatments compared with CT by 36.54%, 77.39%, 12.17% and 5.56%, 6.67%, 3.77% respectively. PRB organic content was also highest, probably due to zero tillage and permanent tracks enhancing bacterium, actinomyces and fungal quantities in the soil (Table 1.). PRB plants were shorter than CT treatments, but had larger leaf areas (Table 1.). Increased vigour and partitioning of photosynthates were readily observed in zero till treatments, possibly due to increased sunlight and availability of nutrients adjacent to tracks. Applied irrigation water was 223mm less for PRB, the equivalent of two irrigations. Considerably more water could be saved once the technicians at the research station gain further experience in irrigation scheduling and water measurement. This season’s irrigation of CT sites were scheduled and monitored as for the other treatments. That is, the Chinese technicians did not follow district practice, which apparently applied 7 irrigations, (estimated at 6 of 100m$^3$/mu and 1 of ~50m$^3$/mu) approximately1000mm plus or minus rainfall. If this irrigation volume is anywhere near reality it could mean that CA (PRB/ZT) farming could reduce irrigation water use by 50% with minimal measurement and scheduling.

**Table 1**  Comparison of field preparation, irrigation volume, planting parameters and yield for four wheat production methods during a single season in Hexi corridor.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>FRB</th>
<th>PRB</th>
<th>CT</th>
<th>ZT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubble / cover after planting (%)</td>
<td>0</td>
<td>20cm standing / 86</td>
<td>0</td>
<td>20cm standing / 10</td>
</tr>
<tr>
<td>Mould board plough</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Harrowing  
Roller  
Form beds/renovation  
Irrigation + rainfall (mm)  
Planting Date  
Planting population/mu (667m$^2$)  
Emergence (%)  
Yield (kg/ha) $P<0.05$  
wt/1000 grains (g)  
Leaf area (flag leaf stage) cm$^2$/20plants  
Incidence of soil borne fungi

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harrowing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roller</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form beds/renovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation + rainfall (mm)</td>
<td>766</td>
<td>560</td>
<td>783</td>
<td>699</td>
</tr>
<tr>
<td>Planting Date</td>
<td>28/3</td>
<td>26/3</td>
<td>22/3</td>
<td>30/3</td>
</tr>
<tr>
<td>Planting population/mu (667m$^2$)</td>
<td>333400</td>
<td>339900</td>
<td>410400</td>
<td>373500</td>
</tr>
<tr>
<td>Emergence (%)</td>
<td>64.45</td>
<td>65.71</td>
<td>85.36</td>
<td>77.68</td>
</tr>
<tr>
<td>Yield (kg/ha) $P&lt;0.05$</td>
<td>5306.17$^b$</td>
<td>5575.87$^b$</td>
<td>6088.57$^a$</td>
<td>5420.32$^b$</td>
</tr>
<tr>
<td>wt/1000 grains (g)</td>
<td>42.38</td>
<td>41.80</td>
<td>40.27</td>
<td>43.50</td>
</tr>
<tr>
<td>Leaf area (flag leaf stage) cm$^2$/20plants</td>
<td>1678.96</td>
<td>1564.33</td>
<td>1140.82</td>
<td>1659.64</td>
</tr>
<tr>
<td>Incidence of soil borne fungi</td>
<td>1.5$\times$10$^3$</td>
<td>3.4$\times$10$^3$</td>
<td>3.9$\times$10$^3$</td>
<td>2.7$\times$10$^3$</td>
</tr>
</tbody>
</table>

**Conclusion**

Conservation tillage research started with the support from the Ministry of Agriculture (MOA) and an Australian Centre for International Agricultural Research (ACIAR) project in 1992. In 1999 MOA established the Conservation Tillage Research Centre and an ongoing CT demonstration project in northern China. By 2004 there was more than 4,000,000ha in 100 counties from 14 provinces under CT. CT is widely viewed as a new agricultural revolution by many agencies in China. However, after a single season of CA using PRB during 2006 in Hexi, the potential benefits are clear, as clear as they are in Australia and the Americas. The challenge now is for Chinese agricultural to embrace the next step in the agricultural revolution, Conservation Agriculture.

**References**


Why Conservation Agriculture for the Canadian Prairies and Western China

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Introduction

Recent studies report that 99% of food consumed by humans comes from the land. Soil degradation is responsible for making from 2-12 million ha or 0.3 to 0.8% of the world’s arable land unsuitable for agricultural production every year, with wind and water erosion accounting for 84% of the total degraded area. Good soil management is therefore required to protect the soil against further degradation and to sustain the long-term productivity of our soil resource in order to meet the world’s future needs for food and fiber.

The solution to soil degradation from wind and water erosion is working with soil and crop management systems that maintain sufficient crop residues either anchored or partially anchored on the soil surface. This knowledge has been known for a long time and it is only until recent times that the necessary technology has been developed to make conservation agriculture a reality on Canadian prairie farms.

The extent of soil degradation was well documented in Canada in the eighties. The Government of Canada established some important initiatives and programs which when combined with innovative initiatives at the farm gate addressed soil degradation. Canada has vigorously promoted conservation agriculture because it provides the best solution to soil degradation. The use of conservation agriculture on Canadian farms started in the seventies and rapid adoption occurred in the early nineties.

Sonntag and Honglie (2002) documented the situation of soil degradation in China recently and identified the ever increasing problem of desertification. Based on the Canadian experience, we believe that Chinese farmers will adopt conservation agriculture but they need some time to assess the risks and benefits of the change and to learn the new technology and associated production practices.

Problems and solutions

Problem #1: One of the major causes of soil erosion on the Canadian prairies associated with continuous cropping systems was excessive tillage. Due to inability of seeding equipment to handle surface residues and standing stubble, farmers felt compelled to partially bury the crop residues to ensure proper operation of the seeding equipment. Excess tillage in the fall pulverized the soil and left the surface soil without protection from crop residues and therefore vulnerable to wind and water erosion.

Solution(s) #1: One of the solutions was to reduce the number of tillage operations to ensure that enough residues were left on the soil surface to protect the surface soil without impeding proper seed to soil contact that ensures proper crop establishment. Another solution was the development of air
seeding equipment that was capable of proper seed placement under heavier surface residues and standing stubble conditions. This technology allowed the farmer the ability to seed and cultivate at the same time thus providing weed control. This approach also ensured that enough residues were left on the soil surface to protect the soil from wind and water erosion.

Problem #2: In the drier areas of the Canadian Prairies, farmers employed fallow cropping systems as a way to conserve more water and to make nitrogen available for the subsequent crop by mineralization of the soil organic matter during the fallow season. This meant that fields were not cropped for one season. In order to control weeds, farmers employed tillage. Over the course of the fallow period, the tillage required to control weeds resulted in loss of crop residues and soil pulverization which in turn made the soil vulnerable to wind and water erosion due to lack of ground cover. However another form of degradation was also observed. Over time, we observed more problems with lost of soil organic matter, salinization and leaching of nitrogen below the rooting zone. We also observed a gradual decrease in soil N mineralization and the needs for supplemental nitrogen was needed to maintain crop yields even on fallow fields.

Solution #2: One of the first radical change observed in the drier areas of the prairies where fallow cropping systems were employed, was a shift from tillage fallow to chemical fallow. This shift occurred in stages until herbicides, like glyphosate, could compete economically with tillage to control weeds during the summer fallow period. This meant that the surface and anchored residues were maintained thereby protecting the soil from wind and water erosion. It reduced but did not eliminate the problems associated with nitrate leaching. When this was combined with the first airseeders capable of seeding and cultivating in one operation, it ensured sufficient ground cover until the growing crop could protect the soil. Over the years as conservation agriculture evolved to conserve more water, we observed a shift from fallow cropping to continuous cropping with greater crop diversification.

Canadian examples

A number of tillage studies were initiated in the sixties and expanded in the eighties on the Canadian prairies to determine the performance of conservation agriculture relative to the conventional tillage system in use at that time. We will refer to results from a more recent study located mid-way between semi-arid and sub-humid areas of the Canadian prairies. The study consisted of quantifying the effects of three tillage methods [no-till, minimum till and conventional till] and three four-year crop sequences [spring wheat - spring wheat - winter wheat – fallow; spring wheat - spring wheat - flax - winter wheat; spring wheat - flax - winter wheat - field pea] on agronomic and economic performance over a 12-year period. Conservation tillage (reduced and no-till) showed a yield benefit over conventional till of 7, 12.5 and 7.4% for field pea, flax and spring wheat grown on cereal stubble, respectively. Much of the yield increase was due to an increase in soil water in the 0-30 cm soil layer. Overall, rainfall accounted for 73, 72, 67 and 65% of total water used by field pea, flax, winter wheat and spring wheat, respectively. This explained the large year effects on grain yields as a result of variation in growing season (May-August) precipitation. The positive benefits of conservation agriculture were expressed over a wide range of growing conditions and the study also showed that knowledge about cropping systems developed under more conventional tillage practices also apply to conservation agriculture. The economic analysis demonstrated the superior performance of conservation agriculture and reduced overall production risks.
Lessons from Canada

In the process of conducting conservation agriculture research and observing the evolution and adoption of conservation agriculture by farmers, some important principles were observed and some unexpected benefits uncovered.

In terms of principles, crop residue management is critical to successful conservation agriculture. Given that crop residues are left standing or on the surface of the soil implies that proper management is necessary so as to not impede planting or crop emergence. On the Canadian prairies, this involves chopping the straw and uniformly spreading the cut straw and chaff on the soil surface and this usually occurs during the harvesting operation. Many failures in the early adoption could be ascribed entirely too poor crop residue management.

The next important principle is crop rotation. Crop rotation provides control of root and leaf diseases and of certain insect pests. It also ensures different types of residues that may simplify management. For example residues from crops like canola, are much easier to seed through than that from cereal residues while pea residues for example will decompose more rapidly than cereal residues because of the higher nitrogen content.

The presence of surface residues also creates a dilemma with respect to nutrient management and more specifically nitrogen fertilizer management. Nitrogen is more effective when applied at time of seeding to be in contact with the soil beneath the surface residue but away from the seed to avoid germination and emergence problems.

Another important principle is appropriate seeding equipment. The equipment must have the desired configurations and specifications so as to be able to penetrate undisturbed soils and capable of seeding through above-average residue conditions for a wide range of crops. It must also be capable of separating seed and fertilizer when using a one-pass seeding and fertilizing operation to prevent damage to germinating seeds and emerging seedlings. It must be capable of uniform and shallow seed placement. Some general rules have been formulated with respect to the design of seeding equipment for reduced and no-till production systems. These rules include the minimum distance between openers on a given rank, the distance between the different ranks of openers on the tool bar and the minimum distance between the soil surface and the frame of the tool bar. Care must also be taken during the design of the tool bar to avoid pinch points where crop residues can get caught.

Given that conservation agriculture means partial or complete lack of tillage implies that some alternative form of weed control is required and this usually involves the use of herbicides. Special care and attention must be given to weed control. If the above principles are adhered to and clearly understood, success with conservation agriculture should be obtained.

With the evolution of conservation agriculture on the Canadian Prairies, we also observed other important benefits. For example, research with stubble height in the drier areas of the prairies showed that grain yields and water use efficiency could be increased in crops like spring wheat, field pea, lentil and chickpea when grown in stubble of 30 -35 cm in height. In addition, conservation agriculture was capable of increasing soil organic carbon thereby increasing soil quality and making soil a sink for carbon dioxide, an important greenhouse gas.

Potential benefits for China

Western China is currently faced with devastating sand and dust storms, conditions that are similar to
the Canadian Prairies in the 1970’s and earlier. Some of causes can be attributed to improper soil management practices. Therefore, the adoption of conservation agriculture provides an important solution to this problem. This is very important to the long-term sustainability of food production in China. Reducing dust storms will also reduce health hazards. As observed on the Canadian Prairies, not only does conservation agriculture protect the soil but it can also enhance soil quality, productivity and overall economic returns on a long-term basis.

Conclusions

The climate of Western China has many similarities to that of the Canadian Prairies. Conservation agriculture has successfully been adopted on many parts of the Canadian Prairies therefore it could also be successfully adopted in China. The knowledge, principles, technology and approaches to conservation agriculture developed on the Canadian Prairies are, too a large extent, applicable to Western China. Canada can assist the conversion of China’s large and small farms to conservation agriculture. The key to conservation agriculture is to keep crop residues on the fields. This could impose a major challenge in China as farmers are highly dependent on crop residues for animal feed and also as a source of domestic fuel.

References

China has experienced significant soil loss and degradation under both wet and dry climatic conditions because of extensive management of cropping and animal production. These production systems that involve significant tillage and sub-soiling for weed control and seedbed preparation, and extensive removal of crop residues by gathering for fuel, feed, bedding, animal grazing or burning. The soil lost is the most valuable topsoil and generally reduced soil fertility. This loss has also accelerated desertification under dry climatic conditions.

Conservation agriculture or the sustainable use of soil, water, and nutrient for crop and animal production has been proposed as a solution that will reverse the existing downward trend in the quality of China’s soil resource. Conservation tillage (CT) is one important part of this solution. In the Chinese context CT is described as a crop production system that preserves a minimum of 30% of the surface crop residues from the preceding growing year. In the Canadian context, conservation tillage is defined more broadly to include those tillage, herbicide and cropping practices and principles that reduce wind and water induced soil erosion to sustainable levels while maintaining or improving soil quality and overall economic viability of the farming system. Canadian uses a system approach to CT for crop production. For large size of farm field, mechanized farm equipment is essential for successful CT and this equipment might not be applicable to small size of fields. Equipment design, operation, and use within the cropping system therefore must consider all aspects of the crop production system, including seeding, fertilization, weed control, and harvest such that the soil and water resources are preserved as much as possible while maximizing the economic production of field crops. Therefore, equipment design engineers have to work closely with specialists in other disciplinary such as in above-mentioned fields.

In Canada, CT has come to be described by the following characteristics

1. Crop residues are chopped and spread or gathered following harvest, but adequate crop stubble is left on the field to protect the soil from erosion, reduce moisture loss, and trap snow to improve spring soil moisture for the germinating crop;

2. Except for fertilizer injection, there is no pre-seeding soil disturbance unless crop residues pose a problem for seeding;

3. Soil inversion caused by a mouldboard plough or disc implement is done only when crop residues pose a serious problem for the seeding operation. This type of operation is done only immediately prior to seeding to preserve soil moisture and reduce the chance for soil erosion.

4. Weeds are controlled with herbicides and crop rotation. Cultivation is only used under certain special circumstances and the cultivation must be done in a way that it preserves surface residues.

At least 30% of the previous crop’s stubble remains on the top of field after seeding to protect seedlings, soil from erosion, and preserve soil moisture for the germinating crop. This system has improved crop yields, soil quality, and reduced economic costs and risks for Canadian Prairie farmers. Conservation tillage begins at harvest of the crop in the preceding year. It is imperative that crop
residues are properly managed if CT is to be successful. Adequate crop residues must be retained on the land to provide adequate protection from wind and water erosion. A portion of these residues (~750 kg per hectare or 25 jin per mu) should be left as standing for Canadian Prairies, anchored stubble whenever possible, with the rest of the residues either removed or chopped and spread evenly into the standing stubble immediately following the harvest. For cereals, this generally means cutting the ripe crop at a height of 15 to 25 cm and using of straw choppers and chaff spreaders mounted on combine harvesters to spread residues evenly across the harvested field. Existing Chinese harvesters generally do not have straw or chaff spreading technology. See Figure 1 for a comparison of the spread of residues after Canadian and Chinese combines.

![Figure 1: Canadian and Chinese combines, and concentrated residues from a Chinese combine.](image)

The seeding operation requires special consideration in CT systems. The major items to consider are crop types, soil conditions, fertilizer requirements, crop residue amounts, and power requirements.

**Crop Types:** Each crop has a proper depth for planting, a proper planting density, and proper row spacing to maximize crop yield. In China, a CT seeder would ideally be able to plant crops with seeds as small as flax and canola (15 – 25 mm deep), or as large as soybeans or corn (50 – 80 mm deep). This requires seed row spacing from 15 cm to 40 cm, depending on crop type, location, and growing season moisture. However, no matter what type of crop is sown, the seeder must be able to plant the crop at a uniform depth throughout the field.

**Soil Conditions:** The presence of stones, soil moisture conditions, and typical soil structure affect the design or choice of the seeder or seed opener. Stones will require tripping mechanisms and rugged designs for either disc or hoe openers. The choice of hoe or disc opener depends on fertilizer placement, overall seeder cost, crop residues routinely expected from crops grown, soil type and soil physical conditions to be created.

Soil that lacks good structure may be resistant to proper seed opener penetration and create many soil lumps in the seed furrow making proper furrow packing and seed to soil contact difficult. In this case on-row packing generally improves crop emergence and potential yield in dryland farming systems. The packer should be design to match or exceed the width of the seed furrow, operate in a wide variety of soil moisture conditions, and provide good seed opener depth control when the packers are used as the seed depth controlling mechanism.

**Fertilizer:** Given the low fertility often seen in some of eroded soils in China, the seeder should be designed to place fertilizer with or near the seed in such a way that the fertilizer maximizes the economic return from the crop. Recommendations for fertilizer placed with the seed are deeper than
that placed between rows or banded away from the seed in the seeder furrow and these recommendations are available through other extension publications. The terms ‘single shoot’ and ‘double shoot’ refers to how the seed and fertilizer are delivered to seed opener. A single shoot system places the seed or the seed granular fertilizer in the same place in the furrow. A double shoot opener places the seed and fertilizer in separate locations in the seed furrow. Optimum placement in double shoot systems depends on crop type, but a generally accepted practice is to locate the fertilizer 25 mm below and 25 mm to the side of the seed in the furrow.

**Crop Residue:** Crop residue that is adequately spread or removed, with anchored standing stubble present on the soil surface can be managed by designing the seeder with adequate spacing between each seed opener and seed openers with minimal soil disturbance. Disc openers usually have minimal soil disturbance but may require significant amount of seeder weight to press them into the soil to an adequate depth for each crop. Narrow knife or hoe openers may increase the amount of soil disturbance, but generally do not require excessive amount of seeder weight to reach the proper depths. Also, as soil disturbance increases, more stubble is knocked down and loosened which may become a problem for successful CT seeder operation.

**Power Requirements:** The tractors used in China are generally low horsepower units equipped for three point hitch operation. Given that three point hitches are commonly used for field implements, often the limit of opener number is determined by seeder weight. Power requirements for seeders depend on the number of seed openers, seeding depth, opener type, and operation speed.

CT may require tillage for seedbed preparation, weed control, levelling, or structural improvement for problematic soils. Some general principles for tillage for these purposes should follow some general rules:

1. Maintenance of crop residues on the soil surface. Sweep type cultivators, rod weeders, light harrows, or a combination or a cultivator with one of the latter implements mounted or drawn behind can be used for seedbed preparation. This also means that the use of sub-soilers, mouldboard or disc ploughs should be avoided. The figure 2 illustrates some tillage equipment options.

2. Maintenance of good soil aggregation. This requires tillage that is done at a speed adequate to disturb the soil for levelling, residue spreading, and weed control, but not so fast as to cause excessive breakdown of soil aggregates or bury the surface residue. Also, mechanical or powered tillage should not be considered because of the excessive damage to soil aggregates and surface residues, and the
subsequent loss of soil moisture and soil particles by erosion.

3. Proper timing. Whenever possible, seedbed tillage should be done as close to the time of planting as possible to prevent excessive soil moisture loss. In addition, tillage should not be used following harvest to prevent over winter loss of moisture, snow, and soil.

With the reduction in field tillage, weed control needs to be done using a combination of crop rotation, tillage, and herbicides, either applied in-crop or as pre-harvest desiccants and/or pre-seeding weed control, the latter being accomplished by a non-selective herbicide, such as glyphosate. Good weed control requires:

1. proper weed identification. Herbicides are effective if applied to the proper target weed community, so early and proper identification of weeds in the crop is an important first step.

2. proper herbicide selection. Depending on the types of weeds present, one or two herbicides may be applied at the same time to achieve economic control.

3. proper timing. This requires the application of the herbicide according to the crop and weed growth stage to effectively kill the weeds without crop damage. For example, in the case of spring pre-seeding spraying, Canadian experience has shown that this application should be done approximately 1 week before seeding when seedbed tillage has not been done regardless of the number or types of weeds present.

4. proper herbicide application. Proper spraying equipment is essential for herbicide application. For tractor powered sprayers, there are three main components that must be in good repair: the tank, lines and filter (plumbing), the pump, and the nozzles and boom. The nozzles are the first consideration as they must be able to apply the correct amount of spray mixture in a consistent pattern to the field without excessive spray drift. The nozzles should be mounted with the proper spacing on a boom that is placed on the sprayer at the proper height above the crop canopy. This is essential to ensure the spray pattern provides full coverage of the field without excessive overlaps or dripping, which would damage the crop. The pump, lines, and filter must then be matched to the nozzle type and the number of nozzles so that it can provide the correct amount of spray mixture at the correct pressure consistently across the field. The tank should be large enough to provide a reasonable amount of spray mixture for the size of field normally sprayed.

There are several general principles that should be considered for effective sprayer operation. Cleanliness of the tank and all lines, filters, pump, and nozzles is critically important to ensure consistent operation. Clean water with a neutral pH should be used to prevent herbicide deactivation, plugging of the filter and nozzles, and the inconsistent application of herbicide and lost time that can result. The water and herbicide must be thoroughly mixed prior to application to the crop. Wind direction and speed must be closely monitored to ensure any spray drift that does occur does not affect a susceptible crop adjacent to the sprayed field, and that the chemical reaches the target weeds. The time of day, air temperature, and the presence or expected occurrence of dew or rain must be considered as the effectiveness of some herbicides may be affected by these factors. As with all farming operations, good safety practices need to be followed, and this is especially true when handling and spraying pesticides of any kind. Operators need to limit their exposure and exposure by other people, livestock, and other animals and plants by the proper use of protective equipment, handling, and operating procedures.
In conclusion, the CT equipment information provided in this paper is meant as a basic introduction to the principles of equipment selection and operation. It also indicated that the equipments are tools for CT production systems. The tools have to achieve proper seeding, fertilizer application, pesticide application, residue management, harvest and soil protection. In order to achieve those objectives, the agriculture engineers who design various CT equipments must work closely with other disciplinary such as agronomist, weed control specialist, soil scientist, pathologist and entomologist etc. As China develops CT farming practises suited to its crop types, soil types, and farm scale, farm equipment that is reasonably priced, reliable and effective will need to be made available to Chinese producers. Training in proper equipment selection, operation, and maintenance will also be necessary as farmers receive and adopt new ideas concerning crop rotation, fertility, crop protection, harvesting, and residue management within a complete CT system. There is a significant difference between the CT equipment design and operation as practised in Canada and the existing tillage equipment and systems currently used in much of the dryland farming in China, and it is hoped that the lessons learned in Canada can provide assistance to Chinese agriculture.
Conservation Agriculture: Western Canada Experience in Effects on Soil Quality

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Previous articles have discussed the principles of and developed techniques for the conservation agriculture in Canada. This article will focus on one of the key benefits of conservation agriculture.

One of the main objectives of conservation agriculture is to maintain or improve soil quality. What is soil quality? Agriculture and Agri-Food Canada defines soil quality as “soil's fitness to support crop growth without resulting in soil degradation or otherwise harming the environment”. Soil quality can be measured with soil indicators such as soil organic matter content (SOM), soil physical indices (such as soil structure, infiltration, bulk density, and water holding capacity etc), chemical indices (pH, electrical conductivity, extractable N-P-K, mineralizable N, and plant available nutrients etc.) and biological indices (microbial biomass C and N, soil respiration rate, and microbial activity properties etc.).

How do conventional/non-conservation agriculture production systems affect soil quality? Conventional agriculture production systems in Western Canada often involve intensive tillage, mono-culture cropping or summer fallow in small grain rotations. The intensive tillage would invert the soil and bury crop residue and leave a bare soil surface for part of the year. In this process, it achieves:

1. The reduction of previous crop residues that interfere with herbicide/fertilizer application or seed placement
2. The control of germinated weeds
3. Easier placement of soil-applied herbicides or fertilizers
4. A loose seedbed to facilitate easy seed placement, good aeration, water infiltration and a warmer soil.

At the same time intensive or unnecessary cultivation:

1. Increases energy consumption
2. Depletes seedbed moisture
3. Degrades soil structure and promotes crusting
4. Creates conditions conducive to soil compaction
5. Intensifies soil organic matter decomposition and increases soil and organic matter loss through erosion

The main benefits of conservation agriculture or even no-till, with appropriate agronomic management, include:

1. Almost no soil erosion because of crop residue retention (especially in sandy soils);
2. Greater flexibility of farm operations through less time used for cultivation and seedbed preparation;
3. Improved soil structure leading to better trafficability, more manageable soils and more timely seeding;
3. With appropriate equipment more precise seed placement with more uniform crop emergence;
4. More water harvested and improved water-use-efficiency to grow the crop in dry areas;
5. Greater microbial diversity and biomass retention leads to a more ecologically active soil that improves nutrient availability and earthworm activity;
6. More competitive crops often reduce the need for in-crop weed control with herbicides
7. Less labour, fuel and machinery costs per hectare; and
8. Better whole farm profitability and sustainability.

With the availability of safe and effective non-residual herbicides and the development of seeding technologies that enhance the feasibility of no-till production, the need for traditional tillage is questionable, except in special circumstances. With no-till or reduced tillage the retention of crop residues has the potential to improve soil organic matter content (Table 1) and conserve soil moisture (Fig 1). The soil organic C contents of surface 15 cm soil have increased in the Canadian Prairie by the adoption of no-till practices (Table 1) in non-fallow rotations. The available water content (AWC) in the 150 cm soil depth under no till (NT) was higher than under conventional till (CT) in 7 of 11 years in Lethbridge, Alberta (Fig. 1). The high AWC would result in higher crop production. The high crop residue returned to the soil under NT would increase soil protection from soil erosion (Fig. 2, 3 and 4) and maintain or increase surface soil organic matter content (Fig. 2). Thus, it will improve soil properties and increase sustainability. It can also improve and modify soil biological activity (Fig. 4), which provides improvements in all aspects of soil fertility and biological soil processes. These improvements lead to better farm management and sustainability.

The purpose of assessing soil quality is to measure aggregate stability, biological activity, or some other soil property. The fundamental purpose of improved soil quality is to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms. Conservation agriculture could help enable farmers achieve this critical objective.

References

Table 1. Estimated gains in soil C in no-till or reduced tillage treatments relative to conventionally-tilled treatments. (Adapted from Janzen et al 1998)

<table>
<thead>
<tr>
<th>Site</th>
<th>Years</th>
<th>Depth (cm)</th>
<th>C gain (Mg ha⁻¹ y⁻¹)</th>
<th>Treatment</th>
<th>Baseline</th>
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<td>Stewart Valley, SK</td>
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</tr>
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</table>

Figure 1. Ratios of available water content (AWC) between no till (NT) and conventional till (CT) treatment (NT/CT) in 150 cm soil profile at Lethbridge (adapted from Larney and Lindwall 1995).
Figure 2. Leaf litter improving soil structure, organic C and soil microbial activity.

Figure 3. Poor soil structure, vulnerable to wind and water erosion induced by tillage.

Fig. 4. No-till canola seedlings emerged through the retained surface residues.
Retained residues increased surfacessoil moisture content and improved crop emergence.
Impact of Crop Rotations on Conservation Agriculture

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Introduction

Crop rotations involve growing different crop species in consecutive years on the same piece of land. This practice has been used for many centuries and is still in practice today as a result of the many direct and indirect benefits. Crop rotations coupled with conservation tillage can enhance soil physical properties, improve seasonal nitrogen mineralization, and provide nitrogen inputs through symbiotic nitrogen fixation by legumes. In general, grain yields of crops grown in rotations are frequently 10-30% greater than those when grown in continuous monoculture.

Crop sequences for rotations and Canadian examples

Selection of crop types must consider soil conditions (soil type, topography, drainage) and climate (growing season, precipitation amount and distribution, and temperature or heat accumulation). Similar crop types are often prone to suffer from the same soil borne pests and diseases; therefore it will be helpful to alternate the sequence and perhaps change the frequency of crop types in the rotation to prevent the build-up of pests and diseases in the soil. Oilseeds, pulse crops and broadleaf crops are often included in rotations with cereal crops. Usually, it is advisable to not grow more than two cereals or broadleaf crops in succession. New crop rotations are often created to adapt to the changes in market demand.

Common crop rotations in arid or semi-arid regions such as western Canada are cereal – oilseed – cereal – pulse legume, where soil water conservation prior to spring planting is the key for the success of the crop in any particular year. Cereals include spring wheat, barley, durum, oats and rye; oilseeds include canola or rapeseed, flax and sunflower; pulse legumes include field pea, lentil, chickpea and field bean. Warm season crops such as corn and soybeans are the major cash crops in eastern Canada. They require good seedbed conditions in the spring time and adequate moisture during the growing season to achieve their yield potential. Common crop rotations in eastern Canada include corn – soybean – wheat, corn – soybean and soybean-wheat.

General benefits of crop rotations

Crop rotations improve economic benefit and crop yield

The economic benefits of crop rotations are achieved through increased yields. The improved yields are demonstrated in long term rotation experiments established on a loam soil in Ottawa, Ontario in 1992 and on a clay soil in Woodslee, Ontario in 1959. Corn yields in a corn-alfalfa rotation with no added nitrogen fertilizer in the Ottawa experiment were similar or greater than a continuous corn
treatment which received the recommended amount of fertilizer. Similarly, corn following soybean often produced yields which were comparable to well fertilized continuous corn. Both alfalfa and soybean are legumes which are capable of fixing atmospheric nitrogen through a legume-Rhizobium symbiotic system. At the Woodslee experiment, grain yields of fertilized corn in a four-year rotation (corn-oats-alfalfa-alfalfa) have steadily increased over time. For example, yields for rotation corn were consistently about 25% higher than for fertilized continuous corn (Figure 1). Soils from the rotation plots contained higher concentrations of organic carbon and had better soil structure than soils under continuous corn.

![Figure 1. Five year corn grain yield moving averages for rotation corn (corn-oats-alfalfa-alfalfa) and continuous corn](image)

**Crop rotations improve residue management and reduce soil erosion**

Crop rotations are an integral part of conservation agriculture as improved residue management can result in better erosion control and improved machinery clearance. The sequence of crops can be important, especially when some crops do not provide adequate amounts of crop residue after harvest, or when the residue from crops such as soybeans rapidly breaks down after harvest. In this case, winter wheat can be direct seeded into soybean stubble to provide some cover in late fall and winter. Management of crop rotations is essential to provide sufficient crop residue throughout the year for satisfactory control of wind and water erosion. However, too much residue in the spring time can result in colder and wetter soil conditions which may impede crop emergence under no-till situations. Cereal crops contain up to 5 t ha\(^{-1}\) of residue which can protect the soil against wind and water erosion. However planting into cereal crop residue requires reliable no-till planters or residue management equipment especially on clay and clay loam soils.

**Crop rotations improve pest management**

Weed control poses a major challenge in conservation agriculture, especially when no-till systems are used. In these situations weeds are exclusively controlled by herbicide application. Certain crops can
also provide competition and suppress certain weed species. Different crops in a rotation allow a
greater range of herbicides with different modes of action to be used which helps prevent the build-up
of herbicide resistant weed species. For example populations of wild mustard can be reduced by
growing small grains in rotation with row crops; populations of grassy weeds which often occur in
small grains, can be reduced by the use of selective herbicides when the rotation is in a row crop.
Planning the correct sequence of crop rotations together with the use of selective herbicides is an
important aspect of crop rotation management.

Crop rotations have a great potential to reduce the incidence of insect infestation and pathogen
accumulation. Where crops are grown as a monoculture, insects and disease organisms can build up
in the soil especially where tillage has been reduced through conservation tillage. Crop rotations
break the cycles of many diseases which are specific to one plant species as their host and make it
more difficult for emerging insects to find their preferred food. Numerous studies in Canada have
demonstrated that rotations in combination with cultural practices are effective method for controlling
insects and soil-borne diseases.

_Crop rotations improve soil fertility and soil organic matter_

Different crops have different root systems and may have different nutrient, water and air
requirements. For example, legumes in the rotation can be used to increase the available soil nitrogen
and reduce the need for nitrogen fertilizer in the subsequent year. Symbiotic nitrogen-fixing bacteria
form nodules on the roots of legume plants, which convert atmospheric nitrogen into inorganic
nitrogen. Fixed nitrogen in the soil not removed during crop harvest can be released and available to
the subsequent crop in the rotation when roots and residue decomposes in the soil. When a legume
crop is seeded, especially for the first time in a given area, the correct inoculum should also be applied
with the seed to ensure that appropriate bacteria strain capable of fixing atmospheric nitrogen are
available to form the legume-bacterium symbiotic system. Cover crops included in rotations can
increase the amount of carbon added to soils, improve soil structure and provide a plant cover and
thereby reduce soil erosion. Improved soil organic matter and soil structure resulting from the use of a
cover crop can also reduce the energy required for tillage.

_Crop rotations improve nitrogen use efficiency_

Nitrogen use efficiency (NUE) refers to the proportion of nitrogen removed with the harvested grain
compared to the total amount of nitrogen applied to the soil. A rotation study conducted in Ottawa,
Ontario showed that the NUE was highest for corn following alfalfa whereas the NUE was lowest for
continuous corn. On average, NUE was 35% higher in corn-alfalfa rotation, and 24.5% higher in
corn-soybean rotation than continuous corn. Contribution to increased NUE for corn in rotation with
alfalfa and soybeans is from both the direct nitrogen credit from symbiotic fixation as well as from
improved soil nitrogen mineralization.

_Crop rotations improve soil structure and soil water utilization_

Alternating shallow-rooted crops with deep-rooted crops allows the crop roots to do much of the soil
loosening that would otherwise have to be done by hand or machine. This is sometimes called
“biological” tillage, and is more important in no-till and minimum till practices to improve water
infiltration. Spring seeded small grains usually deplete soil water about 1.0 m deep. In contrast,
sunflower, safflower, corn, sugar beet and alfalfa are deep-rooted crops which can exploit soil water to
depths of over 1.5 m.
Lessons learned from Canada and potential benefits to China

Crop rotations play a very important role in conservation agriculture and suitable crop sequences have been successfully developed for different soil conditions and climate in Canada. However, when these technologies are transferred to China, they have to be modified and adapted to the specific soil and climatic regions. The major difference in farming systems between the two countries is the scale of operation or farm size. In eastern Canada, an average farm is about 200 hectares; while in western Canada, farms with 500 or more hectares are not uncommon. In contrast, many farms in China are less than one or two hectares in size. With China’s large population and limited land resource, the available land is intensively farmed and expected productivity is large. We must keep this in mind when introducing any new technology to adapt local situations.

Crop rotations must suit local soil conditions, climate, traditional cultural practices and market situations.

Plan crop sequences that aid in controlling weeds. Small grains compete strongly against weeds and may inhibit germination of weed seeds; row crops permit mid-season cultivation to control escaped weeds; forage or sod crops that are mowed regularly or intensively grazed help control annual weeds.

Avoid following one crop with another closely related species since the same insects, diseases and nematodes frequently attack closely related crops.

Where possible, follow a legume forage crop with a high nitrogen demanding crop, such as corn to take advantage of the additional residual nitrogen supply left by the legume, and then grow less nitrogen demanding crops such as oats, barley or wheat in the second or third year after a legume crop.

Try to grow crops in rotations that will leave a significant amount of residue in the soil to both improve soil organic matter, soil structure and prevent erosion. This is especially important after low residue generating crops.

Drifting of herbicide, migrating of insects and distribution of disease are some factors which are particularly important with small sized farms. Consider community planning where neighbouring farms have similar crops in the same year.
Weed Management in Conservation Tillage Systems

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Potential tillage effects on weeds

Farmers have used tillage for centuries to kill weeds. However, tillage can be both good and bad in terms of weed control. Tillage uproots, dismembers and buries weeds; thereby killing many plants. However, infrequent tillage can actually increase infestations of some perennials by fragmenting rhizomes and tubers and thus stimulating growth of new shoots. Additionally, tillage implements can spread vegetative fragments and seeds throughout a field, or from field to field, and thus contribute to weed dispersal.

Tillage moves weed seeds vertically and horizontally and changes the soil environment in ways than can promote germination and establishment. In the absence of tillage, most weed seeds remain at or near the soil surface. Seeds on the soil surface, compared to buried seeds, are more susceptible to harsh environmental conditions and predation by rodents, soil fauna, and pathogens. Thus, tillage can increase weed seed survival.

Tillage promotes germination of many weed species. Agricultural weeds have adapted to respond to cues associated with soil disturbance. Recently tilled land is often warmer, has greater diurnal temperature fluctuations, higher nitrate concentration, and increased aeration. Additionally, tillage exposes buried seeds to light that facilitates germination of many weed species.

Crop residues on the soil surface increase with zero tillage. Crop residues can suppress weed establishment by altering environmental conditions related to germination, physically impeding seedling growth, and through allelopathic interactions. Zero tillage also tends to increase the number and/or diversity of soil microbes, soil fauna, and earthworms. These organisms can directly or indirectly affect weed seed survival and germination as well as weed growth.

Conservation Tillage on the Canadian Prairies

The Canadian Prairies is a large area of 35 million ha of crop land that is situated in the northern region of the Great Plains of North America. The primary limiting factors to crop production are low annual precipitation (350 – 500 mm) and a short growing season (90 - 130 frost-free days). Historically, this region has been dominated by spring cereal production with fallow being a common part of the rotation. Fallow was practiced primarily to save moisture for the next crop but also for weed control. However, fallow markedly increased the potential for severe soil erosion (mainly wind erosion). Farmers needed to reduced soil erosion, conserve soil moisture, and decrease production costs. This requirement for change occurred at the same time large effective equipment for direct seeding into stubble without cultivation became available and the cost of glyphosate for pre-plant weed control decreased dramatically. These factors resulted in a large decrease in tillage intensity in the 1980s and 1990s, a 75% reduction in fallow area, and a change to continuous cropping sequences that included more oilseed (canola, flax) and pulse (peas, lentil, dry beans) crops. Recent surveys indicate that about 1/3 of the cropped land on the Canadian Prairies is seeded with reduced tillage and 1/3 is seeded with zero-tillage.
Weed concerns with Conservation Tillage

Farmers adopting zero tillage expressed concerns that weed densities would increase, weed populations would shift to more difficult-to-control weeds, and that herbicide use (and costs) would rise. It was predicted that annual grass weeds, volunteer crops, and perennial weeds would become increasing problems and reduce crop yields in conservation tillage systems.

The Canadian experience

Densities of some biennial and perennial weeds have increased with zero tillage in Canada. Additionally, winter annual weeds that emerge in fall and survive cold Canadian winters often became more prevalent with conservation tillage, perhaps due to the combined effect of less fall tillage and the insulating effect of increased snow cover facilitated by standing crop stubble. Summer annual weeds with wind-disseminated seed capable of germinating on or near the soil surface sometimes increased with zero tillage. However, densities of many other annual weeds declined markedly with conservation tillage.

Herbicide use in Canada has not increased with adoption of zero tillage. However, the timing of herbicide applications has changed. In conventional tillage systems, herbicides were mainly applied in-crop to control weeds. In zero-tillage systems, herbicides are now applied before seeding and after harvest to manage weeds. Herbicides are still applied in-crop to control weeds but the number of applications and/or dose has decreased.

It is important to note any effects of conservation tillage on weed populations can be partially offset by other cropping practices. Research studies have shown that weed populations are more affected by crop rotation than by tillage intensity. Farmers using diversified crop rotations (cereals, oilseed, pulses, and forages) found that they had few weed problems with zero tillage. Indeed, many reports indicate that the overall weed density is lower after 5 – 10 years of zero-tillage crop production. The widespread acceptance of zero tillage systems by Canadian farmers is evidence that weeds have not become unmanageable and that weed control costs have not increased markedly. Farmers also report reduced equipment and labour costs and increased crop yields with zero tillage systems.

Potential benefits to China

Conservation tillage is a main step in achieving more sustainable agricultural systems. Soil erosion is reduced and soil quality can even be improved over many years. In semi-arid regions, crop yields are increased due to greater moisture use efficiency in zero tillage systems. In wetter areas, zero tillage can improve water infiltration into soil and thus reduce flooding problems and improve crop yields.

Canadian farmers adopting conservation tillage have decreased their production costs and increased their profits. Zero tillage allows farmers to cover more hectares with the same amount of equipment and labour, thus increasing the efficiency of their farming operations. Concerns about severe weed problems with zero tillage are largely unfounded and should not stop farmers from utilizing conservation tillage systems.
The Benefits of Conservation Tillage on the Resource & Environment

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Abstract: More people, insufficient resources and environment deterioration are heavy challenge to the human being. China is an even more people, less resources and environment fragility country, especially insufficient water and petroleum have been limited the social economy development and human living improvement.

Many research and practice have approved that CT (Conservation Tillage) not only can increase yield and farmer income, but also reduce nature resource consuming, conserve soil and environment. Based on the outstanding social benefits of CT on reduce energy consumption, improve soil productivity, cut down wind erosion and reduce GHG (Green House Gas) emission, extension of CT should be mainly profitable to the whole society, thus, government making plan and governmental and private both sectors investment are necessary.

Key words: Conservation Tillage, Resource Saving, Environment Protection

CT Reduce Farm Machine Power and Fuel Consumption

Chinese mechanized agricultural techniques mostly come from human and animal power tillage system, the key objective was obtained higher yield from intensive tillage, therefore, required more operations, more machines and energy consumption.

For example, the wheat-maize double cropping system of Hebei province contains 16 operations, consuming fuel 180-195 kg/hm², plus irrigation spending fuel 60-75 kg/hm², total 240-270 kg/hm² of fuel consuming and not included the going to be mechanized operations like maize mechanical harvesting and so on. In recent years, traditional mechanized techniques have been improved, like using rotary hoeing instead of moldboard plowing, put crop straw back into field instead of moving the straw out with making manure moving back into field, thus, the energy consumption was reduced, but still have about 13 field operations and consuming fuel of 180-240 kg/hm². The farm machine power mainly spend in 3 aspects: tillage, seeding & harvesting, transportation, they occupied 18.3%, 7.14%, 17.2% of total farm machine power in 2004.

The change from TT (Traditional Tillage) to CT system will be directly related to tillage and transportation. The advantage of CT is fully using soil (soil bacteria and micro-animals) ability to loose soil and decompose straw it-self, thus, largely reduce the tillage and transportation operations. A comparison of TT and CT on machine power and fuel consumption in Fall operation season of Hebei province at table 1 is shown that, CT has 5 operations and reduced 2 operations, reduced machine power 20%, reduced fuel consuming 33% than TT system.
Table 1  A Comparison of TT & CT system on operations, machinery and fuel consumption at fall operation season of Hebei Province

<table>
<thead>
<tr>
<th>No.</th>
<th>Traditional Tillage</th>
<th>Conservation Tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name of operation</td>
<td>Machine used</td>
</tr>
<tr>
<td>1</td>
<td>Transport Maize ears</td>
<td>Trailer</td>
</tr>
<tr>
<td>2</td>
<td>Transport Maize stalk</td>
<td>Trailer</td>
</tr>
<tr>
<td>3</td>
<td>First Rotary hoeing</td>
<td>Rotary tiller</td>
</tr>
<tr>
<td>4</td>
<td>Second Rotary hoeing</td>
<td>Rotary tiller</td>
</tr>
<tr>
<td>5</td>
<td>Wheat seeding</td>
<td>Wheat drill</td>
</tr>
<tr>
<td>6</td>
<td>Transport Seed Fertilizer</td>
<td>Trailer</td>
</tr>
<tr>
<td>7</td>
<td>Compaction after seeding</td>
<td>V type roller</td>
</tr>
<tr>
<td>8</td>
<td>Subtotal</td>
<td></td>
</tr>
</tbody>
</table>

Sum up the results of CT adoption in single and double cropping area of North China, CT can reduce machine power 15-20%, reduce fuel consumption 25-30%. If extension of CT in 60% of NC crop land, the fuel consumption could be reduced 5 Mt at 2020.

![Figure 1 Prediction of fuel consuming on TT & CT in NC](image)

**CT improve soil productivity**

Soil productivity is declining in most of NC crop land, it show the soil Organic Matter (OM) content, N, P, K nutrition continuous reducing, structure become poor and micro-organism decreasing. The reasons of soil productivity reduction are soil erosion and soil over utilization. China is a serious soil erosion country, annual soil erosion reached 5Bt, among it 3.3Bt come from crop land, which
equivalent to loss top soil 2.5mm each year. There are wind erosion in major in NC and water erosion in major in loess tableland and north-east China. Since 90 years of last century, Chinese water & soil conservancy staffs have done a lot of measuring works on wind erosion, the results shown that the wind erosion is between 10-80 t/hm$^2$ and cropland concentrated in 10-20 t/hm$^2$ (table 2).

### Table 2 Wind erosion measuring results in North of China

<table>
<thead>
<tr>
<th>No</th>
<th>Region</th>
<th>climate</th>
<th>Type of soil</th>
<th>Amount of W.E (t/hm$^2$)</th>
<th>Method Of measure</th>
<th>Measure time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Farmland, Beijing</td>
<td>Semi-Humid</td>
<td>loam</td>
<td>11.28</td>
<td>Set pole</td>
<td>2005</td>
</tr>
<tr>
<td>2</td>
<td>farmland, Shanxi</td>
<td>Semi-Humid</td>
<td>loess</td>
<td>13.7</td>
<td>Set Pole</td>
<td>1990</td>
</tr>
<tr>
<td>3</td>
<td>Farmland, Sandong</td>
<td>Semi-Humid</td>
<td>Sand-loam</td>
<td>21</td>
<td>Set pole</td>
<td>1992</td>
</tr>
<tr>
<td>4</td>
<td>Farmland, Shaanxi</td>
<td>Semi-Humid</td>
<td>Loess</td>
<td>18.9</td>
<td>Modeling</td>
<td>1998</td>
</tr>
<tr>
<td>5</td>
<td>Sand, Hebei</td>
<td>Semi-arid</td>
<td>sandy</td>
<td>96</td>
<td>Set pole</td>
<td>2002</td>
</tr>
<tr>
<td>6</td>
<td>Sand, Inner Mongolia</td>
<td>Semi-arid</td>
<td>Windy sand</td>
<td>80</td>
<td>Set pole</td>
<td>1993</td>
</tr>
<tr>
<td>7</td>
<td>Farmland, Inner Mongolia</td>
<td>Semi-arid</td>
<td>Sand Soil</td>
<td>21.6</td>
<td>Trap Collection</td>
<td>2002</td>
</tr>
<tr>
<td>8</td>
<td>Farm/Grass land, Qinghai</td>
<td>Arid</td>
<td>Sand Soil</td>
<td>7.5~43</td>
<td>Cs-137 label</td>
<td>2000</td>
</tr>
<tr>
<td>9</td>
<td>Farm/Grass land, Xinjiang</td>
<td>Arid</td>
<td>Sand Soil</td>
<td>31-60</td>
<td>Cs-137 label</td>
<td>1998</td>
</tr>
</tbody>
</table>

The soil nutrition in wind dust is higher than in the top soil, CAU has measured the top soil and wind collection materials in Hebei and Inner Mongolia, the results put at table 3. Take the wind dust 10-20t/hm$^2$ with contain 3% of OM and 0.16% of full N, then, the soil nutrition loss by wind erosion are 300-600 kg/hm$^2$ of OM and 16-32 kg/hm$^2$ of full N, which would decrease the soil OM content 0.012% annually. Without moldboard plow, soil fine articles would gradually be depressed in top soil and wind erosion intensity reduced until stop, but moldboard plow turns bottom soil up, makes new fine articles available and erosion continuing. If continuing moldboard plow 100 year, soil fallow in bare condition, wind erosion would make soil OM decrease 1%, rich soil become poor soil, poor soil losses all productivity.

### Table 3 The nutrition contents in top soil and “wind collection” Unite: %

<table>
<thead>
<tr>
<th>Place &amp; Time</th>
<th>Soil OM</th>
<th>Total N</th>
<th>Total P</th>
<th>Total K</th>
<th>Method of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fengnin, Hebei 2002</td>
<td>Top Soil (5cm)</td>
<td>1.3</td>
<td>0.096</td>
<td>0.014</td>
<td>1.83</td>
</tr>
<tr>
<td>Wind Collection</td>
<td>3.016</td>
<td>0.167</td>
<td>0.038</td>
<td>1.99</td>
<td></td>
</tr>
</tbody>
</table>
In Yellow river basin, water erosion makes 1.6Bt soil into the sea annually, the average water erosion is above 15 t/hm². It is more serious in slope land, water erosion on 15° slope land is higher 5 times than 5° slope land measured by Shanxi Agricultural University(SAU).

CT takes off moldboard plow, left residue covers soil ground and reduce soil surface disturbing, thus, largely reduce soil erosion and protect soil productivity. CAU and other units have measured the soil erosion in TT and CT system, the results shown that CT can reduce wind erosion 60% and water erosion 80% in average. (Table 4).

Table 4 Water erosion comparison between TT and CT

<table>
<thead>
<tr>
<th>Place &amp; Unit</th>
<th>Field slope</th>
<th>Water erosion</th>
<th>Method</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanxi Shouyang CAU</td>
<td>5°</td>
<td>7.34 (t/hm²)</td>
<td>Run-off Plot, Tipping Bucket</td>
<td>1998-1999</td>
</tr>
<tr>
<td>Henan Academy of Agri.Scienc Luoyang</td>
<td>0°</td>
<td>0.525 (t/hm³)</td>
<td>Soil Bin Rainfall simulate</td>
<td>2000-2001</td>
</tr>
<tr>
<td>Shanxi Shixian Shanxi Agri.Univ.</td>
<td>5°</td>
<td>0.454 (g/s)</td>
<td>Artificial Slop Rainfall Simulate</td>
<td>1999</td>
</tr>
<tr>
<td></td>
<td>10°</td>
<td>3.327 (g/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15°</td>
<td>6.046 (g/s)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For torsion of soil productivity decline, speed up the CT extension is necessary and must guarantee the quality of residue mulch and direct seeding during extension.

**CT reduce dust storm**

Most of soil dust are larger articles and rolling forward on the ground or jump forward leave ground a certain height, those articles could damage crop and field.

The fine articles can be suspended in the sky and moving to thousands miles away, but the amount is
small, specially the diameter less than 10 μm (called PM$_{10}$) is less than 1%. However, it can entry human lung, harm human health and environment, so it is the major monitoring index in aerobic environment control.

CAU measured the PM$_{10}$ content in different soil surfaces at table 5.

<table>
<thead>
<tr>
<th>Soil Surface</th>
<th>Growth weight</th>
<th>Paper weight</th>
<th>PM$_{10}$ weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow field</td>
<td>2.65</td>
<td>2.4386</td>
<td>0.2114</td>
</tr>
<tr>
<td>Short residue</td>
<td>2.5633</td>
<td>2.4386</td>
<td>0.1247</td>
</tr>
<tr>
<td>Chopped stalk</td>
<td>2.5037</td>
<td>2.4386</td>
<td>0.0651</td>
</tr>
<tr>
<td>Chopped stalk plus High residue</td>
<td>2.4862</td>
<td>2.4386</td>
<td>0.0476</td>
</tr>
</tbody>
</table>

The rule of total amount of PM$_{10}$ production is: Plow field > short residue cover > chopped stalk mulch > chopped stalk plus high residue mulch. Comparing to plow field, short residue cover field has less 41%, chopped stalk mulch field has less 69.21%, chopped stalk plus high residue mulch field has less 77.48% of PM$_{10}$.

PM$_{10}$ article is only small percentage in wind dust, but to large area, the total amount of PM$_{10}$ also can be quite large. For example, if all crop land plowed in Beijing, it could produce 840,000 t of PM$_{10}$ with each people undertaken 70kg in 12M people of Beijing. Adoption of CT can efficiently reduce soil dust and PM$_{10}$, while adoption of CT in whole Beijing with 4t/hm$^2$ residue mulch, PM$_{10}$ could be reduce to 190,000t.

**CT reduce GHG**

GHG (Green House Gases) mainly are CO$_2$, CH$_4$ and N$_2$O, the potential of N$_2$O emission warming atmosphere is greater 290~310 times than CO$_2$, 10 times than CH$_4$, therefore it is specially concerned in protect of environment.

The total annual N$_2$O emissions are 0.31~0.398Mt in China and 3.6 Mt in the world, and 90% come from farming land.

CO$_2$ emission mostly comes from dry land, the Canadian research shown that OM reduced in soil & CO$_2$ increased in atmosphere during traditional tillage (moldboard plow) period, reversely, OM increased in soil & CO$_2$ decreased in atmosphere during CT period. It is clearly CT can reduce CO$_2$ emission from farm land.

CH$_4$ basically comes from paddy field, no more studies to show the effect of CT on the production of CH$_4$.

N$_2$O emissions are about 75% come from dry land and 25% come from paddy field.

Many year experimental researches and production practices in China and other countries have shown the follow advantages of CT related to the reduction of soil N$_2$O emission:
1) Reduce soil wind erosion
2) Reduce soil water erosion
3) Avoid burning crop residue
4) Reduce fossil fuel consumption
5) Improve soil structure
6) Improve soil fertility

**Reduce soil wind erosion**

China is a serious soil erosion country, wind erosion area is approximately 1.6 Mkm$^2$ in total and about 12~14 Mhm$^2$ is farmland mainly located in North and West of China. The wind erosion losses in farmland are 10~20 t/hm$^2$ and the “wind collection” has contained 1.2~2.3 times higher of OM and 1.3~1.7 times of N fertilizer than top soil, respectively. (see table 3)

Taking the soil wind erosion 10~20 t/hm$^2$, with the 3% of OM content in the wind collection, a 300~600 kg/hm$^2$ of OM loss from wind erosion can be estimated and with 0.17% of full N content in wind collection, a 17~34 kg/hm$^2$ of full N loss from wind erosion can be estimated.

The reduction of wind erosion from TT to CT system is 60% in average, whereas, the change of TT to CT can reduce 180~360kg/hm$^2$ of OM and 10.2~20.4 kg/hm$^2$ of full N loss. Employ the IPCC default factor that 1.25% of applied N fertilizer can be transformed to N$_2$O emission, then, the tillage system change from TT to CT can reduce 2001~6024 t of N$_2$O emission through reduction of wind erosion, which taken 0.56~1.77% of total N$_2$O emission in China.

\[
12~14 \text{ Mhm}^2 \times 10.2~20.4 \text{ kg/hm}^2 \times 1.57 \times 1.25\% = 2001~6024 \text{t}
\]

Note: Consider the atomic weight of nitrogen is 14 and oxygen 16, then, 1 kg of N is converted to (14+14+16)/(14+14) = 1.57kg of N$_2$O emission.

**Reduce soil water erosion**

Take Shanxi province as an example, the average water erosion was about 15 t/hm$^2$, among eroded soil, there were 50kg/hm$^2$ of full N and 25kg/hm$^2$ of full P fertilizer.

Soil water erosion could be reduced 80% on 4~5% slope field by adoption of CT system, which slope is typical in Yellow river basin. As taken 80% of water erosion reduction, CT would reduce about 40kg/hm$^2$ of full N loss in approximately 10~13 Mhm$^2$. Thus, a total reduction of 0.32~0.4Mt full N loss can be calculated from water erosion and times the same transform rate of 1.25% of N$_2$O emission to N fertilizer, the total reduction of N$_2$O emission from water erosion reduced in Yellow river basin are 7850~10200t,

\[
40\text{Kg/ hm}^2 \times 1.57 \times 1.25\% \times 10~13 \text{ Mhm}^2 = 7850~10200 \text{t}
\]

**Avoid burning crop residue**

Approximately 600Mt of crop stalks are produced each year in China, it contains 3Mt of N, 0.7 Mt of P, 7 Mt of K fertilizers. To stop burning crop residue, which has great contribution to Greenhouse Gases, Chinese government has paid great attention, but Currently still has 25% of crop residue burned in china, those would produce 0.0075Mt of N$_2$O emission, 0.379Mt of CH$_4$ emission and less
of CO₂ emission from burning crop residue. If through adoption of CT system to stop 10% of crop stalks burning, thus, 3000t of N₂O emission and 151,000t of CH₄ emission could be eliminated.

**Reduce Fossil Fuel consumption**

CT can largely cut down tillage operations and transportation works (moving crop stalks out of field and transport organic manure into field). From typical investigation, saving 30 kg/hm² of fuel or 40% of fuel consumption in one crop a year region and 78 kg/hm² of fuel in double cropping region in north China could be expected through adoption of CT system.

While CT adopted on 70% of crop land in North of China, the total fossil fuel saving could be 2.3Mt each year.

- One crop a year area: 35Mha * 0.7 * 30 kg/hm² = 1.05 Mt fuel saved
- Double cropping area: 16Mha * 0.7 * 78 kg/hm² = 1.25 Mt fuel saved

Fossil fuel reduction represents the Greenhouse gas reduction from the engine of farm machinery, the amount of gas is estimated approximately 3.2 kg of CO₂ or 0.01kg of N₂O for 1 kg of fuel burning. (15)

Assume 30% of GHG is in N₂O emission, thus, 5.15Mt of CO₂ and 6900t of N₂O emission could be reduced,

- 2.3Mt * 3.2 * 0.7 = 5.15Mt of CO₂ emission
- 2.3Mt * 0.01 * 0.3 = 6900t of N₂O emission

Analysis of above 4 aspects, they have immediate and indirect influences with reduction of 19751～26124t N₂O (5.5～7.5% of whole N₂O emission of country), 0.379Mt CH₄ and 5.15Mt CO₂ emission in China.

Other 2 aspects have direct influence, which means the N₂O emission change can be measured directly from cropland using “close chamber method”, but lack of scientific figures to show the influence clearly at the moment.

From positive side, the improvement of soil fertility and structure would be useful to reduce the amount of N fertilizer application, then, reduce N₂O emission. However, the rich soil base would produce more N₂O emission itself. Some research mentioned that the frequent exchange of soil dry and wet condition would induce N₂O emission production, soil waterlogging easy creates anaerobic environment, thus produce more N₂O emission. The situation is rather complex and uncertainty. Dr. Johan Six in California university of US concluded that the CT system can directly offset the GHG emissions (CO₂, N₂O, and CH₄), only in longer-term adoption, say, adoption of CT system 10 years in paddy field (humid area), the fluxes GWP ((global warming potential) becomes negative, means reduce GHG and 20 years in paddy and dry land areas both show negative GWP fluxes. In the short term of CT application, the GHG may be less, may be more, this is the true situation.

**References**


Impact of Farmland Wind Erosion on Sand Strom in Northern China

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Abstract: The soil erosion by wind under conservational and traditional tillage systems was investigated in a 3 years period by means of monitoring field sand losses, wind tunnel simulations and marking pole experiments. The results of the study show that the annual amount of the soil eroded by wind was 6 billion tons in northern China, and the losses of N, P, K and organic matter were 6.67, 1.00, 122.00 and 89.35 million tons, respectively. Among them, the annual soil wind erosion in Beijing was 18 million tons. Compared with tradition tillage, conservation tillage including no till with crop stubble and straw coverage reduced 40% of wind erosion. In order to control sand storms in China, more emphasis should be given to conservation tillage due to its great effectiveness in reducing wind erosion from farmland which is a source of dust, in addition to planting more trees and grasses.

Key words: sand storms, resource of dust, contribution, conservation tillage, farmland

Introduction

Sand-dust weather happened more than 100 times in the northern China from 2000 to 2005, among which strong sand storm accounts to 14 times, dust storm happens 38 times (Figure 1). Sand-dust weather has brought great influence on people’s daily life. According to the result of Survey of Groundwater Resource and Environment by the Institute of Geographical Sciences and Natural Resources Research of CAS, by the end of 2005, Land desertification area in northern China is 175,510,000 square kilometers [1].

Figure 1 Dust weather Days

Reports from National Bureau of Meteorology and National Bureau of Environment Protection show that, there are three main paths for sand storm to influence Beijing: Northern route is from Mongolia, to east of Inner Mongolia, west of Liaoning and Bashang Plateau of Hebei, then arrive Beijing and Tianjin; Northwestern route is from Xinjiang and Mongolia, then arrive Beijing and Hexi Corridor.
China-Canada Conservation Agriculture Forum

and Alashan plateau, then to Beijing, Tianjin and northeast of China; Western route is from east of Zhungeer basin, strengthen in Hexi Corridor and Alashan plateau, then to North of China and Shaanxi, Gansu. National Bureau of Meteorology analyze all sand-dust weathers since 2000, the results show that, most sand-dust weathers happened in northern China.

Conservation tillage demonstration project started from 2002 by Ministry of Agriculture. By 2006, 167 counties have been demonstrated with conservation tillage, the total demo areas are more than 800 thousand hectares. Conservation Tillage Research Centre (CTRC) of MOA began to study the Impact of farm land wind erosion on Sand Strom in Northern China.

Materials and methods

Sites

After surveying, China bureau of environment protection has determined three routes that influence on the sand-storm in Northern China, especially in Beijing. The route I is the northern route, which starts from the southeast of Mongolia, passes through inner Mongolia and Hebei province and enters Beijing. The route II is the northwestern route, which starts from the middle and south parts of Mongolia and passes through Inner Mongolia, Shanxi and Hebei provinces.

The sand dust from this route has the greatest impact on Beijing. The route III is the western route that goes through Xinjiang, Hexi of Gansu province, Shanxi, Shanxi and then to Beijing. The impact of this route is less than others.

Based on this condition, farmland floating dust inspect spot has been set up in a part of counties that are passed through by the three routes. Wind tunnel simulations and field sand collectors were installed.

In the northern route, Chifeng and Zhenglanqi lie in the middle and east of inner Mongolia, north of Beijing, with the average altitudes of from 1000 to 1500m, the average temperatures of from 3 to 70℃ and the frost-free season of 110~135 days. Average annual precipitation is from 350 to 450 mm. Single crop system is adopted. Fengning county of Hebei province basically has the similar climates and cropping systems. In Changping county, The average altitude is 400m and the average temperature is 120℃. Frost-free season lasts 180~200 days. Average annual precipitation is 600 mm. Maize and wheat are grown each year. By the influence of geography factors, The average altitude in Chifeng, Henglanqi and Fengning are 800~1300m higher than Beijing. In winter and Spring which are full of winds, the dust blewed from the northern area of Fengning looks as if sprinkling dust from the roofs. In the northwestern route, the main crop is spring wheat. The average altitude is from 1000 to 1400m, average temperature from 2.5 to 40℃, frost-free season 90~115 days, and average annual precipitation from 300 to 350 mm. In the western route, Hetian lies in warm temperate zone and has drought deserted climate. Frost-free season lasts 210 days and average annual precipitation is 33.5mm. The weather in Yanggao is similar to that in Zhangbei.

Experimental design

Field sand monitoring

The quantities of the soils eroded by wind from traditional fall-tillage fields and conservation (minimum tillage, zero tillage & straw covered) fields were monitored. The field tests were done each spring from 2002 to 2005. Sand sampling instruments were installed in the fields. The empennage can
adjust the direction of sand inlet and make the wind blow into the inlet directly (figure 2). The monitored sites were Chifeng, Zhenglanqi, Fengning, Changpin of the northern route, WuChuan, Zhangbei, Yanqing of the northwestern route, and Hetian, Yanggao of the western route.

Wind tunnel simulation experiment

In the spring of 2003, the wind tunnel experiments were conducted with two tillage modes, five mulch heights, six straw coverage rates and four different wind speeds in Zhenglanqi; with two tillage modes, five mulch heights and five different wind speeds in Fengning in the september of 2003; and two tillage modes and five different wind speeds in the spring of 2004 in Changpin, Yanqing and Daxing of Beijing. The quality of wind erosion from farmland surface in different wind speeds through simulating natural condition was measured. Samples were taken every five minutes. Wind tunnel experiment adopts traveling outdoor wind tunnel. Its length reaches to 10.2m, the experimental part is 6m. The section area is 100cm×80cm. The wind speed can continuously be adjusted from 0.5m/s to 30m/s (Figure.3).

Marking pole experiment

Marking pole experiment method is to insert two fixed poles of 20cm spacing into fields, put a level plank on the summits of the two poles and adjust it to a horizontal direction, then measure the vertical distances between the plank and field surface at the equidistant points on the plank and write them down. After a period of time, measure the distance of different spots again. Subtract the corresponding points in the two measurement and eliminate the exceptional quality, then you can obtain the soil wind erosion depth.
erosion in the farmland. The pole experiment was done from 29th March to 22th April 2005 in Changping and Yanqing, Beijing.

Conclusions and discussion

Sediment transport by wind

Magnitudes of sediments transported by wind from fields

The magnitude of sediment transport is one of the important indexes to evaluate soil wind erosion and its intensity. Field tests were conducted in the counties, which are within the three main routes of dust storms in the northern part of China. Table 1 shows the sediment transport quantity under different tillage systems. The data showed in this table are the averages of the three different testing points in different heights.

<table>
<thead>
<tr>
<th>Testing site</th>
<th>Collection time</th>
<th>CT(g)</th>
<th>CK(g)</th>
<th>Compared to CK(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi feng</td>
<td>2003.4.22~2003.5.3</td>
<td>4.66</td>
<td>7.08</td>
<td>34.18%</td>
</tr>
<tr>
<td>Zheng lanqi</td>
<td>2003.3.23~2003.4.27</td>
<td>11.29</td>
<td>24.97</td>
<td>54.79%</td>
</tr>
<tr>
<td>Feng ning</td>
<td>2002.3.22~2002.4.21</td>
<td>12.72</td>
<td>42.46</td>
<td>70.04%</td>
</tr>
<tr>
<td>Chang ping</td>
<td>2005.3.28~2005.4.17</td>
<td>16.70</td>
<td>19.00</td>
<td>12.11%</td>
</tr>
<tr>
<td>Wu chuan</td>
<td>2003.3.26~2003.4.6</td>
<td>2.85</td>
<td>7.43</td>
<td>61.64%</td>
</tr>
<tr>
<td>Zhang bei</td>
<td>2002.4.8~2002.5.8</td>
<td>12.72</td>
<td>42.46</td>
<td>70.04%</td>
</tr>
<tr>
<td>Yan qing</td>
<td>2005.3.16~2005.3.20</td>
<td>4.15</td>
<td>5.00</td>
<td>17.00%</td>
</tr>
<tr>
<td>He tian</td>
<td>2004.3.16~2004.27</td>
<td>7.4</td>
<td>105.5</td>
<td>92.90%</td>
</tr>
<tr>
<td>Yang gao</td>
<td>2004.3.25~2004.4.3</td>
<td>8.36</td>
<td>15.12</td>
<td>44.71%</td>
</tr>
</tbody>
</table>

Notes: CT=conservation tillage; CK=conventional tillage

According to the trials in the north, northwest and west paths, the sediment transport under no tillage with cover was reduced by 42.78%, 49.56% and 68.81%, respectively, compared to that under conventional tillage. The differences in the reduction of sediment transport among different tillage patterns vary. The greatest reduction in sediment transport was found at Hetian. It is obvious that Conservation tillage, which combines zero or minimum tillage with straw cover, keeps the soil surface from direct striking, increases the roughness of surface, reduces soil surface wind momentum, retains the corrodible particles under straw cover, so as to reduce soil wind erosion and ground sanding.

Analysis of the constitutes of soil eroded by wind in different heights

Table 2 shows the soil wind erosion substance content in different heights under different treatments. All of them were collected from field testing. As the table reveals, the particle sizes of eroded soil under conventional tillage and conservation tillage were dissimilar in the vertical direction. As the height increased, the sand particle (0.5~0.25mm) decreased, and fine particle (0.045~0.002mm) and clay particle (<0.002mm) increased. This is because of the fact that the closer (<25cm) the wind to the ground surface, the bigger the particle is.

<table>
<thead>
<tr>
<th>Height(cm)</th>
<th>Particle size (mm)</th>
</tr>
</thead>
</table>

Table2 Soil particle content in different height under CK and CT (%)(2002-2004)
According to the 2002-3004 tests in both conservational and conventional fields, it was found that the particle sizes varied from 0 to 1.5 m heights over soil surface. About 70% of particle sizes were 0.045-0.25 mm, and the bigger ones were mainly distributed in the height less than 30 cm from the ground.

According to the samples collected in field test, the percentages of the less than 0.002 mm particles that were blown into air and then became suspending were 0.844% in conservational fields and 1.744% in conventional fields. That is to say, conservation tillage reduced 52% suspending particles compared with conventional tillage.

**Wind tunnel simulations**

Test results in mixed farming and herding areas

Wind tunnel tests were conducted in Zhenlanqi, Inner Mongolia and Fengning, Hebei province in 2003. The two areas are classic farming and herding interleaving area. The altitudes are a range of 1000~1500 m. The soil in these two areas contains a high level of sand and is prone to loss soil water, so wind erosion easily occurs. They are well known as two of the sources of Beijing sandstorms by Chinese public media. Wheat was harvested in October 2002 with a fallow period of 4 months in the Zhenlanqi and Fengning test areas. In the 0-10 cm topsoil layers covered with 10 cm, 20 cm, 25 cm, 30 cm and 40 cm residues, soil moisture contents were 3.42%, 3.56%, 5.38%, 7.43%, 7.66% and 8.12%, respectively. During the ploughed fallows in the Zhenlanqi testing areas, and 3.86%, 4.36%, 5.78%, 7.85%, 8.50% and 11.40% in the Fengning testing areas. The wind tunnel tests in Zhenlanqi and Fengning mainly targeted at sediment transport from farmlands under different cultivating methods, heights of stubble and rates of straw covering. Samples were taken every 5 minutes. Different stubble height’s sediment transport with different wind velocities are as Figure 5.

Figure 5 shows, under different stubble coverings, the sediment transport increased with wind velocity, and decreased regularly with stubble height. When the stubble height was over 30 cm, wind erosion of soil reduced obviously. As the wind velocity was about 13 m/s, wind erosion was not found. Micro-erosion happened only at strong winds. When stubble height was under 30 cm, soil losses
increased obviously. So a stubble height of 30cm is recommended as a threshold value of preventing wind erosion and sand storm. Executing CT in dryland, half dryland and cold sandy farming areas and keeping a 30cm or higher stubble height in fallow fields can control wind erosion effectively. Different straw coverage’s sediment transport under different wind velocities is shown as follows.

Figure.6 shows that straw coverage could control wind erosion of soil effectively. At the same wind velocity, wind erosion increased gradually with the decrease of straw coverage. When the rate of straw coverage was 57.60% and wind velocity was under 14m/s, soil losses were very little. Only when wind velocity was over 14m/s, sediment transport occurred. With the reduction of straw coverage, wind erosion increased slowly and the threshold wind velocity causing sediment transport decreased. When the rate of straw coverage was 45.12% and 32.24%, the threshold wind velocity of sediment transport is about 11m/s. However, when cover was under 32.24%, the threshold wind velocity dropped to 5m/s. Using 32.24% straw coverage reduced 60.06%, 79.35% and 94.07% in sediment transport, respectively, compared to using 20.56% and 9.68% straw coverage and CK. This shows that when the rate of straw coverage on the surface of farmland was over 32.24% and there was a strong wind (>11m/s), sediment transport happened. So we recommend that 32% straw coverage be
a threshold value of preventing soil from wind erosion and causing sand storms under conservational systems. It is advised that in dry, cold and sandy areas, CT should largely be extended and the rate of straw coverage should not be under 32%.

Results of wind tunnel tests in the suburb of Beijing

In 2004, wind tunnel tests were conducted in Changping, Yanqing and Daxing of Beijing in order to analyze the sediment transport under various wind velocities and cultivating methods. The soil moistures at the depth of 0~10cm under CK and CT were 7.28% and 9.64%, respectively, in Changping test areas, 6.98% and 9.92% in Yanqing, and 6.82% and 9.54% in Daxing. The tests were carried out after wheat harvesting. The results are shown in Figure 7.

As Figure 7 shows, sediment transport from farmland increased with wind velocity under different cultivating methods. When wind force increased from 5 (9.6m/s) to 8 (20m/s), sediment transport increased 17 times under CK and 7 times under CT. At the wind velocities of 9.6m/s, 15.6 m/s, 20 m/s, 23.63 m/s, 25.05 m/s, the differences of sediment transport between CT and CK were 0.22g, 1.77g, 9.01g, 13.31g and14.38g, respectively. Therefore, it was concluded that when wind velocity increased, sediment transport from CT fields was far less than that from CK fields, and its increase was slow.

The tests show that the stronger the wind velocity was the more the sediment transport. CT controlled sediment transport from farmland more effectively than CK through keeping stubble and straw coverage, this effect was more obvious when the wind velocity was over force 5. When wind force was from 5 to 8 sediment transport under CT reduced 33%~71% than CK.

Wind tunnel simulation in the northern farmland areas

According to the results of the wind tunnel tests, sediment transport under CT and CK is shown as follows.

<table>
<thead>
<tr>
<th>Site</th>
<th>Cultivating method</th>
<th>Wind velocity (m/s)</th>
<th>Force 5-7 (8.0m/s -17.1m/s)</th>
<th>Over force 8 (≥17.2m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yanqing, Changping, Daxing</td>
<td>CK</td>
<td>0.78</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>0.4</td>
<td>0.78</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7  Relationships between sediment transport and wind velocity
Based on Table 3 and annual average strong wind data in Northern China, wind tunnel tests were designed and conducted on the northern farmlands.

According to weather data published by China Weather Bureau (Table 4), every year there are about 309 hours with wind force 5~7 in Northern China, and about 112 hours at wind force 8. Now sand storms happen frequently in 13 provinces and cities in northern China. The impacted area is about 60,040,000.62 ha (data from Ministry of China National Soil Resource).

When calculated by the equation:

\[
\text{annual wind erosion} = \frac{\text{wind erosion (per ha per hour)}}{\text{time of wind erosion}} \times \text{cultivate area}
\]

Annual sediment transported from the farmlands of northern China is about 6,667,530,000 ton. Table 5 illustrates the soil organic and nutrient contents of the trial fields with different treatments in northern China. It was calculated based on Table 5 that losses of soil N, P, K and organic matter were 6.668, 1.00, 12.2016 and 89.345 million ton, respectively, which are about the total of the annual outputs of 20 large nitrogenous fertilizer factories, 8 large phosphor fertilizer factories and 40 large kalium fertilizer factories.

The annual sediment transported away form farmland under CT reduced 3468.27 million ton or 48%, compared to that under CK. Likewise, the losses of soil N, P, K and organic matter under CT decreased 5.202, 0.624, 65.55 and 66.938 million ton or about 22%, 38%, 46% and 25%, respectively.

Table 4  Strong wind events in northern China

<table>
<thead>
<tr>
<th>Province</th>
<th>Force 5-7 (8.0m/s -17.1m/s)</th>
<th>Over Force 8 (≥17.2m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xinjiang</td>
<td>140</td>
<td>80</td>
</tr>
<tr>
<td>Gansu</td>
<td>130</td>
<td>65</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Hebei</td>
<td>70</td>
<td>45</td>
</tr>
<tr>
<td>Average</td>
<td>110</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 5  Content of soil organic and nutrient with different treatments (%)

<table>
<thead>
<tr>
<th>Cultivating method</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Organic content</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>0.10</td>
<td>0.015</td>
<td>1.83</td>
<td>1.34</td>
</tr>
<tr>
<td>CT</td>
<td>0.15</td>
<td>0.018</td>
<td>1.89</td>
<td>1.93</td>
</tr>
</tbody>
</table>
Results of marking pole experiments

The marking pole experiment continued 25 days, from March 29 to April 22, 2005, in Changping and Yanqing of Beijing, the results are as follows.

<table>
<thead>
<tr>
<th>Cultivating method</th>
<th>Time (days)</th>
<th>Depth of wind erosion (mm)</th>
<th>Amount of wind erosion (t/hm²)</th>
<th>CT’s decrement than CK (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>25</td>
<td>0.94</td>
<td>11.28</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>25</td>
<td>0.51</td>
<td>6.63</td>
<td>41.22%</td>
</tr>
</tbody>
</table>

The test results show that in Beijing, the daily wind erosion was 0.45 t/hm² and 0.27 t/hm², respectively, under CT and CK, and the depths of monthly wind erosion of soil were respectively 0.6 mm and 1 mm, indicating CT reduced wind erosion over 40% than CK. According to statistical data from Ministry of China National Soil Resource, the present area of ploughed lands in Beijing is about 408,300 ha. If calculated with 100 days of wind erosion of soil every, the annual sediment transport in Beijing is 18.3735 million ton. Based on the results of the section 3.1.2, the clay contents (<0.002 mm) of the eroded soil by wind under CK accounts for about 1.774% in average. Therefore, about 325,900 tons of soil in Beijing is blown away. The 0.045-0.002 mm particles are also important part of the farm soil at long blows, so the soil blown away from Beijing would actually be far more than the above value. Using CT will reduce sediment transport 11.0241 million ton in Beijing. Every year soil blown away by wind will reduce to about 93,000 tons.

To prevent sand storms, advise to plant more trees and build strong protective forest project in forestry, and strengthen grassplot building and prevent grassland degenerated and adopt no (minimum)-tillage and straw coverage and reduce transported farmland soil mass, and cut the sources of sandstorms, and realize sustainable development of agriculture.

Conclusions

In northern China, conventional farming methods are degrading soil structure and making it susceptible to wind erosion, so more sand storms are coming from farmlands. The field tests in this study illustrates that in northern China, the soil transported away from farmland by wind is about 6,667.53 million ton each year. Compared to conventional tillage, conservational tillage can reduce about 40% of farmland soil erosion by wind, which is an effective way to prevent sand storms.

The soil loss of farmlands under conventional tillage systems is about 118.28 million ton every year in northern China. Among them, Beijing’s soil loss of farmlands is about 18.37 million ton, soil blown away is about 0.33 million ton. It is recommended that in China, more emphasis should be given to conservational tillage due to its great effectiveness in reducing wind erosion, in addition to planting more trees and grasses to prevent sand storms.

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References


The Succession and Development of Conservation Tillage Techniques in Chinese Traditional Agriculture

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Abstract: There are homemade conservation tillage techniques in Chinese traditional agriculture. Based on the succession of intensive cultivation techniques, we should integrate the advantages of conservation tillage techniques in traditional agriculture into modern agro-techniques so as to set up a soil tillage technique according to various cases, therefore develop a comprehensive dryland farming technique system including agriculture, mechanism, and environment protection.

Key words: traditional agriculture, conservation tillage, sustainable development

The ecological conditions in the dryland farming zone of the northwest China is fragile, therefore, a soil tillage and dryland farming system, which changes with seasons, areas and crop types, must be set up in the area from the aspect of long-term stratagem for the sustainable development agriculture and conserve eco-environment. A good soil tillage technique is to extend reservoir of soil water and to create better conditions for the crop growth by using reasonable soil tillage, which would ultimately improve economic effects of farmland.

The development of conservation tillage techniques

For thousands of years, traditional agriculture was gradually formed in long-term agro-production practices. In ancient times, farmers plant crops in a primordial way by which stone knife and fire was used. Generally, they choose appropriate grassland or forestry land in spring, cut the forest or burn the grass, the plant crops by hole sowing or broadcast sowing, then waiting to harvest the crops in fall. In this approach, after several years, the yield would decrease, farmers started to choice a new land for the planting in such method. Prior to the dynasty of West Zhou, a rotation and fallow system was adapted to renew land productivity. While in West Zhou, rotation and fallow system has been transitioned to fallow system. With the invention of cattle plowing and steel plough, traditional tillage technique began to be used in Han Dynasty. From then on, various tillage tools, such as plough, harrow and other tools were used to cultivate intensively, and a traditional agro-tillage system including routine tools was formed.

Advantages of traditional tillage.

Characterized by the intensive cultivation, traditional tillage was conducted by the using of plough, harrow, and other tools to change status of surface soil and ground condition so as to adjust soil water and nutrients and other fertility factors. Therefore, rainfall and soil water was contained and a fitting soil environmental condition was formed to guarantee the sowing, emergence and growth of crops. By the adoption of intercropping, continuous cropping and rotation, land productivity was increased. Crop residues and fertilizers were mixed with surface soils, by the deep plowing and shining in summer, soil nutrients in surface soils was therefore increased. Besides, weed was cut and pests and
diseases were also controlled and perished. All these contributed to the increase in crop yield.

**Disadvantages of traditional tillage.**

Excessive tillage destroyed soil structure, a hard plow pan was formed and crop growth was thus impeded. The more and deeper the tillage was conducted, and the dryer the air was, the more the lost water from soil was. With the intensive tillage, loosen and bared soils where the evaporation was occurred was increased and soil erosion caused by wind and water was accelerated. Meanwhile, due to the increased cost and energy consumption and low economic effects, the routine tillage should not be adopted continuous.

**Homemade Conservation Tillage techniques have been used in ancient traditional agriculture**

Drought is one of the natural disasters in agro-production in the Loess Plateau. In order to prevent drought, tillage should be conducted in the proper times. For example, the tillage principles proposed by the “Sisheng’s Book” written in West Han Dynasty read: “The basic requirements for the tillage depend on the proper tillage time, cover soils, fertilization, early uproot and early harvest”, while the experience for the water retaining in cornfield were: “Till in May and June rather than in July, arrange the land for the seeding in proper time”. Besides, in the agro-production practices, some tillage methods were invented to reduce water loss in soils, such as Quanmu method and Daitian method.

**Quanmu method**

Quanmu method was first appeared in the Spring and Autumn Period and the Warring States Period (770-221 B.C.) in ancient China. This method has been described in “Lu’s Book” in Qin dynasty. The basic structure was presently used ridge and trench. Soil water content in trench is higher than that in ridge. In upland, seeds were sown in the trenches, after emergency, intertillage was conducted to cut weeds, then stuff the ridge soil to the root region of the crops to retain soil water, resist lodge and drought. In lowland, seeds were sown in ridge for the convenience of drainage and preventing flood. Quanmu method is the method firstly used in the dryland farming in the Loess Plateau to resist drought and prevent flood.

**Daitian method**

On the basis of Quanmu method, Daitian method was developed in the period from West Zhou to the Warring States period, which was characterized by the alternated ridge and trench. In this method, seeds were always sown in the trench, and then covered with soils accompanied with intertillage to cut weeds. Land was used repeatedly and fallowed. As a result, yield in land with Daitian method were often greatly higher than that in flat cultivated field, and the purpose of “lower cost corresponded with higher yield” was fulfilled.

**Qutian Method**

In this method, plot bands with different size were constructed in filed. All the tillage, management, seeding, fertilization, and irrigation were conducted in the plot and the potential productivity in plot land is fully exerted. Qutian Method is a cultivation technique corresponded with higher yield and drought resistance.

Up to now, many areas still used these ancient less and no tillage techniques and dryland farming tillage systems. For example, the widely used “fertility trench”, “fertility tunnel”, “corrugation cultivation” and “contour trench cultivation” and presently strongly popularized mulch farming and
stubble mulch farming in hill sloping lands in northwest China are all the succession and development of the homemade conservation tillage technique in traditional agriculture. Conservation tillage technique is an important component of the cultivation system in ancient China, therefore, we should succeed and carry forward the intensive cultivation, retaining soil water to fight a drought and conserving soil and water techniques from the Chinese traditional agriculture.

**Development of the conservation tillage techniques**

*The concept of Conservation Tillage was derived from America.*

In middle 19th century, America energetically encourages the transmigration to west part. The main work of that time was to cultivate wasteland which was characterized by the fertile soils, high yield and economic benefits. As a result, amount of prairie and forest were quickly cultivated and become farmland. The excessive assart and cultivation destroyed the vegetation and original ecosystem, twice world shaking sand and dust storm were occurred in America in 1930s, consequently, soil degraded and crop yield reduced markedly. The severe lesson made American government organize various experts in agriculture, ecology, mechanism and other fields study the problem. Initially, less and no tillage was proposed and has been adopted since 1940s. Finally, this technique has developed into the conservation tillage technique.

After several decades exploration, America has put the application of conservation tillage into a long-term developing stratagem, a perfect system and measures for the application has been formed. Conservation tillage technique has become the efficient approach not only for the prevention of sand and dust storms, but also for the reduction of runoff and increase of soil water reservoir, and hence the increase in crop yield. Presently, approximately 70% farmland in America, above 80% farmland in Canada and above 70% farmland in Austria has used the conservation tillage technique. Totally, more than ten countries over the world has popularized and applied conservation tillage technique at large scale.

*Conservation Tillage is the ideal cultivation system and tillage technique presently.*

Actually, conservation tillage is a dryland farming cultivation technique with the specific aims. From the development of dryland farming technique over the world, we can see that conservation tillage can meet the double requirement for the protecting environment and developing agro-production. It is a tillage system with the core of soil and water conservation, which characterized by the less or no tillage, stubble mulch combine with chemical control for the occurrence of weeds, plant diseases and insect pests. The main measure for the system is stubble mulch to guarantee the emergency of emergency of seeds.

*Conservation Tillage meets the requirement for the regional development.*

The specialty of the agriculture in China is that little land supports much people. The agriculture in China is always managed by farmhouse through adopting the intensive cultivation. Conservation tillage has prompted the transformation of traditional cultivation system and may alter the habits and ideas in traditional agriculture from the base. With the rapid development of the local social economy, the transformation from traditional cultivation into conservation tillage will induce the new changes in the agro-production organization in a deeper level. Consequently, crop structure and plantation pattern will change accordingly. In addition, the transfer of labor in country and rapid popularization of mechanization of farming created necessary condition for the popularization of conservation tillage.
techniques. By and large, we should combine with the modern agricultural technique on the bases of succession of the intensive cultivation in tradition agriculture so as to build up a set of soil tillage technique system which adjust measures to local conditions, and finally exert the function of conversion tillage in the transformation from traditional agriculture to modern agriculture.

**Application of conservation tillage technique in the Gully region of the loess plateau**

In the Loess Plateau, dryland farming was always focused on the rotation and experienced a several technique using stages from manure fertilization, deep plough, compacting, etc. In 1970s, terrace was cosmically start constructed and mulch technique was greatly used. Presently, film mulching, rainfall collecting and water saving irrigation, and conservation tillage and other advanced techniques have been adopted.

**Less and No-Tillage**

Less and no tillage is a technique in tillage amount and intensity. The less tillage is characterized by the shallow tillage combine with stubble mulch. The aim of the technique is to reduce soil water loss from surface soils. For the no tillage system, no tillage will last about 3 to 5 years until the previous formed plow pan disappeared and soil water reservoir renewed.

**Mulch cultivation technique**

Mulch cultivation technique includes film mulch and stubble mulch. We have researched the effects of both conservation tillage techniques. Here some results are shown.

**Film and stubble double mulching technique**

Film mulching can effectively reduce soil water evaporation and increase soil water use efficiency. In film mulched winter wheat, hole seeding was taken for the place of broadcasting seeding and band seeding. The yield was increased more than 15%. Film and straw mulched winter wheat have increased crop yield by 15.8% and water use efficiency by 7.2% compared with the film mulched winter wheat. Besides, corn straw can improve soil fertility. After 2 years’ corn straw mulching, soil organic matter increased from 10.5 g/kg to 11.6 g/kg, total nitrogen increased from 0.825 g/kg to 0.866 g/kg, Olsen phosphorus increased from 8.3 mg/kg to 8.9 mg/kg, available potassium increased from 117.3 mg/kg to 125.8 mg/kg.

**Double ridge planting and water collecting technique**

The technique have significant function to collect rainfall and maintain soil water and thus increased rainfall water use efficiency to corn. Planted in wide film (140cm) can restrain the soil water evaporation during the growing period. The water use efficiency of corn was increased from 13.9 kg/hm$^2$·mm to 15.8 kg/hm$^2$·mm.

<table>
<thead>
<tr>
<th>Cultivation approaches</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>Water use efficiency (kg/hm$^2$·mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted in double ridges</td>
<td>9800.5</td>
<td>10214.3</td>
<td>9977.8</td>
<td>11486.3</td>
<td>26.9</td>
</tr>
<tr>
<td>Planted in wide</td>
<td>8943.3</td>
<td>9914.3</td>
<td>9733.3</td>
<td>11372.0</td>
<td>25.2</td>
</tr>
</tbody>
</table>
Orchard mulching technique

In orchards, straw, fresh grass and film mulch have increased soil water content in 0~60 cm soil depth by 23.1%, 5.0% and 32.1%, respectively. Soil water contents in straw and film mulched orchards have been increased significantly compared with control. The average increase in soil water contents in film and straw mulched orchard are 30.9%, 32.2% and 34.2% in 0~20 cm, 20~40 cm and 40~60 cm soil depths, respective. Fresh grass used in the experiment was clover and the soil water changes in orchard mulched with clover was not obvious compared with that mulched with straw and film because the growth of clover also consumed some soil water.

Table 2  Effects of mulch approaches on soil water conditions in orchard soils

<table>
<thead>
<tr>
<th>Depth(cm)</th>
<th>Date</th>
<th>0516</th>
<th>0613</th>
<th>0715</th>
<th>0818</th>
<th>0918</th>
<th>1014</th>
<th>1116</th>
<th>Average increased (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~20</td>
<td>Control</td>
<td>6.4</td>
<td>3.4</td>
<td>4.4</td>
<td>14.0</td>
<td>18.6</td>
<td>9.8</td>
<td>11.9</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Straw</td>
<td>12.4</td>
<td>6.2</td>
<td>6.0</td>
<td>15.9</td>
<td>18.9</td>
<td>12.6</td>
<td>12.6</td>
<td>30.9</td>
</tr>
<tr>
<td></td>
<td>Film</td>
<td>16.5</td>
<td>10.2</td>
<td>11.2</td>
<td>15.2</td>
<td>18.6</td>
<td>16.9</td>
<td>10.5</td>
<td>30.9</td>
</tr>
<tr>
<td></td>
<td>Fresh grass</td>
<td>11.7</td>
<td>5.0</td>
<td>4.7</td>
<td>15.2</td>
<td>18.6</td>
<td>10.5</td>
<td>12.4</td>
<td>3.2</td>
</tr>
<tr>
<td>20~40</td>
<td>Control</td>
<td>10.6</td>
<td>5.2</td>
<td>4.3</td>
<td>11.2</td>
<td>13.5</td>
<td>9.1</td>
<td>10.0</td>
<td>23.5</td>
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<tr>
<td></td>
<td>Straw</td>
<td>13.7</td>
<td>7.9</td>
<td>6.7</td>
<td>14.7</td>
<td>18.2</td>
<td>12.4</td>
<td>10.0</td>
<td>32.3</td>
</tr>
<tr>
<td></td>
<td>Film</td>
<td>15.7</td>
<td>12.3</td>
<td>10.3</td>
<td>13.1</td>
<td>15.8</td>
<td>15.3</td>
<td>11.8</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Fresh grass</td>
<td>10.7</td>
<td>4.9</td>
<td>5.7</td>
<td>13.2</td>
<td>14.1</td>
<td>9.8</td>
<td>9.9</td>
<td>10.0</td>
</tr>
<tr>
<td>40~60</td>
<td>Control</td>
<td>11.2</td>
<td>6.0</td>
<td>5.5</td>
<td>8.3</td>
<td>8.2</td>
<td>8.6</td>
<td>10.0</td>
<td>26.8</td>
</tr>
<tr>
<td></td>
<td>Straw</td>
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<td>9.2</td>
<td>7.8</td>
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<td>9.9</td>
<td>10.4</td>
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</tr>
<tr>
<td></td>
<td>Film</td>
<td>16.2</td>
<td>13.0</td>
<td>10.4</td>
<td>10.8</td>
<td>12.6</td>
<td>12.6</td>
<td>12.2</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
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<td>10.6</td>
<td>7.0</td>
<td>5.8</td>
<td>8.2</td>
<td>8.4</td>
<td>9.2</td>
<td>11.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Develop the conservation tillage technique with Chinese characteristic

Since have obvious characteristics in clime and approach, conservation tillage technique includes the techniques applied in the whole agro-production process, such as tillage, fertilization, seeding, management, harvesting and so on, and contains the technique systems in agriculture and mechanism.

Develop the localization Conservation Tillage technique according to the various conditions and based on the rural economical and mechanism developing levels.

Presently, tillage, seeding, and harvesting of major crops north China has become mechanization. A
set of conservation tillage machines has been used to conduct the works of fertilization, seeding and filed managing under the condition of filed mulching. Thus the working efficiency has been increased and great benefits have been gained. The application of conservation tillage at large scale is depended on the degree of mechanization and hence the influencing factors for the popularization of conservation tillage are the machine and farmhouse. Therefore, we should develop the conservation tillage fitted machines and increased the allowance for the application of such machines so as to guarantee the application of conservation tillage techniques through machine popularization. Gradually, the application of conservation will be extended to larger scale.

**Build the Conservation Tillage technique corresponded with local climate, landform, rotation system and crop structure**

We should follow the diversity in the agricultural production conditions in China and put the engineering measures, biological measures, tillage measures and managing measures together and combine these aspects. And further study the conservation tillage approaches through which soil water and nutrient can be used fully, the crop structure and variety arrangement, various mulching technique, and weed control techniques so as to meet the different conditions and requirement for the agro-production.

Extend the demonstration zone of conservation tillage technique, increase the pertinence and practicability of conservation tillage techniques, gradually prompt the modernization and standardization, and enhance the popularization of applicable techniques. Therefore, fitting policy and supporting measures should be established to favor the development of conservation tillage, and thus increases extend of organization, socialization, and at large scale for agro-production so that the conservation tillage can be developed in a sustainable way.

**References**


Thoughts about establishing long effective system of CA

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Abstract: Long effective system of CA is composed of five secondary systems each of which performs its own function. The properties of long effective system determine its guiding system, which determines its development mode. The development mode is that the development system in which the government behavior plays a leading role gradually changes into completely marketlize system. In other words, the long effective system of CA is a system that government behavior changes from strength to weakness, up to its complete disappearance and nurture marketing behavior up to its maturity. In the course of establishing long effective system of CA, we should make an overall plan, lay stress on the key points, cooperate in harmony and promote the whole system.

Key words: CA, long effective system, government behavior, marketing behavior

There is no doubt that the establishment of long effective system of CA is a basically problem which is relative to continuous and healthy development of CA. Today I want to take this opportunity to address my points of view about the following three questions for your comments ——

What is long effective system of CA?
What is our needed long effective system?
how to establish the Long effective system?

What is the long effective system of CA

Since early 90s last century when CA was adopted in Shanxi province of China, it has been expressing outstanding advantages beyond other agricultural tillage technologies. After experiments and researches for some years, it is observed that the technology can reduce cost, increase the benefit, increase farmer’s income, increase soil fertility and improve the environment. Its this basic properties and important functions can happen be used by all level governments which are do their best on “three problems about countryside, agriculture and farmers”. Because the technology can integrate economic benefit, ecological benefit and social benefit which could not be obtained in the past, we regret not to have known it before. The miraculous effect of the technology lies in that if farmers want to increase yield with the aid of the technology, they must do something to improve the environment first. So they improve the environment without their noticing it. So you can see that putting the technology into force can integrate the goal of government and farmer’s interest very well. As a result, governments at all levels popularize the technology. Shanxi is the first province the to popularize the technology, followed by more than ten provinces (cities or districts) in north of China. The establishment of long effective system of CA is put on the schedule gradually shortly.

The so-called long effective system of CA is in fact the long effective system of the popularization of CA, which belongs to the scope of popularization of technology. As everyone knows, the popularization period of technology starts with the popularization of technology and ends up with
farmer’s accepting the technology of their own free wills. During the period, judging by system level, the long effective system of CA must not only satisfy nature of long effect but also must nurture a complete marketized system; Judging by effect level, the long effective system of CA must not only express long effect but also continue to give full scope to its radical effect after the popularization period ended. Judging by operation level, the long effective system of CA is refer to the process and code in which all elements or parts within the operating system of putting CA into force can have long-term interaction and produce far-reaching influence. Make further study on the operation level and we obtain that all elements or parts within the operating system of putting CA into force includes technical setup, machine and tool system, farmers, peasant householders, tractor drivers, agricultural machinery departments and service organizes. The basic requirement for these elements is that technical setup must be effective and suitable; machine and tool system must satisfy technical requirement, and be interdependent and supplementary to the technology; Farmers and tractor drivers must deepen the understanding on the new technology and increase the precision of implement operation with the aid of training; agricultural machinery departments and service organizes integrate inner needs of all production factors organically. According to the above-mentioned requirements, by integrating these elements to interact anew relations of production will be formed and followed by superstructure composed mainly of modern agriculture tillage culture. At the same time, if the process and code in which these elements interact with each other can produce active far-reaching influence, it satisfies the essential features of long effective system of CA.

So you can see that the long effective system of CA contains productive forces as well as relations of production, is related to economic foundation as well as the superstructure and is not only the present task of reducing cost and increase efficiency but also the historic task of continuous development of agriculture.

**What is our needed effective system and how to establish**

After the analysis of composition elements of the long effective system of CA, we obtain that the long effective system of CA is composed of guiding system, input system, service system, management system and innovation system which are the secondary systems of the long effective system. To all-sidedly understand, establish and perfect the long effective system of CA, it is necessary to approach it from basic functions, structure key points and integration of all elements.

**About guiding system**

It is orientation system of the long effective system which mainly solves the problems of “Who is the guider and what is the orientation”. As far as I know, the experiment-research and demonstration-dissemination of CA is powered by the unfolding and radiation of scientific research items and technical dissemination. At the initial stage of the process, the main body which organizes and puts these items into force is R & D institution and agricultural machinery departments. Afterwards, in the wake of higher extent of acknowledge and acceptance of CA, governments at all levels emphasize CA as an important project one after another, so some comrades consider it as the transition from department behavior to government behavior. It’s my belief that although R & D institution and agricultural machinery departments play an important role at initial stage and these behavior impress us as department behavior, but it is part of government behavior in essence. After CA goes into the stage of demonstration and popularization over large areas, originally superficial department behavior suddenly displays as government behavior, in other words government behavior
goes to proscenium from backstage. In the process, the essence of government guiding doesn’t change throughout. In the process of popularization of CA, the government is the guider all along, in other words it is agricultural machinery departments that discharges of functions and powers of government guide the popularization of CA.

Then what is the directing of government guiding? I thank transition from government behavior to farmer’s conscious behavior for popularization of CA is the most fundamental macro directing. In other words, government behavior taken for the popularization of CA must eventually develop into by marketing behavior accepted by farmers of their own free wills. So in the process the first priority should be given to deal properly with the relations between government behavior and marketing behavior, which is the prerequisite of government’s giving full scope to guiding and the norm during the whole process. We should notice that CA can not come into being spontaneously in the traditional production practice and it’s difficult to integrate CA and farmers without guiding of government. At the same time, we should also notice the limitation of government behavior and the importance of marketing behavior and if government behavior is not aided by marketing behavior, the popularization of CA is an infant who can not do without the embrace of government forever and is far from the farmer’s conscious behavior. From here we see that the importance of the government behavior mainly reflect in the starting point and measures, however that of the marketing behavior mainly reflect in the goal and end-result. In other words, the former one is a bridge and the later one is destination. Although government behavior goes ahead of intervening, do not forget the final destination of government behavior and although we stress the importance of the goal, do not neglect the bridge and measure achieving the goal. If we can grasp and deal with the relation of discriminating well, the basic problem of guiding system is solved.

We also have a point to stress that no hard and fast line can not be drawn between the behaviors of government and marketing during the process of practice and behavior, which are not antagonistic basically. If this point is realized, we should continuously increase the percentage of marketing operation, and take measures to breed market, main body of market and the farmer’s abilities to go into market and participate in competition, when start taking government behavior. From this sense, marketing behavior is breed by government behavior. We should never think it of the end of the government behavior as soon as marketization is referred, and should regard marketized government behavior as perfect government behavior and the reflection of government’s breeding market. There is no doubt that marketing behavior will completely substitute government behavior but the process can not go without government behavior. This is another basic point during the establishment of guiding system.

About input system

This is the engine system of the long efficiency system, which mainly solves the problems that “Who input?” and “How much should be input?” That CA can not come into being spontaneously in the traditional production practice is above-mentioned. The advanced agricultural technology in the world goes into my province 90s last century. The process from experiment-research to demonstration-popularization goes always under the help of government input. That the popularization of CA must depend on the engine —— government input has been proved again and again by practice. The above-mentioned so-called government guiding is the macro directing that should be clarified by governments at all level. However, that government input a certain funds as guiding allowance for the popularization of the technology is the most realistic and practical guiding
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for farmers. From this sense, establishing and perfecting government-input system is not only further development of government-guiding system but also materialized guiding system. Then in the course of carrying CA which embodies a concentrated reflection of government behavior, how to give full scope to the guiding function of allowance fund?

Firstly, further clarify the problem that “who is the receiver of the allowance?” Certainly, generally speaking the scope and the target of allowance is the farmers in the program-carrying area. But CA program is not “help the poor” program, and it give priority to give the allowance to young farmers of culture. Because the young farmers of culture is good at receiving and using the advanced technology, and the tractor of culture is not only the operator of CA machine but also the propagator of CA. One agricultural machinery tractor who concentrates his or her affection on the CA may attract more agricultural machinery tractors and farmers into the program.

Secondary, further clarify the problem of “What need the allowance and how much is needed?” “The more, the better” is not suit for allowance fund. The allowance fund have tow main functions. One is to subsidize the farmer’s operation-risk, which is called operation allowance; The other is to overcome farmer’s partial difficulties in capital, which is called machine-purchase allowance. Although the advantage of CA is to reduce cost and increase efficiency, where is operation risk from? Here, operation risk mainly refers to the result of wrong operation or the influence of natural calamity. We can say the possibility of operation risk is very low, and in fact to great extant the operation allowance is a award for farmers participating in the program. In a word, we should take a moderate manner in allowancing and determinate the quality of allowance according the extent of farmer’s acknowledgement on the technology.

Thirdly, we should further clarify the problem of “how to allowance”. The code of allowance can not be chosen at will. By this base, we should act according strict standards and increase the transparency of acting to gradually form canonical, order systems of government input and allowance.

About the system of service

This is the transmission system of the long efficiency system, which mainly solve the problem of “who service, who are serviced and how to service?” The taking its place of input system starts the engine of the long efficiency system; Only when the service system takes its place at the same time, can the long efficiency system transform CA into the practical productivity. Scanning the process of interaction of all elements composed the long efficiency system of CA, we obtain that it’s essence is the process from unidirectional service of government to internal service between farmers and machine-operators. According this stage, the service-system of most of the program province is to take as the main body and take government behavior as the leading factor. Service system of operator and farmer’s cooperation, self-service, self-responsibility for their own profits and losses, appears in some villages of Raodou and other countries which deserves to be mentioned. According the operation results, technology system, equipment system and application main body integrate organically, which function perfectly and whose developing speed is beyond expectation. In short, the service system takes farmers as the main body, and takes marketing behavior as leading factor and we should initiate and perfect it.

However the relatively ideal service system can not be done at one go. That’s why it comes into being firstly in the district of Raodou? Ten-years popularization of CA in the district of Raodou and all kinds of service provided by service team and big agriculture-machine owners are the main reasons which
in fact has gradually breed the market-main-body and market demand. In the final analysis, it is the driver force that makes the new system sprout, break though the soil and grow sturdily. The research-demonstration districts are established by the service teams is the parent body of the new system. Denying the function of the parent body is to violate the materialism. But if we remain at the stage of service teams’ demonstration to breed new system, that is to violate dialectics. We should breed and perfect the new system in the view pf the theory of process and theory of stage.

According the view of theory of process, the role of service team in country and town is very important and not substituted at the initial stage. So to spread the CA between farmers, the agriculture machine department must depend on agriculture machine service team to demonstrate farmers, make them master the nuclear technology and the main points of operation, and make the result and benefit of CA visual to the by the establishment of the district of testing and demonstration. This stage is usually tow or three years. The agriculture machine service team can play the lead in this stage and in a certain sense it further specify the government behavior. The risk (from technology, machine, soil condition, crop variety and other factors) which is accepted by it depend mainly on program fund to digest. Generally speaking, as a result relatively small experiment district and relatively ripe technology system, the risk will not be very full. Totally speaking the operation risk accepted by operation main body is to extent of mature of technology and implements. Operation risk’s nearing zero is a necessary condition of popularizing CA over large areas. At the same time, another necessary condition which is to won a batch of agriculture machine operators who master the core technology and the key points of operation has arisen. As a result of the logical need, at present we put forward the question. If we look at the problem like this in practice, we will let good opportunities slip. The scientific attitude and practice is that put breeding agriculture machine operators on daily work schedule. In other words the breeding of agriculture machine operators must go with perfecting of technology and implement simultaneously. Even at determining the address of experiment, we should take the quality and quantity of agriculture machine operators into consideration. Only at this time, can agriculture machine service team go to open new front. Certainly if there is no new front to open, they can join the competition with other agriculture machine operator, or popularize new technology.

In the view of theory of stage, the development of CA can be classified tow stages, namely experiment-demonstration stage and popularization stage. At experiment-demonstration stage, agriculture machine service team play a leading role and at popularization stage agriculture machine operator do so far as the implement main body is concerned. So far as target is concerned, the former is the stage of perfecting technology and implements, breeding operators and demonstrating benefit, the letter is the stage of fighting the drought, increasing the production, reducing the cost, increasing the efficiency, enlarging the area and improving the quality. In other words at certain stage, a certain implement main body undertake certain task is the existing problem at present. For example, some countries only depend on agriculture machine service team instead of taking care to breed farmers, as a result the implementing program far exceeded my ability and the expect result is discounted badly. These lessons told us that the implementing of CA possess an impassable stage nature. We can make full use of original organize resource to let agriculture machine service team fully display their skills to accomplish historical mission at this stage. But doing what is not in its department is absolutely not allowed. In fact we dong have the ability to do everything all by ourselves. Of course, agriculture machine service team does not exist again in some countries. But it doesn’t mean that agriculture machine service team which is run by government should be organized in these countries, which will reduce a great of waste. A relatively choose is that
choose some people from agriculture machine holders especially larger one to organize a civilian-run agriculture machine service team with good stuff like the countries of Changzi, Xiaoyi and Pingyao. The allowance of national input, technical training, and considerably attractive incoming exception are the adhesive agent of the service team. The cost paid by agriculture machine departments for this is not higher than that is used to rebuild country-level service team. So it is a double-win strategic choose. The relatively quick development of CA in Changzi, Xiaoyi and other countries or cities is directly relative to outstanding accomplishment of the mission at first stage depending on agriculture machine holders.

In total the breeding of implement main body of CA is quite important to the establishment and completion of service system of CA. To breed agriculture machine holders and large one and further breed stock system, stock cooperation and seems more important. This is an important standard to determine what stage or level CA program in a place go into the starting points and condition in all place is different, but they share the same final goal. To achieve the goal, we should bring about steady improvement in the service system of CA, namely unceasingly breed double-win service system taking agriculture machine holders as main body and marketing behavior as leading factor.

**About management system**

This is the control system of long effective system, which solves the problem of “coordinated growth, healthy development and harmonious development” Make an positive explore on the management system which fits in with the need of marketing economic and conform to local reality. To the end, we make and perfect “program management method” and “assessment criteria”; Make procedure of releasing guide, working out a production plan, organizing program, implementing program, checking program and accepting program clear.; increase work efficiency and According to assessment criteria, inspiring system of program rolling development is established by the check on the program. At recent years the nation level CA program demonstration countries recommended by my province stand first in provincial level key program countries.

**About the innovation system**

This is the soul of long effective system and upgrade system, which mainly solves the problem of “improve the quality of development and continuous development ” The innovation system is composed of technology innovation, management innovation and culture innovation. To innovate technology, we have to start with the establishment of experiment plots and endeavor to perfect the technology system and implement system. Various farming systems determined by various crops, complexity of agriculture demand and variety of production condition determine the complexity and variety of CA system. To realize the goal effectively and in low cost, we have to start with the establishment of experiment plots. In view of this acknowledgement, we establish experiment plot over a long period of time to guide the popularization of CA in the whole province. At the same time of technology innovation, we also have to increase the executive ability of program of CA by perfecting the train of thought of work and management, management innovation. We are devoted to increase the quantity of science and cultural of the great majority of farmers and to ensure healthy and continuous development of CA.

In a word, long effective system of CA is an indivisible organic whole included five secondary systems each of which performs its own function. From their functions and essential properties, guiding system determine the and ensure the
Input system continuously strength the main body status of former input by guiding of government input. Service system continues increases the main body of former input by guiding of government input. Management system integrates various factors of productivity organically by guiding of government input. Innovation system brings motive power continuously by overall innovation in technology, management and culture. We must treat and establish long effective system from overall point of view. There is only one long effective system of CA. During the course of establishing the long effective system, we should make an overall plan, lay stress on the key points, cooperate in harmony and promote the whole system. By “The long effective system in different places are different to some extent”, we means the extents of development and integrity are different, however the trend of development is same.

Conclusions

Long effective system of CA is an indivisible organic whole included guiding system, input system, service system, management system and innovation system. It contains productive forces as well as Relations of production is related to economic foundation as well as the superstructure and is not only the present task of reducing cost and increasing efficency but also the history task of agriculture continuous development.

The five secondary systems composed the long effective system is mutual linked and distinctive. We should treat and establish the long effective system with a overall perspective. During the course of establishing the long effective system, we should make an overall plan, lay stress on the key points, cooperate in harmony and promote the whole system. There is only one long effective system of CA. By “The long effective system in different places are different to some extent”, we means the extents of development and integrity are different, however the trend of development is same.

The properties of long effective system determines its guiding system, which determines its development mode. The development mode is that the guiding system leads other systems to completely marketrize CA.

Observed and studied from procedural of development, long effective system of CA is system that the development system in which the government behavior play a leading roll gradually change into completely marketlized system.

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Practical Experiences, Problems and Measures of Conservation Tillage in Double-Crop A Year Regions of Hebei Province

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Abstract: A small section of site description on conservation tillage for summer maize is presented here giving us chance to have a general preview on current state of CT in Hebei Province. Based on practical experiences of CT, this paper intends to seek appropriate and effective measures to settle those problems to CT in terms of its acceptance, instruments, marketable operation system, fitting technical research, and application, etc, by means of farmers instructing, instruments modification, collaborate research, and training as well.

Key words: winter wheat, summer maize, conservation tillage (CT), no-tillage, straw-mulched fertilizing-combined seeder for wheat

Introduction

Wheat and maize are two primary types of crops in the North area, and what’s more, the double-crop a year pattern of winter wheat and summer maize is the most common mode in the region of middle-southern Hebei, even in the Yellow-Huaihe-Haihe Rivers Plain region. Given the important pole they are playing, we spend years and months on research and application and attempt to seek a way to a satisfactory state in perspectives of production, economics and resources. More than two out of three areas in Hebei province are dry land or semi-dry-land suffering from lack of water which is variably scattered and just 500MM annually in average. Winter wheat grows exactly in a dry season, so its state primarily depends on irrigation. Therefore, the serious situation of water resources resulted from excessive exploitation of groundwater and ever-declining water level have been pushing us to take immediate initiation to effectively promote the long-term beneficial CT mechanization and water-economized agriculture in dry-land.

Retrospections of CT and water saving mechanization development on dry-land in Hebei

Since middle stage of 1980s, agricultural machines departments in Hebei province have organized many times of seminars or machine displays over CT and water saving agriculture. With the help of introduced technologies, we keep on researching and have successively explored a batch of distinguished experiment patterns utilizing water saving mechanizations and CT, such as: no-tillage stubble-mulched seeding for maize; furrow seeding for wheat; hill-seeding under Film mulched for wheat, peanut and cotton; side-seeding under film mulched for wheat; and machines combined with straw pulverizing and covering. What’s better, hill-seeding under film mulched for cotton and no-tillage stubble-mulched seeder for maize have been widely spread since late stage of 1990s.

No-tillage stubble-mulched seeding for maize is such a kind of tillage mode providing greater yield
with lower cost than conventional tillage that features thorough plow and no straws or weeds over the farmland. Because it aims at reducing primary, intercrop tillage operations such as plowing, diskng, ripping and disposing, fewer labors and less time are used to get greater yield besides of longer effective temperature accumulation, higher soil fertility, better ability to contain water, and stronger anti-lodging maize. The results of fixed-point tests and random-point tests in recent ten years indicate that no-tillage stubble-mulched seeder can improve soil water use efficiency by 10-20%, save water by 454.5m³/hm, raise yield by about 300 kg/hm, while cut operation cost by 300-600 yuan/hm. Till now, there have been nearly 70 thousand no-tillage stubble-mulched seeders throughout Hebei Province covering a large scale of 1.34 million hm² totally. If we have the areas hand-seeding and ridge-relay cropping wheat involved, almost the whole areas of summer maize in Hebei will have been applied no-tillage.

Practical experiences on CT for wheat in Hebei

Based on the successful achievements on CT for maize, we went a step further to carry out research experiments on whole-year-course CT for double-crop mode of wheat and maize in 2000. After 6-year efforts, we have extended its area to more than 100 thousand hm². Several pieces of experiences derived from practical operations are described here.

Successfully developed the no-tillage straw-mulched fertilizer combined seeder

In 2000, Hebei Agricultural Mechanization Bureau coordinated departments in relation to agricultural mechanizations including aspects of researching, manufacturing, exploring, and extending as well to cooperate together and successfully developed a type of no-tillage straw-mulched seeder 2BMFS-5/10. With that instrument, we got significant outcomes from diverse 18 demonstration sites in that autumn and thus received great support from provincial government. The next year, after some appropriate modifications to it, we went on spreading it more widely to 60 counties and then set up a one-million-mu demonstration site in Gaocheng. Besides, outcomes of the two years tended to be agreeable. Those inspiring results not only boosted our confidence but also made us be soundly clear about how important instruments are. In 2002, upon the large-extent support from Agriculture Ministry, we took further steps to reinforce the pace. On the basis of original design we made some proper modifications and transformed them into central-transport equipment, with the troubles of winding and blocking settled, seeder and compressor improved. To cope with the problems of surplus line-with, another new type of instrument 2BMFS-6/12 was presented. Presently, the two types are both prevalent in practice, though several problems remain to be solved. Meanwhile, researches and experiments on new type instrument that features low power consumption and small soil disturbance are undertaken.

Applying CT in double-crop regions could raise wheat yield

We have reason to believe that CT is a reliable technology, because during the two years most of 70 demonstration sites raised yield and the trend of results towards agreeable between annual tests and unit tests. CT for wheat is a multi-processing technology applied by no-tillage straw-mulched fertilizer-combined seeder, which can practice following operations: straw and residue pulverizing, stubble left, opening, side fertilizing, and compressing, at one bout. Besides, CT is a also multi-technology which combines straw mulching, deep fertilizing, and furrow seeding together to achieve greater yield with less water. There is no reason not to raise yield under CT. However, currently, yields just moderately raised by about 6%, and even less in the years under abnormal
climate. It is likely due to the immature instruments performance and relevant technologies to some extent.

**CT can remarkably benefit in economic, ecological, resource and environmental perspectives**

Farmers can be significantly benefited financially

1. Cutting operation costs by 300-600yuan/hm; 2. Saving watering expense about 150-400yuan/hm by lessening irrigation times; 3. Reducing cost of labor and time; 4. Making full use of time and selecting breeds with greater potential and longer period of duration to increase the whole year’s yields; 5. Increasing profit by 225-600yuan/hm. Counting up the profit raised by water saving, costs cutting, yield increasing, without considering workers’ fees or potential yields, it could be increased by about 675-1800yuan/hm merely due to wheat. There is another about 600-900yuan/hm by maize, and the increment could be up to 1275-2700yuan/hm.

CT could not only protect resources and enhance resources efficiency but also be favorable to agriculture sustainable development

1. Taking full advantage of natural rainfall in order to economize the use of water for irrigation, protect and save water resources; 2. Refraining soil erosion by wind and water, increasing soil moisture as well; 3. Making extremely use of fertilizer so as to save chemicals; 4. Leaving straw covering the farmland rather than wastefully burning up, for the purpose of maintaining and enriching living things and microorganisms in the soil, increasing soil organisms and nutrient contents, improving soil structure and the physical soil properties, enhancing soil fertility, and finally providing higher yield as well.

CT is also a great contributor to protect and beautify ecological environment

1. Restraining sand raising from farmland; 2. Dropping burning up stubbles to prevent the air from pollution; 3. Step by step lessening the use of chemical fertilizers for the purpose of heightening crops quality and protecting underground water against pollution.

**Fitting agronomic measures are necessarily required in the course of promoting and applying CT for maize**

Generally speaking, agronomic measures will be consequently altered with the changes of the tillage. According to current study on CT, we are supposed to take following points into consideration: 1. Seeding performance. To guarantee precise quantities of fertilizing and seeding and uniform seeding-depth of 2-4cm, the operator must be exactly clear about the functional differences between this new type CT seeder and those conventional seeders; 2. Fertilizer performance. It requests high-condensed and compounded chemical fertilizers of 600-750 kg/hm; 3. Insects and diseases management. To deal with the bad effects due to insects and diseases, encapsulated seeds are adopted; 4. Seeding quantities. More 10-15% seeds than usual quantities are demanded; 5. Watering performance. Make sure of properly watering maize prior to seeding and after being in milk, and the same water in duplicate use; 6. Irrigation performance. Irrigations for wheat are supposed to be along with the furrow trends.

**Analysis on problems to CT for wheat in Hebei Province**

Though there have been comparatively significant achievements, problems are still noticeable.

*Conventional tillage remains deep-rooted in double-crops a year regions*
There is a long history of thorough plow and careful preparations in such double-crop a year regions as Hebei. Traditional operations and performances, such as the so-called “three-time plowing and nine-time harrowing” and fertilizing before seeding to get fine clods, flat and snake farmland, are still deep-rooted and have considerable effects. With the extension of simplified tillage, although farmers do not pay so much attention to the so-called “three-time plowing and nine-time harrowing”, and gradually follow steps of CT, to some extent, it is still unacceptable for them to just left straws and stubbles there covering their farmland No-tillage straw-mulched technologies for summer wheat have been popularly applied, but there is still a preparing operation before seeding wheat, which is the right factor why no-tillage seeding pattern is comparatively acceptable for farmers. Therefore, it will be more difficult and more efforts should be taken to practice and extend CT for wheat under the background of CT for maize.

**No-tillage straw-mulched fertilizing-combined seeder for wheat still needs modifications**

Although the two types of no-tillage straw-mulched fertilizing-combined seeder for wheat (2BMFS-5/10 and 2BMFS-6/12) have been largely produced and extensively applied, problems still exist: 1) Much lower work efficiency than other instruments; 2) Much power consumption. There is a conflicting between current individual management and demand of large or moderate-sized tractors; 3) The quality and efficiency of operations are always badly affected lying in the disappointing materials, shape changes, unendurable share parts or lower reliability.

**It’s hard to form a marketable operation system.**

The pace of CT extension depends on two aspects. One is the initiative from farmers who practice CT and the other is the initiative from instruments operators or those professional instrument households. Moreover, the later one occupies more important place. What’s the point is that operators are trapped in an embarrass trouble that no one to pay for higher fees and no incomes for lower charges. Besides of lower work efficiency and reliability that directly lead to lower incomes, operators will have few desires to purchase instruments. Consequently, it will be quite difficulty to form a marketable operation system not to say the large-scale extension.

**Corresponding agronomic technologies are still immature; meanwhile, the already formed measures haven’t been suitably implemented yet**

In spite of that instruments design has taken the agronomic demands into consideration as far as possible, given the limitations of instruments themselves, it is unlikely to exactly meet every agronomic demand. With the appearance of new type instrument, concerning agronomic technologies are required to be perfectly fitting. To find a way out, we have to take action in two aspects: to carry out further experiments and researches so as to draw conclusions and then put them into practice; to have more extensive introductions to farmers (including operators or cultivators) and persuade them to switch from those conventional instruments to these newly emerged ones. However, neither of the two aspects is mature yet. When coming to researches, the properties of no-tillage instruments for maize and their primary performances such as stalks and stubbles disposal, soil preparations, seeding, fertilizing, subsoiling, insects and diseases controlling, and other sectors such as secondary management, haven’t developed as a complete and soundly available technologic system. Despite under experiments and researches, the realities are still not so active as supposed, primarily limited by funds, staff and other factors. Similarly, in course of practicing, restrained by funds, staff, inadequate introductions to farmers as well as the effects of deep-rooted conventional practices, going out of
work usually happened in one segment or another, which will make impact on the results in some sense, slow down the extension pace and even draw it back.

**Insufficient project funds**

Although the allocated funds from central administration have been fully invested on the project, the organization are still struggling to operate it, owing to local government’s always delayed financial supports.

**Measures to promote the development of CT for wheat**

*More instructions to farmers so as to guide them to switch from those conventional practices to these advanced CT*

Through practices we’ve clearly noticed that it is the prerequisite for developing CT to reinforce instructions to farmers so as to guide them transfer practices from those conventional tillage to these advanced CT. Here are three effective ways to make them better taught: more training, more excessive demonstration sites, and more publications. More than 95% of the trained demonstration villages or cultivators succeeded in putting it into practice. In fact, in 2001, the great demonstration site of one thousand mu were established by those well-trained farmers who knew nothing about CT before training. Generally speaking, the farmers after touring demonstration sites mostly desire to have a try, and for most part of the ones informed by publications have an impulse to get a closer tour. Furthermore, as long as you put it into practice using trained techniques, you will surely succeed. So we are supposed to follow the way step by step as: public instructing→demonstrations touring→technically training→further interpreting→practices transferring→putting in use→interacting→widely spreading. As we all know, agriculture producing has a close connection with the weather, so the training course is likely to be influenced by the abnormal weather. Only more training and practicing are the right way to superior techniques. Since we regard CT extension as a ‘ tillage revolution’, we must make our full efforts to fight for its success. Remarkably, the collaboration of training and demonstrating is the key.

**To continually improve instruments and establishing marketable operation system**

Instruments stand in the center of tillage sector. Nowadays, instruments operator is the key, because they can decide whether to buy or not by himself just depending on his incomes. However, till now, there are still a couple of problems to those no-tillage instruments such as: high power consumption, low work efficiency and bad reliability. Especially, it is the low work efficiency that will largely impact on operators’ desire to purchase, which will throw the establishment of the long-term marketable operation system into a difficult situation and then slow down the extension pace of CT. Turning back to look the development course of CT for wheat in Hebei province, we can say that CT is a type of technologies that has developed much faster than any others in the sector of agricultural mechanizations. However, what is much worth noticing is that the development of CT depends its survival on various subsidies for purchasing, practicing or others. Supposing that we couldn’t settle those problems to instruments and then establish the long-term marketable operation system in time, the CT wide spreading pace will be seriously slowed down as soon as the government or organizations withdraw those financial subsidies.

**To heighten the level of research, and further to solidify the technical foundations**

Innovations of CT technologies, especially the whole-course CT for wheat and maize in the
double-crop a year regions that is unique all over the world, consist of two primary parts: innovations in material equipment; technical innovations in technology system. The latter one is too difficult to accomplish if only in the effort of agricultural mechanizations departments. To deal with this tough question, we propose to construct a superior grade platform where the researchers and scholars from related institutions or colleges of agriculture mechanizations, agronomy, crop protection, resources as well as environment can conveniently and extensively communicate with each other, undertake more deep going research tasks and make more innovative and integrated technologies. Besides, they are also supposed to make great contributions to complete the development mode by forming an advanced regulation system with high individuality, practicability, and pragmatism as well. This platform could be organized by some government-titled departments to form a research group in which they can work together in concert with each other. In another way, they also can share the same program but practice and carry out experiments individually, and then elect a generally honored and well-experienced one to make ultimate checks or tests and finally install them up. Definitely, no matter which method is chosen, the related departments of government should financially support them both.

To integrate agricultural mechanizations and agronomy together; to set up a step-by-step training system

Without the participations and help from agronomic experts, agricultural mechanizations departments couldn’t do so good a job in demonstrating and extending CT. The achievements in the course of CT extension in Gaocheng have connected close relationship with the friendly combination of agricultural mechanizations and agronomy.

As aforementioned, to have technical training and demonstration sites touring is the key to the door of success. So we need to set up a step-by-step training system to cultivate other more trainers in order to effectively train more farmers. Detailed moves as following: selecting a block of technicians from inferior counties or villages, then training them and employing them to make instructions to farmers. Effects will be more remarkable with the help of those publications and special-used amplifiers in villages. In that way, we could soon remarkably explore the scale of training and instructing. To go a step further, we can even expand our instructing range as possible as we can by means of comprehensive collaborations: superior training to those specialists (in chief or selected demonstration sites), inferior training to those outstanding technicians or trainers, basic instructions to farmers, in addition to publications, amplifiers, video, and special designed programs in TV.

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The Use of Controlled Release Fertilizer in No-tillage Maize Growth

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Abstract: Experiments were carried respectively on no-tillage cinnamon soil of Yan Zhou and chao soil of Yu Cheng, resin coated urea were used as the controlled release fertilizer. Analyze the series outcomes we got following elementary results: The use of resin coated urea could significant reduce nitrate accumulation on soil section plane, besides nitrate accumulation continues decrease with the control time extending, which can do benefit to circumstance. Mixed seed fertilizer experiment show: There are no negative effects in maize germinating using resin coated urea as seed fertilizer, but merely common urea or that mixed with resin coated urea used as seed fertilizer, severe intimidate comes up, bud even can survive. Equal nitrogen proportion condition, gain higher maize yield when resin coated urea were use. The results of different proportion of common urea and resin coated urea experiment show that: the maximal leaf area of maize rise with common urea proportion enhance in fertilizer but no significant affect to plant height.

Key words: Resin coated urea, Controlled release, Nitrate

Since Justus Von Liebig found the Theory of mineral nutrition, agriculture production is rapidly promoted by the use of fertilizer and the development of fertilizer industry. Base on the investigation about 69,000 experiments from 1961 to 1986, the increase production of foodstuff is about 51.4% owe to the effect of fertilizer. When come to our country, the results about countrywide fertilizer experiment net show that more than 53% foodstuff increase are due to the using of fertilizer. So the importance of fertilizer in agricultures is gone without saying.

In recent years, the rapidly increase of the amount and wrong method in using of fertilizer cause many problems such as the decline of fertilizer efficiency, resource waste and the pollution of circumstance, all that convince of nations about the importance in further enhancing fertilizer efficiency, reducing use of fertilizer and restrain pollution duo to irrationality fertilization. The research and apply of new control release fertilizer might be one of efficient ways to solve the problem. Especially in recent 10 years, with the circumstance legislation within world more and more pay attention to controlling the fertilizer quantity, dosage of fertilizer are some content minus increasing, however the applying of control fertilizer is increase about 5% each year. Control fertilizer is called one of key directions of 21st century of fertilizer industry.

After long-term and big quantity applies nitrogenous fertilizer to soil, part of nitrogenous element is flowing with water, which not only waste the fertilizer but also cause the accumulation about $\text{NO}_3^-$ in soil section plane and the pollution of soil, furthermore the accumulation of $\text{NO}_3^-$ is increase with the fertilizer quantity rise; accumulation of $\text{NO}_3^-$ did not show significantly difference in soil space, but there is disciplinarian in the depth of 400cm soil, separate appear peaks in the depth of 60cm and 200cm(Li Xiaoxin, Hu Chunsheng, Cheng Yisong, 2003).
In order to study the affection of resin coated urea on maize germinate, growth in all stage, yield and the NO$_3^-$ N accumulation in soil section plane etc. we carried out experiments respectively on no-tillage cinnamon soil of Yan Zhou and chao soil of Yu Cheng from 2002-2006 year, resin coated urea and carbamide are compared in series treatments. Following are some results:

**The effects of resin coated urea on maize yield and accumulation of NO$_3^-$N in soil section plane**

The experiment is carried on in June 2002, Yan Zhou Shan Dong province, there are four treatments in experiment: ①CK$_1$, the nitrogen of carbamide used as base fertilizer 207kg per ha.; ②CK$_2$, the nitrogen of carbamide 207kg per ha. and apply in to soil as base fertilizer and fertilize at jointing stage, each is 50%; ③CU is the abbreviation of resin coated urea, in this treatment the nitrogen of CU apply to soil is 207kg per ha. In the form of base fertilizer. Maize variety is ZhengDan958, section area is 0.033 ha., treatments are random blocks design, manage at high yield standard, menstruated the yield and the NO$_3^-$N in soil section plane at depth 0-200cm.

**Maize yield**

Table1 is the yield of all treatments. From the result we can see that use resin coated urea can got higher yield than two sorts of traditional method, which can improve yield about 5.5% than use carbamide fertilize in one time and 2.4% than apply carbamide separate in two times. The results indicates release speed of resin coated urea fit maize growth in Shan Dong province, released elements can satisfy maize growth need in whole growth stage, which can enhance efficiency of fertilizer and increase production of crop.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (kg·hm$^{-2}$)</th>
<th>Compare with CK$_1$±%</th>
<th>Compare with CK$_2$±%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK$_1$</td>
<td>10769.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CK$_2$</td>
<td>11091.3</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>CU</td>
<td>11361.15</td>
<td>5.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**The accumulation of nitrate in soil section plane**

Base on the accumulation of nitrate in soil section plane of 0-200cm in all treatments (table 2), we can obviously see that resin coated urea can reduce accumulation of nitrate in soil section plane especially 60cm depth, the treatment of CU, average accumulation of soil section plane 60-200cm is 9.13mg/kg, which is only 43.94% of average of CK$_1$ and CK$_2$ (20.78mg/kg), from above results we can find that using resin coated urea can reduce the risk of polluting the groundwater. As to traditional fertilize method, CK$_2$ is more popular than CK$_1$ in practice production. Compare both fertilize method, in soil layer 0-60cm the accumulation of nitrate of CK$_1$ is significantly higher than CK$_2$, but when come to soil layer below 60cm there are no obvious difference between two treatments. Average accumulation of nitrate in whole soil layer, which of CK$_1$ is 20.89mg/kg higher than CK$_2$ 18.21mg/kg to degree about 14.72%, so we can find that environment risk of polluting groundwater CK$_1$ is obviously bigger than CK$_2$.

If the accumulation of NO$_3^-$N zoology threshold is 10ml/L, applying resin coated urea could reduce
the risk of accumulation nitrate in polluting groundwater than common carbamide, when applying resin coated urea the accumulation of NO\textsubscript{3}-N is lower except 0-20cm, the accumulation of NO\textsubscript{3}-N in deep soil layer most is less than 12mg/kg, average is 10mg/kg, below the zoology threshold. As to the common carbamide, the treatment CK\textsubscript{1} and CK\textsubscript{2} which in deep layer of soil accumulation of NO\textsubscript{3}-N is most beyond 10mg/kg, the risk of polluting groundwater is obviously.

Table 2  Effects of resin coated urea on the nitrate accumulation of soil section plane

<table>
<thead>
<tr>
<th>Soil layer (cm)</th>
<th>CK\textsubscript{1}</th>
<th>CK\textsubscript{2}</th>
<th>CU</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>29.09</td>
<td>15.32</td>
<td>15.32</td>
</tr>
<tr>
<td>20-40</td>
<td>20.89</td>
<td>7.37</td>
<td>6.91</td>
</tr>
<tr>
<td>24-60</td>
<td>21.51</td>
<td>5.88</td>
<td>6.24</td>
</tr>
<tr>
<td>60-80</td>
<td>15.49</td>
<td>11.26</td>
<td>6.68</td>
</tr>
<tr>
<td>80-100</td>
<td>16.79</td>
<td>20.58</td>
<td>6.14</td>
</tr>
<tr>
<td>100-120</td>
<td>22.02</td>
<td>23.77</td>
<td>7.77</td>
</tr>
<tr>
<td>120-140</td>
<td>24.40</td>
<td>26.00</td>
<td>8.79</td>
</tr>
<tr>
<td>140-160</td>
<td>22.52</td>
<td>25.78</td>
<td>10.08</td>
</tr>
<tr>
<td>160-180</td>
<td>20.18</td>
<td>23.10</td>
<td>12.56</td>
</tr>
<tr>
<td>180-200</td>
<td>16.05</td>
<td>23.03</td>
<td>11.94</td>
</tr>
</tbody>
</table>

Effect of resin coated urea and carbamide to maize germinate

Fertilizer especially quick result nitrogenous fertilizer has the problem of intimidate in seeding stage, which is a sustaining problem affect the crop insemination and incorporate fertilize mechanization, in order to resolve the problem we carry out the compare experiment between two kinds of carbamide.

Table 3  Ratio of maize germinate in treatments of urea and resin coated urea as seed fertilizer( %)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fertilize method</th>
<th>Mix seed and fertilizer</th>
<th>Below 5cm</th>
<th>Below 10cm</th>
<th>Beside 10cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Common urea</td>
<td>2.90 D</td>
<td>93.23 A</td>
<td>92.75 A</td>
<td>86.96 B</td>
<td></td>
</tr>
<tr>
<td>60% Common urea and 40% resin coated urea</td>
<td>12.08 C</td>
<td>92.75 A</td>
<td>93.71 A</td>
<td>94.68 A</td>
<td></td>
</tr>
<tr>
<td>100%Resin coated urea</td>
<td>92.75 A</td>
<td>95.65 A</td>
<td>95.17 A</td>
<td>93.72 A</td>
<td></td>
</tr>
</tbody>
</table>

Experiment is carried out in Yu Cheng Shan Dong province June 2006. Treatments as follow in table3. Different proportion of two sorts urea and four different place of fertilize is used. From the result we can see that the treatment of mix seed and fertilizer, when use 100% resin coated urea the ratio of germinate can reach 92.75%, hardly show intimidate in seeding stage; but when use 100% carbamide as seed fertilizer, the ratio of germinate only about 2.9%, maize can hardly germinate; as to 60%
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Carbamide + 40% resin coated urea used as seed fertilizer, ratio of germinate can only reach 12.08%; above results indicated that seed bring in to contact with carbamide directly, server intimidate comes up, so we should avoid the contact of seed and fertilizer in production. But when use resin coated urea as seed fertilizer there are no such problem, so seed and fertilizer can mix together, which can handle in real production widely, so this can help mechanizations in seeding and fertilize incorporate, then can reduce labor intensity and enhance the efficiency. There is important meaning in generalize the technology.

The effect of different proportion of carbamide and resin coated urea on maize growth

In order to find out the effect of carbamide and resin coated urea on maize growth, also provide experience for further popularize of control released fertilizer, we carried out the carbamide and resin coated urea contrast experiment in Yu Cheng Shan Dong province June 2006. experiment is select 60-day control released resin coated urea (nitrogen content is 43% ) and common big grain carbamide (nitrogen content is 46%), on condition of the same quantity nitrogen and apply method (pure nitrogen 225 kg/ ha., used as seed fertilizer and apply into soil in one time), each has 8 treatments: ① 100% carbamide ② 80% carbamide + 20% resin coated urea ③ 60% carbamide + 40% resin coated urea ④ 40% carbamide + 60% resin coated urea ⑤ 20% carbamide + 80% resin coated urea ⑥ 100% resin coated urea ⑦ traditional fertilize method (CK1, 100% carbamide, 50% use as base fertilizer, 50% apply to soil at jointing stage) ⑧ no fertilizer (CK2), treatment plot 5×5=25m², 3 repetition, arranged at random. The experiment is carrying out now, following is some summarize about part of results.

Maize height transformation of all treatments

Maize is enter its male stage in 10 August 2006, 10 days after male stage, then the maximal maize height appear, we measure height choose 2 from 8 rows, in the 2 rows we measure continual 20 individual plant and got the average, results is in table 4. Analyze the difference $F_{\text{treatments}}=0.516$, $P=0.8078$, there is no significant difference in treatments, the results show that carbamide and resin coated urea has similar effect on maize finally height.

Table 4  Maize heights in all treatments (cm)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>250.1</td>
<td>237.7</td>
<td>245.3</td>
<td>244.4</td>
</tr>
<tr>
<td>②</td>
<td>248.6</td>
<td>251.4</td>
<td>241.4</td>
<td>247.1</td>
</tr>
<tr>
<td>③</td>
<td>249.2</td>
<td>252.5</td>
<td>249.1</td>
<td>250.3</td>
</tr>
<tr>
<td>④</td>
<td>250.4</td>
<td>243.1</td>
<td>248.7</td>
<td>247.4</td>
</tr>
<tr>
<td>⑤</td>
<td>247.4</td>
<td>245.6</td>
<td>251.9</td>
<td>248.3</td>
</tr>
<tr>
<td>⑥</td>
<td>247.3</td>
<td>247.6</td>
<td>253.7</td>
<td>249.5</td>
</tr>
<tr>
<td>⑦</td>
<td>252.7</td>
<td>248.6</td>
<td>243.1</td>
<td>248.1</td>
</tr>
<tr>
<td>⑧</td>
<td>255.1</td>
<td>241.4</td>
<td>254.3</td>
<td>250.3</td>
</tr>
</tbody>
</table>

Maize maximal leaf area in all treatments

Maize come in to spin stage at 12 August 2006, we measure maximal leaf area at 22 August, choose 2
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from 8 rows and measure continual 10 individual plants, leaf length and width is measured in order to account ratio of leaf area. The leaf area are list in table 5, Analyze the difference we found that the P value between treatments can reach 0.0072, difference level reach highly significant level. Further analyze in Duncan method find that the leaf area between treatments are as following order: ①>②⑦>⑧. Base on the result we can find that maize maximal leaf area is increase with the proportion of carbamide enhance. From above result we can draw a conclusion that when use mix carbamide as seed fertilizer, if proportion of carbamide enhance, much nitrogen release at early stage, which can accelerate vegetable growth of maize; on the contrary these treatments may appear lack of fertilizer in later stage.

Table 5  Ratio of maximal leaf area of maize in all treatments

<table>
<thead>
<tr>
<th>Treatments</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>4.5446</td>
<td>4.7292</td>
<td>4.5566</td>
<td>4.6101 A</td>
</tr>
<tr>
<td>②</td>
<td>4.7382</td>
<td>4.6705</td>
<td>4.3238</td>
<td>4.5775 A</td>
</tr>
<tr>
<td>③</td>
<td>4.1481</td>
<td>4.2888</td>
<td>4.0586</td>
<td>4.1652 AB</td>
</tr>
<tr>
<td>④</td>
<td>4.3148</td>
<td>3.8426</td>
<td>4.3440</td>
<td>4.1671 AB</td>
</tr>
<tr>
<td>⑤</td>
<td>4.0012</td>
<td>3.9192</td>
<td>4.0972</td>
<td>4.0059 AB</td>
</tr>
<tr>
<td>⑥</td>
<td>3.9858</td>
<td>3.8797</td>
<td>4.4324</td>
<td>4.0993 AB</td>
</tr>
<tr>
<td>⑦</td>
<td>4.7480</td>
<td>4.1598</td>
<td>4.0672</td>
<td>4.3249 AB</td>
</tr>
<tr>
<td>⑧</td>
<td>3.8340</td>
<td>3.8584</td>
<td>3.5567</td>
<td>3.7497 B</td>
</tr>
</tbody>
</table>

References

[1] Resin coated urea can significantly reduce nitrate accumulation on soil section plane, low the zoology risk of polluting groundwater.

[2] On condition of mix seed and fertilizer, resin coated urea did not show negative effect to maize germinate, but when use carbamide or carbamide mixed resin coated urea as seed fertilizer, seeding hardly comes up. So this can help mechanizations in seeding and fertilize incorporate, then can provide directions in reducing labor intensity and enhancing the efficiency.

[3] Apply same quantity of nitrogen to soil, resin coated urea can get higher yield contrast to carbamide.

[4] The results of different proportion between carbamide and resin coated urea show: if all the fertilizer apply to soil as seed fertilizer in a time, maize maximal leaf area increase with carbamide proportion enhance; but as to plant height, there is no obviously effect when carbamide proportion change.
Preliminary Studies on Weed and Pest Management under Conservation Tillage

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Abstract: A field study was conducted to determine the effects of herbicide on weed management and to investigate the occurrence of weed, corn disease and insect under conservation tillage in the two-cropping area of the Shandong plain. Weed severity under conservation tillage and conventional tillage was greater without application of herbicide, however, weed in the summer field can be management by application herbicide in corn seedling stage. Corn disease and insect severity was similar in different tillage practices, corn virus disease and corn borer in field more serious. The finding of this experiment indicated that occurrence of corn disease and insect has closed relation with the amount of weed in field.

Key words: Conservation tillage (CT), corn disease, corn insect, weed

Introduction

Occurring of pest in field has a closed relation with cropping system and cultivation methods. Change in cropping system and cultural practice will increase or decrease group species of crop disease, insect and weed and alter regularity of pest in field[1]. Interest in utilizing conservation tillage for crop production in the north of China has been increasing since 1991. At present different conservation tillage acreage has risen over approximately 600,000 hr. in the last few years [2,3,4]. Conservation tillage in China applied as a method of ensuring environmentally sustainable agricultural production, has shown better effects on wind and water erosion reduction and increasing yield of crop. However, some problems such as the weed and pest increasing have occurred in some region. The objective of this study was to investigate group species of weed and pest under conservation tillage and to determine some methods to control pest and weed in the future.

Materials and methods

Field experiment

The tillage experiment, established in 2005, was located on a Shandong province loam soil. The winter wheat was reaped in May 20, 2006, the height of wheat stubble was 15-30 cm and the wheat straw was all covered on the soil surface. The summer corn, Zhengdan 958, was furrow sowed with 60cm wide and distance between hills was 27cm in July 24, 2006.

Six treatments were designed in the field experiment, Treatment 1: one mixed herbicide (MH) made by Institute of plant protection, CAAS, was sprayed 3 days after corn planting. Treatment 2: one mixed herbicide made by Institute of plant protection, CAAS, was sprayed 4 days after emergence of corn seedling. Treatment 3: one insecticide was mixed with corn seed and herbicide was sprayed 4 days after emergence of corn seedling. Treatment 4: one insecticide was mixed with corn seed and a herbicide, in common use in local area, was sprayed 4 days after emergence of corn seedling. Treatment 5: No tillage, no herbicide and insecticide was used. Treatment 6: the soil was ploughed
with the depth of 25cm, no herbicide and insecticide was used.

**Investigating corn disease, insect and weed**

Weed investigation in field was done in five sites (1m2) selected in each treatment in corn seedling stage and adult plant stage. Investigation of corn disease and insect was done in each treatment selected row and corn plant.

**Results and analysis**

**weed species and occurrence under conservation tillage field**

Under conservation tillage there are crab grass (*Digitaria sanguinalis* (Lim.) Scop), panic grass (*Echinochloa crusgalli* (L.) Beauv), green foxtail (*Setaria viridis* (L.) Beauv), great burdock (*Eleusine indica* (L.) Gaertn), three-coloured amaranth (*Amaranthus retroflexus* L.), *Acalypha australis* (L.), Common purslands (*Portulaca oleracea* L.), field bindwees (*Convolvulus arvensis* L.), green ramie (*Abutilon theophrasti* Medic) and volunteer wheat in the summer corn field. The main species of weed are crab grass and panic grass, three-coloured amaranth and Common purslands are secondary species (Fig 1).

![Graph](image-url)

**Fig. 1 Investigating weed species and number in fields under CT and conventional tillage**

The species of weed and number of different weed in summer corn field under conservation tillage is similar with those of conventional tillage, crab grass and panic grass are the main weed both of conservation tillage and conventional tillage. The emergence and growth of weed in CT corn field is earlier and faster than the plough field, the weed biomass (fresh weight) is 2879.11g/m$^2$ and 1870g/m$^2$ respectively in CT and conventional field.

The amount of weed in corn seedling stage will directly influence growth of adult corn. Investigation on corn plant height after emergence seedling, average of corn plant height in CT field and conventional tillage is 197.03cm, 207.70cm respectively, obviously lower than these of the CT field which applied with herbicide. The result showed that it is important for CT summer corn field to control weed in seedling stage. The result of field experiment also showed that in seedling stage application herbicide can manage weed injury under conservation tillage.

**Corn diseases in summer corn field with conservation tillage**

The result of investigation on corn diseases in different treatment showed, in seedling stage, there
were corn virus diseases such as maize streak and Dwarf mosaic, and in stage of adult plant, corn leaf blight, leaf spot and stalk rots were founded (table 1). Corn virus disease is more often in different treatment.

Table 1. Investigation of corn diseases in different treatments

<table>
<thead>
<tr>
<th>Corn diseases</th>
<th>CT</th>
<th>Conventional tillage</th>
<th>CT Herbicide + seed dressing</th>
<th>CT + herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP</td>
<td>% DP</td>
<td>DP</td>
<td>% DP</td>
</tr>
<tr>
<td>Leaf blight</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td>Leaf spot of corn</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maize streak</td>
<td>9</td>
<td>11.25</td>
<td>6</td>
<td>7.5</td>
</tr>
<tr>
<td>Dwarf mosaic</td>
<td>1</td>
<td>1.25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corn stalk rots</td>
<td>2</td>
<td>2.50</td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>15.00</td>
<td>8</td>
<td>10.00</td>
</tr>
</tbody>
</table>

Note: Total 80 plants were investigated. DP(disease plant), % disease plant = (disease plant/80) \times 100\%

**Corn insect in summer corn field with conservation tillage**

The result of investigation on corn insect in different treatment showed, in seedling stage, there were corn soil insect such as maize grub and black cutworm, and in stage of adult plant, Corn borer, arm worm and snail were founded harming corn plant in different treatment field (table 1). Corn borer is more serious and harmful to corn growth, snail in CT and conventional tillage also occurred more serious.

Table 2. Investigation of corn insect in different treatments

<table>
<thead>
<tr>
<th>Corn Insects</th>
<th>CT</th>
<th>Conventional tillage</th>
<th>CT + Herbicide + seed dressing</th>
<th>CT + herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHI</td>
<td>% CHI</td>
<td>CHI</td>
<td>% CHI</td>
</tr>
<tr>
<td>Corn borer</td>
<td>12</td>
<td>15.00</td>
<td>9</td>
<td>11.25</td>
</tr>
<tr>
<td>arm worm</td>
<td>1</td>
<td>1.25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>snail</td>
<td>2</td>
<td>2.50</td>
<td>3</td>
<td>3.75</td>
</tr>
<tr>
<td>grub</td>
<td>1</td>
<td>1.25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>black cutworm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>20.00</td>
<td>13</td>
<td>16.25</td>
</tr>
</tbody>
</table>

Note: Total 80 plants were investigated. CHI( Corn harmed by insect), Rate of corn harmed by insect = (CHI/80) \times 100\%

**Conclusions and discussion**

The findings from this field experiment, conducted in the two-cropping region of the Shandong plains, indicated that summer corn field under conservation and conventional tillage resulted in a greater severity of weed injury, regardless of the plough used. This is different to what was reported
previously $^{[4,5]}$. Results of investigation on corn diseases and insects in corn seedling and adult stage in natural condition, indicated that a similar density of infection in corn field both under conservation tillage and conventional tillage, which is also different from what was reported previously $^{[6,7]}$. The finding of effects of herbicide on control weed in corn field showed that application of herbicide which farmer used can reduce weed injury under conservation tillage, ensuring extension of conservation tillage in north China.

The finding of this experiment indicated that occurrence of corn disease and insect has closed relation with the amount of weed in field. The research in relationship between weed, corn disease and insect will be important for improving technique of conservation tillage.

The research in regularity of outbreak for plant disease, insect and weed needs a long term experiment and field investigation. The results of a two-year experiment can not explain the regularity of disease, insect and weed in field under conservation tillage, further study and survey should be did in a long period and in wide scope $^{[8,9]}$.

Acknowledgements

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References


Soil Physical Characteristics as Influenced by Conservation Tillage under An Intensive Cropping System

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Abstract: Conservation tillage is a viable technique for sustainable agricultural development in the North China Plain. Yet few studies exist on the influences of conservation tillage practices on soil properties and processes. The objective of this study was to investigate changes of soil physical properties as related to the shift from conventional moldboard plow to conservation tillage systems based on a long-term field experiment. The study, initiated in 2001, included three tillage treatments for winter wheat, moldboard plow (CT), rotary tillage (RT), and not-till (ZT). In 2005, soil organic matter (OM) content, bulk density, aggregate distribution and stability, and water retention curves were measured after harvesting winter wheat, and soil saturated hydraulic conductivity (Ks) was determined after harvesting corn. The results indicated that comparing to the CT, soil OM contents under the ZT treatment were increased significantly in the 0-30 cm layer, and as a result, soil physical properties were improved. On the other hand, RT influences on soil OM and physical properties were limited within the 0-10 cm layer. Overall, the conservation tillage systems increased soil OM content, the contents of macro-aggregates (>0.25 mm) and water-stable aggregates, available water content, and saturated hydraulic conductivity. Nevertheless, soil bulk density increase and saturated hydraulic conductivity decrease was observed in the 0-5 cm layer under ZT, and in the 5-10 cm layer under RT. Soil physical quality evaluation using the S theory showed that the ZT and RT treatment had higher S values, and therefore better soil physical quality, than the CT treatment. Although the S value was an effective soil quality indicator, it may not be able to reflect the connectivity of soil pores. A combined application of S value and Ks was recommended.

Key words: Conservation tillage, soil physical property, water retention curve, S value

Introduction

Winter wheat is the most popular crop in the North China Plain, yet it is also the crop of highest input, lower economic return, lowest water and fertilizer use efficiencies. Because of improper farming practices, winter wheat field is characterized by low organic matter content, poor structure and water holding capacity. It is estimated that more than half of the irrigation water loss occur in winter wheat field (Li, 1990). Consequently it is vital to develop improved farming systems (e.g., crop rotation, tillage technique, and irrigation technology) for sustainable agricultural development in the North China Plain.

Conservation tillage affects soil structure. In the first few years, conservation tillage generally increases soil bulk density and compaction, reduces soil porosity and modifies the pore size distribution in the soils (Hill, 1990; Wu et al., 1992; Gregorich et al., 1993; Osunbitan et al., 2005). The long-term response of soil structure to conservation tillage, however, may differ among soils, climates, and crops. In the US Northwest, there was significant increase in soil bulk density and decrease in available water content at the earlier years when zero tillage practice was introduced.
After 17 years, no differences in bulk density and water content were observed (Wilkins et al., 2002). Hill (1990) noticed that 12-year zero tillage practice decreased the volume of pores $>15 \mu m$, but did not affect the pores of $<15 \mu m$. A study on a sandy soil by Rasmussen et al. (1990) in Denmark showed that after six years of continuous direct seeding of barley, the macropores ($>60 \mu m$) in the 5-10 cm and 15-20 cm soil layers were reduced while the medium-size pores (0.2-60 $\mu m$) were increased significantly. In Italy, Pagliai et al. (2004) compared the performance of conventional tillage versus conventional tillage on a loam soil. Reduced tillage and stripe subsoiling improved the soil pore system, i.e., the portion of water storage pores (0.5-50 $\mu m$) and the continuous pores (50–500 $\mu m$) were increased.

With modification of soil structure and pore system, conservation tillage influences soil hydraulic conductivity and water holding capacity. A large number of studies have shown that reduced tillage and zero tillage increased soil hydraulic conductivity (Pagliai et al., 2004), and improve water infiltration (Cunha et al., 1996). Arshad et al. (1999) compared soil water retention curves under various tillage systems. The results indicated that zero tillage soil conserved more available water than the conventional tillage, which was explained by the fact that there were more micro pores under zero tillage system. Zhu et al. (1991) pointed that mouldboard plow produced larger pores that had less water holding capacity, and the total porosity and air-filled porosity was decreased rapidly under irrigation, precipitation and gravitational force. For the zero tillage soil, on the other hand, there was appropriate water holding porosity/air-filled porosity ratio, which resulted in higher available water content than the soil under conventional tillage. Nevertheless, some researcher found there was no significant difference in water infiltration rate between mouldboard plow and zero tillage (Ankeny et al., 1990).

Reports on the relationship between conservation tillage and soil attributes come mainly from areas with one crop in a year. In China, due to the lack of long-term tillage experiments, no data is available in the literature to describe the changes of soil properties as affected by conservation tillage practices. Therefore, the objective of this study is to investigate two conservation tillage systems, rotary tillage and zero tillage, on soil physical characteristics based on a long-term tillage experiment under a winter wheat/corn double cropping system.

**Materials and methods**

**Experiment site**

The experiment field locates at the Luancheng Agricultural Ecosystem Experimental Station, Luancheng County of Hebei Province. The elevation is 50.1 m, the average annual temperature is 12.5 °C, and the average precipitation is 536.8 mm, which occurs mainly in June, July and August. The soil is a sandy loam, with 13.8%, 66.3%, and 19.9% sand, silt and clay content, respectively. Winter wheat (early October to early June) and corn (mid-June to later September) double cropping is the most popular cropping system in the area.

**Experiment design**

The experiment was initiated in the winter wheat season of 2001. There are three tillage treatments for winter wheat, conventional tillage (CT), rotary tillage (RT), and zero tillage (ZT), with three replications. The plot area is 900 m² (60 m x 15 m). Details of the treatments are:

- **Conventional tillage**: Crop residue was chopped twice after corn harvest and chemical fertilizers were
broadcasted on the soil surface. Both residue and fertilizer were incorporated into the soil by mouldboard plow (10-15 cm). Winter wheat was seeded using a conventional seeder with uniform row spacing of 15 cm. The seeding rate was 195 kg ha\(^{-1}\).

**Rotary tillage**: Crop residue was chopped twice after corn harvest and chemical fertilizers were broadcasted on the soil surface, and then mixed with soil using a rotary tiller (about 7 cm). Winter wheat was seeded using a conventional seeder with uniform row spacing of 15 cm. The seeding rate was 210 kg ha\(^{-1}\).

**Zero tillage**: After corn harvest, crop residue was left standing in the field. A paired-row zero tillage seeder (model 2BMF-5/10, Hebei Nong Ha Ha Inc., Handan, Hebei) was used to complete the partial rotary tillage (in the seeding zone), seeding, fertilizer application, and packing operations. The width of the seeding-row was about 12 cm, and the spacing between two pairs was about 26 cm. The seeding rate was 262.5 kg ha\(^{-1}\).

For all the tillage systems, fertilizer application rate at seeding time was 75 kg ha\(^{-1}\) urea and 300 kg ha\(^{-1}\) diammonium hydrogen phosphate. In the spring, urea was applied at a rate of 300 kg ha\(^{-1}\). Three irrigations were applied before soil freeze in the winter, at elongation stage, and shooting stage, at a rate of 450, 525, and 600 m\(^3\) ha\(^{-1}\), respectively.

After winter wheat harvest, corn was seeded into the wheat stubble (about 20 cm long) using a zero-tillage corn seeder. The row spacing of the corn crop was 20 cm.

**Soil sampling and analysis**

Disturbed and undisturbed soil samples were collected in the 0-5 cm, 5-10 cm, 10-20 cm and 20-30 cm soil layers after winter wheat harvest in 2005. The undisturbed sample size was 100 cm\(^3\) (5-cm high and 5-cm in diameter) and 22.9 cm\(^3\) (1 cm high and 5.4 cm in diameter) for determination of soil bulk density and water retention curve, respectively. Disturbed soil samples were collected to analyze soil texture, particle density, and aggregates.

The disturbed soil sample was air-dried and passed through a 2-mm sieve. Soil particle density and particle size distribution was measured with the pyconometer method (Flint and Flint, 2002) and the pipette method (Gee and Or, 2002), respectively. For soil organic matter content analysis, part of the sample was further passed through a 0.25 mm sieve, and the Walkley-Black procedure was applied (Tiessen and Moir, 1993).

For soil water retention curve, the low-pressure portion (0, 0.5, 1.0, 2.5, 4.9, 10.1, 20.3, 30.5, and 56.5 kPa) was measured using a tension table, and the high-pressure portion (98, 296, 500, 980, and 1379 kPa) was measured using the pressure plate method (Dane and Hopmans, 2002). When all the pressure measurements were completed, final soil water content was determined gravimetrically, and the water contents under different pressures were calculated.

Dry-sieving was applied for soil aggregate-size analysis, wet-sieving was used for water-stable aggregates analysis, and the micro-aggregates was determined using the pipette method (Nimmo and Perkins, 2002).

Undisturbed soil samples were collected from the 0-5 cm and 5-10 cm layers in September 2005 (after corn harvest), and saturated hydraulic conductivity (\(K_s\)) was then measured in laboratory using the constant head method (Reynolds and Elrick, 2002). The sample size was 100 cm\(^3\) (5-cm high and
5-cm in diameter). For each treatment, three replicated measurements were conducted.

**Models and calculations**

Soil available water content was calculated as the difference between water contents at field capacity (volumetric water content at –33 kPa) and wilting point (-1.5 MPa) (Romano and Santini, 2002).

The van Genuchten (1980) equation was applied to describe the relationship between soil matric potential \( h \) and water content \( \theta \):

\[
\theta = \theta_s + (\theta_s - \theta_r) \left[1 + (\alpha h)^{\gamma}\right]^{-m}
\]

where \( \theta_s \) was the saturated water content, \( \theta_r \) was the residual water content, and \( m, n, \) and \( \alpha \) were fitting parameters \((m = 1-1/n, n>1, 0<m<1)\). In this study, we assumed that \( \theta_r \) equal to the wilting point.

We applied pedo-transfer functions to calculate the S values (Dexter, 2004). The value of \( \theta_s \) was from the actual measurement and \( \theta_r \) was taken as the water content at wilting point.

The mean weight diameter (MWD) of the water-stable aggregates was calculated using the data from aggregates and particle-size analysis:

\[
MWD = \frac{\sum_{i=1}^{n} \bar{x}_i w_i}{\sum_{i=1}^{n} w_i}
\]

where \( \bar{x}_i \) was the mean diameter of a given aggregates class, and \( w_i \) was the ratio of the corresponding aggregate class.

**Results and discussion**

**Soil organic content**

![Fig. 1 Soil organic matter content as affected by tillage treatments. The horizontal bars indicate standard errors of the means.](image)

Figure 1 shows soil OM content as affected by tillage treatments. On average, soil OM content in the 0-30 cm layer is 1.35%, 1.52% and 1.51% for CT, RT, and ZT treatment, respectively. Both RT and
ZT treatments show higher OM content than the CT treatment. Tillage effects on soil OM differ between soil depths. In the 0-5 cm layer, soil OM content is in the order of RT (2.41%) > ZT (1.95%) > CT (1.73%). Below 5-cm depth, the ZT treatment has the highest OM content in all the three soil layers, while no significant difference is observed between CT and RT treatments.

Soil OM content as affected by tillage treatment is related to crop residue distribution in the soil and its decomposition rate. As a result of tillage and seeding operation, crop residue is mainly distributed on the soil surface under ZT, in the 0-7 cm soil layer for RT, and in the 0-15 cm layer for CT. The CT treatment generally has higher soil temperature, air-filled porosity, and intensive microbial activity. As a result, OM oxidation rate is higher under CT than that of under RT and ZT (Peterson et al., 1998; Drijber et al., 2000). Lower decomposition rate and higher OM accumulation is expected under ZT because of its higher water contents, lower soil temperature, and less soil disturbance than under CT and RT. Nevertheless, the higher OM content in the 10-30 cm layer under ZT is unexpected. We anticipate that it may relate to the enhanced microbial activity under ZT environment. The higher OM content in the 0-5 cm horizon under RT results from the fact that most of the returned residue is distributed in this layer, and there is less soil disturbance, relatively low temperature, and higher water content than the CT treatment.

**Soil bulk density**

The results of measurements after winter wheat harvest is shown in Fig. 2. In general, \( b \) increases with depth, and there are larger differences between treatments in the 0-10 cm soil layer than in the 10-30 cm layer. In the 0-5 cm layer, \( b \) for CT and ZT is 1.24 g cm\(^{-3}\) and 1.27 g cm\(^{-3}\), respectively, significantly lower than that of ZT. In the 5-10 cm layer, \( b \) is in the order of RT > ZT > CT. At soil depth below 10-cm, \( b \) under RT is slightly higher than that of CT and ZT, and the difference between CT and ZT treatments is negligible.

![Fig. 2  Soil bulk density as affected by tillage treatments. The horizontal bars indicate standard errors of the means.](image)

Under traditional mouldboard plow, the soil has a loose top layer (0-10 cm), and the plow pan locates below 10-cm depth. After four years of tillage treatment, the plow pan “moves up” to 5-10 cm under the rotary tillage treatment, and the separation between the loose layer and plow pan disappears under the ZT treatment. Shukla et al. (2003) reported that after nine-year experiment, \( b \) of 0-10 cm layer under conservation tillage (RT and ZT) is smaller than that of mouldboard plow. Azooz et al. (1996)
reported that under zero-tillage did not differ significantly from that of conventional tillage. Our study indicates that in four years, conservation tillage increased soil bulk density in the 0-10 cm soil layer, but does not affect soil bulk density considerably at soil depth below 10 cm.

**Soil aggregates**

Figure 3 presents the distribution of macro-aggregates (> 0.25 mm) in the 0-30 cm soil layer. The difference between tillage treatments occurs mainly in the 0-10 layer where ZT treatment has significantly higher amount of macro-aggregates than the RT and CT treatments. Difference between tillage treatments in the 10-30 cm soil layer is negligible.

![Fig. 3](image1.png)

**Fig. 3** The content of soil aggregates >0.25 mm as affected by different tillage treatments.

![Fig. 4](image2.png)

**Fig. 4** Mean weight diameter of water-stable aggregates under different tillage systems.

Water-stable aggregates are defines as the part of aggregates that are able to maintain stability in water. These aggregates are vital for absorbing soil nutrients and organic matter, and secure soil structure. The more water-stable aggregates, the higher MWD, and the more stable in soil structure (Nimmo et al., 2004). Tillage effects on the MWD of water-stable aggregates are shown in Fig. 4. A declining MWD of water-stable aggregates with depth is observed. In the 0-5 cm soil layer, the order of MWD is RT>ZT>CT. Below 5-cm depth, ZT treatment shows considerable higher MWD values than the CT
and RT treatment, whereas no difference is found between CT and RT. Comparing Fig. 1 and Fig. 4, it is clear that the changes of soil OM content and MWD as affected by tillage and soil depth follow the same trend. Therefore, we conclude improves soil aggregate stability results from soil OM content increase. The largest MWD is observed in the 0-5 cm soil layer of RT treatment where the highest OM content is recorded.

**Saturated hydraulic conductivity**

Table 1 lists measured saturated hydraulic conductivity ($K_s$) and bulk density ($\rho_b$) results after corn harvest in 2005. In the 0-5 cm soil layer, the $K_s$ values are in the order of RT>CT>ZT, opposite to that of $\rho_b$. In the 5-10 cm soil layer, ZT treatment has the highest $K_s$ (136 x 10^-4 cm s^-1) value, which is 1.5 and 3 times the value of RT and CT treatment, respectively. On the other hand, no much difference between tillage treatments is observed for the $\rho_b$. We hypothesize that in the 0-5 cm layer, $K_s$ value is dominated by soil porosity, while it is determined by pore connectivity in the 5-10 cm layer. Hussain et al. (1998) indicated that although mouldboard plow produced higher amount of macro-pores, there was poor connectivity between pores of different layers. Bouma et al. (1982) and Green et al. (2003) showed that earthworm holes and pores left by root decomposition were the main sources of soil macro-pores. These pores were well preserved under ZT, but were break down by tillage operations, which inturn reduced soil hydraulic conductivity. Logan et al. (1991) and Warkentin (2001) also demonstrated that reduced tillage improved water transport path, including effective macro-pores and bio-channels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>0-5cm</th>
<th>5-10cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$K_s$ (x 10^-4 cm s^-1)</td>
<td>$\rho_b$ (g cm^-3)</td>
</tr>
<tr>
<td>CT</td>
<td>5.95 (2.11)</td>
<td>1.28 (0.03)</td>
</tr>
<tr>
<td>RT</td>
<td>6.97 (0.45)</td>
<td>1.30 (0.01)</td>
</tr>
<tr>
<td>ZT</td>
<td>1.73 (0.22)</td>
<td>1.47 (0.03)</td>
</tr>
</tbody>
</table>

The numbers are means and standard errors.

**Soil water retention curve and soil quality evaluation**

Soil porosity and pore-size distribution can be well represented by its water retention curve. The measured soil water retention curves under different tillage systems are shown in Fig. 5. These curves demonstrate the following characteristics. First, in the 0-5 cm soil layer, CT has lower water contents than RT and ZT at a given matric potential. When pF>3, ZT holds more water than RT, and the opposite is true when pF<3. Second, in the 5-10 cm soil layer, the difference between tillage treatment becomes apparent at pF<1.5, and the water content at a given matric potential is in the order of ZT>CT>RT. Third, at soil depth greater than 10 cm, CT shows lower water content than RT and ZT when pF>2.0. No difference is found between RT and ZT except at pF<1.3, where ZT has higher water contents than RT at a given matric potential.

To investigate tillage influences on soil water holding capacity, we calculate the available soil water contents (AWC) using the fitted van Genuchten equations and the results are shown in Table 2. Comparing tillage effect at different soil depths, the AWC is in the order of ZT>RT>CT for the 0-5
cm and 10-20 cm soil layers, and RT>ZT>CT in the 20-30 cm layer. Only at 5-10 cm soil layer, CT treatment has higher AWC than RT and ZT. On average, the AWC in the 0-30 cm layer is 0.098, 0.117, and 0.124 cm$^3$ cm$^{-3}$ for CT, RT, and ZT, respectively. Therefore, it is concluded that conservation tillage improved soil water holding capacity, which is attributed to the improvements in soil structure and OM content.

The calculated S values for the three tillage treatments are also presented in table 2. The order of S value follows the order of RT>CT>ZT in the 0-5 cm soil layer, ZT>CT>RT in the 5-10 cm soil layer, and ZT>RT>CT at soil depths greater than10 cm. On average, the S value for CT, RT, and ZT is 0.057, 0.066, and 0.073 in the 0-30 cm soil layer. It is evident that conservation tillage increased soil S value, and therefore improved soil quality. In addition, all the S values results are greater than 0.035, a critical soil quality value proposed by Dexter (2004), indicating that the experimental field is in good quality.

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**Fig. 5** Soil water retention curves as influenced by different tillage treatments.
Table 2: Soil available water content (AWC) and S value under different tillage systems

<table>
<thead>
<tr>
<th>Soil depth</th>
<th>AWC (cm³ cm⁻³)</th>
<th>S value</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>CT</td>
<td>RT</td>
</tr>
<tr>
<td>0-5</td>
<td>0.095</td>
<td>0.116</td>
</tr>
<tr>
<td>5-10</td>
<td>0.121</td>
<td>0.104</td>
</tr>
<tr>
<td>10-20</td>
<td>0.084</td>
<td>0.131</td>
</tr>
<tr>
<td>20-30</td>
<td>0.091</td>
<td>0.119</td>
</tr>
</tbody>
</table>

Except for the 5-10 cm soil layer, the changes of S value as influenced by tillage treatments are consistent with the changes of soil OM, water-stable aggregates, Kₚ, and water retention curve. Therefore, conservation tillage improved the overall soil physical quality in the 0-30 cm layer, and S value is a useful soil quality indicator. In the 5-10 cm soil layer, the order of S value (ZT>CT>RT) differs from the order of Kₚ (ZT>RT>CT), may be a result that S value does not reflect soil pore connectivity.

Conclusions

In this study, we compared soil physical properties as influenced by conventional versus conservation tillage practices for a winter wheat/corn double cropping system in the North China Plain. The results showed that after four years (eight crops), conservation tillage (RT and ZT) improved soil OM content, the contents of >0.25 mm aggregates and water-stable aggregates, saturated hydraulic conductivity, and available soil water content in the 0-30 cm layer. Meanwhile, increased soil bulk density and decreased saturated hydraulic conductivity were observed in the 0-5 cm layer and 5-10 cm for ZT and RT, respectively. Calculated S value indicated that with the introduction of conservation tillage practices, the overall soil physical quality was improved.

The S theory proposed by Dexter (2004) can be used as an effective indicator of soil physical quality. Nevertheless, further research is required to assess if the S value is capable of representing soil pore connectivity. It appears that a combination of S value and saturated hydraulic conductivity provides more realistic results.

References


**CO₂ Emission Fluxes with Different Tillage Patterns in North China Plain**

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**Abstract:** Based on different tillage patterns experiments of the CO₂ emission fluxes were investigated in north China plain. The effluent CO₂ was collected and analyzed by the static-chamber/gas chromatography method at a frequency of ten days in spring and summer, and once a month in spring and winter. The results indicated that CO₂ emission fluxes showed two perks in winter wheat one was after tillage and the other was in jointing stage, and the average CO₂ emission fluxes by different tillage was PT (moldboard plow tillage) > RT (rotary tillage) > NT (no-tillage). In winter wheat growth season, the CO₂ emission fluxes was 487.10 mg·m⁻²·h⁻¹ for PT, 456.64 mg·m⁻²·h⁻¹ for RT and 274.89 mg·m⁻²·h⁻¹ for NT CO₂ emission fluxes and soil temperature had a significant exponential correlation, specially the correlation of soil temperature at the depth of 10cm was best for PT and at the depth of 20cm was best for RT and NT. CO₂ emission fluxes and soil temperature had a significant exponential function, and using the continuously soil temperature we simulation the dynamics of CO₂ emission fluxes. At the same time we calculated CO₂ emissions was 1.778 kg/m² under PT, 1.755 kg/m² under RT and 0.911 kg/m² under NT.

**Key words:** soil tillage, CO₂ emission fluxes, soil temperature, north China plain

**Introduction**

The global soil organic carbon pool is the second largest terrestrial C reservoir estimated at 1500Pg (1Pg=10¹⁵g) to 1 m depth, and the soil-plant system and the pedosphere-atmosphere interface are sites of intense C exchange with 10% of atmospheric C passing through soils annually. An increase in atmospheric concentration of CO₂ from 280 ppmv in 1750 to 367ppmv in 1999 is attributed to emissions from fossil fuel combustion estimated at 270 Pg C and land use change at 136 Pg. Of the emissions from land use change, 78 Pg is estimated from depletion of soil organic carbon pool. As the atmospheric concentration of carbon dioxide grows, there is increasing interest in a mechanism for reducing the rate of atmospheric buildup and increasing soil organic carbon reserves. Conservation tillage is primarily used as a means to protect soil from erosion and compaction, to conserve moisture and reduce production costs. By building SOM the adoption of CT, especially if combined with the return of crop residues, can substantially reduce CO₂ emission. There are many papers which include increasing in yield and controlling soil degradation from erosion under CT, and there are also many studies on CO₂ emissions under different fertilizer and with day or season change. There are a few researches on emission fluxes with different tillage in China. The objective of this paper was to investigate how tillage practices to influence CO₂ emissions and soil temperature during wheat-growth season in north China plain under the winter wheat and summer maize doubled-crop rotation. In this period difference in soil temperature may be pronounced during the different tillage, affect carbon fluxes in the agroecosystem.

**Materials and methods**
Study sites

The experimental site was located at Luancheng (114°40′E, 37°50′N) Comprehensive Experimental Station of the Chinese Academy of Science, Hebei, China. The soil was a drab soil. The climate is semiarid temperate with a mean annual temperature of 12.2°C and a mean annual precipitation of 480.7mm. It is a typical farming system of winter wheat and summer maize doubled-crop rotation.

Experimental description

The experiment was started in 2001 including in three treatments: plow tillage, rotary tillage and no-tillage, and each treatment had 5m². Except tillage the other managements were the same.

Table 1. Design of Experiment Treatments in North China Plain

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Tillage and stubble return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow tillage</td>
<td>After corn harvest dispersing stubble and plowing the soil up to 15cm depth by disking</td>
</tr>
<tr>
<td>Rotary tillage</td>
<td>After corn harvest dispersing stubble and rotary the soil up to 5cm depth by disking</td>
</tr>
<tr>
<td>No-tillage</td>
<td>After corn harvest using no-tillage machine to direct drilling</td>
</tr>
</tbody>
</table>

Methods

CO₂ flux

CO₂ flux was collected and analyzed between October 2005 and June 2006 by static-chamber/gas chromatograph method. The chamber, made of PVC material, consisted of two parts: a quadratic section (30cm*30cm long) inserted 5cm into the ground, and a lid fitted with a gas sampling port. The atmosphere immediately above the soil surface is enclosed by the chamber and is samples at 0, 10, 20 and 30min after closure. Samples are collected by pumping and injecting into special gases (0.5L) for analyzed. For a constant net emission of CO₂, we have found that the increase in concentration within closed chambers is linear over a period. This change in concentration is a result of net emission from by the soil.

Once installed, the gas sampling chambers (three per plots) remained in place during the entire monitoring period. The first sampling occurred after installation of the chambers and proceeded at a frequency of approximately once a month in winter and spring, and once ten days in summer. Gas sampling was typically conducted between 9:00 and 11:00h. The chromatogram analyzer is HP6890N, and the CO₂ detector is FID with 200°C. The column is Porpak Q with 70°C. CO₂ flux was computed as: F=dc/dt(hM_wT_st)/(M_o (T_st+T)). Where F is CO₂ flux (mg·m⁻²·h⁻¹), dc/dt is the rate of CO₂ accumulation inside the chamber, h is the chamber height, M_w is 44, T_st is 273.2k, T is temperature.

Soil temperature

The soil temperature was automatic recorded under 2.5 cm, 5cm, 10cm and 20cm soil depth using external soil temperature thermocouples when 9:00-11:00 daily. This device determinates every 10min, and records once half an hour for average. The soil temperature thermocouples were placed in row for plow tillage and rotary tillage, and ridge for no-tillage.
Results

**CO$_2$ emission fluxes**

![Graph showing CO$_2$ emission fluxes](image)

**Fig. 1** The effect of CO$_2$ fluxes with different tillage

![Graph showing soil temperature](image)

**Fig. 2** The effect of soil 10 cm depth temperature with different tillage

CO$_2$ flux was highest when tillage and CO$_2$ flux for plow tillage soil and rotary tillage soil were increased 378.24 mg·m$^{-2}$·h$^{-1}$ and 311.02 mg·m$^{-2}$·h$^{-1}$ than that of no-tillage. After the first flush CO$_2$ flux was reduced until February 20 in all the treatments. While CO$_2$ flux was increased from February 20 to April 30 reaching the second flush. But there had a difference between no-tillage and the other two tillage treatments, as after April 30 CO$_2$ flux with no-tillage was declined all long and the other two treatments had a small flush on May 20 when falling. Results show CO$_2$ flux under no-tillage soil were lower than those of plow and rotary tillage soil in winter wheat field, expect March 30 and April 30 the difference reached 5% significant level, especially the difference reached 1% significant level on April 20 and June 10. But CO$_2$ flux associated with rotary tillage soil were not all lower than that of plowed tillage soil during the determined days. There are two periods of times which CO$_2$ flux associated with rotary tillage soil were higher than that of plowed tillage soil, those were from December 4 to March 20 and from April 20 to May 10. CO$_2$ flux was averaged for each treatment during observed days, as CO$_2$ flux for plow tillage soil was highest and that of no-tillage soil lowest. The means of CO$_2$ flux was 487.10 mg·m$^{-2}$·h$^{-1}$ for plow tillage soil, 456.64 mg·m$^{-2}$·h$^{-1}$ for rotary tillage soil and 274.89 mg·m$^{-2}$·h$^{-1}$ for no-tillage soil. Decrease of soil CO$_2$ flux from rotary tillage and no-tillage to plow tillage was respectively 6.25% and 43.57%.
The correlations of CO$_2$ flux and soil temperature with different tillage

Table 2. The Correlation of CO$_2$ Flux and Soil Temperature with Different Tillage

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2.5cm</th>
<th>5cm</th>
<th>10cm</th>
<th>20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow tillage</td>
<td>0.712**</td>
<td>0.713**</td>
<td>0.722**</td>
<td>0.711**</td>
</tr>
<tr>
<td>Rotary tillage</td>
<td>0.595*</td>
<td>0.596*</td>
<td>0.624*</td>
<td>0.625*</td>
</tr>
<tr>
<td>No-tillage</td>
<td>0.608*</td>
<td>0.635*</td>
<td>0.643*</td>
<td>0.645*</td>
</tr>
</tbody>
</table>

n=13, *p<0.05, **p<0.01
CO₂ flux and soil temperature had a significant correlation, specially the correlation for plow tillage reached 1% significant level (table 2). The correlation of soil temperature at 10cm depth was best for plow tillage and at 20cm depth was best for rotary and no-tillage soil, the correlations were respectively 0.722, 0.625 and 0.645; soil temperature at 10cm depth and CO₂ flux under rotary and no-tillage soil also had good correlation with 0.624 and 0.643 respectively. Here we collected soil temperature at 10cm depth to analyze. From sowing to April 20 soil temperature at 10cm depth for no-tillage was lowest which accorded with CO₂ flux, during this period the correlations were respectively 0.898 for plow tillage, 0.851 for rotary tillage and 0.870 for no-tillage which all reached 1% level. But from that soil temperature at 10cm depth for no-tillage was highest which didn’t accord with CO₂ flux, during this period the correlations were respectively -0.764 for plow tillage, -0.861 for rotary tillage and -0.919 for no-tillage. This study was presented the lowest CO₂ flux in no-tillage soil in the three treatments was due to soil temperature before April 20, while it may be others reasons after April 20 such as lower quantity of corn returned.

The simulation equation of CO₂ flux using soil temperature with different tillage

Table 3  Simulation Equation of CO₂ Flux Using Soil Temperature with Different Tillage

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Simulation equation</th>
<th>Correlation coefficient (r²)</th>
<th>CO₂ flux (mg/m²·h)</th>
<th>CO₂ emission (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow tillage</td>
<td>Y=116.970*e^{0.1031X} (X is 10cm depth soil temperature)</td>
<td>0.662**</td>
<td>302.24</td>
<td>1.778</td>
</tr>
<tr>
<td>Rotary tillage</td>
<td>Y=139.620*e^{0.0788X} (X is 20cm depth soil temperature)</td>
<td>0.506**</td>
<td>298.55</td>
<td>1.755</td>
</tr>
<tr>
<td>No-tillage</td>
<td>Y=21.833*e^{0.1751X} (X is 20cm depth soil temperature)</td>
<td>0.605**</td>
<td>154.87</td>
<td>0.911</td>
</tr>
</tbody>
</table>

n=13  Y is CO₂ flux.  ** p<0.01  , CO₂ flux and CO₂ emission are for winter wheat growth season.

0.506 for rotary tillage and 0.605 for no-tillage soil. Using the continuously daily soil temperatures we simulated the dynamics of CO₂ emission fluxes 302.24 mg/m²·h for plow tillage soil, 298.55 mg/m²·h for rotary tillage soil and 154.87 mg/m²·h for no-tillage soil. At the same time CO₂ emissions
calculated was \(1.778 \text{ kg/m}^2\) for plow tillage soil, \(1.755 \text{ kg/m}^2\) for rotary tillage soil and \(0.911 \text{ kg/m}^2\) for no-tillage soil.

**Conclusions and discussion**

The result was the same as other studies for plow and rotary tillage soil, but a few studies were recorded for no-tillage in north China plain. On February 20 \(\text{CO}_2\) flux for no-tillage soil was only 4.30 \(\text{mg·m}^{-2}·\text{h}^{-1}\) about twentieth of \(\text{CO}_2\) flux for plow and rotary tillage soil. It was due to the lowest temperature about 0.0067°C for no-tillage while 0.36°C for plow tillage and 0.05°C for rotary. Tillage may produce important changes in soil microclimatic conditions, which may induce a stimulation of soil microbial activity. Tillage on \(\text{CO}_2\) flux is higher when soil climate is more favorable to microbial activity. In winter wheat growth season, the \(\text{CO}_2\) emission flux was 487.10 \(\text{mg·m}^{-2}·\text{h}^{-1}\) for plow tillage soil, 456.64 \(\text{mg·m}^{-2}·\text{h}^{-1}\) for rotary tillage soil and 274.89 \(\text{mg·m}^{-2}·\text{h}^{-1}\) for no-tillage soil. Decrease of soil \(\text{CO}_2\) flux from rotary tillage and no-tillage to plow tillage was 6.25% and 43.57%.

Many overseas researchers advanced the correlations equation, they also thought using soil temperature at 5cm or 10cm depth better than air temperature. Our experiment used external soil temperature thermocouples when collected gas and analyzed correlations between \(\text{CO}_2\) flux and soil temperature. \(\text{CO}_2\) flux and soil temperature had a significant correlation, specially the correlation for plow tillage which could reached 1% significant level. The correlation of soil temperature at 10cm depth was best for plow tillage and at 20cm depth was best for rotary and no-tillage soil, so we can use soil temperature at 10cm depth to simulate the \(\text{CO}_2\) fluxes for plow tillage soil and 10cm or 20cm depth to simulate the \(\text{CO}_2\) fluxes for rotary tillage and no-tillage soil. Some researches considered when the temperature was under 15°C, \(\text{CO}_2\) flux of microbes respiration would be in the majority, and soil temperature was the key to microbes respiration and \(\text{CO}_2\) flux. As the growth of root, root respiration became the important portion, and temperature was not the only factor. Our finding proved that \(\text{CO}_2\) fluxes had a positive correlation under 16°C, while had negative correlation up 16°C.

Some events detected there had a conic or logarithm correlation between \(\text{CO}_2\) flux and soil temperature. Our experiments used external soil temperature thermocouples to simulate the \(\text{CO}_2\) flux and soil temperature as an exponential equation, and it may be because we just collected gas in winter wheat growth season while the other researches for a year. Using the continuously daily soil temperatures we simulated the dynamics of \(\text{CO}_2\) emission flux 302.24 \(\text{mg/m}^2·\text{h}\) for plow tillage soil, 298.55 \(\text{mg/m}^2·\text{h}\) for rotary tillage soil and 154.87 \(\text{mg/m}^2·\text{h}\) for no-tillage soil. The result from simulation was lower for all the treatments compared with the means of the thirteen measured result, it was due to the fewer collected frequency in winter.

**References**


Weed Management in No-till Corn in Wheat-corn Double Cropping System in North China

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Abstract: Weed management system has been studied from 1996 to 2005 which was suitable to no-till corn in wheat-corn double cropping in north China. Comparing to traditional tillage, weeds emerged earlier than corn and most of them were above 3-4 leaf stages before corn emerged in zero-till corn field, furthermore perennial weeds increase after several years of zero till practice, that makes weed control more difficult.

Wheat stubble mulching before corn planted showed some weed suppression in wheat-corn double cropping system both because of the physical force and the allelopathic effect of the straw. Some other methods as increasing wheat seeding rates and decreasing wheat row spacing also helped weed management. Wheat stubble mulching and increasing wheat seeding rate connected with herbicide rate, the reduced rate of atrazine [6-chloro-N-ethyl-N’-(1-methylethyl)-1,2,5-triazine-2,4-diamine] and acetochlor [2-chloro-N-(ethoxymethyl)-N-(2-ethyl-6-methylphenyl) acetamide] mixture with nicosulfuron[2-[[4,6-dimethoxy-2-pyrimidinyl-amino]carbonyl]amino]sulfonyl]-N,N-dimethyl-3-pyridinecarboxamide] as spot postemergence treatment and atrazine and acetochlor with or without glyphosate [N-(phosphonomethyl)glycine] provided good control of weeds.

Key words: weed management, wheat stubble mulching, seeding rate, herbicide reduction

Introduction

Conservation tillage programs can range from no-till (or zero till) to some level of reduced tillage. Conservation tillage has become an integral component of sustainable agriculture reducing both input costs and soil loss. Reduced tillage and no-till systems can conserve energy, reduce soil erosion, reduce labor costs, improve soil productivity, and improve profitability without sacrificing yield (Wilson, James, Curtis et al. 2006). Nowadays it is very well adopted by farmers in corn growing in wheat-corn double cropping system in north China (Li Xiangju and Su Lijun 2004).

Winter wheat and summer corn double cropping is the most popular cropping system in north China. In this system, corn was planted in early June as soon as wheat harvested or intercropped into wheat field 5-10 days ahead of wheat harvesting without till the soil. In this case, weeds emerged before wheat harvested continued growing in the corn field. These weeds which emerge early than corn were more competitive and would decrease corn yield in a large degree (Li Xiangju and Li Binghua 1996).
High temperature, humid climate and heavy rainfall prevented timely hand weeding and off-farm jobs were more prevalent during summer. Herbicides such as atrazine and acetochlor usually failed to control weeds above 3 leaf stages in corn field and high rate of atrazine and acetochlor caused more and more injuries in following wheat and some broad leaf crops. Postemergence herbicides, which had broad weed spectrums, were seldom to be found. Nicosulfuron, a good postemergence herbicide in corn field, sold at high price and not popularly accepted by the farmers (Li Xiangju, Wang Guiqi and R.E. Blackshaw 2005). Corn yield was usually decreased by 10-30% accordingly. It is very important to find a feasible weed control method in zero-till corn field in double cropping system.

Weed management system has been studied from 1996 to 2005 which was suitable to zero-till corn in wheat-corn double cropping in north China. The specific objectives of the study were to:

a. Determine the emergence timing of weed in different tillage system and changes of weed flora in no-till corn;
b. Determine the effect of wheat stubble on weed control and the connecting effects of wheat stubble and herbicides in no-till corn;
c. Determine weed control effects by increasing wheat seeding rate and the connecting effects of wheat seeding rate and herbicide in no-till corn.

This paper is the summary of the results after nearly 10 years study.

**Materials and methods**

Field and greenhouse studies were conducted in Hengshui, Shijiazhuang, and Beijing. The field had sandy clay loam soil with the pH7.5- pH8.1 and 2.39% - 1.85% organic matter. All fields were well irrigated.

The crop growing system was winter wheat-summer corn double cropping system. Corn was planted as soon as wheat harvested in early June. Before wheat planting, fertilizers were broadcast and incorporated to bring the total N and P to100-150 and 40-50kg/ha, respectively. In the seedling stage of corn, fertilizers were broadcast with the total N of 30-50kg/ha. Wheat was harvested in early June and corn was harvested in later September.

All data were subjected to ANOVA and the data of percentage scale for weed control were arcsine-transformed prior to ANOVA. Treatment means were compared by Fisher’s protected LSD test at the 5% level of significance. All statistical tests were performed using SAS (Chinese).

**Weed emergence timing and growing stages in different tillage system**

The experiment was conducted in Hebei and Beijing. Weed species, frequency, density and influence on corn yield were collected within five 1m$^2$ samples in each piece of land at 53 locations. The dominant weed communities were calculated to use DCA and TWINSPLAN. And also timing and growing stages of weeds were observed in Shijiazhuang location. Time of weed emergence was collected by weed species within ten 1m$^2$ samples both in disked and zero tillage fields.

**Wheat straw mulching and herbicides in weed control in corn field**

The experiment was located in Hengshui and Shijiazhuang in a factorial arrangement of treatments. Plots were 4 by 8m. Factor A was wheat straw mulching at 5 levels from 0-7500kg/ha and factor B was herbicide rates from 0-100% of normal rate (nicosulfuron 4% EC 1125 ml/ha plus atrazine 40%
1500 ml/ha as normal rate). Wheat straw mulch was applied before or immediately after corn was seeded and herbicides were spot applied postemergent when weeds were at the 3-6 leaf stages with a CO$_2$-pressurezed small plot sprayer delivering 450 L ha$^{-1}$ at 205 Kpa.

Weed density was recorded 3 days after wheat harvested by measuring four spots with 0.25m$^2$ of each in every plot. Plots were rated for weed control in density at 15 and 45 day after herbicide applications and weed biomass was measured 45 day after application. All control ratings based on a scale of 0 (no control) to 100% (complete control).

**Wheat seeding rates and herbicides in weed control in corn field**

The experiment was located in Shijiazhuang. It was arranged as a split-split-plot design, with wheat seeding rate as the main plots, row spacing as the subplot and herbicide as the sub-subplot. Main plots, subplots and sub-subplots measured 15 by 36 m, 15 by 6 m and 5 by 6 m, respectively.

Wheat seeding rates were 37.5, 75, 112.5, 150, 187.5, and 225 kg/ha with two-row spacing for each. Row spacing was designed as two narrow rows and one wide row with row spacing 15 and 30cm, respectively, or three uniform rows with row spacing 20cm, both of which are typical planting models of wheat in Hebei. The herbicide treatments were glyphosate plus the mixtures of atrazine and acetochlor (glyphosate 41% 2250 ml/ha plus the mixture of atrazine and acetochlor 38% 2250 ml/ha), the mixture of atrazine and acetochlor (atrazine and acetochlor 38% 2250 ml/ha) and no herbicide. The herbicides were applied preemergence as soon as corn planted with a CO$_2$-pressurezed small plot sprayer delivering 600 L ha$^{-1}$ at 205 Kpa.

Weed density was recorded in the same method described in study two.

**Conclusions and discussion**

**The emergence timing and dominant weeds in no-till corn**

As the result of weed survey during 1996-2005, there were 84 weed species in no-till corn in north China and about 10 species were dominant. Comparing with the survey in 1995, frequency of problem weeds and perennial weeds such as Abutilon, Cephalanoplos segetum, Hemistepta lyrata had been increasing (Table 1). That was probably due to yearly application of atrazine and zero tillage.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>1995 Frequency %</th>
<th>2003 Frequency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitaria spp</td>
<td>92.8</td>
<td>81.2</td>
</tr>
<tr>
<td>Portulaca oleracea</td>
<td>78.0</td>
<td>60.9</td>
</tr>
<tr>
<td>Acalypha australis</td>
<td>76.0</td>
<td>68.4</td>
</tr>
<tr>
<td>Eleusine indica</td>
<td>74.4</td>
<td>33.1</td>
</tr>
<tr>
<td>Armaranthus retroflexus</td>
<td>52.8</td>
<td>33.4</td>
</tr>
<tr>
<td>Chenopodium album</td>
<td>41.0</td>
<td>42.6</td>
</tr>
<tr>
<td>Convolvulus arvensis</td>
<td>23.1</td>
<td>23.1</td>
</tr>
</tbody>
</table>
There was significant difference between no-till and disked corn in weed emergence timing and weed density. In disked corn, almost all weeds emerged after corn planting because most weeds emerged in wheat field was eliminated by disk practice. Preemergence herbicides provided good control to weeds which emerged after corn and corn yield was not affected by weeds even if weed density is slightly higher than zero-till corn. However, in zero-till corn, weeds emerged in wheat field continued growing and weed density was above the level of control threshold (Figure 1). That brought potential decrease in corn yield for most weeds above 3-5 leaf stages were difficult to be controlled by preemergence herbicides. These results are very helpful to work out weed control strategy.

Wheat straw mulching and herbicides in weed control in no-till corn field

Wheat residues markedly reduced weed density and biomass production in corn (Figure 2). Progressively larger reductions in weed density and biomass occurred as wheat residue amount was increased from 0 to 7500kg/ha. At 7500kg/ha of wheat residue, weed density was reduced by 75.3-82.8% and biomass was reduced by 43.5-60.3%, respectively. Previous studies have similarly found that the level of weed suppression is highly correlated with the amount of plant residue on the soil surface (Teasdale et al. 1991; Vidal and Bauman 1996; Li et al. 2000). The large reductions in weed density and biomass from wheat residues noted in this field study may have been due to the combined effects of physical shading and allelopathic chemicals((Li Xiangju, Wang Guiqi and R.E. Blackshaw 2005)). In this case, the efficiency of weed control achieved 90% by spot applying nicosulfuron at 50% and 75% of its normal rate in the 7500kg/ha and in 4500 kg/ha plots, respectively (Table 2).

<table>
<thead>
<tr>
<th>Mulching weight kg/ha</th>
<th>0</th>
<th>1500</th>
<th>3000</th>
<th>4500</th>
<th>7500</th>
</tr>
</thead>
<tbody>
<tr>
<td>nicosulfuron 0.5 normal rate</td>
<td>35.5d</td>
<td>61.3c</td>
<td>70.0c</td>
<td>77.8bc</td>
<td>91.0a</td>
</tr>
<tr>
<td>nicosulfuron 0.75 normal rate</td>
<td>74.4c</td>
<td>77.3bc</td>
<td>94.3a</td>
<td>93.5a</td>
<td>98.6a</td>
</tr>
<tr>
<td>nicosulfuron normal rate</td>
<td>86.0ab</td>
<td>85.2b</td>
<td>94.5a</td>
<td>91.7a</td>
<td>99.2a</td>
</tr>
</tbody>
</table>

*Means within columns not followed by the same letter are significantly different (LSD0.05). Same as the following tables.
Wheat seeding rates and herbicides in weed control in no-till corn field

Increasing wheat seeding rate could control weeds both in wheat field and in corn field. The results of weed ratings 5 days before wheat harvesting showed that density of biannual weeds (Descurainia sophia and Capsella bursa-pastorise) in high wheat seeding rate were not significantly lower than that in low seeding rate. But the density of early-spring emerged lambsquaters (C.album) and the density of late-spring emerged weeds (Digitaria ciliaris, Eleusine indica and Amaranthus retroflexus) were deceased by 70.3% and 83.6% in planting pattern of uniform rows with row spacing 20 cm and by 50.4% and 66.9% in planting pattern of two narrow rows and one wide row with row spacing 15 and 30 cm, respectively, as wheat seeding rate increased from 37.5 kg h^{-1} to 187.5 kg h^{-1} (Table 3). Weed height was also significantly shorter in the high wheat seeding rate.

<table>
<thead>
<tr>
<th>Seeding rate Kg/ha</th>
<th>lambsquaters density (plants/m²)</th>
<th>lambsquaters height cm</th>
<th>late emerged weeds density (plants/m²)</th>
<th>late emerged weeds height cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 cm row spacing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The results above illustrated very important information. Former studies showed weeds emerged earlier than corn are more competitive and reduce corn yield in a large degree. In wheat corn double cropping system, a large part of weeds, such as crabgrass, emerged in wheat field when wheat density is lower. Corn yield was much more influenced by these weeds than weeds emerged after corn in no-till system. And preemerged herbicides such as atrazine and acetochlor failed to control weeds emerged earlier than corn. In this case, glyphosate at 2250 ml/ha should be added to pre-emergence herbicide so that weeds emerged before corn could get good control. However, in no tillage corn planted after the 187.5-225.0 kg/ha wheat seeding rate, excellent weed control efficacy, usually 90%-95%, was achieved by only applying a mixture of atrazine and acetochlor at normal rate because of smaller and sparser weeds. Wheat yield was not significantly lower at 187.5 kg/ha seeding rate, input of wheat seeds was acceptable and herbicide input was 75-90 yuan lower than normal practice.

**Table 4**  Weed control efficacy following different wheat seeding rate and row spacing (Shijiazhuang)

<table>
<thead>
<tr>
<th>Seeding rate kg/ha</th>
<th>37.5</th>
<th>75.0</th>
<th>112.5</th>
<th>150.0</th>
<th>187.5</th>
<th>225.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20cm row spacing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>atrazine and acetochlor</td>
<td>0</td>
<td>2.3</td>
<td>33.8</td>
<td>89.5</td>
<td>90.3</td>
<td>98.5</td>
</tr>
<tr>
<td>Atrazine, acetochlor and roundup</td>
<td>95.5</td>
<td>96.8</td>
<td>95.8</td>
<td>97.2</td>
<td>97.5</td>
<td>98.8</td>
</tr>
<tr>
<td>untreated</td>
<td>3515.0</td>
<td>3318.9</td>
<td>2888.3</td>
<td>2500.5</td>
<td>2008.8</td>
<td>1583.7</td>
</tr>
<tr>
<td><strong>two narrow rows and one wide row</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>atrazine and acetochlor</td>
<td>0</td>
<td>0</td>
<td>39.5</td>
<td>84.3</td>
<td>89.8</td>
<td>95.8</td>
</tr>
<tr>
<td>Atrazine, acetochlor and roundup</td>
<td>94.5</td>
<td>95.3</td>
<td>96.8</td>
<td>96.2</td>
<td>97.0</td>
<td>98.5</td>
</tr>
<tr>
<td>untreated</td>
<td>3631.1</td>
<td>3412.7</td>
<td>2881.5</td>
<td>2401.0</td>
<td>2301.5</td>
<td>1770.3</td>
</tr>
</tbody>
</table>

*Numbers following untreated lines are weed biomass*

**Summary and conclusions**

Weeds emerged in wheat field could not eliminated by disk or plough in zero tillage corn in wheat-corn double cropping system, which were more competitive and had large potential in reducing
corn yield. Weed control in zero till corn was more difficult because larger size and higher leave stages. From a long-term point of view, weed control in zero tillage corn would be more difficult because of the increase of perennial weeds.

Wheat stubble mulching provided some weed suppression. Weed density was lower as mulching weight increasing. At the weight of 7500kg/ha straw mulching, weed density was reduced by 75.3-82.8% and biomass was reduced by 43.5-60.3, respectively. In the plots with 4500 kg/ha wheat straw mulching, weed density was much lower than the unmulched plots and spot applying nicosulfuron at 75% and 50% of its normal rate showed 95% to 85% weed control efficacy. The reason of it was the physical force and the allelopathic effect of wheat straw. Visual observations indicated that corn emergence was slightly affected by winter wheat residues and corn seedlings were weaker in the mulched plots than in mulch-free control. Similar results were obtained by Ma (1993) on his work of wheat straw mulching on the corn cultivars. Although corn seedlings were weak in mulched plot, corn yield was not significantly affected compared with the control, which may be due to some of the weaker seedlings pulled out by hand in early stage of corn.

Increasing wheat seeding rate to 187.5kg/ha could control weeds both in the wheat field and in the corn field. A large amount of weeds such as crabgrass emerged in wheat field affected corn yield when wheat density was lower and without tillage of the soil. To control weeds like these, glyphosate at 2250ml/ha should be added to pre-emergence herbicide such as atrazine plus acetochlor at low seeding rates. In no tillage corn planted after higher seeding rate of 187.5 kg/ha excellent weed control efficacy, usually above 90%, was achieved by only applying a mixture of atrazine plus acetochlor at normal rate. But increasing wheat seeding rate should consider more on wheat price and net profit of wheat and corn growing.

References

[9] Li Xiangju,Wang Guiqi and R.E. Blackshaw.2005, Allelopathic effect of winter wheat residues on germination and growth of crabgrass (Digitaria ciliaris) and corn yield, Allelopathy


Studies on Yield and Benefit of Conservation Tillage for Wheat/Corn Intercropping

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Abstract: The effect of conservation tillage in wheat/corn intercropping on crop yield, soil wind erosion, soil water content, soil temperature were studied in this paper. The results indicated that the conservation tillage can enhance the crops yield, increase soil moisture content and reduce the soil wind erosion. No-tillage with surface mulching is superior to traditional tillage on yield, out-put ratio and ecological and social benefit. This intercropping model can be widely demonstrated and extended in Hexi Corridor of Gansu province and the other similar area.

Key words: Conservation tillage, wheat/corn intercropping, yield benefit

The wheat/corn intercropping is mainly cultivation in the northwest of the Xinjiang, Hexi Corridor, Yinchuan plain, Inner Mongolia and Northeast Loop plain. Currently, the pattern in Hexi Corridor has been over 10,000 hectares of farmlands in the high-yield super-ton record. In the next 20-25 years, the promotion of national might reach 267 million hectares of area, 3.75 ha of production tons, 10 million tons of grain production, ease the food shortage will play a key role to this in northwest. However, the main maize-wheat growing areas because of weather drought, wind-sand large, poor water resources, sparse vegetation and fragile agro-ecological environment, drought, wind, sand and soil fertility decline have become the mainly intercept factors of sustainable development in wheat-corn intercropping. In recent years, frequent drought in northern China, and sandstorms increasing every year, exacerbating in wheat corn-producing areas of ecological environment deterioration. Therefore, innovative research of conservation tillage in wheat/maize intercropping become very important for accelerating construction of ecology environment, achieving grain industry sustainable development, increasing income of peasants, stabilizing community of countryside, lessening pressure of provision security, promoting agriculture development and exploitation in west of china.

Materials and methods:

The field experiment was carried out in Liuquan village, Zhuwang town, Yongchang County, Jinchang city, Gansu province, in the northwest of China which was located in the Shi Yanghe oasis irrigation areas where is border in Tenggeli desert and is one of sand storm origin.

This area belongs to arid belt. The site is located 15 km and the Annual mean temperature is 7.8℃. Accumulated temperature above 10℃ is 3,010℃, respectively. The frost-free period is 150–165 days. The duration of sunlight is 3020 h and total solar radiation is 140-158kJ/cm every year. The Annual precipitation is 50-120 mm, and potential evaporation is above 2,000 mm, dry degree 3.1, with an average annual wind speed 1.67/m/s and annual blustery day for 5days(wind speed>17.0 m/s), the main destruction of the wind is the northwest wind, the east wind is next. The experimental plot soil is the sanding podzolic soil. Major natural disasters are the spring sandstorms.
The field experiment was conducted during the 2003-2006 cropping seasons at Liberty design with four treatments, that is (i) no tillage and remain high wheat stubble (ii) no tillage and straw mulching (iii) no tillage straw mulching former seeding harrow (iv) traditional tillage and furrow ploughing. These treatments were laid out in plots (the areas is 120m², which length is 30m and width is 4m) in a completely randomized design with four replicates. Adjacent plots were separated by 0.5m wide ridge. This experiment adopts wheat/maize intercropping. Two rows of maize plants were grown in 0.8m strips and six rows of wheat grown in 0.8m, each plot consisted of 2.5 belt.

Dates of sowing were 15 March for wheat and 16 April for maize. Maize seeds were manually sown and covered with a 2cm soil layer. The maize row spacing was 0.26m and 0.20m for wide and narrow rows respectively in the sole maize; wheat density is 4.5 million seeding/ha while maize is 67.5 thousand seeding/ha. The wheat seeds were sown with 15 horsepower small four-wheel tractor and 2BMF-6C-2 pattern no-tillage dressing fertilization seeder machine. It's can be combination furrow fertilizer barrier sowing soil covering and compaction measure. In this experiment wheat variety is Yongliang 4 while corn variety is Shendan 16.

All plots were given a basal application of N at 525 kg/ha as urea, P₂O₅ 180 kg /ha, K₂O 120 kg/ha. Both the K and P fertilizers were evenly broadcast and incorporated into the top 20 cm of the soil prior to sowing with fertilization seeder. All nitrogen divides into four times in dressing maize. That is 20% used in basal dressing, 20% used in seeding stage, 30% used in jointing stage, 30% used in spinning stage, each dressing use fertilizer placement drill.

When the harvest time is coming, the wheat adopted combine harvester reaps and leaves 20-30 cm height straw immediately mulching to the wheat row. The maize adopted manually harvest fringe leave straw decomposition and lodge, it remain maize straw mulching into maize row until maize jointing stage cannot decomposition lodge, the chemical weed yemaiwei and 2.4-D dingzhi were used before sowing and seeding stage while the plant disease insect pest adopted chemical medication prevent according to what happened seriously.

**Result and analysis**

**Yield effects**

**Wheat yield**

The average wheat yield is higher in the traditional tillage (4756.5kg/ha) than conservation tillage (4225.5-4413kg/ha), it is decreased 7.2-11.2% relatively conservational tillage. no tillage straw mulching former seeding harrow treatment is reduced 11.2% than conservation tillage.

**corn plant character and yield**

Test from the maize grain filling period, it indicates that conservation tillage treatment has more significant level than traditional tillage. The no-tillage and straw mulching gain the highest yield in this experiment while the traditional tillage in the least, compare with the traditional tillage maize's plant height increased 28.2-50.4 cm, stem diameter increased 0.4-0.75 cm, leaf length increased 5.02-13.12 cm, leaf width increased 2.1 cm, fresh weight per plant increased 0.315-0.772 kg per plant. The yield of maize conservation tillage is between 57799.5 kg/ha and 6382.5 kg/ha, the production output in each treatment is higher than traditional tillage, The no tillage straw mulching former seeding harrow maize have the highest production, it gains 6382.5 kg/ha, compare to the traditional tillage increase 939.3 kg/ha. The no tillage and straw mulching have the second highest yield, it’s gain
5977.5kg/ha production increase 534.3kg/ha. The no tillage and remain high wheat stubble have the third production compared to traditional tillage, its increase rate is only 6.6%.

The yield of wheat and corn

The result of this experiment indicated that the total yield of the no tillage and straw mulching and the no tillage straw mulching former seeding harrow maize are 10390.5kg/ha and 10608.0kg/ha, compared to the traditional tillage the rate increase 1.9% and 4.0%.

Table 1 Effect of yield on conservation tillage wheat/maize intercropping

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Wheat (kg/ha²)</th>
<th>Maize (kg/ha²)</th>
<th>Total (kg/ha²)</th>
<th>Increase (kg/ha²)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-tillage and remain high wheat stubble</td>
<td>4288.5</td>
<td>5799.5</td>
<td>10088.0</td>
<td>-111.7</td>
<td>-1.1</td>
</tr>
<tr>
<td>No-tillage and straw mulching</td>
<td>4413.0</td>
<td>5977.5</td>
<td>10390.5</td>
<td>190.8</td>
<td>1.9</td>
</tr>
<tr>
<td>No-tillage straw mulching former seeding harrow</td>
<td>4225.5</td>
<td>6382.5</td>
<td>10608.0</td>
<td>408.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Traditional tillage</td>
<td>4756.5</td>
<td>5443.2</td>
<td>10199.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The germination rate of wheat

After 10 days of wheat emerged topsoil the seeding rate was surveying in this experiment the result showed that the wheat seeding of conservational tillage is between in 352 plant per m² and 384 plant per m² while traditional tillage is 358 plant per m², which is increased -1.67% and 7.11% compared to traditional tillage (table 2). The seeding rate of no tillage straw mulching former seeding harrow maize is smaller than traditional tillage, while the no tillage straw mulching and the no tillage remain high wheat stubble were higher than traditional tillage.

Table 2 Effect of seeding rate on wheat conservation tillage

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Repeated (plant/0.8m²)</th>
<th>Seeding Number/666m²</th>
<th>Seeding Rate Increase</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-tillage and remain high wheat stubble</td>
<td>I: 460</td>
<td>II: 540</td>
<td>III: 667</td>
<td>IV: 630</td>
</tr>
<tr>
<td>No-tillage and straw mulching</td>
<td>I: 591</td>
<td>II: 596</td>
<td>III: 502</td>
<td>IV: 616</td>
</tr>
<tr>
<td>No-tillage straw mulching former seeding harrow</td>
<td>I: 555</td>
<td>II: 550</td>
<td>III: 464</td>
<td>IV: 547</td>
</tr>
<tr>
<td>Traditional tillage</td>
<td>I: 516</td>
<td>II: 552</td>
<td>III: 530</td>
<td>IV: 554</td>
</tr>
</tbody>
</table>
Soil moisture content

In order to study the soil conservation moisture ability of conservation tillage, we made four times of survey soil moisture content in four treatments when before irrigation first water, after irrigation first water, after wheat harvest and after maize harvest, the exact time is 17 April, 27 April, 24 July and 25 September. The test of soil depth is 0-20cm, 20-40cm, 40-60cm, 60-80cm, 80-100cm(fig1). From fig1 we can see, before first irrigation, conservation tillage soil moisture content is 12.81-13.1% while traditional tillage is 11.3% in 0-20cm depth, 14.8-17.09% in 20-40cm depth, 14.41-19.35% in 40-100cm depth, which increased 1.5-1.8%, 3.07-5.36% and 0.72-2.60% compared to CK.

While the traditional tillage soil moisture content are 11.3%, 11.7%, 13.69-16.75% in 0-20cm, 20-40cm, 40-60cm soil depth layer the conservation tillage is higher 1.5-1.8%, 3.07-5.36%, 0.72-2.60% than traditional tillage in the soil depth layer of 0-20cm, 20-40cm, 40-60cm.

After wheat harvest(fig2), the soil moisture content of conservation tillage is 9.92-10.99% in soil depth of 0-20cm layer, 12.27-13.11% in 20-40cm, 15.03-18.03% in 40-100cm. The traditional tillage soil moisture content is 10.27%, 11.96%, 14.13% in the soil depth in 0-20cm, 20-40cm, 40-100cm layer.

The result indicated that the preserve moisture in topsoil moisture capability is improved in conservation tillage of wheat/maize intercropping. The reason is before sowing not turn over soil, furrow, fertilizer, sowing and mulching accomplished immediately applied conservation tillage of wheat/maize intercropping, because soil moisture could not evaporate and immediately compaction by surface soil while the dry degree of surface soil wear away become more seriously in fall ploughing.
Soil temperature

The average results determined every 5-day from April 5 (wheat sowing) to March 15 (wheat germination) revealed that the soil temperature reduced by 2-2.5°C than CK. This is not advantageous to crop germination and growth in early period. It is indicated (table 3) the conservation tillage soil temperature is lower 1-3 compared to traditional tillage. Under the 0-25cm depth, mean temperature is decreased average 2-2.5 °C, 13.3-16.6% while the no-tillage straw mulching soil temperature decreased most.

Table 3 Effect of soil temperature on conservation tillage

<table>
<thead>
<tr>
<th>Soil temperature (°C)</th>
<th>decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>treatment</td>
<td>5cm</td>
</tr>
<tr>
<td>no-tillage and remain high wheat stubble</td>
<td>20</td>
</tr>
<tr>
<td>no-tillage and straw mulching</td>
<td>19</td>
</tr>
<tr>
<td>no-tillage straw mulching former seeding harrow</td>
<td>20</td>
</tr>
<tr>
<td>traditional tillage</td>
<td>22</td>
</tr>
</tbody>
</table>

Soil erosion

3 point in every treatment was testing of soil erosion quantity by strait rule every ten days, from wheat sowing (11 March) to seeding (15 April), test surveying soil erosion quantity by strait rule. In every treatment (3 point each treatment) test total 3 times, the result showed that (table 4) the treatment of no-tillage straw mulching have no soil wind erosion while no tillage straw mulching former deeding
harrow soil erosion quantity is only 4mm. Compared with the traditional tillage, the conservation tillage soil wind erosion quantity is decreased 55.6%.

<table>
<thead>
<tr>
<th>treatment</th>
<th>25March</th>
<th>5 April</th>
<th>15 April</th>
<th>Total</th>
<th>Decrease</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>no-tillage and remain high wheat stubble</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>no-tillage and straw mulching</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>no-tillage straw mulching former seeding harrow</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>55.6</td>
</tr>
<tr>
<td>traditional tillage</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions**

The no-tillage technique have many merits compared to the traditional tillage of wheat/maize intercropping in sand irrigation farmland. The conservation tillage farming system has a wide prospects in popularize.

The soil water temperature and the air condition is difference with ploughing soil, in no-tillage, because of small disturbed. So the soil nutrient condition has obviously distinguished between no-tillage and traditional tillage. Many studies indicated that no-tillage play a important role in improving soil structure, soil spaces, increasing soil water stability aggregating quantity and small spaces quantity, decreasing big and middle spaces, maintaining relativity stability of soil hollow billet spaces.

Compared to conservation tillage and traditional tillage, the different has arrived obviously level, which is indicated wheat production reduced 7.7-11.2%, maize production increased 6.6-17.3%, total yield increased -1.1-4.0% plant height of maize increased 28.2-50.4cm. Per plant fresh weight of maize increased 0.315-0.772kg/plant, No tillage and straw mulching is the most excellent while no-tillage straw mulching former seeding harrow is the next, no-tillage and remaining height wheat stubble is the third.

No tillage play a obviously role in decreasing sandland make deteriorate compared to traditional tillage, at the same time, it is indicated the origin sandstorm and bareness field have a close ration correlation.

It is a effetely manual dominate means analyses this contradiction to decreased sandstorm dangerous in spring and fall of dry areas. By carrying out the straw mulching in no-tillage and less tillage in wheat/maize intercropping and remaining maize straw through winter conservation tillage.

**Discussion**

Carry out conservation tillage in wheat /maize intercropping farmland not only decreased production cost in ploughing rake and land preparation of traditional tillage but avoid strong soilwind erosion because of spring ploughing. Decreased temperature evaporation in spring. promote storage moisture
conservation and strong seeding and improve crop production. so it is very necessary to develop this study and demonstrate in Hexi corridor because of dry and little rain. Strong wind and large sand rare vegetation, extremely the bareness topsoil and the seriously of soil wind erosion trait in winter and spring season.

The conservation tillage of wheat/maize intercropping plays an important role to prevent sandstorm. The reason of making soil desertification is unreasonable farming system in hexi corridor. Soil bareness in winter, a lot of soil particle be moved and lead to soil desertification under traditional tillage, because of large wind in winter and spring according to the test. The soil wind erosion contribution rate is about 20% in traditional tillage farmland. However, it’s a effective measure to govern sand storm in agriculture by using remain maize straw in winter of wheat/maize intercropping.

The straw can reduce wind velocity. Distracted the moving wind quaintly height above field and protect soil particle not moved by large wind. Decrease 40% quantity sand spread 8% soil wind erosion contribution to sandstorm. Conservation tillage in wheat/maize intercropping can reduce soil wind erosion and protect farmland. It is recorded that 3-8mm topsoil can be moved by wind. Much of nitrogen phosphorus potassium and organic materials is lost in soil every year in hexi corridor, adopting conservation tillage can reduce 90% soil wind erosion. Prevent soil degenerate and protect soil production ability.

Conservation tillage in wheat/maize intercropping will protect soil moisture, enhance farmland fertilizer and drought resisting ability, it is can increase soil storage moisture quantity 16%-19% and water availability 12%-16%. In two maturity every year areas of wheat/maize intercropping. One-crops can save once irrigation at least while two-crops can save 100m³/666.7m² water. Because of remaining straw into field, developing conservation tillage not only avoid pollution air by burning straw, but improved soil fertilizer.

Developing conservation tillage in wheat/maize intercropping can save toss cost and improve benefit and effect, reduce 2-5 times working procedure and decrease working cost 20%. And there is a obvious increase in the production and income such as maize yield increased 9.8%, wheat yield increased 4.3%. The conservation tillage is a great importance of improving cereals production ability in main areas and can save cost enhance efficiency.

Form a long time, conservation tillage will be producted good social benefit and ecology benefit in Hexi corridor. In recent years it can be improved peasants’ income and living condition. The income increase 10% of demonstrative peasant compared to the whole country peasant average income.

Because of drought climate, large wind and sand, shortage water resource, bare vegetable weak agriculture ecological environment in main plant areas of wheat/maize intercropping. Therefore the mechanical of conservation tillage and matching cultivation techniques in wheat/maize intercropping is used widly in 178 thousand hectares wheat/maize field. It plays a large role in north of china to improve ecological environment, realize cereal industry sustainable development, guarantying the national grain security, promote west of China, agriculture and development strategic sustainable.
Looking Ahead on Conservation Tillage Technology in China

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Abstract: Based on the analysis on the development of conservation tillage technology in different countries, the limitation factors from farm production conditions, technology conditions, management systems and farmers mentality to the development of conservation tillage technology in China had been discussed. The future development directions and emphases had been promoted. Advices had been given for future development of conservation tillage technology in China.

Key words: China, conservation tillage, development trends, discuss

Introduction

Conventional tillage is to turn over the soil using plow and the soil is bare and uncovered after tillage. Conservation tillage is a new type of tillage method, which overcomes the disadvantages of conventional tillage, reduces wind and water erosion, prevents soil and water loss, improves soil structure, increases soil fertility, reduces invalid evaporation of soil water, improves water resources utilization rate, reduces labor, mechanical and energy input, improves productivity and plant output, and realizes sustainable development of agriculture. Conservation tillage is a revolution to conventional tillage and has been the development direction in future all over the world.

Conservational tillage has no a standard definition yet in the world. It is measured usually by the amount of stalk covered on the field. In 1988, the United States called the tillage method that coverage rate of soil surface in field after planting was greater than 30% with no tillage or one time of surface soil operation together with application of herbicide to control weed as conservational tillage. In 2002, Ministry of Agriculture in China named it as advanced tillage technology that no-tillage or reduced-tillage and straw mulching were used during the farm production to reduce wind and water erosion, and improve soil fertility and anti-drought capability.

The connotation, patterns, measures, and effects of conservation agriculture vary with different countries due to different conditions. The experiences to develop conservational tillage in different countries had been discussed in this paper. The future development directions and emphases suitable for the actual conditions of China had been promoted. The purposes of this paper were to promote the development of conservation tillage in China.

Significant sequence of Conservation Tillage

The advantages of conservation tillage had been discussed in the first section of this paper. The purposes of application of this technology vary with countries. The figure 1 shows the sequences of importance of these advantages respectively in USA, Canada, Australia and China.
Conservation tillage was originally invented by USA for the purpose of “Dark Storm” prevention\textsuperscript{[5]}. The first purpose of application of this technology is for environment protection, such as water and soil wind erosion control. The other additional purposes are for anti-drought, reduction of production cost, improvement of fertility and reduction of mechanical operation (in Fig. 1a). In Canada, the conservation tillage is mostly used for prevention of soil water invalid evaporation, salt and soil erosion. The purpose is mostly for improvement of fertility (in Fig. 1b). In Australia, the thickness of soil is small. So, the purpose of conservation tillage is mostly for prevention of water and soil loss (in Fig. 1c). China is short of irrigation water seriously and farmland and water resources are limited. So, the purpose of conservation tillage is both for improvement of farmland output and environment protection (in Fig. 1d). Therefore, China should development this technology based on their national conditions.

**Background of development for conservation tillage in China**

**Environment conditions**

China is a large agriculture majored country and water resources is very limited whose environment varies greatly with regions. Take the Loess Plateau as example, its environment has following features\textsuperscript{[6–8]}:

**Dry and unbalanced distribution in space and season**

Drought and serious shortage of water resources are the most limited factors for agricultural sustainable development in Loess Plateau. The annual rainfall precipitation is only 486 mm in Loess Plateau, lower than 622 mm of China. From 60s to 90s in 20\textsuperscript{th} Century, the annual rainfall precipitation is 503.7mm, 461.1mm, 468.0mm and 428.7mm respectively for each decade. The rainfall in spring and autumn accounts for 15%-20% while winter 2%-3% and at most time the precipitation is lower than 5mm. The rainfall concentrates at August and September that accounts for 60% of total and most of them are rainstorms. The variation among years meets 50% at large. These features of rainfall promote drought and water and soil loss.

**Serious water and soil loss**

The Loess Plateau has been one of the most serious water and soil loss regions in the world due to nature conditions and unreasonable cultivation method. It is estimated that the total water and soil loss area in this region is $53 \times 10^4 \text{km}^2$ in which $43 \times 10^4 \text{km}^2$ are relatively serious lost area that accounts for
68.5% of total and in which 27.6×10^4 km^2 are seriously lost area that accounts for 64.19% of total. There are 2.9×10^4 km^2 of land whose soil erosion intensity is greater than 1000 t/km^2·a while 1.66×10^4 km^2 is 5000t/km^2·a. Some land is more than 20000 t/km^2·a. Serious soil and water loss results in degradation of eco-environment, barren soil, low fertility, and reduction of output. Under the pressure of demand on foodstuff, this region has been over cultivated and the eco-environment has been destroyed seriously. A vicious circle has formed in this region.

The loss of water and soil in the Loess Plateau has threatened the lower reaches of Yellow River. There is 1.6 billion ton of mud and sand flushed into the Yellow River from Plateau every year in which 0.4 billion ton is filled up on the bed of Yellow River, which lift the bed by 10-20 cm every year. The river-ways in the lower reaches of Yellow River are facing with the risk of burst which may greatly damage the economic development of China. In addition, the 1.6 billion ton of mud and sand flushed into the Yellow River results in 40 million ton of nutrients of N, P and K in the soil lost.

More serious problem of dust storms

According to the statistic data, there were 50 times of dust storms appeared in 2000-2004 in China, in which 40 times are related with the Loess Plateau. Especially in recent years, the frequency, strength, and scope of dust storms seem to increase year by year. The environment has been seriously destroyed by these storms. It is estimated that 70% of dust came from over-plowed farmland.

There are 11.8×10^4 km^2 of land in the Loess Plateau threatened by sand, in which 3.57×10^4 km^2 of land are seriously sand threatened which accounts for 30.25% of total threatened. The area sand threatened is increasing by 2460 km^2 each year. The results from sand threatening lead to reduction of farmland yield of plants, and degradation of eco-environment as well as human living conditions.

Barren farm land

The traditional cultivation methods such as high plow intensity, more use of fertilizer and great multi-cropping index lead to reduction of soil fertility. The original black loessal soil in the Loess Plateau disappeared for ever due to water and soil loss. The soil now is young loessal soil developed from loess. The contents of N, P and K are only 48.9 mg/kg, 6 mg/kg and 136 mg/kg respectively. The Zn lack land accounts for 75% of total farmland while MO is also 75%, Bo 70%, Mn 60%, CO and Fe 20%. The barren farm land can not provide enough water, fertility, air and heat for crop growth, which is the most limited factor for the improvement of comprehensive productivity of grain.

Social conditions

Household contract responsibility system with remuneration linked to output

The household contract responsibility system with remuneration linked to output, promoted in 1993, greatly improved the enthusiasm of farmers. However, the household system also limited the scale production of agricultural products as well as the application of large farm machinery. The problem now is how to resolve the contradiction between the small farmland household system and the application of mechanical conservation tillage technology.

The low level of science and technology of farmers

Compared with developed countries, the level of science and technology of farmers in China is very low. This also limits the application of advanced agricultural technology. With the renovation and open of China, many young men flow into cities to find jobs and the old, women and children stay at
home. This also limits the application of conservation tillage technology.

Long history conventional farm production habits

There are more than 2000 years of conventional intensive cultivation farm production habits formed in China. This cultivation habits prevent the further development of agricultural production and lead to degradation of farm production environment and many social problems. It has been a urgent problem that how to achieve both increasing of farmland output, sustainable development of agriculture, environment production as well as the application of conservation tillage.

Limitations for application of Conservation Tillage in China

Limitations from production conditions

a. China is a large agriculture majored country. The natural conditions, economic conditions, crops and agro-technology vary greatly with regions. This increases the difficulty for application of conservation tillage. Moreover, the management systems for farm machinery and agriculture are separated in China, which is also a limit factors for the application of conservation tillage.

b. More less operation units appear due to land household system and equally distribution system. The household land is less than 0.5 hm² for each family in China. However, this land may be divided into small blocks to plant several crops. It is estimated that the land of 0.12—0.4 hm² area accounts for 60% of total farmland in Hebei Plain and Guanzhong districts of Shaanxi. The mechanization and production efficiency have been greatly limited.

Limitations from technology conditions

Technology Research

The research work on conservation tillage in China can not meet the demand in practice. One reason is that the technology is not versatile to be suitable for the north of China and Yellow River and Huaihai River regions. Secondly, the crops tested are only concentrated on winter wheat, spring wheat and summer corn. Thirdly, the scope and depth of research are only limited to the factors such as water content, nutrients, temperature that have influences on yield.

Facilities

Firstly, the technology level on conservation tillage machinery is backward. Secondly, large size conservation tillage machinery is limited while small size machinery is too much. Thirdly, implements are not enough. Fourthly, low technology content machinery is too much.

Limitations from social conditions

a. The machinery owners pay too much attention to the economic reward due to the household contract responsibility system with remuneration linked to output. The social and ecology benefits are neglected.

b. The long history of farm production habits and lack of science and technology knowledge of farmers result in too much for the application of conservation tillage. The technology training has been the bottleneck for the application of mechanical conservation tillage.

The future trends for the development of conservation tillage in China

The authors think that the conservation tillage can not be regarded as only straw mulching and
no-tillage. The concept of conservation in China should be more extensive compared with that in other countries. The conservation tillage in China should include reduce-tillage, no-tillage, soil surface reconstruction and mulching to reduce water loss and soil erosion, protecting field eco-environment, obtaining the best ecologic, social and economic benefits. The trends for the conservation tillage in China can be generalized as following aspects.

**Development from single soil tillage technology to comprehensive sustainable development direction**

The no-tillage, reduced-tillage, stalk mulching, rotate planting, and insect and disease prevention should be developed together to protect farmland soil and water resources, improve the content of organic matter in soil, reduce energy consumption and increase output and income.

**Development towards standardization**

A lot of tests and experimental research work has been done to provide much more experiences for standardization of conservation tillage in China. The standard development models, operation requirements and equipment are the important trends for the conservation tillage in China in future.

**Development towards more types of crops**

The conservation tillage technology has been applied to more crops such as wheat and corn cultivation in one-crop planting, wheat and corn cultivation in double-crop planting and other grains.

**Development towards regional technological system**

Based on the geographic variation, the regional technological system should be built to improve the suitability of conservation tillage in China.

**Conclusions and advices**

**Conclusions**

a. The practices of conservation tillage both in China and abroad show that the conservation tillage is an important way to realize sustainable agriculture. Based on actual national conditions, the development of conservation tillage in China will be a long term task.

b. The development patterns and measures in China are quite different with developed countries. Therefore, the development of conservation agriculture should be suitable to natural and social conditions in China.

c. The application of conservation tillage should be supported by governments in favorable policies and capital investment. The demonstration zones should be built according to the geographic features in different regions to integrate experimental research and technical training together.

d. Comprehensive sustainable development from single soil tillage technology is a main trend in future.

**Advices**

a. It is necessary to build the conservation tillage technology service system to improve the overall level by testing and experimental base demonstration, aiming at the new countryside construction and emphasized on countryside production capability and grain comprehensive production capability.

Mechanization is the important way to achieve conservation tillage. It is necessary to encourage
scientific innovation and strengthen the research work on conservation tillage equipment and implements, especially the no-tillage seeder, multi-functions and low energy consumed implements and insect and disease prevention equipments.

It is advised that the conservation tillage equipments should be listed in the farm machinery supported by national policy in order to promote the extension of conservation tillage technology.

The implementation and research on conservation tillage technology should be integrated with the development of precision agriculture technology in order to achieve more precise input and management and obtain optimal economic and ecological benefits.

References


Annual Report on Challenge Plan-Conservation Agriculture for the Dryland Areas of the Yellow River Basin in Inner Mongolia in 2005

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Introduction
In this project, comparative experiments are carried out on no-tillage and traditional tillage, rain fed rotation and water erosion in two typical slope fields, and then according to experiment results, crop growth conditions, soil physical and chemical properties, water and fertilizer conservation and crop yield increase effects will be analyzed, and finally establishing conservation tillage system in the fields of Yellow River basin in Inner Mongolia.

Objectives and site conditions

Objectives of project

Theoretical bases
(1) Soil structure improving mechanism on conservation tillage.
(2) Water and fertilizer mechanism on conservation tillage.

Technical system
(1) Rain fed conservation tillage system for YRB in Inner Mongolia.
(2) Rain fed rotation system for YRB in Inner Mongolia.
(3) Rain fed fallow land crop cover system for YRB in Inner Mongolia
(4) High-yield and better-return cropping patterns of grains and cover crops.

Demonstrations and extension
(1) Establish illustrated fields for rain fed conservation tillage.
(2) Live TV show, teaching lessons other extending methods.

Description of trial site
Trial site is located in Qingshuihe county, Inner Mongolia, and the experimental site name is Potouyao village, which belongs to Xiaomiaozi town, Qingshuihe country, with E111°39′, N39°57′. There are 31 farmer families, 110 persons in this village, annual average income is 1860 yuan per capita in 2004. In this village, it has 47.49 hm$^2$ of arable land, more than 7.34 hm$^2$ being dry land. Main crops are maize, potato, glutinous millet, millet and beans.
China-Canada Conservation Agriculture Forum

Fig. 1 Location of project site

It is a typical semiarid monsoon climate, with annual average temperature 5.7~7.9 °C, annual average precipitation 410mm, more than 60% occurring during June to September, annual average frost free period 135 days. The detail information is showed in table 1. Qingshuihe country belongs to ecotone between Inner Mongolia plateau and Loess plateau, which includes upland, donga, stone hill and alluvion. Experiments were conducted in two plots of upland, which are 2.6hm\(^2\) and 0.3hm\(^2\) respectively, in which without irrigation condition, and rain is the only water resource for agricultural activities. The slope grade is about 8 degree in the filed which has consistency with soil property, such as soil type, texture and fertility, and Soil features are described as follow: chestnut cinnamon soil, loess parent material, above 1 meter depth, infertility, and the main factors are showed in table 1.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly average temperature(°C)</td>
<td>-10.3</td>
<td>-6.4</td>
<td>0.9</td>
<td>9.4</td>
<td>16.3</td>
<td>20.8</td>
<td>22.6</td>
<td>20.7</td>
<td>15.1</td>
<td>8.1</td>
<td>-0.5</td>
<td>-7.8</td>
</tr>
<tr>
<td>Monthly average rainfall(mm)</td>
<td>2.8</td>
<td>4.4</td>
<td>10.9</td>
<td>17.1</td>
<td>32.3</td>
<td>51.1</td>
<td>112.4</td>
<td>99.1</td>
<td>50.1</td>
<td>21.3</td>
<td>7.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Monthly rainfall in 2005</td>
<td>0.8</td>
<td>11.2</td>
<td>0</td>
<td>11.7</td>
<td>38.3</td>
<td>40.5</td>
<td>74.2</td>
<td>85.5</td>
<td>40</td>
<td>12.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly average evaporation(mm)</td>
<td>38</td>
<td>60.6</td>
<td>141</td>
<td>278.3</td>
<td>378.1</td>
<td>367</td>
<td>313.8</td>
<td>252.4</td>
<td>198.3</td>
<td>154</td>
<td>86.6</td>
<td>14.8</td>
</tr>
<tr>
<td>Monthly average humidity (%)</td>
<td>54</td>
<td>49</td>
<td>44</td>
<td>36</td>
<td>38</td>
<td>46</td>
<td>59</td>
<td>64</td>
<td>59</td>
<td>54</td>
<td>53</td>
<td>54</td>
</tr>
</tbody>
</table>
Design of trials

**Crops selected**

Maize, millet, oat, glutinous millet and soybean were selected in this trial.

**Design of experiment fields**

In the first plot, we divided it into 20 sub-plots which is 50×15 meter and CK, A, B, C and D are maize, millet, glutinous millet and oat, 1, 2, 3, 4 and 5 are previous stubbles of glutinous millet, bean, rapeseed, bean and maize. In one trial, four crops were planted in different stubbles field with traditional and zero tillage methods, the plots of A2, B2, C2, D2 are zero-tillage treatments, which compared to traditional tillage of A4, B4, C4, D4, the 8 plots all in bean stubbles; Another trial is zero tillage of four crops in maize stubbles (figure 2).

![Figure 2  Traditional tillage, residues and covering experiments in 2005](image)

**Table 2** Density, fertilizer and key operational works of experiment fields

<table>
<thead>
<tr>
<th>Crop</th>
<th>Density (10^4/hm²)</th>
<th>Fertilizer type</th>
<th>Fertilizer amount (kg/hm²)</th>
<th>Sowing date (day/month)</th>
<th>Harvest date (day/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>5.0</td>
<td>Compound fertilizer</td>
<td>262.5</td>
<td>5/5</td>
<td>10/8</td>
</tr>
<tr>
<td>Millet</td>
<td>37.0</td>
<td>Compound fertilizer</td>
<td>150</td>
<td>18/5</td>
<td>18/9</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>68.2</td>
<td>ADP</td>
<td>150</td>
<td>31/5</td>
<td>10/9</td>
</tr>
<tr>
<td>Oat</td>
<td>127.3</td>
<td>ADP</td>
<td>150</td>
<td>31/5</td>
<td>18/9</td>
</tr>
<tr>
<td>Flax</td>
<td>224.4</td>
<td>ADP</td>
<td>150</td>
<td>6/5</td>
<td>20/9</td>
</tr>
</tbody>
</table>

Note: Compound fertilizer is with 15% of N, 20% of P and 10% of K; ADP is with 16% of N, 46% of P; The measuring date
are 25 Jun, 29 Jul, 23 Aug, 6 Sept and 21 Sep.

The experiment plot for soil and water erosion is located same village in Qingshuihe country, which area is 2958m$^2$ and planted benne in 2005. There are 3 different treatments, which are no tillage + high stubble (A), no-tillage + high stubble +mulching (B) and traditional tillage (C) respectively. Each treatment divided into three plots surround with dams with $5\times2m=10m^2$ that are adjacent and with same area, slope, direction, crops, soil properties, fertilizer use and sowing rate. Treatment A is with 15-20cm stubble in autumn; Treatment B is with 15-20cm stubble in autumn, and mulching after sowing in spring, the mulching amount was 2475 kg/hm$^2$ and mulching rate was 90%; Treatment C is with 5-10cm stubble in traditional tillage (Fig3). For measuring runoff and soil erosion, in the lowest part of each plot it is established a water collection hole, which is $0.7m\times0.6m\times0.5m$ with plastic covered.

![Figure 3 The trail site of water and soil erosion in 2005](image)

**Parameters and methods**

(1)Soil parameters: soil physical and chemical parameters; soil moisture and temperature

1. Soil temperature: Use soil thermometer in 0-5cm, 5-10cm, 10-15cm, 15-20cm depth.
2. Soil water: Use sample dried method in 0-10cm and 10-20cm soil layer.
3. Soil bulk density: Use ring sample in 0-10cm and 10-20cm soil layer
4. Soil texture: Apply mesh analysis, the diameter class of mesh are 0.1mm, 0.2mm, 0.5mm, 1mm, 2mm.
5. Soil organic matter: Apply potassium dichromate method in 0-20 cm soil layer.
6. Total N: Apply half microcontent and J.Kjeldahl method in 0-20 cm soil layer.
7. Total P: Apply HClO$_4$-H$_2$SO$_4$ method in 0-20 cm soil layer.
8. Alkaline degradation N: Apply alkaline degradation and diffusion method in 0-20 cm soil layer.
9. Rapid available P: Apply sodium bicarbonate method in 0-20 cm soil layer.

(2)Crop parameters:

1. Leaf area index: Length multiple width and constant.

(3) Yield of crops
Grain yield of one-meter long in 5 sites.

(4) Amount of runoff and soil
Collect rain in the holes (covering plastic) in 20 hours.

Results and discussion

The effects of tillage methods on soil characteristics

Soil physical characteristics

Soil temperature
Soil temperature is a key factor for agriculture, it affects germination and crop growth in earlier stage and soil respiration and microorganism activities during later stages. It shows that soil temperature of traditional tillage is lower than zero-tillage in 0-5cm, 5-10cm, 10-15cm, 15-20cm layers in four fields. It has difference in different growth stage, they are little difference in earlier stage (probably because of no mulching in zero-tillage fields this year), and soil temperature of traditional tillage is lower than zero-tillage in later stages.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>Treatments</th>
<th>Soil temperature in 0-5cm</th>
<th>Soil temperature in 5-10cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>29.4</td>
<td>34.2</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>29.5</td>
<td>35.2</td>
<td>21.0</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>28.5</td>
<td>34.0</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>29.8</td>
<td>34.1</td>
<td>22.1</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>29.5</td>
<td>35.8</td>
<td>22.1</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>29.4</td>
<td>36.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>28.8</td>
<td>34.7</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>29.7</td>
<td>34.6</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Table 4
Soil temperature of four crops use traditional tillage and zero-tillage methods (℃)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>Treatments</th>
<th>Soil temperature in 10-15cm</th>
<th>Soil temperature in 15-20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>28.0</td>
<td>32.0</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>28.0</td>
<td>33.0</td>
<td>18.9</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>27.0</td>
<td>31.4</td>
<td>19.4</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>28.1</td>
<td>32.1</td>
<td>19.8</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>27.2</td>
<td>34.2</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>27.3</td>
<td>34.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>25.2</td>
<td>31.0</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>26.0</td>
<td>32.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>
In the trial of different crops in zero-tillage in maize stubble, soil temperature of oat is higher than the other crops, especially in 29 Jul. And soil temperature of maize is the lowest, because of much shadow during later stages.

Table 5  Soil temperature of four crops in maize stubbles under zero tillage methods (℃)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil temperature in 0-5cm</th>
<th>Soil temperature in 5-10cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date 25 Jun 29 Jul 23 Aug 6 Sep</td>
<td>Date 25 Jun 29 Jul 23 Aug 6 Sep</td>
</tr>
<tr>
<td>Maize</td>
<td>26.5 33.5 20.5 20.0</td>
<td>24.7 32.3 19.5 19.3</td>
</tr>
<tr>
<td>Millet</td>
<td>28.5 34.0 23.0 21.0</td>
<td>27.0 32.5 22.0 19.4</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>28.5 34.9 23.0 22.4</td>
<td>27.0 32.6 22.0 20.2</td>
</tr>
<tr>
<td>Oat</td>
<td>27.3 36.2 22.1 21.0</td>
<td>25.6 35.0 21.0 19.6</td>
</tr>
</tbody>
</table>

Table 6  Soil temperature of four crops in maize stubble under zero tillage methods (℃)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil temperature in 10-15cm</th>
<th>Soil temperature in 15-20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date 25 Jun 29 Jul 23 Aug 6 Sep</td>
<td>Date 25 Jun 29 Jul 23 Aug 6 Sep</td>
</tr>
<tr>
<td>Maize</td>
<td>25.0 31.2 19.0 18.1</td>
<td>24.6 31.7 18.5 18.0</td>
</tr>
<tr>
<td>Millet</td>
<td>26.5 32.0 21.0 18.0</td>
<td>26.8 32.0 20.5 18.0</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>26.0 32.0 21.2 19.6</td>
<td>26.0 31.8 21.0 19.4</td>
</tr>
<tr>
<td>Oat</td>
<td>25.3 34.1 19.6 19.0</td>
<td>25.0 33.8 19.6 18.9</td>
</tr>
</tbody>
</table>

Soil water contents

Soil water content is a key factor for rain fed agriculture. It showed in table 7, soil water contents of traditional tillage in 0-10cm is higher than zero-tillage, especially in seedling stage; in later stages, it had little difference between traditional tillage and zero-tillage. Soil water contents of traditional tillage in 10-20cm is higher than zero-tillage, too, and traditional tillage of maize, millet and glutinous millet are higher than zero-tillage in earlier stage, in rainy period, traditional tillage of millet, glutinous millet and oat are higher than zero-tillage, and in later stage, it had little difference between traditional tillage and zero-tillage.

Table 7  Soil water contents of four crops use traditional tillage and zero-tillage methods (%)
To different crops, which apply zero tillage methods in maize stubble, water content of maize is higher than other crops in 0-10cm depth, the situation is obvious in rainy period, which are maize > oat > glutinous millet > millet. In 10-20cm depth, water content of maize is highest, then glutinous millet and millet, the water content of oat is the lowest, the situation in rainy period are maize > oat > glutinous millet > millet.

**Soil bulk density**

Soil bulk density is dry weight per cubic soil, which is a key factor of soil porosity and physical properties. It showed in table 8, soil bulk density of four crops in 0-10cm and 10-20 cm soil depth dropped in all growth stages of traditional tillage and zero-tillage treatments. In 0-10 cm soil depth, the drop range of soil bulk density in zero-tillage is higher than in traditional tillage; while in 10-20 cm soil depth, the drop range of soil bulk density in traditional tillage is higher than in zero-tillage. It illustrated that soil porosity increased much in shallow soil and relatively little in deep soil according above analysis.

**Table 8** Soil water contents of four crops in maize stubbles under zero tillage methods (%)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>3.40</td>
<td>3.45</td>
<td>7.19</td>
<td>5.10</td>
<td>4.83</td>
<td>8.14</td>
<td>9.53</td>
<td>6.79</td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td>3.99</td>
<td>3.39</td>
<td>3.49</td>
<td>3.23</td>
<td>5.20</td>
<td>7.30</td>
<td>6.75</td>
<td>4.88</td>
<td></td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>2.87</td>
<td>2.91</td>
<td>5.40</td>
<td>4.07</td>
<td>4.35</td>
<td>6.89</td>
<td>7.12</td>
<td>5.50</td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td>2.99</td>
<td>2.22</td>
<td>6.40</td>
<td>4.08</td>
<td>4.10</td>
<td>3.89</td>
<td>4.70</td>
<td>4.54</td>
<td></td>
</tr>
</tbody>
</table>

To different crops, which apply zero tillage methods in maize stubble, soil bulk density dropped in 0-10 cm soil depth, and drop range of maize and glutinous millet are higher than oat and millet. Soil bulk density in 10-20cm depth dropped, too, but drop range of oat and millet are higher than maize and glutinous millet, which are millet > oat > maize > glutinous millet (table 9).

**Table 9** Soil bulk density of four crops use normal tillage and zero-tillage methods (%)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize Traditional tillage</td>
<td>1.18</td>
<td>1.23</td>
<td>1.19</td>
<td>1.17</td>
<td>1.46</td>
<td>1.45</td>
<td>1.44</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>Maize Zero tillage</td>
<td>1.27</td>
<td>1.31</td>
<td>1.25</td>
<td>1.22</td>
<td>1.40</td>
<td>1.36</td>
<td>1.39</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>Millet Traditional tillage</td>
<td>1.18</td>
<td>1.15</td>
<td>1.18</td>
<td>1.16</td>
<td>1.36</td>
<td>1.36</td>
<td>1.29</td>
<td>1.28</td>
<td></td>
</tr>
<tr>
<td>Millet Zero tillage</td>
<td>1.23</td>
<td>1.19</td>
<td>1.24</td>
<td>1.16</td>
<td>1.40</td>
<td>1.42</td>
<td>1.39</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Glutinous millet Traditional tillage</td>
<td>1.21</td>
<td>1.21</td>
<td>1.19</td>
<td>1.18</td>
<td>1.29</td>
<td>1.32</td>
<td>1.27</td>
<td>1.22</td>
<td></td>
</tr>
<tr>
<td>Glutinous millet Zero tillage</td>
<td>1.30</td>
<td>1.29</td>
<td>1.24</td>
<td>1.24</td>
<td>1.22</td>
<td>1.26</td>
<td>1.21</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Oat Traditional tillage</td>
<td>1.33</td>
<td>1.32</td>
<td>1.32</td>
<td>1.30</td>
<td>1.33</td>
<td>1.38</td>
<td>1.27</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Oat Zero tillage</td>
<td>1.35</td>
<td>1.33</td>
<td>1.34</td>
<td>1.31</td>
<td>1.34</td>
<td>1.41</td>
<td>1.38</td>
<td>1.31</td>
<td></td>
</tr>
</tbody>
</table>

**Soil granule texture**

158
Soil granule texture refers to the proportion of different soil particles, and the particles whose diameter above 0.2mm is called big particles, and that of below 0.2 mm is called small particles, and the latter is considered of better soil granule texture. It showed in table 10, proportion of particles blow 0.2 mm of four crops in traditional tillage is lower than in zero-tillage in earlier stage, and higher in later stages. Proportion of particles blow 0.2 mm in traditional tillage increased with postpone of growth, but that of zero-tillage decreased gradually.

Table 10  
Soil bulk density of four crops in maize stubbles under zero tillage methods (%)  

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil bulk density in 0-10cm</th>
<th>Soil bulk density in 10-20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>25 Jun</td>
<td>29 Jul</td>
</tr>
<tr>
<td>Maize</td>
<td>1.21</td>
<td>1.28</td>
</tr>
<tr>
<td>Millet</td>
<td>1.19</td>
<td>1.19</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>1.27</td>
<td>1.22</td>
</tr>
<tr>
<td>Oat</td>
<td>1.36</td>
<td>1.35</td>
</tr>
</tbody>
</table>

To different crops, which apply zero tillage methods in maize stubble, proportion of particles blow 0.2 mm dropped, and drop range of millet, glutinous millet and oat are higher than maize, which are millet > glutinous millet > oat > maize (table 11).

Table 11  
Proportion of particles blow 0.2 mm of four crops use traditional tillage and zero-tillage methods (%)  

<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Date</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
<th>21 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>41.70</td>
<td>40.37</td>
<td>46.43</td>
<td>52.00</td>
<td>50.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>46.22</td>
<td>44.00</td>
<td>39.68</td>
<td>46.50</td>
<td>42.62</td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>48.97</td>
<td>39.04</td>
<td>35.20</td>
<td>50.00</td>
<td>53.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>52.55</td>
<td>45.01</td>
<td>38.81</td>
<td>44.60</td>
<td>44.13</td>
<td></td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>41.30</td>
<td>36.00</td>
<td>35.00</td>
<td>48.60</td>
<td>42.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>42.80</td>
<td>42.64</td>
<td>38.68</td>
<td>43.40</td>
<td>36.00</td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>43.94</td>
<td>39.80</td>
<td>35.90</td>
<td>51.70</td>
<td>46.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>48.98</td>
<td>43.50</td>
<td>42.87</td>
<td>44.00</td>
<td>41.14</td>
<td></td>
</tr>
</tbody>
</table>

Table 12  
Proportion of particles blow 0.2 mm of four crops in maize stubbles under zero tillage methods (%)  

<table>
<thead>
<tr>
<th>Crop</th>
<th>Proportion of particles blow 0.2 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>25 Jun</td>
</tr>
<tr>
<td>Maize</td>
<td>43.28</td>
</tr>
<tr>
<td>Millet</td>
<td>44.65</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>44.29</td>
</tr>
<tr>
<td>Oat</td>
<td>44.98</td>
</tr>
</tbody>
</table>
Soil chemical properties

Soil organic matter, total N and P contents

Soil organic matter, total N and P contents are the most important factors which affect soil nutrient condition, and also as a indicator to evaluating high-yield and stable fields. It showed in table 13, soil organic matter contents of maize and glutinous millet in zero-tillage are higher than in traditional tillage, and soil organic matter contents of millet and oat in zero-tillage are lower than in traditional tillage. To different crops, which apply zero tillage methods in maize stubble, organic matter content of maize is higher than millet, glutinous millet and oat (Table 14).

It also showed the change of total N and P contents in Table 12 and Table 13. Soil total N contents of millet and oat in zero-tillage are higher than in traditional tillage, and N contents of glutinous millet and maize in zero-tillage are lower than in traditional tillage. To different crops, which apply zero tillage methods in maize stubble, N content of maize and glutinous millet are higher than millet, oat is the lowest. Soil total P contents of four crops in zero-tillage are higher than in traditional tillage. P content of different crops, which apply zero tillage methods in maize stubble, had the same trend with total N content.

Table 13 Soil organic matter, Total N and P contents of four crops in traditional tillage and zero-tillage

<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Organic matter(%)</th>
<th>Total N (g/kg)</th>
<th>Total P (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>0.71</td>
<td>0.84</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.75</td>
<td>0.81</td>
<td>0.45</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>0.72</td>
<td>0.89</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.70</td>
<td>0.93</td>
<td>0.47</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>0.70</td>
<td>0.87</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.72</td>
<td>0.86</td>
<td>0.45</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>0.76</td>
<td>0.82</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.73</td>
<td>0.84</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 14 Soil organic matter, Total N and P contents of four crops in maize stubble use zero tillage methods

<table>
<thead>
<tr>
<th>Crop</th>
<th>Organic matter(%)</th>
<th>Total N (g/kg)</th>
<th>Total P (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>0.69</td>
<td>0.94</td>
<td>44.11</td>
</tr>
<tr>
<td>Millet</td>
<td>0.72</td>
<td>0.90</td>
<td>41.18</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>0.74</td>
<td>0.93</td>
<td>44.11</td>
</tr>
<tr>
<td>Oat</td>
<td>0.72</td>
<td>0.86</td>
<td>38.65</td>
</tr>
</tbody>
</table>

Soil alkaline dissolved N and rapidly available P contents

Soil alkaline dissolved N and rapid available P are effective nutrients in crop growth period. It showed in Table 15, Soil dissolved N content of four crops in growth period decreased in all treatments, and drop range of soil dissolved N content in zero-tillage is lower than traditional tillage. To four crops,
soil alkaline dissolved N in zero-tillage are higher than in traditional tillage. Soil alkaline dissolved N of four crops with zero-tillage in maize stubble decreased, the drop range are maize > millet > oat > glutinous millet (Table 16).

Table 15 Soil alkaline dissolved N contents of four crops in normal tillage and zero-tillage (mg/kg)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Treatment</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
<th>21 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>42.90</td>
<td>41.79</td>
<td>39.20</td>
<td>33.10</td>
<td>36.00</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>49.00</td>
<td>43.92</td>
<td>46.40</td>
<td>34.65</td>
<td>37.69</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>33.00</td>
<td>26.60</td>
<td>30.80</td>
<td>26.70</td>
<td>27.00</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>47.36</td>
<td>39.87</td>
<td>48.04</td>
<td>36.60</td>
<td>35.00</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>34.00</td>
<td>33.60</td>
<td>28.00</td>
<td>34.40</td>
<td>30.90</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>51.15</td>
<td>44.80</td>
<td>44.00</td>
<td>45.30</td>
<td>44.50</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>39.00</td>
<td>33.60</td>
<td>34.00</td>
<td>34.65</td>
<td>33.10</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>42.00</td>
<td>37.00</td>
<td>41.79</td>
<td>38.81</td>
<td>37.60</td>
</tr>
</tbody>
</table>

Table 16 Soil alkaline dissolved N contents of four crops in maize stubble use zero tillage methods (mg/kg)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
<th>21 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>47.10</td>
<td>44.90</td>
<td>44.80</td>
<td>45.80</td>
<td>44.70</td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td>41.00</td>
<td>40.40</td>
<td>42.00</td>
<td>39.00</td>
<td>39.50</td>
<td></td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>42.40</td>
<td>41.90</td>
<td>43.29</td>
<td>42.00</td>
<td>41.50</td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td>38.60</td>
<td>37.50</td>
<td>35.51</td>
<td>37.40</td>
<td>37.20</td>
<td></td>
</tr>
</tbody>
</table>

It showed in Table 17, Soil rapidly available P content of four crops in growth period decreased in two treatments, and drop range of soil rapidly available P content in zero-tillage is lower than traditional tillage. To four crops, Soil rapid available P in zero-tillage is higher than in traditional tillage. Soil rapid available P of four crops with zero-tillage in maize stubble decreased, the drop range are maize > glutinous millet > millet > oat (Table 18).

Table 17 Soil rapid available P contents of four crops in traditional tillage and zero-tillage (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Traditional tillage</td>
<td>4.87</td>
<td>4.33</td>
<td>3.97</td>
<td>4.08</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>4.99</td>
<td>4.60</td>
<td>4.45</td>
<td>4.40</td>
<td>3.95</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional tillage</td>
<td>4.63</td>
<td>4.43</td>
<td>4.15</td>
<td>4.27</td>
<td>4.15</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>4.69</td>
<td>4.65</td>
<td>4.42</td>
<td>4.67</td>
<td>4.48</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional tillage</td>
<td>4.15</td>
<td>3.97</td>
<td>4.39</td>
<td>4.45</td>
<td>4.15</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>5.11</td>
<td>4.33</td>
<td>4.60</td>
<td>4.87</td>
<td>4.87</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional tillage</td>
<td>4.32</td>
<td>4.15</td>
<td>4.21</td>
<td>4.69</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>4.81</td>
<td>4.21</td>
<td>4.21</td>
<td>4.81</td>
<td>4.52</td>
</tr>
</tbody>
</table>
### Table 18: Soil rapid available P contents of four crops in maize stubble use zero tillage methods (mg/kg)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>4.75</td>
<td>4.39</td>
<td>4.51</td>
<td>4.78</td>
<td>4.49</td>
</tr>
<tr>
<td>Millet</td>
<td>4.09</td>
<td>4.16</td>
<td>4.45</td>
<td>4.21</td>
<td>4.03</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>4.51</td>
<td>4.03</td>
<td>4.27</td>
<td>4.65</td>
<td>4.29</td>
</tr>
<tr>
<td>Oat</td>
<td>4.27</td>
<td>4.03</td>
<td>4.38</td>
<td>4.4</td>
<td>4.21</td>
</tr>
</tbody>
</table>

### The effect of tillage methods on crop growth

**Leaf area index (LAI)**

LAI indicates that the tillage method and stubble left last time in the field affected the crop growth. In general, LAI of four crops have a relatively largest value under traditional tillage than under zero-tillage. Under different growth stage, the LAI of maize and oat are higher than millet and glutinous millet, which in maize stubble and under zero-tillage (Table 19 and Table 20).

### Table 19: LAI of four crops in traditional tillage and zero-tillage

<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>25 Jun</td>
<td>29 Jul</td>
<td>23 Aug</td>
<td>6 Sep</td>
</tr>
<tr>
<td>Maize</td>
<td>Traditional</td>
<td>0.47</td>
<td>1.62</td>
<td>3.36</td>
<td>3.17</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.59</td>
<td>1.42</td>
<td>2.80</td>
<td>2.48</td>
</tr>
<tr>
<td>Millet</td>
<td>Traditional</td>
<td>/</td>
<td>0.32</td>
<td>2.11</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>/</td>
<td>0.21</td>
<td>1.87</td>
<td>1.83</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>Traditional</td>
<td>0.31</td>
<td>2.31</td>
<td>2.01</td>
<td>1.65</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.25</td>
<td>2.17</td>
<td>1.93</td>
<td>1.62</td>
</tr>
<tr>
<td>Oat</td>
<td>Traditional</td>
<td>0.42</td>
<td>2.41</td>
<td>3.86</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>Zero tillage</td>
<td>0.27</td>
<td>2.03</td>
<td>3.02</td>
<td>2.96</td>
</tr>
</tbody>
</table>

### Table 20: LAI of four crops in maize stubble use zero tillage methods

<table>
<thead>
<tr>
<th>Crop</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 Jun</td>
<td>29 Jul</td>
<td>23 Aug</td>
<td>6 Sep</td>
</tr>
<tr>
<td>Maize</td>
<td>0.52</td>
<td>1.47</td>
<td>2.93</td>
<td>3.02</td>
</tr>
<tr>
<td>Millet</td>
<td>/</td>
<td>1.15</td>
<td>1.83</td>
<td>1.88</td>
</tr>
<tr>
<td>Glutinous millet</td>
<td>0.24</td>
<td>2.24</td>
<td>2.14</td>
<td>1.74</td>
</tr>
<tr>
<td>Oat</td>
<td>0.35</td>
<td>2.00</td>
<td>3.24</td>
<td>3.15</td>
</tr>
</tbody>
</table>
Crop biomass

Crop biomass is a very good indicator for state of growth and fundamentals of yield, and the result showed that tillage affect the biomass of 4 crops. In traditional tillage treatment, the biomass of the 4 crops had bigger value than that under zero-tillage treatment (Table 21). And in maize stubble and under zero-tillage, maize had largest biomass (Table 22).

Table 21  Crop biomass of 4 crops under different tillage (kg/hm²)

<table>
<thead>
<tr>
<th>Date</th>
<th>Crop</th>
<th>Treatment</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Jun</td>
<td>Traditional tillage</td>
<td>1160</td>
<td>2268</td>
<td>6996</td>
<td>12064</td>
<td></td>
</tr>
<tr>
<td>25 Jun</td>
<td>Zero tillage</td>
<td>1126</td>
<td>2051</td>
<td>6504</td>
<td>11001</td>
<td></td>
</tr>
<tr>
<td>25 Jun</td>
<td>Traditional tillage</td>
<td>1044</td>
<td>3182</td>
<td>5955</td>
<td>7714</td>
<td></td>
</tr>
<tr>
<td>25 Jun</td>
<td>Zero tillage</td>
<td>880</td>
<td>1975</td>
<td>5229</td>
<td>7173</td>
<td></td>
</tr>
<tr>
<td>25 Jun</td>
<td>Traditional tillage</td>
<td>1156</td>
<td>2875</td>
<td>9148</td>
<td>10631</td>
<td></td>
</tr>
<tr>
<td>25 Jun</td>
<td>Zero tillage</td>
<td>757</td>
<td>1555</td>
<td>6498</td>
<td>9868</td>
<td></td>
</tr>
</tbody>
</table>

Table 22  Crop biomass of four crops in maize stubble use zero tillage methods (kg/hm²)

<table>
<thead>
<tr>
<th>Date</th>
<th>Crop</th>
<th>25 Jun</th>
<th>29 Jul</th>
<th>23 Aug</th>
<th>6 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Jun</td>
<td>Maize</td>
<td>1073</td>
<td>2198</td>
<td>6260</td>
<td>10746</td>
</tr>
<tr>
<td>25 Jun</td>
<td>Millet</td>
<td>/</td>
<td>1698</td>
<td>5927</td>
<td>8655</td>
</tr>
<tr>
<td>25 Jun</td>
<td>Glutinous millet</td>
<td>839</td>
<td>2108</td>
<td>5822</td>
<td>7334</td>
</tr>
<tr>
<td>25 Jun</td>
<td>Oat</td>
<td>860</td>
<td>1729</td>
<td>5450</td>
<td>9911</td>
</tr>
</tbody>
</table>

Effect of tillage methods on soil and water erosion

The results showed in 2004, water and soil erosion of high stubble treatment and high stubble and mulching treatment decreased much compared with traditional tillage treatment, especially high stubble with mulching treatment. The annual average decrease of water erosion was 34.9% and 53.6% of high stubble treatment and high stubble and mulching treatment compared with traditional tillage treatment; and soil erosion decrease were 46.7% and 65.8%, respectively (Table 23).
Table 23: Soil and water erosion experiment in 2004

<table>
<thead>
<tr>
<th>Date</th>
<th>Treatments</th>
<th>Rainfall (mm)</th>
<th>Amount of runoff Water (m³/hm²)</th>
<th>Amount of Soil erosion (kg/hm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 3</td>
<td>No-tillage + high stubble</td>
<td>21.1</td>
<td>4.6</td>
<td>133.5</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>4.1</td>
<td>66.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>5.1</td>
<td>369.0</td>
</tr>
<tr>
<td>Jul 26</td>
<td>No-tillage + high stubble</td>
<td>22.5</td>
<td>0.8</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>1.4</td>
<td>39.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>1.4</td>
<td>49.5</td>
</tr>
<tr>
<td>Jul 29</td>
<td>No-tillage + high stubble</td>
<td>25.4</td>
<td>1.0</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>0.9</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>1.2</td>
<td>37.5</td>
</tr>
<tr>
<td>Aug 2</td>
<td>No-tillage + high stubble</td>
<td>11.2</td>
<td>19.0</td>
<td>45.0</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>18.8</td>
<td>36.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>21.1</td>
<td>49.5</td>
</tr>
<tr>
<td>Aug 13</td>
<td>No-tillage + high stubble</td>
<td>2.7</td>
<td>47.2</td>
<td>105.0</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>24.7</td>
<td>42.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>55.6</td>
<td>111.0</td>
</tr>
<tr>
<td>Aug 21</td>
<td>No-tillage + high stubble</td>
<td>44.5</td>
<td>3.7</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>2.6</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>4.7</td>
<td>42.0</td>
</tr>
<tr>
<td>Aug 27</td>
<td>No-tillage + high stubble</td>
<td>19.5</td>
<td>22.1</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>13.7</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>57.7</td>
<td>42.0</td>
</tr>
<tr>
<td>Sep 13</td>
<td>No-tillage + high stubble</td>
<td>6.5</td>
<td>24.6</td>
<td>187.5</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>21.7</td>
<td>121.5</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>42.4</td>
<td>334.5</td>
</tr>
<tr>
<td>Total</td>
<td>No-tillage + high stubble</td>
<td>153.4</td>
<td>123.1</td>
<td>552.0</td>
</tr>
<tr>
<td></td>
<td>No-tillage + high stubble + mulching</td>
<td></td>
<td>87.8</td>
<td>354.0</td>
</tr>
<tr>
<td></td>
<td>Traditional tillage</td>
<td></td>
<td>189.2</td>
<td>1035.0</td>
</tr>
</tbody>
</table>

The effect of tillage methods on crop yield

Yield of traditional tillage and zero-tillage

The trial of traditional tillage and zero-tillage showed yield decrease because zero-tillage method applied in first year and no mulching (Table 24). The maximum yield decrease is glutinous millet, which dropped 16.7%, the minimum is maize and with 8.1%. The yield decrease of millet and oat are
14.7% and 10.4%, respectively.

It also showed yield decrease in the trial of four crops in maize stubble under zero-tillage (Table 25). The maximum yield decrease is glutinous millet, which dropped 22.0%, and the yield decrease of millet, oat and maize are 19.3%, 15.7% and 13.3%, respectively.

<table>
<thead>
<tr>
<th>Table 24</th>
<th>Yield of four crops under traditional tillage and zero-tillage (kg/hm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Maize</td>
</tr>
<tr>
<td>traditional tillage</td>
<td>5342</td>
</tr>
<tr>
<td>Zero-tillage</td>
<td>4909</td>
</tr>
<tr>
<td>Yield decrease of zero-tillage (%)</td>
<td>8.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 25</th>
<th>Yield of four crops in maize stubble under zero-tillage (kg/hm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Maize</td>
</tr>
<tr>
<td>Traditional tillage</td>
<td>5298</td>
</tr>
<tr>
<td>Zero-tillage</td>
<td>4595</td>
</tr>
<tr>
<td>Yield decrease of zero-tillage (%)</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Yield of soil erosion trials

The soil erosion trial of traditional tillage and high stubble and mulching showed yield increase because zero-tillage methods were applied for three years and with mulching (Table 26). The millet yield increase of high stubble treatment and high stubble and mulching treatment compared with traditional tillage treatment are 9.6% and 16.7%, the oat yield increase are 8.8% and 18.4%, the flax yield increase are 9.3% and 16.4%.

<table>
<thead>
<tr>
<th>Table 26</th>
<th>Yield of different tillage in soil erosion trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Zero-tillage and high stubble and mulching (kg/hm$^2$)</td>
</tr>
<tr>
<td>Millet</td>
<td>2364</td>
</tr>
<tr>
<td>Oat</td>
<td>1197</td>
</tr>
<tr>
<td>Flax</td>
<td>525</td>
</tr>
</tbody>
</table>
Technical application and extension

*Education to village managers and technical staffs*

In economic conference of Xiaomiaozi Town on 27th March, 2006, the speech on CP-YRB project, the importance, key techniques and benefit of conservation agriculture were given to 60 village managers and technical staffs, and they showed great concerned to the project and expressed further cooperative intension.

*Technical education on conservation agriculture to households*

In harvest time on 9-10 October and investigation period on 27-28 December, 2005, the key techniques and benefit of conservation agriculture were discussed with more than 20 households, and some of them are interested in CA and keened to join the project, even made planting plan in details.

*Extension and application of conservation agriculture*

The application of conservation agricultural techniques had extended with the research progress on its mechanism and patterns, the trial field will increase 1.5hm², two demonstration fields in the town were selected in 2006. It estimates that the application areas will extend to the whole county in 2007 and to the Yellow River Basin in Inner Mongolia in 2008.

*Ability building*

*Establishment of Leader committee for CP in Huhhot*

Leader committee for CP in Huhhot was established in November 2005, and the group headed by Dupty-mayor of Huhhot, together with deputy directors of Huhhot Agriculture Bureau. The group included experts on agriculture, environment and economics, and people from local government. The establishment of group will benefit to the carryout of CP and the research and extension of conservation tillage.

*Reception of experts from CIMMYT*

During the site visiting to Inner Mongolia on 24-28 Aug,2005, Dr. Ken Sayre gave a presentation titled “Conservation Agriculture Technology” and discussed with us on the Conservation Agriculture and progress of CP. Dr. Ken Sayre was satisfied with what we had done in Qingshuihe Country, also gave good suggestion of our pilot activities. And also Dr. Changrong Yan, Dr. Hui Ju and Dr.Wenqing He visited Inner Mongolia on 26-28 Sept, 2005, Dr. Erika Meng, Dr. Jinxia Wang visited Inner Mongolia on 25-26 Nov, 2005, they also gave good suggestion on our works.

*Reception of Dr.Lorrence and Dr.Yuqing from Canada*

Canada has always been keeping a friendly relation with Inner Mongolia Agriculture University in the past many years. Dr.Lorrence and Dr.Yuqing, who are specialists of Canada Agriculture Department, visited experimental sites in Qingshuihe Country, Wuchuan Country in 23-26 Sep, 2005. They also had an informal discussion with us and gave their positive comments and constructive suggestions.

*Attended progress and communion meeting in Luoyang*

We attended the progress and communion meeting of CP, which was held in Luoyang city, Henan province in 15th-17th November 2005. According to the outputs and goals of this project, Prof. Liu Jinghui reported the progress about CA trial in Qingshuihe Country. We discussed the contracts and amended them according to uniform request, and brought forward some suggestions for CP improvement.
Main conclusions

*No-tillage could improve soil temperature, increase soil bulk density, while reduce soil water content*

In 0-5cm, 5-10cm, 10-15cm, 15-20cm soil layers, the soil temperature of traditional tillage was lower than no-tillage in maize, millet, glutinous millet and oat fields; In 0-10cm and 10-20cm soil layers, the soil water content of traditional tillage was higher than no-tillage; the soil bulk density increased in no-tillage treatment.

*Soil nutrient contents of no-tillage higher than traditional tillage*

To maize and glutinous millet, the soil organic matter contents of no-tillage higher than traditional tillage; To millet and oat, the soil organic matter contents of no-tillage lower than traditional tillage.

To millet and oat, the soil total N contents of no-tillage were higher than traditional tillage; To glutinous millet and maize, the soil total N contents of no-tillage were lower than traditional tillage.

To all crops, the soil total P contents dissolved N content and Rapid available P content of no-tillage were higher than traditional tillage.

*Yield of no-tillage decreased in first year*

The trial of traditional tillage and no-tillage showed yield decrease because no-tillage method applied in first year and no mulching. The maximum yield decrease is glutinous millet, which dropped 16.7%, the minimum is maize and with 8.1%. The yield decrease of millet and oat are 14.7% and 10.4%, respectively. It also showed yield decrease in the trial of four crops in maize stubble under no-tillage. The maximum yield decrease is glutinous millet, which dropped 22.0%, and the yield decrease of millet, oat and maize are 19.3%, 15.7% and 13.3%, respectively.

*Yield of no-tillage and mulching increased in third year*

The results showed in 2004, water and soil erosion of high stubble treatment and high stubble and mulching treatment decreased much compared with traditional tillage treatment, especially high stubble with mulching treatment. The annual average decrease of water erosion was 34.9% and 53.6% of high stubble treatment and high stubble and mulching treatment compared with traditional tillage treatment; and soil erosion decrease were 46.7% and 65.8%, respectively. The high stubble and mulching treatments showed yield increase, because no-tillage method was applied for three years and with mulching. The millet yield increase of high stubble treatment and high stubble and mulching treatment compared with traditional tillage treatment are 9.6% and 16.7%, the oat yield increase are 8.8% and 18.4%, the flax yield increase are 9.3% and 16.4%.

*Conservation techniques approved and extended gradually*

Under the direction of CIMMYT and hard work of project staffs, the project was carryout smoothly. The setup of leader group showed great approving and supporting by local governments. Through the technical education to technical staffs, village managers and households, the extending areas of conservation agriculture have enlarged gradually.
Research of Conservation Tillage Technology Demonstration and Promotion in Beijing

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Abstract: Based on the conclusion from demonstration and promotion of conservation tillage technology in Beijing recent years, this paper aims at taking full use of experiences to facilitate the wide spread of conservation tillage. Meanwhile, it proposes current problems and solutions so as to jointly explore with the technical personnel engaged in conservation tillage to promote the further development of it.

Key words: conservation tillage, no tillage, minimum tillage

General situation of CT promotion in Beijing

Beijing is a seriously dry area which suffers from lacking water and is confronted with severe ecologic troubles as a result of recent years’ soil desertification, water and soil running off, ever-serious sand-storm and conflicting of water demand and provision, etc. Those disadvantages have not only restrained the development of agriculture and rural economy, but also will directly affect the coming Olympic Game in Beijing. Therefore, in this sense, it is very imperative to preserve eco environment, achieve development of sustainable agriculture and promote agriculture profits and increase farmers’ income.

CT, i.e. no tillage or minimum tillage, replaces the moldboard plough with no tillage seeding under the precondition of land covered by residues, so as to preserve soil’s self-protecting and re-building mechanism, which plays an important pole in preserving eco-environment. CT is able to maintain water and fertility, increase profits while cutting costs and increase farmers’ income, and what’s more, it is one of most effective approaches to enrich farmers.

Beijing have begun to promote CT for the summer maize since 1998, and till now, we have successfully practiced no tillage seeding for summer maize for five years in the whole region, and meanwhile, basically banned straw stalk burning up for six years. Since 2002, we have begun to carry out the testing & demonstration works for the conservation tillage technology of the winter wheat. Experiments and demonstration of CT for winter wheat were carried out in 2002. Based on those years’ tests and improvements, we have gradually perfected the technology & technique route. After importing, modifying, researching and developing related instruments, we have almost confirmed the
types of no tillage and minimum tillage seeders, crop protection instruments, and subsoiles suitable for Beijing. There have been relatively complete technical criterion and working service system for CT in Beijing, which has laid the solid foundation for its promoting and wide spreading. In succession, seven districts and counties as Daxing District, Shunyi District and Pinggu District, etc have been listed as CT demonstration districts or counties on the national level by Ministry of Agriculture. By the end of 2005, those seven national-level demonstration districts have accumulatively invested 68.14 million RMB, including 5.35 million RMB from central government, 34.98 million RMB from local government, and the other 27.81 million RMB from self-raising, to apply CT on a land scale of 1.3 million Mu, to have no-tillage seeder for 3090 sets (packs) and other CT instruments for 17,673 sets (pack), to organize technical training for 173 sessions (times) resulting in a scale of 8188 person-time of farmer and technicians, a number of 50,715 copies of instruction materials.

This year, Ministry of Agriculture and Beijing Municipal Government have reached the consensus: to spend three years (2006~2008) to generally apply CT in main crop regions of Beijing setting up an encouraging sample for reference in promoting CT throughout the whole country. In some sense, CT demonstration, application, and promotion in Beijing have ranked a leading position in China.

In 2003, Mr. Lu Ming, Member of Rural Committee in National People’s Congress and the former Vice-Minister of Ministry of Agriculture, Mr. Niu Youcheng, Vice-Mayor of Beijing and other leaders and technical experts all gave high remarks on this project after they inspected the state of CT in Daxing District and Shunyi District of Beijing. Especially in Oct 2004, when inspecting in the rural area in Shunyi, his excellence Secretary General Hu Jintao especially went to the farmland for the no-tillage seeding for wheat and fully affirmed the stage of this project. On May 29th, 2006, representing two departments respectively, Deputy Minister Zhang Baowen of Ministry of Agriculture and Deputy Mayor Niu Youcheng of Beijing Municipal Government entered the “Implementation Plan to Apply Conservation Tillage in Full-scale Beijing”, which has significantly promoted the development of CT in Beijing. The recognition from higher authorities has powerfully pushed further development of this technology in Beijing, and meanwhile it also can consolidate the confidence of many agricultural machinery workers.

**Main achievements of CT in Beijing**

**CT experiment patterns suitable for Beijing**

The basic patterns of crop planting in Beijing mainly have three types: The first one is single crop in one year, i.e. seeding maize or legume in spring, harvesting in autumn, leaving stubbles till next spring, then continually planting maize or legume. The second one is double crop in one year, i.e. after wheat harvesting in summer, seeding maize or bean, then autumn harvesting, and then seeding wheat. The third one is the triple crops in two years, i.e. seeding peanut in spring, harvesting in autumn, seeding wheat, and after harvesting in next summer, planting maize.

Following are six patterns suitable for Beijing, based on those years experiments and experiences.

**Pattern 1: The straw stalk of maize ensiling and wheat no tillage seeding**

Applicable conditions: double-crop regions, maize harvest for forage

Technical mode: Harvesting → no tillage wheat seeding → spraying → field management →
mechanized harvesting → no tillage summer maize seeding → spraying → field management → harvesting

Machineries: maize harvester, tractor, no-tillage seeder for wheat, machineries for crop protection, harvester for wheat, no-tillage seeder for maize

**Pattern 2: Maize stubbles pulverizing, farmland covering, no-tillage seeding for wheat**

Applicable conditions: Double-crop regions, maize stubbles pulverized, farmland covered

Technical mode: maize ear picking up → straw pulverizing and covering → wheat no tillage seeding → spraying → field management → mechanized harvesting → summer Maize no tillage seeding → spraying → field management → maize harvesting.

Machineries: maize harvester, tractor, straw pulverizer, wheat no tillage seeder, machineries for crop protection, combine harvester for wheat, and maize no tillage seeder

**Pattern 3: maize stubble pulverizing and mulching, wheat minimum seeding**

Applicable conditions: The volume of the straw stalks is relatively huge or the soil is sticky and heavy in the area with two harvests in one year

Technical route: Harvest the maize (or the silage) → Crush the straw stalks and evenly return to the field → Harrow in the shallow layer (Rotate in the shallow layer) → The insemination of the wheat free from or with the few cultivation → The chemical weeding → The farmland management → The mechanized harvesting of the wheat → The insemination of the maize in summer free from the cultivation → The chemical weeding → The farmland management → Harvest the maize (or the silage).

Main agricultural machineries: The maize harvester, the tractor, the machine for crushing and returning the straw stalks to the field, the disc harrow (The machine for the loosening in the shallow layer), the seeding machine for the wheat free from the cultivation, the machineries for the plant preservation, the combine harvester for the wheat, and the seeding machine for the maize free from the cultivation.

**Pattern 4: Insemination of the maize in the deep loose layer free from the cultivation, the insemination of the wheat free from or with the few cultivation**

Applicable condition: The soil with the relatively big capacity or the relatively hard bottom layer of the plough in the area with two harvests in one year

Technical route: Harvest the maize (or the silage) → Crush and evenly return the straw stalks to the field → Free from the cultivation or the harrow in the shallow layer (Rotate in the shallow layer) → The insemination of the wheat free from or with the few cultivation → The chemical weeding → The field management → The mechanized harvesting of the wheat → the insemination of the maize in the deep loose layer free from the cultivation in summer → The chemical weeding → The field management → Harvesting the maize (or the silage).

Main agricultural machineries: The maize harvester, the tractor, the machine for crushing and returning the straw stalks to the field, the disc harrow (The machine for the loosening in the shallow layer), the seeding machine for the wheat free from the cultivation, the machineries for the plant preservation, the combine harvester for the wheat, the combine working machine for the insemination
of the maize in the deep loose layer free from the cultivation.

**Pattern 5: Insemination free from the cultivation with the covered residual stubble**

Applicable condition: The plot with the relatively few spring grass or the relatively thorough chemical weeding

Technical route: Leave the stubble of the spring maize in autumn → Insemination free from the cultivation in the next spring → The chemical weeding → The field management → The mechanical or artificial harvesting of the maize → The stubble in autumn

Main agricultural machineries: The tractor, the seeding machine of the maize free from the cultivation, the machineries for the plant preservation, and the harvesting machineries for the maize.

**Pattern 6: Harrow the land in spring with the stubble left and the insemination with the few cultivation**

Applicable condition: The plot with the big occurrence volume of the spring grass and not suitable to apply the chemical weeding

Technical route: The stubble left of the maize in spring in autumn → Harrow the field and weed with the few cultivation in the next spring → The insemination free from the cultivation → The chemical weeding → The field management → The mechanical & artificial harvesting of the maize → The stubble left in autumn

Main agricultural machineries: The tractor, the disc harrow, the seeding machine for the maize free from the cultivation, the machineries for the plant preservation, the harvesting machineries for the maize.

**Main crops suitable for Beijing; CT technical regulations**

Concerning the characteristics of planting in Beijing and exact situation of individual districts and counties, elaborate technical regulations have been approved especially for spring maize, summer corn, and winter wheat. Each applying directs or counties should practice exactly following those technical regulations, and meanwhile continue to perfect those technical regulations during the practice.

**Analysis for the technical benefits from CT in Beijing**

Demonstration results show that, in Beijing, efficiency improving while cost reducing under the pre-conditions of normal yield is the most prominent benefit from CT. Meanwhile, it can effectively reduce the loss of soil water, save irrigation water for about 750 m³/hm² per crop season in average and slower down the descending speed of underground water; improve soil structure, increase organic material; can effectively refrain field sand raising, and release the effects of sand storm.

**Improving efficiency while reducing costs, increasing farmers’ income** There are 10 operational procedures before next crop season in conventional tillage consuming electricity for irrigation of 1125 yuan/hectare, and the total cost can be up to 3285 yuan/hectare. We can eliminate 4 or 5 operations, save electricity of 937.5 yuan/hectare, totally cost 2662.5 yuan/hectare which is much less than conventional tillage, reduce oil consumption for about 47% while cutting cost for 622.5 Yuan/hectare.
Comparison table of working cost and oil consumption
Between Traditional Cultivation and Conservation tillage

<table>
<thead>
<tr>
<th>No.</th>
<th>Traditional cultivation</th>
<th>Conservation tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operations</td>
<td>Working costs (Yuan/hectare)</td>
</tr>
<tr>
<td>1</td>
<td>Straw pulverizing</td>
<td>225</td>
</tr>
<tr>
<td>2</td>
<td>Fertilizing before seeding</td>
<td>75</td>
</tr>
<tr>
<td>3</td>
<td>Heavy harrow</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>Cross cultivation</td>
<td>270</td>
</tr>
<tr>
<td>5</td>
<td>Lightly harrow</td>
<td>150</td>
</tr>
<tr>
<td>6</td>
<td>Pressing</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>Seeding</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>Weeding</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Field management</td>
<td>300</td>
</tr>
<tr>
<td>10</td>
<td>Harvesting</td>
<td>600</td>
</tr>
<tr>
<td>11</td>
<td>Irrigation</td>
<td>1125</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3285</td>
</tr>
</tbody>
</table>

Retaining soil water; reducing irrigation water. According to tests results, under CT, water runoff can be reduce by 50~60%, soil water can be increased by 16~19%, and water utilization can be improved by 12~16%. Consequently, irrigation water can be saved by 15%~20%.

Increasing soil organic matter, improving field fertility. Based on the survey by Beijing Municipal Agricultural Technology Promotion Station, the organic matter can be increased from 1.517% to 1.811% after applying CT for three years. The quantity of earthworms in cultivation layers will be significantly increased, and within 0~20cm depth, after implementing the Conservation tillage, the earthworms can be increased from 2 to 18 per square meter.

Reducing soil erosion, reducing dust rising, and preserving environment. In 2004, applying simulation tests, China Agricultural University carried out testing for the wind erosion volumes respectively on no-tillage straw mulched farmland and conventional tillage farmland, and the outcomes indicate that: during March to May, the wind erosion depth can be 2.62mm less and 2094.6t less than conventional tillage.
Main experiences from CT in Beijing

Leadership attaches great importance to this technology, and the organization is in-position, ensuring the successful organization of the demonstration & promotion works of the Conservation tillage technology

During several years after developing conservation tillage, the administration departments including charging major, Agriculture Committee, Agriculture Bureau pay more attention on this work. It sign responsibility contract with each district and establish city, district and town third grade organization to make sure the demonstration work developing smoothly. The experiences show this method be efficient.

Attach the importance to the promotion, and specify the training, and promote the demonstration & promotion works of CT to go deep into the people’s heart

The promotion of a new technique may have obstacles; a best way to smoothing the obstacles is to do extensive propaganda. The program group pays more attention on the declaration and makes the policy, technique and advantages of conservation tillage to the peasants and agriculture worker by all sorts of actions, so the extension of conservation tillage works smoothly. The training of conservation tillage directly affects this technique. We invite the related experts to train the technicians, machinery operators and material editors engaging in CT extension. Not only do we get a great number of technicians but also form a lasting mechanism to acquire nice results.

The agricultural machinery as the priority, combining the agricultural techniques, promote the in-depth development of the demonstration & promotion works for the Conservation tillage technology

The essential technical content of the Conservation tillage is the working machineries and tools for no tillage seeding machinery, and the selection of the machineries and tools for no tillage seeding suited for the local planting conditions is the key for fulfilling this technology. During the process of the demonstration and the promotion, instruct various project districts and counties to select the appropriate machineries and tools for the seeding free from the cultivation with the pertinence, and after the exploration for several years, the appropriate machine models basically determined are Agricultural University 2BM-12 Model, John Deer 1590 Model and the Nonghaha series seeding machines free from the cultivation. In order that the measures of the agricultural techniques in various taches of the seeding, the water & fertilizer management and the prevention of the disease, the insect, the weed hazards of the crop, etc comply with the standard of the high output, the quality and the high efficiency, the technical experts in the technical team founded are responsible to direct the technical problems incurred in the implementation process of the project, so as to ensure each technical tache is responsible by the experts accordingly, so as to promote the in-depth development of the demonstration & promotion works of the Conservation tillage technology, and avoid the various types of the problems incurred due to the measures in the agricultural techniques are not in-position, and it has achieved the very good results.

Relying on the service organization for the agricultural machinery, establish the broker system for the Conservation tillage

The demonstration and the promotion of the Conservation tillage technology need the appropriate working service pattern of the agricultural machinery to cooperate with, which can have the functions
of reducing the working cost and increasing the income of the farmers. In the beginning period of implementing the Conservation tillage, it adopts the working service organizations in the district and county level to carry out the mechanical seeding work of the Conservation tillage technology totally for free, so as to improve the enthusiasm for the Conservation tillage technology in the farmer, and promote the extension and the application of the Conservation tillage technology. In the process of the Conservation tillage technology is continuously being matured and the working service patterns are continuously being innovated and applied, Daxing District has established a set of the new-type working service pattern of the agricultural machinery, i.e. carrying out the order agriculture, to be mainly applied in the free-cultivation seeding work of the spring rain rice, which has fulfilled the purposes of reducing the working cost and increasing the income in the farmer. The main operation means is: The service organization of the agricultural machinery will enter the planting contracts with the farmers, to be responsible for the mechanized working service in the whole process from the planting to the harvesting, and meanwhile the agricultural technique department will establish the strict measures for the field management to carry out the field management, and then enter the sales contract with the purchasing party, to be responsible for the sales of the agricultural products, thus to fulfill the full-orientation services before, in the middle of and after the output of the agricultural product.

Working sites of various kinds of the machineries and tools

The Conservation tillage technology is an advanced technology changing the traditional cultivation system that has been extended for thousands of years, and in the process of the demonstration and the promotion, it will definitely encounter various types of problems like the farmer will not recognize,
etc, and in order to thoroughly solve these problems, Beijing has established the broker system for the Conservation tillage, i.e. various types of the personnel who have the advanced ideas, are willing to accept the new stuff, recognize the Conservation tillage technology and have the certain influences within the certain area act as the role of the broker, and they are responsible for the promotion and the application of the Conservation tillage technology within their respective areas, and are commended and praised as the area completed and the quality completed.

Relying on the scientific management means, promote the sustainable development of the promotion works of the Conservation tillage technology

After demonstrating and promoting the Conservation tillage for several years, the administrative authority for the agricultural machinery in Beijing pays attention to the modernization and the information transformation of the project management. In 2004, they equipped the notebook computer and the “Software system for the management information of the agricultural mechanization in Beijing” for nine demonstration and promotion districts and counties for the Conservation tillage of Changping and Tongzhou, etc, and with the GPS, GIS and the database management software, to carry out the tracking-type management for the completion situation of the Conservation tillage projects in various districts and counties, and through the practice, they have achieved the good results.

Existing problems and countermeasures in the process of the demonstration & promotion of the Conservation tillage technology in Beijing

Main existing problems

Current situation of the planting structure

At present, after determining the ownership of the land in the rural area in Beijing, the planting mode of one household has the conflicts with the application of the big-size Conservation tillage machinery. In the current stage, the land scale in the agricultural household is small, the plots are fragmentary, and the varieties of the crops are complicated, which are not good for carrying out the mechanized working. The agricultural household obtains the few benefits from the application of the Conservation tillage technology, and is unable to produce the scale advantages, which have restricted the promotion and the application of the Conservation tillage technology in the great extent.

The cognition in the farmer needs to be improved

Through the testing demonstration, the Conservation tillage technology is proven as successful, and at present, the Beijing area has gradually entered into the big-area promotion stage. But to change the cultivation means in the farmers for thousands of years, and make the cadres and farmers in the grass root accept this technology, it still needs to make the great efforts to carry out the promotion and training works, so as to gradually increase the concept for the environmental protection in the farmers and enhance their confidence.

Agricultural machineries

Agricultural machineries are one important factor in the process of CT application. Though several typical instruments have been determined but there is still some room to further explore their adaptability.

Benefits
Though CT has been proved to be significantly effective, its benefits from sound application are still need further research and analysis, which is one of the most important job for Beijing in next few years.

**Suggestions for the countermeasures**

We can gradually lead the farmers to switch from operating land in each household to developing uniform services provided agricultural service organization and the brokers in the rural area to. In this sense, we can increase farmers’ income while cutting costs so as to achieve the purpose of CT.

CT is a systematic project, and in the process of its early stage, maybe the results are not so prominent, but this technology long-term benefits, and can promote the development of sustainable agriculture. It is suggested to enhance the promotion and the training for the units in the grass root level to promote its application. Meanwhile, the premium efforts should be enhanced, and the farmers who have completed the cultivation-free seeding production and purchased the cultivation-free machineries and tools should be granted with the appropriate economic subsidy, and the units which have relatively well accomplished the tasks should be praised in the certain form, thus to better promote its implementation.

The R & D and the improvement of the machinery and the tool are a work that should be carried out in the long term, and various kinds of the problems incurred in the machinery and the tool must be researched in the process of the demonstration and the promotion, to solve the practical problems with the pertinence, and provide the assurance of the machinery and the tool for the Conservation tillage technology. The manufacturer of the machinery & the tool should be led to enrich the varieties and models of the cultivation-free seeding machines as soon as possible, to meet the requirements in the different specifications of the agricultural techniques, reduce the product price and promote the socialization of the technology application, the market transformation of the sales of the machinery and the tool, and the standardization of the working service.

Fully exert the functions of various expert teams, and within the next few years, the benefit problems after promoting and applying the Conservation tillage technology in big areas should be comprehensively and profoundly researched, to conclude a set of the specific analysis materials for benefits, and then to be used and referenced by other provinces and cities.

The CT is an item of the new-type cultivation technology that benefits both the country and people. Through its large area application, it will definitely play an important role in comprehensively constructing the metropolitan-type modern agriculture, so as to make great contributions in terms of the development of sustainable agriculture, improvement of ecology and economize agricultural sources in Beijing.

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Application of Pest and Weed control technology in Double cropping

Conservation Tillage

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Abstract: 1. Effect on the occurrence and extension of the pests and weeds in the practice of the four primary technology of conservation tillage. 2. The main pests and weeds and their properties existing in the process of implementing conservation tillage in this section. 3. The detailed measures of the pest and weed control. In this paper, it brings effective measures based on the research of the pest and the weed that may happen in the conservation tillage and perfects the technology systems of conservation tillage gradually, thereby making this advanced tillage system well-developed. By five years comparative trails in the demonstration site (53ha²), it proves that the pest and the weed can be fully controlled.

Key words: conservation tillage, pest, weed, control measures

Conservation tillage, which is widely implemented, is one advanced tillage system. But some related experts indicate that conservation tillage can aggravate the regional plant diseases, insect pests and weeds. And there are cases in practice. So it requires new technologies, especially in double cropping areas, which are covered perennially, and it’s difficult to prevent and control. Intensify the research, take effective measures, which has great meaning for promoting the development of conservation tillage.

Effect of conservation tillage on pest and weed

Residue coverage, no-tillage planting. Because of the residue coverage, it can fertilizer the soil, enhance the utilization of the rainfall precipitation, simplify working procedure, decrease the work times of the machine, however, it provides a propagation condition for pests and weeds at the same time.

1. The increasing of organic matter in the soil gives a good place for some pests to live through the winter and ovipositor, such as grubs and cotton bollworms.

2. Large amounts of residue coverage on the topsoil after wheat harvest have increased water conservation quantity, reduced the evaporation, which provide a rest condition for crickets, who like to live in moist, covered place, and also make the armyworms, cotton bollworms propagated in wheat survive.

3. Large amounts of maize stalk returned directly so as to pests such as corn borer can safely pass the winter and ovipositor.

4. Residue coverage, no-tillage planting. There is no treatment to the top soil and the weeds in wheat field including LuCao, digitaria sanguinalis, which can also transfer to maize field; also, too large amounts of the coverage makes the performance of the herbicide correspondingly decline.
Technology of loosening instead of turn-over tillage. At the same time of not destroying the soil structure, smashing the plow sole, improving the infiltration capacity of the water, it also makes it difficult to control the pests and weeds.

1. Long-term no-turning-over field. These perennial weeds, such as phragmites australis, ManMo, propagated by root and stalk, whose roots cannot be destroyed for long-term, have strong breed capability, quick spread speed.

2. Long-term no-turning-over field. Such as grub, chafer, cricket, cotton bollworm and so on, whose eggs can safely live through the winter.

3. Long-term no-turning-over field. The content of the weed seeds in the topsoil and the seedling rates increase.

The chemical weed and pest control methods make the living condition of their natural enemy destroyed.

The main kinds and properties of the pests and weeds existed in wheat and maize

There are hundreds of pests and weeds in the production of wheat and maize in BeiJing and TianJin. After years’ experiments, we have concluded that the main pests and weeds harmful to the production of wheat and maize including:

The main pests and their properties

1. Corn borer, which is one of the main pests in maize production and also is one cosmopolitan pest, has extremely strong drilling and eating capability. The grubs enter from the vagina to the stalk, and eat the marrow of the maize, which seriously blocks the feeding of the nutrient and leads to the produce of not well-stacked seeds and even no seed. The stalk can easily be broken off, causes seriously reduction of output. They mainly pass the winter in the stalk and the residue, first generation grubs destroy the spring maize, the second and the third generations destroy the summer maize in the next year.

2. Armyworm. Because of the air temperature, the armyworms can’t pass through the winter in Beijing and Tianjin. The imagoes migrate in these double-cropping areas and lay eggs in June, where have better watering and fertilizer conditions, and they always need three or four days to hatch. After the harvest of wheat, there are some grubs left, which will damage the plant of summer maize.

3. Cotton bollworms like to make chrysalides in the loose soil. In May and in June, the first generation larva will damage the wheat, not serious, but the harmed field will become the pest origin of the cotton and maize, then the second generation will damage the leaves of the maize, and the third generation will lay eggs on the leaves tine of headed maize. The larva will enter the bracts and eat the fruit until they harvest.

4. Crickets, a kind of field crickets, who are always born in wet meadow and covered farmland, and hatch into grubs in May, become imagoes after eclosion in July, then damage the roots, stalks and leaves. In September, they will lay eggs, which are 2 centimeters under the topsoil to live through the winter.

5. Grub, the imago is also called chafer. The larva eats the budding seeds and the roots of the wheat and maize, which makes shortage of the seedling and the break of ridge. The imagoes eat the leaves and flowers of the maize and damage the fruit. The larva and the imago alternately incorporate into
the soil every other year in the winter, lurking in the animal manure and the rotten organic matter.

6. Aphides are main pest in the production of wheat and maize, which happens every year. They have powerful propagation capacity that can propagate twenty and even thirty generations. They firstly damage the wheat, especially in grouting period then transfer to maize field and damage the maize, especially in fruiting period. After the seedling of wheat at the change of September to October, they again transfer to wheat field, and pass the winter in the roots of the wheat or in the around soil.

The main weeds and their properties

Goosefoot is annual plant propagated by seeds, which is one of the main weeds in wheat field. Goosefoots emerge in every spring, and grow up slowly at first, as the May coming, the temperature is going up, and their growth speed will expedite and the body height will be higher than wheat, which can cause the reduction of output and bring difficulty to machine harvest.

Flixweed tansymustard is an annual or over year plant which has strong vitality. The early plants emerge in September or October and blossom the next year after Tomb-sweeping Day and mature in May, which has great harmfulness; the late plants emerge in March, because they don’t mature at the harvest time, so the harmfulness is smaller compared with early plants.

Shepherd's-purse is also an annual or over year plant weed propagated by seeds. There are two emergence peak-hours one year. First is in October and mature in May; the other is in March or in April and they compete with wheat for light and fertilizer, and mature at the same time as wheat.

Wormseed mustard is annual and over year plant weed propagated by seeds. They come up in early spring or in autumn, blossom in April, form the seeds in May and fall to the ground as they ripe, compete light and fertilizer with wheat.

Morning glory is annual plant weed propagated by seeds and comes up both in spring and summer and grows up slowly in seedling stage. Morning glories have a powerful capacity of fighting a drought, and growing well after the rain, which twist the stalk of the maize, causing seriously reduction of output. The spring plants fruited in July and the summer plants fruited in October.

LuCao is an annual voluble herbaceous plant propagated by seeds and there are poisonous thorns on the vine. And the vines will climb up to the top of the wheat, which causes seriously reduction of output. They always grow well on the side of the channel and the ridge, build pergola on the maize field and effect serious harmfulness.

Digitaria sanguinalis is also annual plant weed propagated by seeds and emerge from May to July, form the seeds from August to October. They grow up quickly in the raining days and outgrow many vines, then quickly produce the roots. After damaged in the seedling period, the maize will turn yellow, thin, and they cannot stand up. But the harm can be alleviated after they stand.

No-awn barnyard grass is also annual plant weed propagated by seeds and their roots are very developed, which has effective tillering capacity and good properties to fighting the drought, fighting the waterlogging. They can revive quickly after transferring and emerge from May to June, form the seeds from August to September, damage the maize seriously.

Wild prosomillet, annual plant weed propagated by seeds. They emerge from May to July, form the seeds from June to September and mature in August. The wild prosomillets have effective tillering capacity and quick growing speed. The height of the plants can reach 1.5 meters, some can reach 2
meters, and seriously damage the maize in seedling period.

Amaranthus retroflexus, annual broad-leaved weed propagated by seeds. They emerge in May and grow up extremely quickly in summer. Their height can reach 1.5 meter, some can reach 2 meters, and seriously damage the maize in seedling period.

Phragmites australis is a perennial weed propagated by roots and stalks whose roots are well developed and they can come into the soil 1.5 meters deep. The growth speed always quickens in the middle of the May and can always be higher than the wheat, which causes great difficulty to the harvest. There are fuzzes on the leaves so that they can avoid suffering from the water.

ManMo is a perennial vine propagated both by seeds and roots. Their roots are well developed and very sturdy. They always emerge in spring and twist the stalk of the maize and seriously damage the maize.

The pest and weed control methods

In the course of implementing the conservation tillage, we have explored a set of measures to the prevention and control of the pests and weeds.

Control of weeds. It effects largely on the output of wheat and maize. The experiments in this area indicate that the output of maize can reduce by 40% and the wheat by 30%.

Physical control

Remain high stubbles when harvest the wheat, sow the summer maize in the up-right stubble field. Decrease the coverage as far as possible and it will give full play to the herbicide.

No-tillage planter of summer maize. With the permitted power, the width of the colter can be properly enlarged, which will widen the seed furrow, ensure the herbicide give closed play to the seed furrow and provide facility for weeding.

For the row-controlled sub-soiling to the summer maize of six to eight leaves, we can install soil-divided device on the standard of the sub-soiling plough, and finish the sub-soiling, inter-tillage work for one time.

Medical control

Weed control in wheat field. ① Broad-leaved weeds. At the time of four leaves stage of wheat, we can spray to the stalks and leaves. One is using the motor-driven ultralow-capacity sprayer, spraying 72% of 2,4-D butyl ester, which can be mixed with pesticide to control pests. Another is diluting 1000ml 2,4-D butyl ester of 72% density by adding 150-220 kg/ ha² water, then with the manual operation, or adding 300-450kg/ ha² water and mechanical drive; or adding 60-75kg/ ha² water and using motive backpack sprayer. ② One-cotyledon grass. Spray to the leaves with 900 to 1000 kg/ ha² diclofop-methyl of 28% or 36% density that adding 220kg water. ③ Perennial weeds. Spray to the leaves with glyphosate (by recommend dosage) adding BiLing additive or 0.5% no-enzyme washing powder (because of the waterproof function of their leaves). Leaf-spraying must be done at the right time, too early will reduce the output of the wheat and too late will lessen the effect of the herbicide.

Weed control in maize field. ① Do the soil treatment after sowing and before seedling with 3000ml/ ha² An’caolin added 450kg water; YumiBao or YumiJing (by recommend dosage); 40% atrazine 1500ml/ ha² added with 25% dichlorfenidim 2.2kg mixed with 450kg water and we can also add 20%
paraquat $2200\text{ml/km}^2$ to wipe out the residue weeds and use $10\%$ glyphosate $400-600\text{ml}$ added with $30\text{kg}$ water to destroy the stubborn weeds. ② Deal with the leaves when discover the weeds in the stage that the maize have three to five leaves. For the grass within three leaves, we can remove them by using $40\%$ atrazine $1500\text{ml/km}^2$ added with $33\%$ pendimethalin emulsifiable $1500\text{ml/km}^2$ mixed with $300\text{kg}$ water. For the double-cotyledon grass within four leaves, the maize that have four to six leaves, we can use $72\%$ 2,4-D butyl ester $750-1100\text{ml/km}^2$ or $20\%$ 2-methyl-4-chlorophenoxy acetic acid $3000-4500\text{ml/ha}$ added with $150-450\text{kg}$ water to spray evenly. ③ When they have six leaves, we can use $20\%$ paraquat $3000\text{ml/ha}$ added with $300\text{kg}$ water, then spray with the manual operation directionally.

**Pest control**

The control of the pest in conservation tillage must follow some definite rules which aim to wipe out insect pests and plant diseases before the winter as far as possible so as to decrease the amount of the overwintering pests so that to control them the next year.

**Physical control**

Crush the stubbles of the maize carefully and make them in silk and the length is shorter than eight centimeters, leaving no stubble on the surface, which can kill the corn borers in the larva stage, and completely destroy the supporter with which they pass the winter.

Reduce the coverage of the stalk after the wheat harvest. The coverage of the standing stalks can improve the light permeation capacity of the surface, ruin the rest places of Crickets.

Suppress the wheat before winter to enhance overwintering capacity of the wheat and kill the pests living in the roots and leaves of them.

Select good strains of seeds.

**Biological control**

It always uses microbe to kill Mingganjun, beauveria bassiana, 1kg bacterium powder that contains one hundred billion spores per gram must add to $1000-2000\text{kg}$ water to pour into the heart leaf of the maize.

**Seed treatment**

Clothing treatment to the maize seeds, which cannot only prevent the pests underground, but also have no harm to their natural enemies, and protect the ecological environment. And the furan can also kill the maize aphis.

Medical treatment to the wheat seeds. The method is to use $50\%$ phoxim emulsifiable with the dose of $0.1\%$ to $0.2\%$ of the seeds weight and dilute it with water, and then spray it to the seeds, sowing after fully absorbed.

**Medical control. Take the pesticide as soon as possible because that resistance to drugs of the pests will enhance after three instars.**

In the first ten-day of April, we must examine the amount of the aphis and control them. Destroy them in first generation with $80\%$ dichlorphos $150-300\text{ml/ha}$ mixed with herbicide.

In the first ten-day of May, we also need to examine the amount of the aphis and control them if necessary, the pesticide can be mixed with other drugs which can also kill armyworms and cotton
bollworms, and it always uses the motive backpack sprayer to enhance the penetrability and uniformity.

Spray pesticide which can kill the pests by contacting or eating it with the herbicide after sowing before seedling to wipe out the residue armyworms and cotton bollworms.

Pay attention to the amount of the pests after seedling, spray deltamethrin added with BiLing additive between the bottom of the maize and the surface.

One control method of corn borer is to scatter 0.3% phoxim granular preparation, 3% carbofuran granules 15 to 30 kg/ha² to the bellmouthing of the maize at the ten leaves stage when the harmed plant go to 10%. The other is to drop dichlorphos added with one thousand times water to the base of the female filament when the diseased plants reach to 5%.

Conclusions

Analysis of the working cost

Convention working: 3045yuan/ha.
Conservation tillage: 2400yuan/ha.
Conservation tillage with enhanced control measures: 2775yuan/ha. And the cost constitution was shown as follows:

<table>
<thead>
<tr>
<th>Working items</th>
<th>Working cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Convention working</td>
</tr>
<tr>
<td>total</td>
<td>3045</td>
</tr>
<tr>
<td>Wheat harvest</td>
<td>525</td>
</tr>
<tr>
<td>Stubble treatment and tillage</td>
<td>210</td>
</tr>
<tr>
<td>Maize seeding</td>
<td>150</td>
</tr>
<tr>
<td>Herbicide and insecticide</td>
<td>90</td>
</tr>
<tr>
<td>Inter tillage</td>
<td>120</td>
</tr>
<tr>
<td>Weed and pest control in maize field</td>
<td>60</td>
</tr>
<tr>
<td>Maize harvest</td>
<td>600</td>
</tr>
<tr>
<td>Maize stalk harvest and transport</td>
<td>675</td>
</tr>
<tr>
<td>Maize stalk smashing</td>
<td></td>
</tr>
<tr>
<td>Rotary tillage</td>
<td>210</td>
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<tr>
<td>Wheat seeding</td>
<td>180</td>
</tr>
<tr>
<td>weeding in the wheat field</td>
<td>105</td>
</tr>
<tr>
<td>Wheat aphid control</td>
<td>120</td>
</tr>
<tr>
<td>Wheat and maize seed dressing</td>
<td></td>
</tr>
</tbody>
</table>
Analysis of the occurrence of weeds and pests

the surface condition before wheat seeding:
① fallow field (no planting before seeding).
② 70% coverage rate after maize stalk smashed.
③ the stalk keep standing after maize harvest.

(2) Tillage forms:
① convention working
② conservation tillage

Conditions of weeds and pests

① Wheat: The monitors were conducted respectively on 23\textsuperscript{rd} November in 2004, 25\textsuperscript{th} March, 12\textsuperscript{th} April, 17\textsuperscript{th} May and 15\textsuperscript{th} June in 2005, the results show that there is no obvious difference in the monitoring indexes for wheat under the two kinds of tillage forms and the three working conditions of conservation tillage.

② Maize: The monitors were taken on June 30\textsuperscript{th}, July 18\textsuperscript{th}, August 23\textsuperscript{rd}, October 2\textsuperscript{nd} in 2005, the results are as follows: there is no pest and weed in the first monitor, but the corn borer emerged universally in the second monitor and the incidence of the disease are: convention working, 16.7% of one hundred plants on average; conservation tillage: 5.6% in the green stubble land, 18.2% in wheat field with the maize stalk smashed, 43% in not smashed field. Dusting the carbofuran granules to 60ha demonstrate field from 20\textsuperscript{th} July to 2\textsuperscript{nd} August for one time, and spraying paraquat directionally to the weeds in the maize field. According to the observation on 5\textsuperscript{th} August, the effective control rate has reach to 95% and the death rate of the weeds is 90%. After the storm of 8\textsuperscript{th} August, the third observation was taken on 18\textsuperscript{th} August, it found that the wind damage and the breaking of the maize are to varying degrees depend on the incidence of corn borer, which are: convention working: wreckage rate is 5%; conservation tillage: 5% in the fallow field, 10% in wheat field with the maize stalk smashed, as high as 40% in not smashed field which is controlled lately.

Analysis of yield

<table>
<thead>
<tr>
<th>Crop name</th>
<th>Convention working</th>
<th>Conservation tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without control measurement</td>
<td>With control measurement</td>
</tr>
<tr>
<td>wheat</td>
<td>5400</td>
<td>5400</td>
</tr>
<tr>
<td>maize</td>
<td>6900</td>
<td>3750</td>
</tr>
</tbody>
</table>

Results of the research

Master the whole technologies of conservation tillage, combine the principal technology with agriculture when implement it, especially for the pest and weed control, or it will cause unnecessary loss, and block the development of conservation tillage.

There is obvious advantage in product cost and grain yield of conservation tillage compared with
convention tillage, which will be much clearer as the time goes on.

References


Author introduction

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Studies on the Weed Developing Regularity and Controlling Technique for Agri-Grazing-Ecotone under Conservation Tillage in Wheat Field

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Abstract: There were 30 species weed in wheat field from agri-grazing-ecotone for conservation tillage, their developing density and frequency were higher in conservation tillage than traditional tillage method about 31.8~42.6% and 13.3~31.6%. Accordingly, their expanding condition was serious increasingly. Weed damage and its control in the wheat field with conservation tillage planting method was investigated and experimented. Some measure were made mainly of Chemical herbicide, mechanical method, artificial control and the rotate farm. The result showed that the weed control amount in the soybean field was larger in the early growth stage than that had good results for chemical herbicide in the seedling stage with 2,4-D butyl ester (2,4-D 丁酯), 2-methyl-4-chlorophenoxy acetic acid, 护麦、骠马(C_{18}H_{16}ClNO_3), 抑阔宁+骠马、护麦(C_{18}H_{16}Br_2NO)+阔莠克, 2,4-D butyl ester (2,4-D丁酯)+骠马(C_{18}H_{16}ClNO_3) and after harvest make use of 草甘膦 in autumn. In addition, weed control of mechanical method had a good effect on fleet-furrow + cultivation. The compositive measure had a better outcome with fleet-furrow + chemical herbicide.

Key words: agri-grazing-ecotone, Conservation Tillage, wheat field, weed controlling

The conservation tillage technique was an agricultural farming method through little or no-tillage for farmland. Consequently, it will be reduced the disturbance in soil, meanwhile, this technique should prevent the soil erosion by wind and water as well, with this tillage method application and development, the weed have erupted accordingly. Therefore, prevention and cure of weed is a important for farmland.

We take a weed examination in Wuchuan country, Huhhot city, Inner Mongolia, studies on the weed developing regularity and controlling technique for agri-grazing-ecotone under conservation tillage in wheat field.

Materials and methods

Sample spot general situation

The experiments were set up in the greenhouse of the Xuhai experimental garden, Wuchuan county, Huhhot, China (40°47′37″N, 110°41′57″E). The agrotype is the medium loam, arid and rainfall little in spring, annual mean precipitation is 345mm; western monsoon is strong, annual mean air temperature is about 3 ℃, Frost-free period is about 110d. The weed developing regularity has an obvious terrain characteristic. The primary weed included Chenopodiaceae, Fallopia convolvulus,
Geraniaceae, Cirsium setosum as well.

**materials**: The local wheat.

**Plant materials**: The local wheat.

**Chemical herbicide**

The single factor experiment was used 10 herbicides, which mainly included (燕麦畏、骠马、2,4-D丁酯、二甲四氯、阔草枯、护麦、抑阔宁、麦乐宁、阔莠克、草甘膦); the multiple factors experiment was used 5 herbicides (二甲四氯+麦乐宁、骠马+护麦、抑阔宁+骠马、护麦+阔莠克、2,4-D丁酯+骠马).

**Machines**:

Weeding machines are IQG—120, IS—5 fleet-furrow machines, 200Z4/8A8 revolve-plough machines and 3ZF—1.2 multiple weeding machines. Plant protection and spray machines are MIFB—18AC,3WP—100.

**Experimental design**

The experiments were set up in the wheat field of the Wuchuan county, Huhhot, China. Three weeding combination treatments were applied while the other factors. Within each treatment were designed randomly. The experiments were weeded for the chemical herbicide, mechanical method and crop-rotate.

**Results and analysis**

**Weed developing and succession regularity**

**Weed species**

The dominating weed species were mainly included such as *Setaria glauca*, *Avena fatua* L., *Echinochloa caudata*, *Elymus dahuricus Turcz.*, *Chenopodiaceae*, *Polygonum aviculare* L., *Salsola collina* Pall., *Amaranthus retroflexus*, *Fallopia convolvulus*, *Convolvus arvensis*, *Anemisia scoparia*, *Artemisia annua* L., *Cirsium setosum*, *Geranium sibiricum* L. and so on.

**Annual and Biannual weed**

There were important weed in wheat field such as *Avena fatua* L., *Chenopodium boritrys* L., *Polygonum aviculare* L. etc. in early spring. Otherwise, They were important weed in corn field such as *Setaria glauca*, *Echinochloa caudate*, *P. bungeanum*, *Xanthium sibiricum* Patr and *Amaranthus paniculatus* L. as well in later spring. Biannual weed in the wheat field has *Artemisia annua* L. etc.

**Perennial Weed**

Perennial weed mainly were including *Plantago depressa* Willd., *Taraxacum sinicum* Kitag., *Runmex japonicus* Houtt., *Cirsium setosum*, *Brassica integrifolia*, *Sonchus arvensis* L.

**Weed succession regularity**

Weed Biological characteristic in wheat field
## Table I  Weed growth period in wheat field (Date: month/day)

<table>
<thead>
<tr>
<th>Species</th>
<th>Seedlings</th>
<th>Anthesis</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>金狗尾草  Setaria glauca (L.) Beauv.</td>
<td>5/15—5/26</td>
<td>7/15—7/30</td>
<td>8/20—9/6</td>
</tr>
<tr>
<td>卷茎蓼  Fallopia convolvulus (L.) A. Love</td>
<td>5/3—5/15</td>
<td>7/20—7/30</td>
<td>8/5—8/30</td>
</tr>
<tr>
<td>猪毛菜  Salsola collina Pall.</td>
<td>5/7—5/25</td>
<td>7/25—8/15</td>
<td>8/30—9/20</td>
</tr>
<tr>
<td>藜  Chenopodiaceae</td>
<td>5/6—5/18</td>
<td>7/10—7/25</td>
<td>8/15—9/5</td>
</tr>
<tr>
<td>草地风毛菊  Saussurea amara (Linn.) DC.</td>
<td>4/20—5/3（turn green）</td>
<td>7/20—8/5</td>
<td>8/27—9/15</td>
</tr>
<tr>
<td>牦牛儿苗  Geranium sibiricum L.</td>
<td>4/15—4/29</td>
<td>7/20—8/5</td>
<td>8/25—9/7</td>
</tr>
<tr>
<td>苦荞麦  Fagopyrum Tartaricum</td>
<td>5/20—5/30</td>
<td>7/15—7/30</td>
<td>8/16—8/30</td>
</tr>
<tr>
<td>披碱草  Elymus dahurcus Turcz.</td>
<td>4/5—4/10</td>
<td>7/25—7/31</td>
<td>8/10—8/20</td>
</tr>
<tr>
<td>篇蓄  Polygonum aviculare L.</td>
<td>5/10—5/15</td>
<td>6/10—7/10</td>
<td>8/5—8/10</td>
</tr>
<tr>
<td>反枝苋  Amaranthus retroflexus L.</td>
<td>5/5—5/15</td>
<td>7/20—7/30</td>
<td>8/25—9/5</td>
</tr>
<tr>
<td>苋属蒿  Anemisia scoparia</td>
<td>4/25—5/10（turn green）</td>
<td>7/5—7/15</td>
<td>8/10—8/20</td>
</tr>
<tr>
<td>刺儿菜  Cirsium setosum</td>
<td>5/10—5/20（turn green）</td>
<td>7/30—8/10</td>
<td>8/30—9/20</td>
</tr>
<tr>
<td>田旋花  Convolva arvensis</td>
<td>4/20—5/20</td>
<td>7/5—7/15</td>
<td>8/20—8/30</td>
</tr>
</tbody>
</table>

The weed developing characteristic of agri-grazing-ecotone under Conservation Tillage

Weed seed mainly centralized on the upper soil layer. seed mainly distributed in upper soil layer 3～5 cm, upper soil layer has a good moisture content. Seed germinate concentrate, has a high germinate rate and germinate early. as upper soil layer has a good moisture content perennial weed increased the rate of living through the winter, developed greater quantity. So weed has more harm, harder to control, controlling period become early, it’s conflict with the situation that crop seedling period has
little endurance over weedicide. It require the best time to machine-weed and chemic weed, with the right quantity to get the best effect.

Maize Farmland main weed include Gramineae, Poaceae, Asteraceae, Compositae, Convolvulaceae, Chenopodiaceae, amaranthaceae, portulaceae, Zygophyllaceae, Solanaceae, Malvaceae and so on. Main weed community: Convolvus arvensis, Amaranthus retroflexu, *Setaria glauca*, Chloris virgata, Xanthium mongolium; Kochiascoparia(L.) Schrad, Anemisia scoparia. Gramineous weed of the dominant population are, Phragmites communis and so on. Broad weed were mainly Chenopodiaceae and Herba Acalyphae.

There are two different developing situation of weed in maize farmland in spring, 1)nearly the same time with crop germinating, 2)later than crop germinating. A part of weed crop germinate in the crop grow period, after big precipitation, the soil moisture content become very high. this part of weed usually grow up in bloom period, crop were raged in field, growth was restrained. They has little harm to crop.

Synthetically, experiment plot set at Agri-Grazing-Ecotone where serious windy erosion has occurred. The weed seed there is not only the seed which local grown, but also some come from other land transport by wind. the harm that weed grow is serious, but with Conservation Tillage and ecological construction progressing, sand storm has been effectively restrained, so the distribution of weed seed was under control. After implement weed controlling technique under conservation tillage for years, weed in conservation tillage farmland will gradually decrease.

**Effect of the different weeding treatment**

After each using of the weedicide for 45 d, we did the investigation of the weed in the farmland, each 5 d after the using, we did a investigation of the effect of weedicide. We get the sample with the method of diagonal, 0.25 m$^2$ each point, results as label below:

The effect of weedicide

the fiveth -seventh lamina and edge turn yellow after the using of 燕麦畏 for 5-15 d. Part of the leaf became totally yellow., 60% of edge of the fourth -fiveth leaf turned yellow after the using of 骠马 for 5—11 d. there is no other damage showed.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Treatment</th>
<th>ways</th>
<th>The effect of seeding (%)</th>
<th>The effect of fresh weight (%)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical herbicide</td>
<td>Control herbicide in one way in seeding</td>
<td>2,4-D 丁酯</td>
<td>90.5</td>
<td>90.2</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>二甲四氯</td>
<td>83.1</td>
<td>89.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>阔草枯</td>
<td>65.3</td>
<td>69.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>护麦</td>
<td>85.3</td>
<td>87.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>抑阔宁</td>
<td>66.2</td>
<td>69.6</td>
<td></td>
</tr>
<tr>
<td>Control weed in multi-way</td>
<td></td>
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<td>---------------------------</td>
<td>---</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>燕麦畏</td>
<td>77.5</td>
<td>69.1</td>
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<tr>
<td>骠马</td>
<td>86.6</td>
<td>85.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>抑阔宁 + 骠马</td>
<td>97.7</td>
<td>84.6</td>
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<tr>
<td>护麦 + 骠莠克</td>
<td>97.5</td>
<td>96.6</td>
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<tr>
<td>护麦 + 骠马</td>
<td>80.9</td>
<td>95.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-D 丁酯 + 骠马</td>
<td>92.3</td>
<td>87.8</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical method</th>
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<tbody>
<tr>
<td>Fleet-furrow</td>
<td>88.9</td>
<td>85.8</td>
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<tr>
<td>Scarification gently</td>
<td>66.7</td>
<td>64.8</td>
</tr>
<tr>
<td>Cultivation</td>
<td>80.1</td>
<td>93.4</td>
</tr>
<tr>
<td>Fleet-furrow + Cultivation</td>
<td>90.6</td>
<td>86.4</td>
</tr>
<tr>
<td>Scarification gently + Cultivation</td>
<td>93.1</td>
<td>96.7</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Artificial control</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89.9</td>
<td>86.2</td>
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<table>
<thead>
<tr>
<th>Rotate farm</th>
<th></th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>30.1</td>
<td>28.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compositive weed control</th>
<th></th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>95.6</td>
<td>94.8</td>
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</table>

<table>
<thead>
<tr>
<th>Multi-way weed control</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>fleet-furrow + Chemical herbicide</td>
<td>浅旋 + 抑阔宁</td>
<td>62.3</td>
</tr>
<tr>
<td>fleet-furrow + Chemical herbicide</td>
<td>浅旋 + (2,4-D 丁酯 + 骠马)</td>
<td>92.3</td>
</tr>
<tr>
<td>Scarification gently + Chemical herbicide</td>
<td>浅松 + (2,4-D 丁酯 + 骠马)</td>
<td>86.9</td>
</tr>
</tbody>
</table>
Result analysis

Mono-factor weed

We can draw conclusion from the effect of chemical herbicide which spraying on the stem and leaf in the way of 2,4-D 丁酯、二甲四氯、护麦、骠马、 artificial ways and fleet-furrow weed were good, the dead ratios are more than 85%.

The effect were investigated that the effect of spraying on the stem and leaf in the ways of 2,4-D 丁酯、二甲四氯、护麦、骠马、 fleet-furrow and cultivation are good, the dead ratio are more than 85%.

multi-factor control weed

we could learn from the deed ratio in individual. When we control weed in the way of chemistry in seeding 抑阔宁+骠马、 护麦+阔莠克、2,4-D 丁酯+骠马、 Scarification gentlely+Cultivation and mechanical weed control add the chemical way were all good. The dead ratio are more than 90%.

The effect were investigated from the dead ration in fresh -weight. Spraying in 护麦+阔莠克、护麦 +骠马 in weeding and scarification gentley+Cultivation and mechanical weed control, and added and compounded were better. Especially compounded control weed, the dead ratio in individual and fresh-weight are all more than 94%.

We could learn from the phenomenon that 骠马 has better effect on the weed of Gramineae,Poaceae in one-way, 95% of them were dead, but 2,4-D 丁酯、二甲四氯、护麦 have good effect on broad leaf weed; 阔草枯、抑阔宁、燕麦畏 could only restrain the growth of weed, the dead ratio was low.

In a word, Spraying on the stem and leaves in2,4-D 丁酯、二甲四氯、护麦、骠马，抑阔宁+骠马、 护麦+阔莠克、2,4-D 丁酯+骠马 is good means. Mechanical way mainly fleet-furrow and scarification gentley, and it is connected with chemical herbicide and compound means all have the good effect. In the crop-rotate field, the direct dead ratio is 2.8%, indirect dead ratio is 27.3%, and that of compound ways is 30.1%. The dead ratio of fleet-furrow and scarification gentley before seed in field was 88.9% and 66.7% respectively. After harvest, if there is more Perennial weed, it could be sprayed with the 草甘膦 400ml and 40kg water. It is investigate that the dead ratio reached 85% after 7 and 15 days.

The effect of different treatment on the botanical properties and yield of wheat

The yield of spring wheat in conservation

<table>
<thead>
<tr>
<th></th>
<th>The number of ear in a unit of area (万)</th>
<th>Height of stem (㎝)</th>
<th>The grain of spike</th>
<th>1000-grain weight (g)</th>
<th>Practicable yield kg/a unit of area</th>
<th>The increasing rate (%)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ck</td>
<td>22.5</td>
<td>76</td>
<td>16.5</td>
<td>36.2</td>
<td>134.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical herbicide</td>
<td>22.2</td>
<td>86</td>
<td>18.2</td>
<td>37.7</td>
<td>152.3</td>
<td>13.3</td>
<td>24-D丁酯</td>
</tr>
<tr>
<td>Mechanical methods</td>
<td>20.6</td>
<td>80</td>
<td>19.0</td>
<td>37.1</td>
<td>145.2</td>
<td>8.0</td>
<td></td>
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<tr>
<td>artificial control</td>
<td>21.1</td>
<td>83</td>
<td>18.9</td>
<td>37.6</td>
<td>149.2</td>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>Crop-rotate</td>
<td>21.4</td>
<td>79</td>
<td>19.7</td>
<td>37.8</td>
<td>154.4</td>
<td>18.6</td>
<td></td>
</tr>
</tbody>
</table>
We could learn from the table that the highest field is 257.8% and 203.5% in the field of 护麦+阔莠克 and cultivation than normal. The increasing yield ratio is higher than 50% are including 89.7% in field of false control, 88.6% in field of scarification gently and cultivation, 61.1% in field of 护麦+骠马 and 56.8% in field of 抑阔宁+骠马. There were two field which increased by 37.5% (护麦+骠马) and 46.5% (2,4-D 丁酯+骠马). However the wheat were in reduction of output by 28.9% because the effect of 二甲四氯 and cultivation on the population of *Elymus dahurcus* Turcz. was weak, which induce to lack of wheat seeding and restrain from growth.

### The choosed herbicide and machine for wheat in conservation

After mono-factor experiment in 2004 and multi-factor experiment in 2005, we find out the weedicide which suit to conservation tillage. In wheat farmland, using 草甘膦 after seedtime before seedling stage, the proportion of control weed is over 75%. Using 2,4-D 丁酯+护麦+阔莠克、2,4-D 丁酯+骠马、抑阔宁+骠马 in grow period as spray on culm, the proportion of dead is over 90%. Use 草甘膦 in fall after harvest

Test of remnant: There was no pesticide remnant after the institute of testing for the quality of primary product measure the wheat and soil.

It should mainly rely on control weed before or after seeding and harvest in chemical ways, connected with spraying on stem and leaf in growth time. It would but only control weed but also popularize.

### Machine for controlling weed in wheat field

Weeding machines are IQG—120、IS—5 fleet-furrow machines, 200Z4/8A8 revolve-plough machines and 3ZF—1.2 muliple weeding machines.

<table>
<thead>
<tr>
<th>fleet-furrow + cultivation</th>
<th>8.71</th>
<th>38</th>
<th>16.6</th>
<th>29.76</th>
<th>40.9</th>
<th>88.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D 丁酯 +cultivation</td>
<td>5.58</td>
<td>26.9</td>
<td>15.5</td>
<td>28.84</td>
<td>23.7</td>
<td>9.2</td>
</tr>
<tr>
<td>二甲四氯 +cultivation</td>
<td>4.2</td>
<td>35.7</td>
<td>12.95</td>
<td>29.7</td>
<td>15.4</td>
<td>-28.9</td>
</tr>
<tr>
<td>Cultivation</td>
<td>7.74</td>
<td>44.5</td>
<td>17.8</td>
<td>33.7</td>
<td>44.1</td>
<td>103.5</td>
</tr>
<tr>
<td>CK1-3</td>
<td>6.04</td>
<td>38.8</td>
<td>13.5</td>
<td>27.97</td>
<td>21.7</td>
<td>0</td>
</tr>
<tr>
<td>麦乐宁+二甲四氯</td>
<td>5.51</td>
<td>33.3</td>
<td>15.3</td>
<td>29.53</td>
<td>23.7</td>
<td>0</td>
</tr>
<tr>
<td>抑阔宁+骠马</td>
<td>4.4</td>
<td>36.4</td>
<td>17.41</td>
<td>32.76</td>
<td>23.8</td>
<td>1</td>
</tr>
<tr>
<td>CK4-6</td>
<td>5.29</td>
<td>38.5</td>
<td>15.52</td>
<td>29.8</td>
<td>23.7</td>
<td>0</td>
</tr>
<tr>
<td>护麦+阔莠克</td>
<td>9.4</td>
<td>40.8</td>
<td>17.02</td>
<td>25.83</td>
<td>45.3</td>
<td>157.8</td>
</tr>
<tr>
<td>护麦+骠马</td>
<td>4.7</td>
<td>38.07</td>
<td>21.33</td>
<td>29.77</td>
<td>28.3</td>
<td>61.1</td>
</tr>
<tr>
<td>2,4-D 丁酯+骠马</td>
<td>4.97</td>
<td>40.4</td>
<td>17.07</td>
<td>32.08</td>
<td>25.7</td>
<td>46.5</td>
</tr>
<tr>
<td>抑阔宁+骠马</td>
<td>6.94</td>
<td>37.1</td>
<td>14.7</td>
<td>28.4</td>
<td>27.6</td>
<td>56.8</td>
</tr>
<tr>
<td>CK7-9</td>
<td>4.54</td>
<td>30.9</td>
<td>15.7</td>
<td>26</td>
<td>17.6</td>
<td>0</td>
</tr>
</tbody>
</table>
Conclusion

After two years study, we ravel the weed developing regularity from Agri-Grazing-Ecotone under conservation tillage in wheat farmland in principal. We also ravel the main weed population which harm the wheal in Agri-Grazing-Ecotone at north of the Yin mountain and the degree of it. According to it we find out the best method to control the weed and the time. EXP: using 草甘膦 to deal with perennial weed has good effect.

In the study, we figure out over 10 kinds of weed machine through over 20 kinds weed machine which suit for the situation under conservation tillage. We also improved some machine, most of them which has good effect was accept by the farmer of the sample spot.

Based on the weeding experience before, we filter out sixteen kinds of weedicides which adapt to wheat farmland under conservation tillage weeding with high-efficiency and low pollution in over forty categories. Respectively studying on the chemical weeding of the cornfield, we filter out five groups of weedicide which adapt to wheat farmland under conservation tillage weeding, and harvest good purpose and successful experience.

We did lots of experiment in mechanic, chemical, agriculture weed technique, set over 10 treatments, using 15 different kinds of machine and 7 kinds of weedicide. the effect of both weed and crop production increase is distinct.

References


Studies on the Weed Developing Regularity and Controlling Technique for Agri-Grazing-Ecotone under Conservation Tillage in Maize Field

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Abstract: There were 30 species weed in wheat field from agri-grazing-ecotone for conservation tillage, their developing density and frequency were higher in conservation tillage than traditional tillage method about 31.8~42.6% and 13.3~31.6%. Accordingly, their expanding condition was serious increasingly. Weed damage and its control in the maize field with conservation tillage planting method was investigated and experimented. Some measure were made mainly of Chemical herbicide, mechanical method and the rotate farm. The result showed that the weed control could be treated in soil by莠去津、乙草胺、乙草胺+莠去津 after seeding. It had good results for chemical herbicide in the seedling stage with玉农乐、玉农乐+2,4-D丁酯 and after harvest make use of草甘膦 in autumn. In addition, weed control of mechanical method had a good effect on fleet-furrow +scarification deeply+ cultivation. The compositive measure had a better outcome such as fleet-furrow + chemical herbicide, scarification deeply+ chemical herbicide, cultivation+ chemical ways.

Key words: agri-grazing-ecotone; Conservation Tillage; maize field; weed controlling

The conservation tillage technique was an agricultural farming method through little or no-tillage for farmland. Consequently, it will be reduced the disturbance in soil, meanwhile, this technique should prevent the soil erosion by wind and water as well, with this tillage method application and development, the weed have erupted accordingly. Therefore, prevention and cure of weed is an important issue for farmland.

We take a weed examination in Wuchuan county, Huhhot city, Inner Mongolia, studies on the weed developing regularity and controlling technique for agri-grazing-ecotone under conservation tillage in maize field.

Materials and methods

materials:
The local maize species.

Plant materials
The local maize species.

Chemical herbicide
The single factor experiment was used 8 herbicides, which mainly included (乙草胺(C_{14}H_{20}ClNO_2)、莠去津(C_{14}ClN_3)、2,4-D丁酯(C_{12}H_{10}Cl_2O_2)、二甲四氯(C_{8}H_{4}Cl_2O_2)、溴苯腈(C_{8}H_{8}BrNO)、玉农乐(C_{15}H_{18}N_6O_S)、都尔(C_{12}H_{22}ClNO_2)、利草净(??)); the mulriples factors experiment was used 5 herbicides (乙草胺+莠去津、玉农乐+莠去津、玉农乐+2,4-D丁酯、乙草胺+2,4-D丁酯、二甲四氯+莠去津).

Machines
Weeding machines are 1GQN—200S fleet-furrow machine, SGTNB—180Z4/8A8 revolve-plough machines and 2BG—6D、1SZF—3 and 1SND-140 scarification deeply and cultivation machines. Plant protection and spray machines are 3WS-1500 and NS-16.

Sample spot general situation
The experiments were set up in the greenhouse of the Xuhai experimental garden, Wuchuan county, Huhhot, China (40°47′37″N, 110°41′57″E). The agrotype is the sand, where were irrigated. Annual mean air temperature is about 5.8℃ and annual mean precipitation is higher than 350mm; Frost-free period is about 142d. The period for plant growth is about 220d, the period for the mean air temperature higher 5℃ is about 160d, and 190d for that higher 10℃. The weed developing regularity has an obvious terrain characteristic. The primary weed included Setaria glauca, Digitaria sanguinalis (L.) Scop., Chloris virgata Swartz of Gramineae Poaceae weed, Chenopodiaceae, Fallopia convolvulus, Geraniaceae, Cirsium setosum of broad weed as well.

Experimental design

The experiments were set up in the maize field of the Wuchuan county, Huhhot, China. Three weeding combination treatments were applied while the other factors. Within each treatment were designed randomly. The experiments were weeded for the chemical herbicide, mechanical method and crop-rotate.

Results and analysis

Weed developing and succession regularity

Weed species

The dominating weed species in maize field were mainly included such as Setaria glauca, Calamagrostis acutiflora, Digitaria sanguinalis (L.), Scop., Salsola collina Pall., Amaranthus Chenopodiaceae, Anemisia scopari, Kochia scoparia (L.), Schrad Convulv arvensis, Xanthium sibiricum Patr., Solanum nigrum L., Abutilon avicennae, Gaertn Sonchus arvensis L., Artemisia annua L., Chloris virgata Swartz and so on.

Annual and Biannual weed

There were important weed in wheat field such as Avena fatua L., Chenopodium bortrys L., Polygonum aviculare L. etc. in early spring. Otherwise, They were important weed in corn field such as Setaria glauca, Echinochloa caudate, P. bungeanum, Xanthium sibiricum Patr and Amaranthus paniculatus L. as well in later spring biannual weed in the maize field.

Perennial Weed

Perennial weed mainly were including Plantago depressa Willd., Taraxacum sinicum Kitag., Runmex japonicus Houtt., Cirsium setosum, Patriniavillosa TJuJuss Sonchus arvensis L. and Phragmites australis.

Weed succession regularity

Weed Biological characteristic in wheat field

<table>
<thead>
<tr>
<th>Table1</th>
<th>Weed growth period in maize field (Date: month/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed Species</td>
<td>Seedlings month/day</td>
</tr>
<tr>
<td>芦苇草 (Phragmites australis)</td>
<td>4/20—5/10</td>
</tr>
<tr>
<td>狗尾草 (Setaria glauca)</td>
<td>5.10—5.30</td>
</tr>
<tr>
<td>虎尾草 (Chloris virgata)</td>
<td>5.10—5.30</td>
</tr>
<tr>
<td>马 唐 (Digitaria sanguinalis)</td>
<td>5.1—6.10</td>
</tr>
</tbody>
</table>
The weed developing characteristic of agri-grazing-ecotone under Conservation Tillage

Weed seed mainly centralized on the upper soil layer, seed mainly distributed in upper soil layer 3~5cm, upper soil layer has a good moisture content. Seed germinate concentrate, has a high germinate rate and germinate early, as upper soil layer has a good moisture content perennial weed increased the rate of living through the winter, developed greater quantity. So weed has more harm, harder to control, controlling period become early, it’s conflict with the situation that crop seedling period has little endurance over weedicide. It require the best time to machine-weed and chemic weed, with the right quantity to get the best effect.

Maize Farmland main weed include Gramineae, Poaceae, Asteraceae, Compositae, Convolvulaceae, Chenopodiaceae, amaranthaceae, portulaceae, Zygophyllaceae, Solanaceae, Malvaceae and so on. Main weed community: Convolvul arvensis, Amaranthus retroflexus, Setaria glauca; Chloris virgata, Xanthium mongolium; Kochiascoparia(L.) Schrad, Anemisia scoparia. Gramineous weed of the dominant population are, Phragmites communis and so on. Broad weed were mainly Chenopodiaceae and Herba Acalyphae.

There are two different developing situation of weed in maize farmland in spring, 1)nearly the same

<table>
<thead>
<tr>
<th>Weed Name</th>
<th>Flowering Period</th>
<th>Seed Germination Period</th>
<th>Germination Rate</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xanthium sibiricum</td>
<td>May 1–June 10</td>
<td>July 10–August 20</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>Sonchus arvensis</td>
<td>April 10–May 20</td>
<td>June 10–August 20</td>
<td>75%</td>
<td>85%</td>
</tr>
<tr>
<td>Artemisia annua</td>
<td>April 30–May 20</td>
<td>July 10–August 20</td>
<td>85%</td>
<td>90%</td>
</tr>
<tr>
<td>Salsola collina</td>
<td>April 30–May 20</td>
<td>July 10–August 20</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Convolvul arvensis</td>
<td>April 20–May 15</td>
<td>May 20–August 10</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>April 20–May 30</td>
<td>July 15–August 5</td>
<td>75%</td>
<td>85%</td>
</tr>
<tr>
<td>Kochia scoparia</td>
<td>April 15–May 30</td>
<td>July 1–August 20</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Salsola collina</td>
<td>April 25–May 15</td>
<td>June 10–August 15</td>
<td>85%</td>
<td>90%</td>
</tr>
<tr>
<td>Amaranthus retroflexus</td>
<td>May 15–June 20</td>
<td>July 20–August 15</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Portulaca grandiflora</td>
<td>May 20–June 30</td>
<td>July 15–August 30</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>Tribulus terrestris</td>
<td>May 10–May 30</td>
<td>June 10–July 20</td>
<td>75%</td>
<td>85%</td>
</tr>
<tr>
<td>Solanum nigrum</td>
<td>May 1–May 20</td>
<td>July 10–August 10</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Abutilon avicennae</td>
<td>May 20–May 30</td>
<td>July 10–August 10</td>
<td>85%</td>
<td>90%</td>
</tr>
</tbody>
</table>
time with crop germinating ,2) later than crop germinating . A part of weed crop germinate in the crop grow period, after big precipitation, the soil moisture content become very high. this part of weed usually grow up in bloom period , crop were raged in field, growth was restrained. They has little harm to crop.

Synthetically, experiment plot set at Agri-Grazing-Ecotone where serious windy erosion has occurred. The weed seed there is not only the seed which local grown , but also some come from other land transport by wind .the harm that weed grow is serious ,but with Conservation Tillage and ecological construction progressing , sand storm has been effectively restrained, so the distribution of weed seed was under control . After implement weed controlling technique under conservation tillage for years, weed in conservation tillage farmland will gradually decrease.

**Effect of the different weeding treatment**

After each using of the weedicide for 2d, we did the investigation of the weed in the farmland, each 7 d after the using, we did a investigation of the effect of weedicide till after using them for 15d. We investigate the effect and the dead ratio of individual and weed fresh weight. We get the sample with the method of diagonal, 0.25 m² each point, results as label below in maize field:

**The effect of weedicide**

The fifth -seventh lamina and edge turn yellow after the using of 玉农乐 after 2d., then it become normal for one weeks. 60% of the maize leaf became yellow, it is for 7d that the leaves turn normal. If the leaves were sprayed with 玉农乐与 2,4-D 丁酯, they would be dry rot. It would become natural after 8d.

**Table 2**  **The effect of control weed in maize field**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Treatment Ways</th>
<th>The effect of seeding (%)</th>
<th>The effect of fresh weight (%)</th>
<th>Remark</th>
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<td>Chemical herbicide</td>
<td>86.1</td>
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<td>herbicide after seed</td>
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<td></td>
<td>乙草胺</td>
<td>96.9</td>
<td>98.57</td>
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<td>94.0</td>
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</tr>
<tr>
<td></td>
<td>2,4-D 丁酯</td>
<td>73.0</td>
<td>91.48</td>
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<td></td>
<td>都尔</td>
<td>73.4</td>
<td>91.4</td>
<td></td>
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<tr>
<td></td>
<td>玉农乐+莠去津</td>
<td>89.0</td>
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<td>二甲四氯+莠去津</td>
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<td>玉农乐+玉农乐</td>
<td>96.0</td>
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<td>Method</td>
<td>Seeding</td>
<td>Mechanical Method</td>
<td>Artificial Control</td>
<td>Rotate Farm</td>
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<td>Fleet-furrow</td>
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<td></td>
<td></td>
<td>Scarification gently</td>
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<td>Cultivation</td>
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<td>Fleet-furrow</td>
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<td></td>
<td>+ Scarification gently + Cultivation</td>
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<td>97.2</td>
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<td>Scarification gently</td>
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<tr>
<td>Cultivation</td>
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<td>64.8</td>
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<td>+ Scarification gently</td>
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<td>Scarification deeply + Chemical herbicide</td>
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</tr>
<tr>
<td>Cultivation + Chemical herbicide</td>
<td></td>
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<tr>
<td>Multi-way weed control</td>
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<td>Result analysis</td>
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<tr>
<td>Mono-factor weed</td>
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</table>
| We can draw conclusion from the effect of chemical herbicide which were treated to soil by莠去津、乙草胺 and sprayed on the stem and leaf in the way of玉农乐, artificial ways were good, the dead ratios reached 90%.
| The effect were investigated that the effect of spraying on the stem and leaf in the ways of乙草胺、玉农乐、2,4-D 丁酯、二甲四氯、都尔 were good, the dead ratio are more than 90%.
| multi-factor control weed    |         |                   |                    |             |                          |                        |    |
we could learn from the deed ratio in individual. When we control weed in the way of chemistry before seeding with 乙草胺+莠去津, spraying in seeding with 玉农乐+莠去津、玉农乐+2,4-D 丁酯, and also used them, fleet-furrow + scarification gently + cultivation and mechanical weed control add the chemical way were all good. The dead ratio are more than 90%.

The effect were investigated from the dead ration in fresh -weight. We used 乙草胺+莠去津 before seed, Spraying in 玉农乐+莠去津、玉农乐+2,4-D 丁酯, 乙草胺+2,4-D 丁酯, 二甲四氯+莠去津 in weeding and both used, fleet-furrow + Chemical herbicide, scarification deeply + chemical herbicide, and cultivation + chemical herbicide and compounded were all good. Especially compounded control weed, the dead ratio in individual and fresh-weight are all more than 94%.

We could learn from the phenomenon that 玉农乐 has better effect on the weed of Gramineae, Poaceae in one-way, 95% of them were dead, but 2,4-D 丁酯, have good effect on broad leaf weed; multi-factor 玉农乐+2,4-D 丁酯 have good effect on both broad leaves weed such as Xanthium sibiricum, Chenopodiaceae and the weed of Gramineae, Poaceae. 二甲四氯+莠去津 could restrain the growth broad leaves weed, however 2,4-D 丁酯+乙草胺 has effect on weed. There were some weed which was dry out in field used for 玉农乐+莠去津.

In a word, treating the soil with 玉农乐+乙草胺,乙草胺+莠去津 were added spraying on the stem and leaves in 玉农乐,玉农乐+2,4-D 丁酯 is good means. Fleet-furrow + scarringification deeply + cultivation is good. The mechanical methods were connected with chemical way such as fleet-furrow + Chemical herbicide, Scarification deeply + Chemical herbicide, Cultivation + Chemical herbicide have good effect.

The effect of different treatment on the botanical properties and yield of maize

The table showed that mechanical way and chemical herbicide both has good effect on controlling weed. Thus we should rely on the crop rotate mainly, then mechanical way were connected with chemical herbicide to promote the progress.

The yield of compound ways and “mechanical ways + chemical herbicide were better than other, which increased by 193-204kg/ace. On the one hand they were connected for having good effect to reduce the damage of weed, on the other hand fleet-furrow, scarringification deeply and cultivation could make the soil loosen to make good use of water.

Compound ways and “mechanical ways + chemical herbicide have good effect on the height of stem and ?? than other treatment, which is higher 2-12cm and 0.08-0.26cm respectively.

The chosen herbicide and machine for maize in conservation

After mono-factor experiment in 2004 and multi-factor experiment in 2005, we find out the weedicide which suit to conservation tillage. In maize farmland, using 草甘膦、乙草胺或乙草胺+莠去津 after seedtime before seedling stage, the proportion of control weed is over 85%. Using 玉农乐 and 玉农乐+2,4-D 丁酯 in grow period as spray on culm, the proportion of dead is over 90%. Use 草甘膦 in fall after harvest.

Test of remnant: There was no pesticide remnant after the institute of testing for the quality of primary product measure the maize and soil.

It should mainly rely on control weed before or after seeding and harvest in chemical ways, connected with spraying on stem and leaf in growth time. It would but only control weed but also popularize.

Machine: Plant protection and spray machines are 3WS—1500 and NS—16.

Machine for controlling weed in maize field

Weeding machines are 1GQN—200S fleet-furrow machines, SGTNB—180Z4/8A8 revolve-plough machines and 2BG—6D、1SZF—3 and 1SND-140 scarringification deeply and cultivation machines.

The technology of controlling weed in maize conservation tillage
The first it should take fleet-furrow before seed and then mechanically seed, then spraying on the stem and leaves in seeding, last take cultivation to control weed basing on the crop rotate.

The second, it should take chemical herbicide before seed and then seed without plough, then scarification deeply in seeding, last take cultivation to control weed basing on the crop rotate.

**Conclusions**

After two years study, we ravel the weed developing regularity from Agri-Grazing-Ecotone under conservation tillage in maize farmland in principal. We also ravel the main weed population which harm the maize in Agri-Grazing-Ecotone at north of the Yin mountain and the degree of it. According to it we find out the best method to control the weed and the time. EXP: using 乙草胺+莠去津 to
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Item</th>
<th>The height of stem (cm)</th>
<th>The thickness of stem (cm)</th>
<th>The length of spike (cm)</th>
<th>The thickness of spike (mm)</th>
<th>The row of spike (g)</th>
<th>The unit of row per a unit of area (kg)</th>
<th>The yield of a unit of area (kg)</th>
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<td><strong>Chemical herbicide</strong></td>
<td>Control</td>
<td>249.7</td>
<td>2.52</td>
<td>15.67</td>
<td>41.8</td>
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<td>247.8</td>
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<td>16.3</td>
<td>45.5</td>
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<td>50.7</td>
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<td>248.7</td>
<td>2.47</td>
<td>16.8</td>
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<td>35</td>
<td>249.9</td>
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<td>莠去津</td>
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<td>莠去津+玉农乐</td>
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<td>16</td>
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<td>(乙草胺+莠去津)+(玉农乐+2,4-D丁酯)</td>
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<td>253.8</td>
<td>2.51</td>
<td>15.3</td>
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<td>306.9</td>
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<tr>
<td>Control</td>
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<td>49</td>
<td>15</td>
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</tbody>
</table>
deal with perennial weed has good effect before seed.

In the study, we figure out over 10 kinds of weed machine through over 20 kinds weed machine which suit for the situation under conservation tillage. We also improved some machine, most of them which has good effect was accept by the farmer of the sample spot.

Based on the weeding experience before, we filter out sixteen kinds of weedicides which adapt to maize farmland under conservation tillage weeding with high-efficiency and low pollution in over forty categories. Respectively studying on the chemical weeding of the cornfield, we filter out five groups of weedicide which adapt to maize farmland under conservation tillage weeding, and harvest good purpose and successful experience.

We did lots of experiment in mechanic, chemical, agriculture weed technique, set over 10 treatments, using 15 different kinds of machine and 6 kinds of weedicide. the effect of both weed and crop production increase is distinct.

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Investigation about Techniques and Spreading Adaptability of Conservation Tillage Technology

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Abstract: The superiority and effects of conservation tillage technology has been favorably accumulated with the extending of practice time in the aspects of ecological environment and production efficiency, and it could get a good effect as long as the areas are in connection with each other. Then, the selection of application technology model, the scheme of machinery collocation and the production management should be correlated with the benefit for large area application. The paper analyzed the relationships among the techniques, spreading adaptability and the execution effectiveness according to the experiences of practices in Inner Mongolia Autonomous Region and the conditions of nature, climate, cropping and production level.

Keywords: Conservation Tillage, technical process, spreading, adaptability.

As a modern agricultural technology, the conservation tillage technology is kind of agricultural production technology that harmonizing the ecological system with production. Taking both efficiency and development into consideration, the conservation tillage made double wins both nation and individual and given attentions both present and long term. The essences of core technology and rationale are basically the same wherever, the application forms of the technology are, however, very different as the agriculture production being affected by natural conditions, farming modes, variety of crops, planting structure and agriculture technique requirement. The technology system also represented complexity and variety. It is not scientific evidently to use only one or several fixed conservation tillage models and technologies. It is, therefore, necessary to learn from others and/or use others for reference, the abuse and copy from others would cause problems. The acceleration of production development and the gain of better application effects could be realized only when the combining the rationale of the conservation tillage with local actual situations and selecting the appropriate techniques.

Modern farming and Conservation Tillage

Modern farming
In the course of agricultural development, the stages of falchion tillage and fire seeding, man and animal power tillage and mechanization tillage were experienced, and each transformation from one stage to another promoted a leap of productivity. The mechanization farming particularly represented by the farming manner in which the soil is turned over by moldboard plough made human have strong tools for changing nature, in turn, the mechanization promoted labor productivity and land productivity, and it became traditional tillage in a sense of modern. This farming mode, however, has the pure purpose of changing nature, prominently materializes the desire and the will of human, overemphasizes to use man-made and external force without considering the enginery of nature and objective regulations. The farming mode, therefore, leads to break up and loss the function of natural protection and recovery, finally leads to the serious outcomes such as land degradation, soil erosion, dust storm rampancy and overrun of rivers.

**Conservation tillage**

As a re-understanding and an innovation to traditional tillage system, the conservation tillage system emphasizes conforming to natural law, reasonably taking use of man-made and external power and keeping the tillage measures to harmonize with the capacity of nature. The essence of conservation tillage is a technique of cultivation category. Its keys are (1) covering protection of land, (2) reducing the tillage of land. The problems to be critically solved are how to cover, how much should cover, whether or not it needs to be treated before and after seeding and how to treat. During the development and application of conservation tillage, a series of problems will be faced such as soil properties, layout of crops, planting structure and plant protection; these will enrich the meanings of conservation tillage and make it become a comprehensive technology. By taking contour farming, strip planting, crop rotation and intercropping for examples, these are the representation and development of the viewpoints of conservation tillage in layout of cropping; fixed strip is the prolongation of conservation tillage viewpoint in the aspect of soil tillage. In practice, only by putting all the factors in consideration and comprehensive application can the technology obtain the favorable effects and bring into large function.

**The relative factors of spreading adaptability for technical process**

There are many conditions to adapt for the spreading of the technical process modes. By aiming at the conservation tillage it has the aspects as follows:

- **Nature conditions:** landform, physiognomy, soil texture and fertility;
- **Climate characteristics:** rain and snow fall, accumulative temperature, seasonal wind, frostless period;
- **Farming conditions:** conventional planting modes, irrigation conditions, cropping structure, distribution of plant diseases and insect pests;
- **Production conditions:** adaptability of machines, guarantee of machine collocation, economic foundation;
- **Expectation requirement:** desire of peasants, acceptable degree

**Selection of technical processes**

**Technological system**

Agricultural production technology is a combination of different processes to realize the agriculture
production and the foundation for selecting the machinery equipments of agriculture; an integrated technology of conservation tillage system includes all the processes from seeding, harvesting up to land treatment. As the crop structure, tillage system, typy of region, agriculture requirements etc. are much different from place to place, these differences of planting manners, the complexity of agriculture requirement and variety of production conditions determine the difference in thousand ways of conservation tillage technologies.

**Technical process system**

The establishment of technological system of conservation tillage needs to be divided by region type, farming manner and crop structure. For example, it was divided by region type in Inner Mongolia Autonomous Region: the cross region of agriculture, forestry and animal husbandry of Nen River drainage area, the cross region of agriculture and animal husbandry of Kerqin sandy land, the cross region of agriculture and animal husbandry of HunsanDaker Pasture, the cross region of agriculture and animal husbandry where is the wind erosion region in the north foot of Yin mountains and the cross region of agriculture and animal husbandry in up-wind and middle-wind of yellow river where the soil erosion is serious; it can be divided into ridge culture and flat culture according to the farming mode; it can be divided into bunch planting crop, drill panting crop, root crop, tuber crop, foodstuff crop and economic crop according to crop structure.

**Contents of technical processes**

It is necessary to include three aspects of the content in the design of conservation tillage technology, they are production process, operation content and technical mode. The design of production process must be carried out according to one circle of the crop growth and its influential factors; the content includes the form of coverage protection, no tillage and reduced tillage modes, field management, measures of plant protection (checking, thinning out seedling, filling seedling, adjusting growth, preventing ruderal and plant diseases and insect pests) and improvement of soil environment and so on. The job content should endow with techniques and measures for every production process, and these techniques and measures should be benefit for realizing the goal. It is necessary to emphasize that there should be main aim and several concrete goals, but there should not be contradictions between goals, in the case of unavoidable contradiction, it should first ensure the main aim. The design of technical mode should mainly consider the feasible production technique process under the suitable farming system and agriculture requirement, the content of it includes planting mode, main crop, planting structure and rotation system and son on.

**The design requirement of technical processes**

The origination and development of the conservation tillage is the outcome of pondering by human-self and the re-understanding to nature during the production practice. it may say that the conservation tillage is both a great innovation of farming system and a sublimation of consciousness transformation. In design of technical process of conservation tillage, the consciousness of overall situation must be established foremost; firstly, by adjusting the measures to local situations and improving the occasions, it makes the representation of human’s desires to conform to the objective demands of natural law; secondly, the use of natural resource and its development should be reasonable and effective as much as possible; thirdly, the development of production should harmonize with environment protection, and it can not take the sacrifice of ecological environment as the cost to development production; finally, the current benefit should combine with the long term
benefit. The second problem to be considered in designing the technological processes is that if the design agrees with the rationale of the conservation tillage. What is the materials to be used for mulch? Is the soil disturbance minimum? Does the protection function work well? Can the agriculture production develop continually? The third problem to be considered is that whether the techniques and measures to take can represent the content and essence of the conservation tillage. After the technology is carried into execution, some upstanding effects and functions should be emerged in the aspects such as environment protection, reasonable use of natural resources, reduction of soil erosion and land fertility loss, promotion of the capacity to fight drought, saving energy and decreasing consumption, lowering the production costs and increasing of output efficiency. The forth problem to be considered is that if the technological processes designed can be realized and how to realize (feasibility).

The conservation tillage has been developed as a technical system, and the mulch protection is the foundation, the machinery equipments are the support, no tillage seeding is the main body and plant protection measures are the key. For example, the mulch mode and coverage amount are different among the different crops, therefore, the different seeding manners and seeders are required because it will influence the capacity to pass, trouble rate, job efficiency, production cost, seeding amount and the final output (as shown in the following figure).

The guidelines for determination of technological processes

According to the natural conditions, climate characteristics, farming system, agriculture and production techniques, the related main technological contents and execution methods are to be selected by aiming at the main problems of conservation tillage to be solved.

Determination of technological processes

Protective mode
According to the coverage amount it can be classified as total coverage and partial coverage, according to the coverage state it can be classified as erection stalk coverage, stubble residual coverage, fell stalk coverage and smashed stalk coverage.

Under the nature conditions of less rainfall and insufficient sunlight, the velocity of stalk decomposition is very slow, normally it needs 3～4 years for complete decomposition and in a large extent the stalks left previous year would affect the capacity to pass during seeding, therefore there are two kinds of mulch modes can be selected as follows:

**Stubble residual coverage**

The stress should be concentrated on preventing soil from erosion, protecting ecosystem, realizing cost saving and enhancement of efficiency. This coverage mode is adaptable to the sandy soil region where seasonal wind is strong, wind erosion is serious and the stalks need to be comprehensively put in use. Smashed stalk coverage: the stress should put on increase land fertility, promotion of sustainable development of production and realization of high production yield and output. This mode is adaptable to the clay region where resources were over consumed and land fertility decreased seriously.

**Soil improvement**

The traditional farming originated from land reclamation, and developed following the routines of extensive cultivation, rough management up to intensive cultivation, this kind of farming brought many negative effects to natural environment, and urged land degradation and desertification day by day. The improvement of plow land is also very important and it is an urgent task in Inner Mongolia, its job processes can adjectively solve some other problems, such as water and soil loss and plow land harden etc., among the job processes, the deep scarification job is especially necessary just before the execution of the conservation tillage. If the dry slop land dominates the plow land where water and soil loss exhibit as radial flow, the first process to actualize is deep scarification, then increase the stalk mulch. This can reach the effects of reducing surface area that rain strikes and increase the water holding ability of surface soil, in turn, it can reach a goal of keeping the water and soil loss within the limits and improving the plow land.

**Other guidelines to determine the technological processes**

The content of the conservation tillage contains four basic technologies, they are no tillage seeding and fertilizing, the stalk and surface soil treatment, the prevention of ruderal, plant diseases and insect pests and deep scarification; The adaptability, maneuverability, economics, the problems existed during applications, solution steps and technical emphasized techniques of the overall technical routines formed around the four basic technologies should be considered. It is better to get only one or two technology generalized because too many techniques will lead to adverse factors in the aspects of machine collocation, job service and production cost etc., and there will also be a large drawback to the spreading works. In the concrete applications, a set of specific technology system should be established for each region as the geographical conditions, climate characteristics, farming method, crop structure are very different from place to place. During the establishment, only when the two aspects to be considered, can the technology take effects, one aspect is the feasibility of the technology system, and other aspects is application value of that. For examples, four basic main body technologies for farm land and two main body technologies for pasture were determined through demonstration and verification in Inner Mongolia Autonomous Region, the five year practice proved
that it was feasible in technology and it was adaptable in production; the other example is the strip type conservation tillage technology in WuChuan County, where the potato is the strut industry. As it must plow the planting land for the potato planting and harvesting, this leads to a contradiction with conservation tillage requirement. In order to solve the contradiction, a strip intercropping technology between potato and drill crops was developed according to local crop structure, climate characteristics and the particular requirements of the production. The WuChuan County becomes an example of using the conservation tillage technology and successfully developed conservation tillage technology.

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Intension of Technology and Trend of Development of CT——Approach the Practice and Development of CT in Liaoning Province

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Abstract: This paper gives the intension of minimum tillage and mulch after the analysis of the concept and mechanism of CT. By analysis and discussion of innovative process of CT in Liaoning Province, that no-till is the trend of CT is put forth, so do the need for CT implements and the suggestion for CT implements

Key words: CT, intension, technical mode, trend

The concept of CT and technical intension

CT is a technical system whose core is preserving water and soil and which integrates minimum-tillage, no-tillage, mulch, and .It arms at overcoming many shortcomings of mouldplow, reducing the wind-erosion and water-erosion on soil, preventing loss of water and soil erosion, improving the texture of soil, increasing the soil fertility, reducing moisture evaporation in soil, making good use of valuable water resource; reducing the input of labors, machines and energy, increasing the productivity and crop yield, realizing the sustained development of agriculture. The development of CA is a turning point where the pure production task of agricultural mechanization changes into double tasks of production and environment protection, and a revolution of tillage technology.

The concept of CT

American is one of the first countries that develop CA. The definition given by《No Tillage Farming》 and《Minimum tillage farming》 which is published in 1973 by American is as follow.

Minimum tillage is a kind of tillage code that decreases the tillage to the level that can not only insure the crop effective and timely growth, but also avoid the destroy of soil texture and the damage of crop.

No-tillage is the limiting code of minimum tillage.

No-tillage is a kind of tillage code that does not need any soil preparation, and directly open furrow in the un-tilled soil which can satisfy the requirement in width and depth of sowing.

Minimum tillage and no tillage all can conserve water and soil obviously, and both of them is called CA.[1 p27]
Three tillage modes of American:

1. conventional tillage —— cover percentage after sowing is less than 15%, sub-soiling or turning over and topsoil tillage;
2. minimum tillage —— cover percentage after sowing is 15%~30%, multiple topsoil tillage;
3. CT —— cover percentage after sowing 30%, no-tillage or once topsoil operation before sowing, chemical weeding.

In Europe, the tillage is classified into no-tillage, minimum tillage, brief tillage or CT tillage according to the extent of disturbing soil before sowing. And the tillage whose mulch percentage is larger than 30% after sowing is called CT.[2]

The CT is defined as tillage technology that use a lot of stalk and stubble to cover the field, reduce tillage to the level that can insure the seed sprout, and mainly use pesticide to control weed and pest in our country.

Because it is advantageous to conserve water and soil, it is called CT. According to this definition, CT can be briefly summarized in “stubble mulch, sowing without tillage, loosing substitutes for turning, chemical weed control”.

**The intension of CT**

There are tow most important elements in the above concept, namely, minimum tillage and mulch. From this we can obtain that reducing tillage, increasing the mulch percentage and realizing water and soil conservation is the technical intension of CT.

CT realizes water and soil conservation by residue cover. Cover residue can reduce the direct impact of rain drop against soil, absorb moisture, reduce runoff, reduce the surface runoff velocity, improve soil structure, increase the ability to contain water, reduce water erosion. The stubble can reduce the surface wind velocity and enlarge, increase the soil pellet in size, thereby reduce wind erosion. The study on the west and middle area in America shows that, at the stubble cover percentage of 20%~30%, the soil erosion under CA is reduced at least 50% than that under conventional tillage.[3]

Reducing tillage can increase the stubble covering percentage. Tillage methods have an effect on the stubble cover percentage; for instance, turning over barrel more than 90% stubble into soil, once tillage with subsoiler reduce cover percentage by 25%, once harrowing reduces cover percentage by 40%. From here we can see that turning over is not allowed under CA. To increase the stubble percentage, the number of times of tillage should be reduced. The higher stubble covering percentage under CA, the better effect of soil and water conservation.

Certainly when farming method is chosen, crop, ground temperature, pest control, oil consuming, yield and other factors should also be taken into consideration except it’s affect on stubble percentage.

**Research of CT in Liaoning Province**

**Significance**

There is a water shortage in Liaoning Province. The average per capita water resource is one fourth that of the whole country. The nearly seventy percent of the total cultivated area is short for the irrigation condition. The traditional farming system mainly composed of turning up is still adopted in most of the arid farming area. Serious water and soil loss, the decrease in soil fertility and the frequent
drought the prominent problems that restrict the increase in agricultural benefit and farmers’ income.

The practice of developing CT shows that CT can save water, fight drought protect environment, save cost and increase benefit. CA is a agriculture sustainable development technology, is a transition to conventional tillage system, is an important measure to establish agriculture and develop economic, and is an important way to promote the sustainable development of agriculture. Devoting major efforts to developing CA is also the strategic choose of our province’s realizing sustainable development.

The situation of development

Our province started plot experiment of CT from 1999, and demonstrations and popularization from 2000. At present, there is 36 demonstration countries in the whole province, include ministry level program countries 15 and provincial level program countries 21. According to the statistic results ,the maize yield under CT increase by 3%—12.5% than that under conventional tillage, the spring soil moisture content increase by 3%—10% ,cost reduce 15%—30%.The implementing area is up to 2,060,000 mu.

The popularization of CT also promotes the transformation of the tillage system in our province. Up to now, the implementing area of maize precise drill technology is up to 800,000mu ,that of subloss technology is 17,520,000mu, that of mechanics stubble cleaning technology is 16,413,000mu.It lays a solid foundation for the all-round implement of mechanized CT.

Technology code

The geoponics requirments of maize planting in Liaoning province: ridge or, spacing between ridges of rows is 500-700mm. The spacing between ridges is 500-600mm in arid or semi-arid area in the west and north of Liaoning Province. Its yield is 500-700kg/mu.

high stubble and minimum tillage/no-till cover technology code

Maize harvest and stalk carrying out of the field —high stubble cover overwintering seed strip rotary tillage cleaning stubble plowing（the operation can be eliminated when no-tillage）—sowing/no-till sowing—artificial or chemical weed control（at least once intertill at ridge tillage）.

smash the stalk and minimum tillage/ no-till cover technology code

Maize harvest—stalk plowing cover—spring disc harrow/ rotary cultivator /seed strip rotary cultivator/topsoil treatment by seed strip rotary cultivator with straight cutter—no-till sowing—chemical weed control（at least once intertill at ridge tillage）.It is fit to flat plowing or ridge tillage.

choped stalk sub-soiling minimum till cover technology code

Maize harvest —chopping stalk returning to the field—subsoil（stubble treatment）—harrow—sow without tillage—chemical weed control. Subsoil can not only treat the stubble but also break hard pan to improve the capacity of water containing. When the CT is firstly adopted , the sub-soiling should be carried out. Afterwards subsoil once every 3～4 years.

whole stalk-minimum tillage-mulch technical code

Maize harvest—overwintering with standing stalk—seed strip rotary tillage /disc harrow/straight cutter seed strip rotary tillage topsoil treatment —sowing（no-till drill with narrow furrow opener）.
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—chemical weeding (at least once intertill when riged)

whole stalk-no-tillage-mulch technical code

Maize harvest—overwintering with standing stalk— sow without tillage by the dill with straight cutter rotary part chemical weeding (at least once intertill when riged)

**CT drill**

All technology codes make the guarantee of sowing quantity as a prerequisite. Adaptability of drill is determined to large extent the number of working items and the length of technical process. For example, no-till can not be realized without good no-till drill. The trend of drill also reflects the trend of CA technology.

**The adaptability test of drill**

The experiment for choosing type of CT implement was conducted in the test ground of agriculture machinery institution in the City of Buxin from 17th ~ 19th in 2001. There are total 4 models in testing, all of which are 2 row sowing and application implement. According the culter, they are classified into four types:

(1) arrow shovel stubble breaking ridger and double-disc furrow opener.
(2) chisel stubble breaking ridger and share furrow opener.
(3) enclosure shovel stubble breaking ridger and hoe furrow opener.
(4) foe stubble breaking ridger and double-disc furrow opener.

Test result is as follows. After the operation of stubble cleaner, the four types of drills make a sowing, which all can satisfy the sowing requirement when planting on the ridge with 16~17cm maize stubble, the above-mentioned (1) and (2) models will have bridged ground wheels, which leads to the failure of sowing, the model (3) and (4) do not make the ground wheel bridge, but they have bad nature of earthing. The exposed seed account for the 20% of the seeds, the seed under the stubble account for 10% of the seeds. So the four models are all not fit to sow on the ridge with stubble.

Return the stalk to the field and furrow plant. The common question between the four models is that the berried chopped stalk is turned out of the field and the seed drop in the mixed level of stalk and soil, which makes it difficult to sprout.

In view of the above experiment results, the imagination was put forth in the meet. After the meet, some manufactures in our province soon developed new type of drill product.

**Achievements in scientific research on CT drill and analysis on it**

By the end of 2002, 4 new kinds of no-till drill which have come out.

(1) 2BISJ-2110 chopping stubble precise drill (second generation) developed by farm machinery No.2 manufacture of Buxin City match with 14.5KW power. There is a stubble plowing cutter roller before a double disc harrow opener, which is drived by the P.T.O of the tractor and rotate at the speed of 530r.p.m. Since the cutter roller can chop the stubble and stalk, it can complete stubble plowing, precision sowing, deep application, suppression, earthing and other operations one time under the
condition of high stubble, chopped stalk and whole stalk mulch. The drill has relative good passing nature and sowing. The disadvantageous is that when rotary till with the width of 300mm and tillage level of 70-90mm, the area of disturbed soil accounts for about 70% of the total area, have bad affection of soil and water conservation.

(2) 2BQM-3 no-till application air drawing precise drill developed by Changqing universal machinery works of Shenyang match 9.6KW power. The driving disc cutter stubble equipment is installed in the front of drill, which is drove by the tractor and can cut open the cover stubble and crop root system. The direct no-tillage seeding under the situation of high stubble, chopped stalk, and whole stalk cover have the small tillage area, the high cover percentage, good water and soil conservation. The disadvantage is that disc saw has a high cost, it is not fit to rocky field, there is hidden danger to safety.

(3) 2BQMS-2 no-till drill with application developed by farm machinery institution of Liaoning Province matches with 11--13.2KW power. It is equipped by the spade chopping stubble. It first break stubble and furrow in the untilled soil to eliminate the surface dry soil and the stubble. It can pen narrow furrow, adequate fertilization, pore water into field, separate seed with application, which is fit to no-till seeding with application.

(4) 2BQX-2D air drawing no-till precision drill developed by precision drill manufacture limited company of Wafangdian City can match with 12kw power. It equipped with and double furrow opener, and has good nature of passing under stalk mulch.

Models as (3)、(4) have relatively better nature of passing and sowing quality in the stubble mulch field, but the stubble cleaner instrument will dig the maize stubble out of the topsoil to form a cavinity, which affects the uniformity of sowing depth. At the same time the root system diged out may form a soil ball to affect the uniformity of coverage, and even cause the effect on seedling because of the pressure of seeds.

By analysis and comparison of these types of these no-tillage drills, we obtain that the main problem lying in the noneffective stubble treatment. And the main factor affecting the sowing quantity of no-till drill is the condition of stubble dealing. The good on-till drill should satisfy the following properties: cut apart the stubble and the root system, leaving no cavities in the seedbed, and the roots can remain in the soil after application and sowing and there is no soil ball taken out by the roots, the sowing depth and soil coverage are even and uniform, there is no the stubble in the seed bed, the soil disturbed is small and coverage rate is high.

From 2004, we have undertaken the research job of “Experimental study on the ridge planting of conservation tillage in cold, windy and sandy areas of Northeast” issued from MOA, and cooperate with China Agriculture University and Shenyang Agriculture University in successfully developing two kinds of no-till drills.

(5) 2BML-2 no-till ridging planter. There is a narrow rotary knife before furrow opener which is used for treatment of the stubble. The width of single ridge rotary tillage is 100-110mm, and the depth is 60-80mm, which adopts colter and double disc earthing. The experiment shows that 2BML-2 no-till ridging drill can complete stubble clean, application, sowing, earthing, compacting for one time, which can reduce the frequency of the implement coming into the field and reduce the compaction to the land; lessen the amount of the disturbed soil and lower power dissipation; and it also has effective stubble treatment and powerful the row guide capacity and also can keep the ridge shape after sowing,
effectively increase ground temperature, and the rate of maize emergence is higher than traditional sowing code. This model has been put into production in commission, and more than 60 have been popularized by 2006, which work well. The practice shows that the drill still has low quality in manufacture and a bad stability in chain drive, which needs to further perfect.

(6) Rolling disc ridging planter, which has rolling disc stubble cutter, double disc helix ridge cleaner, single disc fertilization furrow opener, double disc sowing furrow opener, guiding instrument.

The experiment results of small area show: the rolling disc stubble cutting coulter has better property than the moving stubble cutting component, which need no drive and the disturbed soil rate is less than 10%. The unit of the drill with blaster of 175kg can cut the root knobs 8~10cm below the earth; the field test of the rolling disc tillage drill shows that at the mulch rate of 0.8kg/m², the drill can’t occur blocking and the drill will not offset the ridge; all working part getting in touch with soil is rolling disc, and the resistance force is small. The complement of 2 ridge planter and 13.2kW small four-wheel tractor, not only accord with the agriculture requirement of CT, but also suit the power outfit in the countryside today.

Fig 1. Single rolling disc stubble cutting colter of rolling disc ridging planter
2. double disc helix ridge cleaner 3. application colter 4. double disc sowing colter
5. flat cultivation wheel 6. compacting wheel.
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Fig 2. the principle diagram of tillage-sowing

(1) The stubble cutter can cut apart the joint upper the root (the common saying is “five cross thigh”, the same below), and penetrate through the hard surface of the soil to open the furrow 5cm width, which is advantageous to take root and grow as shown in fig 2.

(2) Helical ridge clearing part move the stubble to rear flank to provide smooth surface for the depth limiting wheel, which makes it easy to control the seeding depth. Furthermore, the cleared ridge has high earth temperature and the seeds sprout early.

(3) The falling site of the seeds must be at the bottom of the V-shaped narrow ditch opened by furrow opener shown in fig 2 and reach to stable depth. Drop the seeds with no speed so that there will be no rolling movement and then arrange them by regular plant space in good order along the ditch.

(4) Press the seed into the wet soil by seed compacting wheel and realize seeding with moisture conservation and then cover the seed ditches by porous soil evenly and compact at the same time, so make the seeds and the soil contact close together and prevent evaporation.

(5) Fertilize deep at the side of the seeds as shown in fig 2.

The model is used in the technological procedure of the high reserving stubble mulches tillage system, which can reduce the frequency of the implement coming into the field and also can work as flat cultivating no-planter, after removing of the stubble cutting and ridge cleaning parts, it can be used as common planter.

Model (5) and (6) fill the gap which has hitherto exited in no-till drill of our province, and basically meet the demand for CT system.

The experiment and analysis of “change bent cutter into straight, wide into narrow”

From the practice of popularization of CT, we obtain that increasing the use rate of the implement and decrease the cost by improving the conventional implement is an important way to promote CT operation socialization and increase the smallholders’ benefit. For this reason, in 2006 we put forth the
technical measures that change the cutters of stubble cleaner and rotary cultivator into straight knifes, and change the wide furrow opener of ordinary drill into narrow one.

(1) Change the cutters of stubble cleaner and rotary cultivator into straight. The experiment condition is in whole standing stalk or lying stalk mulch. Because the stalk is not crushed and returned in the field beforehand, with small operation resistance and small operation load, and well-distributed stalk mulch, which is suit to sowing operation. The area of stubble plowing in our province is up to 1642.3 ten thousand Mu, which proves the implement can not only increase the application scope of stubble cleaner, but also has advantage to reform the tillage code mainly for stubble plowing, which make it even accord with the concept of CT.

(2) Change the wide furrow opener of ordinary drill into narrow one. The purpose is to lessen the amount of the disturbed soil of furrow opener, increase the passing nature of the implement under the situation of stubble mulch and increase the rate of surface stubble mulch areas. This method is easy to realize and remake and the cost is inexpensive.

The coordination of the two improved models can satisfy the requirements of CT operation in high stubble mulch field, which has great importance to cut down the cost of CT, increase the benefit of marketing the machines.

**Thought about the trend of the development of CT**

The land of high temperature, long frost-free season and good drainability is fit to carry out no-tillage. When it is hard to take no-tillage for too much mulch, we should take necessary topsoil operation for sowing without tillage. In order to decrease the tillage intensity of soil and oil consumption, we should use subsoil cultivater and topsoil cultivater and disc horrow as fully as possible, and change the bent cutter of medium and small rotary cultivater into straight cutter.

The land of low temperature and bad drainability is fitted to ridge plowing.

Ridge is advantageous to thicken the top soil, increase the ground temperature and resist to lodging. As shown in fig 3, from left to right is stubble mulch after harvest and before sowing(Before Planting); after no-till sowing(After planting); after intertillage and earthing up the ridge(After Cultivation).

![Fig.3 The diagram of the variation of ridge shape](image)
The ridge should be constructed at the time when intertillage, the width of cultivating implement had better match with the width of the drill. At the same time, field management, transportation and topsoil operation should not crush the ridge and to keep the shape of the ridge in good condition.

Topsoil treatment implement which doesn’t up turn or smash the soil, and only cut the root system to create the suitable condition for sowing will become the key point of the study and development of topsoil treatment implement. And there is a further improvement of straight rotary topsoil treatment implement.

The recommended weeding method is chemical control combined with mechanical intertillage control, spraying herbicide on the ridge kill the weeds between the seedling and the weeds in the harrow are controlled by residue coverage and intertillage, which can reduce the using of herbicide, reduce the cost and also can give play to the advantage of intertillage weed control method, control the inter-row weeds at the same time of earthing up the ridge.

The development trend of ridge no-till drill

The key part of no-till ridging planter is the cutting and clearing stubble part. Sliding or rolling cutting and clearing stubble part cut into the soil by the unit weight of drill, so the weight of the drill should be relatively heavy, which is fit to large or medium drill. However, the medium or small drill is more fit to use for driving rotary tillage part. On the premise of cutting the crop root system, reduce the crushing of the soil as far as possible and lower the oil consumption, reduce the tillage intensity on soil and alleviate the destroy to the soil structure. According to the test, we know that it can’t carry off the soil block after seeding and fertilization and can sow regularly even the cutter pass through the middle of the root, which indicates that the width of the rotary straight cutter can fully satisfy the requirement of sowing and fertilization.

In developing the no-till ridging drill, we should study the rolling cutting and cleaning parts and driving rotary part simultaneously.

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Study on Technology of Maize Planted in Wide Line and Narrow Line Alternately (MPWNL)

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Abstract: The technology of maize planting in width line and narrow line alternately has been being studied for many years. The results showed that the technology may improve soil environment, promote maize growth, enhance amount of roots, leaves area, foster ability of soil production, reduce invested capital of the production, enhance maize yield and increase economy benefit.

Key words: maize, width lines, plant technology, study

Operation procedures of maize planting in wide line and narrow line alternately are that present uniformity ridge with 65cm width in a field is altered to wide ridge with 90cm width, narrow ridge with 40cm width, then plant maize in the narrow ridge. Fertilizing and loosing soil deep at top application period in the width ridge. Remaining maize stalk stubbles with 40cm height on seedling strip narrow ridge during harvest time. Plough to the wide ridge with strip rotary cultivator after autumn harvest until make it to be planting state, the stubbles on narrow nature rot and return to field.

At second spring, plant seed on the wide ridge, this ridge becomes new narrow ridge with seedlings, fertilize and loose soil deep at top application period in the width ridge again, and so on year after year.

Experiment materials and method

Experiment site: Chaoyangpo town of Gongzhuling city in Jilin Province, experiment field area: 1.0 hectare;
Demonstration site: Chaoyangpo town of Gongzhuling city in Jilin Province, Demonstration field area: 20.0 hectares.
Varieties of the experiment and demonstration: Simi25, Simi21, Jidan209, Laiyu3119, Jidan180, Yinhe101, Jidan342, these are main popularization varieties in Jilin province.

The experiment treatments, necessary agriculture machines equipments and experiment method

The treatments:
1. maize planting in width ridge with 90cm,narrow ridge with 40cm,remaining the stubbles with 40cm height;
2. present tilth method with uniformity ridge plant(CK)

The agriculture machines equipments:
1. tractor with 804 wheel model and tractor with 18 horsepower for agriculture made by Tianjing tractor factory;
2. double lines precision seeding-machine with 2BD-2 model;
3. cultivation and deep loosing soil topdressing machine;
4. strip rotary cultivator with 1GQN-320T3 model.

Experiment method:
The experiment adopted big section antitheses, mechanization big area demonstration
The experiment results and analysis

Effect of maize planting in width line and narrow line alternately on soil environment

Soil nutrient change after maize planting in width line and narrow line alternately

Table 1  Soil nutrient change after maize planting in width line and narrow line alternately

<table>
<thead>
<tr>
<th>treatments</th>
<th>Organic matter (g/kg)</th>
<th>Active nitrogen (mg/kg)</th>
<th>Active phosphorus (mg/kg)</th>
<th>Active potass (mg/kg)</th>
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<tr>
<td>Before first year MPWNL  (CK)</td>
<td>23.30</td>
<td>204.15</td>
<td>30.24</td>
<td>115.0</td>
</tr>
<tr>
<td>Forth year MPWNL</td>
<td>25.00</td>
<td>117.2</td>
<td>43.9</td>
<td>125.1</td>
</tr>
<tr>
<td>compare with CK</td>
<td>+1.7</td>
<td>-86.95</td>
<td>+13.7</td>
<td>+10.1</td>
</tr>
<tr>
<td>Fifth year MPWNL</td>
<td>25.92</td>
<td>182.1</td>
<td>51.9</td>
<td>173.5</td>
</tr>
<tr>
<td>compare with CK</td>
<td>+2.6</td>
<td>-22.05</td>
<td>+21.66</td>
<td>+58.5</td>
</tr>
<tr>
<td>Sixth year MPWNL</td>
<td>26.678</td>
<td>131.8</td>
<td>35.82</td>
<td>147.8</td>
</tr>
<tr>
<td>compare with CK</td>
<td>+3.37</td>
<td>-72.35</td>
<td>+5.58</td>
<td>+32.8</td>
</tr>
<tr>
<td>Seventh year MPWNL</td>
<td>30.3</td>
<td>149.25</td>
<td>32.54</td>
<td>165.1</td>
</tr>
<tr>
<td>compare with CK</td>
<td>+6.73</td>
<td>-54.9</td>
<td>+2.3</td>
<td>+50.1</td>
</tr>
</tbody>
</table>

Know from table 1 that soil organic matter content increased by 6.73g/kg, soil active phosphorus content increased by 2.3g/kg, soil active potass content increased by 50.1g/kg, soil active nitrogen content decreased by 54.9g/kg after maize planting in wide line and narrow line alternately for 7 years. Main reason of soil active nitrogen N content decrease is that some N can be consumed during maize stalks decompose and some maize stalks was returned in soil during maize planting in width line and narrow line alternately.

The change of soil moisture content after maize planting in width line and narrow line alternately

Table 2  Soil water content difference value between maize planting in wide line and narrow line alternately and traditional cultivated method from 1998—2005

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>平均</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before spring sowing</td>
<td>+1.9</td>
<td>+2.7</td>
<td>+0.7</td>
<td>+0.5</td>
<td>+0.9</td>
<td>+2.0</td>
<td>+1.3</td>
<td>+3</td>
<td>+1.63</td>
</tr>
<tr>
<td>Average of whole maize growth period</td>
<td>+2.1</td>
<td>+2.4</td>
<td>+1.2</td>
<td>+0.9</td>
<td>+0.5</td>
<td>+0.9</td>
<td>+1.2</td>
<td>+1</td>
<td>+1.28</td>
</tr>
</tbody>
</table>

Know from table 7 that Soil water content after maize planting in wide line and narrow line alternately for 7 years is more 0.5-3.0% than that under present uniformity ridge plant, this Soil water content difference value equal to 4.0-22mm rainfall more; Soil Average water content of whole maize growth period is more than 0.5-2.4%, this equals to 4.0-19mm rainfall.

Effect of maize planting in width line and narrow line alternately on maize growth course

Maize planting in width line and narrow line alternately can advance maize roots develop
Maize roots growth after maize planting in wide line and narrow line alternately is better than that under maize planting in uniformity ridges, the roots weight increased obviously, the average wind dry weight added by 32.5% in 0-40cm deep.

Effect of maize planting in wide line and narrow line alternately on maize leaves area growth

Table 4 shows that average maize leaves area per plant is less 1361 cm$^2$ under uniformity ridge cultivation than that under width lines cultivation when maize individual plant leaves reach biggest, less 1431 cm$^2$ when maize silks for 45 days, the green leaves area less 3199 cm$^2$; Table 5 shows that average maize leaves area per plant is less 457.2 cm$^2$ under uniformity ridge cultivation than that under width lines cultivation when maize individual plant leaves reach biggest at Jul 24, the green leaves...
area less 1394.3cm² when maize silks for 51 days; Table 6 shows that average maize leaves area per plant is less 746.8cm² under uniformity ridge cultivation than that under width lines cultivation when maize individual plant leaves reach biggest at Jul 27, the green leaves area less 485.4cm² when maize silks for 46 days;

Effect of maize planting in wide line and narrow line alternately on maize dry matter accumulation and intensity of photosynthesis

Table7  The dry matter weight of difference times in difference treatments in 1999(average individual plant weight) unit: g

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Jun 15</th>
<th>Jul 27</th>
<th>Aug 20</th>
<th>Sep 07</th>
<th>Sep 16</th>
<th>Sep 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width lines</td>
<td>4.33</td>
<td>171</td>
<td>325.8</td>
<td>378.5</td>
<td>506.7</td>
<td>528.3</td>
</tr>
<tr>
<td>Uniformity ridges</td>
<td>3.33</td>
<td>138.4</td>
<td>291.7</td>
<td>332.4</td>
<td>454.9</td>
<td>475.4</td>
</tr>
<tr>
<td>Compare</td>
<td>+1.0</td>
<td>+32.6</td>
<td>+34.1</td>
<td>+46.1</td>
<td>+51.8</td>
<td>+52.9</td>
</tr>
</tbody>
</table>

Table8  The dry matter weight of difference times in difference treatments in 2000(average individual plant weight) unit: g

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Jun 14</th>
<th>Jul 24</th>
<th>Aug 2</th>
<th>Sep 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width lines</td>
<td>404.3</td>
<td>6859.2</td>
<td>6728.7</td>
<td>5269.2</td>
</tr>
<tr>
<td>Uniformity ridges</td>
<td>296</td>
<td>6402</td>
<td>6247</td>
<td>3874.9</td>
</tr>
<tr>
<td>Compare</td>
<td>108.30</td>
<td>457.20</td>
<td>481.70</td>
<td>1394.30</td>
</tr>
</tbody>
</table>

Table9  The dry matter weight of difference times in difference treatments in 2001(average individual plant weight) unit: g

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Jun 8</th>
<th>Jun 28</th>
<th>Jul 20</th>
<th>Jul 23</th>
<th>Sep 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width lines</td>
<td>1.9</td>
<td>26.1</td>
<td>110.1</td>
<td>130.6</td>
<td>455.4</td>
</tr>
<tr>
<td>Uniformity ridges</td>
<td>1.4</td>
<td>22.3</td>
<td>105.6</td>
<td>112.1</td>
<td>426.5</td>
</tr>
<tr>
<td>Compare</td>
<td>0.5</td>
<td>3.8</td>
<td>4.5</td>
<td>18.5</td>
<td>28.9</td>
</tr>
</tbody>
</table>

Know from table 7-8-9 that maize dry matter accumulation under width lines cultivation is higher than that under uniformity ridges from seedling period to elongation stage, curves of maize dry matter accumulation in different years are basic identical.

Table10  Intensities of photosynthesis in difference treatments unit: (d.m²)/hm²

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Seedling-elongation</th>
<th>Elongation to staminant flower</th>
<th>Staminant to silk</th>
<th>13 days after silk</th>
<th>Silk from 13 day to 38 day</th>
<th>From Silk 38 day to mature</th>
<th>photosynthesis intensity of whole growth time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width lines</td>
<td>179309.6</td>
<td>258624</td>
<td>328576.2</td>
<td>460134.1</td>
<td>808977.5</td>
<td>421062.2</td>
<td>2456683.6</td>
</tr>
<tr>
<td>Uniformity ridges</td>
<td>153975.4</td>
<td>231526.2</td>
<td>287524.9</td>
<td>406667.2</td>
<td>795033.3</td>
<td>356212.5</td>
<td>2230939.3</td>
</tr>
<tr>
<td>compare</td>
<td>25334.2</td>
<td>27097.8</td>
<td>41051.3</td>
<td>53466.9</td>
<td>13944.2</td>
<td>64849.7</td>
<td>225744.3</td>
</tr>
</tbody>
</table>

Know from table 10 that photosynthesis intensity of whole maize growth time under width lines cultivation is high 225744.3(d.m²)/hm² than that under uniformity ridges
Maize planting in wide line and narrow line remaining high stubbles alternately can increase soil organic matter content

Table 11: Weight of maize straw returned to field by remaining high stubbles unit: g

<table>
<thead>
<tr>
<th>Variety</th>
<th>Wet weight of Simi21 straw</th>
<th>Wet weight of Simi25 straw</th>
<th>Wet weight of 1243 straw</th>
<th>Wet weight of Laiyu3119 straw</th>
<th>Wind dry weight of Simi25 straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw weight of 10cm stubble</td>
<td>2858</td>
<td>3002</td>
<td>2100</td>
<td>3900</td>
<td>206</td>
</tr>
<tr>
<td>Straw weight of 40cm stubble</td>
<td>219.1</td>
<td>247.2</td>
<td>201.4</td>
<td>309.3</td>
<td>10.9</td>
</tr>
<tr>
<td>Increased weight of 40cm %</td>
<td>7.6</td>
<td>8.2</td>
<td>9.6</td>
<td>7.9</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Wind weight of 2.78t/ha maize straw will be returned to field per year by remaining high stubbles base on least wind weight of Simi 25 straw to account. Nutrient content of Simi 21, Simi 25 straw is that full nitrogen: 6.71g/kg, full phosphorus: 2.332g/kg ,full Potassium 11.399g/kg ,then equal to fertilizing urea 40.57kg/ha, twain

Effect of maize planting in wide line and narrow line alternately on maize yield

Table 12: The yield result compare

<table>
<thead>
<tr>
<th>Variety</th>
<th>Treatments</th>
<th>years</th>
<th>Yield per hectare(kg/ha)</th>
<th>Range of increasing production (%)</th>
<th>Economy coefficient (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Width lines</td>
<td>1997</td>
<td>11869.1</td>
<td>115.5</td>
<td>53.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1998</td>
<td>11796.0</td>
<td>117.2</td>
<td>54.1</td>
</tr>
<tr>
<td>Uniformity ridges (CK)</td>
<td></td>
<td>1999</td>
<td>12693.0</td>
<td>115.2</td>
<td>53.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>9122.0</td>
<td>114.4</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001</td>
<td>8363.4</td>
<td>110.8</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2002</td>
<td>9731.1</td>
<td>116.4</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>9977.0</td>
<td>117.5</td>
<td>52.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2004</td>
<td>8959.0</td>
<td>104.9</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005</td>
<td>8928.6</td>
<td>110.9</td>
<td>50.8</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td></td>
<td>10159.9</td>
<td>113.6</td>
<td>53.0</td>
</tr>
<tr>
<td></td>
<td>Uniformity ridges (CK)</td>
<td>1997</td>
<td>10276.3</td>
<td>100</td>
<td>51.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1998</td>
<td>10064.8</td>
<td>100</td>
<td>50.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1999</td>
<td>11018.2</td>
<td>100</td>
<td>51.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>7973.8</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>Uniformity ridges (CK)</td>
<td></td>
<td>2001</td>
<td>7548.2</td>
<td>100</td>
<td>51.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2002</td>
<td>8360.1</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>8489.6</td>
<td>100</td>
<td>51.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2004</td>
<td>8539.2</td>
<td>100</td>
<td>—</td>
</tr>
</tbody>
</table>
Know from table 12 that average maize yield per hectare increased by 13.6% under width lines cultivation than that of CK from 1997-2005 except 2004, main reasons of increasing production are to select dense-endured varieties and increase plant density.

Table 13: The yield of demonstration varieties and CK Site: Chaoyangpo town

<table>
<thead>
<tr>
<th>Years</th>
<th>Tilth methods</th>
<th>Varieties</th>
<th>Yield per hectare (kg/ha)</th>
<th>Compare yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Present Tilth methods (CK)</td>
<td>Simi25</td>
<td>8264.7</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Width lines</td>
<td>Jidan209</td>
<td>9806.3</td>
<td>118.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simi25</td>
<td>9712.3</td>
<td>117.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simi21</td>
<td>9643.8</td>
<td>116.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laiyu3119</td>
<td>8839.5</td>
<td>107.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jidan180</td>
<td>8678.0</td>
<td>105.0</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td></td>
<td>9336.0</td>
<td>113.0</td>
</tr>
<tr>
<td>2002</td>
<td>Present Tilth methods (CK)</td>
<td>Simi25</td>
<td>9243.8</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Width lines</td>
<td>Haoyu9</td>
<td>10395.8</td>
<td>112.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simi25</td>
<td>11127.0</td>
<td>120.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jidan209</td>
<td>10328.3</td>
<td>111.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fayu No.1</td>
<td>10609.8</td>
<td>114.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yuandan22</td>
<td>9873.7</td>
<td>106.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laiyu3119</td>
<td>11676.1</td>
<td>126.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tiedan14</td>
<td>9228.2</td>
<td>99.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jidan342</td>
<td>10521.3</td>
<td>113.8</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td></td>
<td>10470.03</td>
<td>113.3</td>
</tr>
<tr>
<td>2003</td>
<td>Present Tilth methods (CK)</td>
<td>Yinhe101</td>
<td>8670.0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Width lines</td>
<td>Yuandan22</td>
<td>9851.4</td>
<td>113.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yinhe101</td>
<td>9787.5</td>
<td>112.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simi25</td>
<td>9693.6</td>
<td>111.8</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td></td>
<td>9777.5</td>
<td>112.7</td>
</tr>
<tr>
<td>2004</td>
<td>Present Tilth methods (CK)</td>
<td>Simi25</td>
<td>8840.0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Width lines</td>
<td>Jidan260</td>
<td>10003.0</td>
<td>113.0</td>
</tr>
<tr>
<td></td>
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<td>DenghaiNo9</td>
<td>10247.6</td>
<td>115.9</td>
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<td>Simi25</td>
<td>8904.2</td>
<td>100.7</td>
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<td>Sidan111</td>
<td>8957.4</td>
<td>101.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yinhe101</td>
<td>10074.5</td>
<td>114.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jidan29</td>
<td>10645.9</td>
<td>120.4</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td></td>
<td>9805.4</td>
<td>110.9</td>
</tr>
</tbody>
</table>
Know from table 13 that there were 5 demonstration varieties in 2001, yield per hectare of same varieties increased more 17.5% than that of CK, yield per hectare of different varieties increased more 13% than that of CK. There were 8 demonstration varieties in 2002, yield per hectare of same varieties increased more 20.4% than that of CK, yield per hectare of different varieties increased more 138% than that of CK. There were 4 demonstration varieties in 2003, yield per hectare of same varieties increased more 12.9% than that of CK, yield per hectare of different varieties increased more 12.7% than that of CK. There were 7 demonstration varieties in 2004, yield per hectare of same varieties existed no difference compare with that of CK, yield per hectare of different varieties increased more 10.9% than that of CK. There were 5 demonstration varieties in 2001, yield per hectare of same varieties increased more 12.1% than that of CK, yield per hectare of different varieties increased more 10.2% than that of CK.

**Analysis on the cost of maize planting in width lines and uniformity ridges**

<table>
<thead>
<tr>
<th>Plant styles</th>
<th>Leveling up ground</th>
<th>seed</th>
<th>seeding</th>
<th>Field management</th>
<th>total</th>
<th>Cost saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting in width lines</td>
<td>Autumn rotary cultivation 100</td>
<td>200</td>
<td>Machine seeding 100</td>
<td>Weeding 150 Deep loosing and topdressing 100</td>
<td>650</td>
<td>——</td>
</tr>
<tr>
<td>Turning up, harrowing the soil and seeding</td>
<td>Turning up and harrowing 260</td>
<td>300</td>
<td>Machine seeding 100</td>
<td>Weeding 150 Two times cultivation and topdressing 200</td>
<td>1010</td>
<td>-360</td>
</tr>
<tr>
<td>Destroying stubbles and ridging</td>
<td>Destroying stubbles and ridging 230</td>
<td>300</td>
<td>Livestock force machine seeding 100</td>
<td>Weeding 150 Two times cultivation and topdressing 200</td>
<td>980</td>
<td>-330</td>
</tr>
</tbody>
</table>

Know from table 14 that planting maize in width lines may decrease production cost 330-360 yuan Renminbi per hectare than that of CK except increasing yield and fertilizing soil.

**Conclusions and discussion**

Planting maize in width lines can foster soil, improve soil environment, promote maize growth, advance amount of the roots, leaves area, intensity of photosynthesis and elongate green leaves time.

Planting maize in width lines may save 330-360 yuan Renminbi and increase yield by 10% than that of CK.

Remaining high stubble with 35-45 cm when autumn harvest in planting maize in width lines.

Loosed depth is about 30-40 cm.

Deep loosing time, depth and width need further study and discuss under different conditions.

**References**


The Constraints to the Development of Conservation Agriculture in Shandong Province and Countermeasures

Dou Lezhi
Shandong Agricultural Machinery Technology Spreading Center, Jinan 250013;
Kong Linan, Wang Fahong
Shandong Academy of Agricultural Science, Jinan 250100)

Abstract: A number of programmes aimed at promoting the adoption by smallholder farmers, principles and practices of conservation agriculture (CA) have recently been initiated in Shandong province. And Shandong has made considerable progress in fostering the use of CA. Although smallholders who had tried CA generally asserted that it increased yields and reduced the cost of inputs of labor, oil, water and others, some minus factors involved considerably deterred the adoption of CA. By examining and analyzing the extension process of CA technology in Shandong, we attempt to elucidate some of the constraints to the adoption of CA, and provide several suggestions to address these problems.

Key words: conservation agriculture, mechanization, development, problem, countermeasure

Initiated in 2003 in Shandong province, CA has been practiced on 163,000 Chinese mu in 2005, out of it 146,000 mu in Huimin, Zhangqiu and Changyi, the three demonstration counties established by Ministry of Agriculture. The results of farmer participatory field trials in 2003-2005 showed that the wheat yield increased by 6%, input decreased by about 100 Yuan RMB per person under conservation tillage practice compared with that under conventional tillage. The field experiments has been proved that under wheat-maize rotation system, the CA technology could be practiced with low inputs of labor, time, irrigation water, fertilizers and oil, leading to high yield and environment benefits, all of which are crucial to sustainable development of agriculture. Despite these apparent advantages, CA has spread relatively slowly. The transformation from conventional agriculture to CA seems to require considerable farmer management skills and involves investment in new equipment. However, it is very encouraging that the Shandong agricultural machinery office issued “The position paper on province-wide launch of the mechanized conservation agriculture with residue retention in Shandong province” in 2006, which marked the beginning of farming system revolution. In practice, some problems and constraints are currently present there in the large-scale extension of CA technology, needing to be resolved.

Main constraints and problems

The introduction and adoption of CA technology are badly restrained by conventional tillage practice and farmers’ quality. In Shandong, the smallholders are deeply fettered by traditional agriculture. Therefore, it is very difficult to transform the traditional ploughing and intensive farming practices into no-tilled conservation agriculture. Additionally, the low quality of farmers limits their ability to accept new and different ideas, and the new technique seemed difficult to them. In other hand, the farmers are not very enthusiastic about this technology, because large part of farmers shows a skeptical attitude. Only the seeing is believing. To generally extent the CA technology in Shandong, a
lot of work needs to be done.

The progress of extension of CA technology is seriously retarded by low rural economics and farmers’ purchasing power. The main cost for CA adoption comes from the need to have the equipment available. To initiate the CA technology, part of existing machinery fall into disuse, so another set of large tractors, corn harvesting machines and no-till planters is required. The additional burden on smallholders for replacing machinery in the first or second year of launching CA technology partially eliminates their initiative.

Applicability is another constraint yet to be solved in further accelerating this technology, and is aggravated by the shortage of CA-required machinery. As the planting conditions differ, the farmers are still yet inexperience in crop germplasm selection and row spacing and fertilization determination at early stage of adoption of CA technology. Consequently, many participating farmers experienced unsatisfactory yields compared to conventional intensive cultivation. Currently, the availability of drills is yet not sufficient to satisfy the demand of the farmers. The process of technology extension has been considerably deterred by lack of local manufacturers to produce CA-related machinery as well as by the high price, small amount, unperfected performance and low adaptability and reliability of introduced machines.

Extension agents including project-related leaders and technicians in agriculture and machinery fields as well as policy makers have not fully understand the system, which is a key minus factor to ensure a more widespread, holistic and sustained adoption of CA. Moreover, the farmers can hardly be educated in CA principles and practices, to say nothing of recognition and adoption. In demonstration counties, some of the machine operators have not been so skilled as to ensure the operation quality to meet a prescribed standard. Financial assistance from government is far from enough, which results in the limited purchasing power for equipment and delayed adoption of CA.

The block of the adoption of CA could partially be attributed to the weak cooperation and poor administration in implementing CA in Shandong. CA was a multidisciplinary practice at relatively large scale, involving mechanical engineering, agronomy, soil and fertilizer managements and plant protection. So the practice of CA is a systems engineering, with a key focus on building partnerships across a range of sections. However, organization management is a multilevel, arduous, demanding and difficulty task, any careless omission of which can directly affect the progress of CA extension. In present Shandong, the cooperation mechanism for CA extension is being under construction, the study of integrated suitable techniques and technical extension have only been half done, which will badly affect the CA adoption efficiency.

Countermeasures and suggestions

*Promote recognition of CA and seek extensive support or cooperation*

Multifaceted assistance and technological cooperation are fundamentally needed in the promotion of CA practice. Using the mass media including the broadcast, TV program and the press creates a favorable atmosphere for recognition of CA, attracting attention from social circles, seeking policy support from government and assistance from financial departments. Therefore, it is essential to take advantage of our powerful media predominance to promote Conservation Agriculture in Shandong province. Responsible cadres of agricultural machinery sector at various levels must take the lead to advertise the CA practices through public media and comprehend well the importance and basic techniques of CA as soon as possible. And they should introduce the CA project to the local Party
Committee, government and other sectors related, enlisting the policy support to promote the rapid development of CA. CA is a complex set of technologies, altogether new idea and knowledge that may require changes in many parts of a farming system, ranging from seeding equipment, seeding time and seeding method; fertilizer application techniques and times; residue management practices. It is particularly important to popularize the principles, benefits and consequences of CA technology, deliver this technology and policy associated with CA to farmers, thereby to advance the quality and level of science and technology of farmers and machine operators.

**Strengthen technical training for farmers and local agricultural technicians to ensure technology application effects**

The proficiency in use of CA technology by people who are responsible to demonstration and extension of the technology is closely related to the success of CA adaptation. Therefore, the professional training for technicians and machine operators should be intensified, making them fully understand the CA technology, the key elements and the rules of operating the machines. Centralized training coupled with classified training should be taken for local leaders and principal technicians at agricultural machinery departments at city, county and township levels. After then, the principals and the benefits of adoption of CA technology should be delivered to smallholders in ways of the meeting on the spot, the short-term training, and direct contact with farmers, publicizing on market occasion and technical demonstrations. Additionally, training should put a high premium on agricultural knowledge, such as pest and disease control measures, germplasm selection and seeding rate determination. The special emphasis should be laid on training of machine operators and pilot farmers, giving full scope to their forward roles.

**Seek policy support to excite farmers’ initiative**

Agricultural machinery should actively win the recognition of CA and policy support from local government, bringing CA technology within the overall planning of rural economic development as a key part of project for building new socialism countryside and improving farmers’ income. By contact and cooperation with the plan department, financial department, agricultural sector and water resource department we could obtain multi-sided assistance and strengthened policy and financial supports. To make the most of the supplied funds as from “Special subsidies for agricultural machinery purchase”, “Funds for project of high quality food industry” and “Funds for model project of innovation”. The use of fiscal funds should give its priority to the CA project; the policy-makers should be induced to establish a policy of fiscal subsidies for purchasing CA equipment, thereby inspiring enthusiasm of small farmers for the CA technology. Taking advantage of funds from “Agricultural Machinery Purchase Subsidies”, together with project propaganda, technical services and guidance and preferential treatment for the earlier purchase of machinery to promote the broad adoption of CA machine.

**Integrate technologies to hasten our steps in innovating technology**

As the conditions tend to be different across environments, every planting are needed to typically tailor CA principles to local conditions, using different cropping system, especially for this integrated technology. Given the CA technology in Shandong is far from matured at present, there are too much we are required to do: a) to integrate machinery performance technology with agronomy and to optimize the varieties suited, fertilizer application techniques and times, seeding rate, pest and disease control measures, residue management practices and water management according to local conditions;
b) to carry out comparative study of the minimum-tillage with zero-tillage and of furrow planting with raised bed planting, thereby determining the optimal planting and extension model; c) to reasonably unit every links between mechanized operations into a integrated CA technology with high efficiency and lower costs, gaining perfect technical effects; d) the experiments for CA technology should be extended to a wide range of kinds of crops such as maize, soybean; e) to conduct the theoretical study on soil property changes, water and fertilizer absorption and translocation in plants, dynamics of plant growth using agricultural, biological, chemical and mechanical means, optimizing variety breeding, cultivation, balanced fertilization, crop rotation system, water saving irrigation and other techniques.

An instruction party is strongly suggested constructed by provincial agricultural machine office loosely united and composed of experts on machinery, agronomy, soil fertility management and seed sciences. The optimization grouping will organically unite the dominances from institutions of scientific and technological research, corporations, universities and extension services agencies, giving systematic research on the CA technology.

**Take teamwork to promote and adapt the manufacture of no-till planters and a set of suited machinery**

As there will be wide extension of CA technology, a good deal of attention should be paid to the development of suitable implements for direct sowing. These implements are required to achieve good crop establishment, with low cost of inputs and high efficiency. The key elements for no-till planters were their high adaptability, reliability and economy, which are the preconditions of widespread adoption of these practices. With which the advanced machines will cut the road to successful extension of CA technology. Presently, several types of machines are desiderated: a) the roto-till and fertilization seeding machines but needing to be improved to increase the working efficiency, seeding quality and to make irrigation easier; b) the no-till and direct fertilization seeding machines for both wheat and maize planting in dry-land; c) the no-till and direct fertilization seeding machines for the permanent raised bed planting under wheat-maize rotation system. Considering the veracity in their realizing farmers’ demands and knowing well the performance of existing machines, the agricultural machine extension personnel are required to support and instruct the project workers from academies of scientific researches, universities and corporations. Independent planter innovation coupling with improvement of introduced implements is the best way to gradually enhance our own ability of machine manufacture. It is suggested that some provincial and civic departments related increase the inputs for new equipment development, providing CA extension with high-quality machinery. Given the high potential of application of CA equipment, the local implement manufacturers should take this opportunity, developing diversiform advanced cheap machines for both the farmers and themselves.

**Reasonably select the trial and demonstration locations**

The demonstration plots are established for project propaganda to both leaders and smallholders. For only seeing is believing, the demonstration plots must be built to show farmers the effects and benefits of CA technology. And on the trial plots, the farmers will be instructed how to practice the CA technology. Therefore, the selection of demonstration plots is an important step towards the promising extension of CA technology. The demonstration plots had best be qualified with that: a) where the local leaders have enthusiasm, and project teams have competence; b) the machine operators and smallholders in the villages that demonstration plots located in would well understood the CA technology and are highly supporting; and c) locations are easy of access, well-marked, with large planting area of wheat and maize around, which can do best for radiate demonstration. The demo
plots should be elaborately built to be high standard samples. Avoiding cutting down the water and nutrient managements by farmers, production contracts are not necessary to be made with them. Additionally, frequent supervise and urge are required. The demo plots should be built at every city, county and township, with the emphasis on immediate action rather than plot area. At different seasons, various meetings need to be held for demo or view and emulate of CA technology. Dissemination of CA principles and practices on the demo plots could inspire much interest amongst local farmers, promoting the wide extension of this technology.

_Uphold five combinations to do demo well_

First, we should insist on that the agricultural machinery technology combine with agronomy, engineering technology with biotechnology. Farm machinery technicians are required to cooperate with experts at cultivation, soil fertility, plant protection and other fields to promote CA demonstration. Second, we will adhere to the policy as well as respect farmers’ wishes. In demonstration, we should take the initiative and activity but not be anxious for soon success. The demo must be implemented step by step under the guidance of natural and economic laws. Farmers being the mainstay of CA extension, we can not take compulsion to them, otherwise the farmers will emotionally make the management lags behind, causing the production reduced, which can easily lead to undesirable consequences. Third, promote the combination of demo with development of market. During the demo period, we should actively develop the agro-services market. As the machine operators are of importance in publicity, we should focus on supporting large machinery users, encouraging and piloting them to develop cooperation organizations and farm machinery association for CA extension, to enhance the industrialization level of farm machinery services, with the ultimate goal of establishing a long development mechanism. Fourth, pay same attention to key breakthroughs as the overall progress. The corn combine harvesting should be adapted to the CA practices. The practice integrating corn harvesting and residue retention and no-till seeding for wheat into one process is strongly recommended. Taking the advantages of benefits of residue retention, we would strive to promote the development of no-till planting mechanization technology, achieving the great progress in extension of CA technology.

_Strengthen organizational leadership and implement the target management_

Farm machinery sector at all levels should take the development of CA technology as a top priority. Corresponding organizations and authorities should be set up, and the main leading comrades must personally attend to this work. The authorities must focus on the organization and coordination for agricultural research and on the supervision and inspection; actively seek the policy and funding support of local governments and the financial sectors. A sound system of accountability and coordination mechanisms should be established, under which the specific responsibilities of departments and personnel to the project will be clearly worked out, annual plans developed, management with expected objectives implemented. These measures can obtain higher efficiency, and get CA extension done well. The project implementation team wants to be set up, with the responsibilities of the research and drafting of technical programmes, of the demonstration zone construction, the introduction of technology and instruments, technical instruction, training and propaganda, organizations of CA implement and other specific tasks. To ensure the successful completion of mission objectives, panel members will work strictly under the administration of accountability, and the team should attach great importance to administrative role in promoting the CA project. The mandate indicators will be implemented through administrative means to township,
village, or household, and a timely inspection, supervision and implementation are specially needed. The progress of CA extension will be regarded as an important indicator of farm machinery works. We should pay attention to summing up experiences and the promotion of advanced models, and we should commend and award the outstanding performances.

**Exploit the talents of experts; get the technical guidance and services done well**

Technical guidance group composed of experts at farm machinery, cultivation, soil fertility management, plant protection and other fields related should be set up. The main tasks are to study and analyze relevant technological developments in and out of China, to develop technical routes, technological specifications, operating instructions technology promotion programmes and other relevant technical documents, to select key instruments, test technical data, to research and solve the technical problems associated with technologies and instruments, and to take responsibility for technical training and technical guidance. Local administrations should take the initiative to seek the support of experts, to bring the roles of experts in technical advisory, training and instruction into full play. In operating season, the technical personnel should be promptly to give the farmers instructions in installation, commissioning, use, maintenance, etc. of new instruments, ensuring the operational quality and effectiveness of machinery.

**Primarily support large farm machine users and encourage socialization services.**

We must focus on improving the level of socialization, organizations and marketization of technical services. In virtue of the steering roles of administrative power, financial guidance, the technical support of farm machinery technology sectors, the driving force of benefits to farmers and farm machinery hands, we will establish and improve the operation mechanisms in socialization and marketization. As the specialized households of farm machinery and large farm machinery users have the closest relations with farmers, understanding well the farmers’ needs in actual production, and farmers have trust in them, so they are the best promoters of new technologies and the main objectives we want to support. The insurance of their initiative and benefits is the key of long development mechanism of CA technology. We should start the CA project with the large, agro-machinery and agro-specialized households as pioneers, enabling them to acquire the technology, to use instruments expertly, to benefit from the CA project, and then to inspire the interesting of farmers around in CA technology. The resources to agricultural machinery should be rationally allocated. For the natural lands with the same basic conditions, seed and fertilizers had better be uniformly provided to save time depending on purchasing. Scientific selection of germplasm and fertilization and uniform seeding rate are necessary. These measures can give rise to scale operations, professional services, reduced production costs, improved machinery operational efficiency and agricultural efficiency, and increase of farmers’ incomes, improvement of overall level of services, and high enthusiasm to CA practices. We should draw on the experience in inter-district operations for joint harvesting of wheat, get farm machinery specialized households and village farm machinery team organized, and sign operating service agreements with neighboring farmers, expanding the size of operations and enhancing operational and service efficiency.

Promoting CA techniques is an important measure to improve food production, to increase incomes, and develop rotational agriculture, resource conserving agriculture and the environment-friendly agriculture. Presently, the required conditions to promote the CA technology are ripe in Shandong, and the problems will be solved. We should accelerate the development of appropriate
countermeasures. The local farm machinery management and technology promotion departments must enhance their sense of mission and responsibility, increase their awareness of CA, seize opportunities, blaze new trails, and work hard. With the focus on demo plot establishment, we must increase policy mobilization, administrative promotion, demonstration and market pull, striving to open up a favorable new situation for CA extension. All the workers engaged in the CA project would make a greater contribution to the improvement of the overall production capacity of agriculture, to the increases of farmers’ incomes, agricultural efficiency and sustainable development, and to the building of new socialist rural and powerful province of farm machinery.

References

[1] The speech by Liu Hengxin at the 2006 meeting for conservation agriculture project.
[2] The opening ceremony speech by Lin Jianhua (director) for the course of mechanized maize harvest under conservation agriculture conditions in Shandong province.
The Study and Analyzing of the Affection to the Winter Wheat by Conservation Agriculture Technology in the Dryland Farming Area

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Abstract: The conservation agriculture has changed the winter wheat planting method and custom in the dryland farming area. Basing on the comparison experiments, the thesis studies and analyzes the situations of the soil moisture, diseases & insects and weeds protection, the natural disaster resistance, crops growth and development, production input and planting benefit for the winter wheat by means of the dryland farming and conventional technologies. The conclusion is that the key elements to promote the winter wheat growth & development and increase the planting benefit are the technologies of crop residues covering and sewing after rotation plow in the planting belt in the area that the wheat and maize are two harvests in one year in the dryland farming area.

Key Words: Conservation Agriculture, Winter Wheat Affect Study

In order to study the affection to the growth and plant benefit of the winter wheat by conservation tillage technology in the dryland farming area, in 2005, the comparison experiment was carried out in Yanman village, Guanzhuang township, Zhangqiu City, by Shandong Provincial Agro-machinery Technical Extension Station and Zhangqiu City Agro-machinery Bureau. The experimental results have been summarized and analyzed:

The basic situation of experiment field

Field spot
Covering land with smashed maize straw and rotation plowing in planting belt in the first spot (for short: covering & sewing in no tillage); removing the maize straw but remain the stubble and rotation plowing in planting belt in the second spot (for short: remain stubble & sewing in not tillage); removing soybean straw but remain stubble and direct sewing wheat in the third spot (for short: no covering & direct sewing); and removing maize straw and sewing with rotation plowing in the forth spot (for short: sewing in conventional tillage). Among above mentioned, the covering & sewing in no tillage and remain stubble & sewing in no tillage belong to conservation tillage (CT).

The experimental field situation
With little fluctuation of the land surface and light soil, the layer is depth. The annual precipitation is about 650mm. The yearly yield of the winter wheat is 2400kg/hm². The sewing time of the wheat: 10, October, 2005. Before sewing time, there was a heavy rain thus the soil being high moisture. The wheat variety is No.20 of Jimai. The sewing quantity is 150kg/hm²; The basal fertilizer is pellet.
compound of ammonium phosphate. The application quantity is 525kg/hm$^2$ (for no covering & direct sewing, the quantity is 150kg/ hm$^2$).

**Selection of the machinery tool and instruments**

For maize harvest, the machine is 4YW-2 combine; for the wheat sewing in no tillage, the machine is 2BMFS-5/10; for wheat direct or conventional sewing, the machine is 2BMF-6 with fertilizer application tool and the gutter is arrow spade; the rotation plowing machine is 1GQN-200; for the IPM, the machine is manual sprayer of back bear type; for the wheat harvest, the machine is Poton 4L-2 combine; for the soil moisture testing, the instrument is TSCII that is intelligent (the data is percentage in bulk), the conventional instruments are scale, meter ruler, steel ruler.

**Affection to wheat sewing in straw covering**

Before and after wheat sewing, we monitor the straw covering situation. For the sewing in no tillage covering with the smashed maize straw, the covering quantity reaches 4875kg/hm$^2$; for the field with the height of the maize stubble being 20cm, the covering quantity is 786kg/ hm$^2$; for the field without covering but the remain 5cm height of soybean stubble, the covering quantity is 945kg/ hm$^2$, and in the conventional tillage with the remain 5cm height of soybean stubble, the covering quantity is 600kg/ hm$^2$.

<table>
<thead>
<tr>
<th>Sewing Way</th>
<th>Quantity (kg/hm$^2$)</th>
<th>Before (%)</th>
<th>After (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Covering &amp; Sewing in no Tillage</td>
<td>4875</td>
<td>69.6</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>2.Remain Stubble &amp; Sewing in no Tillage</td>
<td>786</td>
<td>13.3</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>3.No Covering &amp; Direct Sewing</td>
<td>950</td>
<td>15</td>
<td>11</td>
<td>Prior crop is soybean</td>
</tr>
<tr>
<td>4.Conventional Sewing</td>
<td>600</td>
<td>8</td>
<td>3.2</td>
<td></td>
</tr>
</tbody>
</table>

Because of the much more quantity of the straw in the covering & sewing in no tillage field, it gently affects the through ability of 2BMFS-5/10 of the wheat no tillage sewing machine; in the remain stubble field, there is basically not any affection to the through ability of 2BMFS-5/10. However, adopting the no tillage sewing, the soil will be tossed to no plowing part from planting belt thus forming soil layer to cover land. That increases the covering quantity and thickness. It refrains from the moisture evaporation. In the no covering & direct sewing and conventional sewing field, under the condition of the existing straw covering, there is basically not any affection to the through ability of the conventional sewing machine.
We have tested 6 times for the moisture in 0~20 cm soil layer from wheat sewing to harvest. (see table 2).

**Table 2**  The Soil Moisture in the Different Comparison Field

<table>
<thead>
<tr>
<th>Planting Way</th>
<th>Date</th>
<th>05.10.1 0</th>
<th>05.12.3</th>
<th>06.2.24</th>
<th>06.3.29</th>
<th>06.4.30</th>
<th>06.6.2</th>
<th>Growth stage average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
<td>180*</td>
<td>8</td>
<td>15.1</td>
<td>3</td>
<td>8</td>
<td>103</td>
<td>137.1</td>
<td></td>
</tr>
<tr>
<td>1. Covering &amp; sewing in no tillage</td>
<td>31.23</td>
<td>22.1</td>
<td>24.3</td>
<td>16.4</td>
<td>12.18</td>
<td>24.38</td>
<td>21.77</td>
<td></td>
</tr>
<tr>
<td>3. No covering &amp; direct sewing</td>
<td>27.07</td>
<td>14.63</td>
<td>11.23</td>
<td>8.29</td>
<td>9.45</td>
<td>23.44</td>
<td>15.69</td>
<td></td>
</tr>
</tbody>
</table>

Note: 180* means the total rainfall from September 1 to October 10; The moisture is the average value of the bulk percentage in 0—20cm soil layer.

During periods of September to 10 October of 2005, the rainfall is heavier thus the moisture being high. However, from sewing time to the end of April of 2006, there generally is not any precipitation. The soil moisture has been decreasing. The moisture change chart (chart 1) shows that the soil moisture almost reaches the wither coefficient in the different planting models on 30 April, 2006: In May of 2006, the rainfall is heavier, therefore, the moisture is getting high when the wheat harvest.

The monitoring results show that the soil moisture in the field adopting CA technologies is higher 47.59% than that in the field adopting the conventional tillage within the all wheat growth life. The reasons include as following:
Covering refrains from the soil moisture evaporation

The cover materials cut off the capillary linkage between evaporation surface and soil and reduce the exchange capacity between soil air and atmosphere. Therefore, it limits the soil moisture evaporation effectively. Particularly in the period after wheat sown to before turning green (middle of February), the cover materials decrease the soil moisture evaporation obviously (covering & sewing in no tillage and remain stubble & sewing in no tillage). It makes the soil moisture in the higher level.

Rotation plowing in the planting belt forms soil covering

Rotation plowing in the planting belt (remain stubble & sewing in no tillage) tosses the earth to the no till part from the planting belt thus forming soil covering. Even though this earth losses the moisture immediately, it prevent the most part of the soil moisture in the no till land from losing. It makes the soil moisture in the higher level thus promoting the wheat growing and developing. It plays a role of “small against big”.

The covering is significant for keeping the soil moisture

Without covering & direct sewing wheat, the soil is no tillage. It is a “0” till the wheat sewing. However, because there is not any covering material, the soil moisture is evaporated very fast. It is similar to the conventional tillage.

The soil moisture in the shallow level is adjusted by no tillage sewing technology

After no till sewing wheat, it forms soil structure of the void alternating with solid in the shallow soil layer. The void part is in the planting belt that is rotation plowed. The soil moisture is loss mostly in this part. The moisture level is lower (see the table 3): The no plowing soil forms solid part with the covering materials. Under the action both soil capillary moisture and evaporation motive force, the solid part gets the soil water from depth layer. It makes soil moisture in higher level. The monitoring results show that the moisture in 20 cm in ridge is 2.28—3.37% higher than that in the planting belt within the crop growth period. The water will be supplied from solid part with higher moisture level to the planting belt with the lower moisture level. It would promote the wheat growth and development.

Tamping does not keep but also increase soil moisture

After no till sewing wheat, the no till machine tamps the planting belt. It does not break the clods, close the cracks and prevent the gaseous water from evaporation but also combine the soil closely and recover the soil capillary function. It makes soil water get higher. That plays a role of increasing the soil moisture thus ensuring the wheat emergence rate in the good moisture condition. It also makes the wheat become strong seedling.

<table>
<thead>
<tr>
<th>Date</th>
<th>1. Covering &amp; sewing in no tillage</th>
<th>2. Remain stubble &amp; sewing in no till</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ridge</td>
<td>Planting belt</td>
</tr>
<tr>
<td>05.10.10</td>
<td>31.23</td>
<td></td>
</tr>
<tr>
<td>06.2.24</td>
<td>24.97</td>
<td>19.23</td>
</tr>
</tbody>
</table>

Table 3 Soil Moisture in the Planting Belt and Ridge
Field observation

*The cool resistant ability is strengthened for the wheat adopted the conservation till*

In the spring of 2006, the climate was got warm quickly. The wheat, in the conventional way and no covering & direct sewing field, got turning green early because the soil moisture is lower and the land temperature increases fast due to no covering materials in the field. In the field adopting the conservation till technology, due to the higher soil moisture, the land temperature increases slow. The wheat turns green slowly. There was a cool weather to affect the Shandong province in March 11～12. The experimental field fall snow. In this case, the much more wheat in the conventional way and no covering & direct sewing field was freezed to death (see chart 2) while the wheat in the field adopting conservation till technology did not die.

The main reason is that the covering material reduces the temperature exchange ratio between atmosphere and soil air. The crop straw absorbs the heat in the day. During the night, the straw limits the earth heat radiation thus prevent the temperature to loss. Meanwhile, because the moisture is higher in the soil adopting the conservation till technology, the variation of the land temperature is little like ocean climate. Therefore, the temperature in the field adopting CT is lower and stable. That protects the wheat from die of frost.

*There is less weed in the wheat field adopting CT*

By the inspection to the wheat growth, there is not any weed basically in the field while there are much more weeds in the field adopting conventional way and direct sewing. The chart 3 shows the
comparison result between the conventional field after 5 days sprayed herbicides and the CT field without spraying any herbicide.

The key reasons are: firstly, the CT adopts no tillage sewing and straw covering technologies. The surface soil with more weed seeds is tossed to the ridge without plowed. That forms a covering layer with bigger cracks. Therefore, the soil moisture is evaporated quickly. The moisture in the covering layer soil is lower. That is not suitable for the weed growth. Secondly, the weed seeds in the no plowing part are covered. They cannot get enough sunshine. Therefore, the generation condition for the weed seeds is bad.

*The occurrence of the diseases & insects is similar in the CT field and conventional & direct sewing field*

After inspection, there is affection by mites in the any spots before winter and after wheat turning green. That needs protection and treatment. In the flowering period, the spots need to protect and treat the wheat aphid with chemicals.

**The wheat growth and development**

After the wheat sown, we inspect the wheat growth and development situation associating with the soil moisture monitoring. The results see table 4.

**Table 4**  The Wheat Growth and Development Situation

<table>
<thead>
<tr>
<th>Planting Way</th>
<th>Basic seedlings (‘0000/hm²)</th>
<th>Emergence rate (%)</th>
<th>Tiller before winter</th>
<th>Max body (‘0000/hm²)</th>
<th>Ears (‘0000/hm²)</th>
<th>Mature ears (%)</th>
<th>Grains in a ear (grain/no)</th>
<th>Weight of 1000 grains (g)</th>
<th>Aver. yield kg/hm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.C &amp; S in no till</td>
<td>293</td>
<td>88.36</td>
<td>2.7</td>
<td>1084.55</td>
<td>542</td>
<td>44.04</td>
<td>22.43</td>
<td>40.63</td>
<td>4199.47</td>
</tr>
<tr>
<td>2.R &amp; S in no till</td>
<td>295</td>
<td>88.96</td>
<td>2.3</td>
<td>1058.9</td>
<td>539.5</td>
<td>44.61</td>
<td>22.37</td>
<td>40.3</td>
<td>4133.49</td>
</tr>
<tr>
<td>3.NC &amp; Direct</td>
<td>301</td>
<td>90.77</td>
<td>2.2</td>
<td>963.65</td>
<td>298.5</td>
<td>26.80</td>
<td>23.3</td>
<td>37.17</td>
<td>2197.22</td>
</tr>
</tbody>
</table>
Note: the weight of 1000 grains is 43g for seed, pure rate is 98%, germination rate is 97%, the average yield is 85% of the theory output.

**The results show**

The emergence rate is similar basically between CT and conventional field. Due to the good moisture condition in the planting time, the emergence rates are higher in the any comparison spots. However, the rate in the CT field is little bit lower because of the higher quantity of the covering materials.

The number of tiller before the winter in the CT field is more than that in the conventional field. Because the moisture in the CT field is higher before the winter, it promotes the wheat seedlings growing. The tiller is much more. In the conventional field, because the soil is tossed and rotated frequently, the evaporation is bigger thus affecting the wheat growing. Therefore, the tiller before the winter is little.

The matured ear rate in CT field is higher than that in the conventional field. Because the moisture in the CT field is higher, it can resist the “spring cool weather” effectively. The tiller died much less. The matured body is bigger. The rate is higher. However, because the moisture in the conventional and direct sewing field changes quickly, it is affected the wheat growth obviously by the “spring cool weather”. The tiller is died much more. The matured ear body is little. The rate is lower.

The yield in CT field is higher than that in conventional field. Even though the weight of 1000 grains and the grains in a ear in the conventional field are higher than that in CT field lightly, the yield still is lower because the matured ear body is too little. According to the calculation, the yield in CT field is 1574.02kg/hm² higher than that in conventional field in average level. For the wheat in the no covering & direct sewing field, due to the less basal fertilizer application, less rainfall in the spring, and no way to application fertilizer additionally, the weight of 1000 grains is even much more lower. That affects the yield seriously.

**Monitoring to the water usage rate**

According to the monitoring to the wheat yield and soil moisture within 20cm layer, the water usage situation in the different planting models see table 5.

<table>
<thead>
<tr>
<th>Planting Way</th>
<th>Sewing time (mm)</th>
<th>Harvesting time (mm)</th>
<th>Total rainfall (mm)</th>
<th>Water consumption (mm)</th>
<th>Yield (kg/hm²)</th>
<th>Water usage rate (kg/mm.hm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.C &amp; S in no till</td>
<td>62.42</td>
<td>48.76</td>
<td>137.1</td>
<td>150.76</td>
<td>4199.47</td>
<td>27.86</td>
</tr>
<tr>
<td>2.R &amp; S in no till</td>
<td>58.32</td>
<td>46.88</td>
<td>137.1</td>
<td>148.54</td>
<td>4133.49</td>
<td>27.83</td>
</tr>
<tr>
<td>3.NC &amp; Direct sewing</td>
<td>54.14</td>
<td>45.38</td>
<td>137.1</td>
<td>145.86</td>
<td>2197.22</td>
<td>15.06</td>
</tr>
<tr>
<td>4.convention</td>
<td>57.34</td>
<td>36.46</td>
<td>137.1</td>
<td>157.98</td>
<td>2625.45</td>
<td>16.62</td>
</tr>
</tbody>
</table>
The results show: in the dryland farming area, the winter wheat fully uses the water resource in the CT field. The water usage rate is 67.62% higher than that in the conventional field. It is obvious.

**Production Cost and Benefit**

According to the monitoring and investigation to the production stages in experimental spots, the production cost and benefit see table 6.

<table>
<thead>
<tr>
<th>Planting Way</th>
<th>Production cost</th>
<th>Income form products</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize harvest</td>
<td>Straw treatment</td>
<td>fertilizer</td>
</tr>
<tr>
<td>1.C &amp; S in no till</td>
<td>750</td>
<td>918.75</td>
<td>330</td>
</tr>
<tr>
<td>2.R &amp; S in no till</td>
<td>600</td>
<td>918.75</td>
<td>330</td>
</tr>
<tr>
<td>3.NC &amp; Direct sewing</td>
<td>750</td>
<td>262.5</td>
<td>330</td>
</tr>
<tr>
<td>4.convention</td>
<td>600</td>
<td>918.5</td>
<td>330</td>
</tr>
</tbody>
</table>

*The results show:*

The production cost in CT field is lower than that in conventional field. The CT reduces operation activities. Even though additional 75 y/ hm² has to be paid for the harvest because the wheat growth is good, the total production cost is lower 150 y/ hm² comparison with the conventional field.

The benefit in CT field is higher than that in conventional field. Because of reduction of the production cost and increment of the yield, the production benefit of the winter wheat is higher 2416.59 y/ hm² comparison with the conventional field.

In the no covering & direct sewing field, the production cost is lower. However, the yield still is lower thus the production benefit being also lower.

**Conclusions**

The straw covering and sewing in no tillage are the key elements to affect the winter wheat growth & development and production benefit. Covering fully uses the crop straw and limits the soil moisture evaporation. Sewing in no tillage increases the covering quantity, adjusts the soil moisture, and promotes the wheat growth. It is a key element to increase the wheat yield.

The winter wheat direct sewing has to associate with straw covering. Under the no straw covering, the soil moisture and temperature change obviously after the winter wheat direct sown. That affects wheat growth and development seriously and limits the production benefit.

The conventional tillage affects the production benefit of the winter wheat. The soil moisture and temperature with the conventional tillage change frequently and obviously. That affects the wheat growth and development seriously and limits the production benefit.
growth & development and yield. Additionally, there are more production activities. That causes higher production cost. It affects the production benefit seriously.

To sum up: it is significant to increase the winter wheat yield and production benefit by conservation tillage technical system consisted of maize harvested with combine and the wheat sown with no tillage technology in the dryland farming area with two harvests in one year.

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Status and Development Countermeasure of Mechanized Protective Cultivation of Qingdao City

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Abstract: According to the actual status of increasingly worsened agricultural ecological environment caused by drought, water and soil erosion, excessive cultivation and straw burning, etc., this thesis has established the development strategy of conservation cultivation for double-crop with 4 stages and 6 sectors, raised the opinion of programming and constructing the two regions of “Protective Cultivation Belt along the Yellow Sea” and “Pinglai Protective Cultivation Belt” and confirmed the countermeasure of fully mechanized protective cultivation technology of wheat and corn taking land reuse after corn harvest as key point, breaking through technology of no-till seeding of wheat and improving technical level by steps.

Key words: ecological environment, development strategy with 4 stages and 6 sectors, improving technical level by steps, protective cultivation belt

As an important economic center of China, Qingdao City needs a nice matching agricultural ecological environment. The protective cultivation technology promoting sustainable development of agriculture is not only favorable for ecological construction, but also an inevitable choice of establishing circulative economy and resource-saving agriculture. In this year, the Ministry of Agriculture has listed our city into coastal cities actualizing protective cultivation demonstration projects, which has brought nice opportunity for us to generally actualize protective cultivation.

Mechanized protective cultivation technology is imperative under the situation.

Drought of Qingdao city

All people who have been to Qingdao have impressions that the beautiful tourism city has wonderful landscapes. However, Qingdao is one of the coastal cities in north China lacking water seriously, water resources for per person and per Mu farmland are only 342m$^3$ and 330m$^3$, which cover only 13% and 18% of average value of China. Annual rainfall is concentrated in flood season, and rainfalls in July and August cover 45% of annual total rainfall. Downpour in summer causes serious water and soil erosion. Our city is of temperate zone monsoon climate, its temperature increases year by year and sunlight ratio reaches 58%. Drought is the largest threatening of agriculture and one of the important causes of dust storm. Especially in spring, Qingdao is also under disaster of dust storm.

Serious water and soil erosion
Qingdao is located in highland region, and its hilly area covers 67% of total area. Such geographic situation can influence seasonal runoff of rivers within the city, which can cause serious water and soil erosion. Area of water and soil erosion is 6,228km$^2$, which covers 58% of the total area. Total quantity of soil erosion is 22.967 million ton. Water and soil erosion can cause thinning of soil and decrease of fertility. Annual lost organic compounds are 192,800t, lost nitrogenous fertilizers are 12,900t, lost potassium is 1700t, lost phosphor is 100t and lost standard fertilizers are 95,000t. Endangered farmland is 185,700hm$^2$, which covers 31% of total farmland. Mud accumulated in rivers, pools and reservoirs of the city annually is 17 million m$^3$, among which 14.46 million m$^3$ is of hilly area, which covers 85.1% of total quantity. The above mentions facts are sufficient to prove serious water and soil erosion of our city.

**Mass use of chemical fertilizers**

In 2005, total quantity of chemical fertilizers used in farmland of our city was 330,000t, which is 1.8 times comparing with 1990, and it is universal that some farmers misuse chemical fertilizers and pesticides. According to traditional fertilization, about 20% of chemical fertilizers are spread on surface of farmland, which can cause waste and pollution. At present, quantity of chemical fertilizers used annually is increasing continuously, and high yield of wheat and corn is supported by mass use of chemical fertilizers. Overuse of pesticides can seriously pollute environment, rivers and groundwater, and pesticide residue can greatly endanger health of citizens. Overuse of fertilizers can make soil be hardened and structure be destroyed, which can restrict sustainable development of agriculture.

**Excessive cultivation**

Level of agricultural mechanization of Qingdao City is comparatively high, and nearly 300,000 various cultivating equipments include plows, cultivators and harrowers. Annual deeply cultivated land is 272,000hm$^2$, traditional cultivated land is 207,400hm$^2$ and rotary cultivated land is 104500hm$^2$, which cover 98% of total farmland. “Intensive Cultivation” is typical, and continuous increasing of cultivation has increased bareness degree of soil. Development of agricultural mechanization has played an important role in highly effective agricultural production. However, on the sectors of environment protection of farmland, there is misunderstanding on a certain extent. Excessive cultivation can make soil be exposed sufficiently, which can not only reduce water storage ability, but also increase water and wind erosion degree. Variety and quantity of agricultural machinery will certainly be increased because of numerous farming procedures, which can increase cost of production.

**Pollution caused by straw burning**

Aviation of our city is developing quickly, 66 domestic and international flight courses have been opened, and there are nearly 1,000 scheduled flights every week. Road traffic is developed, and 9 speedways have been constructed with total length of 524km, which is 1/60 of total length in China and primarily reaches level of developed countries. Our city is also the host of Regatta of 2008 Olympic Games. Therefore, we must create and keep a nice ecological environment and reduce air pollution to satisfy requirements of each function of the city. However, large quantities of straws have not been disposed effectively, which is disharmonious with such requirements. Large quantities of straws are burned or thrown away, and dirty smoke rises from all directions while burning straws, which not only pollutes environment, but also influents takeoff and landing of planes and causes
serious accidents and hidden troubles for speedways and railways. Meanwhile, large quantities of straws are wasted, which makes soil lose fertility and destroys agricultural ecological environment. In order to improve natural environment of Qingdao City and lighten influences to agriculture and city life caused by traditional cultivation, constructing circulative economy and resource-saving agriculture and generally promoting protective cultivation technology is our inevitable choice.

**Development strategy of mechanized protective cultivation with 4 stages and 6 sectors**

In order to promote protective cultivation technology designedly by steps, this thesis has established the development strategy of conservation cultivation for double-crop with 4 stages and 6 sectors according to actual status of our city. The 4 stages are combine harvest of wheat, no-till seeding of corn, combine harvest of corn and no-till seeding of wheat, and the 6 sectors are double-seeding, double-harvest and double-covering, namely seeding of wheat and corn, harvest of wheat and corn and straw covering of wheat and corn. Such 4 stages and 6 sectors are confirmed according to growing law and characteristics of crops, research and development level of equipments, systematization degree of agricultural machinery services, cognition process of farmers and development level of economy. At present, 2 stages and 3 sectors of protective cultivation of our city, namely the 2 stages of combine harvest of wheat and no-till fertilization and seeding of corn and the 3 sectors of harvest of wheat, straw covering of wheat and no-till seeding of corn have been completed.

**Stage 1:** Start from mechanized combine harvest of wheat to actualize straw covering technology of wheat. In middle and last 1990s, our city had organized and actualized promotion of mechanized straw returning technology of wheat. In 2005, number of combine harvester of wheat reached 6,106, mechanized harvest ratio of wheat reached 98% and integrative using ratio reached above 70%, which further improved mechanization level of straw returning and using of our city. Reasons of realizing the first stage and the 2 sectors: firstly, straw of wheat is thin, and height of wheat is basically same. Therefore, it is convenient for mechanized harvest; secondly, combine harvester of wheat has rational structure, high efficiency and complete functions. Therefore, farmers are willing to accept it; thirdly, promote service organization of agricultural machinery and successful experience to market of wheat mechanized harvest and straw returning, which can accelerate process of the first stage.

**Stage 2:** Through “one-stop” service of agricultural machinery, realize no-till fertilization and seeding. Since 1990s, our city had introduced 2BX-3F corn seeder, and successfully organized one-stop service of wheat combine harvest (straw crushing and covering) → corn no-till fertilization and seeding, which had made corn no-till fertilization and seeding technology be promoted in our city. Reasons of realizing the second stage: firstly, corn no-till seeder has high efficiency, low price, simple structure and reliable performance, and can work with small tractor to satisfy requirements of products; secondly, after straws of wheat are crushed and returned, the stubbles basically will not influent seeding of corn; thirdly, cold weather in early spring of Qingdao makes growing period of corn be shortened by a month. Therefore, seeding should be made in time before coming of rainy season; fourthly, operators find the opportunity brought by corn no-till fertilization and seeding. Therefore, farmers are willing to accept the labor and time saving planting mode. At present, there already have been 11,338 corn no-till seeders, and no-till seeding area reaches above 75%.

**Stage 3:** Through promoting mechanized combine harvest technology of corn, intensify strength of corn straw returning and covering. At present, 2 sectors of the third stage, namely corn harvest and corn straw returning and covering are under research. Before 2004, direct crushing and returning
mechanized technology of corn straw was under test, and returning ratio of corn straw was only about 10%. Reasons why the third stage is developing slowly: firstly, straw of corn is high and thick, and positions corn cobs are not same, which bring trouble to mechanized harvest; secondly, corn harvester has imperfect structure, too many malfunctions and low efficiency, which influence using; thirdly, straw of corn is thick and big, which can influence development of straw covering technology. Under the basis of realizing mechanized harvest and straw returning of wheat, our city has expanded multiregional services of agricultural machinery from wheat harvest to corn harvest, and developed the new market taking mechanized harvest of corn and returning of straw as key points. At present, mechanized harvest ratio of corn has reached 25%. The municipal government of Qingdao has issued Notice on Relevant Problems of Actualizing Mechanization of Corn Production, and in 2005 and 2006, the government paid CNY 10 million every year mainly for allowance of purchasing corn combine harvester and straw crushing and returning machinery. At present, there have been more than 800 corn combine harvesters and 793 straw crushing and returning machines, which have powerfully accelerated returning and covering of straw. In this year, our city plans to organize multiregional services of corn combine harvesters and straw returning machines in autumn. It is planned to accomplish corn mechanized harvest area of 60,000hm², and straw returning area covers above 35% of corn harvest area.

Stage 4: This stage is under beginning period. Wheat no-till seeding is the last sector of protective cultivation, and it is also the most important and difficult sector. Problems: firstly, stubble of corn is big, which can bring worse growing environment to wheat. The custom of “intensive cultivation” of wheat planting is not easy to be changed. Therefore, wheat no-till seeding is difficult; secondly, straw of corn is thick and big, while performing wheat no-till seeding, the machines are easy to be winded, which can influence quality of seeding; thirdly, development of wheat no-till seeder is slow. Work of this stage should be directed by Demonstration of Protective Cultivation issued by the Ministry of Agriculture in 2006 to promote mechanized protective cultivation technology taking abandoning deep plow in autumn and wheat no-till fertilization and seeding as main sectors.

Conclusions

Through the above analysis, this thesis has made conclusions as follows:

As an important economic center and coastal opening city of China, Qingdao is also facing the problem of worsened agricultural ecological environment. Modern agricultural construction of Qingdao City must adopt protective cultivation to improve agricultural ecological environment and promote sustainable development of agriculture.

Economic development of Qingdao City has reached a higher level, and support to “Agriculture, Farmer and Village” of the government is stronger and allowances of purchasing equipments are comparatively more, which have established nice economic foundation for promotion of protective cultivation.

Qingdao City is located in coastal region and plays an important role in integrative development of Shandong Province. With nice regional advantage and economic foundation, integrative level of agricultural mechanization is comparatively high. As the largest coastal city in north China carrying out protective cultivation, Qingdao City has premise of realizing fast development of protective cultivation leadingly in Shandong Province.

The strategy of conservation cultivation for double-crop with 4 stages and 6 sectors accords with
actual status of our city. At present, 2 stages have been completed, and 3 sectors have been realized. The 2 sectors of the third stage are under development, and the fourth stage of wheat no-till seeding is under beginning period. The 4 stages require one another, and the 6 sectors connect with one another. Wheat straw crushing and covering, which creates condition for corn no-till fertilization and seeding cannot be realized without development of wheat combine harvest, and corn no-till fertilization and seeding technology can solve problem of corn harvest, which creates condition for corn combine harvest. Corn combine harvest can solve problem of corn straw covering, and wheat no-till seeding can solve problems of too many plowing procedures, difficult ordinary seeding and high cost after corn combine harvest. According to development of the stages, promotion of protective cultivation should follow the laws of wheat combine harvest and corn no-till seeding. Development of corn combine harvest mechanization has driven promotion of protective cultivation technology, which can also promote development of corn combine harvest mechanization. Fast development of protective cultivation technology must confirm the development countermeasure of taking corn harvest and straw reuse as key points to break through technical sector of wheat no-till seeding and improve technical level of protective cultivation by steps.

Promotion of protective cultivation requires support of farmers, and agricultural machinery service institutions and large owners are main force to realize protective cultivation technology.

Countermeasure of accelerating mechanized protective cultivation of Qingdao city

Confirm the development countermeasure of taking corn harvest and straw reuse as key points to break through technical sector of wheat no-till seeding and improve technical level of protective cultivation by steps. At present, corn harvest mechanization of our city has acquired distinct development, and mechanized harvest ratio in 2006 will reach 35%. In the future, the following work should be accomplished: firstly, improve mechanization level of corn harvest and straw reuse. Corn mechanized harvest ratio should be increased by 8%-10% every year, and increase number of corn combine harvester to 3,000 up to 2010. Introduce 3,000 processing machines (one machine in every village) to make corn mechanized harvest ratio reach 65%, and mechanization level of corn production reach above 80%; secondly, promote machinery of protective cultivation. In 2006, area of protective cultivation taking actualizing wheat no-till seeding as main content should reach 3,300hm² in the 5 towns of Qingdao City, and number of wheat no-till seeders reach 100.Wheat mechanized no-till seeding ratio should be increased by 5%-6% every year, and area of protective cultivation should reach 40,000hm² up to 2010, which covers above 20% of total seeding area; thirdly, update wheat combine harvesters or equip them with straw crushing devices to improve quality of straw crushing and covering and standardization level of protective cultivation technology.

Make Development Programming. Protective cultivation should be combined with collective agriculture development of our city such as high quality crop project and the 4 farm product areas of 67,000hm² and programming of ecological demonstration region. From 2006 to 2010, program and construct the 2 regions of “Protective Cultivation Belt along the Yellow Sea” and “Pinglai Protective Cultivation Belt” and establish the support system of protective cultivation taking technical innovation, equipment guarantee and integrative service as contents. From 2006, it is planned to use 5 years to construct a state level demonstration area, a provincial level demonstration area, 3 municipal level demonstration areas and 30 demonstration towns, train some science and technology demonstration farmers, promote 1,200 wheat no-till seeders, 1,500 corn no-till seeders and 1,500 deep scarifiers and plant protectors.
Strive for more investment of protective cultivation provided by government. Protective cultivation has been an important way of ecological construction and socialist new villages. Through intensifying allowances of purchasing agricultural machinery, mainly support corn combine harvester and protective cultivation machinery, attract multilevel investment of farmers and society, try to list protective cultivation into material development and using programming of Development and Reform Committee of Qingdao City, grasp new opportunities and accelerate development of protective cultivation machinery.

Emphasize construction of protective cultivation demonstration projects. Firstly, make construction of protective cultivation demonstration counties of Ministry of Agriculture in 2006 well. Intensify arrangement and management of projects, make technical system, introduction and promotion of new machinery well, guarantee fulfillment of area of demonstration regions. Secondly, Program and construct some provincial demonstration regions. Within the “Protective Cultivation Belt along the Yellow Sea”, construct demonstration regions such as Jiaozhou, Jiaonan, Jimo, Chengyang, Huangdao and Laoshan, etc. by taking agricultural environment construction as key point to improve ecological environment of our city. Within the “Pinglai Protective Cultivation Belt”, construct demonstration regions such as Pingdu and Laixi, etc. by taking crop production as key point to improve integrative production capacity.

Establish and perfect development system of protective cultivation. Promote the “one-stop” processing of corn mechanized harvest – straw reuse – wheat no-till seeding, found and develop new agricultural machinery service institutions and large owners to continuously improve level of socialization, professionalization and market, complete change from traditional cultivation to protective cultivation as quickly as possible, and promote healthy and continuous development of protective cultivation.

References


Observation and Thought about Protective Tillage Projects of Henan Province

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Abstract: In this paper, the author brings forward comprehensive appraisal and evaluation for protective tillage projects and the corresponding implements by applying high technology methods. On one hand, we shall make further researches and improvement on protective tillage implements to adapt agricultural and agricultural machinery demands of protective tillage in all areas. To satisfy the purchase and use of farmers, we shall improve price performance ratio and quality of protective tillage implements furthermore. On the other hand, we shall strengthen protective tillage popularization team construction, and the funds supervision and management for protective tillage projects. Current management mode is comprised of more than three investment subjects (ministry, province and county), and the administrative contract is signed between administrative subjects. Factors like cadre blocked, dependency management, separated finance, graded operation guide, policy regulation and control and indiscrete government affairs and government and enterprises, lead to absent and default funds supervision and management of protective tillage projects.

Key words: protective tillage, Henan province, project, observation, thought

Introduction

Started in 2002, protective tillage technique test of Henan province had been successively carried out in 12 municipalities under the provincial authorities and 53 counties (cities and areas) up till 2005 with more than 500,000 Mu utilization areas. Including: 5 state-level projects, 21 province-level projects, 27 test demonstration projects developed by counties and cities themselves. In 2006, other 7 state-level projects and 13 province-level demonstration and testing projects are implemented. Test and demonstration results indicate that, the implementation of protective tillage has multiple effects on operation links and production cost reduction; on grain output increase and agricultural benefit improvement; on soil erosion reduction and farmlands protection; on water storage and preservation of soil moisture; and on prevention of farmlands dust emission and improvement of ecological environment. It also belongs to an agricultural scientific and technological measure with synchronous economic and social benefit, giving attentions to both current and long-term benefit and realizing “win-win” between farmers and state.

Being part of north drought areas, Henan province totally has more than 38,000,000 Mu dry land areas, which occupy about 40% farmland areas of the whole province. Fact that only about 1% protective tillage areas in drought areas of Henan province that had been popularized and demonstrated for 4 years, shows the huge development potential and aboard foreground of protective tillage, it also indicates that we will shoulder heavy responsibilities for the popularization of protective tillage. Still more, it requires people who engage in the popularization of protective tillage to observe and think in multiple point of views and channels, so as to facilitate experience summary, perfect and
improvement of current operation mechanism, and enhance our popularization, service level and quality, and then make our due contributions for the construction of socialist new country and sustainable development of rural economy.

Application of traditional technique methods and modern high technology

Methods that we apply currently for the check and testing on protective tillage effect are basic traditional routine ones. However, these methods can’t adapt the development of protective tillage technique any more. Protective tillage is a systematic project integrated with multiple subjects including agriculture (agronomy), agricultural machinery, forestry (sandstorm forecast and calamity evaluation), land and resources, meteorology, environmental protection evaluation (total suspended particulate matte density in the air, etc.), medium and long-term natural disaster forecast, rather than single agriculture (agronomy), agricultural machinery, soil, plant protection or other departments. Due to multiple natural factor effects on agriculture, we shall find out sandstorm reasons and mechanism combined with rose map and hydrological data of meteorological wind direction, pressure and speed in previous years, so as to make right judgment and countermeasures. As sandstorm and dust emission are natural phenomena existed for a long term with frequent fluctuations, we can’t simply evaluate governing work efficiency according to annual situations. We shall establish and perfect dynamic supervision and early warning system of sandstorm weather, establish mathematical models to dynamically analyze practical effect. (During the middle ten days of July 2006, State Meteorological Administration firstly appointed working personnel to Fujian and other places to shoot the actions of Typhoon--“Bilis”, obtained the first-hand materials of practical and on-site land situation of typhoon, which provides admirable references for the departments of agricultural machinery popularization)

Suggestions: Agricultural Mechanization Department, General Agricultural Machinery Popularization Station and Protective Tillage Research Center of Ministry of Agriculture and other units lead to organize, coordinate and integrate above multiple systems, subjects and departments technical experts to compose protective tillage technique expert team (which is not only comprised of experts from agriculture and agricultural machinery departments. At present, knowledge structure of protective tillage technique expert guiding teams in all areas is unreasonable, what is more, the technician knowledge structure is severely out of date.) By taking province as basic unit, applying modern high technology, adopting satellite remote sensing, telemetry information, GPS positioning and monitoring technique (presently, ±2cm accurate positioning of GPS has been realized), monitoring technique that take γ-ray near infrared detection, we shall make quantity value treatment and plant technical guidance for relevant protective tillage project points (counties, cities and areas) from implementing areas to plant diseases and insect pests testing, from grain output to soil, water, available nutrient and other key indexes, so as to make comprehensive appraisal and evaluation for protective tillage projects. If we still apply current “small farmer production” testing technique and methods, such as for the yield survey of grain output, we still use an iron ring manual operation to test, use manual farmlands measurement, even without a basic geodetic instrument, it is hard to ensure the accurate obtained data as well as providing accurate scientific reference.

Problems existed in protective tillage machinery

Price performance ratio of protective tillage implements
The current wheat no-tillage seeding machine is with high price, heavy load, easily blocked fertilizer pipe, entwining and hipping during working, which will lead to lower working efficiency, and lower economic benefit, thus it causes unwilling wheat no-tillage planting of farmers, and affects the popularization of protective tillage technique (shown in Picture 1) to a certain degree.

Picture 1: Wheat no-tillage seeding machine popularized in Henan province

**Inadequate quality and performance stability of implements with certain troubles**

Wheat no-tillage seeding machine is a new type machine with short application time. Though it has experienced continuous improvement and enhancement, the quality and performance of machines are still unstable with certain troubles. Main troubles of this machine are easily blocked sow (fertilizer) pipes; many fractures of rotary tillage blades; no measuring scale for the adjustment of sow and fertilizer amounts, difficult adjustment of seed (fertilizer) sowing amounts; with regard to heavy earth and soil moisture or a lot of straws, it will happen entwining and hipping of straws, and leads to seedlingless and seedingless ridges. Though we increase the amount of planting seed, seedlingless rate is still up 5%, even up 3% seedlingless ridges rate, which affects later watering and other operations. This type of machine has lower whole economic benefit compared with other rotary seeding machines (fore-rotary rear seeding machine or light rotary seeding machine), and also directly affects using and popularizing activeness of farmers.

**Inadequate functions of protective tillage implements with some problems**

Functions of current wheat no-tillage seeding machine are not perfect, the main exited problems are no banking of wheat no-tillage seeding machine, after wheat grow up, due to ridge forming carving and blocks of wheat at gully bottom, water can’t flow smoothly, thus it will lead to difficult watering. Some farmers are even unwilling to implement protective tillage due to troubled watering; wheat no-tillage planting adopts irrigation furrow planting, after harvest, though the depth of furrow decreases, soil at gully bottom is empty compared with solid soil under furrow, and affects the corn seeding quality; wheat no-tillage planting adopts rotary farming in belt shape, but the rotary farming width is large, quick soil piling up at the part of rotary farming, to speak strictly, it doesn’t meet minimum tillage and no-tillage requirements of protective tillage.
Smaller single land areas affect working efficiency

At present, land intensification degree in countries is not high, single land area is smaller, it requires seeds changing and fertilizer cleaning of seeding machine for each household, in this way, it affects seeding speed and reduces working efficiency to a certain degree.

Machine purchase price and economic benefit comparison

Wheat no-tillage seeding machine: purchase price is about RMB 8,000 Yuan, oil consumption for operation is 100 liter/100Mu, working efficiency is 3Mu/h, working price is RMB 35 Yuan/Mu, and the economic income for each planting season is RMB 10,000 Yuan.

Rotary seeding machine: purchase price is about RMB 6,000 Yuan, oil consumption for operation is 65 liter/100Mu, working efficiency is 10Mu/h, working price is RMB 25 Yuan/Mu, and the economic income for each planting season is RMB 20,000 Yuan. Compared with no-tillage seeding machine, this machine has merits of simple operation and maintenance, cheap price and high working efficiency, lower oil consumptions, thus it becomes first chosen model (see Picture 2) for the farmers in some project demonstration points.

Simple comparison and analysis for the problems and economic benefit of protective tillage machinery show that the popularization work of protective tillage is hard and long-term, which can’t be finished in a minute. We can’t reach our expected objectives and achievements during a short time.

Economic benefit analysis for protective tillage projects

In 2005, funds invested by Ministry of Agriculture, Henan provincial finance and demonstrative countries (cities and areas) is RMB 3,754,870 Yuan, self financing funds of farmers is RMB 3,848,384 Yuan, and the total investment funds is RMB 7,603,213 Yuan. Including: RMB 2,532,960 Yuan machine purchase subsidies, RMB 884,990 Yuan application subsidies and RMB 39,988 Yuan propagation and training fees. (See following table1)
Table 1  List for Funds Resources and Usage of Henan Protective Tillage in 2005

<table>
<thead>
<tr>
<th>Entity</th>
<th>Funds of Ministry of Agriculture</th>
<th>Local counterpart funding</th>
<th>Self financing of farmers</th>
<th>Total</th>
<th>Machine purchase subsidy</th>
<th>Application subsidies</th>
<th>Training fees</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bo’ai County</td>
<td>45</td>
<td>13.95</td>
<td>54.7</td>
<td>113.65</td>
<td>36.58</td>
<td>23.01</td>
<td>4.5</td>
<td>64.09</td>
</tr>
<tr>
<td>Huaxian</td>
<td>40</td>
<td>3</td>
<td>64.7</td>
<td>107.7</td>
<td>25.5</td>
<td>12.8</td>
<td>4.7</td>
<td>43</td>
</tr>
<tr>
<td>Xuchang County</td>
<td>40</td>
<td>23.36</td>
<td>64.7</td>
<td>185.89</td>
<td>47.36</td>
<td>12</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td>Xiuwu County</td>
<td>40</td>
<td>43.16</td>
<td>85.16</td>
<td>122.53</td>
<td>28</td>
<td>6</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Yichuan County</td>
<td>45</td>
<td>26.7</td>
<td>122.53</td>
<td>185.89</td>
<td>47.36</td>
<td>10.556</td>
<td>6.288</td>
<td>45</td>
</tr>
<tr>
<td>Mianchi County</td>
<td>20.22</td>
<td>6.44</td>
<td>26.667</td>
<td>32.1</td>
<td>4.27</td>
<td>1.8</td>
<td>20.227</td>
<td></td>
</tr>
<tr>
<td>Shanxian</td>
<td>20</td>
<td>8.13</td>
<td>28.13</td>
<td>40.23</td>
<td>7.3</td>
<td>2</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Shancheng District</td>
<td>19.95</td>
<td>11.7</td>
<td>31.65</td>
<td>43</td>
<td>7.1</td>
<td>2.4</td>
<td>0.45</td>
<td>19.95</td>
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<tr>
<td>Heshan District</td>
<td>10</td>
<td>3.7</td>
<td>13.7</td>
<td>17</td>
<td>2.4</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Lingbao City</td>
<td>20</td>
<td>6.2</td>
<td>26.2</td>
<td>32</td>
<td>4.1</td>
<td>2</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Xinzheng City</td>
<td>10</td>
<td>1.7</td>
<td>11.7</td>
<td>12.7</td>
<td>3</td>
<td>11.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liangyuan District</td>
<td>10</td>
<td>37.8743</td>
<td>47.8743</td>
<td>2</td>
<td>4.069</td>
<td>2.25</td>
<td>8.656</td>
<td></td>
</tr>
<tr>
<td>Long’an District</td>
<td>15</td>
<td>3.8</td>
<td>18.8</td>
<td>21.6</td>
<td>4.9</td>
<td>3</td>
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</tr>
<tr>
<td>Total</td>
<td>125</td>
<td>250.487</td>
<td>384.8343</td>
<td>760.3213</td>
<td>253.296</td>
<td>88.499</td>
<td>39.988</td>
<td>381.783</td>
</tr>
</tbody>
</table>

Remarks: Funds transferred by Ministry of Agriculture is all on the account. Local counterpart funding means transferred funds by provincial finance and implemented counties (cities and areas). Self financing of farmers means reported numbers made by all project implemented counties.

There are total 102,201.5 Mu test demonstration lands, after weighted calculation, if production increases 31.88kg/Mu, the total production increase will reach 3,258,184kg, cost reduction is RMB 35.6 Yuan/Mu, and total cost reduction is RMB 3,637,889 Yuan. Calculated as RMB 1.4 Yuan/kg of wheat, 1.4×3258184＝RMB 4,561,457 Yuan, and total cost reduction and production increase is RMB 8,199,300 Yuan. Calculated according to common economic investment and return rate= (term end number deducts term beginning number) / term beginning number ×100%. Seen from above 13 demonstrative points summary numbers (summary submitted to provincial station in the end of June 2006) of 2005 protective tillage, the investment and return rate is only 7%, deducting some unreasonable components, the result is lower than above calculated data. Acting on the spirit of taking charge for people and history, all kinds of testing data that we obtained must stand up historical check and test.

To achieve this, agricultural machinery popularization departments shall make right appraisal for funds input-output of protective tillage projects, and provide much more scientific references for the decision making of leading departments.

**Strengthening constructions of basic agricultural machinery popularization departments**

Due to a lack of technical personnel and lower technical quality of basic agricultural machinery popularization station, it can’t reach basic requirements of agricultural comprehensive information service by establishing “organic integration with three information carriers as telephone, television and computer to realize mutual advantages supplementing and interlink)” required by Ministry of Agriculture. Some demonstrative counties (counties and areas) only have one or two fixed phones without fax even less PC Message Processing Facility. Thus, it has no way to establish agricultural machinery affairs information sending system from ministry, province to demonstrative counties.
(cities and areas). Some project units, usually have one person to do this job, have to entrust basic rural personnel to assist testing inspection of protective tillage projects. Therefore, the obtained data accuracy can’t be ensured as well. Also other project demonstrative points have one person engage in protective tillage besides other works. According to the comparison and demonstration samples of the 3 popularized types (irrigable land, drought land and high productive land) 9 modes total 27 testing points in Henan province in 2006, we can’t finish the tested data during the same time period. Due to a lack of personnel, numerous basic personnel are tied and busy enough with their own affairs, some technicians in testing points can’t grasp relevant testing knowledge skillfully, the testing data is inaccurate, some data error can reach up ten times, all of these seriously affect the reliability and reality of the data.

With regard to the “inverse pyramid” structure of protective tillage projects, specific technician is infrequent here. Therefore, it leads to large undertake transfer of basic agricultural machinery popularization personnel.

Some basic popularization departments become the platform for the further studying, and the “school cultivating scientific and technological talents”. After winning prize, some personnel leave the departments immediately.

Therefore, firstly, we must formulate policies to stabilize the protective tillage popularization team as soon as possible; secondly, we must improve the technical quality of agricultural machinery popularization team, apply modern high science and technology to improve technical level and equipment of agricultural machinery popularization team, so as to adapt needs of modern large-scale agriculture. Both two aspects are indispensable.

**Strengthening funds management of protective tillage projects**

*Existed problems*

Several counties that implement projects take earning money from protective tillage projects as objective, striving for projects as “achievements in their official career”. After arranging the projects, they are not serious for the organization and implementation of projects, which affects the carrying out of projects to a certain degree.

*Strengthening funds management of the projects*

To strengthen funds management of the projects, we shall carry out open bid and bidding by acting on open, fair and just spirit for the feasibility report, establishment and review of protective tillage projects, and put an end to projects that rely on “relationship” and “favor”. We shall establish a whole set of evaluation system (which is similar to metrological authentication/examination ratification (acceptance) review criterion), make appraisal and evaluation for the units that apply for popularization of protective tillage projects, and strengthen funds management and use of the projects furthermore. (Suggestions: Protective Tillage Research Center of the Ministry of Agriculture brings forward and formulates protective tillage evaluation system and normalized serial documents like operation quality standard.)

*Regional integrated planning*

By applying advanced scientific methods, we shall make point to plane to regional integrated planning. Regional integrated planning that takes province as basic unit is recommended rather than the
dispersed points. Most demonstrative points are so far from each other, which can’t be seen the technical advantages and demonstration, radiation and driving functions of protective tillage. We shall make protective tillage become beneficial technical advantages for numerous farmers.

**Allocation and use of the popularization funds**

Allocation and use of the popularization funds is not the common relief and salvation for the lack of office funds. Because current protective tillage projects popularization is obtained under beneficial driving of popularization funds, it can’t be permanent. For large areas over which protective tillage project popularized, however, it can’t gain expected effect due to insufficient popularization funds. Counties (cities and areas) that are inadequate for the conditions can only finish the specified task. At present, all counties (cities and areas) are separated for working, thus it is hard to create innovative technical mode and experience. Only filling in forms basically, objectively and really according to the requirements of ministry and provincial popularization departments, the demonstrative points is busy enough, say nothing of other works.

**Worry about protective tillage projects**

If there were no popularization fund, would there be the stopping of projects, as well as abandoned popularization of protective tillage projects? Each person who engages in the popularization of protective tillage projects must think about this problem seriously. Through recent several years’ popularization of protective tillage, we must think about that what mechanism we shall adopt for the next step on earth.

**Strengthening funds auditing of the projects**

Current management mode is comprised of more than three investment subjects (ministry, province and county), and the administrative contract is signed between administrative subjects. Factors like cadre blocked, dependency management, separated finance, graded operation guide, policy regulation and control and indiscrète government affairs and government and enterprises, lead to absent and default funds supervision and management of protective tillage projects.

Therefore, we suggest social medium institutes to audit funds of protective tillage projects, and comprehensively evaluate the input-output of protective tillage.

**Conclusions**

It is no doubt that the implementation of protective tillage is a great cause beneficial to modern society and the future. With regard to current problems like rural labor transfer and employment and training, if these problems can’t be settled properly, it is hard to establish long-term mechanism for the popularization of protective tillage. This is beyond the referred pure protective tillage technique problem, for any common and large-scale popularized projects, we shall not only make comprehensive and long-term development strategic planning, but also give long time test and demonstration in the tactics of implementing projects. Assume bravely that, rural labor transfer in China is up 50%, if the government supports to invest funds and guide techniques, the protective tillage and no-tillage techniques will be carried out blazingly. If we want to implement former traditional agricultural operation mode of intensive cultivation, it is not enough. Only in this way, we can realize “win-win” easily. If we want to finish task relying on quick success and instant benefit, it is impossible, even it will bring us unexpected outcome.
“Failure to prepare is preparing to fail.” We shall be aware of our deficiency from achievements rather than indulging in self-admiration. How to innovate protective tillage and make it possess self-development thought with provincial and regional characteristics are rough tasks for us. By shouldering heavy responsibilities for the implementation of protective tillage projects, we must insist on the job continuously.

References


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Conservation agriculture on the western Loess Plateau: research practice, problems and advices

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Zhang Renzhi
Resource and Environment College, Gansu Agricultural University

Abstract: Definition of conservation tillage, conservation agriculture and its history, adoption of conservation agriculture around the world were reviewed in this paper. Referred to some of the results from conservation agriculture research had been done in the western Loess Plateau, the need of conservation agriculture adoption in the area was put forward. Obstacles preventing conservation agriculture adoption were: traditional conception on intensive and meticulous farming; lack of fund for transition from traditional agriculture to conservation agriculture; lack of management skills on conservation agriculture and strong conflict between stubble retention and lack of forage and fuel is conflict. To solve this obstacle to give way to a wide adoption of conservation tillage and sustainable agricultural development, new policy, training workshops and more demonstration works are needed to help conservation agriculture extension and adoption, government need to fund research and design of suitable machinery, and other required inputs for conservation agriculture.

Key Words: Western Loess Plateau, conservation agriculture, No-till with stubble retention

Definition of Conservation Agriculture and its history

Conservation Tillage

Conservation tillage is a generic umbrella term that includes several tillage practices and systems (Allmaras and Dowdy 1985). Consequently, various definitions exist and these have changed over time. It is variously interpreted depending on which subset is emphasized (Lee and Stewart 1983). Early definitions tend to be more abstract and emphasize crop residue cover rate and relative erosion (Mannering and Fenster 1983). Current definitions are more operational and tend to emphasize the soil cover threshold of 30% (CTIC 1998). For example, Allmaras stated “When a conservation-tillage-planting system is defined rigorously, based on the requirement that at least 30% of the surface should be covered with crop residue” (Allmaras and Dowdy 1985). In 1984, the Soil Conservation Service changed the definition to: “Any tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 184 kg per hectare of flat, small grain residue equivalent on the surface during the critical wind erosion period. Two key factors influencing crop residue are: a) the type of crop, which establishes the initial residue amount and determines its persistence; and b) the type of tillage operations prior to and including planting.” (CTIC 1998).

Conservation Agriculture

Conservation agriculture (CA) is now widely recognized as a viable concept for practicing sustainable
agriculture. Grouped under the title “Conservation agriculture”, an inner-related and synergetic set of principles and practices have developed to combat land degradation, falling soil fertility, rapidly decline production levels, inefficient use of scarce water resources and desertification. The four principles of CA are: a) maintaining soil cover with plant residues, b) reducing mechanical soil disturbance by tillage, c) restricting in-field traffic to permanent wheel tracks, and d) the use of crop rotations and cover crops (Benites, Derpsch et al. 2003).

**History of Conservation Agriculture**

Research on conservation tillage started when the “Dust Bowl” occurred in 1930’s. Soon after that, the Soil Conservation Service (SCS) and Soil Conservation Society of America (SCSA) came into existence in 1935 and 1945 respectively to start research on conservation tillage for soil and water conservation. In 1951, Edward H. Faulkner published a book titled as “Ploughman's Folly”, in the book he explained that the “Dust Bowl” was resulted from ploughing (Faulkner 1951). After that, conservation tillage research started widely around the world. But before 1977, for the term “conservation tillage” was called minimum tillage which aimed at reducing the number of tillage trips over a field (Uri 2000).

Yet tillage provided many benefits, including weed control and the creation of a favorable environment for crop sowing and emergence (e.g. Kuipers 1991), but tillage and stubble burning practices conflict directly with the conservation tillage, thus held back of conservation tillage development for a while. The discovery and commercial development of herbicides provided part of the solution. During the WW II, post-emergence herbicides were discovered (2,4-D and MCPA). Other herbicides followed in the 1950–1960s—including triazines etc. (Rijn 1982). With time, herbicides increasingly provided an economic substitute for the weed control function of tillage (Unger 1990). Another crucial component for mechanized agriculture was the development in the post-war years of planting equipment (direct seed drills) that could adequately sow through the mulch. Both the herbicides and planting equipment allowed for the successful establishment of crops while using conservation tillage. With further fine-tuning of the technology and favorable market developments, such systems became an increasingly attractive economic alternative for crop production on well-drained soils in the USA from the 1970s onward (Allmaras and Dowdy 1985). The USA is generally perceived to be the cradle of this technology—with a large body of literature to document the advances of research and its use (Hatfield and Stewart 1994). The success of the technology in the USA has generated substantial interest to replicate such conservation farming systems elsewhere. The practice of retaining crop residues as mulch is indeed increasingly reported from various corners of the world (Unger and McCalla 1980; Erenstein 1999).

Conservation tillage research in China started from early 1980’s, single techniques such as no-till, stubble cover etc. were introduced from overseas at that time. However, the adoption rate was lower due to traditions of intensive cultivation, although no-till and stubble retention achieved very good field results. From 1992, China Agricultural University, in cooperation with the University of Queensland and Shanxi Farm Machinery Bureau started conservation tillage experiment in Shanxi Province (Gao and Li 2003), mainly in development of no-till machinery for various of crops. From 2001, Gansu Agricultural University and Gansu Grassland Ecological Research Institute, in cooperation with the University of Adelaide, NSW Department of Primary Industries and Agricultural Production Systems Research Unit of CSIRO, started conservation tillage research on the western Loess Plateau of Gansu Province (Huang, Zhang et al. 2003; Li, Huang et al. 2004). The results
from all these research showed that conservation tillage is an advanced technology which can help to solve ecological environment problems, increase crop productivity, improve sustainability of rainfed agriculture.

**Adoption of Conservation Agriculture around the world and its potential**

Farmers and farming communities in several countries across a wide range of soils and latitudes have dramatically and rapidly adopted the conservation tillage. Worldwidely, there are 72 million ha using conservation tillage, in which approximately 47.5% in Latin America, 36.7% in United States and Canada, 12.5% in Australia and 3.3% in the rest of the world, including Europe, Africa and Asia (Table1). A lot of research on conservation tillage has been done in large areas under many cropping systems worldwide. In summary, the benefits from conservation tillage are as follows: a) increased yields; b) reduced fuel use and labor requirements; c) reduced need for external inputs due to signficant increases in organic matter; d) reduced erosion; and e) the return of biological diversity to the soil, particularly earthworms (Buckerfield 1992; Buckerfield, Lee et al. 1997; Chan 2001). In developed countries, conservation tillage is attractive to farmers primarily because of the potential for reduced production costs compared to convention tillage. The conservation profitability is of secondary interest in most cases even though they accrue from the use of conservation tillage (Allmaras and Dowdy 1985).

**Table1**  **Area under conservation tillage in the different countries**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>America</td>
<td>19,750,000</td>
<td>22,410,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>13,470,000</td>
<td>17,356,000</td>
</tr>
<tr>
<td>Argentina</td>
<td>9,250,000</td>
<td>14,500,000</td>
</tr>
<tr>
<td>Australia</td>
<td>8,640,000</td>
<td>9,000,000</td>
</tr>
<tr>
<td>Canada</td>
<td>4,080,000</td>
<td>4,080,000</td>
</tr>
<tr>
<td>Paraguay</td>
<td>800,000</td>
<td>1,300,000</td>
</tr>
<tr>
<td>North India and Pakistan</td>
<td>-</td>
<td>561,000</td>
</tr>
<tr>
<td>Bolivia</td>
<td>200,000</td>
<td>417,000</td>
</tr>
<tr>
<td>South Africa</td>
<td>-</td>
<td>300,000</td>
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<tr>
<td>Spain</td>
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<td>300,000</td>
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<td>Uruguay</td>
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</tr>
<tr>
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<td>130,000</td>
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<tr>
<td>Italy</td>
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<tr>
<td>Total</td>
<td>58,106,000</td>
<td>72,069,000</td>
</tr>
</tbody>
</table>

Source: *FAO; **Jose R.Benties,etc. International Soil Tillage Research Organization Conference
Conservation Agriculture is needed in the Western Loess Plateau

Conservation Agriculture is needed to reduce severe erosion

Severe soil erosion is one of the most serious problems preventing the development of the western Loess Plateau (Zhang, Liu et al. 2000; Huang and Zhang 2002). Reasons for severe erosion on the western Loess Plateau are many, and traditional agriculture has been one of the most important human influences. Traditional crop production practice involves intensive cultivation where it is common for soil to be ploughed three times and harrowed twice between harvest and spring sowing. The soil surface is left bare during the 7-8 month-long fallow, which coincides with part of the wet season. All stubble and residues are removed from the field at crop harvest for use as forage and fuel. All these practices exacerbate degradation of soils, promote erosion and reduce production potential. Consequently, local farmers are trapped in a cycle of soil degradation and poverty.

The severe erosion has been recognized by central and provincial governments, provincial strategies aim to reduce farmer reliance on grain production and retire crop land to forestry and grass (MOA 2001; Feng, Yang et al. 2003). However, the western Loess Plateau is an area with a long history of crop production and local farmers are reluctant to convert their cropland to grass and forestry (Shi and Shao 2000; Rui, Liu et al. 2002; Zhang, Fu et al. 2004). Furthermore, erosion problems will persist on cropland which is not converted. Therefore, development of effective agronomic practice is needed to reduce erosion, increase crop productivity, and thereby ameliorate poverty.

Conservation agriculture was developed in the USA to combat soil loss and preserve soil moisture (Bradford and Peterson 2000). It has been thoroughly studied under many cropping systems worldwide, including the USA (Wiese 1983). The potential for conservation tillage to contribute to effective and sustainable use of soils is indisputable (Blevins and Frye 1993). Therefore, developing conservation agriculture is an effective way to combat serious soil erosion on the western Loess Plateau while continuing crop growing.

Low crop productivity needs to be improved

Main crops in the western Loess Plateau are spring wheat, field pea, potato, linseed and millet and so on, surveys done in 2003 shown that average grain yield of spring wheat and field pea were only 0.98 t/ha and 0.79 t/ha under farmers condition, main crops’ yield was very low (Nolan, Unkovich et al.).

An experiment on different conservation tillage systems was designed for a one-year one-crop rotation of spring wheat and field pea, and implemented from August, 2001 in Dingxi, a typical semi-arid area on the western Loess Plateau, by Gansu Agricultural University. Six different tillage systems were involved in the experiment, they are: conventional tillage (T); no-till without stubble (NT); conventional tillage with stubble incorporated (TS); no-till with stubble retention (NTS); conventional tillage with plastic film mulch (TP) and no-till with plastic film mulch (NTP). Results in 2001-2005 showed that: NTS improved the rotation grain yield significantly while no-till without stubble retention had the worst grain yield compare to conventional tillage system. The average yield of field pea under NTS was 14%, 24%, 17%, 5% and 9% higher than T, NT, TS, TP and NTP respectively. The average yield of spring wheat under
NTS has 16%, 26%, 14%, 3% and 6% of yield advantage than T, NT, TS, TP and NTP respectively. The average system yield of NTS within 2 rotation cycles has 16%, 25%, 15%, 4% and 7% of system yield advantage than T, NT, TS, TP and NTP respectively (Huang, Zhang et al. 2003; Li 2006). Therefore, no-till with stubble retention is a system can improve crop productivity on the western Loess Plateau.

**Lower water use efficiency needs to be improved**

Rainfall is the only water resource for agriculture and living on the Western Loess Plateau. However, average annual rainfall at Dingxi is only 391 mm over the last 36 years, ranging from 245.7 mm (1982) to 564.5 mm (2003). On average, about 54% of annual rainfall is received between July and September (Figure 2). Almost all crops are mature before the end of July. Therefore, under the traditional agricultural practice, the soil surface is left bare during the 7-8 month-long fallow, which coincides with part of the wet season, and lots of water was lost through strong evaporation from bare soil surface during fallow, this gives rise to a very low water use efficiency.

Researches in the area done by scientists in Gansu Agricultural University shown that surface (0-10cm) soil water content under no-till with stubble retention was greatly improved up to 90% compare to conventional tillage, no big difference among different treatments’ water storage at 0-200cm, but, more water is available for crops and crops are able to extract more water from the soil under no-till with stubble retention(Li, Huang et al. 2005; Huang, Guo et al. 2006). Thereby, water use efficiency was improved by no-till with stubble retention, the average WUE of field pea under NTS cross years was 12%, 20%, 14%, 2% and 8% higher than that of T, NT, TS, TP, and NTP, respectively. The average WUE of spring wheat under NTS cross years was 11%, 21%, 9%, 2% and 5% higher than that of T, NT, TS, TP, and NTP, respectively (Li, Huang et al. 2005; Li 2006).

![Figure 2 Monthly rainfall in 1970-2005 in Dingxi, a typical semi-arid area on the western Loess Plateau](image)

**Labour can be saved and income can be improved by conservation agriculture**

Because of the low profitability of agricultural production, off farm income is getting more and more
important for local farmers on the western Loess Plateau. It is well known that conservation agriculture can save labour significantly compare with traditional tillage, therefore, even if conservation agriculture has no yield advantage, it is still preferable for this area.

Researches show that no-till with stubble retention is the practice had the highest profitability. After 2 rotation cycles of spring wheat-field pea, total profitability of NTS was 81%, 38%, 75%, 165% and 66% higher than that of T, NT, TS, TP and NTP. This is because not only cost was reduced by eliminating tillage operations under no-till with stubble retention, yield was increased too, consequently, profitability was improved greatly under no-till with stubble retention. With time, profitability of crop production in this system can be improved further with the further improvements on soil fertility and crop yield(Li, Huang et al. 2004; Li 2006).

Therefore, adopting of conservation tillage of no-till with stubble retention in the Western Loess Plateau is a high effective agricultural way to reduce soil erosion, improve crop productivity and WUE, increase farmers’ income, and agricultural sustainability in the area.

Main problems with Conservation Agriculture adoption in the Western Loess Plateau

Inrooted traditional conception on intensive and meticulous farming

Although China started researches on conservation agriculture since 1980’s, intensive and meticulous farming are traditions with a rather long history, traditional procedures of ploughing, harrow and sowing had been inrooted in farmer’s thoughts. Therefore, it is not easy to let local farmers to accept no-till with stubble retention, to accept conservation agriculture. Moreover, effects of demonstration also depend on farmers’ accept ability. Thereby, lots of work needs to be done on training farmers, technology demonstration and so on.

Extra fund is needed for transition from traditional agriculture to Conservation Agriculture

The western Loess Plateau is an area with low mechanization, where crops are always sown and harvested by labor and animal power. To adopt conservation agriculture in the area, suitable harvest machinery, planter, more herbicides and so on are required. From the machinery of view, big, sophisticated and expensive conservation tillage machinery is available, but it is not suitable for small scale land, small tractor power, poor farmer technical background and low economic ability in the area. Therefore, it needs to research and design for conservation agricultural machinery. However, Western Loess Plateau is one of the poorest area in China, lots of poor farmers can’t afford such required input. Thus, lack of fund is another obstacle preventing conservation agriculture adoption. Therefore, enough funds are needed for transition from conventional agriculture to conservation agriculture.

Lack of management skills on Conservation Agriculture

Any crop production system is a complicated system, because agriculture production is a continuous system, so is conservation agriculture. Farmers need to know all of practice details to make conservation agriculture working in the area. Therefore, to adopt conservation agriculture successfully, farmers need to be trained on detailed and complicated managerial skills with conservation agriculture.

Strong conflict between stubble retention and lack of forage and fuel is conflict

Conservation agriculture requires at least 30% of stubbles to be retained in the field, but local farmers also need the stubbles as forage for their animals and fuel for cooking and heating. Thereby, the
confliction between stubble retention and lack of forage and fuel is another obstacle for conservation agriculture adoption.

**Advises on adopting Conservation Agriculture in the western Loess Plateau**

*New policy is needed to help Conservation Agriculture extention and adoption*

Conservation agriculture is rather new in China, by the experiences on conservation agriculture adoption in other parts of the world, it takes decades of years to get to a wide adoption. That is, its extension and adoption is a long-term systems engineering. Therefore, related polices are needed to help extension and let farmers adopt conservation agriculture. First, a detailed plan for extension system should be made; second, government should organize and supervise all the extension work; third, government should guide farmers to solve the conflict between forage, fuel and stubble retention to increase the adoption of conservation agriculture.

*Hold training workshops and do more deminstration work*

It is necessary to do a lot of demonstration and training workshops to change farmers’ traditional conception on intensive and meticulous farming, to let more and more farmers know detailed managerial skills and advantages of conservation agriculture on saving labors, saving time, high efficiency, high yield and so on. Only through this way, can farmers adopt it reasonably.

*Fund reseach and design of suitable machinery, and other required inputs for Conservation Agriculture*

Since lack of fund is one of the biggest obstacles preventing conservation agriculture adoption in the Western Loess Plateau, government should help local farmers with enough fund for research and purchase of suitable machine and other required input, such as herbicides, sprayers and so on, to give way to a wide adoption of conservation agriculture and sustainable development in the western Loess Plateau.

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Major Issues and Solutions of Implementation of Protective Cultivation in Qinghai

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Abstract: This paper briefs the implementation of protective cultivation in Qinghai province and the achievements, then analyzes in details the major problems encountered in the process of implementing protective cultivation program, which include lack of sufficient awareness from some leaders and farmers, scarce of enough funds to carry out this project. In response, it offers five solutions, which are calling for strong administrative supports, constructing good demonstrative regions, sticking to the combination of agronomy and farming machinery in order to better up the system, importing and transforming new machinery and setting up sustainable development strategy.

Key words: protective cultivation, developing issues, problems, solutions

Basic Info about implementing protective cultivation program in Qinghai and its achievement

Qinghai province is located in the north west part of China, noted as the source of wind and sand. Since 2000, the protective cultivation research program was conducted by the local farming machinery station, which led to quite a few fruitful results. In 2003, Huangzhong County was appointed as the first county put this program into practice. In 2004, Huzhu County and Xinghai County were appointed as the second ones carrying out this program. In 2006, Datong county and Ping’an County were the third ones to be enlisted in the implementation of this program. By doing so, the protective cultivation technology has been finally introduced and spread far and wide in the area of Qinghai province.

In order to facilitate this program, the local farming machinery station put all efforts together to edit and comply a series of training literature and brochures, such as Crash course for Protective Cultivation Technology, Regulations for Protective Cultivation. Besides, it made full use of the mass media to popularize the technology and trained farmers and cadres in various ranking with the hope to enhance their awareness. By the end of 2006, the satisfactory results had been achieved. The area that were in the project of protective cultivation added up to 278,000 mu. And in 2005, this program has been awarded the third prize by the Ministry of Agriculture.

To sum up, the protective cultivation technology was quite effective, mostly due to the following reasons. Firstly, it suits the characteristics of local condition; secondly, it holds onto the combination of agronomy and farming machinery,thirdly,it strictly follows the procedure experiment demonstration popularization to spread its technology, which is in line with the natural and economic principles. Last, it exerts its potentiality in popularizing the technology, which helps farmers to accept it.
Major issues lies in implementing protective cultivation technology

The program has been carried out for nearly four years, and it is generally acknowledged that it is a hard though glorious task. It is true that this technology is obviously environment-friendly and beneficiary for the sustainable agricultural development, but a lot of problems are springing up too. If they are not overcome efficiently and effectively, it will hinder the further implementation of protective cultivation technology.

The problems are

1) Protective cultivation is an agricultural revolution, and greatly differs from the traditional agricultural cultivation in various ways. Facing with this new technology, a lot of farmers and even cadres show their inefficiency in accepting the new technology because of their poor education. Besides, the farmers cares about only their interests in the short but the protective cultivation is a long and transitional process.

2) Protective cultivation program is funded on the investment of farmers and local financing department. But Qinghai is an economically backward province. The average yearly income of every farmer is no more than 2000 yuan. Therefore, a large amount of investment should be poured into to carry out the protective cultivation program but in reality it becomes a mission impossible.

3) Qinghai province is an agro-pastoral area. In most of areas the oil-seed cabbages are planted, which are hard to establish crops rotation and also quite hard to get rid of weeds. Take Xinghai County, one of the counties carrying out this program for example, at the war against weeds, the best results are 80 percent but mostly are 50 percent.

4) The in-coordination lies in between imported planters and corollary technology, farming machinery and agronomy. For example, Qinghai is a dry land, so the level-planting is no better than ditch planting, but from the year 2003-2005, most of the planters imported are level ones. Furthermore, regarding agronomy, the line distance between wheat is 150mm, cabbage 350mm, oil-seed cabbage less than 150mm, but the ones imported for Shangxi, Shanxi, the line distances are much wider, which results in the low production of cabbage in Qinghai province; And some machinery are poor in quality and left a lot of room to be improved.

5) It is difficult to establish a long sustainable system. The ultimate goal of establishing a long sustainable system is to socialize and market-ize the cultivation, but in order to achieve this goal, it takes a long and gradual step. It needs the coordination from the governmental officials and the farmers. But considering the various limitations, a lot of farmers are still worried about its feasibility and dare not take risk.

Conclusions

1) To strengthen the administrative efforts to popularize this program, since most of oversea countries are sponsoring their farmers to carry out the protective cultivation technology, and Qinghai province is weak in its economic power, it is advisable that the central government should financially and politically supporting this program. In the meanwhile, it should cut down or cancel the fees imposed on the enterprises which produce farming machinery, taxation.

2) To build up demon area and carry forward the popularization of protective cultivation. The
farming department in various level should put great emphasis on the construction of demon area, lead farmers to adopt protective cultivation technology with consciousness.

3) To stick to the combination of agronomy and farming machinery. It is encouraged to learn from advanced oversea experiences in this field, and then exploit the technology in line with the local conditions in terms of natural condition, economic level, bug.

4) To work on the production and importation of new planters, especially the corollary technology. It is advised that the key labs should be established to study and research on the planters.

5) To enhance protective cultivation socialized and market-ized and gradually establish a long and effective sustainable development strategy for protective cultivation. Taking the real conditions of Qinghai province into consideration, firstly, it should better up the long-run planning of protective cultivation, and ensure that farmers and local cadres have great confidence on this program. Secondly, it should encourage to establish farming machinery association or other forms of organizations to be involved in this program, to regulate its service and to stimulate the people involved, thereby a long and effective sustainable development system being formed.

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Analysis on the Effect and Development of Technology of Conservation Tillage in Different Areas of Ningxia Hui Autonomous Region

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Abstract: 39 thousands hm$^2$ have been used on technology of conservation tillage in 9 demonstration counties from 2003 in Ningxia. With the extending the technology of conservation tillage, winter wheat planting problem has been solved successfully, summer corn seeding with no-tillage has been rapidly popularized in irrigated area, and comprehensive effect of seedbed strip rotary tillage was remarkable in semi-arid mountainous area, the advantage of grass seeding with no-tillage was clear in mid-arid zone. Extension of the technology of conservation tillage in Ningxia was in a sustainable development way.

Key works: Ningxia, conservation tillage, effect, analysis

Brief instruction of agricultural condition in Ningxia

Ningxia is situated at the middle-upper reaches of the Yellow River. It covers a total land area of 66.4 thousand km$^2$. Although the territory is small, there are many kinds of topography such as irrigated plain, desert, Gobi, grassland, arid and semi-arid loess hill, wet mountainous land. Southern of Ningxia is mountainous area and semi-arid area. Northern of Ningxia is the irrigated area by Yellow River. The middle part is arid area. Annual precipitation is about 183.4 to 677 mm, while annual evaporation is about 1500 to 2300 mm in Ningxia. Wind erosion gradually aggravate from southern to northern. The problems of Ningxia agriculture mainly include arid, fragile ecological, limit irrigation from the Yellow River and shortage of water resource. Therefore, the extension of technology of suitable conservation tillage in Ningxia, was a profound significant in reducing soil loss and increasing ability of fighting, water saving and environmental. But, The conversation tillage technology in arid farm on the edge of desert and irrigated area by Yellow River has no advanced experience as reference only CT experience in typical district.

Test and demonstration in irrigated area by Yellow River

General situation of trial area

6 trial plots respective in Pingluo, Helan, Lingwu and Wuzhong county of Yinchuan Plain area were selected for trailing. The total trial areas are 8 hm$^2$ and the conditions among them are almost same. Annual temperature is about 7.6 °C, annual precipitation and annual evaporation respectively are 187.2 mm and 1756 mm.. The main crops are wheat, corn and rice. Wheat intercrop corn is a main planting model in these area. The average yield of wheat are 5025 kg/hm$^2$ and average yield of maize are 7830 kg/hm$^2$. With ratio of 6:4 (the width of wheat tripe is 1.3m, the width of corn tripe 0.9m). The
model extent to vegetable and summer corn interplanting after the harvest of wheat, called three-dimensional plant structure in agronomy. Extension of winter wheat planting technology to north China is conducted by local government. Since irrigation is difficult before autumn seeding. The problem of worse emergence, death emerge cross winter is serious and blocked extension of technology, the step of extension of winter wheat planting is very slow. The farmers used to complex planting model have high expectation of land output due to water, fertilizer, sunshine, temperature etc. fitting condition. Because the agricultural conditions of water, fertilize, sunshine and heat are good enough in this area. It brings a lot of inconveniences for using agricultural machinery.

**Model and treatment of trial**

Because of predominant agriculture resources condition and high expectation of farmers to land output, the plant mode of trial must respect the mode of agricultural expansion and the choice of the farmers. So 3 planting models are designed in this area as below:

1. Wheat seeding with conservation tillage in spring/intercrop corn-------Wheat harvesting and straw spreading-----Summer corn seeding with conservation tillage-------Corn harvesting-------Land spending winter with high straw

2. Wheat and corn seeding with traditional tillage--------Winter wheat seeding by conservation tillage in autumn--------Intercropping corn in next spring--------Wheat harvesting and straw spreading--------Summer corn seeding with conservation tillage--------Corn harvesting--------Land spending winter with high straw

3. Rice seeding with traditional tillage--------Winter wheat tripe seeding with conservation tillage in autumn--------Wheat harvesting and straw spreading in next year--------Summer corn seeding with conservation tillage--------Corn harvesting--------Land spending winter with high straw

Seeding with no-tillage, seedbed tripe rotation seeding and traditional seeding are designed for wheat. Seeding with no tillage and traditional seeding are designed for corn.

**Evaluation and analysis of different treatment**

1. Spring wheat seeding with conservation tillage. No-tillage seeding and seedbed tripe rotation seeding influence greatly by freezing soil, and if meeting ice the quality of seeding will worse resulting in output reduction, so it is not suited for popularization. It is easy to defrost when soil defrosts and the output is more or less the same as traditional seeding. Although the cost of seeding reduces, the time of seeding is limited and it influence planting of following crop. Therefore, the farmers are difficult to accept. This technology for spring wheat does not have the advantage of extension.

2. Winter wheat/grass seeding with conservation tillage. Compare to the traditional tillage, the fulfilled trials that were used technology of conservation tillage have stated advantages. Such as higher rate of crop emergence, stronger emergence, lower rate of death of wheat emergence during wintertime and etc. The reasons for those are deeper seeding depth and higher soil moisture, especially no-tillage tripe rotation seeding trailed in 2005. In the harrow the seedbed has a better effect of preserve soil moisture after compaction, it is advantageous to gather rain and storm and there is a damp climate relatively. The advantage of the trial of upper rice is obvious during seedling period so it invites a good many of the leaders and experts to visit. But agricultural machinery is not good at the precaution of disease and field management, it occurs yellow leaf’s disease when heading
resulting in reduction of output. While the trial of upper corn grows well obviously and it doesn’t occur disease, so the output is high comparing to traditional seeding. Because the yield has something to do with various agricultural factors, we can’t give a conclusion according to the yield only, so it needs cooperation agricultural machinery with agronomy for further research. But it can be sure that winter wheat no-tillage seeding has resolved the problems of low crop establishment and seedling which haven’t been resolved by agronomy all the time. Winter wheat with no-tillage trip e rotation seeding after the harvest of rice grows well. Local agricultural experts are very satisfied and it has great expending potential.

③ Corn seeding with no-tillage. Summer corn no-tillage seeding after the harvest of wheat saves time, labor and money and it can alleviate the busy problem availably. The farmers welcome summer corn no-tillage seeding very much since it has advantages of saving production cost and increasing benefit. The technique has been popularized at present and the effect of trial and demonstration is obvious.

④ Weeds control. Selecting high stem wheat variety is the better way for wheat weeds control. This method neither pollutes nor increases input, just lowering the ability of anti-lodging. Because the dose is difficult to control, and weeds control by machinery is more suitable for corn in irrigated area.

Situation of trial and demonstration in mid-arid zone

General situation of trial area

Yanchi and Zhongwei were selected for trial. The total trial areas are 6 hm². Annual temperature is about 8.1 °C, while annual precipitation and annual evaporation are 225 mm and 2129 mm. The main crops are wheat, corn, foxtail millet and hog millet. A handful of farmlands has irrigated condition and the ratio of irrigation to drought is 6:4. The grounds of trial are made at the drought that closes to the desert and has irrigation and at the pure drought without irrigation. The crop yield is very low since the land is poor and arid. The yield of wheat in arid land is only 1650 kg/hm².

Model and treatment of trial

① Previous crop harvesting with keeping straw + subsoil
② Corn seeding with conservation tillage in arid area
③ Corn seeding with conservation tillage in irrigated area
④ Wheat seeding with conservation tillage in arid area
⑤ Wheat seeding with conservation tillage in irrigated area
⑥ Traditional plating
⑦ Subsoil + grass seeding with no tillage in grass planting area

Evaluation and analysis of different treatment

① It is not suitable to extend seeding with conservation tillage for wheat and corn in the area without irrigation. Compare to wheat seeding with conservation tillage, the output is more or less the same. It is difficult to reach the recognition of government and farmers. The corn with no-tillage seeding is difficult to seedling, even seedling, it is also a late seedling, the growth is slow, the plant is thin and feeble, and the yield is very low. Traditional planting with plastic has higher crop yield, therefore, it is quite difficult for farmers and government to accept using seeding with conservation tillage.
Seeding with conservation tillage has advantages of saving production cost and increasing benefit in irrigated area. Under the condition with enough headwater, the ability of reservoir after subsoil is strong and the time of irrigation is long. Under the condition that water can’t satisfy the need of irrigation. Compare to traditional planting model, the crop yield and benefit of crop seeding with conservation tillage increase a lot. Therefore, crop seeding with conservation tillage has great potentiality in this irrigated area.

It has nice effect to seed grass with no tillage after raining in desert area. Compare to manual work and air seeding, grass seeding with no tillage has high grass emergence, and the rate of grass covering increased to 68% from 30%. 18.7 thousand hm\(^2\) grass has been planted with no tillage during recent three years in total.

**Situation of trial and demonstration in semi-arid mountainous area**

**General situation of trial area**

5 trial areas from Yuanzhou, Xij and Longde county of Guyuan city were selected for trial. The total trial areas are 6.7 hm\(^2\). Annual temperature is about 5.6\(^\circ\)C, while annual precipitation and annual evaporation are 558 mm and 1550 mm. The main crops are winter wheat, corn, potato and hog millet. The crop yields vary a lot with the rainfall. The yield of winter wheat is only 800 kg/hm\(^2\) during arid years and the yield of winter wheat 2205 kg/hm\(^2\) in 2003 with abundant rainfall.

**Model and treatment of trial**

Winter wheat was only selected for trial since plastic is normally used for planting corn due to the low temperature.

1. Harvesting with keeping high straw + seeding with no tillage
2. Harvesting with keeping high straw + subsoil + seeding with no tillage
3. Harvesting with keeping high straw + subsoil + seedbed triple rotation seeding
4. Traditional planting

**Evaluation and analysis of different treatment**

1. Harvesting with keeping high straw + seeding with no tillage. Compare to traditional planting, the yield of wheat decreased 45.9%.
2. Harvesting with keeping high straw + subsoil + seeding with no tillage. Compare to traditional planting, the yield of wheat increased 28.8% and the comprehensive economic results were 1012 RMB/hm\(^2\).
3. Harvesting with keeping high straw + subsoil + seedbed triple rotation seeding. Compare to traditional planting, the yield of wheat increased 41.4% and the comprehensive economic results were 1386 RMB/hm\(^2\). It is estimated that the model will be the best model for winter wheat planting in semi-arid mountainous area.

**Conclusions and suggestions**

*Extending technology of conservation tillage must think about the local objective reality.*

From the trial and demonstration of technology of conservation tillage in different area of Ningxia, we may conclude as below:
It is not suitable to extend seeding with conservation tillage if annual precipitation of the area is lower than 400mm and the area can not irrigate.

It should be supported to extend winter wheat seeding with conservation tillage in the Yellow River irrigated area.

Comprehensive effect of seeding with conservation tillage is the most remarkable in semi-arid mountainous area. Therefore, the governments should pay more attention to support this area for extension of seeding with conservation tillage.

**Extending technology of conservation tillage must insist on “effect is first”. Basic on increasing the crop yield, saving production cost and increasing benefit, “conservation” will have more significance.**

It is a fact that average land per farmer is shortage in China. In this case, crop yield is always the important thing. Therefore, it is better to select the demonstration area, which can increase crop yield and save production cost at the beginning time of extending technology of conservation tillage. It is harmful to select bad condition area if only thinking of “conservation”.

**Extending technology of conservation tillage must insist on combining agricultural machinery with agronomy.**

From the trial and demonstration lands in irrigated area, we found that the condition of growth of winter wheat by using technology of conservation tillage was better than the land that planted and managed by agricultural organization at the beginning time. But the crop by using technology of conservation tillage lost the advantage later and its yield was lower than the land planted and managed by agricultural organization. Therefore, combining agricultural machinery with agronomy is very important for extending technology of conservation tillage.

**Extending technology of conservation tillage must insist on innovating technology and stretching intension.**

In order to extend more area to use technology of conservation tillage and get better effect, it is better to innovate technical content of conservation tillage to resolve the problem of using of farm’s fertilize and controlling of pests. It is also better to encourage to use the technology of conservation tillage separately. Such as, grass seeding with no–tillage also belongs to the content of extending technology of conservation tillage.

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Where Is the Way to the Conservation Tillage Technology in Xinjiang

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Abstract: The ecological environment of Xinjiang is abominable. It is the important area to apply technology of Conservation Tillage. But there were only more than 300,000 units of area which had apply the technology of conservation tillage framing. Lots of reasons affect application of the Conservation Tillage, like the traditional ideal in grain, shortage of capital guarantee, policy support. We should improve cognition, renew concept, draw policy and promote extending.

Key words: Conservation Tillage Farming

Introduction
Our municipality is a serious aridity and semiarid area, at the same time it is one of the sand dust devil and zoology environment relatively abominable area, so it should turn into the emphases section of extending conservation tillage technology. But the fact is widely divergent. Until the end of 2005, our municipality demonstration extended the conservation tillage technology acreage was only more than 300 thousand units of area. The majority area of the north in our country already came into a large area spread phase, the inner Mongolia which is neighbour to our municipality have owned the area of conservation tillage technology attach to more than 5000 thousand units of area.

The revolution of agriculture cultivation system
The conservation tillage is a new-style agriculture cultivation technology and it takes the no-furrow technology as core. It request to cancel the plough and plant directly in the precondition of reserving the earth’s surface deck and maximum decreasing the surface soil destruction, and mostly control the weed and plant diseases and insect pests by using the pesticide. Because it made for protecting water and soil, we call it conservation tillage technology. Its former name is “no-furrow method”, with the research depth thoroughly and scale-up, we have discovered that no-furrow method only adapted part of soil and nature condition, since 1980 it has developed into conservation tillage technology.

Conservation tillage is propitious to hold and resume the self-protection and construction enginery of soil, it can turn the task of agriculture cultivation into taking production and environment production for assignment from the past only taking production for assignment. So since the mechanized farming appeared, it is another revolution of the agriculture cultivation technology.

Conservation tillage is an advanced engineering technology which has boosting up the sluice ability of soil and sufficiently using the rainfall. It can improve the efficiency of water resource utilizing by protecting water and soil and exert sufficiently the predominance of nature resource collocation which takes the water and soil as corn. In the same time of increase production and harvest, it attends to protect agriculture environment and is an importance approach which can get rid of aridity and keep within limits the depravation of environment as well as improve agriculture continual development.

A great deal of facts inside and outside of our country and some years practice in our area sufficiently
proved that the conservation tillage has 6 benefits, they are restraining cropland raising dust, prevention water and soil losing, making the soil fertile, saving and defending water, decreasing the cost of agriculture production, and increasing the yield of provision.

Conservation tillage as a modern time farming technology, at present there are more than 70 countries applying and extending it, the total area already reached to 2 hundred million hectare. The UN grain and farming organization estimated that the conservation tillage is a revolution of cultivation technology and a method of agriculture production and environment production. It will bring much more active effect in continual development of agriculture. A lot of country practice which father the sand dust devil proved that carrying out the conservation tillage in cropland is one of the important methods to father the sand dust devil. Sinkiang locate the northwest headstream of sand dust devil, and it is a serious aridity and semiarid area. As a long time, because of the soil suffered from the eroding of wind and water, the quality of the plantation degenerated day by day, the phenomena of water and soil lost seriously day by day, agriculture environment exacerbated gradually. In that case, we will have available plantation less and less. From 1980’s we built conservation tillage experimental unit, and in 1990’s we made it become demonstrate and extending, until 2002 agriculture department built the conservation tillage demonstrate section in 13 province, city, municipality in north of our country. Yinzisha, Qitai, Aletai etc., these county or city in our municipality have became agriculture department demonstrate area early or late, now 100 conservation tillage demonstrate county have been already established and the conservation tillage acreage have exceeded more than 10000 thousand unit of area in demonstrate area.

The technology was introduced early but the tempo was slowly

The no-furrow planting technology as the key technology was introduced in our municipality in 1980s, our municipality is one of the early developing the conservation tillage province. At that time, in the Yinzisha and Bachu county of Kashi, the local farmer adopted wheat by destroy-stubble seeding-machine and directly seeded corn after summer harvest of winter wheat without furrowing, because in this way can we reduce the working procedure, increase the output, shorten the farming time, the farmer supported it very much. Since 1990s, some farmer used the routine seeding-machine and no-furrow technology to seed wheat in the loose soil of brae at some county in north of Sinkiang, until 2001, the acreage of no-furrow planting technology in the aridity area have already reached more than 100 thousand unit of area. Deep-loosen technology as saving water technology also extended to a large acreage in part of irrigation area. All the things have paved the way to our conservation tillage technology and accumulated many experience.

Since 2002, farming machine department established some kinds of conservation tillage demonstrate area more than 10 and 20 counties introduced conservation tillage technology which was through developing project of national agriculture department and municipality science and technology and so on. Because of various reasons, our section owned this technology acreage only 300 thousand unit of area until the end of 2005, the tempo was far away from a lot of other province.

What’s the reason of extending difficulty?

The traditional idea in grain

Although the conservation tillage is an advanced cultivation system, everyone was difficult to accept it at short time. Some people thought that cultivate land must deeply and intensively cultivated, only in this way can plant grow well, another people argued that conservation tillage is the measure of lazy
beggar. A farming machine department technology personnel who developed the conservation tillage in grass roots also met various difficulty because of this traditional idea. Some cadre of countryside didn’t understand when the conservation tillage was extended. They asked: cultivating land without plough, what our tools used to do? If you want to renew these tools, it is an unimaginable thing for these poverty areas. In fact, according to municipality farming machine department survey, if 20000 thousand units of area provision crop all turned to conservation tillage, only needed to prepare corresponding no-furrow seeding-machine, deep-loosen machine and another plant protect machine, and plunged into capital about 5 hundred million yuan, while 20000 thousand unit of area provision crop at least could save the cost of production 3 hundred million yuan, save water 3 million stere, increase output 400 thousand ton every year, increase receiving and saving cost approximately 10 hundreds million yuan, you can take back all the devotion in five years.

Be short of capital guarantee

Agriculture department regard the extending conservation tillage working as emphases, and they quite concern conservation tillage working in Sinkiang. From 2002, we begun to take on the conservation tillage demonstrate extending job of agriculture department, at present we have established three demonstrate section. Although the nation devotion only account for 30 percent of entire item capital, 40 percent capital of the rest still needed farmer self to prepare for, only in this way can conservation tillage working go with a swing. The farmer of Kashi area has a high enthusiasm and the leaders have a high understand, but so short of capital that conservation tillage extending acreage cannot enlarge straight.

Farming machine department isolation

Conservation tillage is a system engineering, it comes down to agriculture, environment protect, finance, science and technology etc, at the same time it is necessary to gain help and aid from above units and all society. While in our section only the farming machine department reacted on, the other department and units did not take part in this working, even some units set obstacle for conservation tillage. For example, last year a missionary of one farming machine station went to the weather bureau and hoped they can offer some weather data for past years when developed the conservation tillage working, the weather bureau personnel asked so high price at that moment, that the department of agriculture machine met a big difficulty in developing working. Municipality convoked conservation tillage conference many times, almost all attendees were in the farming system.

Policy lag and lack composition of forces

Some provinces which do well with conservation tillage working always put the conservation tillage working on overall situation for accelerating the development of agriculture. Benjing, Tianjing, Hebei, inner Mongolia, Shanxi, Qinhai, etc, their government came on decision and idea that sustain document of conservation tillage and accelerate the conservation tillage. Enter the conservation tillage into schedule and draw development programming. Shunyi section in Beijing have listed the full-scale fathering the bareness cropland into one of the job which the government done for local people. Beijing also intended to cancel furrow within 3 years. Shanxi, Tianjing came on the conservation tillage locality standard, and made the conservation tillage walking up to the regulation and standardized orbit. However, all levels of our government still have no document of conservation tillage to guide us. Even there was no document of conservation tillage in “11·5” programming which guided our development of economy and society in the future 5 years. Because short of government
support, the agriculture department of government also lacked of uniform command and harmony, there had no composition of forces been formed. At last, the process of extending conservation tillage fall across very large difficulty.

**Where is the way to accelerate extending?**

**Improve cognition and renew concept**

These years, the practice of our country indicated that the conservation tillage was an agriculture science and technology project measure which could own economy benefit and zoology benefit at the same time, and consider the current and long-term simultaneously, and profit both the farmer and country. In 2005 and 2006, the number one document pointed out it is necessary to reform the tradition way of cultivation, and develop the conservation tillage. This sufficiently illustrated that the center make high difference to conservation tillage. The department of agriculture also ranked the conservation tillage into important extending item during “11·5” and important content in the “new country building” program. At the same time, the center made the extending conservation tillage as one of 15 jobs for farmer. If you want to fulfil the number one document, the key is to spurn the bondage of traditional cultivation concept. We should understand the great signification from the standard of fulfilling scientific development view and agriculture durative, and of establishing economy society and improving the environment.

Our section is the typical oasis agriculture, a lot problems such as aridity and soil sanded always involved with the development of agriculture production, in order to solve the conflict which is “not only improve the output of provision but also save the water of agriculture, and not only develop the production of agriculture but also protect the environment”, our municipality have explored for every section for several decades, although acquired any effect, but it haven’t solved the problem in radically. Several decades practices inside and outside our country proved that conservation tillage as a new pattern agriculture cultivation mode has got very remarkable benefits from society and zoology. Conservation tillage posed all-important significance on increasing agriculture production ability. So we must improve our cognition and fulfil the spirit of center consciously.

**Draw policy and promote extending**

It is imperative to extend conservation tillage working, all levels government must give enough support. The first, we should enter the conservation tillage working into the total program which is mainly about development of economy and society, and bring into the important schedule, take it as important content of building the new country. Secondly, we can come on some policy to sustain the conservation tillage working, such as give peculiar at capital and item, give guarantee at exploitation of scientific research, establish conservation tillage demonstrate area. The third one is reinforce the management and harmony between every department, beside that we must enhance the linking of production, study and research, then formed composition of forces. The forth one is enhance the education of technology personnel, build a high quality agriculture technology troop.

**Increase publicize, improve cognition**

It is difficult to extend conservation tillage in our section, one of the main problems was lack of drumbeating. It is acknowledged that not only some farmer did not understand the conservation tillage but also a lot of leaders didn’t. There are many people only take no-furrow planting as conservation tillage technology. The history of traditional cultivation had several thousand years, while the
conservation tillage had beginning at moment. Unless increase the degree of drumbeating, it is quit
difficulty to extend conservation tillage job. Therefore, all levels government must increase the degree
of drumbeating, through various drumbeating forms to make the farmer indeed perceived that the
conservation tillage technology takes them the benefits, and also in favour of ensuring the
environment and agriculture continuance development. From the case of developing conservation
tillage technology of our section, we found that generally public sustained this technology positively.
In despite of some farmers limited by low culture level and accepting the new things and technology
slowly, only if take them glimpse at the effect and receive boon, they finally accept this new
technology. It is necessary that only the leader at first study the knowledge of conservation tillage
technology, they must understand and then give a good drumbeating and better extending, only in this
way can our section conservation tillage technology became more and more health.
Effect of Furrow Opener for No-till Wheat Planter on Seed Zone Properties and Root Establishment

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Abstract: The furrow openers are one of the key parts of the no-till planters, its structure can effect the soil disturbance and the root growth. Experiments were conducted in Daxing district of Beijing city containing a loam soil to assess the effect of the soil disturbance, the wheat root, the plant weight and the yield of three furrow openers. The furrow openers compared were the tine opener, the single-disc opener and the rotary opener. The result showed that different furrow openers can form different the seed groove, so it can effect the seed germination, the root growth and the yield. The rotary opener can form the loose groove, compared to the tine opener and the single-disc opener, gave the maximum the counts of the adventitious root and tillering counts, but the soil disturbance is the biggest, up to 40~60%, so the fuel consumption is the highest; The minimum yield and the counts of the adventitious root and tillering counts were obtained with single-disc opener, but the soil disturbance is the lowest, just about 10~15%. The coefficient of the tine opener was obtained between the others furrow openers. So we should design and elect the suitable furrow openers which can form shatter sub-surface seedbed and minimum soil disturbance.

Key words: conservation tillage, no-till drill, furrow openers, seedbed

Introduction

In the last few years, the environmental and economic implications of conservation tillage have led to demonstration and extension of no-tillage in the double cropping situation of North China (Gao Huanwen et al., 2004; Liu Lijing et al., 2004). The requirement of no-till seeders, including the anti-blocking capability and planting quality, is higher than conventional seeders when no-till plant winter wheat after harvest maize because the maize straw mulch is more and the maize root is bigger. After research and experimentation of several years, two types no-till wheat seeder which included 2BMDF-12 type no-till wheat seeder and 2BMFS-6/12 type no-till wheat seeder have been resolved the question of anti-blocking. In additional, the John Deere 1590 type no-till wheat seeder can no-till plant wheat (Yao Zonglu, 2005). But there are some problems for the planting quality, namely need to research the furrow openers form the seedbed which in favor of the seed germination.

Compared with conventional seeders, the no-till seeders have high requirement to the furrow openers which can form seed bed except have better anti-blocking capability. The reason is that the furrow openers can form seed bed in loosen soil and require little horizontal force in the tilled soil, but in the no-till soil, the furrow openers require more horizontal force because the soil surface stability and more straw mulch. So the furrow openers must cut seed groove of 3~5cm wide and 8~10depth, it can supply the seed bed in favor of the seed germination and the root growth, at the same time, the furrow openers should reduce the soil disturbance. Gao Huanwen et al., 2004; Jiang Jinlin et al., 1996; Su Yuansheng et al.,1994)
Many investigators have studied the effects of various types furrow openers, including hoe, shoe, shovel, disc, chisel-type furrow openers, on soil disturbance, soil moisture in the furrow, evaporation rate of soil moisture, variation in depth of sowing in the laboratory soil bin or field condition (Baker 1976; Ozmeri 1986; Baker & Afzal 1986; Damora & Pandey 1995; Choudhary & Baker 1982; Tassier 1991a, 1991b; Doan et al., 2005). These investigations analyzed and evaluated the characteristic of different type furrow openers effect soil physical properties. But there were less investigation on the furrow openers form seed bed effect the wheat root in the no-till field under straw mulch.

So the objective of this paper is that evaluated the furrow openers, including the tine, the rotary and the single-disc opener, effects the soil disturbance and the wheat root growth. It will supply theoretically to adoption or design the furrow openers, and it can help to extensive the conservation tillage.

Materials and methods

Description of Equipments

Three contrasting furrow openers were assessed in this study: The 2BMDF-12 type strip-shatter no-till wheat seeder adopt the tine opener, the 2BMFS6/12 strip-rotary no-till wheat seeder adopt the rotary opener and the John Deere 1590 type no-till wheat seeder adopt single-disc opener.

The tine opener

The 2BMDF-12 type strip-shatter no-till wheat seeder which has been designed by the Conservation Tillage Research Center of MOV adopts the tine opener come from Australia. The groove profile was typically is U-shaped (Fig.1-a), the advantage is that have better the penetration ability and can form a moisture groove, the disadvantage is that an increase in the soil disturbance and the horizontal force increase furrow depth.

The rotary opener

The 2BMFS6/12 strip-rotary no-till wheat seeder which was manufactured Nonghaha Machinery Co., Ltd in Hebei Province adopt the rotary opener. Its feature is that the no-till seeder adopt strip tillage which rotary tillage the seed bed, so it can reduce the fuel consumption as compare to the rotary tillage total soil. The rotary opener can scatter the straw mix with the soil, and form the loosen seedbed. (Fig.1-b)

The single-disc opener

The John Deere 1590 type no-till wheat seeder which was manufactured by John Deere experiments
design consisted in a complete randomized factorial with three replicates of each test. The previous crop was corn, with undisturbed soil and under stubble mulch conditions. Total crop residues amounted to 26,000kg/ha in fresh weight before no-till seeding. The soil temperature at 0 to 50 mm of 18°C, the soil gravimetric water contents at 0 to 5cm depth of 10.2% Machinery Co., Ltd adopts the single-disc opener. The single-disc opener which the diameter was 460mm was mounted on a compound angle of approximately 7º. The shape of groove is V type (Fig.1-c), the feature is that it have minimum the soil disturbance and the depth variation. But the penetration of the opener is a problem, especially under stubble mulch condition due to the tendency of the opener to push the dry soil and stubble into the soil groove. It can effect the performance of the no-till seeder.

Field Trials

Field tests were conducted at a private farm with three-years history of conservation tillage in Beijing city Daxing district. The area of the field was about 30ha, so there were about 10ha per no-till wheat seeder, and the and at 5~10cm of 13.6%, the average soil bulk densities was 192.7×10⁴Pa based on measured of 50 randomize site.

Winter wheat was no-till planted on 7~10 October 2005 with above no-till wheat seeders at 375kg/ hm² of seed and 225kg/ hm² of fertilizer. Every no-till seeders were adjusted to provide soil cover of approximately of 40mm over seeds.

The tractor matched with no-till wheat seeders was TN-654L.

Measurement

Soil disturbance

The furrow opener need to the less soil disturbance during the no-till planted wheat, it can achieve straw mulch and reduce the power requirement of tractor. The theoretically soil disturbance (η) as follows:

\[ η = \frac{d}{D} \]  \hspace{1cm} (1)

Where η—the theoretically soil disturbance; d—the width of the furrow opener; D—the row space;

Soil disturbance at the surface caused by the furrow openers was measured after no-till planted. The soil disturbance (η) as follows:

\[ η = \frac{d'}{D} \]  \hspace{1cm} (2)

Where η—the soil disturbance; d’—the width of the seed groove after no-till planted; D—the row space;

The adventitious root and tillering counts

The wheat root at 0 to 20cm depth was dug at the regreening date (15 March 2006). Then the adventitious root and tillering counts was measured after washed roots.

The plant weight
The plant was oven-dried at 70°C for 48h, and weighted the per-plant weight.

The wheat yield

The wheat samples were hand collected within 1 m² area confined by a quadrant at five random locations per site before harvest at 15 Jun 2006. Samples were brought to the laboratory and threshed to obtain the grain. The coefficient, included the high of plant, the length of spike, the counts of spike and the weight of 1000 grain, were measured. The grain samples were oven-dried at 60°C for 72h to determine the dry matter yield.

Results and discussion

Soil Disturbance

Soil disturbance at the surface was significantly different among three furrow openers. The results in the table 1 showed that the furrow openers have significant effect on the soil disturbance and the fuel consumption. The soil disturbance of the rotary opener was the highest, up to 40–60%, compared with the others opener, because the rotary opener need to rotary the seedbed which can form shatter groove, and it displaced soil from within the sowing row to between the sowing rows, so the fuel consumption was up to 17.5 L/hm². For the single-disc opener, the soil disturbance was the lowest, just was 10–15%, because it created a groove or slit without any sideways shatter compared with the rotary opener, so the fuel consumption was also lowest. For the tine opener, the soil disturbance and the fuel consumption were 15–25% and 13.5 L/hm², respectively.

<table>
<thead>
<tr>
<th>The furrow openers</th>
<th>The theoretical soil disturbance</th>
<th>The soil disturbance</th>
<th>Fuel consumption (L/hm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tine opener</td>
<td>15%</td>
<td>15~25%</td>
<td>13.5</td>
</tr>
<tr>
<td>The rotary opener</td>
<td>31.6%</td>
<td>40~60%</td>
<td>17.5</td>
</tr>
<tr>
<td>The single-disc opener</td>
<td>10%</td>
<td>10~15%</td>
<td>10.2</td>
</tr>
</tbody>
</table>

The Adventitious Root and The Tillering Counts

Table 2 shows that the adventitious and the tillering counts for the three furrow openers at the regreening date. The rotary opener gave significantly better the adventitious root and the tillering counts as compared to the tine opener and the single-disc opener. the adventitious of the tine opener and the rotary opener were 6.358 and 6.674, respectively, there was no significantly difference, but compared to the single-disc, which the adventitious was 6, there was significantly difference. Similar, there was no significantly difference for the tillering counts of the tine opener and the rotary opener, but for the single-disc opener, there was significantly difference.

Although the oil disturbance of the rotary opener was maximum, it can formed the shatter sub-surface seed
groove which in favor of the wheat root growth, so the adventitious root and the tillering counts were maximum. The single-disc opener gave a minimum soil disturbance, but it was disadvantage for wheat root growth.

The Plant Weight

The plant weight for the three furrow openers was obtained at the regreening date. Table 1 showed the furrow openers have significant effect on the weight per plant. The weight per plant of the tine opener and the rotary opener were 261.93mg and 262.17mg, respectively, have no significant difference. In contrast, just about 245.51mg for the single-disc opener, there was significant difference with others openers. So the seed bed of shatter sub-surface can effect the adventitious root and the tillering counts, thereby, it effect the weight per plant of different furrow openers.

Table 3  Comparison of the plant weight of the three type furrow openers

<table>
<thead>
<tr>
<th>The furrow openers</th>
<th>The weight per plant(mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tine opener</td>
<td>261.93 a</td>
</tr>
<tr>
<td>The rotary opener</td>
<td>262.17 a</td>
</tr>
<tr>
<td>The single-disc opener</td>
<td>245.51 b</td>
</tr>
</tbody>
</table>

The results showed that the length of spike, the high of plant, the counts of spike and the wheat yields were better for the rotary opener as compared to those for tin-and single-disc opener. But there were no significant difference for three types furrow openers. Many factors which weather and the soil fertility effected of growing season were not studied, so care should be given when using the results of the wheat yields.

Table 4  Comparison of the yield of three types furrow openers

<table>
<thead>
<tr>
<th>The openers</th>
<th>The length of spike/g</th>
<th>The high of plant/cm</th>
<th>The counts of spike</th>
<th>The weight of 1000 grains /g</th>
<th>The (万穗/亩)</th>
<th>Yields (kg/mu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tine opener</td>
<td>6.915</td>
<td>67.83</td>
<td>32.4</td>
<td>38.08</td>
<td>32.9</td>
<td>405.06 a</td>
</tr>
<tr>
<td>The rotary opener</td>
<td>7.05</td>
<td>69.15</td>
<td>32.3</td>
<td>41.24</td>
<td>31.25</td>
<td>413.84 a</td>
</tr>
<tr>
<td>The single-disc opener</td>
<td>6.6</td>
<td>63.73</td>
<td>31.6</td>
<td>40</td>
<td>31.3</td>
<td>395.6 a</td>
</tr>
<tr>
<td>Conservational tillage</td>
<td>7.23</td>
<td>69.6</td>
<td>33.8</td>
<td>38.94</td>
<td>31.2</td>
<td>400.7 a</td>
</tr>
</tbody>
</table>

Yields

Table 4 was the comparison of the yield of three types furrow openers. The results showed that the length of spike, the high of plant, the counts of spike and the wheat yields were better for the rotary opener as compared to those for tin-and single-disc opener. But there were no significant difference for three types furrow openers. Many factors which weather and the soil fertility effected of growing season were not studied, so care should be given when using the results of the wheat yields.

Conclusions

The different type furrow openers can form the different seedbed or seed groove which it can effect the root growth in the conservation tillage. The results of the trial indicated that the opener type have statistically significant effect the soil disturbance, the adventitious root and the tillering counts in the field under with the straw mulch.

The maximum soil disturbance was obtained with the rotary opener, but it can form the shatter seedbed, so the rotary opener gave the largest the adventitious root and the tillering counts. The minimum soil disturbance was obtained with the single-disc opener, but it was found to restrict
growth of roots. so the single-disc opener gave the smallest the adventitious root and the tillering counts. The coefficient of the tine opener was obtained between the others furrow openers. The furrow opener which can form shatter sub-surface seedbed and the minimum the soil disturbance was the optimum openers for the no-till tillage. So the consideration of the effect of the different type furrow openers on the soil disturbance and the root growth is recommended for the selection or design of no-till drill openers

References


Ridge Loosening Machine Improved Water Infiltration and Crop Yield under Permanent Raised Beds

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Abstract: Permanent raised beds (PRB) with ridge tillage and furrow irrigation has obvious advantages in water saving, waterlogging controlling and low operation cost etc, and currently many irrigated corps are planted under PRB in northern China, however, while the ridge is wide (centre to centre spacing of furrows $\geq 75cm$), the water in furrow can't infiltrate to the centre of bilateral ridges effectively, and it can cause low seedling emergence and result in yield decreasing. A ridge loosening machine was designed to solve the problem of wide ridge’s weak water infiltration under PRB, and in Hexi corridor's irrigation farming areas, the data of water content, soil continuous water infiltration effect, ground temperature, seedling emergence, plant characters and yield etc were tested in the ridge, which was loosened by machine, to evaluate the machine's performances and its ability of improving soil water infiltration and crop yield. The experimental results show, in the depth of 0-100cm under the earth’s surface, the ridge loosening machine can accelerate water infiltration from the earth furrow to the centre of wide ridges, intensify soil’s permeability, increase 20% of soil water content in the centre of ridge and $0.1^\circ C-0.2^\circ C$ of ground temperature, moreover, it can also enhance 17% rate of emergence and heighten 6%-8% yield. We recommend that, in the irrigation areas adopted PRB farming system, ridge-loosing machine should be extended to solve wide ridge's weak water infiltration due to its great effectiveness in accelerating water infiltration and enhancing crop yield.

Key words: Conservation tillage, Controlled traffic, ridge loosing machine, furrow irrigation

Introduction

Compared with the traditional flat till, flood irrigation farming systems, Permanent raised beds (PRB) is a contemporary farming system with the essential features of furrow irrigation and ridge tillage. (Figure 1) (Sayre KD and Moreno Ramos OH, 1997). It requires keeping the ridges (beds) and furrows permanently in the same position and only repairing the bed every year before next crop (Singh Y, 2003). The new technology has been adopted in many countries to increase water use efficiency, control water-logging, remove compaction from the cropping zone and manage crop residues on the bed (Wang et al., 1999; Dhillon et al., 2000; Talukder et al., 2002; Hobbs and Gupta 2003). The system also has been shown to improve mechanical and chemical weed control, facilitate

![Figure 1 Generalized schematic of a permanent raised beds system](image_url)
zero (no) tillage and reduce tractor power requirements (Timsina and Connor 2001; Agustin Limon-Ortega et al., 2002; Ren, D.C et al., 2001). The contemporary PRB farming systems began in Yaqui Valley, northwestern Mexico, and it had been extended widely to other countries all over the world (Limon-Ortega et al., 2000). Francois Molle et al. (1999) put forward a new cropping system to manage water under PRB in Thailand based on Asian rice-based system and Hobbs et al (2000), E. Humphreys et al (2004) synthetically researched PRB farming system in the rice-wheat systems of the indo-Gangetic plains of southern Asia; Wang et al. (2004) contrastively analysed the effects to wheat between PRB and traditional tillage from 1998 to 2002 in northern China; Ockerby et al. (2002) studied the management of rice grown on raised beds with continuous furrow irrigation in northern Queensland, Australia. In all of these counties’ research it has been demonstrated that relative to the flat till and flood irrigation systems, PRB has obvious advantages in increasing plant available water, enhancing fertilizer and solar energy efficiency and reducing water-logging etc.

However the problem often arises where water infiltration from the furrow to the centre of wide beds is generally poor. Crop water use requirements are not met, which causes low germination and reduced production in the middle of the bed. Wang et al. (2004) reported that, in loamy soil, wide beds (>75cm) reduced seedling emergence of wheat, water content in the middle of bed and yields relative to narrow beds (75cm); Ken Sayre et al (2005) found that use of the narrower beds (70-90cm) provides tremendous flexibility for gravity irrigated conditions to more efficient management options like fertilizer banding option, easier handling of high levels of crop residues and better irrigation water use efficiency as compare to wide beds (1.0 to 2.0m);

This study investigated the design of a ridge-loosing machine to solve the problem of low infiltration on wide beds and investigates the performance of machine in irrigated farms in China’s Hexi Corridor. The experimental results demonstrated that the simple adaptable machine could improve wide bed infiltration effectively and facilitate the growth of crops.

**Figure 2** The principle of operation of a flat and V type cutters on PRB farming system

**Machine design**

To facilitate water penetration form the furrow to the centre of the bed it was feasible to design several kinds of different cutters to create a channel of loosened soil at the bottom of ridge along its direction without destroying the shape of ridge. The result was accelerated water penetration to the centre of ridge and improved wide bed water infiltration.

Two cutters (flat cutter, V cutter) were designed to loosen the soil as indicated in Figure 2. The flat cutter was 5mm thick in a double-wing shape. This shape facilitated the cutter entering into soil and reduced operational resistance. The V cutter was designed into down-V shape, which can loosen the...
ridge base on a larger scale (the loosen depth is from 15cm to 20cm under ridge’s top) and intensify soil’s permeability, however it requires about 20% more power than flat cutter. The ridge-loosing machine is made up of toolbar frame, fastener device and cutter (Figure 3). The toolbar frame is designed into multipurpose structure on which can different cutters can be installed according to the need.

**Experimental design**

**Experimental condition**

The experimental site was located in Xiaoman township, Zhangye city, Gansu province, northwest of China. The cold arid climate and high altitude (1570m) allows only 170 frost free days per year. Rainfall is low, less than 150 mm/year and therefore irrigation is not supplemented and annual evaporation capacity is 2048mm. The soil, with organic matter content of 1.0g kg$^{-1}$, is irrigation desert soil. Local cropping system is one crop per year, generally a two-year wheat and one-year maize rotation system.

Permanent raised beds were established in 2003 on 100cm centres, furrow to furrow. Actual bed width was 65cm with a furrow depth of 15 cm. Following irrigated maize from the previous season, spring wheat, Longfu 2 cv., was planted on 25th March 2005 at a seeding rate of 450kg ha$^{-1}$ in five rows 15 cm apart. Fertiliser was applied at the rate of 225 kg N ha$^{-1}$ and 180 kg P ha$^{-1}$. The crop was harvested on 25th July 2005. The crop was irrigated 3 times on 25th April, 20th May, and 10th June 2005.

**Experimental treatment and measurements**

The experiment consisted of 3 treatments in 3 replicates; cutting the bottom of ridge with flat cutter, cutting the bottom of ridge with V cutter, and bottom of ridge without cutting immediately after planting.

Volumetric water content, ground temperature, and plant performance for each treatment were measured before and after irrigation and at harvest.

**Results and discussion**

**Water content**

After irrigation, the water content of ridge (bed) is one of the important indexes to evaluate ridge-loosing machine’s performance in improving ridge’s water infiltration ability. In the depth of
0-100cm, the average volumetric water contents of 3 kinds of ridges with different treatments (V cutter, flat cutter and without cutting) were 11.03%, 10.73% and 10.86% separately before the first irrigation in April. Stable water content of the ridges with different treatments in different depths were tested respectively in April (seedling stage), May (jointing stage), June (heading stage) after irrigation. Thereinto, it was seedling stage when the water was irrigated in April, so only the soil water content in the depth of 0-40cm was measured (Fig. 4).

![Fig.4 Volumetric water content of the ridges with different treatments in different depths, April](image)

Fig. 4 shows, in the depth of 0-40cm under the earth’s surface, the volumetric water contents of the ridges with different treatments roughly increased with the increase of depth, and it also regularly increased from the ridge without cutting, the ridge with cutting of flat cutter to the ridge with cutting of V cutter, especially in the range of 20-40cm depth. In seedling stage, the root of spring wheat lied in the range of 0-40cm depth, and in this range, the average volumetric water contents of the ridge without cutting, the ridge with cutting of flat cutter and the ridge with cutting of V cutter are 19.56%, 21.46% and 17.81% separately. Compared with the ridge without cutting, flat cutter enhanced 9.8% of volumetric water content of ridge and the difference is significant, V cutter boosted 20.5% and improved volumetric water content high significantly based on the analysis of LSD.

Volumetric water contents of the ridges with different treatments in different depths of May and June are shown in Figure 5.

Fig. 5 shows that the volumetric water contents of the ridges with different treatments also gradually increased from the ridge without cutting, the ridge with cutting of flat cutter to the ridge with cutting of V cutter after irrigation in May and June. In the depth of 0-100cm under the earth’s surface, compared with the ridge without cutting, flat cutter and V cutter enhanced 10% and 34% of ridge’s volumetric water content respectively after irrigation in May, enhanced 8% and 20% respectively after irrigation in June. The water contents under different treatments were different obviously, especially in the range of 20-80cm depth.

According as the analysis of LSD, in the depth of 0-100cm under earth surface, flat cutter advanced
water content significantly and V cutter increased water content high significantly in both May and June.

**Fig.5 Average volumetric water content of the treatments (flat cutter, V cutter, without cutting) in different depths, May, June**

Soil water content experimental results in April, May and June after irrigation indicate that ridge-loosing machine, which is able of loosing the soil in the bottom of ridge through the cutting of ridge’s bottom, can accelerate the water in earth furrow to permeate to the bilateral ridges, thereby improve ridge’s water infiltration ability. Among them, the ridge’s water infiltration effect with V cutter is better than with flat cutter.

**Soil continuous water infiltration effect**

Table 1 shows the average volumetric water content of ridge’s centre and edge in different depths under the earth’s surface. All of them were collected continuously after each irrigation in April, May and June according to the soil water content experiment. The data shown in the table were mensurated in the third day after each irrigation when the soil water content had already been steady in the ridge.

**Table1** Average volumetric water content of the ridges with different treatments in different depths

<table>
<thead>
<tr>
<th>Month</th>
<th>The position of ridge</th>
<th>Flat cutter (%)</th>
<th>V cutter (%)</th>
<th>Without cutting (%)</th>
<th>Increased rate in comparing flat cutter to without cutting (%)</th>
<th>Increased rate in comparing V cutter to without cutting (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>Edge</td>
<td>20.53</td>
<td>22.38</td>
<td>18.82</td>
<td>9.1%</td>
<td>18.9%</td>
</tr>
<tr>
<td>(0–40 cm)</td>
<td>Centre</td>
<td>18.59</td>
<td>20.54</td>
<td>16.80</td>
<td>10.7%</td>
<td>22.3%</td>
</tr>
<tr>
<td></td>
<td>The ratio of centre and edge</td>
<td>0.91:1</td>
<td>0.92:1</td>
<td>0.89:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>Edge</td>
<td>17.65</td>
<td>21.34</td>
<td>16.52</td>
<td>6.8%</td>
<td>29.2%</td>
</tr>
<tr>
<td>(0–100 cm)</td>
<td>Centre</td>
<td>15.99</td>
<td>19.61</td>
<td>14.03</td>
<td>13.9%</td>
<td>39.7%</td>
</tr>
</tbody>
</table>
In the soil depth ranges which are shown by Table 1, the ratios of centre and edge in the ridges with cutting of flat cutter were 0.91:1, 0.91:1, 0.92:1 respectively; the ratios of centre and edge in the ridges with cutting of V cutter were 0.92:1, 0.92:1, 0.86:1 respectively; and 0.89:1, 0.85:1, 0.84:1 in the ridge without cutting respectively, the ridge loosening machine can increase water content’s ratio of centre and edge, and reduce the difference between the centre and ridge during the period from April to June. Furthermore, flat cutter increased 9.1%, 6.8% and 4.4% of volumetric water content in ridge’s edge in April, May and June, respectively, compared to the ridge without cutting, and increased 10.7%, 13.9% and 14.1% in ridge’s centre respectively. The volumetric water content of ridge’s edge that was cut by V cutter was heightened by 18.9%, 29.2% and 17.8% in April, May and June, respectively, compared to the ridge without cutting, and in ridge’s centre, it was heightened by 22.3%, 39.7% and 21.1% respectively. From April to June, the water infiltration ability of ridges that were cut by flat cutter and V cutter was weaken to some extent as the increase of time, however, the soil average waters content of June were still up to 14.99% and 16.43% separately in the depth of 0-100cm, which was greater than 13.77% of the ridge without cutting. The effect is more obvious.

At the same time, in April, May and June, the average water contents of ridge’s centre that was cut by flat cutter and V cutter were 18.59%, 15.99%, 14.33% and 20.54%, 19.61%, 15.21% separately. Compared with 16.80%, 14.03%, 12.56% of the ridge’s centre which hadn’t been cut, the increase of ridge’s centre water content was great.

So it is evident that the ridge-loosing machine can add soil water content of the ridge effectively, speed water permeation from the furrow to bilateral ridges, and improve ridge’s water infiltration ability continuously during the growth period of spring wheat.

**Ground temperature**

Table 2 shows ground temperatures of the ridges with different treatments in the depths of 7cm, 17cm and 27cm under the earth’s surface after irrigation in April, May and June. The data shown in the table were the average daily ground temperature of continuous 5 days after each irrigation.

<table>
<thead>
<tr>
<th>Month</th>
<th>Depth</th>
<th>Flat cutter</th>
<th>V cutter</th>
<th>Without cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7cm</td>
<td>13.7</td>
<td>13.8</td>
<td>13.3</td>
</tr>
<tr>
<td>April</td>
<td>17cm</td>
<td>13.3</td>
<td>13.0</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>27cm</td>
<td>12.4</td>
<td>12.3</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>13.1</td>
<td>13.0</td>
<td>12.7</td>
</tr>
</tbody>
</table>

Table 2 Ground temperatures of the ridges with different treatments
Table 2 shows that the ground temperatures of the ridges with different treatments in different depths raised with the rise of external temperature, and the differences among different treatments were slightly significant. The different depths’ average ground temperatures of the ridge with the cutting of flat cutter were 13.1°C, 16.0°C and 19.8°C in April, May and June respectively, and the values of the ridge with the cutting of V cutter were 13.0°C, 15.8°C in April, May respectively. Except for the value of V cutter in June, All the data were greater than the corresponding average ground temperatures of the ridge without cutting, whose values were 12.7°C, 15.8°C and 19.7°C in April, May and June respectively. The improvement of the ground temperature has very important meanings to the growth of spring wheat in cold areas. The experimental results indicate that the ridge-loosing machine is helpful to the improvement of ground temperature because it can meliorate soil structure of ridge’s bottom, make the soil coarse, soft and easy to store heat energy and strengthen penetrating performance of the soil.

**Seedling emergence of spring wheat**

Table 3 shows the seedling emergence of spring wheat in the ridges with different treatments. Because flat cutter and V cutter quickened up water infiltration from the earth furrow to bilateral ridges and improve water content of ridge accordingly, the seedling emergences of the ridges which were cut by flat cutter and V cutter were better than the ridge without cutting. According to the analysis of LSD, compared with without cutting, V cutter and flat cutter enhanced 22.1% and 12.8% of seedling emergence, respectively, and both improved seedling emergence high significantly. Among them, the number of seedling emergence of the ridge that was cut by V cutter was the best among three treatments.

<table>
<thead>
<tr>
<th>Disposal</th>
<th>Average number of seedling emergence</th>
<th>Increment in comparing to without cutting and prominence</th>
</tr>
</thead>
<tbody>
<tr>
<td>V cutter</td>
<td>458</td>
<td>83**</td>
</tr>
<tr>
<td>Flat cutter</td>
<td>423</td>
<td>48**</td>
</tr>
<tr>
<td>Without cutting</td>
<td>375</td>
<td></td>
</tr>
<tr>
<td>LSD0.05</td>
<td>13.45</td>
<td></td>
</tr>
<tr>
<td>LSD0.01</td>
<td>20.95</td>
<td></td>
</tr>
</tbody>
</table>

**Plant characters**

The plant characters of spring wheat in seedling stage, jointing stage, heading stage and maturing stage were shown in Table 4.
Table 4  Comparison of spring wheat’s characters in the ridges with different treatments

<table>
<thead>
<tr>
<th>Growth period</th>
<th>Flat cutter</th>
<th>V cutter</th>
<th>Without cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling stage</td>
<td>Leaf area (cm²/60 plants)</td>
<td>72.56**</td>
<td>59.16*</td>
</tr>
<tr>
<td></td>
<td>Plant dry weight (g/10 plants)</td>
<td>0.217*</td>
<td>0.185</td>
</tr>
<tr>
<td>Jointing stage</td>
<td>Leaf area (cm²/plant)</td>
<td>46.07*</td>
<td>51.55*</td>
</tr>
<tr>
<td></td>
<td>Stem dry weight (g/plant)</td>
<td>0.273</td>
<td>0.299</td>
</tr>
<tr>
<td></td>
<td>Fibrous root length (cm)</td>
<td>19.55</td>
<td>20.64</td>
</tr>
<tr>
<td></td>
<td>Root dry weight (g/plant)</td>
<td>0.101*</td>
<td>0.131*</td>
</tr>
<tr>
<td>Heading stage</td>
<td>Leaf area (cm²/plant)</td>
<td>45.80*</td>
<td>48.45*</td>
</tr>
<tr>
<td></td>
<td>Stem height (cm)</td>
<td>64.98</td>
<td>64.65</td>
</tr>
<tr>
<td></td>
<td>Root dry weight (g/plant)</td>
<td>0.972**</td>
<td>0.712</td>
</tr>
<tr>
<td>Maturing stage</td>
<td>thousand kernels weight (g)</td>
<td>48.89*</td>
<td>49.72*</td>
</tr>
</tbody>
</table>

Notes: * shows the difference is significant compared to without cutting; ** shows the difference is high significant.

According to the results of single factor analysis, the differences of spring wheat’s characters under different treatments were significant in seedling stage, jointing stage, heading stage and maturing stage. In the ridge without cutting, only the fibrous root length with the value of 20.06cm in jointing stage and root dry weight with the value of 0.793g per plant in heading stage were better than other two treatments, however, all the other indexes were worse than the ridge with cutting during the four growth phases of spring wheat, and most indexes had significant differences. So integrating above analyses of spring wheat’s characters in the four growth phases, it is clear that spring wheat’s characters of the ridge with cutting is better than the ridge without cutting, and the ridge-loosing machine can improve every index of plant characters, facilitate the growth of spring wheat.

Yield

The spring wheat yields of 2005 in the ridges with different treatments are as follows.

Table 5  The yields of Spring wheat in the ridges with different treatments (2005)

<table>
<thead>
<tr>
<th>Disposal</th>
<th>Average of yield(kg/hm²)</th>
<th>Increment in comparing to without cutting and prominence</th>
</tr>
</thead>
<tbody>
<tr>
<td>V cutter</td>
<td>6236.27</td>
<td>472.04**</td>
</tr>
<tr>
<td>Flat cutter</td>
<td>6142.47</td>
<td>378.24**</td>
</tr>
<tr>
<td>Without cutting</td>
<td>5764.23</td>
<td></td>
</tr>
<tr>
<td>LSD_{0.05}</td>
<td></td>
<td>93.18</td>
</tr>
<tr>
<td>LSD_{0.01}</td>
<td></td>
<td>145.14</td>
</tr>
</tbody>
</table>

According to Table 5, the yields of different treatments of V cutter, flat cutter and without cutting were 6236.27kg ha⁻¹, 6142.47kg ha⁻¹ and 5764.23kg ha⁻¹. Compared with the ridge without cutting, the
ridges with cutting of flat cutter and V cutter had high soil water content, ground temperature and number of seedling emergence, so they also had high yields. Among them, flat cutter increased 6% of yield and V cutter increased 8% of yield. Furthermore, V cutter and flat cutter can both enhanced yields high significantly based on the analysis of LSD.

**Conclusions**

The ridge-loosing machine, which can accelerate water to infiltrate from the earth furrow to the centre of ridge (bed), solve the shortage of water in ridge’s centre, and improve ridge's infiltration ability, has strong adaptability to the requirements of agricultural production under PRB farming system. Preliminary experimental results show, compared to the treatment of without cutting, the ridge-loosing machine can enhance about 20% of water content in the centre of ridge, and about 17% of water content in the whole ridge when the width of the ridge is 100cm from furrow bottom to furrow bottom. It is an effective means to boost soil water content in PRB farming system.

According to the experimental results of soil durative water infiltration effect, the ridge’s water infiltration effect, which is created by ridge-loosing machine, can last all the growth period of spring wheat, and meet water demand of spring wheat.

Through improving the structure and permeability of the soil, the ridge-loosing machine is capable of increasing 0.1°C-0.2°C of ground temperature in the depth of 0-30cm under the earth’s surface.

It is recommended that in the areas, which adopt PRB farming system, more emphasis should be given to extend the ridge-loosing machine due to its great effectiveness in adding soil water content of ridge, facilitating the growth of spring wheat and enhancing the yield.

**Acknowledgement**

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**References**


Sustainable Agriculture Development Project

The majority of China’s poorest women and men live in the Western Regions of China and still rely primarily on agriculture for their livelihood. Continued and enhanced growth in the economy of the Western Regions is absolutely essential if China is to continue to reduce poverty, prevent social instability, and reduce the inequity between the poor western regions and the better off coastal areas. However, sustainability of natural resources remains a key constraint to future growth in the Western Regions.

Continued poverty reduction programming in many parts of Western China compromised by widespread land degradation and dust storms have proven to be a tough challenge. To support the development of innovative land management technologies and extension services to promote sustainable land use in the Western Regions, the Canadian International Development Agency (CIDA) and the Ministry of Commerce (MOFCOM) agreed to implement the second phase of the “Sustainable Agriculture Development Project” in selected western provinces, including Inner Mongolia, Gansu, Xinjiang, Sichuan, Xiangxi Prefecture of Hunan and Enshi Prefecture of Hubei.

The expected outcomes for the rural western regions where the project will be active are: 1) Adaptation of land resource management systems for sustainable agriculture; 2) Enhanced Sustainable Agriculture Extension Systems, and; 3) Improved enabling environment for sustainable land resource management.

China and Canada officially began the implementation of this project on April 1, 2005 in consultation with key Chinese government ministries, industry representatives, research institutes and other international donors. Canada’s contribution to the project is estimated at CND$ 20,000,000 (approximately 130 million RMB) over a period of 5 years and this will be supported by an equivalent counterpart budget from the Government of China. Canadian project inputs concentrate on the provision of Canadian and Chinese Long-Term Technical Advisors (LTTAs), short term consultants and training programs in China and Canada.

The Canadian executing agency for the project is Agriculture and Agri-Food Canada (AAFC), while the Ministry of Agriculture of China assumes the Chinese responsibilities related to the implementation of the project in China. The project implementation is overseen by a Central Coordination Committee co-chaired by CIDA and MOFCOM and consists of the Director General for Sustainable Production Systems from AAFC, relevant MOA departments and institutions, and the Directors General of the agriculture and animal husbandry bureaus of the project provinces/prefectures.

This Phase of the SADP builds on the experience from the first phase which was implemented in Inner Mongolia that have the potential for broader applicability to other western development areas. Project activities involve the sharing of Canadian experiences, institutional capacity building, the enhancement or development of appropriate policies, technologies and systems to improve land management and extension services, training in Canada and in China, practical attachments in Canada and assistance in the creation and development of farmer organizations. Project activities will be implemented at both the central and provincial levels, while demonstration sites are supported at the
county, village and household levels. At the national level the project will focus on capacity building for senior administrators and decision-makers and policy research in support of project objectives. Field based programs will focus on pilot counties to demonstrate sustainable agriculture strategies and their extension to other areas and regions.

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