Managing pests through plant diversification

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Agroecology provides guidelines for developing diversified agroecosystems that take advantage of the integration of plant and animal biodiversity. Successful integration of plants and animals can strengthen positive interactions and optimise the functions and processes in the ecosystem, such as the regulation of harmful organisms, recycling of nutrients, biomass production and the build up of organic matter. In this way agroecosystems can become more resilient. Farmers need to identify and support processes that strengthen the functioning of the agroecosystem. These will include:

- natural pest control;
- decreased toxicity through avoiding the use of agrochemicals;
- optimised organic matter decomposition and nutrient cycling;
- balanced regulatory systems such as nutrient cycles, water balance, energy flow and populations of plants and animals;
- enhanced conservation and regeneration of soil and water resources and biodiversity;
- increased and sustain long-term productivity.

Today there is a wide selection of practices and technologies available to improve the functioning of agroecosystems. When these agroecosystems are developed so that they are in tune with existing environmental and socioeconomic conditions, the end result is improved ecological sustainability. By adopting key ecological management practices the farmer can increase the stability and resilience of the agroecosystem. These practices should contribute to:

- increasing the plant species and genetic diversity in time and space;
- enhancing functional biodiversity (for example natural enemies);
- enhancing soil organic matter and biological activity;
- increasing soil cover and crop competitive ability; and
- removing toxic inputs and residues.

In this article we explore one example of agroecology – the restoration and management of agricultural biodiversity for pest control in vineyard monocultures in California, U.S.A. The principles for improving ecologically vulnerable vineyard monocultures can be applied to other simplified cropping systems. Improved biodiversity establishes a sound ecological base where key ecological processes, such as pest regulation, can function effectively. It is also crucial for crop defences: the more diverse the plants, animals and soil-borne organisms within a farming system, the more diverse the community of pest-fighting beneficial organisms.

Photo: M.A. Altieri

Creating habitats for natural enemy species on the least productive parts of the farm is an important strategy. The island of flowering plants, behind the fence in this photo, acts as a push-pull system for natural enemy species.

In vineyards, farmers can enhance biodiversity by:

- increasing plant diversity by growing cash crops between the vines;
- planting cover crops between the vines;
- managing the vegetation in surrounding fields to meet the needs of beneficial organisms;
- designing corridors of plants that make it possible for beneficial organisms to move from nearby forests or natural vegetation towards the centre of the fields; or by
- selecting non-crop plants grown as strips in fields, whose flowers match the requirements of the beneficial organisms.

All these strategies provide food (pollen and nectar), as well as hiding places, for predators and parasitic wasps, thereby increasing the diversity and numbers of natural enemies in vineyards. These factors contribute to optimising a key ecological process: pest regulation.

Biodiversity in vineyards

There are two distinct types of biodiversity in vineyards. The first, called planned biodiversity, includes the vines and other plants grown in the vineyard such as cover crops or corridors. The second type, called associated biodiversity, includes all flora and fauna that come from surrounding environments to live in the vineyard, and which will, under suitable management, thrive there. The relationship between these different types of biodiversity is illustrated in Figure 1.

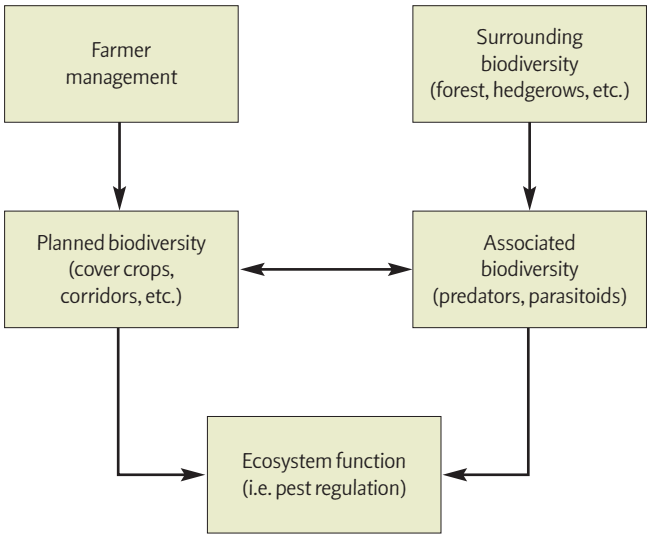

Figure 1. Relationship between several types of biodiversity and their role in pest regulation in a diversified vineyard.

Planned biodiversity has a direct function. For example, cover crops enrich the soil, thus helping vine growth. They have a direct function in enhancing soil fertility. Yet, they also have an indirect function, in that their flowers contain nectar which attracts wasps. These are the natural parasitic wasps of pests that normally attack the vines and are part of the associated biodiversity.

The challenge for farmers is to identify the type of biodiversity that they wish to maintain and enhance on their farms in order to enable specific ecological services (i.e., pest regulation), and then to decide on the best practices for encouraging such biodiversity. In our experience, cover cropping and creation of habitats within and around vineyards are key strategies.

Increasing biodiversity

In California, many farmers either manage ground vegetation or plant cover crops to provide a habitat for natural enemies during the winter. These practices reduce the numbers of mite and grape leafhoppers but are often not sufficient to avoid economic losses from pest attacks. Usually the problem is due to the common practice of mowing or ploughing under the winter cover crops or weedy resident vegetation at the beginning of the growing season. As a result, from late spring on, these vineyards become virtual monocultures without floral diversity at the beginning of the growing season. Pest control is better achieved by providing habitat and food for natural enemies throughout the entire growing season. The green cover should therefore be maintained during spring and summer. One way to achieve this is to sow summer cover crops that flower early and continue to flower throughout the season. This provides a highly consistent, abundant and well-dispersed food source, as well as microhabitats for a diverse community of natural enemies. In this way it is possible to build up the number of natural enemies in the system early in the growing season, which helps keep pest populations at acceptable levels.

In a vineyard near Hopland, northern California, summer cover crops such as buckwheat (*Fagopyrum* sp.) and sunflower were maintained throughout the growing season. This floral diversity increased the associated natural enemies and reduced the abundance of western grape leafhoppers and western flower thrips (see box). During two following years (1996-1997), the areas with flowering cover crops had lower densities of thrips and grape leafhoppers and there were more predators on the vines in the cover-cropped sections than in the monocultures. Generally, the number of predators was low early in the season, but increased as prey became more numerous as the season progressed. Dominant predators included spiders, *Nabis* sp., *Orius* sp., *Geocoris* sp., coccinellids, and *Chrysoperla* sp.

Designing corridors

The abundance and diversity of beneficial insects within a field depends on the diversity of plants in the surrounding vegetation. To take advantage of this insect diversity, some farmers have established corridors composed of several flowering species, which connect to forests near water sources and cut across their vineyards. Such corridors serve as "biological highways" for the movement and dispersal of predators and parasitic wasps into the centre of the vineyards.

Studies conducted in the Hopland organic vineyard showed that predator species, including spiders, were often found on the flowers of the plants in the corridor, demonstrating that populations of key predator species become established and circulate within the corridor. In both years studied (1996-97) the number of harmful adult leafhoppers was clearly lower in the vine rows close to the corridor and gradually increased toward

Key pests in vineyards and their natural enemies

Key pests	Natural enemies
Frankiniella occidentalis (Thrips)	Orius spp. (minute pirate bug), coccinellids, spiders, Nabis sp.
Erythroneura elegantula (Grape leafhoppers)	Anagrus epos (parasitic wasps), spiders, Geocoris sp., chrysopids

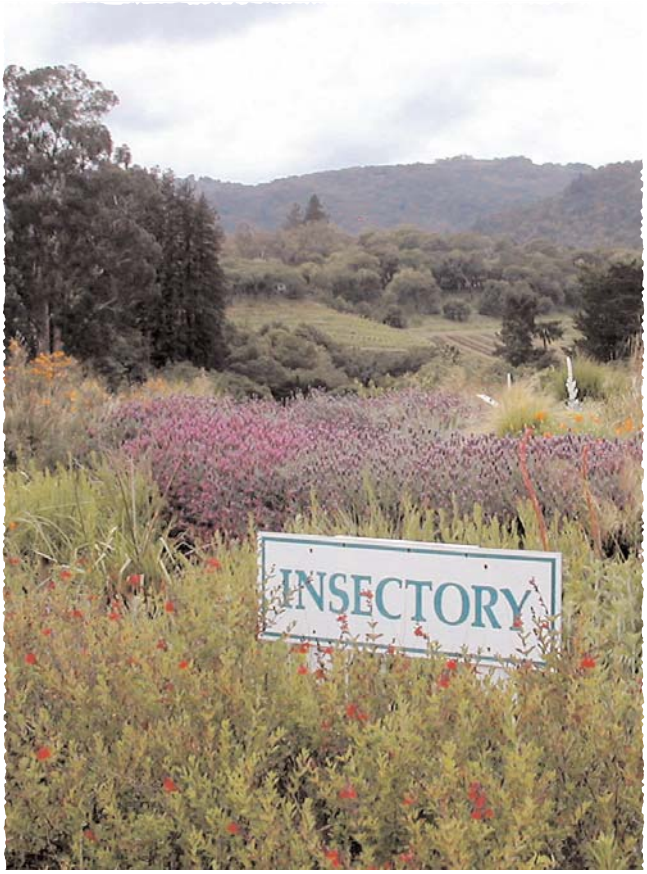

Photo: M.A. Altieri

The size and shape of flowers determine which insects are attracted to the "insectory".

the centre of the field. The highest concentration of leafhoppers and thrips occurred 20 to 25 rows (30 to 40 metres) downwind from the corridor. In both years substantially more thrips were caught in the central rows than in rows near to the corridor.

Flowering islands

Creating habitats on the least productive parts of the farm to concentrate natural enemies is another important strategy. This approach is used in a biodynamic farm in Sonoma County, where an island of flowering shrubs and herbs was created at the centre of the vineyard, which acts as a push-pull system for natural enemy species.

The island provides pollen, nectar and neutral insects from early April to late September for a variety of predators and parasites including *Anagrus* wasps. During the 2004 season, the island was dominated by neutral insects that forage on the various plants, and which provide food for natural enemies. As a result, the natural enemies slowly increased in number in the adjacent vineyard as the season progressed. Many natural enemies moved from the island into the vineyard, a distance of up to 60 metres. *Orius* sp. and coccinellids move to the vineyard at the beginning of the season, followed later in the season by syrphid flies and *Anagrus* wasps. Parasitisation of leafhopper eggs by *Anagrus* wasps was particularly high on the vines near the island, but lower nearer the centre of the vineyard.

Ways forward

A key strategy in agroecology is to enhance biodiversity at the landscape and field level. As in the case of vineyards, diversified agroecosystems develop ecological properties that increase their capacity for self-regulation. The basis for ecological pest management is increased agroecosystem diversity. This serves as a foundation for establishing the beneficial interactions that promote the ecological processes needed for pest regulation.

It is important to establish a diversity of plants to attract an optimal number and mix of natural enemies. The size and shape of the flowers determine which insects are attracted, as only those who are able to access the flowers' pollen and nectar will make use of the food sources provided. For most beneficial insects, including parasitic wasps, the flowers should be small and relatively open. Plants from the Compositae (for example, daisy or sunflower) and Umbelliferae families are especially useful.

The period during which the flowers are available is as important as the size and shape of the flowers. Many beneficial insects are only active as adults and for specific periods during the growing season; they need pollen and nectar during these active periods, particularly in the early season when prey is scarce. With this knowledge farmers can provide mixtures of plants with relatively long, overlapping, flowering times.

Current knowledge about which plants are the most useful sources of pollen, nectar, habitat and other critical needs is far from complete. Clearly, many plants encourage natural enemies, but scientists have much more to learn about which plants are associated with which beneficial insects, and how and when to make desirable plants available. Because beneficial interactions between plants and insects are site-specific, the geographic location and overall farm management are important aspects to consider.

Farm planning

Once farmers have a good knowledge of the characteristics and needs of key pests and their natural enemies on their farm, they can develop a management strategy. A few guidelines need to be considered:

- Consider the size of the habitat which is to be improved (e.g., field or landscape level);
- Understand the predator-parasite behaviour which will be influenced by managing the habitat;
- Decide on the most beneficial arrangement (within or around the fields) of the plants considering local conditions and time of flowering;
- Select the most appropriate plant species; preferably those with multiple benefits, such as improving pest regulation and contributing to soil fertility and weed suppression;
- Be aware that adding new plants to the agroecosystem can affect other agronomic management practices and be prepared to develop ways to manage this.

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References

- Altieri, M.A. and C.I. Nicholls, 2004. **Biodiversity and pest management in agroecosystems.** Food Products Press, Binghamton, New York, U.S.A.
- Altieri, M.A., L. Ponti and C.I. Nicholls, 2005. **Manipulating vineyard biodiversity for improved insect pest management: case studies from northern California.** *Journal of Biodiversity Science and Management*, 1: 191-203.
- Landis, D.A., S.D. Wratten, and G.M. Gurr, 2000. **Habitat management to conserve natural enemies of arthropod pests in agriculture.** *Annual Review of Entomology*, 45, 175-201.
- Nicholls, C.I., M. Parrilla and M.A. Altieri, 2001. **The effects of a vegetational corridor on the abundance and dispersal of insect biodiversity within a northern California organic vineyard.** *Landscape Ecology*, 16, 133-146.
- Nicholls, C.I., M. Parrella and M.A. Altieri, 2000. **Reducing the abundance of leafhoppers and thrips in a northern California organic vineyard through maintenance of full season floral diversity with summer cover crops.** *Agricultural and Forest Entomology*, 2, 107-113.