Impact of Organic Matter and Method of Addition on Selected Soil Parameters, Growth and Yields of Mungbean Grown an a Minor Season in the Humid Tropics

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ABSTRACT

A field experiment was conducted over a minor (dry) season to ascertain the impact of two organic materials (Gliricidia leaves and rice straw) applied as a surface mulch or incorporated into the root zone, on selected soil parameters, growth, nodulation and yields of mung bean (*Vigna radiata* L. R. Wilcz). The beneficial effects were compared to soils and the growth of the crop without organic matter. Organic matter, especially Gliricidia leaves, enhanced soil physical properties and plant nutrients (N, P and K) at the time of crop establishment and early growth. Incorporation had a greater beneficial impact, especially on physical properties of soil. While the organic materials increased germination, the method of addition had no significant impact. Growth of shoots, roots and nodulation were enhanced by incorporation of organic matter, again, the greater benefits were derived with Gliricidia leaves. Root growth measured in terms of root length densities was stimulated by organic matter incorporation. In contrast, surface application of the organic matter, especially rice straw, reduced weed growth. The benefits of the organic matter were also evident in seed yields and harvest indices, although incorporation did not increase seed yields to the same magnitude observed in vegetative growth or harvest indices and relative crop yields. The benefits of incorporating organic matter, especially material with low C: N ratios such as Gliricidia leaves in tropical smallholder organic systems are presented.

Keywords: Organic matter, Incorporation, Growth, Tropical legumes, Soil parameters

Short title – Organic matter enhances mungbean growth and yields in dry seasons

INTRODUCTION

Crop productivity in organic farming is achieved by a combination of management strategies, among which the development of an efficient and effective nutrient cycle plays an important role. This is due to the large-scale export of nutrients through produce and stubble, which in conventional systems is replaced by chemical fertilizers In contrast, ex situ or in situ green manures, animal manure, cover crops or different types of organic matter are used individually or in combination to replenish exported nutrients in organic systems (Stockdale et al., 2000). In the tropics, where soil fertility is generally low (Hartemink, 2003; Zingore et al., 2003), the decline in crop yields, even in conventional cropping systems due to excess soil mining calls for the inclusion of organic matter to maintain soil fertility (Gachengo et al., 1999; Eilitta et al., 2004). Hence the addition of organic matter becomes very important in tropical organic cropping systems, the numbers of which are increasing due the demand for chemical free products from the temperate developed regions and due to the ever increasing prices of fertilizers.

Nutrient replenishment and quality enhancement of tropical soils could be achieved by the addition of inorganic fertilizers, organic matter or both. While short-term benefits could be gained by inorganic fertilizers, harmful effects could develop in the long term (Nosengo, 2003). In organic systems where inorganic fertilizers are not used, the replenishment of nutrients and soil quality maintenance is dependant on organic materials, due to beneficial impacts in terms of soil physical, chemical and biological properties (Rawls et al., 2003).

In tropical smallholder farms, which are intensively cultivated, organic matter is primarily added from external sources with the exception of crop residues. The most common crop residue in tropical Asian systems has been rice straw due to its abundance (Whitbread et al, 1999; Reddy et al, 2003). The addition from external sources is generally termed biomass transfer (Graves et al, 2004). The external sources include loppings of forest trees or vegetation, agroforesty systems where biomass of species such as *Gliricidia sepium*, a fast growing tree legume (Sanchez, 1999, Rao and Mathuva, 2000) or if available, animal manures. The ability of these organic materials to supply nutrients differs, as they relate to the rates of decomposition, nutrient release rates and patterns (Kumar and Goh, 2000).

Organic matter alone does not support crop yields, as the method of application also has a significant effect on its potential benefits for improving soil quality and crop productivity. While mulching with organic matter can control weeds, which is an important problem in organic farming systems (Bond and Grundy, 2001), incorporation could help improve soil characteristics to a greater extent (Stockdale et al., 2000). Incorporation could also help develop root systems, which are important in maximizing nutrient and moisture uptake. However the impact of organic matter applied as a mulch or incorporated on crop growth and root development has not been clearly identified especially in field studies on tropical smallholder organic systems, although experiments in pots show the enhanced root development of maize in soils to which green manures had been added (Sangakkara et al, 2004). A field study was therefore conducted over a dry season to ascertain the impact of either mulching or incorporating two common tropical organic materials (Gliricidia leaves C: N ratio 18.8) and rice straw (C: N ratio 45.7) on selected soil properties and vegetative growth, root development and seed yields of a very popular tropical Asian grain legume, mung bean (*Vigna radiata*), under rainfed conditions.

MATERIALS AND METHODS

The project was carried out at the University Experimental Station (418 m above sea level, 8°N, 81°E) of the University of Peradeniya, Sri Lanka, located in the mid country Intermediate zone of the island, over the period April – July 2004, to encompass the minor (DRY) season, that correspond to the South West (Late April – August) monsoons. The soil of the site was an Ultisol (Rhodoult) (Panabokke, 1996), with a sandy clay loam texture. The site receives some 1600 mm of rainfall per annum, with a mean temperature of 31°C. Approximately 30% of the annual rainfall is received in the minor season corresponding to the Southwest monsoon, and the evaporation exceeds rainfall in this season (Department of Agriculture 2004).

The site had been planted with an organic maize crop in the previous major (WET) season (October 2003 – February/March, 2004) that corresponded to the Northeast monsoon. The plots were left fallow from March until the initiation of the trial.

At the onset of the rains in late April, 2004, 20 plots of 3 x 2 m dimensions were prepared and divided into 4 replicates, each containing 5 plots. The organic matter (rice straw or fresh Gliricidia leaves) were added to randomly selected plots in each block at a rate of 600 $g.m^{-2}$ (6MT. ha^{-1}) and either incorporated manually or left on the surface as a mulch. One plot per replicate did not receive any organic matter. Thus the experiment had five treatments within a randomized block design with four replicates.

Uniform seeds of mung bean (*Vigna radiata* Var MI 5) were planted at a spacing of 20 x 10 cm to obtain 300 plants per plot 14 days after the application of the organic matter, after obtaining soil samples for analysis.

The crops were managed under rainfed conditions, and weeded on two occasions after determining weed numbers. Inorganic fertilizers were not applied.

Germination was recorded in all plots 10 days after planting within a 1x 1 m quadrat. At 7 day intervals until flowering, three plants per plot were carefully uprooted, roots washed and dried at 80°C for 48 hours to determine the dry weights of shoots and roots. These weights were used to calculate Relative Growth Rates as described by Hunt (1982). At the onset of flowering in mung bean, 4 plants within each plot were uprooted carefully, roots washed and numbers of nodules counted. At the same time, roots in the soil were determined by using core samples (5 cm diameter and 20 cm length). The soil of each plot was randomly sampled at 4 places, using a soil sampler at depths of 0 – 20, 20 – 40 and 40 – 60 cm, as described by Böhm (1979). The soil cores were individually washed onto a 0.5 mm mesh and roots collected. The total root lengths were determined using the grid technique (Tennant, 1975) and dried at 80°C before weighing. The root length density (RLD) and root weight density (RWD) were calculated as follows:

RLD ($cm.cm^{-3}$) = Total length in a soil core/ Volume of core

RWD ($mg.cm^{-3}$) – Total dry weight of roots in core/Volume of core (adapted from Garcia – Barrios 2003)

At harvest, in late July and early August, seed and residue weights of mung bean were determined after drying at 80°C for 48 hours. The Harvest Indices and Relative Crop Yields (RCY) were calculated using the data.

The soils sampled before planting were analysed for the following: Physical properties: Bulk Density, Soil moisture and Texture (Smith, 2001), Total N (Kjeldhal) P (Olsen, Spectrophotmetry) and K (NH_4OAc extraction and flame photometry).

The data was subjected to appropriate statistical analysis as described by Gomez and Gomez, (1984) using probability values (P=0.05) to test significance of observed differences and LSD for mean separation.

RESULTS AND DISCUSSION

Application of organic matter reduced bulk densities of soil (Table 1), which is a vital soil characteristic for successful root development (Kuchenbuch and Ingram, 2004). There were no significant differences in the bulk densities of soils to which the two organic materials were added. However, incorporation reduced soil bulk densities to a greater extent than surface application. This could be attributed to the greater distribution of the organic biomass within the soil profile by incorporation, which facilitates the development of soil pores (Kay and Munkholm, 2004) and confirms similar reports on rice soils (Mandal et al, 2003).

Incorporation of organic matter increased soil moisture contents; again due to better soil pore development. Surface application of organic matter did not have a similar effect on soil moisture, although this method could reduce evaporation losses (Ji and Unger, 2001). The greater impact of rice straw on soil moisture retention when compared to Gliricidia leaves could be attributed to the slower microbial breakdown, due to the higher C: N ratio. However, the organic matter or method of incorporation had no impact on soil texture, and could be attributed to the short duration of this study, especially as long term application of organic matter could have a beneficial impact on soils with poor textures (Dexter, 2004).

Organic matter improves nutrient availability (Seiter and Horwath, 2004), a phenomenon observed under field conditions of this study (Table 1). The mean increment in soil N due to application of rice straw and Gliricidia leaves was 3% and 9% respectively when compared to the soils that did not receive organic matter. The higher N content in Gliricidia leaves increased the N contents of soils at the time of planting mung bean. Incorporation of organic matter reduced soil N contents marginally when compared to surface application, and the impact was greater with rice straw. The utilization of N by microorganisms to decompose the organic matter could be considered the causal factor, especially with rice straw, which has a higher C: N ratio. A similar phenomenon was also observed with soil P; mean values of soil P were enhanced by 8% and 16% when rice straw and Gliricidia were applied. Incorporation of organic matter reduced soil P contents, especially with rice straw. However soil K contents were increased by rice straw, which is generally high in this nutrient (Raju and Reddy, 2000), and surface application had a greater beneficial impact. While the causal phenomenon for this observation needs elucidation, the results clearly highlight the importance of organic materials in improving soil quality and fertility. Incorporation develops greater benefits confirming the reports (Schjonning et al, 2004) under a diverse range of ecological conditions.

Root length densities (RLD) were stimulated by organic matter (Table 2), again, the impact being greater with Gliricidia. This is attributed to the beneficial impact of organic matter on the rhizosphere (Mandal et. al, 2003). However the most important aspect of the data was the distribution of RLD within the soil profile. In the absence of organic matter RLD in the soil profile was significantly lower and declined rapidly with depth (Regression equation Y = -8.853 Ln (X) + 15.571 r^2 = 0.844, where Y = RLD and X = Depth). Application of organic matter on the surface stimulated root length expansion in the surface layer of soil, and the beneficial effect was greater with rice straw. This could be due to the slower decomposition of straw than Gliricidia, which could retain soil moisture and thus stimulate root growth in this dry season.

Incorporation of organic matter increases RLD through the soil profile. A greater RLD was thus observed in the 40 – 60 cm layer when organic matter was incorporated. Rates of decline in RLD with depth, when straw was applied to the surface or incorporated were Y = -14.294 Ln (X) + 24.931 r^2 = 0.943 and Y = -8.584 Ln (X) + 21.357 r^2 = 0.741 respectively. The rates of decline in RLD when Gliricidia was surface applied or incorporated were Y = -8.041 Ln (X) + 20.951 r^2 = 0.714 and Y = -3.856 Ln (X) + 19.019 r^2 = 0.658 respectively. This data also highlighted the better distribution of RLD through the soil profile by incorporation of organic matter, especially with Gliricidia, and the phenomenon could be attributed to the improvement of the rhizosphere by the added organic matter, especially those with a lower C: N ratio (Graves et al, 2004).

Root Weight Densities (RWD) (Table 3) were not stimulated to the same extent as RLD by organic matter or method of addition. As anticipated, the lack of organic matter reduced dry matter accumulation in roots, and hence the lower RWD at all sampling depths. This again confirmed the benefits of organic matter in promoting overall root growth, by increasing dry matter accumulation and expansion. Surface application of organic matter had a lower benefit on RWD than incorporation and the use of Gliricidia leaves increased RWD at all depths. However rates of decline in RWD were lower than those of RLD. In the plots which did not receive organic matter, the rate of decline in RWD was Y = -1.421 Ln (X) + 2.2481 r^2 = 0.608. The rates of decline when rice straw as surface applied or incorporated were Y = -1.623 Ln (X) + 2.522 r^2 = 0.840 and Y = -1.593 Ln (X) + 1.982 r^2 = 0.611 respectively. With Gliricidia, the rates of decline in RWD with depth were Y = -0.668 Ln (X) +2.508 r^2 = 0.908 when surface applied and Y = -0.595 Ln (X) + 2.922 r^2 = 0.593 when incorporated. Unlike RLD, these rates illustrated that while organic matter stimulated RWD, the method of application had a minimal impact. Hence, organic matter and its method of addition seem to stimulate root expansion to a greater extent within the rhizosphere than the accumulation of dry matter in the root system, as shown by Sangakkara et al (2004) for maize in pot studies.

Although organic matter increased germination (Table 5), due to a more conducive environment, the method of application had no effect. This also showed that the two organic materials have no allelopathic effects, and could promote germination of mungbean in the minor season. Organic matter increased the RGR of both roots and shoots significantly, especially when incorporated. Again the benefits of using material with low C: N ratios, such as Gliricidia leaves were clearly observed, and impact was greater in promoting the RGR of shoots than on roots. This could be attributed to increases in soil N by the addition of these leaves. Nodulation was also promoted by organic matter as shown by Olayinka et al (1998) for cowpea, and the benefits of incorporating Gliricidia leaves was evident. The decomposition of rice straw could induce a deficiency in rhizospheric N, thus causing a possible N hunger for the developing nodules. In contrast the enrichment of rhizospheric N by Gliricidia leaves could stimulate nodule development.

Weeds are a significant problem in organic systems (Bond and Grundy, 2003), and surface application of organic matter reduced weed populations significantly (Table 4). In contrast to the benefits accrued to plant growth and nodulation by Gliricidia, the application of rice straw on the surface reduced weed populations by 25% when compared to weed numbers in the straw incorporated plots. The beneficial impact of surface application of Gliricidia leaves in terms of weed numbers when compared to incorporation was 17%. The slower decomposition of rice straw could be considered the causal factor for this phenomenon as it acts as a barrier for the germinating weeds.

Organic matter increased seed yield, Harvest indices and Relative Crop Yields (RCY) (Table 5). The beneficial impact of Gliricidia was greater than that of rice straw, where the increment in yields over the plots without organic matter was 20% and 15% respectively. Incorporation of rice straw and Gliricidia leaves increased yields by only 7% and 9% respectively when compared to plots where the organic matter was applied on the surface. This suggested that the benefits of incorporation on seed yields were not as evident as in other measured growth parameters. This could be due to the greater yields obtained with the application of Gliricidia leaves, which could mask the benefits of incorporation. In contrast, Harvest Indices and RCY were significantly raised by incorporation, thus warranting the incorporation of organic matter into the rhizosphere to develop a more conducive environment for growth, nodulation and yield of field grown mung bean in a dry season, when the crop could easily be subjected to moisture stress. Thus smallholder farmers in the tropics could derive greater benefits of incorporation of applied organic matter in the form of crop residues or green manures. Extension and demonstration programs needs to provide encouragement to utilize material with lower C: N ratios as added organic matter to derive the maximum benefits.

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Table 1. Impact of organic matter and method of addition on selected soil properties at the onset of the planting season

Soil Parameter	Rice Straw		Gliricidia Leaves		Control	SE*
	Surface	Inc	Surface	Inc**		
Bulk density ($Mg.m^{-3}$)	1.25	1.16	1.27	1.19	1.31	0.04
Soil moisture (%)	18.65	19.44	18.59	19.37	17.99	1.29
Soil Texture	SCL	SCL	SCL	SCL	SCL	
Soil N ($mg.100g^{-1}$ soil)	1.10	1.06	1.16	1.13	1.04	0.03
Soil P ($\mu g.100g^{-1}$ soil)	9.17	8.56	9.59	9.32	8.11	0.42
Soil K ($m.eq.100g^{-1}$ soil)	0.76	0.84	0.76	0.84	0.75	0.15

* SE = Std Error of Means (n = 20)

** Surface and Inc represent surface mulching and incorporation respectively.

Table 2. Root length density (mm.cm^{-3}) of mungbean at flower initiation as influenced by organic matter and its method of addition

Depth of sampling	Rice Straw		Gliricidia leaves		Control	Probability
	Surface	Inc	Surface	Inc**		(P=0.05)
0 – 20 cm	25.16	21.54	20.54	19.27	15.65	0. 031
20 – 40 cm	14.40	17.62	16.53	21.94	10.87	0.029
40 – 60 cm	9.62	12.53	11.42	14.59	7.11	0.021
Total	**49.18**	**51.69**	**48.49**	**55.80**	**33.63**	**0.043**
LSD (P=0.05) (for comparing different soil depths)	1.43	2.57	0.96	1.99	3.55	

** Surface and Inc represent surface mulching and incorporation respectively.

Probability (P=0.05) Interaction Organic matter x method of addition = 0.042 Significant

Table 3. Effect of organic matter and its method of placement on root weight density (mg.cm^{-3}) of mungbean at flower initiation

Depth of sampling	Rice Straw		Gliricidia leaves		Control	Probability
	Surface	Inc	Surface	Inc**		(P=0.05)
0 – 20 cm	2.41	1.95	2.45	2.81	2.15	0.038
20 – 40 cm	1.46	1.74	2.38	2.76	1. 53	0.024
40 – 60 cm	0.62	0.97	1.66	2.12	0.52	0.046
LSD (P=0.05)	0.21	0.17	0.40	0.33	0.09	

** Surface and Inc represent surface mulching and incorporation respectively.

Probability (P=0.05) Interaction Organic matter x method of addition = 0.039 Significant

Table 4. Vegetative growth of mungbean as affected by organic matter ad its method of addition

Parameter	Rice Straw		Gliricidia leaves		Control	Probability
	Surface	Inc	Surface	Inc**		
Germination (%)	84	81	80	83	75	0.043
RGR ($mg.g^{-1}.d^{-1}$) (Shoot)	21.4	24.3	28.6	30.4	19.8	0.028
(Root)	18.6	20.1	24.0	26.7	21.4	0.044
Shoot water potential (MPa) at flowering	-5.56	-4.71	-5.28	-4.18	-6.01	0.046
Nodules at anthesis (Number.plant-1)	36	48	54	68	27	0.019
Weeds ($plants.m^{-2}$)	85	154	128	181	149	

** Surface and Inc represent surface mulching and incorporation respectively.

Probability (P=0.05) Interaction Organic matter x method of addition = 0.017 Significant

Table 5. Seed Yields, Harvest indices and Relative Crop Yields[@] of mungbean as affected by organic matter and method of addition

Parameter	Rice Straw		Gliricidia leaves		Control	Probability
	Surface	Inc	Surface	Inc**		
Seed yield ($Kg.ha^{-1}$)	766	821	793	864	688	0.035
Harvest index	0.35	0.38	0.38	0.42	0.31	0.042
RCY[@]	1.11	1.19	1.15	1.25	1.00	0.047

@ RCY = Yield of plots with Organic matter / Yield of control plots

** Surface and Inc represent surface mulching and incorporation respectively.

Probability (P=0.05) Interaction for yield (Organic matter x method of addition) = 0.018 Significant