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Review

Green manure in fruticulture: Aspects on soil quality and use in agriculture

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The farming practices have a direct impact in ecosystems and cause changes in the basic structures involved in the environment. Cultivated soils, after years of use, show changes in the physical, chemical and biological attributes, requiring improve production processes, with the intention of management alternatives that minimize environmental degradation and, consequently increasing the sustainability of agricultural environment. In the search for sustainable agricultural practices, it indicates the green manure, which is the use of plants in rotation or intercropped with crops of economic interest. The practice of green manure provides many improvements in chemical, physical and biological characteristics, through increases in organic matter content and microbial activity, nutrient cycling, disruptions of compacted layers, decreased erosion, incidence of pests and diseases, and suppression of weed plants. Thus, appearing to be an agricultural practice efficiently for sustainable fruit production system. In this sense, the present study aims to conduct a literature review on the benefits of green manure in fruticulture in order to improve soil quality and use in agriculture.

Key words: Cover crop, root system, sustainable management.

INTRODUCTION

The farming practices have a direct impact in ecosystems and cause changes in the basic structures involved in the environment. Cultivated soils, after years of use, show changes in the physical, chemical and biological aspects (Soares et al., 2005; Carneiro et al., 2009), in which the organic matter in the soil is an important factor in detecting imbalances in the system due be related to the cation exchange capacity, aggregate stability, and nutrient availability (Ciotta et al., 2003; Conceição et al., 2005; Pavinato and Rosolem, 2008), and negatively

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influenced by human action (Pereira et al., 2010).

Intense soil disturbance provided by the introduction of modern agriculture modifies the balance of pre-existing organic matter in the system, reflecting the decline in organic matter in the soil (Silva et al., 1994), in which it is maximized by erosion, compaction and decreased soil fertility (Llanillo et al., 2006). Thus, requiring improve production processes, aiming management alternatives that minimize environmental degradation, and thereby increasing the sustainability of agricultural environment.

In the search for sustainable agricultural practices, it indicates the green manure, which is the use of plants in rotation or intercropped with crops of economic interest (Calegari, 1995; Silva et al., 1999; Carvalho et al., 2005), resulting in improvements in the characteristics of cultivated soil, and indirectly increased agricultural production (Singh et al., 1991; Pikul et al., 1997; Fageria, 2002, 2007). The used species can be native and/or introduced (Calegari, 1995; Silva et al., 1999), which may be of annual cycle, semi-perennial, and perennial plants (Carvalho et al., 2005), and therefore present in the field for several months or during the year. After its cutting, it can be incorporated in the soil or maintained in covering the soil surface (Espindola et al., 2004).

The main benefits from the use of green manures are: increase in soil organic matter, decreased evapotranspiration and erosion produced by plant residue, nutrient cycling and disruption of compacted soil layers (Calegari, 1995). Other important benefits are the increased microbial activity, decreased incidence of pests and diseases, and suppression of weed plants (Fageria et al., 2005).

In this sense, the present study aims to conduct a literature review on the benefits of green manure in fruticulture in order to improve soil quality and use in agriculture.

HISTORY OF GREEN MANURE

There are reports of the practice of green manure in the various civilizations that inhabited the Earth (Singh et al., 1991; Pikul et al., 1997; Fageria, 2007). The Greek and Roman civilizations cultivated the *Vicia faba* L. and some species of *Lupinos* sp. at 300 years BC in order to improve soil fertility and provide some of the nutrients required by crops used in food. The pioneer settlers in North America used *Fagopyrum esculentum*, *Avena sativa* and *Oryza sativa* to incorporate organic matter to the soil (Fageria, 2007). In China, India and Japan, some legumes were recognized as an important source of nitrogen for irrigated rice, previous use of agricultural inputs (Singh et al., 1991). In the XVIII century and the first half of the XIX century, agricultural productivity was totally dependent on natural resources (Pikul et al., 1997). However, this agricultural trend was modified from the 60's, due to the reduction in the amounts of chemical fertilizers, the adoption of intensive cropping systems and the high demand for nutrients by the modern cultivars (Fageria, 2007). In Brazil, the first studies were conducted by the Instituto Agronômico de Campinas, which aimed to determine the best legumes for the production of green manure and concomitantly, the effects of organic matter incorporated into the soil in crop production economically (Miyasaka, 1984).

ROOT SYSTEM OF GREEN MANURE

Despite the great importance in the ecosystem and agricultural activity, the roots are poorly studied compared to the shoots of plants. This is mainly due to the difficulties imposed by methodological techniques, by their three-dimensional complexity and their temporal and spatial variability (Zonta et al., 2006). The importance of studying the root system of the plant species used in agriculture, discussing their distribution, extent and activity, is indisputable and fundamental to the scientific understanding of agricultural production, since it provides location information of fertilizers, spacing, intercropping and soil management and irrigation. The rooting varies with the species and cultivars, plant age, chemical and physical characteristics of the soil, cultivation, and phytosanitary conditions (Fracaro and Pereira, 2004).

The development of the root system has a direct influence on some plant characteristics, such as: drought resistance, efficient absorption of nutrients from the soil, tolerance to pest attack, germination capacity, and tolerance to handling farm machinery (Vasconcelos and Garcia, 2005). However, according to the authors, it is not the amount of roots that is the determining factor of these benefits, but their distribution in the soil profile during the year, since high amount of roots in the surface layers mean an excessive expenditure of synthesized metabolites in the shoot translocated to the roots, as well as higher risk of water stress during drought periods in non-irrigated areas.

The roots of green manures show important role in the maintenance and improvement of characteristics of the soil structure, by providing the breaking of the compacted layer, which contributes to improving soil aggregation (Camargo and Alleoni, 1997).

EFFECTS OF GREEN MANURE ON SOIL CHARACTERISTICS

The green manure used in the plant cover provides numerous beneficial effects in soil (Ladha et al., 1988; Ganry et al., 2001; Mandal et al., 2003), in chemical, physical and biological attributes of soils (Silva et al., 1998; Mueller and Thorup-Kristensen, 2001; Moraes et al., 2006).

Effects on the chemical attributes

In order to improve the characteristics of soil, the use of legume species is widespread in agriculture to be able to provide nitrogen to the production system (Seganfredo, 1995; Rufato et al., 2006), through the symbiotic relationship involving legumes and *Rhizobium* bacteria (Faria et al., 2004; Pinto et al., 2007), the associations between plants and cyanobacteria (Pinotti and Segato, 2004), or non-symbiotic association between free-living diazotrophs bacteria with the roots of the plant (Peoples and Craswell, 1992; Weber et al., 1999, 2000). The symbiosis result in fixation, mainly, atmospheric N_2 is available in large quantities for the production environment (Kanmegne et al., 1999; Moreira et al., 2010; Ribeiro et al., 2011).

Ramos et al. (2001) studied the amounts of nitrogen fixed by *Crotalaria juncea*, *Mucuna aterrima*, and *Canavalia ensiformis* in different soils, which verified that the quantities of nitrogen fixed by the *C. juncea* were on average 40% higher than those of other species. Mueller and Thorup-Kristensen (2001) assessed the potential for nitrogen fixation in two species of *Vicia* and three species of *Trifolium* in an organic system of crop rotation for two years, founded that all species contributed with more than 100 kg ha^{-1} of N, wherein the species *Vicia villosa* had the most fixed atmospheric N_2 (149 kg ha^{-1} of N).

The biomass produced by green manures positively influences the chemical characteristics of the soil, enabling increase in organic matter over the years, which increases the cation exchange capacity and therefore, the retention of nutrients in the soil particles (Ciotta et al., 2003). Ganry et al. (2001) report the importance of green manure in the management of soil organic matter in African semi-arid regions. In those conditions, with annual rainfall of less than 800 mm, the *Mucuna pruriens* intercropping of maize with a positive impact on productivity, reached values of 3.5 Mg ha^{-1}. Another beneficial effect of green manure on soil chemical properties is the cycling of nutrients. The branched and deep root system of legumes results in an increase in the efficiency of utilization of fertilizers, since there was increase in topsoil due to nutrients lost by leaching, especially potassium, calcium, magnesium, and nitrate (Silva et al., 2002). In addition, green manure is characterized as being a "miner agent" of the limited availability of nutrients as phosphorus and molybdenum (Alvarenga et al., 1995).

Borkert et al. (2003) estimated the quantity of recycled nutrients for five plant species (*Avena strigosa* Schreb; *V. sativa* L.; *M. aterrima*; *Cajanus cajan* Millsp; *Lupinus albus* L.) used as ground cover in a crop rotation system. After four years, it was found that all species evaluated were effective in accumulating macro and micronutrients, especially the *A. strigosa* and *V. sativa* in potassium accumulation, while the *M. aterrima*, *C. cajan*, *V. sativa* and *L. albus* in nitrogen accumulation. The calcium, magnesium, and micronutrients were satisfactorily accumulated for all species evaluated.

Effects on biological attributes

The presence of organic material provided by green manure promotes the activity of soil organisms, while their wastes act as a source of energy and nutrients (Lavelle and Spain, 2001). Besides the presence of vegetation cover influence on soil temperature. The amount and type of plant residue correlate with the thermal properties of the soil, determining the levels of moisture and organic matter, influencing the temperature fluctuations, especially in surface horizons, wherein the variation amplitudes are more intense due to direct incidence of sunlight (Eltz and Rovedder, 2005). In addition to reducing the temperature fluctuations and humidity, plant residue provides conditions that enhance the development of organisms (Espindola et al., 1997) increasing the population of native mycorrhizal fungi (Espindola et al., 1998), in some cases, inhibit harmful effects of nematodes (Moraes et al., 2006). Eltz and Rovedder (2005) observed that *Lupinus albescens* and *A. strigosa* were effective in softening temperature variations, when compared to treatment without cover. Derpsch et al. (1985) to evaluate the residual effects of *L. albus*, *V. villosa*, *Lathyrus sativus*, *Secale cereale*, *A. strigosa*, *Triticum aestivum*, *Raphanus sativus*, *Brassica napus*, *Helianthus annuus,* and the control treatment (without cover) in the water content and soil temperature, observed a lower temperature in the soils covered with *A. strigosa*, and higher in treatments corresponding to without cover.

Effects on physical attributes

The occurrence of compacted layers promoted by intensive agricultural implements reduces water infiltration into the soil. However, this negative effect can be decreased by the cultivation of green manures that show well-developed root system, enabling the breaking of compacted layers (Rosolem et al., 2002; Foloni et al., 2006). The intensity in occurring disruption varies according to the type of soil, as they present different clay classes, have different values of critical density (Reichert et al., 2003), as well as the specifics of each species of green manure (Rosolem et al., 2002). When executed, the breakdown in the soil provides the so-called biopores that are used in subsequent cultures for root depth (Dexter, 1991; Silva and Rosolem, 2002).

Some plants used for green manure, *C. juncea*, *M. aterrima*, and *C. cajan,* provide large amounts of dry matter to the productive system, reaching average values of 6, 10, and 15 Mg ha^{-1} $year^{-1}$, respectively (Calegari, 1995). After the senescence of the plant, this material produced increases the organic matter content of cultivated soil. This process improves soil physical attributes by decreasing the density and improves aggregate stability, porosity, water infiltration rate, and moisture retention (De Polli et al., 1996). The adoption of management to maintain soil protection systems through organic residue inputs continuum is critical to maintaining good physical soil structure (Alcântara et al., 2000; Boer et al., 2007). Systems commonly known as "conventional", resulting in soil disturbance, generally exhibit reduced aggregation indexes (Silva et al., 2000; Wendling et al., 2005).

Silva et al. (1998) evaluated the stability and aggregates of a Dark-Red Clayey Oxisol in different systems of succession corn and green manure under the conditions of the Cerrado biome. Cover crops grown in the off-season period were: *C. juncea*, *C. cajan*, *M. aterrima*, *Brachiaria ruziziensis*, and *Canavalia ensiformis*. Results were that *B. ruziziensis* as cover provided greater soil aggregation.

The water infiltration is also improved in soil covered by plant mass. Derpsch et al. (1991) evaluated the infiltration of water into a soil subjected to precipitation of 60 mm h^{-1}. When the coverage rate was 100%, the soil showed complete infiltration of water, whereas in the treatment which did not have coverage, only a quarter of the precipitated water infiltrated, the remainder being lost by surface runoff.

The organic matter content is able to positively influence the retention of plant nutrients and reduce losses by leaching (Hernani et al., 1995). According to the authors, the most important effect of the decomposition of plant residues is the improvement of soil attributes, which consequently improves the water/air relation, allowing increased infiltration and retention of water and nutrients in the soil and better root development, resulting in improved physical soil structure and control of water erosion.

Silva and Rosolem (2001) evaluated the effect of subsurface compaction on root growth of six species of green manure (*A. strigosa*; *C. cajan*; *Pennisetum americanum*; *Stilozobium aterrimum*; *Sorghum bicolor*; and *Lupinus angustifolius*). The authors found that density of up to 1.6 Mg m^{-3} at a depth of 0.15 m did not restrict root growth of *A. strigosa*, *C. cajan*, *P. americanum*, *S. aterrimum*, *S. bicolor* and *L. angustifolius*.

RESULTS OF GREEN MANURE IN FRUTICULTURE

In the area of fruit culture, studies that have been conducted aimed at assessing the effect of green manure on soil chemical properties, vegetative growth and fruit yield.

Results in *Citrus sinensis*

Marrero et al. (2009) evaluated the effect of intercropping between *Teramnus labialis* and 'Valência' orange (*Citrus sinensis* L. Osbeck) on the physical properties of a loamy soil in Cuba country. After four years, the intercropping increased soil water content, the total specific pore volume and the percentage of stable aggregates, when compared to treatments with natural vegetation and soil without vegetation cover. Bordin et al. (2008) evaluated the lines of an 'Folha Murcha' orange (*C. sinensis* (L) Osbeck) grafted with Cravo' limon (*Citrus limonia* Osbeck) with a history of soil compaction on the influence of the scarification on growing green manures, in the performance of trees and the physical properties of an Oxisol. The vegetation covers in the soil were: spontaneous vegetation, *C. cajan*, and *P. americanum*. The authors observed that the mass of the aerial part of *C. cajan* and *P. americanum* increased with scarification of the soil and the growth of the root system of *P. americanum* was higher than that of *C. cajan* in the management scarified and similar to this in the non-scarified management.

Results in *Prunus persica*

Rufato et al. (2007) evaluated the effect of cultivation of *A. strigosa*, *R. sativus*, *L. sativus*, *Pisum sativum*, *L. angustifolius*, and control treatment (spontaneous vegetation) on the vegetative development of *Prunus persica* after two agricultural cycles. The variables measured were: stem diameter, length of branches, fertility rate and canopy volume. Except the *R. sativus*, all green manure increased the development of *P. persica* compared to the control treatment.

Results in *Vitis vinifera*

Faria et al. (2004) studied the influence of intercropping of *C. juncea* and *C. ensiformis* in chemical soil characteristics, productivity and quality of fruit of *Vitis vinifera*, and observed that green manure provided improvement in soil chemical characteristics, increasing the organic matter content, exchangeable calcium and the value of the cation exchange capacity of the layer from 0 to 0.10 m depth, compared to the control treatment without cover crops. However, there was no significant effect of green manure on yield and fruit quality.

CONCLUSION

The practice of green manure provides improvements in chemical, physical, and biological attributes, through increases in organic matter content and microbial activity, nutrient cycling, disruptions of compacted layers, decreased erosion, incidence of pests and diseases, and suppression of weed plants, showing to be a sustainable agricultural practice, with proven efficiency for fruit production system.

Conflict of Interests

The authors have not declared any conflict of interests.

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