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Rotational Crops for Sugarcane Grown on Mineral Soils[1]

R. M. Muchovej[2]

Sugarcane in Florida is grown primarily on organic soils, however approximately 20% of the state's production is on adjacent sandy soils. The percentage of sugarcane grown on mineral (sandy) soils has been increasing due to an increase in demand in production, unavailability of alternative soil, urbanization of agricultural land and subsidence of organic soils.

Florida sugarcane is harvested approximately at yearly intervals from October to April; it is allowed to ratoon (stubble) after each harvest and fields remain in production for several years before being replanted. Generally, each ratoon crop is less productive than the previous crop and replanting is done when sugarcane yields drop to a level no longer acceptable to the producer (Alvarez et al., 1979). Soil factors, such as pH or Si content, may play an important role in yield decline of sugarcane. The reduction in sugarcane yield is also accentuated in sandy soils with low organic matter content, following repeated harvesting.

Many authors agree that soil organic matter is the key to soil fertility and productivity. In the tropics and subtropics, soil organic matter decays very rapidly. There are several forms of maintaining and/or increasing organic matter in soils:

1. Addition of inorganic nutrients in amounts that are adequate for crop production, taking into consideration what will be removed by the crop from the field;

2. Addition of organic materials as organic amendments: animal manures, composts, municipal and industrial biosolids, municipal solid waste, food-processing wastes.

3. Addition of organic matter as green manure and/or cover crops.

The establishment of cover crops (grasses or legumes) prior to planting sugarcane offers many potential agricultural and ecological benefits to the grower. Potential benefits from using cover crops include production of organic matter to enrich the soil, ground cover to reduce wind erosion (soil), weed control (less herbicide being used), reduced runoff, improved infiltration, soil moisture retention, improved soil tilth, nutrient enhancement, and food

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[2] R. M. Muchovej, Senior Biological Scientist, Southwest Florida Research and Education Center, Immokalee, FL; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

for wildlife. By improving soil organic matter, cover crops directly influence the soil water holding capacity by increasing water retention and lateral water movement within the soil.

Rotation of susceptible agronomic crops with crops that are not hosts for nematodes or are resistant to certain nematodes has been a successful nematode management strategy in many instances (Watson, 1922; Reddy et al., 1986). The continuous use of a monoculture may encourage certain diseases, weeds, or insects; the continuity of the pest cycle may be interrupted by an alternative crop. Well-fertilized thick stands of a grass, such as corn, will produce more above ground residues than will a legume and tillage will favor a more rapid decomposition of organic matter produced (Tisdale and Nelson, 1975).

Cover crops may increase soil organic carbon levels or reduce their rate of depletion. The selection of appropriate cover crops to increase soil organic carbon requires good knowledge of the quality and quantity of plant biomass produced and its rate of decomposition in soil (Kuo et al., 1997). Fallowing the field without plant residue returning to soils typically increases the rate of organic C depletion (Hargrove, 1986; Havlin, 1990).

Planting cover crops after sugarcane harvest increases cropping intensity and residue return and reduces the length of time the soil is left fallow. Cover crops may also reduce soil erosion (Smith et al., 1987) and NO_3-N leaching during high rainfall periods (McCraken et al., 1994). Cover crops in South Florida are normally planted in the spring and plowed down in the fall.

Kuo et al. (1997) examined the soil organic carbon and carbohydrate concentrations in soil as affected by several leguminous and non-leguminous cover crops after a 6 yr of a corn cover crop double cropping system in a temperate humid region, in Washington State. In that region, cereal rye and annual ryegrass were better suited as winter cover crops for building soil organic carbon than winter pea, hairy vetch, and canola, primarily because of their greater biomass and carbohydrate production.

Utilization of leguminous plants is a promising alternative to a forage grass cover crop for many agronomic crops, including sugarcane. Although elemental N occupies about 78% of the air by volume, is not used by most organisms. A group of bacteria, the Rhizobia group, or nodule bacteria, is able to utilize this free N by associating with legumes.

Biological nitrogen fixation is the biochemical process by which elemental N is combined into organic forms. It is carried out by many species of bacteria (in association or not with legumes), some actinomycetes (a special group of bacteria), and blue-green algae (cyanobacteria). On a global scale, more N_2 is fixed biologically than the amount applied in chemical fertilizers.

The process is:

$$N_2 \;+\; 6H \quad 6\,\bar{e} \quad \xrightarrow[\text{(Fe, Mo)}]{\text{(Nitrogenasc)}} \quad 2\,NH_3$$

Nodule formation in legumes is accomplished by rhizobia bacteria entering a single-celled root hair. The bacteria then multiplies and a nodule is formed. The N fixed within the nodule is used by the bacteria, the host plant, some may be excreted from the nodule into the soil, or is released by decomposition of the nodules or legume residues after the legume plant dies or is plowed under. A good legume plowed down may supply 60 to 80 lb N/acre (Tisdale and Nelson, 1975).

Perennial peanut (*Arachis* spp.) is a tropical legume that presents tremendous potential for uses in Florida. Ecological and environmental benefits from using perennial peanut in citrus have been explored to a certain extent (Mullahey et al., 1995; Rouse et at., 2001). Usually, the application of N fertilizer is not required, since the element is obtained via nitrogen fixation from atmospheric sources, by the Rhizobium system. Nitrogen fixation from perennial peanut is approximately 235 kg/ha/year (210 lb N/acre/yr), when planted as an only crop. When inter-cropped with citrus, 1/3 of this amount of N is incorporated in the biomass. Perennial peanut has a high forage value for grazing cattle and wild animals, such as deer and rabbits, which have been reported to feed on this legume in citrus groves. Minimal fertilizer inputs are necessary for establishment and maintenance, thus making it very appealing as a sustainable agriculture systems species. The extensive rhizome and root system developed by some species could also allow for interception of excess fertilizer and pesticides, so that water quality degradation is alleviated and leaching is minimized.

Several varieties are known to survive long drought periods and withstand high rainfall and temperatures on well-drained soils. Perennial peanut has been used as a *living mulch* in orange groves in south Florida, with considerable degree of success. A living mulch is a cover crop that remains alive for part or all of the cropping season (Teasdale, 1996). Species are typically perennials but may be self-seeding annuals. Living mulches have the advantage of not requiring reseeding every year, but have the disadvantage of competing with the crop for available nutrients and water. Since the period for rotational crops in sugarcane is rather short, the use of a perennial cover crop may not be desirable, though.

Utilization of Green Manure Legume Crops

Green manuring is a practice of fundamental importance within management systems used to recover low fertility soils, aiming to increase productivity of sugarcane (Zambello Jr. and Orlando Filho, 1981). The green manure crops commonly used in biofertilization are plants from the legume groups, since they normally have higher proportions of nutrients, when compared with other plants. Furthermore, leguminous plants produce a large volume of green biomass in relatively short periods of time, and can fix atmospheric N in the order of 225 kg/ha (200 lbs/acre) under optimal conditions. See Table 1 for N fixed by various legumes.

When a nonlegume is turned under, only the N from the soil or that supplied in the fertilizer is returned (Tisdale and Nelson, 1975). Green manure will not only help maintain the soil organic matter but will sometimes even increase it (Tisdale and Nelson, 1975). The P in green manure may be even more effective than fertilizer P, probably because of its gradual release during decomposition, localized placement, presence of organic acids to maintain availability and the formation of certain complex ions (Tisdale and Nelson, 1975). Decomposition of green manure crops is fast, however the residual effects are well recognized.

Some of the advantages from the utilization of leguminous plants as green manuring and its benefits for soil properties, as listed by Allison (1973) are summarized below:

1. Increases microbial activity in soils;
2. Increases soil water retention;
3. Fixes atmospheric N;
4. Provides recycling of nutrients;
5. Controls weeds;
6. Controls soil erosion.

Furthermore, the use of certain legumes as green manure has been shown to be effective in the control of plant parasitic nematodes (*Meloidogyne javanica, Pratylenchus brachyurus, Dilyenchus sp.*, etc) (EMBRAPA, 1979).

Upon selecting a legume for green manuring, several factors must be considered, such as adaptation of the species to the prevailing conditions of the area, ease in obtaining the seed, green matter production, among others. There are large variations regarding the production among the legumes, and even within the same legume planted in different conditions (time, locality, etc) (Orlando Filho, 1983). There is also a lot of variation in the minimum and maximum concentrations of nutrients in the legumes. Several factors may be responsible for these variations, including the type of soil, age of the plant when sampled, climatic conditions of the area, especially sunlight, temperature, and moisture.

General Recommendations Regarding Green Manure for Sugarcane Production

A) For sugarcane growing, the practice of green manure with legumes is recommended when fields are being re-planted, since during this time, it presents the following advantages:

1. Does not result in loss of one cropping year;
2. Does not interfere with germination of the cane;
3. Has a relatively low cost, considering the returns;
4. Promotes significant increases in the sugarcane production (plant cane and at least two stubble crops);
5. Protects the soil from erosion and prevents multiplication of weeds.

B) Several legumes may be used in this biofertilization, and the crop should be selected based on its adaptation to the climatic conditions, production of biomass, price, availability, among other considerations. In Florida, for instance, cowpeas and beans are used by sugarcane growers.

C) The management practices for the respective legume should be closely followed to obtain the best performance; for instance, if seed is previously imbibed in water, incorporation must be immediate so that seed coat is not broken and negatively affect germination. Certain legume seed must be treated with boiling water for 10 to 15 seconds to break dormancy and improve germination.

D) Whenever possible, legume seed should be inoculated with the appropriate *Rhizobium* species, to ensure good nitrogen fixation.

E) Before planting the legumes especially in areas where sugarcane is being re-planted, it is important to verify which herbicides were used in the sugarcane, and their residual time since many may damage legume plants.

F) The lime and fertilizer requirements should be determined from soil analysis since legumes have high requirements, especially regarding P, Ca, Mg, and are not extremely tolerant of high soil acidity.

G) Legumes **should be incorporated**, by discing them into the soil, **when approximately 50% of the plants are flowering**. Going beyond that stage will result in lower N returns to the soil. The subsequent sugarcane crop **should be planted about 20 days after incorporation** of the green biomass.

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Table 1. Average Nitrogen Fixation by Legumes

Legume	N Fixed (lb/acre)	Legume	N fixed (lb/acre)
Alfalfa	194	Lespedezas (annual)	85
Ladino clover	179	Vetch	80
Sweet clover	119	Peas	72
Red clover	114	Soybeans	100
Kudzu	107	Winter peas	50
White clover	103	Peanuts	42
Cowpeas	90	Beans	40

After Tisdale and Nelson, 1975.