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ACACIA, LEUCAENA AND SESBANIA GREEN MANURES AFFECT MAIZE GROWTH IN THE TABORA REGION OF TANZANIA

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Donati A. Asenga

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Douglas O. Lantagne
Major professor

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ACACIA, *LEUCAENA* AND *SESBANIA* GREEN MANURES AFFECT MAIZE GROWTH IN THE TABORA REGION OF TANZANIA

By

Donati A. Asenga

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ABSTRACT

ACACIA, LEUCAENA AND SESBANIA GREEN MANURES AFFECT MAIZE GROWTH IN THE TABORA REGION OF TANZANIA

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A pot experiment was used to examine the green manures of *Leucaena leucocephala*, *Sesbania sesban* and *Acacia julifera* on maize growth. In conjunction with the pot experiment, a decomposition study for the same tree species was also conducted. Three levels of green manure; 0, 4 and 8 tons/ha for each tree species were used. Maize dry matter yields of treatments incorporating green manures of *L. leucocephala* were 70 to 190 percent higher than controls and 14 to 70 percent higher than those of *S. sesban*. The use of green manure from *A. julifera* did not affect maize dry matter yield. Maize dry matter yield increased as the amount of green manure increased.

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1 INTRODUCTION

The population in tropical Africa is increasing faster than the capacity of the region to increase food production. In many areas, food production is decreasing as the population continues to grow. Declining food production is associated with changes in the traditional farming methods and soil nutrient depletion (Kang et al., 1984). Traditional farming methods incorporated fallow periods of sufficient length to maintain soil productivity of the highly weathered kaolinitic soils of the region. Soil productivity has declined as fallow periods have been shortened and/or eliminated to increase food production. The result has been a net decline in the amount of food produced.

The use of chemical fertilizer is a solution, however, chemical fertilizer is prohibitively expensive for most small farmers. There are also environmental concerns that are associated with fertilizer use. A potential alternative to chemical fertilizer is the use nitrogen fixing (commonly leguminous) tree species as green manures. Leguminous tree species help maintain and improve soil fertility, help to control water and wind erosion, provide fuelwood, fodder, improve microclimatic conditions and enhance soil moisture conservation (Winterbottom and Hazlewood, 1987). In addition they provide litter for incorporation into the soil as green manure.

There are several benefits from soil incorporated green manures. They include: (i) slow conversion of unavailable organic sources to more readily available inorganic plant nutrients, (ii) conservation of residual fertilizers that might otherwise be lost through leaching, (iii) provision of ground cover during erosion-prone periods and (iv) maintenance of organic matter content which indirectly affects soil structure, buffering capacity, cation exchange capacity, water holding capacity, infiltration, microbial diversity and soil porosity (Frankenberger and Abdelmagid, 1985).

There are a number of studies relating to N mineralization of tree leaves. Such studies have dealt with only a limited number of tree species and geographical locations. Because rate of decomposition and nutrient release are also governed by edaphic and climatic conditions, time and quantity relationships must be determined for each agricultural system and green manure combination. In view of these circumstances and the direct effect of green manures on the nutrition and growth of plants, a study was initiated to determine: (i) if maize growth is affected by incorporating

Acacia julifera, *Leucaena leucocephala* and *Sesbania sesban* as green manures, (ii) if a time lag between green manure incorporation and maize planting affects the subsequent growth of maize, and (iii) if maize growth is affected by the rate of green manure incorporated.

2 LITERATURE REVIEW

2.1 INTRODUCTION.

Green manuring is a practice of incorporating green plant material into the soil. Any material, whether sod, rye, weeds, clover, cowpea or crop residues when incorporated accomplishes the purpose of green manuring. Green manures add organic matter and plant nutrients. The added organic matter helps to maintain soil physical and chemical properties (Webster, 1980; Wade and Sanchez, 1983).

The practice is recognized as a very useful tool for increasing soil fertility of saline and wet soils (NAS, 1980). Decomposition of organic matter improves soil permeability and it liberates carbon dioxide and organic acids. Organic acids help dissolve insoluble calcium salt in the soil solution which neutralizes the alkali present (Dargan et al., 1975). Incorporating kudzu green manure lowers soil acidity by reducing aluminium (Al) saturation to levels similar to bare and completely fertilized treatments (Wade and Sanchez, 1983). Additionally, kudzu green manure increases exchangeable calcium (Ca), potassium (K), phosphorous (P) and magnesium (Mg) (Wade and Sanchez, 1983). Green manures also increase the availability of other elements, especially phosphorus (Webster, 1980). Incorporated *L. leucocephala* prunings have been reported to increase organic carbon, exchangeable K, Ca, and Mg (Kang et al., 1984).

The value of a leguminous tree species as a green manure is influenced by its value as forage. Although green manure can be an efficient way to maintain soil fertility where there is no livestock husbandry, a practical man will always keep in mind extra feed for his livestock (FAO, 1980). The value of green manure is also influenced by its ability to supply additional nitrogen. Other considerations when selecting green manures include the ease with which it can be incorporated, its ability to suppress weeds and its biomass yield.

2.2 FACTORS AFFECTING GREEN MANURE DECOMPOSITION.

Nitrogen mineralization of green manure added to the soil is affected by many factors. Among these are: soil moisture, plant material moisture content, soil temperature, age, lignin content, carbon to nitrogen (C/N) ratio and the size of the plant material (Frankenberger and Abdelmagid, 1985; Martin-Prevel et al., 1987).

2.2.1 Soil moisture.

The soil moisture content has been directly correlated to the rate of N mineralization (Myers et al., 1982). Increasing the soil moisture content from 30 to 50 percent leads to a much faster green manure breakdown (FAO, 1980). Wiegert and Evans (1964) and Meentemeyer (1978) found that soil moisture status was an important factor influencing microorganisms. Soils with either very low or very high moisture contents are associated with limited N release. Decomposition in a saturated soil for example can be replaced by anaerobic putrefaction. This is because of the impaired gaseous diffusion resulting in anaerobic conditions. Anaerobic conditions may ultimately lead to N denitrification (Sopher and Baird, 1982). Generally 60 to 80 percent soil moisture content considered optimum for plant material decomposition (Martin-Prevel et al., 1987).

2.2.2 Plant material moisture content.

Microbial processes are also important in the decomposition of plant materials (Palm et al., 1988). Colonization by microbes is influenced by the moisture content of the plant material. Fresh materials tend to attract more microbes than dry ones. Little attention has been given to the amount of air present in litter which influences the activity of decomposers (Williams and Gray, 1974). This knowledge is an important guide to farmers who might not know whether to incorporate dry or fresh plant materials.

2.2.3 Soil temperature.

Soil temperature is one of the major factors controlling litter decomposition. Warm temperatures are necessary to speed the reaction of soil microorganisms (Payne and Gregory, 1988). Longer decomposition periods are often required in temperate zones. In the tropics, prunings of legumes have been found to quickly decompose, loosing 50 percent of their leaf nitrogen within the first 25 days of decomposition (Wilson *et al*., 1986).

2.2.4 Age, lignin content and C/N ratio of the plant material.

In addition to soil moisture content and temperature, the age of the plant material has an even greater influence on N mineralization. Green manures should be plowed under in the green state before they have matured. This is because the percentage of carboneous substances increase and those of N and mineral nutrients decrease as maturity approaches (Bear, 1965). Such materials decompose more slowly than younger ones because of their high carbon to nitrogen ratios (Webster, 1980). As the amount of cellulose and lignin increases, the plant becomes woody and a lower quality green manure source. These compounds are highly resistant to decay (Hall *et al*., 1974; Frankenberger and Abdelmagid, 1985).

2.2.5 The size of plant material.

It is also important to note that the size of the incorporated plant material influences the rate of N mineralization. Larger pieces have less surface area (Foth and Ellis, 1988). Therefore smaller pieces have more surface area and provide more opportunities for microbial attack. Material size manipulation might be a usable method of controlling the rate of decomposition and therefore nutrient release.

2.3 TIMING FOR GREEN MANURE INCORPORATION.

For optimal responses from incorporating green manure, the time of incorporation must be considered. Proper timing ensures that nutrients are released at the proper growth stage of the plant. Best rice grain yields have been reported when *Sesbania* was incorporated a day before transplanting (Beri and Meelu, 1981; Evans and Rotar, 1987; Beri et al., 1989). It was also found that about 80 percent of the total nitrogen and 40 percent of carbon were released by *S. aculeata* in 10 days (Beri et al., 1989). To take full advantage of the released nutrients, seeding should immediately follow green manure incorporation (Beri and Meelu, 1981; Khind et al., 1985).

2.4 SOURCES OF GREEN MANURE.

Many agricultural crops have been tried as green manures. The choice in each case depends on climatic conditions, the cropping system practiced, the availability of seed and local habits. Preference should be given to legumes because of their ability to fix nitrogen and their higher N content (Webster, 1980; Yost et al., 1985; Palm et al., 1988; Little et al., 1989). Deep-rooted leguminous plants seem to have the ability of returning more nutrients to the soil from the subsoil through litter fall and decay than plants with shallow roots (Webster, 1980).

A majority of leguminous plants contain a higher nitrogen concentration in their leaves than non-leguminous plants. Although N is fixed by legumes from the atmosphere by means of bacteria living in their root nodules, the major contribution of legumes as soil restorers is not via direct transfer of nutrients from nodules to the soil. It is through materials released from decomposing leaves, stems and roots (Mmbaga, 1980; Wilson and Kang, 1981). Equally important even within the legume family (Leguminosae) the ability to fix and release nitrogen differ from one genus and species to another. Atta-Krah (1990) and Kang et al. (1985) found that *L. leucocephala* prunings can add from 160 to 250 kg N ha^{-1} yr^{-1}. High nitrogen yields from *L. leucocephala* leaves of 500 to 600 kg ha^{-1} have been reported

(Guevarra et al., 1978). *Sesbania* has been found to fix from 65 to 202 kg N ha^{-1} (IRRI, 1964; Evans and Rotar, 1987; Beri et al., 1989).

2.5 SUBSTITUTION OF GREEN MANURES FOR INORGANIC FERTILIZERS. Green manures can be used without chemical fertilizer supplements. According to Yamoah et al. (1986), maize at 2 months of age requires about 80 kg N per hectare. The amount of N that can be obtained from *L. leucocephala* seems to be more than that required by maize plants (Atta-Krah, 1990; Kang et al., 1985). In the case of *S. exaltata* which can contribute up to 65 kg N ha^{-1}, this amount equals to 80 percent of the amount that is required by maize. The remaining 15 kg N ha^{-1} could be supplied by N fertilizer or from another pruning if alley cropping was practiced. On the other hand, the effect of *S. aculeata* green manuring on rice has been reported to be equal to 80 kg of applied N after fallow (Dargan et al., 1975). These examples demonstrate the importance of green manuring in economizing and/or substituting for chemical fertilizers.

The benefits of using green manures alone has not been fully realized. This is because crop utilization of N derived from prunings is usually low (Kang et al., 1985). Supplementing with commercial N fertilizer becomes necessary for optimum food production. Kang et al., (1981b, 1984) worked with a number of multipurpose tree species, including *L. leucocephala*, and found that the efficiency of N utilization from prunings rarely exceeded 30 percent. The reason for the low efficiency could either be because N from prunings is stored in the soil biomass and organic matter (Ladd et al., 1981), or is lost through volatilization, leaching and denitrification (IITA, 1982).

2.6 GREEN MANURE YIELDS.

In addition to green manure N content and utilization efficiency, it is worth considering the amount of green manure that can be produced. This type of information is necessary to determine the number of hectares that can be treated with green manure sources available. This information is also needed to budget for supplementary fertilizer additions. Green manure dry matter yields of 3.4 t ha^{-1} from inter-cropped *S. sesban* experiments in India have been reported (Evans and Rotar, 1987). Prunings of *L. leucocephala* were reported to produce 5 to 6.5 t ha^{-1} yr^{-1} dry matter (Kang et al., 1981b, 1984, 1985). These green manure yields far exceed those recommended for soil incorporation on a per hectare basis (Evans and Rotar, 1987; Young, 1989). A metric ton of *L. leucocephala* fresh pruning yields 10.4 kg N (Kang et al., 1981b) while that of fresh *S. aculeata* yields 5.5 kg N (Khind et al., 1985). Based on these estimates of nitrogen content, these species would be able to supply sufficient N to crops of maize and rice.

2.7 CROP YIELD RESPONSES TO DIFFERENT GREEN MANURES.

2.7.1 *L. leucocephala*.

Yields of most food crops have been reported to increase with the application of green manure. However the increase depends in part on the species being used as a green manure. A 40 percent increase in maize grain yield has been reported in Nigeria after incorporating *L. leucocephala* prunings (Atta-Krah, 1990). In another instance, maize grain yields were 46 percent higher than treatments that did not receive *L. leucocephala* prunings (Kang et al., 1981b). Maize grain and stover yields were also increased to more than 100 percent after incorporating *L. leucocephala* prunings (Kang et al., 1985).

Normally crop yields increase when amounts of green manure are increased. A point is reached where additional quantities become uneconomical. Kang et al. (1981a) reported on 1283, 2313 and 3213 kg ha^{-1} maize grain yield after applying 0, 5 and 10 t ha^{-1} *L. leucocephala* prunings respectively. When *L. leucocephala* alley cropping was tested over a five year period on a sandy soil of low fertility, maize yield declined in the controls where *L. leucocephala* was not applied. *L. leucocephala* incorporated trials maintained the yield which was significantly higher than the control (B. T. Kang, unpublished data). In a similar trial with the same maize variety, grain yields were 2109, 2732 and 3221 kg ha^{-1} following application of *L. leucocephala* prunings at a rate of 0, 5, and 10 t ha^{-1} respectively (Kang et al., 1981b).

2.7.2 *Sesbania*.

Comparing different green manures, Bhardwaj et al. (1981) reported on increased rice grain yields after incorporating *S. bispinosa* green manures. Their data indicated a general linear response to added green manure. There was also a tendency for yields to level off at higher rates. They also noted that this response to green manure was equivalent to 60 to 80 kg N ha^{-1}.

Rice grain yield from dhaincha (*S. cannabina*) plots were reported to be significantly higher (4660 kg ha^{-1}) over the control (3990 kg ha^{-1}) (Bhardwaj et al., 1981). Increases of rice yields after green manuring with dhaincha over those without were also reported elsewhere (Dargan et al., 1985; Evans and Rotar, 1987). Although N efficiency and/or content might be low, green manuring can sustain productivity of most crops at relatively high yields. Much, if not all of N needed for moderate to high crop yields could be supplied by green manure.

2.8 EFFECTS OF DECOMPOSING PLANT MATERIAL ON ROOT GROWTH.

It is a common practice to look at beneficial effects of incorporated green manures. However, it is worthy also to look at the non-beneficial effects on crop productivity. This is because microorganisms may change non toxic compounds to toxic ones. Chemical compounds may also be produced and escape to the environment. It is also possible for microorganisms to synthesize inhibitors that decompose plant residues (Norstadt and McCalla, 1963; Rice, 1984). These allelochemicals have been found to inhibit radicle growth of rice and lettuce seedlings and growth of rice seedlings (Chou and Lin, 1976). *Eucalyptus globulus* leaves have also been reported to produce allelochemicals that inhibit root growth of cucumber seedlings and also the growth of hypocotyls (Baker, 1966). Different rates and sources of green manures may have different effects on root development.

Delaying planting to allow toxic decomposition products to disappear has, however, been effective in avoiding the depressing effects (Patnaik, 1978). But delayed planting does not seem to offer a viable solution because the rapidly released nutrients may become unavailable to plants. Incorporating them just after germination appears to be a good alternative. Roots will be well established and therefore less susceptible to allelotoxins.

2.9 ROOT AND SHOOT DEVELOPMENT

Root weight is a good parameter for characterizing the total mass of roots in a soil. In all cases in which the productivity of underground vegetation is to be determined, root dry weight should be the criterion for evaluation (Bazilevich and Rodin, 1968; Santantonio et al., 1977). Knowing root weight helps determine the proportion of humus attributed to root death.

Root weight can be regarded as a fundamental measure of photosynthate storage in a plant. According to Bohm (1979) root weight is not well adapted as a parameter for characterizing the amount of soil root absorption. Therefore, the assumption that root weight can be correlated to root activity is not valid. By expressing root data as root weight, the amount of fine roots represents only a small fraction of the total weight, although these fine roots can be the most active part of the root system. Therefore a high total root weight in a soil layer may not be identical with a zone of high water and nutrient uptake.

Maintenance of proper balance between root and shoot is of great importance. If either is too limited or too great in extent, the other will not thrive (Brown and Scott, 1984). The root surface area must be sufficiently widespread to absorb enough water and nutrient for the stem and leaves, which, in turn, must manufacture sufficient food for the manufacture of the root system. Shoots that are too small to manufacture sufficient food, to feed an extensive root system creates an unbalanced condition in the plant, which may retard its development.

2.10 MAIZE NUTRIENT REQUIREMENT.

Nutrient uptake by maize plants can be affected by soil temperature. Cool temperatures at planting has been reported to restrict nutrient absorption and delay germination (Ritchie and Hanway, 1984). This can be avoided by banding small amounts of fertilizer to the side and below the seed. After maize emerges, its growth proceeds slowly until the fourth week. Precise fertilizer application is not very important, although it is desirable to prevent nutrient deficiencies before symptoms appear. Side-dressing with about 5 kg/N/ha may become necessary (Bromfield, 1969; Yamoah *et al*., 1986).

Plants enter the rapid linear period of growth between the fifth and eleventh weeks after emergence. It is also in this period (ninth week) that tassels and silks start to form, marking the beginning of the reproductive stage. Nutrient deficiency at these critical development and reproductive stages may seriously affect the yield of maize.

Nitrogen uptake increases linearly from 5 kg/ha in the fourth week to about 100 kg/ha in the eleventh week (Yamoah et al., 1986). Thereafter the rate slows down and remains constant after reaching a maximum of 132 kg/ha at 17 weeks (Bromfield, 1969; Yamoah et al., 1986).

3 MATERIALS AND METHODS

3.1 SITE DESCRIPTION.

The study was conducted at Tumbi in the Tabora region of Tanzania from late April to mid-July, 1990. In 1987, Tumbi became the center for an agroforestry project established by the International Council for Research in Agroforestry (ICRAF). The project goal is to identify tree species capable of producing high quality fodder and green manure.

Tumbi lies at about 5°S latitude and 32°E longitude. The mean altitude is about 1200 m above sea level. Most rains fall in the November to April period with reduced precipitation between mid-January to mid-February. The mean annual rainfall is 880 mm, ranging from 550-1300 mm. Monthly means of daily temperature maxima ranges from 28 to 30°C. The corresponding minima ranges from 17 to 18°C. Soils are classified as ferric acrisols. They are well-drained, bright reddish brown sandy clay loam (Hennemann and Kullaya, 1978).

3.2 EXPERIMENTAL PROCEDURES.

To determine the effects of green manures on maize growth, a pot experiment was established. Leaf and twig tissue of three tree species were incorporated as green manure into the pots with soil. It was anticipated that the material would decompose and release nitrogen and other plant nutrients for the developing maize plants. In conjunction with this experiment, a decomposition study to determine rate of biomass decomposition was also undertaken for the same tree species.

3.2.1 POT EXPERIMENT

3.2.1.1 Green manures

Leaf and twig tissue of *Acacia julifera*, *Leucaena leucocephala* and *Sesbania sesban* were used as green manure sources. They were obtained from a species trial established by ICRAF at Tumbi, Tanzania. *A. julifera* and *L. leucocephala* tree species were 2 years old and about 3 m high. *S. sesban* was one year old and approximately 2 m tall.

Two composite samples from 5 randomly selected trees of each tree species were collected. These samples were obtained from the upper one-fourth of the trees. They were separated into leaves and twigs and weight of each determined. Samples were taken to an oven and dried at 70°C to a constant weight. The dry matter weights were used to calculate the amount of green manure needed for incorporation in each pot (Table 1). The calculations were based on a per hectare green manure equivalent recommendation (Evans and Rotar, 1987; Young, 1989). The amount of green plant material for pot incorporation was then collected from the same trees. The samples were chopped into pieces about 2 cm long. Twigs up to 0.5 cm in diameter were included.

Table 1. The amount of green manure in grams and the ton per hectare equivalents for each tree species used in the experiment.

Species	Level (tons/ha)	Oven-dry weight equivalent (g)	Fresh weight equivalent (g)
L. leucocephala	4	9.63	31.5
	8	19.26	63.0
S. sesban	4	9.63	29.5
	8	19.26	59.0
A. julifera	4	9.63	23.3
	8	19.26	46.6

3.2.1.2 Soil collection

A site near the species trials was selected for soil collection. Six kilograms of soil was then placed in each of one hundred and thirty five black plastic pots leaving room for green manure incorporation. The pots were 22.8 cm high, and had a capacity of 6 liters. Their top and bottom diameters were 21 and 15 cm, respectively. They had 4 holes at the bottom for draining of excess moisture. After filling the pots with soil, they were randomly selected for treatment and labelled. Green manure treatments were added to the top of the soil in each pot and covered with 3 cm of soil.

3.2.1.3 Planting and harvesting

A 4 month maturing Katumani composite maize (*Zea mays*) variety was used. It is adapted to dry regions where long rains rarely last for more than 2 months. It flowers in about 2 months. An added advantage of composite varieties is that farmers can retain seeds for future crops (Acland, 1971).

After plant material incorporation in all pots, maize was planted in 9 pots from each of the three replications (27 per treatment) representing the first week of plants. Three seeds were planted in each pot at a depth of 2 cm below the soil surface. Maize was planted in 9 pots on a weekly basis for 4 additional weeks (a total of 135 pots). The layout for this experiment is shown in Figure 1. Following germination, one seedling was uprooted leaving two seedlings per pot. One of the two remaining seedlings was harvested after 28 days. The other was harvested at the end of 56 days. The schedule for maize planting and harvesting is illustrated in Figure 2. For example, maize planted in the first week grew for 4 weeks (28 days). One plant was harvested at the end of the 4th week (first harvest) leaving the other to grow for another 4 weeks. This remaining plant was harvested at the end of the 8th week. After each harvest, plant materials were oven dried at 70^{o}C to a constant weight for 30 hours. Weights were then recorded in grams.

Replication 1.

L_1W_4	S_2W_4	S_2W_2	A_1W_5	L_2W_4	L_1W_5	CW_4	A_1W_2	L_1W_3	A_2W_5	A_1W_4	A_2W_1
S_2W_5	S_2W_3	L_2W_2	L_2W_1	A_2W_2	S_1W_3	S_1W_2	L_2W_3	S_2W_1	CW_1	CW_2	L_2W_5
A_1W_1	S_1W_1	L_1W_2	L_1W_1	CW_5	A_1W_3	A_2W_4	S_1W_5	CW_3	S_1W_4	A_2W_3	-

Replication 2.

S_2W_3	A_1W_1	CW_4	A_1W_2	L_1W_2	S_2W_4	A_1W_3	S_2W_2	L_2W_3	L_1W_1	CW_5	L_1W_3
CW_1	A_2W_5	S_1W_1	S_1W_3	CW_3	CW_2	A_2W_3	S_2W_1	A_2W_4	A_1W_5	L_2W_2	A_2W_2
L_2W_1	S_1W_4	L_2W_5	L_5W_4	S_1W_2	L_1W_5	A_1W_4	A_2W_1	S_1W_5	L_2W_4	S_2W_5	-

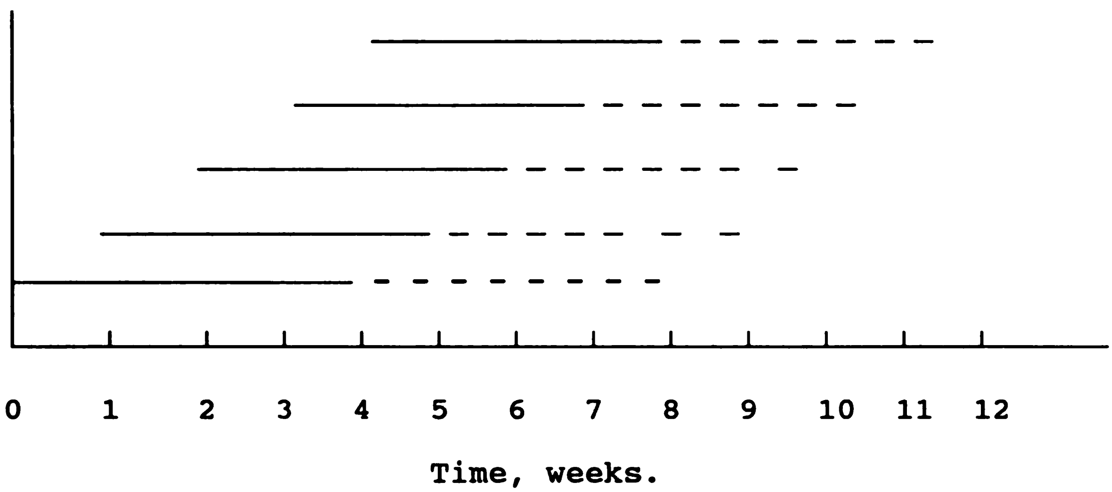
Replication 3.

A_2W_1	A_1W_2	A_2W_2	S_1W_1	CW_2	L_1W_2	S_1W_4	S_1W_3	A_1W_5	L_1W_1	L_2W_1	L_1W_3
CW_3	S_2W_2	CW_1	L_2W_3	L_2W_3	L_2W_5	S_2W_1	S_1W_5	L_2W_2	A_2W_3	A_1W_1	CW_3
A_2W_5	S_1W_2	A_1W_4	CW_5	A_1W_3	S_2W_5	A_2W_4	S_2W_3	L_1W_5	L_1W_4	S_2W_4	-

- Letters A, L and S = *A. julifera, L. leucocephala and S. sesban*.
- Subscript 1 and 2 after A, L and S = 4 and 8 ton/ha green manure rates.
- C = control (0 ton/ha green manure rate).
- W = Dates of planting (weeks).
- Subscripts 1-5 after W = week 1-5.

Figure 1: The layout for the pot experiment.

After the second maize harvest, roots were excavated from the pots. The collected roots were immersed in water to remove soil particles. They were then air-dried followed by oven drying at 70°C to a constant weight in 30 hours. Weights were recorded in grams.



_____ = Time when pots had 2 maize plants
_ _ _ = Time when pots had a single maize plant.

Figure 2. Schedule of planting (beginning of complete line) and harvesting (end of either complete or dotted line) of maize.

3.2.1.4. Watering and recording soil temperatures.

Collected rain water was used to maintain pots at 80-85 percent soil moisture content. Its pH and electrical conductivity were 7.3 and 0.14 mS/cm, respectively. The soil moisture content was determined by the percent weight difference between dry and wet soils. The wet soils were left for about 15 minutes to drain away excess water. In addition, daily soil temperatures at 8.00 and 14.00 hours were collected using 16 soil thermometers in two out of the three replications.

3.2.2 GREEN MANURE DECOMPOSITION.

3.2.2.1. Litter bags.

A total of one hundred thirty five litter bags of two sizes were used. The two sizes were 7.5 x 7.5 cm and 15 x 15 cm with mesh sizes of a square millimeter. The 7.5 x 7.5 cm litter bags were filled with fresh green manure of each species that was equivalent to 4 tons per hectare (Table 1). The green manure equivalent of 8 tons per hectare were placed in the 15 x 15 cm litter bags.

3.2.2.2. Burying the litter bags.

Plant materials placed in litter bags were from the same tree species and were collected in the same manner as for the pot experiment. After filling the litter bags, they were labelled according to treatment and randomly assigned to collection dates. They were then buried 10 cm below the soil surface on ridges. Ridges are recommended in this region to reduce soil erosion and to conserve soil moisture. They are between 15 and 30 cm high and about 50 cm wide. They are normally spaced 1 m apart. Litter bags within a ridge were placed at 1 m intervals. After covering the litter bags with soil, a person weighing 50 kg walked on top of the ridges to firm the soil.

3.2.2.3. Litter bag collection.

After 7 days, 9 litter bags per replication were unearthed. They represented the three tree species and the two levels of green manures plus a control. They were rinsed in water to remove remaining soil particles and were then air dried. The air dried material was then oven-dried at 70°C to a constant weight for 30 hours. Collection of the remaining litter bags continued after 14, 21, 28 and 42 days (Figure 3). Each sampling was treated in the same manner as the first one. The fifth week was excluded to minimize the need for more experimental materials. The trend from the fourth to the sixth week gives reliable estimates of materials remaining for the fifth week. Weight of remaining material was subtracted from original weights to determine weight loss. The control was included to identify weight loss associated with bag decomposition. There was no weight loss determined due to bag degradation. Therefore they were not included in any further analysis of the data.

3.2.2.4. Soil temperature and moisture determination.

Soil temperatures were monitored for the whole period. A soil thermometer was placed on the third ridge of every block. Daily temperatures at 8.00 and 14.00 hours were recorded at a depth of 10 cm below the soil surface. In addition, soil samples for moisture determination were taken 15 cm below the soil surface on the ridges. This was continued weekly for 5 weeks.

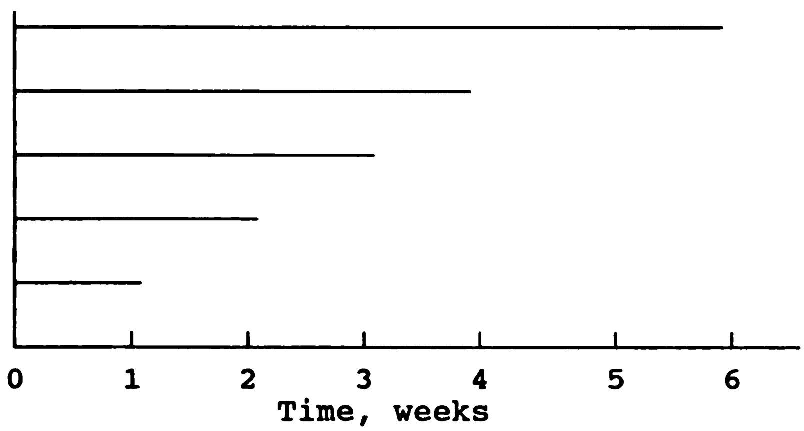


Figure 3. Time schedule for collecting litter bags after burial.

3.3 EXPERIMENTAL DESIGN AND DATA ANALYSIS

A completely randomized block design was used in both the pot and decomposition studies. The design was factorially arranged and replicated three times. There were one hundred and thirty five treatment combinations. These treatments were comprised of (i) the green manures of *A. julifera*, *L. leucocephala* and *S. sesban*, (ii) 4 and 8 tons per hectare equivalent green manures and the control, and (iii) five consecutive weeks of green manure incorporation. Each treatment was randomly allocated to each block. Blocks were independent of each other.

Data from the pot experiment were checked for the assumptions of the analysis of variance (Little and Hills, 1978). They were later subjected to three factor analysis of variance. Planned comparison tests were also carried out to identify sources of interaction (Little and Hills, 1978; Petersen, 1985).

The decomposition study data were also tested for the assumptions of regression analysis (Sokal and Rohlf, 1969). From the original weights, percent weight remaining every week for the three tree species was calculated and plotted against the time of decomposition. The decomposition trend for each of the three tree species was then obtained from the plot.

4 RESULTS

4.1 POT EXPERIMENT.

4.1.1 SHOOT DRY MATTER YIELD.

4.1.1.1 First harvest.

There were strong interaction effects both between species X amount of green manure and between time of green manure incorporation X amount of green manure, on maize dry matter yield (DMY) (Table 2). Species, amount of green manure and time of green manure incorporation also affected maize dry matter yield individually. Blocking did not affect the precision of the experiment.

Table 2. Analysis of variance for maize dry matter yield for the first harvest.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F value
Total	134	40.890		
Replication	2	0.080	0.040	0.568 NS
Species (Spp)	2	10.527	5.264	75.133 **
Time	4	0.902	0.225	3.128 *
Spp x Time	8	0.381	0.048	0.068 NS
Green manure rate (Gm)	2	11.778	5.889	84.059 **
Spp x Gm	4	7.767	1.942	27.717 **
Time x Gm	8	2.013	0.252	3.592 *
Spp x Time x Gm	16	1.281	0.080	1.143 NS
Error	88	6.615	0.070	

** Significant at 0.01
 * Significant at 0.05
NS Not significant

Maize DMY increased as the amount of green manure increased (Table 3). The increase depended upon the tree species. *L. leucocephala* as a green manure increased maize DMY linearly from 0 to 8 tons per hectare (Figure 4). On the other hand *S. sesban* as a green manure increased maize DMY between 0 and 4 tons per hectare, but no additional yield occurred at 8 tons per hectare of green manure. *A. julifera* as a green manure had no significant effect on maize DMY.

Table 3. Maize dry matter yield in grams for three tree species at three green manure levels for the first harvest.

	Green manures rate (tons/ha)		
Species	0	4	8
A. julifera	0.768	0.880	0.872
L. leucocephala	0.766	1.537	2.259
S. sesban	0.774	1.266	1.319

Maize dry matter mean yields were greater at 8 tons per hectare as compared to 4 tons per hectare of green manure in each week (Table 4). The 4 tons per hectare of green manure resulted in better DMY than the control over all five weeks. However the differences in yield were not consistent across

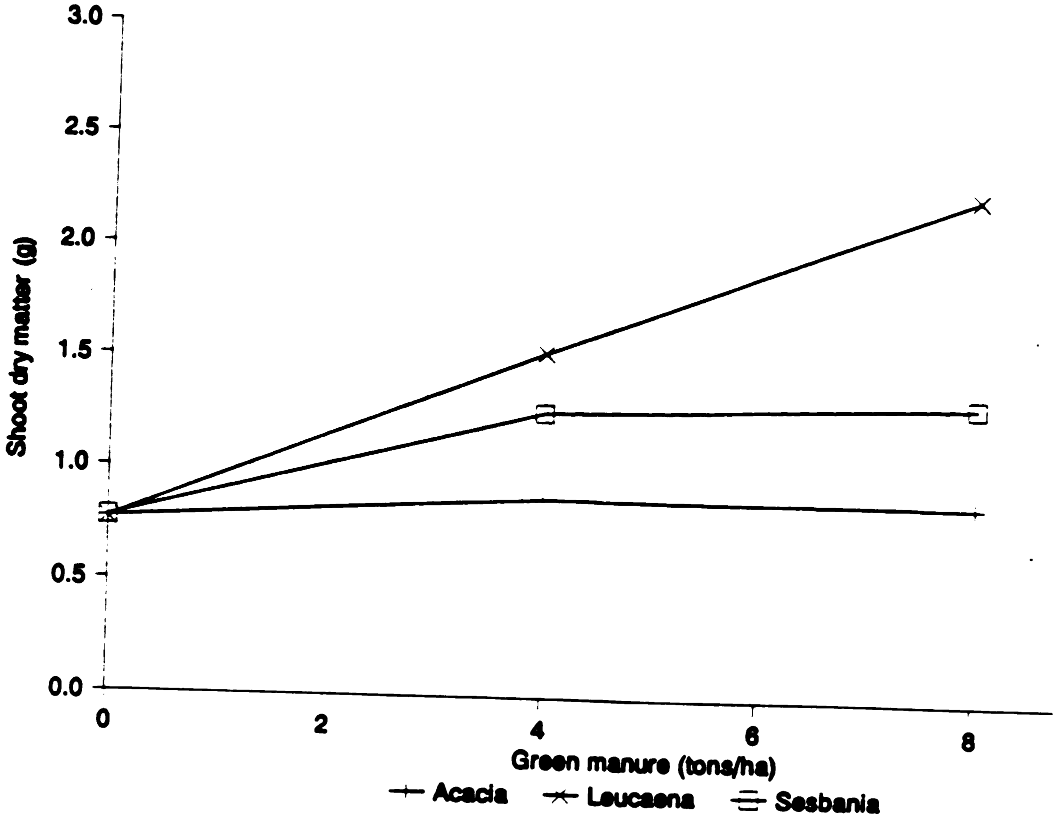


Figure 4: Relationship between maize dry matter yield and amount of green manure for the first harvest.

the five weeks (Figure 5).

Dry matter mean yields from the three tree species were significantly different from one another (Table 5). The relationship between maize DMY and the amount of green manure for *L. leucocephala* and *S. sesban* was found to be linear (Figure 6). The green manures of *A. julifera* were poorly correlated ($r=0.28$) with dry matter mean yields. The linear relationships for *L. leucocephala* and *S. sesban* can be described by the following equations:

(i) *L. leucocephala*: $Y = 0.77 + 0.75X$ ($r = 0.93$ **, $p<0.01$)

(ii) *S. sesban*: $Y = 0.85 + 0.25X$ ($r = 0.78$ **, $p<0.01$),

where Y = The first maize dry matter harvest yields (g) and X = the amount of green manure (tons/ha).

Table 4. Maize dry matter yield (first harvest-28 days) for green manure levels based on time delay of sowing maize seed into pots with green manure.

		Time (weeks)				
		0	1	2	3	4
		Maize dry matter yields (g)				
Green manure rate (ton/ha)	0	0.470	0.746	1.027	0.764	0.840
	4	1.238	1.178	1.117	1.379	1.227
	8	1.564	1.263	1.732	1.458	1.399

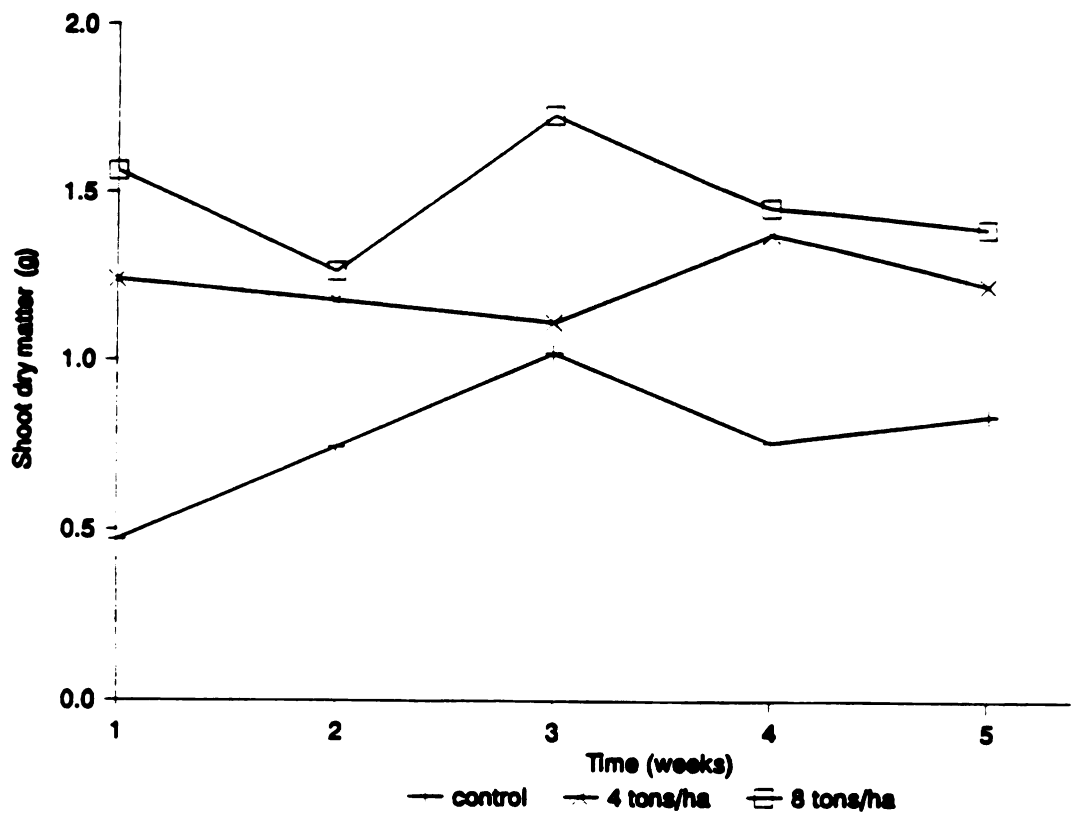


Figure 5: Relationship between maize dry matter yield at first harvest and planting time.

Table 5. Single degree of freedom analysis of variance comparisons for the significant first order interaction and main effects for the first harvest.

Source of variation	Degrees of freedom	Sum of squares	F value
A.julifera vs rest	1	6.915	98.78 **
L.leucocephala vs *S. sesban*	1	3.612	51.60 **
Green manure rate linear (Gl)	1	11.470	163.86 **
Green manure rate non-linear	1	0.307	4.39 *
(*A. julifera* vs rest) x Gl	1	4.186	59.80 **
(*L.leuc.* vs *S.sesban*) x Gl	1	3.365	48.07 **
Gl x Tl	1	0.361	5.16 *

** Significant at 0.01
 * Significant at 0.05

4.1.1.2 Second harvest.

Maize dry matter yields from the second harvest were also affected by tree species X amount of green manure interaction (Table 6). The green manures of *A. julifera* were poorly correlated (r=0.19) with maize DMY as in the first harvest (Table 7). Also as in the first harvest *L. leucocephala* and *S. sesban* continued to show a linear increase in maize DMY (Table 8, Figure 7). These linear relationships (Figure 8) are explained by the following equations.

(i) *L. leucocephala*: $Y = 2.48 + 1.85X$ ($r = 0.92^{**}$, $p<0.01$)

(ii) *S. sesban*: $Y = 2.42 + 1.94X$ ($r = 0.90^{**}$, $p<0.01$)

where Y = The second maize dry matter harvest yields (g) and X = the amount of green manure (tons/ha).

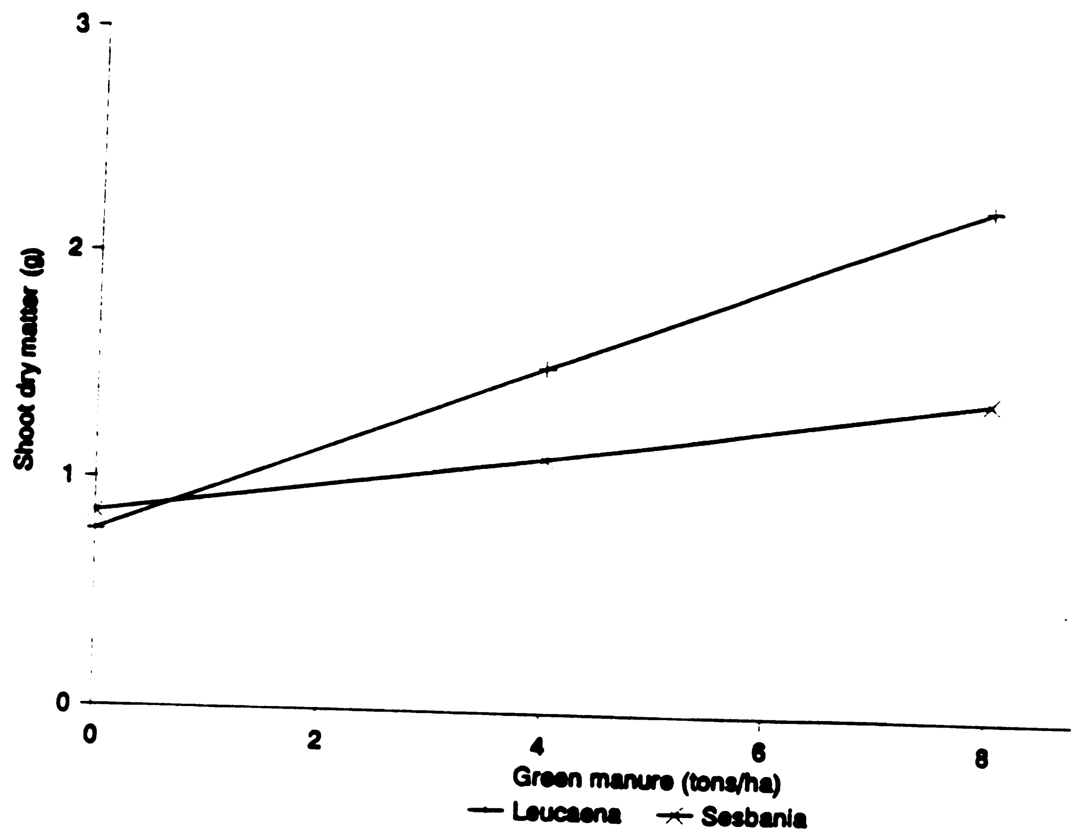


Figure 6: Linear relationship between maize dry matter yield and green manures of L. leucocephala and S. sesban for the first harvest.

Table 6. Analysis of variance of maize dry matter yield for the second harvest.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F value
Total	134	405.527	0.074	
Replication	2	0.148	0.074	0.082 NS
Species	2	117.560	58.780	65.571 **
Time	4	13.639	3.410	3.804 **
Species x Time	8	6.672	0.834	0.930 NS
Green manure rate (Gm)	2	108.195	54.098	60.348 **
Species x Gm	4	66.325	16.581	18.497 **
Time x Gm	8	4.894	0.612	0.682 NS
Species x Time x Gm	16	9.209	0.576	0.642 NS
Error	88	78.886	0.896	

** Significant at 0.01
NS Not significant

Table 7. Maize dry matter yield in grams for three tree species and three green manure levels for the second harvest.

	Green manure rate (tons/ha)		
Species	0	4	8
A. julifera	2.293	2.127	2.109
L. leucocephala	2.293	4.701	6.002
S. sesban	2.300	4.159	5.281

Table 8. Single degree of freedom analysis of variance comparisons for the significant first order interactions and main effects for the second harvest.

Source of variation	Degrees of freedom	Sum of squares	Observed F value
A. julifera vs rest	1	113.607	126.79 **
L. leucocephala vs *S. sesban*	1	3.957	4.42 *
Time linear	1	6.099	6.81 *
Green manure rate linear (Gl)	1	105.798	118.00 **
Green manure rate non-linear	1	2.397	2.68 NS
(*A. julifera* vs rest) x Gl	1	62.257	69.48 **
(*L.leuc.* vs *S.sesban*) x Gl	1	1.980	2.22 NS

** Significant at 0.01
 * Significant at 0.05
NS Not significant

4.1.2 ROOT DRY MATTER YIELD

There were appreciable interaction effects between species X time of green manure incorporation, species X amount of green manure and time of green manure incorporation X amount of green manure on maize root DMY (Table 9). Species, amount of green manure and time of incorporation significantly affected maize root DMY. Blocking was effective in increasing the precision of maize root DMY analysis.

Maize root DMY from pots with *L. leucocephala* and *S. sesban* green manures increased with the amount of green manure incorporated (Table 10). Similar to shoot yields, green

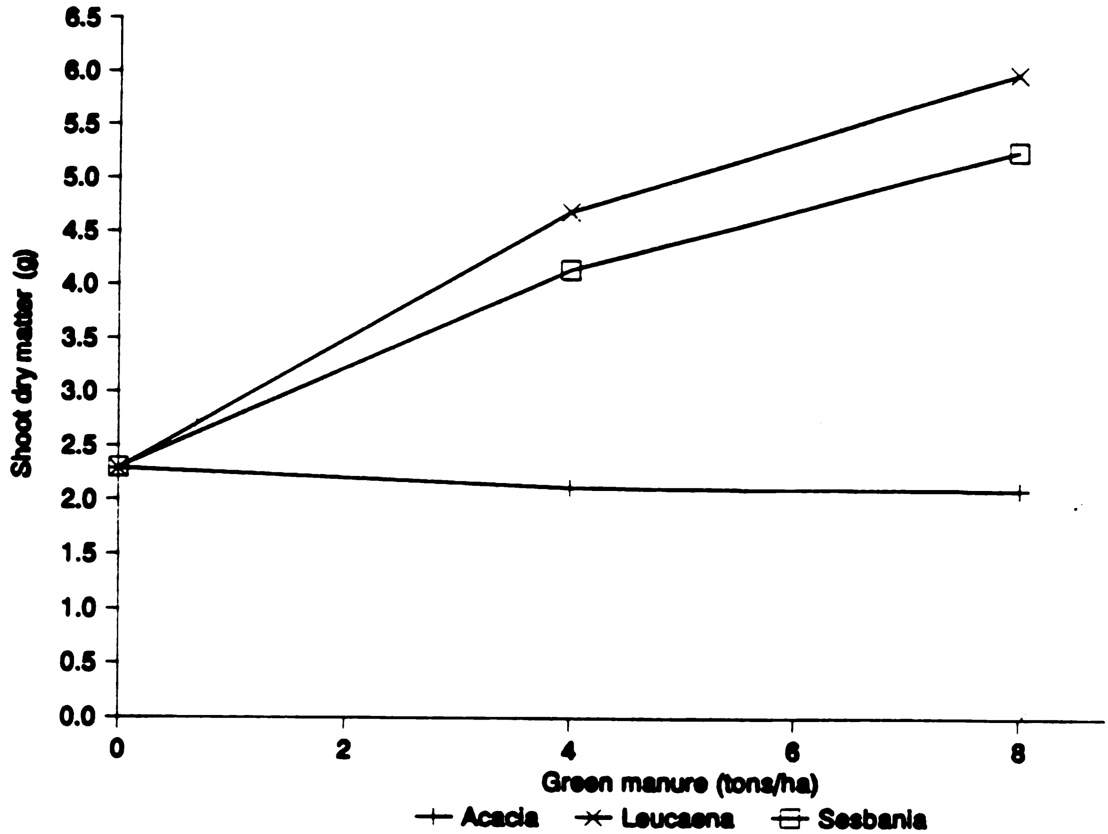


Figure 7: Relationship between dry matter yield and the amount of green manure for the second maize harvest.

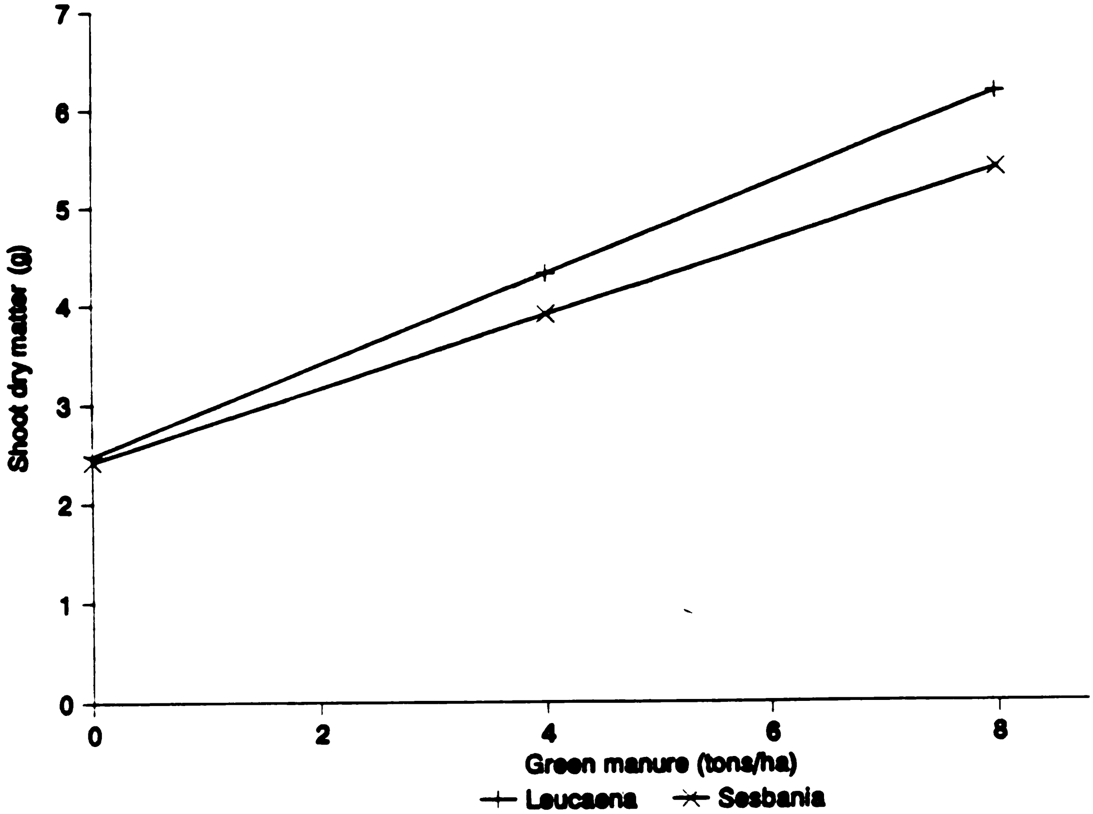


Figure 8: Linear relationship between maize dry matter yield and green manures of L. leucocephala and S. sesban for the second harvest.

manures of *L. leucocephala* produced the greatest maize root DMY followed by *S. sesban*. Maize root dry matter yields from *L. leucocephala* incorporated treatments increased sharply as green manure increased from 0 to 4 tons per hectare (Figure 9). There was also a slight additional increase in root maize DMY at the 8 ton/ha level of green manure application.

Root DMY increased in the order of *A. julifera*, *S. sesban* and *L. leucocephala* (Table 11). The increase was not consistent over the five weeks (Figure 10). *L. leucocephala* as a green manure increased maize root DMY in the second week. The dry matter yields held almost constant between the second and the fourth week. They then fell in week five. Those of *S. sesban* had similar effects although its associated maize dry matter yields were slightly lower in the third and the fourth weeks. Meanwhile, maize root DMY decreased with increased amount of *A. julifera* green manures.

In general, root dry matter yields from the control were much lower than those obtained from either 4 or 8 tons (Table 12, Figure 11). Eight tons of green manure produced better root dry matter yields than 4 tons.

Table 9. Analysis of variance for maize root dry matter yield after eight weeks.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	F value
Total	134	119.834		
Replication	2	1.538	0.769	3.305 *
Species	2	37.051	18.526	79.626 **
Time	4	4.947	1.237	5.316 **
Species x Time	8	4.610	0.576	2.477 *
Green manure rate (Gm)	2	17.980	8.990	38.641 **
Species x Gm	4	20.295	5.074	21.808 **
Time x Gm	8	7.337	0.917	3.942 **
Species x Time x Gm	16	5.602	0.350	1.505 NS
Error	88			

** Significant at 0.01
* Significant at 0.05
NS Not significant

Table 10. Maize root dry matter yield in grams for three tree species and three green manure levels at the end of eight weeks.

	Green manure rate (tons/ha)		
Species	0	4	8
A. julifera	2.292	2.135	1.969
L. leucocephala	2.293	3.894	4.049
S. sesban	2.293	2.870	3.398

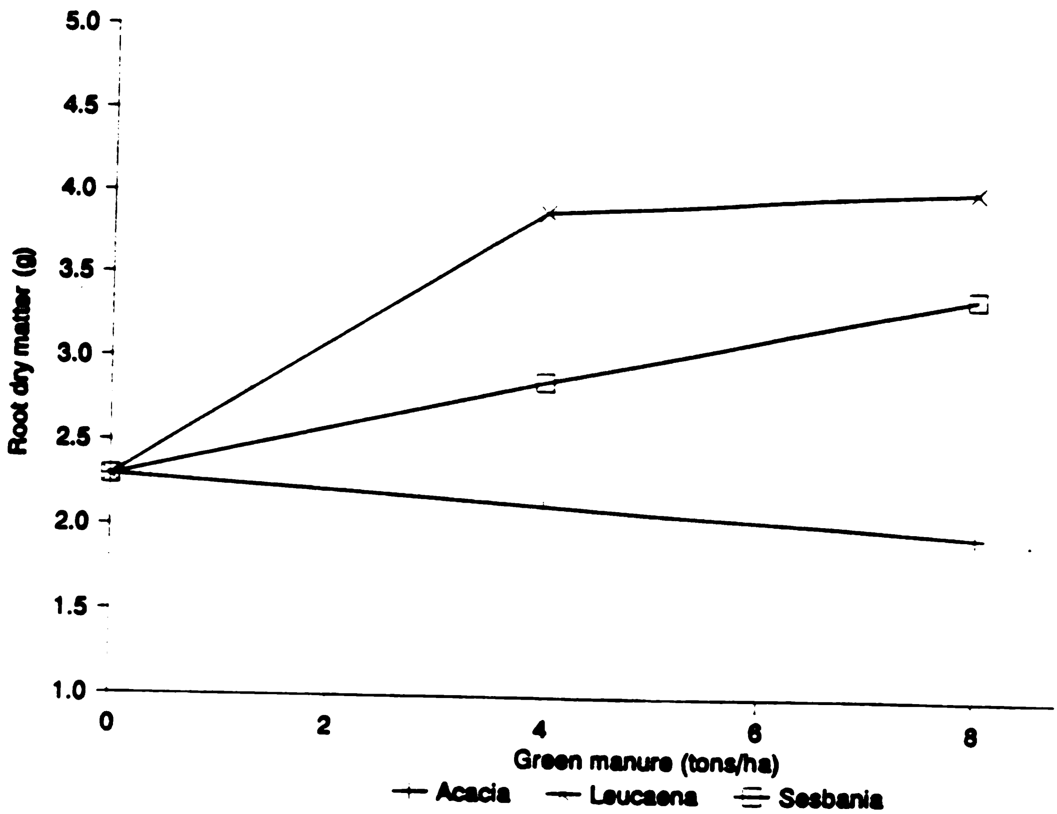


Figure 9: Relationship between maize root dry matter and the amount of green manure at the end of eight weeks.

Table 11. Maize root dry matter (56th day) in grams for the three green manure sources based on time delay of sowing maize seed into pots with green manure.

	Time (weeks)				
Species	0	1	2	3	4
A. julifera	1.968	1.952	2.253	2.272	2.210
L. leucocephala	3.298	3.669	3.521	3.544	3.020
S. sesban	2.268	3.392	2.894	3.044	2.670

Further analyses indicated a linear relationship between root DMY and amount of green manure (Table 13). However *A. julifera* as a green manure was poorly correlated ($r=-0.5$) with maize root DMY. The relationship between maize root DMY (Y) and the amount of green manure (X) for *L. leucocephala* and *S. sesban* (Figure 12) are described by the following equations.

(i) *L. leucocephala*: $Y = 1.66 + 0.88X$ ($r = 0.82^{**}$, $p < 0.01$)

(ii) *S. sesban*: $Y = 1.75 + 0.55X$ ($r = 0.62^{*}$, $p < 0.05$)

where Y = Root dry matter yields (g) and X = the amount of green manure (tons/ha).

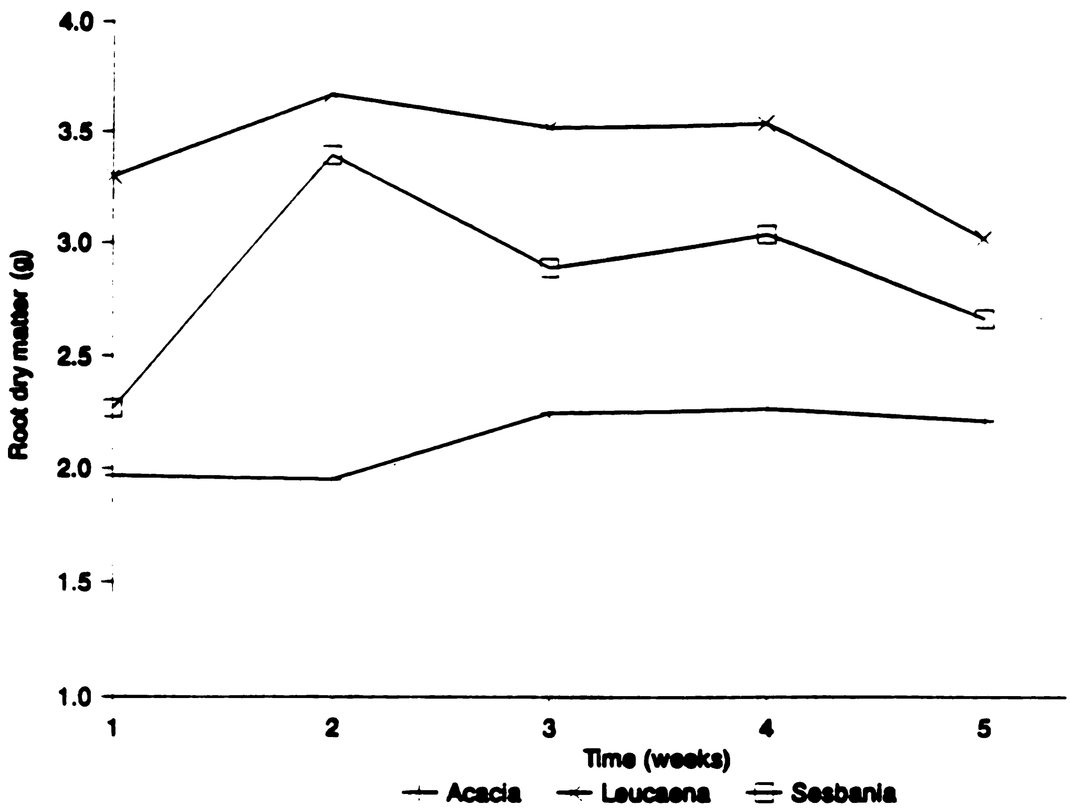


Figure 10: Maize root dry matter yield by tree species over the time delayed before planting.

Table 12. Maize root dry matter yield in grams at three green manure levels over time delayed before planting.

		Time (weeks)				
		0	1	2	3	4
Green manure rate (ton/ha)	0	1.859	2.224	2.541	2.638	2.202
	4	2.916	3.459	2.557	2.916	2.986
	8	2.759	3.330	3.571	3.308	2.726

Table 13. Maize root yield single degree of freedom analysis of variance comparisons for the significant first order interaction and main effects.

Source of variation	Degrees of freedom	Sum of squares	Observed F value
A. julifera vs rest	1	30.04	128.92 **
L. leucocephala vs *S. sesban*	1	7.011	30.09 **
Green manure rate linear (Gl)	1	16.095	69.08 **
Green manure rate non-linear	1	1.885	8.09 **
(*A. julifera* vs rest) x Gl	1	15.359	65.92 **
(*L.leuc.* vs *S.sesban*) x Gl	1	1.588	6.82 **

** Significant at 0.01

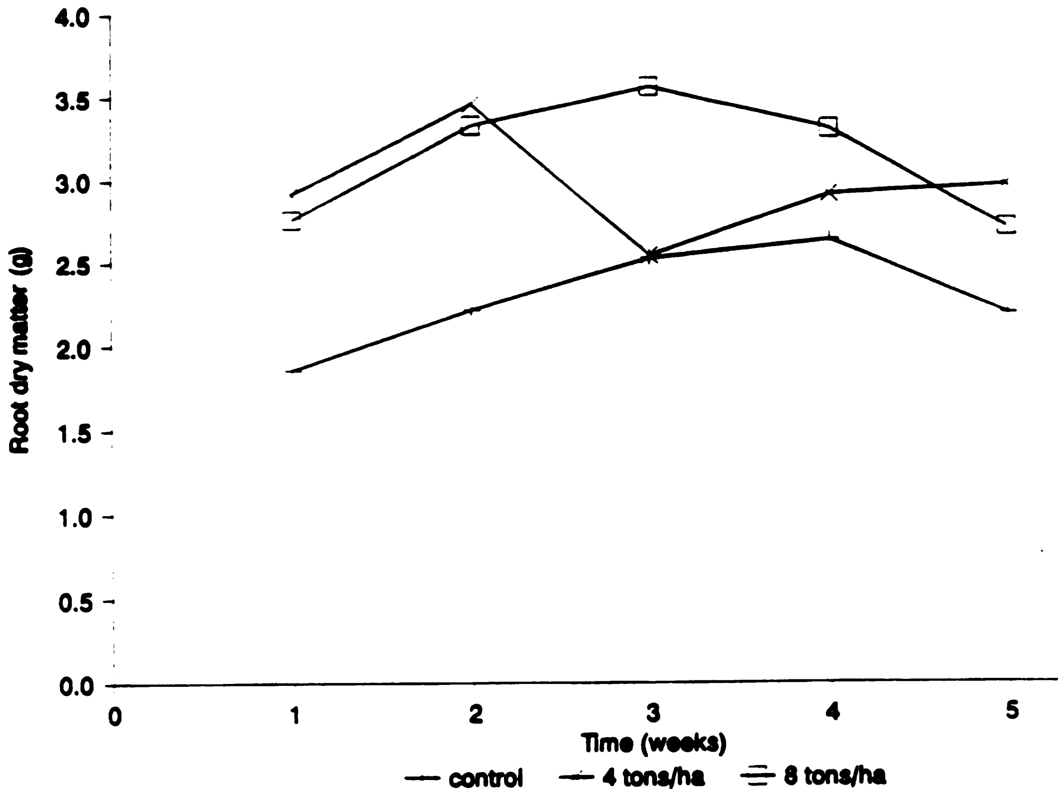


Figure 11: Maize root dry matter yield at three levels of green manure over time waited before planting.

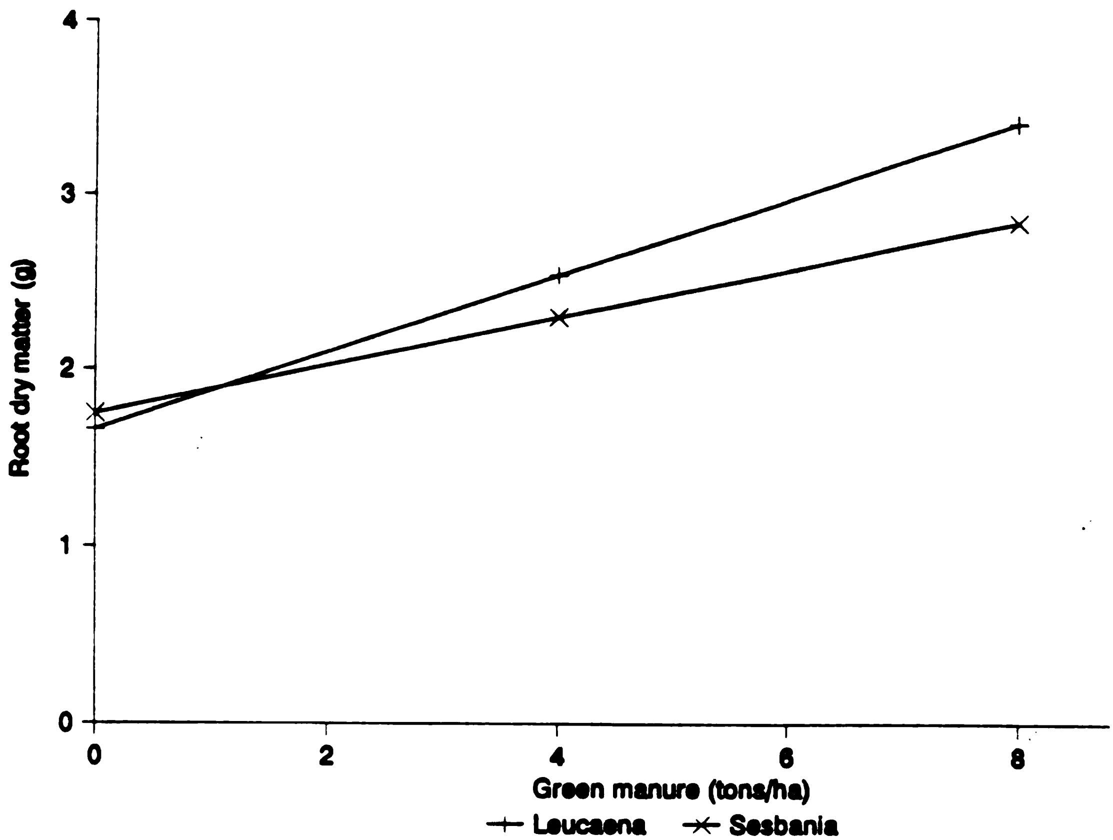


Figure 12: Linear relationship between root dry matter yield and green manures of L. leucocephala and S. sesban.

4.2 GREEN MANURE DECOMPOSITION.

S. sesban decomposed more rapidly than either *L. leucocephala* or *A. julifera* (Table 14). Fifty-five percent of the initial amount of leaf and twig tissue mixture had been lost by the end of the first week. It continued to have the greatest weekly losses followed by *L. leucocephala*. At the end of the sixth week, *S. sesban* had lost almost 80 percent of its original weight. Over the same time period, *L. leucocephala* and *A. julifera* had lost 60 and 22 percent of their beginning weight, respectively.

The weekly weight loss trend is graphically illustrated in Figure 13. Assuming a linear decay rate, daily weight loss for *A. julifera*, *L. leucocephala* and *S. sesban* green manures were 0.8, 1.4 and 1.8 percent respectively.

4.3 SOIL TEMPERATURE AND MOISTURE CONTENT

Morning temperatures for the pot study ranged from 15 to 20°C. Those taken in the afternoon were a little bit higher. The lowest afternoon temperature was 30°C while the highest was 40°C.

Soil moisture content at the beginning of the decomposition study period was 11.5 percent. It decreased over time to about 5.6 percent at the end of the sixth week. Soil temperatures associated with decomposition study did not change with soil moisture. For the whole period, morning temperatures were almost constant. They ranged from 19 to 21°C. Afternoon temperatures were also not different from each other. The lowest and highest were 29 and 32°C, respectively.

Table 14. Remaining dry weight (in percent) for decomposing *A. julifera*, *L. leucocephala* and *S. sesban* over the six weeks of decomposition period.

		Species		
		A. julifera	*L. leucocephala*	*S. sesban*
Week	1	82.6	70.8	45.5
	2	77.1	56.8	32.8
	3	72.9	53.7	25.3
	4	69.4	53.5	21.4
	6	67.9	40.5	22.8

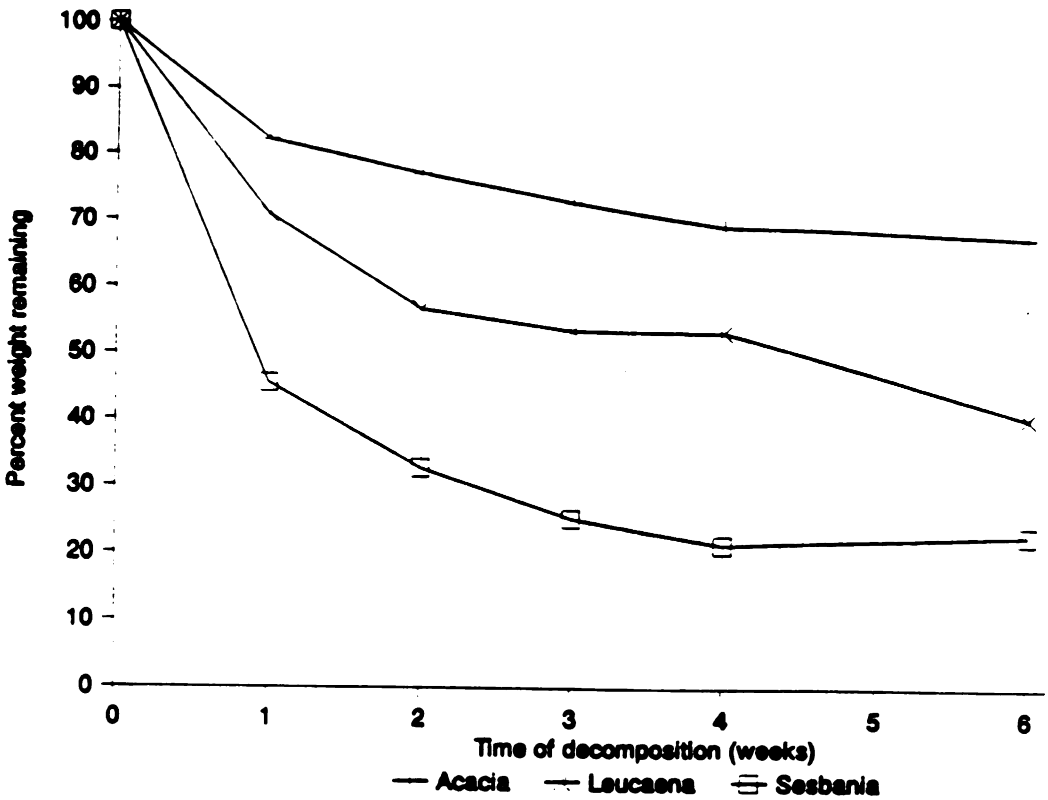


Figure 13: Weekly remaining weight (%) for decomposing A. julifera, L.leucocephala and S. sesban.

5 DISCUSSION

5.1 POT EXPERIMENT

Results indicate that soil incorporated green manures increase maize dry matter significantly. This has been demonstrated in both shoot and root dry matter yields. The increase in maize dry matter yield was also shown to be tree species dependent. Because of the need to increase crop production, the use of green manure seems to be a possible alternative to the use of expensive N fertilizers. It can also be a solution to environmental problems associated with chemical fertilizers such as water pollution.

As green manures decompose, they release nutrients. These nutrients are absorbed by plant roots. In order for green manures to have optimal effect, time of incorporation and nutrient release must be matched with plant needs. The observed differential effects of green manures on maize dry matter yield can be attributed to a number of factors. First, higher N content provides more potentially available N for crops. *L. leucocephala* performed better than *S. sesban* as a green manure source because it has a higher N concentration than *Sesbania* (Little et al., 1989; Oglesby, 1990). A metric ton of *L. leucocephala* fresh prunings yields 10.4 kg N while that of *Sesbania is* equal to only 5.5 kg N (Kang et al., 1981b; Khind et al., 1985). Based on the amount of green manure incorporated, 8 tons per hectare, *L.*

leucocephala and *S. sesban* potentially supplied 83.2 and 44 kg of nitrogen, respectively. Although this is the potential N available, past studies have shown that less than one-third of the total N in green manures becomes available to plants (Kang et al., 1981b; IITA, 1982; Kang et al., 1984; Yamoah et al., 1986).

Second, a high carbon to nitrogen ratio results in slow decomposition. In addition to higher N levels, *L. leucocephala* has a higher carbon to nitrogen ratio than *S. sesban*. However this ratio is affected by the ratio of leaf to twig materials in a given green manure mix. High levels of twig materials raises the carbon to nitrogen ratio and slows decomposition (Webster, 1980; Palm et al., 1988; Oglesby, 1990). Since *L. leucocephala* has a higher carbon to nitrogen ratio than *S. sesban*, it decomposed slowly. Due to its slower decomposition rate, *L. leucocephala* derived N was potentially available to maize plants for a longer period. On the other hand, nutrients from *S. sesban* were available for maize growth for a shorter period due to its faster decomposition rate.

Third, as green manure volume increases, there is an increase in plant nutrients. Since higher maize dry matter yields were associated with increased volume of green manures, the increase was due at least in part to increased

N and other plant nutrients. Increasing the amount of plowed-in green manures has been reported to increase maize grain yield (Kang et al., 1981a and 1981b). Grain yield were 1283, 2313 and 3213 kg/ha after incorporating 0, 5 and 10 t/ha of *L. leucocephala,* respectively. However, yield increases reach a point where further additions become uneconomical. Beyond this point commonly known as a point of diminishing returns, no more green manures would be needed (Gregory, 1972). This study was not intended to determine maximum maize yields, however, future studies should establish the amounts of green manure that produce maximum maize yield under specific field conditions.

Because green manures were incorporated at only one point in time in the pots, the effect of time delayed before planting maize on maize dry matter yield was not clearly demonstrated. However, lower dry matter yields in the first week may be linked to allelopathic effects on developing roots (Rice, 1984). Allelochemicals might have been released during the first week. At this time maize roots were young and more vulnerable to toxicity than the following weeks.

There were no studies found on either the chemical composition of *A. julifera* or its use as a green manure. However, the response could be a result of its morphological characteristics. *A. julifera* has abnormal, reduced leaves in which leaflets and pinnae are absent. The petiole is flattened into a leaf-like organ. There are 3-5 longitudinal fibres with many finer reticulate veins between them (Whibley, 1980; Simmons, 1981). The fibrous nature of *A. julifera*, indicates that it is highly composed of lignin, a compound that is very resistant to decay (Hall et al., 1974; Sopher and Baird, 1982). Usually plants containing higher amounts of lignin are regarded as inferior green manure sources because of their slow nutrient release rates (Frankenberger and Abdelmagid, 1985; Oglesby, 1990).

A. julifera is a tree species that is well adapted to semi-arid conditions (Whibley, 1980). Semi-arid tree species like *Eucalyptus* have the ability to minimize nutrient and water competition by producing allelochemicals that restrict the growth of nearby plants (Rice, 1984). It is also possible to hypothesize that *A. julifera* produce these chemicals. If that was the case, their escape to the soil environment could have restricted root development.

The slow release of nutrients by inferior green manures such as *A. julifera* may have desirable attributes. IITA (1989) found that the residual effects of green manure mixtures of *Leucaena* and *Cassia siamea* resulted in yields that were 45% higher than crops that had received only *Leucaena* green manures in the previous season. This increase is partly due to long term residual effects of *C. siamea* which has a slower decay rate than *L. leucocephala* (Oglesby, 1990). In addition to N, other plant nutrients are added to the soil. These are very important for subsequent crop growth. Mixing materials that decompose slowly with those that decompose fast could potentially reduce nutrient insufficiency. In this way, short and long term effects on soil plant nutrients and crop yields might be improved.

5.2 GREEN MANURE DECOMPOSITION

As the results showed, *S. Sesban* decomposed faster than *L. leucocephala*. This was not expected because *L. leucocephala* has a higher N content and a lower carbon to nitrogen ratio than *S. sesban* (Little et al.,1989; Oglesby, 1990). A possible explanation for this divergence could be the age differences between these two tree species. *L. leucocephala* was two years old while *S. sesban* was one year old. Since *S. sesban* was relatively younger than *L. leucocephala*, its tissues could have been more succulent than those of *L. leucocephala* (Yamoah et al., 1986). Future studies should try to determine the composition of current growth tissues obtained from trees of different ages. Although *S. sesban* lost its weight quickly, several studies have reported even faster rates of decomposition (Palm et al., 1988; Beri et al., 1989; Oglesby, 1990).

As noted in the previous section, *A. julifera* leaves are highly lignified. Its slow decomposition is thought to be due to large amounts of cellulose and lignin compounds (Whibley, 1980; Simmons, 1981). A prolonged decomposition study coupled with its tissue chemical analysis would shed some light on the real cause of its slow decomposition.

5.3 NUTRIENT RELEASE AND MAIZE N REQUIREMENT.

Due to time limitation, it was not possible to determine the effect of green manures on maize grain yield.
Further studies involving both the vegetative and reproductive stages of maize growth are essential.

According to Bromfield (1969) and Yamoah et al. (1986), N requirement for proper maize growth between emergence and the third week is about 5 kg/ha. The demand raises to 22 kg/ha N in the fourth week. Nitrogen requirements continue to raise to 65, 120 and 130 kg/ha in the 7th, 12th and 17th weeks respectively.

The rate at which nutrients are released affects the growth rate of associated crops. If nutrients are released too rapidly vis a vis crop requirement, higher levels will be leached instead of being taken up by growing crops. The N demand for maize was met by *S. sesban* and *L. leucocephala* before the third week. Concurrent with the sharp rise in N demand after the fourth week, *L. leucocephala* and *S. sesban* green manure, N availability was already greatly reduced. The decrease in maize dry matter yield observed in the fifth week could be due to these combined factors, for example, that green manures decreasing N availability no longer met the increasing maize N demand.

From the works of Bromfield (1969), Ritchie and Hanway (1984) and Yamoah et al. (1986) on N requirement by maize, green manures should be applied periodically. The amount to be applied should be different depending on the source of green manure and the stage of maize development. In doing so, plant nutrients will be released at the right time and amount for plant growth.

According to Yamoah et al. (1986) and the findings of this study, *L. leucocephala* should be incorporated as green manure at a rate of 500 kg/ha during maize planting. These rates will supply the required 5 kg N/ha throughout the first three weeks. This amount should increase to 2.2 t/ha on the fourth week to meet the N demand of 22 kg/ha in the fifth week. The amounts should further increase to 7.4, 11 and 14 t/ha in the 8th, 11th and 14th weeks, respectively. These quantities are considered to be minimum because N efficiency from green manures has been reported to be not more than 30 percent of the total available N (Kang et al.,1981b; IITA, 1982; Kang et al.,1984; Yamoah et al., 1986). Periodic applications, such as once after three weeks interval might help if leaching is a problem. Although ideal quantities of *L. leucocephala* to be plowed-in as green manures appear to be high, the situation becomes even worse with *S. sesban*. This is because the amounts of *S. sesban* to be incorporated as green manure in the same period would be twice that of *L. leucocephala* (Kang et al., 1981b; Khind et al., 1985).

Repeated green manure application helps maintain soil organic matter levels. If organic matter addition is neglected, most if not all the beneficial effects on soil chemical and physical properties will be lost. By greatly increasing the soil organic matter content, the soil microorganism populations will greatly increase and maintain continual organic matter turnover (Sopher and Baird, 1982).

There were no efforts made to quantify the amount of *A. julifera* needed for incorporation as green manure. This is because there was no literature found on either its use as a green manure or chemical composition. Furthermore, maize dry matter yields were poorly correlated with the amount of green manure.

5.4 PRACTICAL CONSIDERATIONS

There is no doubt that the quantity of green manure to be incorporated would seem high to an ordinary farmer. On average *L. leucocephala* yields 6.5 t/ha/yr green manure, while N requirement by maize is about 35 t/ha (Yamoah et al., 1986). A sizeable amount of land would therefore be required for green manure production. It is also doubtful if the high level of human energy required for producing green manures would be available. Transportation and incorporation of green manures in the field requires labour, which is in scarce supply.

It has been reported that farmers in Africa do not want to spend time in cultivating a green manure if climate permits the growth of another crop (Vine, 1953). In addition, green manures have to be "cut and carried" from where they have been growing. This practice transfers soil nutrients from one area to another (Wade and Sanchez, 1983). Practical consideration for farming techniques would indicate a small potential for green manuring on small farms. It must also be stressed that production of a good crop of green manure in many parts of Africa requires the application of inorganic fertilizers - a practice which the small farmers can hardly afford (FAO, 1980; Waring, 1985). Under these circumstances therefore, it appears likely that crop production will remain low.

6 SUMMARY AND CONCLUSION

The increasing cost of nitrogen fertilizers and the associated environmental concerns have necessitated more use of green manures. For best results from incorporated green manures, prior knowledge on green manuring is very important. Quantity and proper timing are also important considerations. This kind of knowledge is currently available for a limited number of tree species and geographical locations. A study launched to define this kind of information indicated that: (i) *L. leucocephala* is a better green manure source than *S. sesban* though both increase maize dry matter significantly, (ii) maize dry matter yield increases with the increase in the amount of green manure and (iii) *A. julifera* green manure does not affect maize dry matter yield at rates of 4 and 8 tons per hectare.

Maize dry matter yields were significantly increased by incorporated green manures. *L. leucocephala* as a green manure yielded the greatest maize dry matter. It was followed by those of *S. sesban*. Greater dry matter yields were also associated with increased green manure levels. Green manures of *L. leucocephala* are believed to yield the highest dry matter yields because: (i) they contain more nitrogen than *S. sesban* and (ii) they have a higher carbon to nitrogen ratio and release nutrients slower than *S. sesban*.

Nutrient uptake by plants begins prior to plant emergence from the soil. Incorporating small amounts of fast decomposing green manures during planting would supply the nutrients needed in the early stages of maize development. However, there is a possibility of decomposing plant tissues producing allelochemicals. Allelochemicals would have a depressing effect on developing young roots. Incorporating green manure during planting should be avoided until the presence and effects of such toxic substances are well established. Instead, seeds should be dressed with nitrogen fertilizers to be followed by first green manure incorporation in the fourth week.

If green manures are readily available, they should be applied periodically. In the case of maize, incorporating them at three weeks intervals would maximize availability of the released nutrients. Each incorporation will be different depending on the tree species used as a green manure and the growth stage of maize plants.

A. julifera may have a potential contribution to "tree/crop admixtures" within agroforestry systems. Its slow decomposition may contribute to soil organic matter build-up. It could also be used as a mulch to conserve soil moisture, lower soil temperature and enhance the activity of microorganisms. Its use as a mulch would be enhanced by finding out how long it takes to fully decompose. To represent real field conditions, such studies together with those of *L. leucocephala* and *S. sesban* should also be conducted in field plots.

In the tropics, maize is mainly grown for human consumption. The best way of knowing the potential contribution of green manure on maize yield is therefore to determine its grain yield rather than dry matter yields. Actual maize grain yield from incorporated green manures should be determined first before recommending them for use. The amount of green manure that produces maximum grain yield is also of great interest. It should be established so as to utilize the available resources in the best possible way.

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