Expl Agric. (1998), volume 34, pp. 313–322
Printed in Great Britain

STIMULATION OF TOP AND ROOT GROWTH OF LEUCAENA WITH FARM MANURE IN THE MID-ALTITUDE AGRO-ECOLOGICAL ZONE OF NORTH-WEST CAMEROON

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(Accepted 2 February 1998)

SUMMARY

Leucaena (*Leucaena leucocephala*) is most preferred by development workers for agroforestry in the mid-altitude (600–1600 m) agro-ecological zone of North-West Cameroon because its seeds are common and inexpensive. This study was prompted by farmers' reluctance to accept leucaena for agroforestry because its early growth is poor on acid infertile soils prevalent in the area. Leucaena was planted using four-month-old potted plants and, from four months after planting, the shrub was cut five times in 20 months at 120 day intervals. Manuring improved leucaena's growth and biomass at sites with acid and non-acid soil alike. Total biomass responded linearly ($R^2 = 0.97$) to manure rates at the acid and infertile site and curvilinearly ($R^2 = 0.95$) at the non-acid site. Total leafy biomass from the first cut and subsequent prunings was highest at 12 months after planting. Manuring increased rooting depth and this contributed to the plant's observed ability to cope with moisture stress during the dry season. The economics of manure use for tree establishment on acid infertile soils for agroforestry systems needs further study.

INTRODUCTION

Agroforestry and reforestation practices with tree legumes offer a means to rehabilitate degraded agricultural lands. Among woody legumes, the leucaena (*Leucaena leucocephala*) species has been featured extensively in land reclamation projects in the tropics (Brewbaker, 1987). The success of leucaena in agroforestry land-use systems is attributed largely to its rapid growth and ability to cope with repeated pruning, to produce copious biomass with a high nutrient content for green manuring and supplementary fodder, as well as for fuelwood (NAS, 1980). In the absence of soil chemical limitations such as aluminium toxicity and physical limitations such as an impermeable or gravel layer, the shrub sends out deep roots to retrieve nutrients that have leached from the top soil or been trapped in the subsoil horizon so that they can be used by shallow-rooted food crops (Sanchez, 1987; Kang *et al.*, 1981).

Leucaena continues to attract the interest of extension and development workers in Cameroon because its seeds are common and inexpensive. A major

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drawback with leucaena in the mid-altitude agro-ecological zone of the North-West Province of Cameroon is that it grows poorly on the acid and infertile soils prevalent in the region. The shrub's early growth is protracted and in some cases its expected potential for soil fertility conservation is not realized. Studies elsewhere such as the work by Sivasupiramanian *et al.* (1986) in Queensland, Fox and Whitney (1981) in Hawaii and Yamoah *et al.* (1992) in Rwanda support our experience with leucaena in the North-West Province of Cameroon. Sivasupiramanian *et al.* (1986) reported increases in leucaena shoot dry weight of 31 and 88% after 15 weeks with the application of 25 kg N or 2.5 t lime ha^{-1}, respectively. This is evidence for successful shrub establishment with organic and inorganic amendments. Also, Yamoah *et al.* (1992) obtained an 80% increase in the biomass of leguminous shrubs with applications of farm manure as opposed to a 40% increase with NPK fertilizer. More recently, a team of Iowa-based scientists have explored the possibility of using sludge as a fertilizer to accelerate shrub establishment in an agroforestry setting (Mattila *et al.*, 1993).

In the development community in Cameroon, agroforestry with the 'magic' tree (leucaena) is often portrayed to farmers as a solution to all their land-use problems. Such programmes ignore the fact that leucaena needs a favourable soil environment in which to grow and establish. This misconception has discouraged farmer acceptance of agroforestry technologies because of the lack of immediate gains for their time and labour invested. The experiment reported aimed to determine whether or not an application of farm manure could improve early growth of leucaena on soils with contrasting fertility status. The study was part of the effort to promote sustainable crop–livestock farming systems among smallholders in the North-West Highlands of Cameroon where formerly productive lands have become exhausted.

MATERIALS AND METHODS

The study was conducted to determine the effect of farm manure on the growth of leucaena in the Bambui and Ndop Plains which represent the mid-altitude agro-ecological zone of North-West Cameroon. Detailed information on the characteristics of this environment was presented by Ranst *et al.* (1989). The elevation of the study area ranges from 1178 to 1330 m and annual rainfall from 1400 to 1900 mm. Rains occur from March to October. Temperature varies between 14 and 28 °C with the Bambui Plain cooler and higher in elevation than Ndop. The soils are Ultisols developed from old basaltic materials (Ranst *et al.*, 1989) and in both areas the fertility status has been altered considerably due to continuous cultivation. Specifically, the soils at the Ndop Plain are more fertile (Al saturation $< 2\%$, pH 5.6 and ECEC 11.3 cmol kg^{-1}) and generally more productive than the Bambui Plain soils (Al saturation $> 30\%$, pH 5.1 and ECEC 2.9 cmol kg^{-1}) (Yamoah *et al.*, 1995). The manure was obtained from local poultry farmers and the manuring treatments were 0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg $plant^{-1}$. The manure was mixed with the soil and allowed to incubate in the planting hole for about a week before planting the seedlings. The experimental units comprised 20 four-month old seedlings spaced 1×1 m and the experimental design was a randomized complete block with four replications.

The seedlings were planted in July 1991 and, beginning four months later, four plants were cut at a height of 0.3 m above the ground at 120-d intervals for a period of 20 months. Depending on the stage of growth, height was recorded and leafy biomass, stems and seeds were weighed separately and removed from the plots. Striking growth differences among manuring treatments during the dry season led to further investigations into root development and root zone fertility. Thus, at 12 months after planting, two plants were chosen randomly from the treatments which received 0, 1.0 and 2.5 kg manure plant^{-1} in order to study the rooting pattern of the shrub. Pits measuring $1 \times 1.5 \times 1$ m were excavated and root distribution patterns determined by counting the exposed root tips in a grid measuring 5×5 cm, following the method employed by Ruhigwa *et al.* (1992). Vertical and lateral root spread designated as niche breadth (B) is indicative of the extent to which roots penetrate the soil for nutrients and water. Niche breadth was calculated from the equation:

$$B = 1 / \sum_{s=1}^{6} (P_i^2)$$

(Levins, 1968), where P_i is the proportion of root tips found in six resource states (S) each measuring 0.2 m by 0.5 m. A larger value of B indicates that roots exploit all soil zones with approximately equal probability, a larger niche breadth. Conversely, a small value of B indicates a narrow niche breadth, where only a small fraction of soil zones are exploited by roots. The six resource states are defined as a series of soil horizons at depths of 0–0.20, 0.21–0.30, 0.31–0.40, 0.41–0.60, 0.61–0.80 and 0.81–1.00 m. Thus, our computation of root spread was based on the number of leucaena root tips occupying a surface area of $1.0 \text{ m} \times 0.5$ m in the soil profile. Leucaena root zone fertility was determined by sampling 0–15 cm depth at the base of the plant followed by analysis for nitrogen, phosphorus and exchangeable cations using standard analytical procedures (Juo, 1977). Data were analysed statistically with MSTAT-C and SYSTAT software. Comparison of treatment means was based on standard error and l.s.d. at the 5% confidence level.

RESULTS AND DISCUSSION

Top growth

Early growth and branching of leucaena responded ($p < 0.05$) to manuring at both the fertile (non-acid) and poor (acid) sites (Fig. 1). As expected, growth was better on the non-acid soil than on the acid soil. On the latter soil, the positive effect of manuring on plant height was remarkable even at 12 months after

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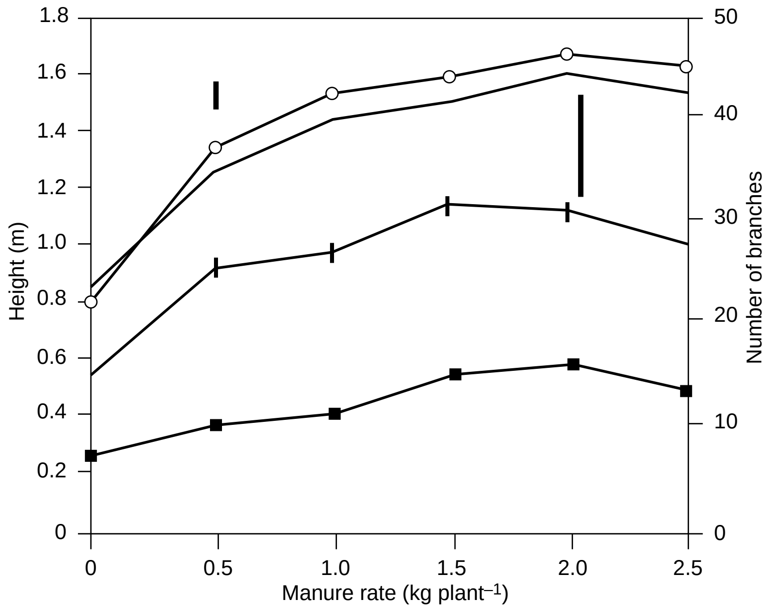

Fig. 1. Effect of farm manure on the height (non-acid soil, —; acid soil —|—) and number of branches (non-acid soil —○—; acid soil —■—) of leucaena at four months after planting on two soil types. Vertical bars represent standard errors.

planting (MAP) ($R^2 = 0.91$). At 12 MAP the height of leucaena given the 1.5 kg rate of manure was almost twice that of the control without manure. The present findings and those of Mattila *et al.* (1993), Sivasupiramanian *et al.* (1986) and Yamoah *et al.* (1992) demonstrate that manuring accelerates revegetation of degraded and non-degraded land alike. The rapid growth rate and branching due to manuring led to rapid canopy development which could be helpful in preventing erosion, particularly during the early stages of shrub establishment when a greater part of the soil surface was exposed. Furthermore, it was found that placing the manure in the planting holes enhanced shrub growth more than broadcasting it over the entire field as in a previous study.

The biomass at cutback was linearly related to the manure rate on the acid soil during the first 16 months ($R^2 > 0.80$, $p < 0.05$, Table 1). The efficiency of manure application increased with time and ranged from 0.11 to 0.46 kg biomass (kg manure)$^{-1}$ during this period. A manure application of 1.5 kg plant^{-1} more than doubled the biomass yield of leucaena at 12 MAP relative to the control. This has direct implications for soil fertility management in hedgerow intercropping systems where the bulk of the nutrients are supplied in the leafy biomass on a sustained basis. It became clear during the course of the study that without manuring one could not expect to derive sufficient biomass from leucaena at the acid site to bring about the so-called improvement in soil fertility.

A curvilinear response of biomass to manuring was obtained at the non-acid site ($R^2 > 0.80$, $p < 0.05$) during the first 12 months. The manure rate that produced

Table 1. Response of leucaena biomass to farm manure on acid and non-acid soils in North-West Cameroon.

Months after planting	Response equation	Probability
	Acid soil	
4	$Y = 0.07 + 0.109X$, $R^2 = 0.91$	0.003
8	$Y = 0.06 + 0.07X$, $R^2 = 0.90$	0.004
12	$Y = 0.40 + 0.381X$, $R^2 = 0.96$	<0.001
16	$Y = 0.24 + 0.456X$, $R^2 = 0.84$	0.01
20	$Y = 0.55 + 0.49X - 0.14X^2$, $R^2 = 0.98$	0.002
	Non-acid soil	
4	$Y = 0.19 + 0.40X - 0.09X^2$, $R^2 = 0.91$	0.025
8	$Y = 0.21 + 0.37X - 0.10X^2$, $R^2 = 0.90$	0.031
12	$Y = 0.77 + 0.86X - 0.18X^2$, $R^2 = 0.95$	0.010
16	$Y = 0.95 - 0.54X + 0.01X^2$, $R^2 = 0.76$	0.120
20	$Y = 0.25 - 0.02X + 0.02X^2$, $R^2 = 0.36$	0.505

the highest biomass during this period was about 1.5 kg plant^{-1}. The effect of manuring on leafy biomass production diminished at this site after 12 months as revealed by the low R^2 values (Table 1). Manuring increased leucaena's root zone fertility which in turn correlated with biomass at 12 MAP months (Table 2). Root zone calcium and phosphorus accounted for 98% of leucaena biomass at 12 MAP ($r = 0.99$, $p < 0.001$) as opposed to either phosphorus ($r = 0.62$, $p > 0.05$) or calcium ($r = 0.90$, $p < 0.05$) alone. Phosphorus and calcium deficiencies caused by elevated soil aluminium are among the common nutritional disorders in acid soils rectifiable by liming and the use of organic amendment (Bohn *et al*., 1985). However, Glumac *et al*. (1987) found a stronger correlation between leucaena biomass and leaf phosphorus ($r = 0.71$, $p = 0.002$) than between leucaena biomass and leaf calcium ($r = 0.55$, $p = 0.028$) on calcareous soils where calcium is not a problem.

Table 3 presents data on leafy biomass yields from the first cut taken at 4, 8, 12, 16 or 20 MAP and on mean biomass from subsequent prunings after four months of regrowth. The highest biomass at both sites was obtained from an initial cut

Table 2. Correlation of root zone fertility of leucaena with biomass on an acid soil in North-West Cameroon at 12 months after planting.

Parameter	Correlation coefficient	Probability
Total nitrogen	0.78	0.06
Extractable phosphorus	0.62	0.17
pH (water)	0.88	0.01
Exchangeable potassium	0.79	0.05
Exchangeable magnesium	0.80	0.04
Exchangeable calcium	0.90	0.01
Calcium + phosphorus	0.99	<0.001

Table 3. Leucaena leaf biomass (kg plant^{-1}) at the first cut taken at different times and mean biomass of the regrowth after four months.

	Biomass	
Time of first cut†	First cut‡	Regrowth after four months‡
	Acid soil	
4	0.20 (0.04)	0.15 (0.03)
8	0.15 (0.03)	0.06 (0.01)
12	0.88 (0.15)	0.39 (0.05)
16	0.81 (0.19)	0.20 (0.02)
20	0.83 (0.06)	—
	Non-acid soil	
4	0.49 (0.08)	0.06 (0.01)
8	0.44 (0.06)	0.17 (0.02)
12	1.44 (0.17)	0.78 (0.09)
16	0.60 (0.09)	1.11 (0.09)
20	0.28 (0.02)	—

†Months after planting; ‡standard errors in parentheses; — = data not available.

taken at 12 MAP. Thereafter there was a sharp drop in leafy biomass at the non-acid site when the first cut was taken at 16 or 20 MAP. The shrub became woody, produced more pods and shed most of its leaves after 12 months (Table 4). Therefore it is not advisable to cut back the shrub after 12 months at the non-acid site when the primary objective of the hedgerow intercropping system is to generate leafy biomass to raise soil fertility. However, regrowth after the twelfth month was better at the non-acid site than at the acid site because the shrubs at the former site appeared to be well established and perhaps suffered less from drought stress. In general, biomass production was affected by rainfall variations in the course of the growing season. The dry season is from November to March in the study area and most trees shed their leaves at this time to adapt to conditions of moisture stress. Relatively little biomass was harvested at 8 MAP because the regrowth and cutback coincided with the dry season. Leucaena was planted at the

Table 4. Wood and pod yields (kg plant^{-1}) of leucaena at 16 and 20 months after planting (MAP) on an acid and non-acid soil in North-West Cameroon.

	Wood		Pod	
Soil type	16 MAP	20 MAP	16 MAP	20 MAP
Acid	0.25 (0.03)†	0.54 (0.08)	0.82 (0.19)	0.17 (0.02)
Non-acid	1.61 (0.15)	1.71 (0.05)	1.74 (0.22)	1.08 (0.03)

†Standard errors in parentheses.

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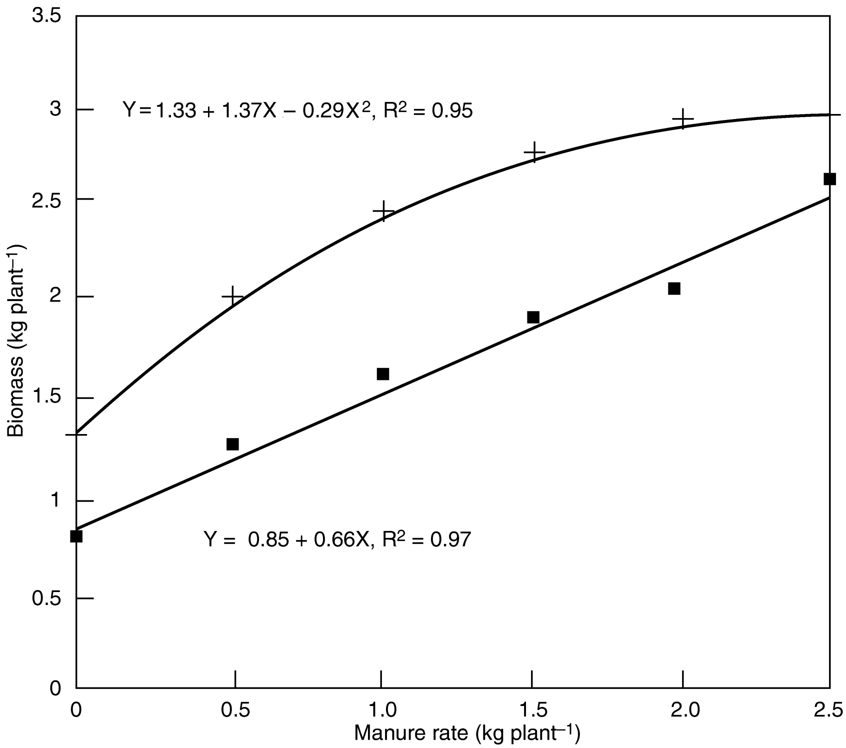

Fig. 2. Effect of the manure rate on the total biomass response of leucaena (kg $plant^{-1}$) at twelve months after planting on acid (+) and non-acid (■) soil.

peak of rainfall in July and the results indicate that 12 MAP was the optimum cutting time with respect to biomass production.

The relationship between manure rates and biomass yield at 12 MAP is shown in Fig. 2. The advantage of manuring at planting is clearly demonstrated at both sites. Biomass production of leucaena at the acid infertile site without manure application was about 0.9 kg $plant^{-1}$ as opposed to about 1.8 kg with an application of manure at 1.5 kg $plant^{-1}$. At the non-acid site, yields of leucaena biomass were about 2.7 and 1.3 kg $plant^{-1}$ respectively for the manured and non-manured plots (Fig. 2). Acquisition of manure for one-time tree establishment does not pose a problem as most farmers in the area keep poultry and livestock or practice some form of composting. However, it is difficult for farmers to secure adequate manure to fertilize their croplands continuously and sustain yields. Therefore, viewed as a long-term investment in soil fertility management, the practice of establishing leucaena with manure appears reasonable and persuasive.

Root growth

Nutrient recycling by deep rooting perennials is essential in agroforestry species. However, deep rooting is usually inhibited in acid soils by a lack of basic cations

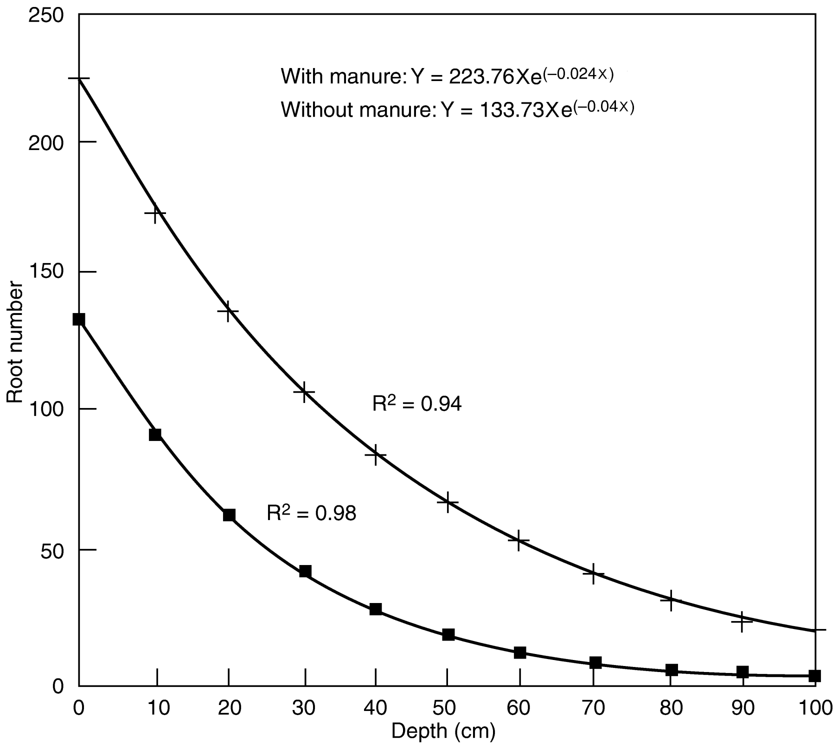

Fig. 3. Regression of root number distribution with depth on an acid soil with manure (+) and without manure (■).

and aluminium toxicity in the lower horizons. Application of manure at planting promoted deep rooting at the acid site (Fig. 3) but gave no distinct pattern at the non-acid site. At the acid site, for example, the number of root tips of leucaena at a depth of 0.5 m was about three times greater for the manured plots than for the untreated control plots. The deep rooting character of plants treated with manure also explains their observed ability to withstand moisture stress during the dry spells. Sumner *et al.* (1986) reported deep rooting and enhanced water extraction of field crops with gypsum application.

Table 5. Vertical and lateral root spread in leucaena based on the proportion of root tips per 0.5 m^2 in an acid and a non-acid soil in North-West Cameroon given varying rates of manure.

Manure rate (kg $plant^{-1}$)	Non-acid soil	Acid soil
0.0	0.41	0.55
1.0	0.40	0.51
2.5	0.44	0.67
s.e.	0.042	

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Root spread was greater at the acid than at the non-acid soil site (Table 5). The findings reported here corroborate those of Mattila *et al.* (1993) and Stark and Jordan (1978) who observed greater root system development on an infertile acid soil than on a non-acid soil. Generally, plants respond to nutrient-induced stress by the production of a large superficial root system to tap all available nutrients (Gerloff and Gabelman, 1983). In an agroforestry setting this is undesirable because it results in severe competition for the limited soil nutrients and water between the shrubs and intercrops with a possible yield reduction of the latter. By ensuring deeper and more uniform root distribution as well as additional nutrient supply, manuring may help to minimize this stress and remove the competition between shrubs and shallow-rooted food crops.

In conclusion, the study has shown that early growth of leucaena can be improved on non-acid soil as well as on acid infertile soils with the use of a single application of a small amount of farm manure. Improved early growth leading to rapid shrub establishment may overcome the frustration on the part of farmers who may have to wait for years before reaping the acclaimed benefits of agroforestry with leucaena on acid infertile soils. In fact, the chances are that farmers may never see the potential value of agroforestry on highly degraded soils without the use of starter manure to facilitate tree establishment. The results of this study are currently being applied by farmers in North-West Cameroon. Further research would be of value to determine the economics of a single application of manure for tree establishment in agroforestry systems in contrast to applications of manure directly on food crops.

Acknowledgements. This article is a contribution from the IITA USAID-supported National Cereals Research and Extension Project, Cameroon. The review comments of Dr. Osiname and Dr. Gichuru (IITA, RCMD) are appreciated. Dr. Charles Francis (University of Nebraska, Lincoln) reviewed the the manuscript.

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