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INTERACTION EFFECT OF TREE LEAF LITTER, MANURE AND INORGANIC FERTILIZER ON THE PERFORMANCE OF MAIZE IN ZIMBABWE

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ABSTRACT

An experiment was conducted over two seasons to evaluate the effects of 5 t ha^{-1} of different organic inputs (manure, *Brachystegia spiciformis* (miombo) leaf litter, *Leucaena leucocephala* senesced leaves) and Compound D (8N-14P-7K) fertilizer (300 kg ha^{-1}), and their combinations on maize growth and yield on a sandy soil at Makoholi Experimental Station, Zimbabwe. Prior to planting, vegetation from a 12 year fallow (primarily annual grasses) was ploughed under in November 1990. Maize (*Zea mays*) hybrid (R201) was planted in both seasons. Yields were extremely high in the first season. Addition of *L. leucocephala* leaf litter and manure to the soil, depressed plant growth up to tasselling and silking of maize, respectively. *Leuceana leucocephala* leaf litter resulted in a decrease in both shoot dry matter and grain yields. Total above ground dry matter was highest from the fertilizer only and the fertilizer plus miombo litter treatments, though both treatments were not significantly different from the control. Application of both manure and miombo litter resulted in suppression of growth compared to the control. Suppression of growth was overcome by the application of Compound D fertilizer. In the absence of fertilizer, there was no difference between manure and miombo litter, but miombo litter performed better than manure in the presence of fertilizer. It is hypothesised that the application of *Leucaena,* manure and miombo litter resulted in immobilisation of nutrients. *Leucaena,* which is rich in N but low in P, probably resulted in P immobilisation.

Key Words: Brachystegia spiciformis, Leucaena leucocephala, **organic inputs, soil fertility**

RÉSUMÉ

Une expérience était conduite en deux saisons successives pour évaluer les effets de différents apports organiques de 5 T/ha constitués d'engrais organiques (excrements d'animaux, feuilles décomposées de *Brachystegia spiciformis* (miombo), feuilles vieilles de *Leucaena leucocephala* et de l'engrais composés 8N-1UP-7K; 300 kg/ha), ainsi que de leurs combinaisons sur la croissance et le rendement de maïs sur un sol sableux à la station expérimentale de Makoholi au Zimbabwe. Avant le semis, une végétation provenant de 12 ans de jachère (constitué d'herbes annuelles) était enfouie en Novembre 1990. Le maïs (*Zea mays*) hybride (R201) était planté dans les deux saisons. Les rendements étaient extrêmement élevés en première saison, et l'absence de réponse à l'engrais indique le haut niveau de fertilité résultant de l'accumulation de la matière organique et des nutriments suite à la longue jachère. Cependant quant on ajoute de la matière décompossée de feuilles de *L. Leucocephala* et des excréments d'animaux dans le sol, on reduit la croissance de plantes de maïs tandis que la matière décomposée de feuilles de *L. leucocephala* reduit significativement ($P<0.05$) la matière sèche de tiges et les rendements en grains. La matière sèche totale de la partie aérienne

était plus élevée (P<0.05) pour les traitements d' engrais seul et d'engrais avec le miombo décomposé bien que les deux traitements n'étaient pas significativement différents du temoin. L'application des excréments d'animaux et de miombo décomposé entrainait un arrêt de croissance par rapport au traitement temoin. L'arrêt de croissance était corrigé par l'application de l'engrais composé. A l'absense de l'engrais, il n'y avait pas de différence entre les excréments d'animaux et le miombo décomposé mais ce dernier traitement se comportait mieux que les excréments d'animaux en présence de l'engrais. L'hypothèse émise sous-entend que l'application de leucaena, d'excréments d'amimaux et de miombo décomposé entrainait un blocage des nutriments des sols. Leucaena, riche en N et pauvre en P, a probablement entrainé le blocage de P. En deuxième saison, les rendement étaient reduits de 10% par rapport à la saison précédente à cause des conditions de sechèresse et les effets résiduels non significatifs des traitements pourvaient être observés.

Mots Clés: Brachystegia spiciformis, Leucaena leucocephala, **apports organiques, fertilité du sol**

INTRODUCTION

With the drive to rehabilitation of the rural areas, and settlement on former rangelands, there is increasing interest in the management of soils found in small-scale farming areas in Zimbabwe (Grant, 1981). About two thirds of the soils in Zimbabwe are sandy, requiring large inputs every cropping season to maintain soil fertility (Grant, 1976). Virgin soils in Zimbabwe are almost without exception very infertile and deficient in nitrogen, phosphorus, and sulphur (Grant, 1981). Manure, anthill soil, inorganic fertilizers, woodland litter especially leaf litter, and wood ash are the most common inputs used to improve soil fertility and crop yields (Grant 1976; Tanner and Murwira, 1984; Wilson, 1988; Shumba *et al.*, 1989).

Cattle manure is one of the major soil inputs used by small-scale farmers (Grant, 1981; Murwira and Mukurumbira, 1984; Shumba *et al*, 1989). In general, the manure generated on small-scale farms has a very low nutrient content and varies widely in chemical composition (Tanner and Murwira, 1984), and response has been found to vary with N content (Murwira and Mukurumbira, 1984). Grant (1981) has also shown that between 10 and 20 t ha^{-1} $year^{-1}$ of manure are required to sustain crop production on a sandy soil, but these quantities are rarely available to small-scale farmers (Scoones, 1990). The low availability of manure and its variable quality, and the high cost of fertilizers means that mixtures of inputs may be the best strategy for soil fertility maintenance. Furthermore, nutrient use efficiency may be increased through the combination of manure and fertilizer (Murwira and Kirchmann, 1993). Other sources of nutrients such as miombo leaf litter, and multi-purpose tree litter remain poorly studied in Zimbabwe.

This study was designed to investigate the response of maize to various combinations of manure, inorganic fertilizer, and tree leaf litter from *Brachystegia spiciformis* and *L. leucocephala* applied to a sandy soil. The objectives of this study were to investigate the effects of *L. Leucocephala* (senescent leaves) and *B. spiciformis* leaf litter (miombo litter), manure, inorganic fertilizer, and their combinations on the growth, total above-ground biomass and grain yield of maize, and to determine their residual effects on maize growth, grain yield, and the above-ground biomass production in the following season.

MATERIALS AND METHODS

The experiment was conducted at Makoholi Experimental Station (19° 50'S; 30°47'E) at an altitude of 1204 m above sea level in Zimbabwe's Natural Region IV. Rainfall is low with a long term average of 600 mm per annum. The site had been left fallow for 12 years. The soil was a loamy sand derived from granite. Soil properties are detailed in Table 1. No lime was applied to the soil to raise the pH. The land was tilled to 30 cm depth using an ox-drawn mouldboard plough. The early season flush of annual grasses and forbs was buried during ploughing of land in November, 1990.

Treatments, arranged in a randomised complete block design of four replications, are detailed in Table 2. The fertilizer treatment refers to a local product called Compund D. Plot size was 25 m^2. Inputs were incorporated in the soil at ploughing and a maize hybrid (R201) was hand-planted immediately, thereafter in late November 1990. Spacing was 30 and 90 cm intra- and inter-row, respectively. Initially, two seeds were planted per station and later thinned to one seedling, three weeks after germination. All plots were kept weed-free throughout the experimental period.

Maize growth was monitored by measuring plant height at 50% tasselling, silking, milk, and hard dough growth phases. Time taken to grow to each of the phases was recorded. At harvest, total above-ground biomass was determined from each plot, following which three 2-kg sub-samples from each plot were oven-dried at 80°C for 48 hr for dry matter yield. Maize cobs were hand-separated from stalks, dehusked and air-dried to 12% moisture content. The cobs were shelled using a hand-sheller and five one-thousand grain samples per plot were taken and weighed.

In the second (1991/92) season, the maize hybrid (R201) was planted on the same plots as in 1990/91 season. The data were analysed using the two way analysis of variance, and means were compared using the Least Significant Difference (LSD) test at 5%.

TABLE 1. Chemical properties of soil at Makoholi Experiment station before treatment application

	Soil depth (cm)	
	0-15	15-30
pH ($CaCl_2$)	4.9	4.9
Initial nitrogen (Mg g^{-1})	6.5	5.0
After Incubation nitrogen (Mg g^{-1})	14.8	11.5
Extractable phosphorus (Mg g^{-1})	7.7	6.7
Potassium (cmol kg^{-1})	0.09	0.08
Calcium (cmol kg^{-1})	1.06	1.07
Magnesium (cmol kg^{-1})	0.45	0.43
Gravel (%)	1	3
Coarse sand (%)	18	17
Medium sand (%)	31	26
Fine sand (%)	36	31
Silt (%)	10	8
Clay (%)	4	18
Texture	mLS	mSal

mLS = Medium loamy sand
mSal = Medium sandy loam

RESULTS

There were significant differences in plant height at tasselling (Table 3). Plants treated with manure and *L. leucocephala* were about two thirds of the height of the control, and were significantly ($P<0.05$) shorter than the other treatments. Up to tasselling, all maize except, for the manure and *Leucaena* treated plots, had attained 56-67% of their final height at physiological maturity, compared to 42% for the *Leucaena* and manure-fertilizer treatment. Differences in plant height narrowed up to the milk dough stage, at which only *L. leucocephala* treated maize was significantly shorter than in the other treatments. Application of *Leucaena* also delayed tasselling by about a week compared to the earliest tasseling treatment (Table 4).

In the first season, application of *L. leucocephala* leaf litter resulted in a significant ($P<0.05$) decrease in both shoot dry matter and grain yields (Fig. 1). With this exception, there was no significant difference in grain yields among the other treatments. Total above-ground dry matter was highest ($P<0.05$) in the fertilizer only and the fertilizer plus miombo litter treatments, although both treatments were not significantly different from the control. Application of both manure and miombo litter resulted in suppression of growth compared to the control (no inputs). A combination of Compound D fertilizer with miombo litter significantly increased above-ground dry matter

TABLE 2. Quantiity of nutrients applied

	amount (kg ha^{-1})		
	N	P	K
Control (no inputs)			
Miombo leaf litter	58	17	6
Manure	47	22	38
Leucaena	78	7	102
Manure + miombo	105	39	44
Fertilizer	24	42	21
Fertilizer + miombo	82	59	27
Fertilizer + manure	71	64	59

Leucaena = *Leucaena leucocephala* senesced leaves yield compared to the sole miombo litter treatment. In the absence of fertilizer, there was no difference between manure and miombo litter, but miombo litter performed significantly better than manure in the presence of fertilizer (Fig. 1).

DISCUSSION

In spite of the high yields reported in the first season, there was no response to fertilizer. This is indicative of the high fertility status of the site resulting from the accumulation of organic matter and nutrients under the 12 year grass fallow. In the second season, yields were reduced to 10% of the previous year's due to drought. Rainfall during the year totalled only 263.3 mm, which was inadequate for crop growth (compared to 354.5 mm received in the first season). As a result, no significant residual effects of the treatments were observed.

In general, addition of organic materials to the soil appears to have depressed plant growth. This agrees with findings of other studies carried out on sandy soils in Zimbabwe (Grant, 1981; Mugwira and Mukurumbira, 1984; Tanner and Murwira, 1994).

Yield suppression resulting from the application of organic inputs can be attributed to microbial immobilisation of nutrients. This is supported by Grant (1981) who stated that when virgin or old

TABLE 3. The influence of tree leaf litter, manure and fertilizer on maize growth

	1990/91 season			1991/92 season		
Height (cm) to 50%	Tasselling	Milk dough	Hard dough	Tasselling	Milk dough	Hard dough
Control	89.43	153.85	161.65	66.10	121.90	123.20
Miombo litter	88.33	156.40	157.60	60.10	102.10	105.40
Miombo + Manure	92.70	149.20	162.55	56.90	104.20	105.50
Manure	63.10	150.45	153.20	61.70	112.60	114.20
Fertilizer	85.60	152.50	154.90	63.00	106.40	113.20
Fertilizer+Miombo	93.23	152.50	153.60	64.30	110.90	112.70
Fertilizer+Manure	103.90	150.60	156.00	62.50	110.20	110.80
Leucaena Leucocephala	59.40	138.85	142.60	55.60	104.60	105.90
LSD 0.05	16.99	6.63	8.16	NS	NS	NS

NS = not significant at 5% level

TABLE 4. The influence of tree leaf litter, manure and fertilizer on maize growth (time taken to tassel and silk)

	1990/91 season		1991/92 season	
Days to 50%	Tasselling	Silking	Tasseling	Silking
Control	71.75	75.00	67.00	85.00
Miombo litter	70.50	75.00	68.50	78.00
Miombo + Manure	71.75	75.75	69.50	90.00
Manure only	72.25	76.50	68.50	77.00
Fertilizer only	70.50	74.50	68.50	85.00
Fertilizer + Miombo	70.25	76.25	67.00	85.00
Fertilizer + Manure	67.75	73.00	68.00	88.50
Leucaena leucocephala	74.50	80.00	70.50	85.00
LSD 0.05	1.72	2.15	2.68	12.56

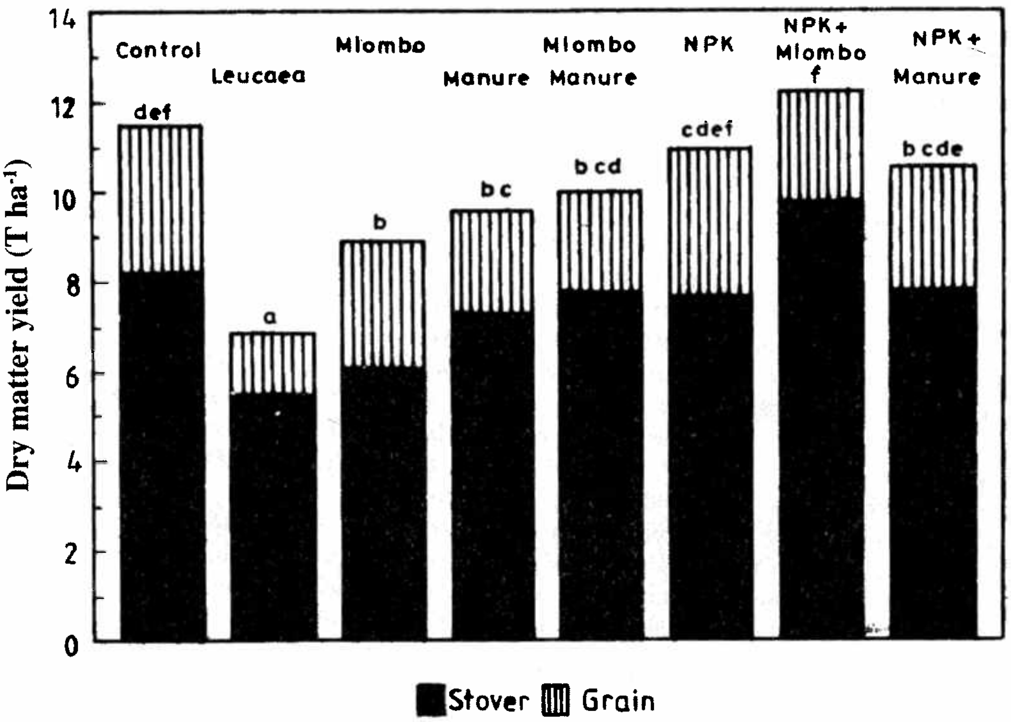

Figure 1. Total (stover+grain) above-ground biomass production of maize supplied with organic or inorganic sources of nutrients and their combinations for the 1990/91 season. Different letters indicate significant differences (P<0.05) in total productivity.

fallow soils in Zimbabwe are tilled for cropping, the problem of low fertility of sandy soils is compounded by competition for available nutrients with soil micro-organisms that proliferate. The fact, however, that a multi-nutrient fertilizer was applied together with the organic materials means that it is not possible to infer which nutrient or nutrients were being immobilised. *Leucaena*, which is rich in N but low in P, resulted in the largest yield decline, and so it is likely that this material resulted in P immobilisation, and poor utilisation of available N. Grant (1981) also reported a temporary increase in the phosphate deficiency of sandy soils in Zimbabwe following ploughing in of unrotted plant residues, as was done in this study. Manure and miombo litter, on the other hand, had relatively high P contents (22 and 17 kg P ha^{-1}, respectively), but this may have been insufficient to cater for the P demand of this high-yielding crop, particularly as most P is organically bound, and may have been mineralised asynchronously with crop demand. The application of Compound D, rich in inorganic P (42 kg P ha^{-1} was applied), may have been sufficient to overcome the yield suppression.

It is also possible that N may have limited productivity in the sole miombo litter and manure treatments, because of the low N content in these materials. The N contents of the materials used in this experiment were below the 2% (or C:N < 25) which lead initially to the immobilisation of mineral N (Myers *et al.*, 1994). Murwira and Kirchmann (1993) also reported N immobilisation, and a decrease in yield, when a low-quality manure was added to a sandy soil in Zimbabwe. Elsewhere in the tropics, studies suggest that N immobilisation is expected during transformation of organic materials in the soil (Castellanos and Pratt, 1981; Sims, 1986; Yadvinder-Singh *et al.*, 1988). The *L. leucocephala* and the manure-treated maize attained less than half of their final height before tasselling, resulting in delayed tasseling and silking, low total above-ground biomass and grain yields. This was apparently due to insufficient available soil N. The two growth phases coincided with the tapering off of rainfall; thus, soil moisture also became limiting for the development of well-filled grain as evidenced by the generally low 1000-grain mass.

Inclusion of inorganic fertilizer as part of a mixture resulted in improved grain, total above-ground biomass yields, and 1000-grain mass. This may have been because the inorganic fertilizer supplied sufficient N and P to overcome yield suppression. The supply of those nutrients limiting productivity may have shortened the period of immobilisation, and may have stimulated nutrient mineralisation at a time when nutrients were required by plants. Further studies of nutrient mineralisation, and crop nutrient uptake during the growing season are required to test this hypothesis. Such research should develop a predictive understanding of the soil biological processes which regulate tropical soil fertility as a basis for recommendations of optimum rates of organic manures and their combination with inorganic fertilizers to maximise nutrient use efficiency.

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