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Enhancement of food productivity using leguminous shrubs in the Eastern highlands of Kenya

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Abstract: Declining soil productivity is a major challenge facing smallholder farmers in eastern highlands of Kenya. This decline is caused by continuous cultivation of soils without adequate addition of external inputs in form of manures and fertilizers. A study was initiated in 1992 to evaluate the feasibility of using two leguminous shrubs Calliandria *(Calliandra calothyrsus*) and Leucaenia (*Leucaena leucocephala*) for improving soil productivity. The shrubs were evaluated in alley cropping and biomass transfer systems. Over the 11 years of study, calliandra and leucaena biomass transfer with half recommended rate of inorganic fertiliser treatments gave the best average maize yields of 3.2 t ha^{-1}. On the other hand calliandra alley cropped with prunings removed treatment recorded the lowest maize yield of 1.2 t ha^{-1}. Though treatments with calliandra biomass transfer had similar yields compared to those of leucaena biomass transfer, all the treatments that were leucaena alley cropped did better than calliandra alley cropped treatments both with prunings incorporated and prunings removed. These long-term results indicate that biomass transfer system of these leguminous shrubs is a more feasible option as opposed to alley cropping in the region.

Key words: Continuous cultivation, biomass transfer, cropping systems, Zea mays,

Introduction

The Central highlands of Kenya is densely populated with more than 700 persons Km^{-2} (Government of Kenya, 2001) and declining land productivity with reduced crop yields has been a major challenge facing smallholder farmers in the region. The declining land productivity is as a result of soil impoverishment caused by continuous cropping without addition of adequate external inputs, and soil erosion on steep slopes (Minae and Nyamai, 1988). Land sizes are small, on average 1.2 ha, and this promotes continuous cropping with limited scope for crop rotation and inadequate soil fertility replenishment. For instance, the use of inorganic fertilisers is as low as less than 20 kg N and 10 kg P ha^{-1} (Muriithi *et al*., 1994). The amount is inadequate - below the recommended level of 60 kg N ha^{-1}, to meet the crop nutrient requirement for optimum crop productivity in the area. Kihanda (1996) observed that less than 25% maize growers in the central highlands of Kenya use inorganic fertilisers. Wokabi (1994) reported that, though high yielding maize varieties have been developed with yield potentials of 7-12 Mg ha^{-1}, maize yields at the farm level hardly exceed 1.5 Mg ha^{-1}.

Leguminous trees species have shown some potential for soil fertility improvement through biomass transfer, short term fallows, nitrogen fixation, re-activation of the 'N bulge' and phosphorus scavenging (Rosecrance *et al*., 1992; Jama *et al*., 1998; Hartemink et al., 2000). However use of these leguminous shrubs is limited within the central highlands of Kenya. An experiment was therefore initiated under the auspices of the National Agroforestry Research Project to investigate feasibility of using leguminous trees for soil fertility improvement. The leguminous shrubs used were *Leucaena leucocephala* (Lam.) de Wit and *Calliandra calothyrsus* Meissn.

Methodology

Study area. The trial was located at the Kenya Agricultural Research Institute Regional Centre (Embu), in the central highlands of Kenya. The site is characterized by a bimodal rainfall distribution, which ranges from 1200 mm to 1500 mm per annum. Agriculture in the region is characterized by smallholder mixed farming activities, which include cash crops (coffee, tea and horticultural crops), food crops (maize, beans, bananas and irish potatoes), trees and livestock (dairy and beef cattle, goats, sheep, poultry and pigs). The soils are commonly known as "Kikuyu Red Clay Loams". They are extremely deep (>2 m), well drained, with moderate structure (Mwangi, 1997). They are derived from rich, basic volcanic rocks and has been classified as Typic Palehumult (Humic Nitisols according to FAO-UNESCO).

Experimental layout. The experiment was initiated in 1992 at the Embu Regional Research Centre, Embu, Kenya. A randomized complete block design with four replicates was used. The plot dimensions were 9 x 10 m while the sample plot is 6 x 4.5 m. The test crop was maize (*Zea mays* L.) Hybrid 511. In six of these treatments fresh leaf prunings of tree species (leucaena and calliandra) were applied, the prunings being obtained from hedgerows grown *In situ* (alley-cropped) or *Ex-situ* (cut and carry) from other sources. They were as follows;

Alley cropping; no fertiliser; Calliandra; prunings incorporated, Leucaena; prunings incorporated, Calliandra; prunings not incorporated, Leucaena; prunings not incorporated

Maize only and no alley cropping but prunings from outside incorporated; Calliandra prunings + no fertilizer, Leucaena prunings + no fertilizer, Calliandra prunings + fertilizer, kg N/ha), Leucaena prunings + fertilizer (25 kg N/ha). Maize only and no alley cropping; With fertilizer (50 kg N/ha) and Without fertilizer.

Lopping of calliandra and leucaena tree hedges was done at a height of 50 cm one to two days before maize planting. Leafy biomass and succulent stems were separated from woody stems and each weighed separately. The leafy biomass was evenly spread on the ground in the treatments designated to receive prunings described above and soil-incorporated by hand hoes as the land was prepared for maize planting. Sub-samples were collected for N content determination before the prunings were soil-incorporated. Leafy biomass applied in treatments 7 and 8 (that received prunings from outside the experimental plot biomass transfer) were obtained from block plantings of calliandra and leucaena hedges established near the site. These treatments received average biomass (dry matter basis) of 2 and 1 Mg/ha for calliandra and leucaena biomass containing approximately 60 and 30 kg N ha^{-1} season^{-1} respectively.

Treatment 9 received the recommended level of inorganic fertilizer (60 kg N/ha) as calcium ammonium nitrate (CAN) while treatments 7 an 8 received half of the recommended rate (30 kg N ha^{-1}) (to approximate the lower levels commonly applied by most farmers in the area). Application was through top dressing in two doses; the first dose (one-third of the full dose) four weeks after maize germination and the second (two-thirds), four weeks later. Resulting data were subjected to analysis of variance using Genstat program (1995).

Results and discusions

The average maize grain yields obtained across the sixteen seasons indicate that treatments 7 and 8 (maize monocrop with prunings + 30 Kg /N ha) gave the highest yields of 3.2/ t ha followed by Treatments 5 and 6 (maize monocrop + prunings) which gave 2.9 t /ha (Table 3). Treatment 3 (calliandra with prunings removed) gave the lowest yields (1.2 t /ha) followed by Treatment 4 and 10 (leucaena with prunings removed and control) with 1.7 t/ha respectively. Leucaena alley cropped treatment with prunings incorporated (Treatment 2) gave better yields (2.8 t/ha) than the recommended fertilizer treatment (2.4 t/ha), whereas the equivalent calliandra treatment (treatment 1) performed poorer than the fertiliser treatment by recording an average yield of 2.1 t/ha. It is further observed that all leucaena alley cropped treatments (with or without prunings incorporated) produced higher maize yields compare to similar calliandra alley cropped treatments.

These results concur with findings of Mafongoya and Nair (1997) and Mugendi *et al*. (1999) who reported significant maize yield increases following application of green manure. The leafy prunings incorporated into the soil (as green manure) at the beginning of the season decomposed and released nutrients especially nitrogen, which enhanced crop performance (Mugendi *et al*., 1999).

Treatments with prunings incorporated with fertilizer gave better maize grain yields compared to treatments with only prunings applied. This could be due to the provision of additional physical, chemical and biological benefits (besides N) by the organic materials (Hatfield and Cambardella, 2001) or due to the prevention of other nutrients deficiencies and/ or enhanced nutrient fluxes (Sanchez and Jama, 2002). Kapkiyai *et al*. (1998) reported that combination of organic and inorganic nutrient sources has been shown to result into synergy and improved synchronization of nutrient release and uptake by plants (leading to higher yields). Tian *et al*. (1993), reported that nutrient uptake and grain yield of the crop was higher when nitrogen was partially applied as prunings, indicating the importance of the combined addition of plant residue and fertiliser N for improving crop production.

Over the sixteen cropping seasons of the study, plots (Treatments 5 & 6 and 7 & 8) that received calliandra and leucaena prunings (biomass transfer), with and without fertilizer, gave identical average maize yields (Table 1). However, maize grain yields obtained in leucaena alley crop (with prunings incorporated or with prunings removed) treatments (Treatment 2 and 4) were significantly higher compared to calliandra alley crop (with prunings incorporated or with prunings removed) treatments (Treatment 1 and 3). This is an indication that leucaena can be used effectively in alley cropping arrangements to improve soil productivity and subsquently crop yields in the region (Mugendi *et al*., 1999; Mugwe *et al*., 1999). Other researchers working with calliandra have reported conflicting results. Some have reported improved crop yields (Heinneman, 1992; Rosecrance *et al*., 1992), while Gutteridge (1992) reported depressed or marginal yields. The poor performance of calliandra may be attributed to root morphology where root studies showed that over 95 % of all maize roots were located in the top 90 cm while for calliandra and leucaena it was 60 % and 25 % respectively in the same depth (Mugendi *et al*., 2003). Calliandra therefore competed with maize more intensely compared to leucaena whose greater percentage of roots were located below the effective rooting zone of

the maize crop. Indeed, Jama et al. (1998) demonstrated that calliandra had the greatest root density in the top 15 cm of soil when compared to four other multipurpose tree species (*Eucalyptus grandis, Sesbania sesban, Markhamia lutea,* and *Grevillea robusta*) evaluated in the western highlands of Kenya.

This study demonstrated the beneficial effects on crop yields of incorporating prunings of calliandra and leucaena especially when biomass is brought from outside (biomass transfer). It is also evident that alley-cropping with leucaena has great potential as a method of improving sustainable yields in the region. Maize grain yields at the farm level that have been reported to range below 1.5 Mg/ha could be substantially increased if farmers adopted the use of leguminous trees to improve their yields.

However, it has been pointed out that the advantages of alley cropping seems to rest in the complementarity of resource capture (Ong and Black, 1995); while it has disadvantages in establishment costs and labour requirements. Therefore, despite these promising results shown by alley cropping with leucaena, the question of labour availability needs to be addressed properly before a wide adoption by farmers can be envisaged.
This technology is labour-intensive with much of the demand for labour occurring during the start of the rainy season, which is the busiest time of the year.

Calliandra alley-cropping system adversely affected crop yields and should not be recommended as an alley-crop species. This observation is probably due to the that calliandra developed a strong superficial root system that competed with associated food crops for growth resources. However, calliandra was found to be effective in controlling soil erosion when used as a contour hedge possibly because of the strong root system that holds the soil together (O'Neill *et al*., 1997). In addition to conserving the soil, calliandra provides up to 24% crude protein and the large tonnage of biomass yield from using hedges as a soil conservation resource can supplement and in some cases substitute input protein rations in animals (Angima, 2000).

Further research by NAFRP has shown great potential for calliandra adoption by smallholder farmers for use in dairy production (Tuwei *et al*., 1999). On-farm feeding trials have confirmed the effectiveness of calliandra both as supplement to the basal diet and as a substitute for dairy meal. The trials found that one kilogram of dry calliandra had about the same amount of digestible protein as one kilogram of dairy meal; both increased milk production by roughly 0.75 kg under farm conditions (O'Neill *et al*., 1995; Paterson *et al*., 1996). The dissemination efforts of calliandra has revealed that the most common niche for planting calliandra is along the contours both for soil conservation and soil fertility (Tuwei *et al*., 1999). Since, dairy production is predominant enterprise in the region and farmers could use calliandra to feed their animals, but this however, means removal of nutrients from the site (nutrient mining) and hence, a means of replenishing soil nutrients is necessary. This could be achieved through recycling manure. This practice is feasible and economical and is likely to have high adoption rates. If adopted, soil conservation and soil fertility improvement could be enhanced.

Conclusion

The study showed promising results using leafy prunings of leguminous shrubs, mainly *Calliandra calothyrsus* and *Leucaena leucocephala* for soil fertility improvement when the leafy prunings are incorporated into the soil. The use of these leguminous shrubs in an alley-cropping system however presented mixed results. Leucaena can be used successfully as an alley species for it gave an average maize grain yields of 2.8 t/ha compared to 2.4 t/ha from the recommended fertilizer treatment and 1.7 t/ha from the control. Calliandra on the other hand is not good as an alley cropping tree species but could be used successfully for stabilizing soil conservation structures on contour bunds. Considering that smallholdings in the central highland of Kenya occur on sloping lands, and the importance of dairy production in the region, there is great potential for using calliandra contour hedges for soil conservation and harvest prunings for fodder. Farmers in the region and similar areas should therefore be encouraged to adopt this practice. Feasibility of replenishing soil nutrients through recycling manure from livestock needs to be explored. Farmers without livestock should use the prunings for soil fertility improvement through direct incorporation of the prunings.

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