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The long-term effects of a gliricidia–maize intercropping system in Southern Malawi, on gliricidia and maize yields, and soil properties

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Abstract

A gliricidia–maize (*Gliricidia sepium* (Jacq.)–*Zea mays* L.) simultaneous intercropping agroforestry system has shown to be a suitable option for soil fertility improvement and yield increase in highly populated areas of sub Saharan Africa where landholding sizes are very small and inorganic fertilizer use is very low. An 11 year old field experiment, gliricidia–maize simultaneous intercropping, with and without a small application of inorganic fertilizer was studied to increase our understanding of the long-term effects of continuous applications of gliricidia prunings on maize yield and soil chemical properties. The main objectives were to assess: (1) the yield of gliricidia prunings under intensive pruning management, (2) the effect of continuous applications of gliricidia prunings and fertilizer on maize yield and soil properties. During 11 years of intensive pruning, gliricidia trees maintained high levels of leafy biomass production (4–5 Mg DM ha^{-1}). Application of gliricidia prunings increased maize yield three-fold over sole maize cropping without any soil amendments (3.8 and 1.1 Mg ha^{-1}, respectively). Maize yield declined with time under sole maize cropping system in both treatments with and without inorganic N fertilizer. Application of inorganic fertilizer (46 kg N ha^{-1}) in agroforestry systems increased maize yield by 29% ($P = 0.002$). Application of inorganic P did not significantly increase maize yield implying that the native P in the topsoil and P recycled through gliricidia prunings application was enough to support maize growth. The trees took up ''native'' soil nutrients (P, Ca, Mg and K) from the depth and pumped these to the surface soil. A net soil nutrient decrease in the gliricidia–maize simultaneous intercropping system was observed due to increased nutrient export.

Keywords: Gliricidia; Maize; Inorganic fertilizer; Intercropping; Agroforestry; Smallholder farmer

1. Introduction

In the sub-Saharan Africa, soil infertility is a major problem constraining agricultural production. Inorganic fertilizers are the first option for soil amelioration, but due to exorbitant prices most farmers cannot set aside sufficient money to buy them. Hence, farmers are encouraged to enrich the soils through planting of desirable woody or herbaceous species as improved fallows or simultaneously with the crops. Woody or herbaceous species in agroforestry systems can enrich topsoil through enabling nutrient cycling from the subsoil, and through biological N_2 fixation by legume species (Kang and Shannon, 2001). The positive effects of planted improved fallows and hedgerow intercropping on soil fertility and on yields of succeeding or associated crops have already been documented (Kwesiga and Coe, 1994; Wendt et al., 1996; Akondé et al., 1997; Kang et al., 1999).

Several authors have expressed their fear that competition between trees and crops in a hedgerow cropping system for resources, e.g. for light, water and mineral elements, will reduce the yields of the associated crops (Ruhigwa et al., 1992; José et al., 2000a,b; Miller and Pallardy, 2001). Smithson and Giller (2002) reviewed different agroforestry

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systems and pointed out that the system of gliricidia–maize mixed (*Gliricidia sepium* (Jacq.)–*Zea mays* L.) intercropping (also known as gliricidia–maize simultaneous intercropping) developed at Makoka, Zomba, in Malawi, was more successful than system of hedgerow intercropping. In Malawi alley cropping was unsuccessful because of low tree biomass production and competition for resources between trees and crops (Itimu, 1997), while gliricidia–maize mixed intercropping has shown to be successful (Ikerra et al., 1999). Gliricidia–maize simultaneous intercropping system is a variant of alley cropping in which the trees are kept short by intensive pruning. Tree rows are closely spaced with only two rows of maize between the tree rows. In standard alley cropping there are five maize rows in the alleys. In the gliricidia–maize simultaneous intercropping we need more information on the value of the prunings as N and P fertilizer, on the effects of intensive pruning management on long-term tree biomass production, and on nutrient availability in both topsoils and subsoils. In this study we set the following objectives: (1) to compare the effects of gliricidia prunings on maize yield with those of inorganic N fertilizer, (2) to study long-term gliricidia biomass production under intensive pruning management and (3) to assess the long-term effect of repeated application of gliricidia prunings on soil fertility and crop yield.

2. Materials and methods

2.1. Site description

The study was conducted at Makoka Agricultural Research Station near Zomba in Southern Malawi (15° 30′ S, 35° 15′ E, altitude of 1029 m asl). The soil had 42% clay, 46% sand and 1.42 g/cm^3 bulk density. The chemical characteristics of the soil were: pH(H_2O) = 6, organic C = 9 g/kg, P-olsen = 26 mg/kg, exchangeable K = 3 mmol (+)/kg, exchangeable Ca = 44 mmol (+)/kg and exchangeable Mg = 16 mmol (+)/kg soil. The soil is classified as ferric lixisol (FAO) (Ikerra et al., 1999). The rainfall is unimodal, most of it falling between November and March, and the growing season of maize is usually from November/December till May. The mean rainfall for the 11 years was 937 mm. The highest total annual rainfall was 1706 mm in 1997 and the lowest was 552 mm in 1993. During the 11 years we experienced two major droughts (1994 and 1995, see Fig. 1) and one season of excessive rainfall (1997).

2.2. Experimental design and management

Previously, on the experimental plot was a cotton (*Gossypium* sp.) agronomy trial with inorganic N fertilizer management. This agroforestry experiment was established in 1992 and since establishment the plots have been continuously cropped with maize as a test crop. The trial was designed as a 2 × 3 × 3 factorial in three replicates with the following factors: (1) with and without *Gliricidia sepium* intercropping (2) three rates of inorganic N fertilizer (0, 24 and 48 kg N ha^{-1}), and (3) three rates of P fertilizer (0, 20 and 40 kg P_2O_5 ha^{-1}). Calcium ammonium nitrate (CAN) fertilizer was used as a source of inorganic N fertilizer and was applied at 4 weeks after planting. Triple super phosphate (TSP) was used as a source of inorganic P and was applied at time of planting. The P treatments were discontinued from 1993/1994 to 2001/2002 because there was no response. They were reintroduced in 2002/2003 season because we thought that after 10 years of continuous cropping without P amendment might have depleted the soil native P via crop harvest and tree wood biomass removal.

Plot size was 6.7 m × 5.1 m, separated by 1 m wide path. In order to minimize tree root encroachment into the neighboring plots, iron sheets were installed vertically to 1 m deep in the borders of the tree plots.

The agroforestry species was *Gliricidia sepium* (Jacq.) Walp ex Reltahaleu, Guatemala. The trees were planted in rows in every other furrow at spacing of 90 cm within row

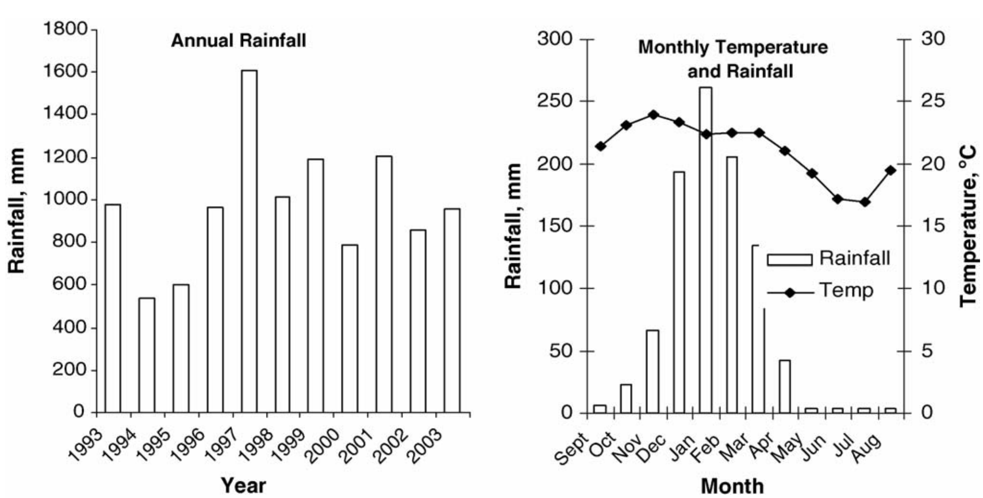

Fig. 1. Total annual rainfall, monthly rainfall means for 11 years and monthly temperature means from 1993 to 2003.