Macro nutrient balances of two *Mucuna* cultivars in *Mucuna*/maize systems in the forest savannah transitional zone of Ghana

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Macro nutrient (N, P, K, Ca, Mg) balances at field level for maize/*Mucuna* rotations were calculated for two different *Mucuna* cultivars in the Forest Savannah Transitional Zone of Ghana in 1999/2000: a late maturing *M. pruriens* var. *utilis* and an early maturing local *Mucuna* variety. All macro nutrients including N had a negative balance for the local *Mucuna* cultivar with -15.7 kg N, -11.5 kg P, -32.7 kg K, -34.4 kg Ca and -18.5 kg Mg per hectare. The system with *M. pruriens* contributed 31.8 kg N per hectare to the system while the budget of the other nutrients was -8.7 kg P, -28.3 kg K, -28.6 kg Ca and -15.7 kg Mg per hectare. The data suggest that *M. pruriens* contributes more to soil fertility maintenance than the local cultivar. However, a rotation of *M. pruriens* with maize is only sustainable if elements other than N are added to the soil in the form of mineral fertilizers or organic amendments.

Keywords: Mucuna, cover crop, nutrient balance, Ghana, West Africa

Introduction

Reduced fallow periods in many parts of West Africa lead to a decline of soil fertility. *Mucuna* cover crop fallow has shown to have a high agronomic potential in Ghana (Fosu, 1999) and there is an increasing interest of farmers to experiment with *Mucuna* cover crop systems (Anthofer, 2000, Gregory and Mensah, 2000). However, despite tremendous yield increases even under on-farm conditions there is a need to analyse nutrient balances in order to assess the sustainability of such systems.

Different *Mucuna* cultivars, mainly characterized by the length of their growing period might fit into different farming systems. However, early maturing varieties might fix less atmospheric N than late maturing ones. Different rates of seed yields and their removal from farmers' fields might also lead to different nutrient balances. Therefore, the present study was undertaken to estimate the macro nutrient balance in *Mucuna/*maize systems comparing a late maturing variety of *M. pruriens* var. *utilis* with a local early maturing cultivar   The objective was to evaluate the potential contribution of both varieties to soil fertility maintenance under on-farm conditions.

Materials and methods

Location, climate and soils

Sunyani district lies between 2 8‘ and 2°31‘W latitude and between 7°7‘ and 7°36‘ N longitude within the Forest Savannah Transitional Zone of Ghana. Rainfall in Sunyani shows a weak bimodal distribution with the main rainy season between March/April and July and the short rainy season between September and November. Annual precipitation is around 1300 mm. Soil chemical and physical analysis on the farms investigated revealed the following properties: pH (H_20 1:1) 6.7±0.1, organic C 2.0%±0.1, total N 0.05%±0.003, available P 1.8 mg kg^{-1}±0.3, CEC 15.8 cmol kg^{-1}±1.6, sand 42.5%±1.9, silt 39.8%±1.4 and clay 17.7%±2.9.

Mucuna/maize systems, selection of case study farms and management

M. pruriens is sown in between maize, after tasseling or cob formation to develop maximum biomass during the short rainy season. Ideally, the planting time is during June, as this month has the highest average rainfall within the year in Sunyani. Short duration *Mucuna* cultivars are being cultivated like a minor season food crop in pure stand at the onset of the minor season rains (Fig. 1). The following year maize was planted to benefit from the improved fallow. Plant spacing for maize and *Mucuna* were 0.9 m x 0.4 m with two seeds per hill.

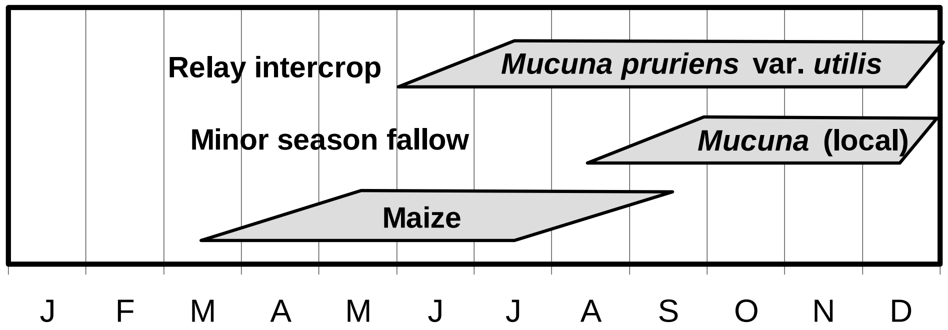

Fig. 1: Cropping calendar for different *Mucuna* systems in Sunyani district: *Mucuna*/maize relay intercrop with late maturing *M. pruriens* var. *utilis* and *Mucuna* minor season fallow with a local short maturing *Mucuna* cultivar

Farmers selected for the study opted within a PTD approach of the Sedentary Farming Systems Project (SFSP) to test *Mucuna* spp*.* as a minor season improved fallow. The selected experimental sites (20 m x 20 m) were chosen in fields being cropped with maize during the major season.

Data collection

Measurements of maize yield components were recorded on 18 farmers' fields in 1999, whilst N fixation, *Mucuna* biomass and seed yield components were assessed on 27 farmers' fields during the 1999/2000 minor season.

At all sites, two 1 m^2 quadrates per field were used to sample total aboveground biomass at the end of November 1999. Plant residues were collected and living plant parts were cut at soil surface to estimate total aboveground biomass. A subsample of biomass was retained for gravimetric determination of moisture content.

Maize was harvested at physiological maturity. Maize cobs were collected from the inner 100 m^2 of each plot and the weight was recorded in the field with an electronic balance. Twenty individual plants were taken at random within each plot, separated into straw and cobs comprising seeds, husk and spikelett and weighed. Seeds were removed from the cobs and all three yield components were taken in the field. The samples were air dried before the dry matter and the macro nutrient concentrations were analysed.

For soil analysis, twenty core samples were taken from a depth of 0-20 cm in each farmer's plot before planting the *Mucuna* fallow. All soil (pH, organic C, total N, available P, CEC, soil texture) and plant tissue analyses (N, P, K, Ca, Mg) were made at the Soil Research Institute in Kumasi following the soil and tissue analytical procedures as described by the Royal Tropical Institute (1984, 1986).

Quantifying nutrient flows

One tool to assess the dynamics of soil fertility is the nutrient balance. The quantity of nutrients entering and leaving a field are analysed (Fig. 2), and the balance is estimated. The model assumes that over time soil

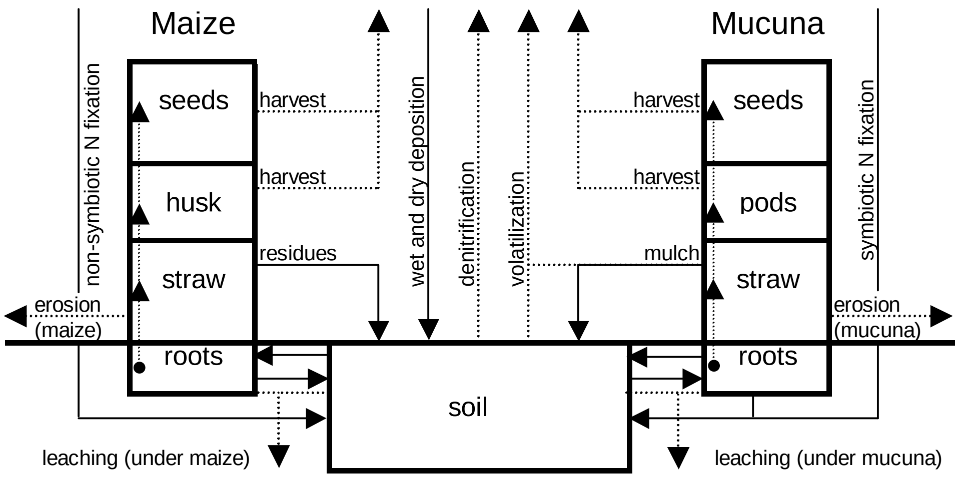

Fig. 2: Nutrient flows in *Mucuna*/maize rotations

fertility is determined mainly by the degree to which nutrient exports are balanced by nutrient imports. Internal fluxes between nutrient pools are considered to be more or less in equilibrium (Van der Pool, 1992). Due to lack of consistent data of all nutrient inputs and outputs for each farm, averages and confidence intervals were estimated for each input and output flow parameter measured at field level.

The N, P, K, Ca and Mg balances were calculated from a combination of two input and four output processes modified from Stoorvogel and Smaling (1990):

- Input: biological N fixation (FLOW 1), atmospheric deposition (FLOW 2).

- Output: removal in harvested maize and *Mucuna* seeds (FLOW 3 and 5), removal in maize and *Mucuna* residues (FLOW 4 and 6), leaching (FLOW 7), gaseous losses (FLOW 8).

Nutrient flow scenarios

Measured data in the study area and secondary data where applicable were analysed for confidence intervals of the mean values at $p = 0.05$ to calculate optimistic and pessimistic nutrient flow scenarios according to Van der Pol (1992). If data derived from secondary sources the data range or single data were applied. An optimistic nutrient flow scenario was calculated by combining high rates of nutrients entering the systems with low rates leaving the system. Conversely, a pessimistic scenario was calculated by combining low nutrient import rates with high nutrient export rates.

Results and Discussion

Non-symbiotically fixed nitrogen through *Azobacter*, *Beyerinckia* and *Clostridium* was assumed to be about 5 kg N ha^{-1} a^{-1} (Stoorvogel and Smaling, 1990). The total nitrogen difference method (TND) was applied to quantify symbiotically fixed nitrogen. The fallow vegetation was chosen as reference, which was dominated by *Chromolaena odorata*. *Mucuna pruriens* var *utilis* was able to fix 106.3±13.9 kg ha^{-1} in the above ground biomass representing 56% of the total nitrogen taken up. In addition, it can be expected that *Mucuna* accumulates about 7-10 kg N ha^{-1} derived from atmosphere in the root biomass (Ibewiro *et al.,* 1998). The local *Mucuna* cultivar fixed only 72.5±21.7 kg ha^{-1}, representing 35.9% of the nitrogen taken up.

The study area is within the influence of the harmattan. Data of atmospheric deposition were adapted from Hermann (1996). Data collected in Agouagon/Benin were used, a location with comparable agro climatic properties compared with Sunyani (7°59'N 2°18'O, 220 m NN, 1100 mm annual precipitation). 5.9±2.0 kg N, 1.9±1.4 kg P, 7.1± 0.4 kg K, 13.7±2.1 kg Ca and 2.6±0.4 kg Mg ha^{-1} were found in the dry and wet deposition per year in 1992 to 1994.

Nutrients removed by maize seed after *Mucuna* were 39.3±6.0 kg N, 8.5±0.8 kg P, 12.8±1.6 kg K, 13.0±1.6 kg Ca and 3.9±0.6 kg Mg ha^{-1} a^{-1}. Losses induced by crop residues were only 0.9±0.1 kg N, 0.8±0.1 kg P, 6.4±0.6 kg K, 4.9±0.6 kg Ca and 1.9±0.3 kg Mg ha^{-1} a^{-1} because only the cob straw is being removed from the field while the stalks are left in the field.

The loss of plant nutrients through harvesting *Mucuna* seeds was considerable. 30.4 kg N (21.0-40.1), 0.3 kg P (0.5-2.6), 7.6 kg K (2.6-14.4), 4.8 kg Ca (2.4-7.8) and 3.9 kg Mg (1.5-7.3) per hectare were removed in *M. pruriens*. This means that 28.5% of the symbiotically fixed N through *Mucuna* fallowing was lost. In contrast, due to higher seed yield potential of the local early maturing *Mucuna* cultivar 42.9 kg N (35.7-50.5), 2.2 kg P (0-5.0), 11.1 kg K (5-18.6), 6.2 kg Ca (4.1-8.7) and 5.1 kg Mg (3.6-5.6) per hectare were removed. Here, even 59.2% of the symbiotically fixed nitrogen was removed in *Mucuna* seeds. Comparing the nitrogen exports with maize seeds the local *Mucuna* cultivar removed more nitrogen through seed harvest while *M. pruriens* seeds removed only 77% of the amount of nitrogen compared to that in maize seeds. Attempts in utilization *Mucuna* seeds for human and animal consumption have to be viewed more critically from this point of view. Leaving most of the seeds in the field and cutting the volunteer seedlings early in the season may lead to better fertilizing effects of the succeeding food crops, e.g., of maize. The nutrients contained in the *Mucuna* pods without seeds which are also removed from the field due to harvesting were 1.7 kg N (07-3.1), 1.0 kg P (0.2-2.2), 5.9 kg K (3.1-9.7), 4.7 kg Ca (3.1-6.7) and 2.5 kg Mg (1.9-3.0) in *M. pruriens* while 2.9 kg N (1.7-4.3), 1.9 kg P (0.6-3.4), 6.8 kg K (4.4-9.7), 9.0 kg Ca (7.0-11.3) and 4.2 kg Mg (2.7-6.0) per hectare were removed in pods of the local cultivar. These residues are normally not brought back to the field.

Leaching rates in cover crop/green manure systems compared to unfertilised fallow systems are hardly investigated. In accordance to Grimme and Juo (1985) and Akonde *et al*. (1997), it was assumed that 8-15 kg N, no P, 1 kg K, 15 kg Ca and 6 kg Mg per hectare were lost through leaching per year.

Denitrification was negligible for the well-drained soils of the investigated plots in the study area and volatilisation from the soil was estimated to be around 1 kg N ha^{-1} a^{-1} (Singh and Balasubramanian, 1980). Volatile losses of nitrogen during decomposition of leguminous green manures were found to be 5% of the applied N after 56 days under controlled conditions (Janzzen and McGinn, 1991). Glasener and Palm (1995) found similar results with a range of 3.4-11.8% losses of the initial nitrogen through ammonia volatilisation in ten tropical legume mulches and green manures. Average ammonia losses were therefore estimated to be 9.1 and 9.2 kg^{-1} ha^{-1} a^{-1} for the local cultivar and *M. pruriens* respectively. These losses might easily be higher considering that the mulch material is exposed to sunlight and heat for about 4 months during the dry season. One of the major advantages of a *Mucuna*/maize rotation is based in the feasibility not to burn because the native vegetation is being suppressed and the *Mucuna* cover crop dies back by itself. All macro nutrients including N had a negative balance for the local *Mucuna* cultivar with -15.7 kg N, -11.5 kg P, -32.7 kg K, -34.4 kg Ca and -18.5 kg Mg per hectare. The system with *M. pruriens* contributed 31.8 kg N per hectare to the system while the budget of the other nutrients was -8.7 kg P, -28.3 kg K, -28.6 kg Ca and -15.7 kg Mg per hectare (Fig. 3). The data suggest that the late maturing *M. pruriens* var. *utilis* contributes more to soil fertility maintenance than the local early maturing cultivar. However, applying optimistic and pessimistic nutrient flow scenarios, the data show, that a positive N balance is not assured even for *M. pruriens* and that, in general, *Mucuna* fallow systems show a high risk of failure for soil fertility maintenance. Therefore, an integrated nutrient management system, combining a *Mucuna* fallow with external nutrient imports such as animal manure or chemical fertilizer are required for both systems in order to be sustainable.

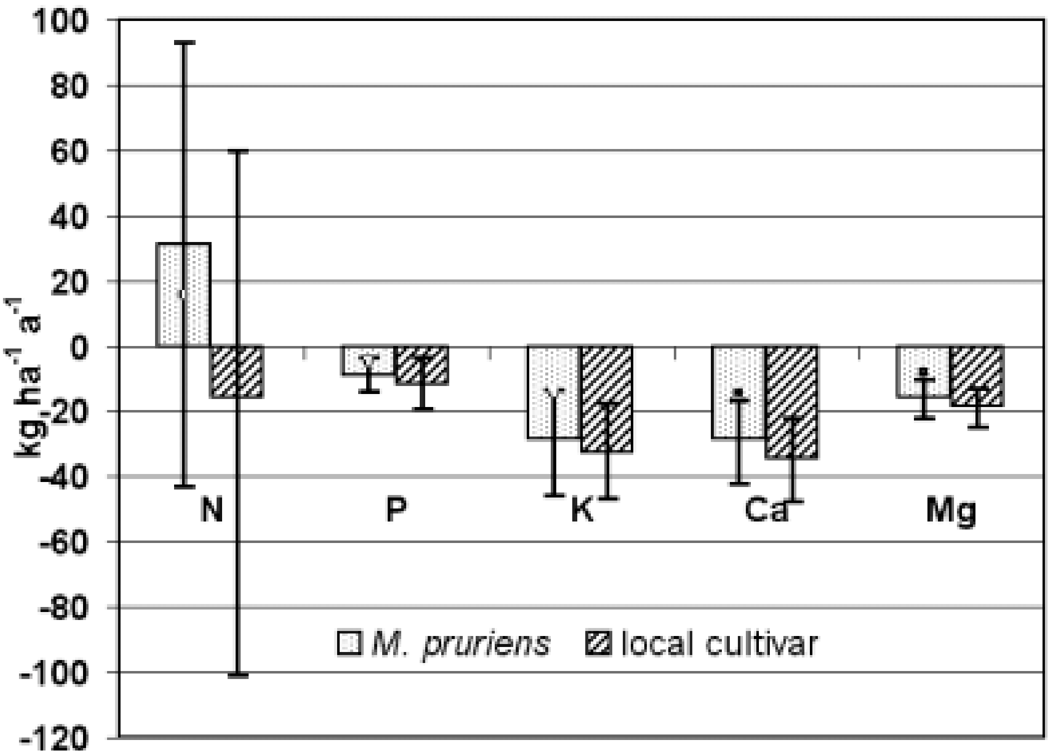

Fig. 3: Macro nutrient balance at farmers' level in *Mucuna*/maize rotations comparing two *Mucuna* cultivars (*M. pruriens*: N=11, local *Mucuna* cultivar: N=12); error bars represent optimistic and pessimistic nutrient flow scenarios.

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