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Maize yield response to *Mucuna pruriens* and *Pueraria phaseoloides* cover crop fallow and biomass burning versus mulching in farmer managed on-farm experiments

S. Hauser[a], B. Bengono[a], O.E. Bitomo[a]

a International Institute of Tropical Agriculture, Humid Forest Eco-regional Center, Mbalmayo, Cameroon. Email: s.hauser@cgiar.org

Abstract

Maize was relay cropped with the cover crops *Mucuna pruriens* or *Pueraria phaseoloides* for between 1 and 7 consecutive years in three sites, Ngoungoumou, located in an area of low land use intensity (LUI), about 100 km away from the next major market, and at Evendissi and Andok, in a medium LUI area, 15 to 20 km away from the next major market. Maize yield was compared with that in natural fallow, with fallow biomass burned versus retained as mulch.

Fallow type had no effect on maize density. Biomass burning increased maize density in the low LUI site but had no effect in the other sites. Maize cob production was neither affected by fallow type nor by biomass management. Across 7 crop years, marketable cob production in the low LUI site was 38.5% higher in mucuna fallow than in natural fallow ($p<0.06$); differences at $p< 0.05$ were found in 1 out of 7 years. In the medium LUI sites, mucuna and pueraria fallow increased marketable cob production by 70 – 132% ($p<0.001$). Maize grain yield was closely related to the marketable cob production in all sites. In the low LUI site the cumulative maize grain yield over 7 years was 30% higher in mucuna fallow than in natural fallow ($p<0.07$). As for the marketable cobs this difference was only in 1 year significant at $p<0.05$. In the other two sites maize grain yield was 65% higher in mucuna fallow ($p<0.001$) and 69-94% higher in pueraria fallow ($p<0.001$). Burning biomass had a cumulative grain yield advantage of 33% at the low LUI site ($p< 0.053$), with significant ($p<0.02$) differences in 2 out of 7 years. Biomass burning had no effects on maize grain yield in the medium LUI sites. No interactions between fallow type and biomass management were found.

Introduction

Maize is not a typical crop of the humid forest zone of West and Central Africa. However, farmers' interest in maize production is increasing because feed industries and breweries purchase dry maize grain in large quantities and the marketing of green cobs is convenient for income generation. With increasing distance to urban centres access to fertilizer becomes difficult and expensive. Farmers have problems to assess when and how much N fertilizer is required. Planted herbaceous legume fallow are known alternative systems to natural fallow and are widely used in South America. Information on the yield response of maize to herbaceous legumes in the humid forest zone of the Congo basin is rare. The potential of *Mucuna pruriens* and *Pueraria phaseoloides* has been demonstrated under humid conditions in researcher managed, on-station trials (Hauser & Nolte, 2002; Hauser et al. 2002).

Continuous crop production is unusual to farmers in the humid forest zone, as is biomass retention or mulching. In an environment in which the vast majority of farmers burn all biomass and where the wild variety *Mucuna pruriens* var. pruriens is well know for its severe skin irritating effects it was expected that this new cropping system can only be introduced by stepwise implementation of individual components. Here, *Mucuna pruriens* var. veracruz and var. utilis, which do not irritate, and *Pueraria phaseoloides* were introduced in combination with biomass burning or mulching to determine effects on maize establishment, cob production and grain yield in a relay cropping system managed by farmers.

Materials and methods

The triala were conducted in southern Cameroon on Ultisols. All sites have a bimodal rainfall pattern: first season rains start in mid March and end in mid July. August is a dry spell and second season rains start in early September to end mid November. *Chromolaena odorata* fallow of 3-5 years was slashed to establish the cover crops by broadcasting 15 seeds m^{-2} of mucuna and 12 kg ha^{-1} of pueraria. All trials were 2 by 2 factorial complete randomised block designs: first factor fallow type, *Mucuna pruriens* or *Pueraria phaseoloides* versus natural fallow and the second factor biomass burned versus biomass retained. Trials were seeded to maize (CMS 8704, open pollinating, about 100 days to maturity) at 0.5 x 0.5 m, with one exception in trial 3, every year in the first rainy season. Plots were manually weeded once during the growing period as deemed required by the farmers. Maize was harvested between 95 and 105 days after planting (DAP). Plant, cob and marketable cob density were determined. A cob sample was dried at $65^{O}C$ to determine grain yield. Mucuna and pueraria were not re-seeded rather did the plots serve as a seed source to other farmers. Neither fertilizers nor pesticides were used.

Trail 1 started in 1998 at Ngoungoumou ($12^{O}03'$ E, $3^{O}15'$ N), southern Cameroon with *Mucuna pruriens* var. veracruz, in 4 replicates of 4 plots of 6 x 6m. Maize was grown for 7 consecutive years. Trials 2 and 3 were conducted at Evendissi and Andok near Mbalmayo ($11^{O}24.6'$ E, $3^{O}26.6'$ N). Trial 2, at Evendissi, was with *Mucuna pruriens* var utilis. Plot size was 6 x 6 m. Treatments were replicated 4 times. Maize was planted for 1 year. Trial 3, at Andok, was with *Pueraria phaseoloides*, replicated 5 times, seeded in 2000, two years before the first maize crop. In 2002 the farmers planted a maize / *Phaseolus vulgaris* intercrop with maize at a density of 2 m^{-2} at 1 x 0.5 m and beans at the same distance between the maize. The beans failed and in 2003 the farmers seeded sole maize at 0.5 x 0.5 m. Plots measured 8 x 6 m. Soil samples were taken at the start of the first maize cropping cycle. Soil pH was determined in a water suspension at a 2:5 soil/water ratio. Organic C, total N, exchangeable Ca^{2+}, Mg^{2+}, K^{+} and available P were determined. Statistical analyses of plant parameters were conducted on untransformed data, percentages were analysed after 'square root' transformation using the GLM procedure (SAS, 1997) in SAS version 8. Least square means were calculated and the levels of significance of differences between means determined by pair-wise comparisons (p diff). p diff values up to 0.10 are presented to allow readers individual judgment.

Results

In none of the experiments were soil chemical properties different between fallow types and biomass management plots. Ngoungoumou had a higher soil pH, more total N and a lower C:N ratio than Evendissi and Andok. Organic C and exchangeable cations were similar in all villages. Available P was highest at the Evendissi mucuna site.

In trial 1 fallow type had no effect on plant density. Across the 7 years maize plant density was higher when biomass was burned (4.06 m^{-2}) than when mulched (3.76 m^{-2}, $p<0.088$). Cob density was neither affected by the fallow type nor by biomass management. Across the 7 years, mucuna fallow produced 38.5 % more marketable cobs m^{-2} than the bush fallow ($p<0.059$). The marketable cob production per plant was significantly higher in the mucuna system over the 7 years. The cumulative grain yield over the 7 years was 30% higher in mucuna fallow (11.36 Mg ha^{-1} versus 8.74 Mg ha^{-1}, $p< 0.072$). In 2003 the mucuna system had a significant yield advantage over the bush fallow system (Figure 1). After biomass burning a higher cumulative grain yield was attained over the 7 years than when biomass was retained (11.48 Mg ha^{-1} versus 8.62 Mg ha^{-1}, p< 0.053). In 2001 and 2004 burning had significant yield advantages over mulching (Figure 2). Across the 7 years the grain yield was strongly determined by the marketable cob density.

In trial 2 plant density was uniformly 4 m^{-2}. Biomass retention increased the marketable cob density (Table 1) but did not affect any other variable. Plant and cob density were unaffected by the fallow type. Marketable cob density and grain yield were significantly greater after mucuna fallow than after natural fallow. The grain yield was closely correlated with the marketable cob density (r^2=0.64, p<0.0001).

Table 1: Plant, cob and marketable cob density and grain yield in Mucuna versus natural regrowth and after biomass burning versus mulching at Evendissi, southern Cameroon, 2003

	Plants m^{-2}	Total cobs m^{-2}	Marketable cobs m^{-2}	Grain DM (Mg ha^{-1})
Natural	3.6	3.78	1.63	1.910
Mucuna	4.0	3.98	3.28	3.155
p diff fallow	Ns	ns	<0.001	<0.001
Burn	3.6	3.88	2.20	2.438
Mulch	4.0	3.88	2.70	2.627
p diff biomass management	ns	ns	0.003	ns

In trial 3 biomass management had no effect on any variable. Plant and cob density were unaffected by the fallow type. Marketable cob density was 0.77 and 1.4 in natural fallow versus 1.3 and 3.3 m^{-2} in pueraia in 2002 and 2003 respectively (p<0.0001 in each year) Grain yield was 1.13 and 1.16 in natural fallow versus 1.91 and 2.26 Mg ha^{-1} in pueraia in 2002 and 2003 respectively (p<0.0001 in each year). Despite the 50 % lower plant density in 2002 than 2003 the grain yield was almost the same in both years. Across fallow types, the grain yield was in both years strongly determined by the number of marketable cobs (2002 r^2=0.77, p<0.0001; 2003 r^2=0.78, p<0.0001).

During the maize growing period between 360 and 880 mm of rain fell. Across the sites and within Ngoungoumou the relationship between the amount of rain and the grain yield was not significant (r^2=0.21, p=0.25).

Discussion

The differences in grain yield response to leguminous cover crops between the villages are of particular interest. Differences in soil chemical properties and in the way the fields were managed by the farmers can partially explain the differences in grain yield. At Ngoungoumou, total N was higher and the C:N ratio was lower than at Evendissi and Andok. Ngoungoumou farmers neglected thinning and reseeding and weeded relatively late, leading to small differences between fallows. Considering that the Andok pueraria site had grain yields similarly low as those at Ngoungoumou and similar P concentrations, it appears that P, which was twice as high at the Evendissi mucuna site than in any other site was a major factor causing nearly twice as high grain yields. Burning had either no or positive effects on marketable cob density and yield. In plots weeded by farmers, maize plants were damaged through abrasions by uncontrolled movement of rigid mulch material. Farmers cannot afford the time to remove and replace mulch in order to weed without causing damages. This is particularly pronounced for mulch of natural fallows, which is largely composed of small sticks and branches.

Conclusions

Despite the lack of frequent significant advantages of the cover crop fallows in the low LUI site, the system can be recommended because it increases food diversity and biomass burning does not demand extra labour while having a cumulative advantage in maize production. In the medium to high LUI sites farmers were immediately convinced of the benefits of the system and have since moved on to grow high value vegetable crops.

References

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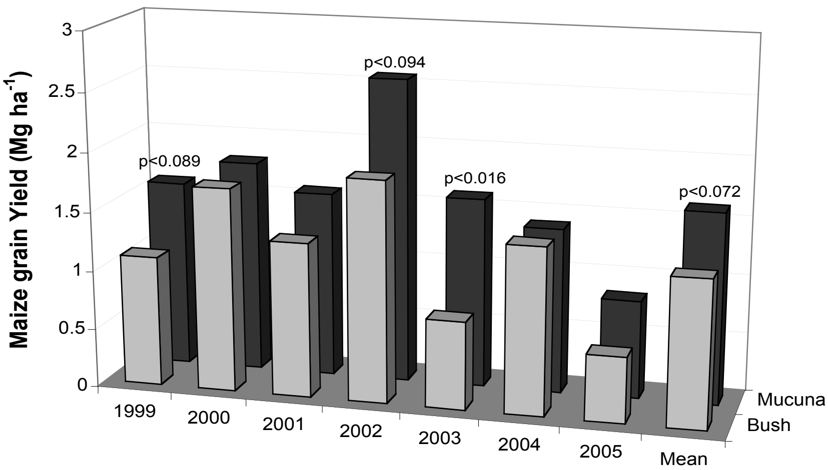

Figure 1: Maize grain yield (Mg ha^{-1}) dry matter over seven consecutive years of cropping in bush fallow versus *Mucuna pruriens* var. veracruz fallow, Ngoungoumou, southern Cameroon, 1999 to 2005. p values over columns indicate level of significance between Bush and Mucuna.

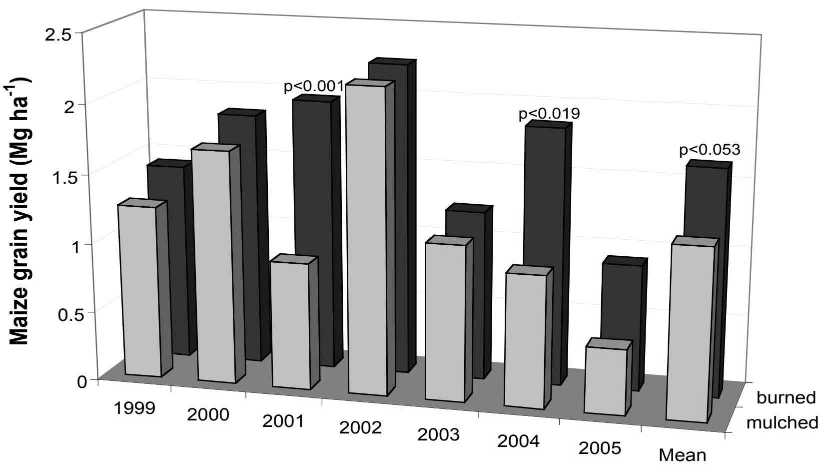

Figure 2: Maize grain yield (Mg ha^{-1}) dry matter over seven consecutive years of cropping after biomass burning versus biomass retention as mulch, Ngoungoumou, southern Cameroon, 1999 to 2005. p values over columns indicate level of significance between burned and mulched.