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Maize yield response to mulch, burning and insecticide application on an Ultisol

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Abstract

Maize is gaining importance in the humid forest zone due to its early maturity, low labor input and ease of marketing. However, farmers face problems of supplying sufficient N to high density maize sole crops. Mulches from species with high N content can overcome this problem at low capital cost, yet retaining large quantities of mulch has been shown to reduce plant density. One reason could be damage to germinating seeds by insect or other pests hiding in the mulch layer. This study evaluated the yield response of maize to mulch application versus bare soil and the consequences of insecticide application to protect seedlings. Maize was planted at 20 plants m^{-2} to determine germination rates and thinned to 6.67 m^{-2} in late May and late September. The trial was a 2 factorial design with 6 replicates; 1^{st} factor was insecticide application versus nil, 2^{nd} factor was biomass management at three levels: Mulch mixed of *Senna spectabilis* (75%), *Chromolaena odorata* (20%) and *Calliandra calothyrsus* (5%) leaves was applied at 10 Mg ha^{-1} and either retained or burned versus bare soil. Mulch application was only in the 1^{st} season. Insecticide application had no effect on germination rate: 93% and 22% in the 1^{st} and 2^{nd} season, respectively. Plant density at harvest was unaffected by insecticide and biomass management in both seasons. Cob density was highest in mulch retained followed by mulch burned. Marketable cobs were only produced when mulch was applied. On bare soil virtually no yield was attained (55 kg ha^{-1}). Grain yield was 269 kg ha^{-1} when mulch had been burned and 795 kg ha^{-1} when mulch had been retained. The difference between mulch retained and the other treatments was significant at $p<0.002$. In the second season, bare soil and previous mulched and burned produced 255 kg ha^{-1} grain, while mulch retained produced 606 kg ha^{-1} ($p<0.002$). Mulch application when burned had thus no yield effect, while a single application of retained mulch increased yield in the following 2 seasons.

Introduction

Maize is gaining importance in the humid forest zone of Central Africa as a food and a cash crop. It is mainly grown as a minor component in intercrops and due to the low plant densities it does not produce high yields (Hauser et al, 2006). Farmers are reluctant to grow sole maize crops as there is a risk of failure at establishment due to low germination rate and later in the season due to nutrient deficiencies and other unspecified reasons. The cropping system in most of the region and specifically in southern Cameroon does not comprise measures to apply nutrient sources such as mulch and even the in situ produced biomass is often discarded rather than used (Buettner and Hauser, 2003).

The simple technique of mulching nutrient rich materials which may be freely available from adjacent fallows has apparently no importance in southern Cameroon (and elsewhere). Farmers dislike biomass on the soil surface in their fields. This may have to do with their suspicion that in mulched conditions germination rates are low and that weeding is difficult as the biomass may impede the work with hand hoes. The combination of these problems attached to mulching may be the reason that virtually all fields are burned and that unburned remaining biomass is either collected for a second burn or discarded outside the field (Hauser et al, 2006; Tonye et al, 1997). However, maize has been shown to respond positively to mulching and specifically to N-rich legumes (Hauser et al, 2002; Hauser & Nolte, 2002). Planted legume fallow has not been introduced on a large scale in southern Cameroon and the few attempts made have not yielded considerable adoption (Kanmegne & Degrande, 2002; Hauser et al, 2006). There is little information from the Ultisols of Central Africa on the effects of mulching versus burning on maize establishment and yield in systems that are not planted to legumes.

This trial was established to address the concerns of farmers on biomass retention in maize cropping systems with the objectives to:
investigate the role of mulch as a habitat for seedling-damaging insects,
investigate the effects of a mulch layer and,
investigate the effects of burning the biomass.

Materials and methods

The trial was established at the research farm of the International Institute of Tropical Agriculture, Humid Forest Eco-regional Center, in the Mbalmayo Forest Reserve, Southern Cameroon (3°51' N, 11°27' E). The soil is an isohyperthermic, Typic Kandiudult. Average annual precipitation is 1513 mm with a bimodal distribution. Rains start in mid-March. From mid-July until the end of August follows a short dry season. The main rainy season lasts from September to the middle of November.

The trial was an incomplete three factorial design, laid out as a Latin square. First factor: Insecticide (Carbofuran) vs. no insecticide, second factor: 10 t/ha mulch versus no mulch (bare soil), third (incomplete) factor: mulch burned versus mulch retained, giving a total of six treatments and was six times replicated. Mulch was a mixture of 70% *Senna spectabilis*, 25% *Chromolaena odorata* and 5% *Calliandra calothyrsus*.
Maize variety CMS 8704 (approximately 100 days to maturity) was planted at 0.5 x 0.1 m and thinned to 0.5 x 0.3 m after germination rate was determined. The experiment was surrounded by a 60 cm high polyethylene sheet fence to avoid crop damage by small rodents. During seed emergence a bird scarer kept birds off the plots. In the second season maize was planted at 0.5 x 0.3 m and neither insecticide nor mulch was applied.

Germination rate was determined at 7, 9 and 11 DAP. Chlorophyll readings were taken with a Minolta SPAD® Chlorophyll meter at 14, 28 and 56 DAP. At maize harvest plants were counted, cobs removed and counted, husks removed and cobs separated by marketable and non-marketable quality. A subsample of cobs was weighed and dried to constant mass, thereafter shelled and the grain dry matter yield calculated. Straw yield was determined from a subsample of 10 plants, weighed fresh, shredded to 2 cm long pieces and dried to constant mass. Empty cobs were calculated into the straw dry matter. In the second season the same maize variety was planted, however, at final density of 0.5 x 0.3 m. Germination was not counted but all other observations on plants and the harvest were conducted as in the first season. Soil was sampled at 28 DAP in 0-5, 5-10 and 10-15 cm depth increments, air dried ground to pass a 2 mm mesh size sieve and analyzed for pH and exchangeable Ca, Mg and K, total N and organic C.

Results and discussion

No differences in soil chemical properties were found with the exception of K in the 0-5 cm layer, which was with 0.42 cmol[+]kg^{-1} significantly higher in mulch burned than on bare soil (0.25 cmol[+]kg^{-1}, $p<0.0012$) and in mulch retained (0.35 cmol[+]kg^{-1}, $p<0.033$). All other chemical properties are presented in Table 1. *Senna spectabilis* and *Chromolaena odorata* the major components of the mulch are high in K which was apparently transferred to the soil through dissolving ash. A similar increase in Ca^{2+} would have been expected, while *S. spectabilis* has usually low Mg concentrations (Hauser et al, 2005). However, previous experiments showed as well that K from burned biomass is the dominant ion found in soil and solution on this Ultisol (Hauser, 2006).

Table 1: Soil chemical properties of an Ultisol at Mbalmayo, southern Cameroon.

Depth (cm)	pH - water	Total N	Organic C	C:N	Ca	Mg	K
		------- g kg^{-1} -------			----------- cmol[+]kg^{-1} ----------		
0-5	6.6	1.69	16.98	10.1	6.06	1.65	0.343*
5-10	6.4	1.05	11.07	10.7	4.57	0.99	0.181
10-15	5.8	0.74	7.15	9.7	2.87	0.77	0.147

* Differences between treatments, see text.

Germination rate was neither significantly affected by insecticide application nor by the presence or absence of mulch. However, insecticide application increased the germination rate by less than 2 % from 92.5 to 94.1. Germination rate on filter paper was 96%. The removal of mulch had a small but stronger impact than the insecticide. The germination rate was 96.3 without mulch and 91.5 % where 10 Mg ha^{-1} of mulch were applied. Burning the mulch had no effect on germination rate. Since all germination rates were above 90 % insects can be excluded as the cause of low maize establishment. Other factors such as pests prevented from accessing this experiment (rodents and lizards) or mechanical impact of the mulch might be the primary cause. No other data on responses in germination rate of maize to insecticide or mulch could be found.

Plant density at harvest was not significantly affected by mulch, yet was lowest in the bare soil treatments. Insecticide had no effect (Table 2). The cob density was significantly different between all mulch treatments and highest in mulch retained treatment followed by mulch burned and bare soil (Table 2).

The second season planting had lower plant establishment with about 4 plants m^{-2} (target density being 6.6 m^{-2}), previous application of mulch and insecticide had no effects. Maize cob density followed a similar pattern as in the first season yet with less pronounced differences between treatments (Table 2).

Marketable cobs were only produced when mulch was applied, with no difference between mulch burned (Table 3) and bare soil which produced both significantly fewer marketable cobs than mulch retained. In the second season, the marketable cob density was as high as in the first season when mulch had been retained and higher than in the first season in mulch burned and bare soil, however, between mulch treatments no significant differences were found in the second season (Table 3).

Maize grain yield was generally low due to late planting in the first season. When mulch was retained a four times higher grain yield was attained (Table 3) than when mulch was burned. On bare soil the maize produced 56 kg ha^{-1} of grain, just about the amount seeded. Second season maize grain yield had a similar pattern as marketable cobs yet the yield advantage of mulch retained was significant (Table 3). In mulch burned and bare soil plots grain yield were equally high and higher than in the first season.

Table 2: Plant and cob density at harvest in the first and second rainy season at Mbalmayo, southern Cameroon.

	Plants at harvest (m^{-2})		Cobs (m^{-2})	
	1. season	2. season	1. season	2. season
Mulch retained	6.02	4.20	3.67	2.59
Mulch burned	5.96	3.92	2.28	2.10
Bare soil	5.49	4.01	0.56	1.57
p diff				
Bare vs retained	ns	ns	<0.0001	0.0053
Bare vs burned	ns	ns	0.0005	ns
Retained vs burned	ns	ns	0.0038	ns

The recommended density for the variety CMS 8704 is around 7 plants m^{-2}. However, no specific data on this varieties response to plant density is available and thus there is a possibility that under constrained conditions, which are likely to be prevalent in southern Cameroon, the variety is capable to yield better at lower densities as shown in yield differences in mulch free plots between first season (higher plant density) and second season (lower plant density).

Table 3: Marketable cob density and grain yield (dry matter) in the first and second rainy season at Mbalmayo, southern Cameroon.

	Marketable cobs (m^{-2})		Grain yield (Mg ha^{-1})	
	1. season	2. season	1. season	2. season
Mulch retained	0.74	0.71	0.795	0.825
Mulch burned	0.03	0.31	0.269	0.343
Bare soil	0.00	0.37	0.056	0.267
p diff				
Bare vs retained	0.0019	ns	<0.0001	<0.0001
Bare vs burned	ns	ns	ns	ns
Retained vs burned	0.0027	ns	0.0017	0.0004

Straw yield in the first season had a similar pattern to grain yield, yet all mulch treatments were significantly different from each other, with around 6 Mg ha^{-1} when mulch was retained when mulch was burned and 3.5 Mg ha^{-1} on bare soil (Table 4). Straw yields were lower in the second than in the first season when mulch was applied, with significantly more straw produced when the mulch was retained than when it was burned or on bare soil (Table 4).

Accordingly the harvest index was higher in the mulch applied treatments (Table 4) than on bare soil. Generally harvest indices were very low, probably due to the late planting, yet this was apparently aggravated in the bare soil plots. Second season harvest indices were higher than in the first season but still very low compared to those obtained in other studies.

Table 4: Straw yield (dry matter) and harvest indices of maize in the first and second rainy season at Mbalmayo, southern Cameroon.

	Straw yield (Mg ha^{-1})		Harvest index (%)	
	1. season	2. season	1. season	2. season
Mulch retained	6.233	3.552	10.6	17.0
Mulch burned	3.028	2.170	7.7	12.5
Bare soil	1.589	1.669	2.8	13.3
p diff				
Bare vs retained	<0.0001	<0.0001	0.0002	ns
Bare vs burned	0.0164	ns	0.0105	ns
Retained vs burned	<0.0001	0.0007	ns	ns

Grain yields were relatively low, compared to other maize experiments using the same variety, yet, being planted earlier than the current trial. The extremely low harvest indices in the first season indicate that the low yield level was mainly caused by delayed planting.

The large differences in yield between mulch retained and mulch burned indicate that cation and P supply may not be a critical factor, as these element should be supplied at he same or even a higher rate after burning. How far the mulch can actually supply N remains questionable, yet Norgrove et al (2000) showed that decomposition rates of *C. odorata* are rather high and that N is released quickly. *Senna spectabilis*, contains about 3.5% N and mass loss is 40-50% within 50 days (Hauser et al, 2005). Thus at 10 Mg ha^{-1} of mulch with around 3.5 to 4% N decomposing at the rate of *Senna spectabilis*, would supply about 20 kg ha^{-1} of N in the first half of the growing cycle of the maize, which is approximately the amount required to produce 1 Mg ha^{-1} (Hauser and Nolte 2002). The delayed planting would have caused a low transfer to grain and thus yields lower than 1 Mg ha^{-1}. N supply from bare soils is unknown for southern Cameroonian conditions.

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