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The effect of post - harvest crop cover on soil erosion in a maize-legume based cropping system in Gatanga, Kenya

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Keywords: Cover crop, soil erosion, maize, Kenya

Abstract

The study was conducted on farmers' fields in Gatanga Division, Thika District of central Kenya with the aim of assessing the effect of selected legume cover crops on soil erosion especially at the onset of the rain season when the soil is bare and of this on erosion - induced nutrient losses. The four systems tested consisted of the following: pure stand of maize (*Zea mays*) (T1), maize intercropped with *Mucuna pruriens* (T2), maize plus *Vicia benghalensis* (T3), and maize plus *Lablab purpureus* (T4). Measurements taken included runoff, soil loss, percent crop cover and analysis of nutrients in the original soil and eroded sediments.

Cumulative soil loss recorded during 1999 long rain season ranged from 58.64 to 61.7 t ha^{-1}. At the onset of the 1999 short rain season, soil loss was significantly different between treatments (P"0.05). This was attributed to post-harvest crop cover provided by the legume cover crops grown from the previous season. The highest (3.3 t ha^{-1}) and the lowest (0.35 t ha^{-1}) soil losses were recorded from T1 and T2 respectively. There were significant differences (P"0.05) in percent cover between treatments. The average percent cover taken at the onset of the 1999 short rain was 0, 43.2, 9.0 and 11.4% for T1, T2, T3 and T4 respectively.

Nutrients in sediments were compared with the original soil and the enrichment ratio (ratio of nutrients in eroded sediment to that of the original soil) for major nutrients (i.e. organic C, total N, available P, Ca and K) was greater than 1. The soil material lost from the plots was on average 262% richer in P than the original soil. The pH of the eroded sediments was slightly higher than that of the original soil. Soil management practices that improve the levels of soil organic matter; nitrogen and phosphorus should be encouraged for sustained productivity of these soils.

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1 Introduction

In Central Kenya highlands, accelerated soil erosion is caused mainly by intensive agricultural activities. Rapidly growing population has led to decreasing farm sizes. Small-scale farmers in Kenya have identified soil erosion as a constraint to crop production (MoALD and M, 1996; TIFFEN *et al.*, 1996). As agricultural activities are spread on steep slopes, the effects of soil erosion are being felt especially where no effective conservation measures are being undertaken (MBOYA *et al.*, 1999; GACHENE *et al.*, 1997). The conventional agricultural practices leave the soil bare during the onset of the rains resulting in severe soil erosion and nutrient losses (ZOBISCH *et al.*, 1994; KIRONCHI and MBUVI, 1996; GACHENE and HARU, 1997). The problem is exacerbated by poor management of the farms due to the limitations in financial resources (THOMAS, 2000; MAINA, 2000). Erosion changes soil properties, removes nutrients and reduces crop yields (BELAY, 1992; GACHENE, 1995; MUKUI, 1991).

A wide range of improved soil conservation practices in Kenya have been suggested for minimizing and controlling soil erosion (MOGES and THOMAS, 1992; GACHENE and HARU 1997; MUTUNGA, 1995; NJUGUNA, 1994). Most of the smallhold farmers in Kenya have generally been slow to adopt physical soil conservation measures because of the high labour requirement for construction, the apparent wastage of land and the lack of a substantial improvement in yields (MAINA, 2000). Where incentives have been used, results have often been disappointing because the work done has not been well maintained after the withdrawal of incentives (KINOTI and GACHENE, 1999). Attention should, therefore, be paid to soil conservation practices which will require less labour and have other advantages such as the addition of soil organic matter to the soil, prevention of crust formation and the general improvement of the soil structure.

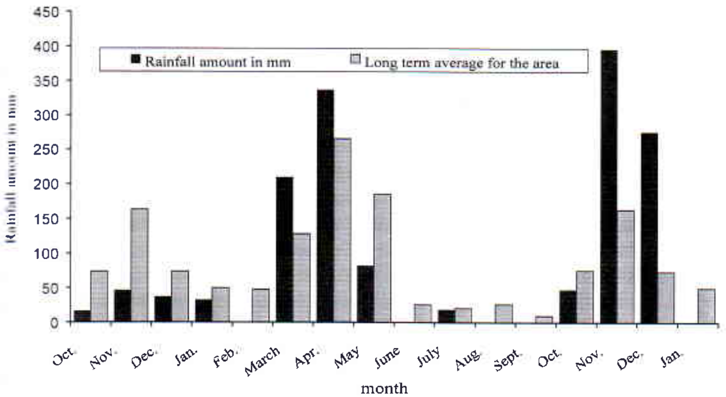
Biological soil conservation measures, such as legume cover crops, are more effective and less costly in controlling soil erosion than physical measures (THOMAS, 2000). In addition to providing nitrogen and organic matter to the soil, legume cover crops (LCC) shade the soil for longer time in a year, a factor, which is extremely important in tropical climates for soil preservation (FLORES, 1990; LATHWELL, 1990; THURSTON, 1997). LCC can be used as a soil conservation measure during the off-season when the ground is bare and vulnerable to water erosion (GACHENE and HARU, 1997). This study therefore addressed the use of selected LCC as intercrops with Zea mays for erosion control, particularly at the onset of the rainy seasons when the ground is normally unprotected and most of the nutrients are lost due to erosion.

2 Materials and Method

The study was conducted in Gatanga Division, Thika District of central Kenya. The area is within ACZ III (SOMBROEK *et al.*., 1980) and is representative, in terms of soils and climate of large areas of central Kenya highlands. The area experiences a bimodal rainfall distribution. The long rains (LR) begin in late March and decreases in frequency towards the end of May and early June. The short rains (SR) occur from mid-October through December and generally are not as reliable as those in the long rain season. The mean annual rainfall for the study area is 1100 mm.

Figure 1 shows the monthly distribution of rainfall received in the area during the experimental period and the long-term average. The rainfall for the 1998 short rain was 132 mm which was from a total of 10 rainy days (defined as the number of days when rainfall was >1 mm, a limit set by the East African Meteorological Department).
The rainfall was below the 20-year average (314 mm) with 35% of the total rainfall falling in the month of November. The rains were low and poorly distributed and did not generate any runoff. The rains in this began on 15th October and fell only twice during the month. Due to soil moisture stress there was total crop failure. The objective of establishing crop cover during the season, which was to provide post-harvest cover during the onset of the following season (i.e. 1999 LR season), was therefore not realized. This necessitated a repeat of establishing LCC during the 1999 LR.

Figure 1: Rainfall distribution during the experimental period (1998 SR - 1999 SR)



The 1999 LR began on 14th March 1999 and the total rainfall for the season was 648mm with 38 rainy days. During this season, the rainfall was close to the 20-year average (655mm) with 81% of the total falling in the first three weeks of the season. Most of the erosive rains in central Kenya highlands fall in the first few weeks after the onset of the rain when the ground is bare and prone to severe soil erosion (GACHENE and HARU, 1997).

Although the rainfall received in this season was 99% of the 20-year average, the distribution was poor. At the beginning of the season, the rains were heavy, but tapered towards mid-April. Of the 38 rainy days that were experienced in the season, 25 generated runoff. By 10th April, 3 weeks after the start of the rain season, 94% of the total soil loss had been recorded within which period there was hardly any ground cover.

Fifty two percent of the total rainfall fell during the month of April. From mid-May to September there was only one rainfall event that generated runoff.

The 1999 SR total rainfall was 720 mm with 47 rainy days. This was 229% of the 20-year average (314 mm). Of the 47 rainy days, 33 events generated erosion. The rainfall during this season began on 26th of October and mainly were concentrated in the month of November, which accounted for 51% of the total.
The altitude for Gatanga ranges from 1400 to 1900 m above sea level and is characterized by undulating to rolling topography with slopes ranging from 6% to 40%. The dominant soils are classified as nitisols based on the FAO - UNESCO system (FAO, 1990). They are well drained, deep, dark-red to dark reddish brown, friable clay. These soils are low in N and P with an average pH of 4.7.

Most of the farms are 0.5 to 1.5 hectares in size and are largely utilized for growing both subsistence and cash crops, mainly maize, beans, potatoes, bananas, avocadoes, tea and coffee. The commonly used soil conservation measures in the area include cutoff drains, level bench terraces, grass strips (common in coffee plantations), strip planting, some agro-forestry and sisal plants grown on very steep slopes for gully reclamation. During a preliminary visit to the farms, it was observed that most of the soil and water conservation structures have been destroyed or modified by the farmers. Due to the steepness of the topography, lack of tanks for roof water harvesting and lack of effective soil conservation measures, the area is currently experiencing very high rates of erosion.

The study was initiated in the short rains of 1998 and conducted on farmers' fields. Workshops involving farmers and researchers were held to select legumes and train the farmers on monitoring erosion and data collection. The selected farmers had been involved in an earlier project involving the use of several legume cover crops for soil fertility improvement and were therefore familiar with most of the legumes suggested for erosion study (MUREITHI *et al.*, 1998). The four systems tested in 1998 SR consisted of the following: T1: pure stand of maize (*Zea mays*); T2: maize plus *Mucuna pruriens* (mucuna); T3: maize plus *Vicia benghalensis* (vetch) and T4: maize plus *Lablab purpureus* (dolichos). The above treatments were repeated in the subsequent seasons. The LCC were planted two weeks after planting maize in order to minimize nutrient and moisture competition with maize (GACHENE et al., 2000).

Maize variety H513 was planted at a spacing of 30 by 75 cm and DAP (18:46:0) was applied at planting at the rate of 200 kg ha^{-1}. The LCC were planted between the maize rows at a spacing of 25 by 75 cm for mucuna and dolichos, while vetch was drilled between the rows at the rate of 45 kg ha^{-1}. The legumes were planted with TSP at the rate of 30 kg P ha^{-1}. At the end of the season, the LCC were left growing in the field after harvesting maize. These legumes were cut and left as surface mulch just before the onset of the following rain season. Agronomic aspects such as time of planting and weeding were carried out according to the prevailing local conditions.

In the absence of an automatic rain gauge, rainfall was measured using non-recording rain gauges that were placed in each farm. Rainfall data was recorded every 24 hours and this was taken as one rainfall event. Field observations on the growth of the crop were made noting differences between plots. Weekly measurements of ground cover (for both maize and LCC) were made using the string method as outlined by LAFLEN *et al.* (1981).

Soil loss was measured using 2 m wide and 4 m long runoff plots which were installed adjacent to each other on a single catenal position. Metal borders made from strips of 28 gauge plain galvanized iron sheets surrounded the runoff plots. The strips were buried at least 15 cm below the ground surface and projecting 15 cm above ground. Runoff was collected in a collecting trough and channeled to a 100 litre-tank through a 4" PVC pipe. An end plate and collecting trough made of heavy-gauged sheets of metal were used to block off the plot ends. For all rainfall events that produced runoff, soil loss measurements and sampling were carried out for each plot following the methods as outlined by LINIGER (1991). Soil loss occurring from each plot was collected every 24 hours.

3 Results and Discussion

3.1 Crop cover

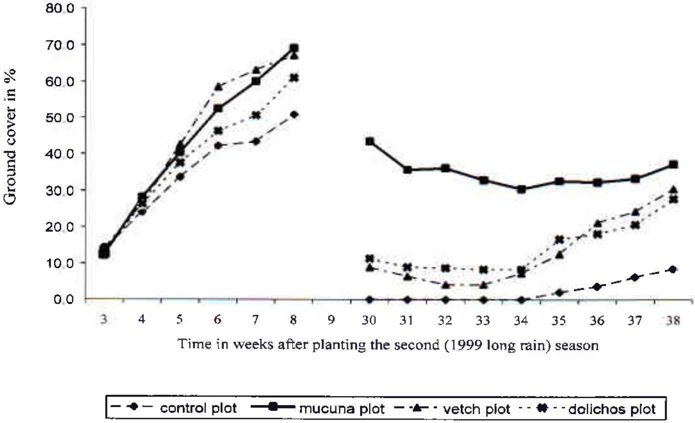
The expected post-harvest cover for the 1999 LR season was not attained due to crop failure experienced during the previous season, i.e 1998 SR. Average percent crop cover for the various treatments are shown in Table 1. At the end of the 1999 LR season, the maximum percentage crop cover attained was 60.0, 69.2, 67.3, and 61.1% for T1, T2, T3, and T4 respectively. Although there was a delay in the establishment of mucuna (Fig. 2), it eventually provided more cover over time than vetch and dolichos. Mucuna produced the highest average dry matter biomass (3 t ha^{-1}) than purple vetch (1.4 t ha^{-1}) and dolichos lablab (1.9 t ha^{-1}) during their growth period.

Table 1: Percent crop cover and cumulative soil loss (t ha^{-1}) during the experimental period

		Treatment				
Season	Parameter	T1	T2	T3	T4	LSD(0.05)
1998 SR	% crop cover	0	0	0	0	
	soil loss (t ha^{-1})	0	0	0	0	
1999 LR	% crop cover	59.9 ^{a}	69.18 ^{c}	67.27 ^{c}	61.08 ^{a}	4.18
	soil loss (t ha^{-1})	61.7 ^{a}	58.64 ^{a}	61.56 ^{a}	61.19 ^{a}	3.16
1999 SR after 2 weeks of onset	% crop cover	0	43.2 ^{a}	9.0 ^{b}	11.4 ^{b}	23.06
	soil loss (t ha^{-1})	3.3 ^{a}	0.35 ^{b}	1.83 ^{ab}	1.32 ^{ab}	2.39
1999 SR at the end of the season	% crop cover	8.4 ^{b}	37.1 ^{ab}	30.6 ^{ab}	27.8 ^{a}	20.84
	soil loss (t ha^{-1})	18.68 ^{a}	12.24 ^{a}	20.31 ^{a}	17.97 ^{a}	14.52

Means followed by the same letters across the row are not significantly different at 5% level;
T1: maize; T2: maize + mucuna; T3: maize + vetch; T4: maize + dolichos

Figure 2: Percent ground cover measured during the experimental period (1999 LR - 1999 SR)



Crop cover measurement taken from the T4 plots was relatively low compared with T2 and T3 plots. *Lablab purpureus* seemed to have been adversely affected by the cold weather that prevailed during the 1999 LR season, such that it constantly suffered from blights in its early stages of growth. This caused poor establishment of dolichos resulting in low crop cover. Vetch established cover as fast as mucuna when there was adequate soil moisture.

The maize crop for the 1999 LR was harvested at the end of the rainy season thus leaving the maize plot bare while the rest of the intercropped plots were left with LCC. Most of the farmers' fields are left bare after crop harvest (as in T1) and are thus left vulnerable to water erosion, especially during the subsequent season when crops have not developed enough ground cover. It is a common practice in many parts of Kenya to feed crop residues to animals immediately after harvesting the crops.

Plots previously planted with legumes provided some cover to the soil (almost 7 months after planting the 1999 LR crop, Fig. 2). Thus during the onset of the 1999 SR, the effect of post-harvest cover on soil erosion in T2, T3, and T4 plots was assessed. At the beginning of the 1999 SR season, the post-harvest percent cover was 0, 43.2, 9.0, and 11.4% for T1, T2, T3, and T4 respectively (Table 1). There were significant differences (P"0.05) in post-harvest percent cover between the treatments with T2 having the highest cover as compared to T3 and T4. The control (Fig. 2) was at this time bare. The post-harvest percent cover in T3 and T4 plots was not significantly different (P"0.05) from each other. The low post-harvest percentage cover observed in T3 and T4 plots as compared to T2, was because mucuna (T2) appeared to be a better drought resistant legume as compared to vetch (T3) and dolichos (T4). Vetch tended to have very high leaf fall especially when it was water stressed, while pests heavily affected the dolichos. Dolichos also appeared to suffer adversely from water stress.

The percent cover started decreasing from 30th to 34th week after planting the crop of the 1999 LR) and then started increasing again obviously due to cover provided by the growth of the 1999 SR crop. The maximum average percent cover attained during the 1999 SR was 53.7, 75.9, 64.8 and 57.4 for T1, T2, T3 and T4 plots respectively. In summary, the data in Table 1 show that treatments T2, T3, and T4 were able to provide post-harvest cover for a period of 8 weeks after harvesting the 1999 LR maize crop. This post-harvest cover was crucial as it was expected to affect the runoff and soil loss during the on-set of the 1999 SR.

3.2 Soil loss

One of the main objectives of this study was to investigate the effect of LCC on soil loss before the onset of the subsequent season. The 1998 SR were below average and no erosion was recorded during this season. During the 1999 LR, the rainfall was high and the cumulative soil loss ranged from 58.64 to 61.7 t ha^{-1} (Table 1). The soil loss recorded during the 1999 LR period was 61.7, 58.64, 61.56, and 61.19 t ha^{-1} for T1, T2, T3 and T4 respectively. Early in the season, there were large amounts of runoff and soil loss from all the plots. Most of the runoff-generating rainfall fell when the maize and legume seedlings were still too small and offered little or no protection to the soil. The first 11 days accounted for 81% of the average cumulative soil loss. The period within which this soil loss occurred was during the first two weeks of the season when normally crop cover is absent on most farmers' fields. From the onset of the 1999 LR season, the rains were received in high frequencies resulting in the formation of rills inside the runoff plots as well as in most of the surrounding farms. On March 29th, April 1st, 3rd, 7th and 9th, an average of 8 t ha^{-1} of soil loss was recorded daily from each plot. By the end of April, an average of 94% of the total soil loss had been collected. An unprotected soil is very vulnerable to erosion and the soil losses from such plots are normally higher than from plots having some degree of ground cover (MATI, 1992; MUTUNGA, 1995; KIRONCHI and MBUVI, 1996).

There was no significant difference in soil loss during the 1999 LR between treatment (P'0.05) (Table 1). This was because most of the erosive events occurred in the first 4 weeks of the season when crop cover was still very low. In Nigeria, LAL (1976) reported that significantly soil erosion was associated with only a few extremely intense storms, which occur at the beginning of the season. However, T2 recorded lower amount of soil loss than the other three treatments (Table 1) indicating that maize-mucuna intercrop has great potential of controlling soil erosion as compared to the other two legume-maize intercrops and maize alone. Cumulative soil losses recorded from the different treatments during the 1999 LR were not significant as there was no post-harvest cover at the onset of the rains.

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There was no significant difference in soil loss during the 1999 LR between treatment ($P < 0.05$) (Table 1). This was because most of the erosive events occurred in the first 4 weeks of the season when crop cover was still very low. In Nigeria, LAL (1976) reported that significantly soil erosion was associated with only a few extremely intense storms, which occur at the beginning of the season. However, T2 recorded lower amount of soil loss than the other three treatments (Table 1) indicating that maize-mucuna intercrop has great potential of controlling soil erosion as compared to the other two legume-maize intercrops and maize alone. Cumulative soil losses recorded from the different treatments during the 1999 LR were not significant as there was no post-harvest cover at the onset of the rains.

The average cumulative soil loss during the first 2 weeks of the 1999 SR (which occurred between 26th October and 11th November) was significantly different (P"0.05) between treatments, with T2 recording the lowest losses (0.35 t ha^{-1}) and the control having the highest (3.3 t ha^{-1}) (Table 1). The effect of post-harvest cover in controlling soil loss during the on-set of the rains when the ground is usually left bare is therefore, clearly demonstrated by this data. Soil losses from T3 and T4 plots were not significantly different from each other although the losses were lower than from T1 and higher than T2 plots. During this time, the pure stand of maize had up to 9, 2, and 2.5 times more soil loss than plots planted with maize + mucuna, maize + vetch and maize + dolichos respectively. Dolichos and vetch were thus not effective in controlling soil erosion.
The cumulative soil loss at the end of the 1999 SR season is shown in Table 1. There were no significant difference in soil loss (P"0.05) between the treatments during the season. As indicated above, most of the rains in this season fell in the month of November when there was hardly any cover. However, the plot planted with maize-mucuna intercrop was still superior in controlling soil loss than the other legume intercrops used in this study. Effective soil erosion control should, therefore, ensure that the field is protected throughout the year (BAUM *et al.*, 1990).

Comparing the results of the 1999 LR and SR seasons, the LR had more soil loss than the SR season though the amount of rainfall received was nearly the same. This could have been because the plots were not tilled prio to the onset of the 1999 SR unlike in 1999 LR when the plots were tilled leaving the soil loose and thus making it easily eroded. Tilling the plots during the 1999 SR was not necessary as there were no weeds in the plots. This brings another advantage of using legume cover crops, namely, weed suppression. Secondly, and more important, was that during the onset of the 1999 SR, there was post - harvest cover provided by the 1999 LR LCC which reduced soil loss as compared to the LR season when the soil surface was initially bare.
Although the tolerable soil loss value for the Kenyan nitisols is not known, these results indicate that the losses recorded during the experiment were much higher than the 12 t ha^{-1} yr^{-1} which is commonly used in the U.S.A. as the tolerable soil loss (MOGES and THOMAS, 1992). Though nitisols are considered to be less erodible when compared with other soil types in Kenya (GACHENE, 1986), it is clear that very high losses can occur if the soil is left bare. The maintenance of terraces and proper crop and soil management practices (such as the use of legume cover crops) are certainly required to further decrease soil loss.

3.3 Effect of erosion on soil chemical properties

The soil properties at 0-15 cm depth for each plot before the 1999 LR season are shown in Table 2. After the 1999 LR, the chemical composition of eroded sediments was compared with that of the original soil. The enrichment ratio, ER (ratio of nutrient element in eroded soil material to that of the original or 'field soil') was greater than 1 for all the major soil elements determined i.e. %OC, available P, %TN and K. This indicates that soil erosion resulted in the selective removal of nutrients thus lowering the fertility of these soils. There was no significant difference (P"0.05) in ER between treatments.

Table 2: Soil chemical Properties of the original soil (0-15cm) and eroded sediments

		Treatment			
Soil property		T1	T2	T3	T4
pH-H2O (1:2.5)	Original soil	4.70	4.70	4.72	4.76
	Sediment	4.80	4.74	4.76	4.78
	Change	+0.1	+0.04	+0.04	+0.02
% OC	Original soil	2.09	2.11	2.19	2.06
	Sediment	2.48	2.45	2.34	2.42
	ER	1.19	1.16	1.07	1.17
% TN	Original soil	0.18	0.19	0.19	0.19
	Sediment	0.21	0.21	0.22	0.22
	ER	1.17	1.11	1.16	1.16
P ppm	Original soil	6.70	7.20	6.30	6.80
	Sediment	21.20	29.90	20.70	26.60
	ER	3.16	4.15	3.29	3.91
K meq/100g.	Original soil	0.39	0.48	0.45	0.41
	Sediment	0.58	0.56	0.59	0.56
	ER	1.49	1.17	1.31	1.37

The sediments had relatively higher pH than that of the original soil (Table 2). In Kenya, rainfall simulation studies conducted by GACHENE (1986) indicated that there were higher concentrations of nutrient elements especially bases (such as Ca, Mg, and K) in the eroded sediment resulting in higher pH values of the eroded sediment. The ER was particularly high for P (Table 2) indicating that phosphorus, which is normally applied to the soil as a fertilizer, is not only utilized by the crop but a substantial amount is lost by erosion. The soil material lost from the plots was on average 262% richer in P than the original soil. GACHENE *et al.* (1997a) reported ER values for P as high as 10 and the sediment being as high as 700% richer in P than in the original soil from on-station studies conducted at Kabete, Kenya. Continued depletion of this nutrient through erosion will thus warrant heavier applications of phosphate fertilizers to meet crop requirement of P. Although ER for organic C, total N and K were not as large, continued loss of these elements is important because this will adversely affect other soil physical and chemical properties. Continued losses of these elements from the soil through erosion have been shown to reduce the productivity of these soils (GACHENE, 1995).

4 Conclusions and Recommendations

For any significant differences in soil loss, the cover crops need to be well established as to provide post-harvest crop cover during the subsequent season. In this study, soil loss was significantly reduced in plots previously planted with LCC due to the post-harvest cover provided by the legumes. The type of legume used as a cover crop, therefore, is important because they differ in their ability to establish a cover canopy and thus control soil erosion. In this study, N and P were the most affected by erosion and management practices should therefore address the application of these elements.

In addition to controlling erosion, LCC have other additional advantages such as suppressing weed and improving soil fertility. LCC can increase plant nutrient supply in the soil thereby improving crop yields. Some studies (e.g. GILLER *et al.*, 1997; PEOPLES *et al.*, 1995) have shown that incorporating herbaceous N - fixing legume cover crops into crop production systems has an important role in the maintenance and improvement of soil fertility. In LCC/cereal intercropped systems, there are increases (+20% up to +100%) in grain yields in comparison to the continuous maize crop (GILLER *et al.*, 1997). It is therefore important that further on-farm studies should be carried out in order to harness their full potential for increased agricultural production in smallhold farming systems.

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