Journal of Soil Science and Environmental Management Vol. 2(10), pp. 311-317, 25 October, 2011
Available online at http://www.academicjournals.org/JSSEM
ISSN 2141-2391 ©2011 Academic Journals

Full Length Research Paper

Effect of *Sesbania sesban* fallows on *Striga* infestation and maize yield in Tabora Region of Western Tanzania

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Accepted 5 October, 2011

The One of the major constraints to maize production in most farmers' fields in Tabora region are is nitrogen deficiency and *Striga* infestation. Trials to investigate the effect of *Sesbania sesban* improved fallows on Striga infestation and maize yield were conducted on farmer's fields in Tabora and Nzega districts for a period of three years (2003 - 2005). Results showed that application of *S. sesban* green manure after a two year fallow led to a reduction of *Striga* infestation from 10.8 counts/8 m^2 of unfertized plots to 0.8 counts/8 m^2 of *S. sesban* plots as well as increase maize yield from 418 kg ha^{-1} in the unfertilized plots to 1366 kg ha^{-1} for the *S. sesban* plots. The *S. sesban* fallow reduced *Striga* incidences by 88 percent after incorporation of the leafy biomass into plots in the third year of the trial. The study on the effect of the fallows on reduction of *Striga* incidences has clearly demonstrated that application of S*esbania* manure can reduce *Striga* infestation on sandy soils of Tabora.

Key words: Maize, *Sesbania sesban*, *Striga* incidence, Tabora.

INTRODUCTION

Maize is the most important staple cereal crop in Tabora region. One of the major constraints to maize (*Zea mays* L.) production in most of the farmers' fields is declined soil fertility and *Striga* infestation. *Striga* is endemic in African savannas and can cause serious devastation in maize production especially on farms of resource poor farmers (Abayo et al., 1997). Even under relatively good crop management conditions, about 79% reduction in crop yield has been reported in susceptible hybrid maize (Kureh et al., 2000). Most local maize cultivars are known to be susceptible to the parasitic weed. The value of total annual crop loss due to *Striga* in Africa has been estimated at 7 to 13 billion US dollars in cereal crops per annum (Khan et al., 2000). Hence, *Striga* spp. affect the livelihood of 300 million people in Africa with 17 countries seriously affected, and another 25 moderately affected (Ramson, 1996).

The most economically important *Striga* species infesting food crops in Africa are *Striga hermonthica* (Del.) Benth; *Striga asiatica* (L.) Kuntze, and *Striga gesnerioides* (Willd.). Among the three dominant species, *S. hermonthica* causes the greatest damage to cereal crops (Snuerborn, 1991). The detrimental effects of this weed is well known to farmers who associate the increasingly wide spread infestation with declining soil fertility. This is also in agreement with research findings from trials in Malawi and other locations in Africa (Ngwira and Nhlane, 1996).

Traditional African cropping systems which have included prolonged fallow, rotation and inter cropping, were common management practices that were used in the past to improve soil fertility and keep the infestation of *Striga* spp. at tolerable levels (Kureh et al., 2000). However, increasing human population has resulted into intensive land use and shifting away from traditional cropping systems, which in turn has resulted in the depletion of soil fertility and increased *Striga* infestation (Kwesiga et al., 1999).

Studies at Tumbi Research Institute in Tabora, Tanzania and Southern Africa have shown that *Sesbania sesban* improved fallows can increase maize yield substantially and give similar or even high returns than

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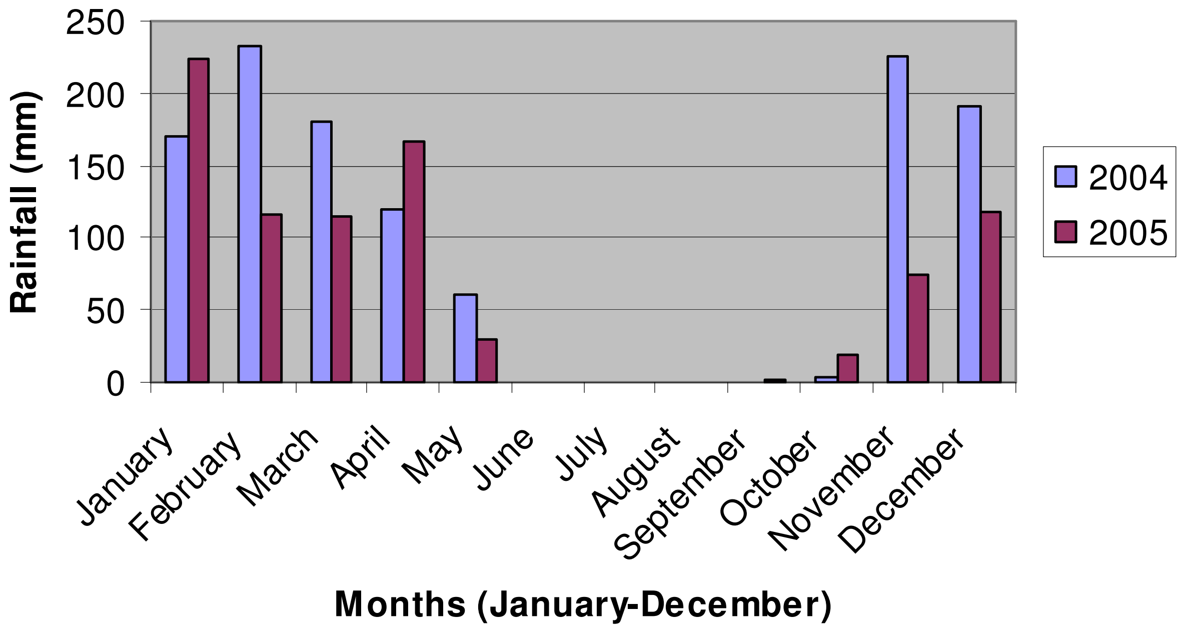

Figure 1. Rainfall distribution pattern at Tumbi Tabora.

chemical fertilizers. The nitrogen (N) fixing tree legumes can replenish soil fertility within the shortest possible time (Sjogren et al., 2010), although tree legumes differ in their effects on soil N availability (Barios et al., 1997) and yield of subsequent maize crops (Kwesiga et al., 1999).

Intercropping of maize with *S. sesban* has been reported to increase the efficiency of land use through improved productivity and reduction of *S. hermonthica* soil seed bank. For example, Kwesiga and Beniest (1998) found out that *Striga* densities were reduced when maize was intercropped with *S. sesban*. *S. sesban* controls *Striga* by stimulating suicidal germination of the *Striga* seeds, (the seeds germinates but then the seedlings does not find a host maize plant to attach to so it dies), and increases soil fertility, making plants more resistant to attack. There has been some evidence of increased adoption of fast – growing, nitrogen fixing, multipurpose trees in tropical countries for land restoration and fallow improvement (Kwesiga and Beniest, 1998). The objective of this study was to investigate the effect of *S. sesban* improved fallows on *Striga* incidences, soil fertility improvement and maize yield.

MATERIALS AND METHODS

The study was conducted in Tabora region which has a uni-modal type of rainfall with an average of 880 mm y^{-1} which mostly falls between November and May (Figure 1). It is located between 4 and 7°S of the equator and between 31 and 34°E of the Greenwich line. It is situated at about 1300 m above sea level, with an average temperature of 23.8°C. Soils are mostly sandy loams which are classified as Ferric Acrisol according to FAO soil classification. The trial was carried out in Tabora and Nzega districts from 2002/2003 to 2004/2005 seasons. Trials were established in eight farmers' fields each in Tabora and Nzega districts. The trial was carried out at Magiri and Kigwa villages in Tabora district and Isanzu, Shila and Mhembe villages in Nzega district. Selection of farmers was done on the basis of their willingness to participate after Participatory Rural Appraisals (PRAs) which were undertaken in the villages in 2000/2001 where soil fertility low and *Striga* infestation were identified as major constraints to maize production.

The experiment was laid out on farmers' fields in three plots each measuring 10 × 10 m: a *S. sesban*, fertilized maize and a control maize plot with no fertilizer and no trees. *S. sesban* seedlings were raised in the nursery for 45 days and transplanted in the field at a spacing of 1 × 1 m on one-meter wide ridges.

On another plot, maize variety Kilima was planted at a spacing of 30 cm between plants on 1 m ridges, giving a plant population of 13,332. Two maize seeds were planted per hill and later thinned to one at 2 weeks after planting. Nitrogen (N), Phosphorus (P) and Potassium (K) were applied at the rate of 100 kg N/ha, 40 kg P_2O_5/ha and 40 kg K_2O/ha in the form of NPK. NPK was applied before planting and urea was top dressed one month after planting. Stalk borers were controlled by application of Thiodan dust 4%. Tree growth parameters including root collar diameter and height were measured to estimate plant vigor, and survival was recorded at 12 and 18 months after planting.

Striga infestation was estimated by counting all *Striga* plants in an area of 8 m^2 within each plot at 63 days (9 weeks) after planting. This measurement was taken on a unit area basis because it was not possible to accurately determine *Striga* infection on an individual maize plant. However, because weeds were judiciously controlled prior to *Striga* emergence, it was assumed that *Striga* was attached to no other hosts than maize.

Maize was harvested when the crop was mature and dry. Plants in the net plot were cut and separated into stover (leaf + stem) and cob (grain + rachis). Grain yields were computed in tones per hectare, based on 80% shelling percentage and 150% g kg^{-1} grain moisture. The weights of cobs and stover were recorded separately. A sample of 10 cobs was taken for dry matter determination. This was done by drying the sample in the oven at 70°C to constant weight. Grain yield was recorded on oven dry weight basis after separating the grains from the rachis. Stover was weighed and a sample taken for dry matter determination and stover yield recorded on oven dry weight basis.

Soil samples were collected in 2002/2003 before the start of the trial, from each plot at 0 to 15 cm and 15 to 30 cm depths at the beginning of the season for soil chemical analysis (that is, pH, organic carbon and total phosphorus). At the beginning of the third season (2004/2005) and before the rain season, the trees were cut and separated into their wood, leaf, and twigs components. A sample of these components was taken, weighed, and oven dried for dry matter determination. The remaining woody biomass was collected by farmers for domestic fuel and the leaf and twig component incorporated into the ridges before maize was sown in all plots and before the onset of rains.

All data were analyzed using Genstat 5, developed by laws Agricultural Trust (Rothamstead Experiment station) in United Kingdom to compare treatment means. Before analysis, raw data for *Striga* count were transformed to the square root to reduce the coefficient of variation often associated with the heterogeneity of *Striga* distribution in the field.

Farmers' assessment of the technology was carried out by conducting interviews with farmers after 3 years of the trial. Information on farmer opinions and perceptions on improved fallows, particularly their effect in controlling *Striga* infestations was gathered using questionnaires through focus group discussions. Data obtained was organized in EXCEL and analyzed using the SPSS statistical program.

RESULTS

Tree growth

There was marked variation in tree growth across sites. In Nzega, *S. sesban* performed better at Shila than Isanzu and Mhembe village in terms of height which ranged from 180.8 to 317.4 cm. Differences in performance of *S. sesban* at different locations were noted in the trial. These were probably due to variations in soil type and management of the fallows. Farmers in Shila village managed their fallows better than Isanzu and Mhembe by proper weeding in the first season leading to better establishment and growth of the trees there than the rest of the villages. In addition, soils at Shila were sandy loam to clay loam but those of Isanzu and Mhembe were very sandy. *S. sesban* is known to do well in relatively deep soils of medium texture and not very sandy soils (Kwesiga and Beniest, 1998). This was also noted in studies on *Sesbania* both on-station and on-farm in Tabora rural district (Gama et al., 2004). Tree survival was variable between sites; it ranges from 81.3 to 100% and 25.5 to 98.9% after 3 and 15 months of growth respectively. Poor survival for *S. sesban* at Shila and Isanzu after 15 months of growth, could be lower rainfall (Figure 1) and probably due to poor management.

Soil analysis results

Soil analysis results (Table 1 and 2) show that the soils at the sites were acidic (pH- 4.7 to 6.0), poor in total nitrogen (0.03 to 0.05), and low in organic carbon (0.24 to0.49%). The soils were sandy with a high sand content (80 to 89%) but low clay contents (9 to 16%) and silt (2 to 4%). Soils at these sites are typical of soils in Tabora district which are poor in nutrients retention, low in water holding apacity and high infiltration rates.

Striga incidence

Striga emergence was significantly affected by the application of inorganic fertilizer; the application of fertilizer N increased the mean *Striga* emergence on maize plots in the third season as compared to second season (Table 4). Furthermore, Table 4 shows that application of fertilizer decreased *Striga* incidences within seasons plots compared to the unfertilized. Application of inorganic plots fertilizer increased *Striga* infestation in the first season compared to the second one. Ramson and Odhiambo (1995) suggested that, under depleted soils conditions, fertilizers may stimulate *Striga* infestation probably by increasing the biomass of host roots thereby encouraging more parasite seeds to germinate. In addition the increase in *Striga* emergence observed in this study may be related to be more extensive maize root system which increased the root surface area and thus stimulated emergence of the parasite. However, *Striga* incidence was higher in the unfertilized treatment plots on the third season compared to first and second seasons (Table 3).

Maize yield

Maize yields at five sites (two in Tabora and three in Nzega districts) for 2002, 2003 and 2004 are presented in Table 4. There were significant ($P<0.05$) differences in maize yield between fertilized and non fertilized (control) plots for season one and two. Maize grain yields ranged from 418 (control) to 1199 kg ha^{-1} with plots fertilized at the rate of 100 kgN ha^{-1}, indicating that there was an increase in grain yield with recommended level of fertilizer across *Striga* infected farmers' fields in Nzega and Tabora districts. Between the treatments, fertilizer application significantly improved maize grain yield as compared to the control during the first and second seasons. Application of this inorganic source of nitrogen probably enhanced soil fertility and hence the higher yield compared to the control. Esilaba et al. (2000) reported that the application of nitrogenous fertilizer, provided that other nutrients are not limiting, increases grain yield of the host crop under *Striga* pressure.

Farmers' assessment

The majority of farmers in both Tabora and Nzega districts had the opinion that improved fallows increase yields, control *Striga* infestations on maize and also increase household incomes. About 32% of farmers in

Table 1. Growth (after 18 months) and survival of *Sesbania sesban* in Tabora and Nzega districts.

District	Village	Plant height (cm)	Root collar diameter (mm)	Survival (%) (months)	
				3	15
Tabora	Kigwa	228.8	35.4	100	51.0
	Magiri	320.9	42.9	99.5	98.9
Nzega	Isanzu	180.8	13.7	96.5	25.5
	Shila	317.4	35.9	81.3	38.6
	Mhembe	188.7	19.5	88.5	62.0

Table 2. Soil properties at five trials before fertilizer and *Sesbania sesban* biomass application 2004/2005.

Site no.	Location	pH (1:2.5 H_20)	Organic carbon (%)	Total N (%)	Particle size (%)		
					Sand	Silt	Clay
1	Kigwa	5.7	0.44	0.03	84	3	13
2	Magiri	4.7	0.29	0.02	87	4	9
3	Isanzu	4.7	0.24	0.02	89	2	9
4	Shila	6.0	0.49	0.05	80	4	16
5	Mhembe	0.25	0.25	0.02	87	4	9

Table 3. Effects of *Sesbania sesban* and mineral fertilizer and *Striga* incidence in experimental plot (*Striga* count / 8 m^2).

Treatment	2002/2003	2003/2004	2004/2005	Mean
Fertilized	3.12	2.64	4.5	3.42
Unfertilized	4.98	4.98	10.9	6.95
Sesbania sesban	*	*	0.8	0.8
LSD (P<0.05)	0.89	0.87	0.86	
CV (%)	12.4	13.0	12.7	

Mean *Striga* counts taken from a net plot 8-m^2 and transformed to square root; **Sesbania* fallow.

Table 4. Effect of *Sesbania sesban* and inorganic fertilizer on maize yield across *Striga* infested farmers' fields in Tabora district 2002/2003 to 2004/2005 seasons.

Treatment	Grain yield (kg/ha)			
	2002/2003	2003/2004	2004/2005	Mean
Fertilized	1085	1273	1239	1199
Unfertilized	461	435	358	418
*Sesbania sesban***	*	*	1366	1366
LSD (P<0.05)	287.6	241.6	163.1	
CV (%)	21.2	16.1	12.4	

**Sesbania* fallow; ** Sesbania biomass incorporated = 3.29 t/ha.

Kigwa village in Tabora district and 33% in Isanzu village in Nzega district said improved fallows increased maize yield (Table 5). In the case of *Striga* control, about 34% of respondents in Kigwa village and 36% in Isanzu village said *Sesbania* improved fallows controlled *Striga* infestations in maize fields. About 25% of respondents in each of the villages mentioned that they obtained more maize yields after using improved fallows than when they were growing maize without any fertilizer. As a result of this, they said their incomes also increased.

Table 5. Number and percent of respondents in Kigwa and Isanzu villages mentioning the benefits of improved fallows.

Village	Different benefits of *Sesbania* fallows				
	Increase yield	Control Striga	Increased household income	Do not know	Total
Kigwa	19 (32.2)	20 (33.9)	15 (25.4)	5 (8.5)	59 (100)
Isanzu	18(32.6)	20 (36.4)	14 (25.5)	3(5.5)	55 (100)
Total	37 (32.5)	40 (35.1)	29 (25.4)	8(7.0)	114 (00)

Number in parenthesis denotes percent within village of respondents.

DISCUSSION

Striga incidences

S. sesban fallow reduced *Striga* incidences considerably from 10.8 counts/8 m^2 of unfertized plots to 0.8 counts/8 m^2 of *S. sesban* plots (Table 4). In the third year after cutting and incorporating the leafy biomass into plots, there was the highest reduction of about 88% in *Striga* infestation as compared to fertilized and unfertilized plots. These results are in agreement with the results reported by Ransom (1996) who found that *Striga* infestation declined with application of organic matter. Other research has shown that when N fertilizer and organic matter were applied in combination, *Striga* emergence declined over three year period in the field studies carried out in Kenya (Gacheru et al., 2001).

Incorporation of organic matter could allow for reasonable rate of organic matter decomposition in the soil which has shown to decrease *Striga* seed bank in the soil. This was probably due to increase in the biological activity of the soil which enhances the natural demise of *Striga* seeds (Mbwaga et al., 2000). Nitrogen fixing legumes like cowpeas and Soyabean reduce *Striga* seed populations in the soil and increase cereal yields (Mbwaga et al., 2000). *S. sesban* being a legume behaved in a similar manner and reduced *Striga*, and at the same time, improved maize yield and most probably due to its high nitrogen content (2.2 to 3.0% DM) in the leaf + stem< 5 mm diameter component (Karachi and Matata, 2000). However, earlier results show that *Sesbania* is a promising species, producing 30 to 60 kg N ha^{-1} from 2 to 3 t ha^{-1} high quality leaf biomass plus fuel wood (Kanyama-Phiri and Snapp, 1997). Therefore, reduction of *Striga* incidences was probably due to the applied green manure, which resulted in an increase in soil fertility. However, reducing *Striga* infestation using fertilizer N is a slow process that requires long-term soil management strategies (Esilaba, 2000). Farina et al. (1985) conducted long-term fertilizer trials using nitrate source and found that N significantly reduced the incidence of *S. hermonthica (*Del*)* Benth.

Further, plots with *Sesbania* were observed to have relatively low weed growth particularly in the third season of *Sesbania* growth when the tree canopy completely covered the plot. *S. sesban* probably reduced *Striga* populations in the same manner and hence the low *Striga* incidence in *Sesbania* plots in the third season incurporated. Comparatively, *S. sesban* fallow reduced *Striga* considerably by 88% after incorporation of the leafy biomass in the third year. Mbwaga et al. (2000) reported that soil cover by legumes creates unfavorable conditions of optimum temperature and water for *Striga* germination thereby reducing production of *Striga* seeds. A study conducted in East and Central Africa has shown that application of mineral fertilizers or organic matter reduces *Striga* infestation (Esilaba and Ramsom, 1997).

Several other studies in Southern Africa have further confirmed that fertilizer trees including *S. sesban* reduce *Striga* incidences hence leading to higher crop production. For example, researchers in Zambia (Sileshi et al., 2006) found out that the highest predicted probability of witch weed occurrence (0.80) was in monoculture maize continuously cropped without fertilizer whereas the lowest ($P<0.10$) was in maize grown in *Senna siamea*, *S. sesban* and *Leucaena leucocephala* fallows. They further observed that the predicted *Striga* abundance was up to five-fold lower in maize grown after *S. sesban* and *S. siamea* fallows than in continuously cropped monoculture maize grown with or without fertilization. This is in agreement with our findings where *Striga* counts were lowest in *Sesbania* fallow plots when compared to fertilize and no fertilizer plots.

Several methods of *Striga* control are available which include manual, chemical, and biological use of hybrid varieties and also organic and inorganic sources of nitrogen to improve soil fertility. However, farmers in Tanzania, due to socio-economic reasons including unaffordable prices of inorganic fertilizers and hybrid seed, are not adopting these methods. Sikwese et al. (2003) reported fertilizer trees including *S. sesban and Tephrosia vogelii* control *Striga* by acting as catch or trap crops or by improving the soil fertility thereby strengthening the host maize crop to fight ill effects of *Striga*. Researcher from the Lake Victoria area of Kenya (Amadalo et al*.,* 2003) reported that improved fallows can control *Striga*. *S. sesban*, *Crotalaria grahamiana* and *Desmodium distortum* though stimulate the germination of *Striga* seeds in the soil, germinated seeds soon die because the fallow species are not their natural hosts. This reduces the number of *Striga* seeds in the soil, and consequently cereal crops planted after the fallow period are much less severely damaged. They observed that the number of *Striga* seeds germinating after 8-month fallows of these species were considerably fewer than in fields that had been under continuous cropping or natural fallow. The reports cited above give an explanation why there was a lower incidence of *Striga* in *Sesbania* fallow plots in the present study.

Maize yield

The application of *S. sesban* leafy biomass at 3.29 t ha^{-1} and fertilizer application at 100 kg N ha^{-1} significantly ($p<0.05$) increased maize grain yield when compared to the control from 358 unfertilized (control), 1239 (fertilized) to 1366 kg ha^{-1} (*S. sesban*) in the third season. Application of *S. sesban* biomass at the rate 3.29 t/ha significantly increased maize yield during the third season (2004/2005). Application of inorganic fertilizer significantly increased yields from 418 kg/ha (control) to 1199 kg/ha (fertilized) in the third season (2004/2005). The application of *S. sesban* biomass enhanced soil fertility (that is, soil fertility and increased crop yields). These results confirm that organic matter application from *S. sesban* improved soil fertility and increased grain yields compared to chemical fertilized and unfertilized plots in low fertility soils, as in the current study. Several other studies have also shown the potential of *S. sesban* fallows in increasing soil fertility. Kwesiga and Coe (1994) found out that improved *S. sesban* fallows of 1 to 3 years increased maize yield even without addition of inorganic fertilizers. Other reports (Amadalo et al., 2003; Gama et al., 2004, Jama et al., 2006, Akinnifesi et al., 2009) have also shown that fertilizer trees and shrubs including *S. sesban* have great potential in increasing crop production particularly maize and can substitute expensive inorganic fertilizer and increase household incomes and food security. Soils at most trial sites were sandy in texture, low in organic matter and available nitrogen and therefore application of mineral fertilizer and *S. sesban* organic matter provided substantial amounts of nitrogen, which increased maize yield.

Farmers' assessment

Farmers indicated their interest in *S. sesban* as a fallow species and were willing to expand their fields after realizing the benefits in terms of maize yield increase. Based on opinions of farmers, *Sesbania* improved fallows have a great potential in Tabora region where farmers cannot afford expensive inorganic fertilizers. Sikwesi et al. (2003) has reported testimonies by farmers in Malawi where incidences of *Striga* in maize field were reduced substantially after a two year *Sesbania* fallow. There is therefore a need to scale up this technology to reach many farmers in Tanzania with similar agro-ecological conditions. The survey in Malawi also showed that farmers had different preferences of tree species for controlling *Striga*. It is therefore important that several other fallow species should be tested and disseminated to farmers for soil fertility improvement and *Striga* control.

Conclusions

Results in this study have confirmed earlier findings that *S. sesban* has the potential to improve soil fertility and maize production in Tabora. The study on the effect of this tree on reduction of *Striga* incidences has clearly demonstrated that application of S*esbania* manure can reduce *Striga* infestation on sandy soils of Tabora. Nitrogen inputs in both organic and inorganic sources are required for the long-term maintenance of maize production. Improving the N status of the soil will also help suppressing *Striga*.

ACKNOWLEDGEMENT

The study was funded by grant from the Ministry of Agriculture and Food Security, Tanzania. The authors wish to thank the Ministry of Agriculture and Food Security for making this study possible.

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