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GREEN MANURE AND INORGANIC FERTILISER AS MANAGEMENT STRATEGIES FOR WITCHWEED AND UPLAND RICE

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ABSTRACT

Weed infestation, especially the Witchweed (*Striga asiatica)* is a serious problem in fertility-depleted soils of Tanzania. The use of urea fertiliser is known to control weed but resource-poor farmers cannot afford this technology due to high costs involved. To alleviate the problem of *Striga* and soil fertility, green-manure applications could be an alternative strategy. Ths study was conducted to (a) evaluate the potential of green manure against *Striga,* and (b) determine the potential of inducing *Striga* suicidal germination by selected green manures. For the first part of the study, treatments included three green manure species, *Crotolaria ochlroleuca* G. (sunhemp), *Mimosa invisa* L.(Colla) and *Cassia obtusifolia* L.(Sicklepod) superimposed with three fertiliser rates 0, 25 and 50 kg N ha^{-1}. The treatments were laid out in a randomised complete block design (RCBD). In the second study part, the 3 green manure species were evaluated for their potential to stimulate *Striga* seed germination in the laboratory and the field. Results showed that green manure applications significantly reduce *Striga* infestation, resulting in significant rice yield increases. Green manure exhibited potential to induce suicidal germination of *Striga*. Based on these findings, green manure applications should be promoted especially among smallholder resource-poor farmers as a strategy for control of *Striga* infestation in rice fields. Additionally, crop rotation using rice and *C. ochlroleuca* is the best option since it reduces *Striga* infestation and increases yield of rice.

Key Words: *Oryza sativa*, soil fertility, *Striga*,Tanzania

RÉSUMÉ

Désherber l'infestation surtout de witchweed *(Striga asiatica)* est un problème sérieux dans les sols de fertilité réduite de Tanzanien. L'usage de l'urée est connu pour contrôler les mauvaises herbes mais les agriculteurs avec les ressources pauvres ne peuvent pas se permettre ces technologies en raison des hauts coûts impliqués. Pour alléger le problème de de *Striga*, les applications de fumier vert pourraient être une stratégie alternative. Cette étude a été dirigée pour (a) évaluer le potentiel de fumier vert contre *Striga*, et (b) déterminer le potentiel d'induire la germination suicidaire de *Striga* pour des fumiers verts choisis. Pour la première partie de l'étude, les traitements ont inclus trois espèces de fumier verte, *Crotolaria ochlroleuca* G. (Sunhemp), le *Mimosa invisa* L. (Colla) et *Cassia obtusifolia* L. (Sicklepod) a superposé avec trois taux d'engrais 0, 25 et 50 kg N ha^{-1}. Les traitements ont été faits dans une conception des blocs complètement aléatoire (RCBD). Dans la deuxième partie d'étude, la 3 espèce de fumier verte a été évaluée pour son potentiel de stimuler la germination de semence de *Striga* dans le laboratoire et le champ. Les résultats ont montré que l'application de fumier vert réduit significativement l'infestation de *Striga*, avec comme résultat des augmentations de rendement de riz significatives. Le fumier vert a exposé le potentiel pour induire la germination suicidaire de *Striga*. A la lumière de ces résultats l'application de fumier vert devrait être surtout promues parmi le petit exploitant agriculteurs pauvre comme une stratégie de contrôle d'infestation de *Striga* dans les champs de riz. En plus, la rotation de récolte utilisant du riz et *C. ochlroleuca* est la meilleure option puisque il réduit l'infestation de *Striga* et augmente le rendement de riz.

Mots Clés: *Oryza sativa*, fertilité du sol, *Striga*, Tanzanie

INTRODUCTION

Efforts of small-scale farmers to feed an ever-increasing population have resulted into continuous cultivation of the land and change of farming practices like abandoning crop rotation, intercropping and fallowing (Buresh and Giller, 1997). This situation has caused poor balance of plant nutrients in the soils and depletion of plant nutrients (Smalling, 1993) with estimated negative nutrient balances approaching 20 – 60 kg N ha^{-1} and 5 – 15 kg P ha^{-1} annually for land under continuous cultivation. In order to alleviate this situation, soil fertility could be improved by addition of nutrients and change of farming practices by re-introducing fallow and crop rotation. Farmers are aware of soil fertility depletion but they rarely use inorganic fertilisers as an effective short-term solution because of poor fertiliser availability, high costs and low profits realised from their use (Lameck *et al.*, 2003).

In this regard, green manures can potentially enhance soil fertility and subsequently control *Striga* which is particularly devastating on infertile soils. It is also probable that the green manures can induce suicidal germination of the witchweed. However, the role of green manures in the control of *Striga* in rice ecosystems are yet to be explored. The objective of this study was to evaluate the use of *Crotolaria ochroleuca*, *Cassia obtusifolia* and *Mimosa invisa* green manures in the control of *S. asiatica* in upland rice and improve yield of rice.

MATERIALS AND METHODS

The experiment was conducted in Kyela district in the Southern Highlands of Tanzania, along Lake Malawi. The district lies between longitudes 30^0 40' and 30^0 00' East and Latitudes 9^0 25' and 9^0 40' South, with an altitude of 400-500 metres above sea level (masl). Kyela experiences monomodal rainfall pattern amounting to 1,000 – 2,600 mm per year, with a growing season starting from November to June. The soils are Alluvial fine sands and clay loams (Mussei *et al.*, 1999), whereas Chromic Gleysols dominate the upland rice soils (National Soil Services, 1993).

Composite soil samples were collected from the 0-20cm depth before setting the experiment, samples were analysed for physical and chemical properties as follows: Soil pH (1:2.5) soil: water (McLean, 1982); nitrogen by micro-Kjedahl digestion method (Bremner and Mulvanay, 1982); organic carbon by wet digestion method Walkley and Black according to Nelson and Sommers (1982). Available P was extracted by Bray and Kurtz-1 method and determined spectrophotometrically according to procedure of Murphy and Reley (1962). Cation exchange capacity was determined by neutral ammonium acetate saturation method as described by National Soil Services (1987). The amount of exchangeable bases in the NH_4OAC extract was determined using atomic absorption spectrophotometer according to Thomas (1982).

Soil particle analysis was carried out by the hydrometer method (Gee and Bauder, 1986). Diethylene triamine pantaacetic acid (DTPA) was used to extract micronutrients and determined by atomic absorption spectrophotometre (Lindsay and Norvell, 1978).

Two sites located in Kilasilo and Itope villages were chosen for the experiment. Kilasilo was selected for having been under continuous cultivation for 5 years, while Itope was under fallow for 3 years. Prior to setting up the experiment, weeds in the experimental sites were identified with the help of a field guide (Johnson, 1997). Supa India rice variety was used in this experiment because, it is planted by about 95% of farmers in the upland rice ecosystem and it is highly susceptible to *Striga* attack.

Green manures species used in this experiment were *C. ochroleuca* (sunhemp) *M. invisa* (Colla) and *C. obtusifolia* (Sickle pod). The colla and sickle pod are locally available and are regarded as weeds in upland rice (Johnson, 1997).

Separate experiments were conducted to evaluate the potential of green manure to control *Striga* through improved soil fertility and to determine the potential of green manure to induce suicidal germination of *Striga* seed in the soil.

Potential of green manure for *Striga* control. The experiment was conducted using 3 green manure species namely, *C. ochroleuca*, *C.*

obtusifolia and *M. invisa* planted in separate plots of 6 m x 5 m with a seeding rate of 25 kg ha^{-1}. The green manure species were left to grow to flowering stage before plowing into the soil. Then rice *(Oryza sativa)* was planted in the same plots. Before planting rice, each plot was divided into 3 sub-plots of 2 m x 5 m. The sub-plots were partitioned by a polythene sheet of 5 m x 0.3 m, of which 0.25 m was placed under the soil to prevent roots and fertiliser from crossing to adjacent plots. Then rice was sown in each plot at 0.2 m x 0.2 m spacing. In the 5^{th} week after germination of the rice, 3 rates of urea fertiliser (F1= 0 kg N ha^{-1}, F2= 25 kg N ha^{-1} and F3= 50 kg N ha^{-1}) were applied to the sub plots. The trial was laid out in randomised complete block design with 3 replications.

Within the 2 m x 5 m sub-plot comprising of 10 rows of rice plants 1 row of rice was excluded from either sides of the sub-plot as border rows leaving 8 rows in the net area of 4.6 m x 1.6 m for data collection.

Determination of the potential of green-manure to stimulate *Striga* seed germination. Seeds of green manure *C. ochroleuca* were collected from Agricultural Research Institute-Uyole, while those of *M. invisa* and *C. obtusifolia* were collected from fallow rice fields in Kyela. *Striga asiatica* seeds were collected from infested rice fields in Kyela. Collection was done according to procedure described by IITA (1997). Floral heads of the fully mature *Striga* plants were harvested, collected in paper bags and taken to a drying area. At the drying area, paper bags with *Striga* floral heads were hanged in a ventilated room and were left in the paper bags for 4 months to ensure effective air-drying. After 4 months, floral heads were tapped gently on a polythene sheet to shed seeds after which the floral heads were burnt to minimise the risk of dispersing remained *Striga* seeds. After threshing, seeds were sieved through mesh sizes 250, 150, 100, 90 microns to remove plant trash. *Striga* seeds were surface-sterilised in 1% (w/v) NaOCl solution for 5 minutes and rinsed using distilled water. Then seeds were air-dried at room temperature (20 to 22 ^{0}C) and stored at room temperature in bottles. In order to allow elapse of their dormancy period, *Striga* seeds were kept for more than 6 months before use. The potential of green manure to stimulate *Striga* seed germination was assessed in the laboratory and field.

In the laboratory, a completely randomised design replicated three times was used to test the treatments. There were 6 treatments, namely root exudates from (1) *C. ochroleuca*, (2) *M. invisa*, (3) *C. obtusifolia*, (4) *Zea mays* (Staha variety-highly susceptible to *S. asiatica*), (5) Ethephone 50 ppm as a standard germination stimulant and (6) distilled water. The root exudates were extracted from roots of the green manure species and maize growing in separate pots containing fine sand. After 3 weeks, whole plants were uprooted and washed to remove sand attached to the roots.

Distilled water was used to rinse the roots. Twenty clean plants were suspended in bottles containing 100 ml of distilled water in such a manner that the roots were submerged in water whereas the shoot remained above the water level for 24 hours. After removal of plants, the water from the bottles was used as germination stimulants based on applicable standard procedures (Souerborn, 1991; IITA , 1997; Kroschel, 2001).

Striga seeds were conditioned for 14 days at 30 ^{0}C, but before conditioning all filter papers and petri-dishes were sterilised under dry condition at 150 ^{0}C for 2 hours. Conditioning was done by putting *Striga* seeds on filter paper discs made by a cork borer. These discs were placed on another filter paper fit into the size of the petri-dish and 2 ml of distilled water was added to keep the seeds moist. Each petri-dish was covered with a lid. The covered petri-dishes were carefully wrapped in parafilm to prevent moisture loss; and then wrapped in aluminium foil to exclude light. The covered petri-dishes were placed in an incubator maintained at 30 ^{0}C for 2 weeks. After the conditioning period, the petri-dishes were removed from the incubator, opened up and the moisture inside dried up by using bloating papers. The seeds were left to air-dry. *Striga* seeds in the petri-dishes were supplied with 2 ml germination stimulants in each petri-dish and returned to the incubator. The second incubation was done for 24 hours at 33 ^{0}C. After incubation, the petri-dishes were removed for counting of germinated *Striga* seed under microscope (X 40 magnification).

For the field study, *Striga* seeds were put in small nylon cloth bags (Eplee bags), each 3 cm x 3 cm, with an opening on one end. At the open end a manila string was fitted to close the bag by tying before burying them in the soil and for pulling when retrieving the bags from the soil. Four Eplee bags containing about 200 seeds each were buried to a depth of 20 cm in plots planted with *C. ochroleuca, M. invisa* and *C. obtusifolia.* A control plot was included in the RCBD used with 3 replications. The Eplee bags were placed close to the green manure plants to ensure that roots reach them.

The Eplee bags stayed in the soil for 4 weeks, then they were retrieved from the soil and cleaned with water to remove soil and other unwanted materials. Seeds from each Eplee bag were taken out carefully for observation under the dissecting microscope (X 40 magnification). *Striga* seeds in Eplee bags from green manure species and the control plots were counted separately and the percentage germination determined.

Data collection and analysis. Five plants picked randomly in the net area, each time, were used to determine number of tillers per plant, number of panicles per plant, panicle length per plant, plant height and grain yield (per plot) adjusted to 14% moisture content. Other collected data were *Striga* count, *Striga* plant height, *Striga* seed production (number of capsules per plant), the number of weeds other than *Striga* and their dry weight. For both laboratory and field studies, number of germinated *Striga* seeds were counted and expressed in percentage.

The collected data were analysed used SAS statistical package (SAS/STAT, 1988). Data for weed counts were transformed before analysis. Transformation for *Striga* count data was done by using the square root of (x + 0.5); other weeds were transformed by square root (Gomez and Gomez, 1984). After analysis, treatment means were separated by Tukey's Test at P=0.05 level of significant. In the presentation of the results, the original means were used.

Economic analysis was also done to assess the viability of the green manure technology. The analysis was done using cost:benefit ratio as described by CIMMYT (1988), then obtained ratios were subjected to analysis of variance.

RESULTS

The physico-chemical properties of soils at both study sites were as presented in Table 1. The soils were sandy clay and among the weed species, broadleaf weeds were the most dominant in terms of coverage. The results on the effect of green manure on weed other than *Striga* are presented in Table 2. Grass weeds counts, broadleaf weed counts, total weed count and total weed dry weight decreased significantly in plots planted with green manure in both sites. *Mimosa invisa* and *Cassia obtusifolia* had significantly more grasses in both sites than *C. ochroleuca. Crotalaria ochroleuca* and *Mimosa invsa* had significantly fewer weed total count compared to *C. obtusifolia* in Kilasilo and Itope, respectively. The potential of green manure to suppress weeds was in the order *C. ochroleuca* >*M. invisa* > *C. obtusifolia.*

The results of growth and yield of rice are presented in Table 3. Green manure significantly increased rice plant height, number of tillers, number of panicles per plant and grain yield increased in plots planted in both sites. The yield varied significantly with the green manure species. In both sites, rice plots planted with *C. ochroleuca* had significantly higher yield than other green manure.

Table 4 shows that, in both sites, control plots had significant high ($P \leq 0.05$) number of *Striga* in 10 m^2 in the 6^t and 12 week. The number of *Striga* shoots, *Striga* plant height, and number of capsules per plant in both sites decreased with the application of inorganic nitrogen fertiliser and green manure. In the sixth week, the number of *Striga* shoots was significantly high in the control without inorganic fertiliser than for any other treatment. Nitrogen application at 25 kg N ha^{-1} and 50 kg N ha^{-1} also reduced *Striga* numbers in both sites except Kilasilo in the 12^{th} week. The number of capsules per plant and plant height were also reduced at 50 kg N ha^{-1}. All combination of green manure and inorganic nitrogen fertiliser inhibited *Striga* germination completely.

TABLE 1. Some physico-chemical properties of experimental soils in Tanzania

Parameter	Site	
	Kilasilo	Itope
pH (H_2O)	5.21	4.56
OC (%)	1.80	2.45
Total N (%)	0.16	0.21
Available P (mg kg^{-1})	5.20	9.10
CEC cmol(+) kg^{-1}	16.90	21.80
BS (%)	26	25
Exchangable cations		
Ca }	1.3	2.2
Mg }	0.54	0.78
K } (cmol(+) kg^{-1})	1.7	1.6
Na }	0.79	0.89
Ca:Mg }	2.41	2.82
	Trace	Trace
Exch. (cmol(+) kg^{-1})		
Zn (mg kg^{-1})	1.26	1.17
Cu (mg kg^{-1})	0.13	0.17
Mn (mg kg^{-1})	162.47	80.04
Fe (mg kg^{-1})	29.56	27.72
	Sandy clay	Sandy clay

TABLE 2. The effect of green manure on weed density in Tanzania

Treatments	Kilasilo				Itope			
	Number of weeds per m^{-2}				Number of weeds per m^{-2}			
	Grasses	Broad leaf	Total count	Total dry weight (gm)	Grasses	Broad leaf	Total count	Total dry weight (gm)
Control	43 a	37 a	80 a	120 a	18 a	34 a	52 a	126 a
C. ochroleuca	13 d	12 b	25 d	24 d	13 b	10 d	23 d	29 d
M. invisa	18 c	12 b	30 c	47 c	18 a	15 c	33 c	51 c
C. obtusifolia	21 b	12 b	33 b	57 b	18 a	21 b	40 b	66 b
SE	0.36	0.39	0.31	0.27	0.30	0.21	0.16	0.21
CV (%)	13.20	16.64	8.26	6.35	12.78	8.47	4.68	6.62

Means in the same column for each site followed by a common letter are not significantly different from each other according to Tukey's Test ($P \geq 0.05$)

TABLE 3. The effect of green manure on growth and yield of rice in Tanzania

Treatment	Kilasilo					Itope				
	Plant height (cm)	Tillers /plant	Panicles /plant	Panicle length (cm)	Grain yield kg ha^{-1})	Plant height (cm)	Tillers /plant	Panicle / plant	Panicle length (cm)	Grain yield (kg ha^{-1})
Control	85.0b	8.5c	8.4b	18.7b	1335d	90.0c	8.1b	7.1b	18.4c	1238d
C. ochroleuca	91.1a	9.1a	8.8a	19.3a	2846a	98.7a	9.1a	8.7a	19.8a	2818a
M. invisa	89.9a	9.8b	8.8a	18.9b	2626b	97.6ab	8.7a	8.3a	19.1b	2252b
C. obtusifolia	92.0a	9.7b	8.8a	19.4a	2010c	96.0b	8.8a	8.2a	19.4a	1960c
SE	1.42	0.15	0.11	0.22	53	1.33	0.23	0.22	0.26	42
CV (%)	4.76	5.06	4.06	3.47	7.20	4.19	8.15	8.50	4.07	6.14

Means in the same column for each site followed by a common letter are not significantly different from each other according to Duncan Multiple Range Test (P>0.05)

TABLE 4. The effect of green manure and fertilizer on *Striga* growth and development in Tanzania

Treatment		Kilasilo				Itope			
Green manure	Fertiliser rate	*Striga* count in 10 m^2		*Striga* height	Capsules /plant	*Striga* count in 10 m^2		*Striga* height	Capsules/ plant
	(kg N ha^{-1})	6 wks	12 wks			6 wks	12 wks		
Control	0	167 a	28 a	22.8b	16 a	126 a	126 a	27.9a	18.6a
	25	30 b	15 b	25.9a	16 a	13 b	25 b	15.3b	9.0b
	50	7 c	15 b	15.3c	6 b	4 c	9 c	15.3b	8.8b
C. ochruleuca	0	0d	0c	-	-	0d	0d	-	-
	25	0d	0c	-	-	0d	0d	-	-
	50	0d	0c	-	-	0d	0d	-	-
M. invisa	0	0d	0c	-	-	0d	0d	-	-
	25	0d	0c	-	-	0d	0d	-	-
	50	0d	0c	-	-	0d	0d	-	-
C. obtusifolia	0	0d	0c	-	-	0d	0d	-	-
	25	0d	0c	-	-	0d	0d	-	-
	50	0d	0c	-	-	0d	0d	-	-
SE		0.48	0.44	0.49	0.28	0.43	0.37	0.44	0.33
CV(%)		36.31	47.25	50.93	34.17	38.36	29.69	47.25	41.56

Means in the same column followed by a common letter are not significantly different from each other according to Tukey's Test ($P \geq 0.05$)

Table 5 indicates an increase in yield and yield components when green manure and inorganic fertiliser were applied in both sites. Plant height increased significantly ($P \leq 0.05$) with the application of green manure and nitrogen fertiliser at 50 kg N ha^{-1} under all green manure species in both sites.

When green manure and nitrogen fertiliser at 25 kg N ha^{-1} were applied jointly, plant height for *M. invisa* and *C. ochroleuca* did not show significant variation but varied significantly ($P \leq 0.05$) with *C. obtusifolia* in Kilasilo. Application of green manure with fertiliser at 50 kg N ha^{-1}at Kilasilo resulted into a higher ($P \leq 0.05$) number of tillers per plant than with 25 kg N ha^{-1}, except where *M. invisa* was applied together with fertiliser (25 kg and 50 kg N ha^{-1}.

The number of panicles per plant showed no significant difference among green manure species when 50 kg N ha^{-1} was applied in Kilasilo. In Itope *M. invisa* and *C. obtusifolia* showed no significant ($P>0.05$) variation between 0 N ha^{-1} and 25 kg N ha^{-1}; so was 25 kg N ha^{-1} and 50 kg N ha^{-1} under *C. ochroleuca.* When green manures and 25 and 50 kg N ha^{-1}were applied, grain yields varied significantly ($P \leq 0.05$) *C. ochroleuca* had the highest yield followed by *M. invisa* and *C. obtusifolia*. In Itope, grain yield in the green manure and all fertiliser rates varied significantly ($P \leq 0.05$) from each other except for *C. ochroleuca* with 0 kg N ha^{-1} and *C. obtusifolia* with 50 kg N ha^{-1}, that were similar. Among the green manure species, *C. ochroleuca* showed a significantly higher benefit per unit cost incurred than *M. invisa* and *C. obtusifolia* in Kilasilo and Itope, respectively (Table 8).

Ethephone (an artificial stimulant), applied at the rate of 50 ppm, resulted in the highest ($P \leq 0.05$) germination percentage followed by Staha a susceptible maize variety. The green manure species showed significant differences ($P \leq 0.05$), among themselves in the ability to stimulate germination. *C. ochroleuca, C. obtusifolia, and M.invisa* stimulated 40%, 28%, and 6%, respectively (Table 6).

In the retrieved Eplee bags *C. ochroleuca* stimulated the highest ($P \leq 0.05$) germination percent of *Striga* seed, compared to *M. invisa* and *C. obtusifolia*. In Kilasilo the percent *Striga* seed germination was higher than Itope. *Crotolaria ochroleuca* stimulated significantly high percent of *Striga* seeds germination followed by *C. obtusifolia*, and *M. invis*a . In both sites Itope and Kilasilo control treatment did not stimulate *Striga* germination. The trend of *Striga* seed germination across sites was *C. ochroleucca* > *C. obtusifolia* > *M.invisa* (Table 7). The benefit per unit cost incurred was higher in treatments with green manure applications (Table 8). The benefit cost ratio varied depending on the green manure type with *C. ochroleuca* having the highest.

DISCUSSION

The textural class of both sites is suitable for upland rice production, but due to poor fertility status application of organic/inorganic fertiliser is important to improve rice yield. The textural class for both sites also favours the growth of *Striga* because they are sandy clay and are well drained (Data not presented). Heavy soils with poor drainage can have excess moisture that discourages *Striga* germination by lowering soil temperature and diluting the germination stimulant.

Under strong to medium soil acidity, Al^{3+} is highly soluble and can be toxic to the plants. On the contrary, the levels of Al^{3+} in all sites are very low (trace). Probably the amount of Al^{3+} in the soil combined with phosphates to form insoluble compounds hence low levels of Al^{3+}. The parent materials can also be composed of low or no Al. The level of micronutrients in the soil is also low. It was reported by Landon (1991) that the level of micronutrients, Cu, Fe, Mn, and Zinc, under such acidic conditions should be high or reaching the toxic levels. On the contrary, the results from soil analysis showed that the levels of micronutrients Cu, Fe, Mn, and Zinc are below toxic levels. Perhaps the parent material has low level of micro-nutrients, hence, little is released to the soil solution. The results indicate that soils in both sites do not supply rice with adequate amounts of phosphorus. This low P status can be due to low amount of available P, precipitation by Al, Fe, Mn, and by fixation of both oxides of Al, Fe, Mn and kaolinitic clays.

Organic carbon of soils at both sites was very low (less than 2 %), as were the levels of nitrogen

TABLE 5. The effect of green manure and inorganic fertilizer on growth and yield of rice in Tanzania

Treatment		Kilasiko					Itope				
Green manure	Fertiliser rate (kg N ha^{-1})	Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length	Grain yield (kg ha^{-1})	Plant height (cm)	Tillers per plant	Panicle counts / plant	Panicle length	Grain yield (kg ha^{-1})
Control	0	77.7d	7 d	7 b	17.9b	815g	78.7b	6.7 c	6.0c	17.3b	825h
	25	86.5 bcd	9 bc	9 a	18.6ab	1406ef	93.5a	7 bc	7 bc	19 ab	1230g
	50	90.8abcd	10 ab	9 a	19.7ab	1784de	97.7a	10 a	9 ab	19 ab	1633ef
C. ochruleuca	0	84.2 cd	8 cd	8 ab	18.7ab	2300c	96.7a	8 abc	7 bc	18.7ab	2458c
	25	88.5abcd	9 bc	9 a	19.0ab	2798b	96.5a	9 ab	9 ab	19.7ab	2870ab
	50	100. 7a	10 ab	9 a	20.3a	3442a	103.a	10 a	10 a	21.0a	3126a
M. invisa	0	86.0 bcd	9 bc	8 ab	17.7b	2227cd	92.1a	8 abc	7 bc	18.7b	1894de
	25	86.7 bcd	10.ab	9 a	19.0ab	2592bc	99.7a	8 abc	8 abc	19.0ab	2238cd
	50	95.2 abc	11 a	9 a	20.0a	3059ab	101.1a	10 a	10 a	19.7ab	2623bc
C. obtusifolia	0	85.7 bcd	9 bc	8 ab	18.7b	1238fg	92.7a	8abc	8 abc	18.7ab	1363fg
	25	92.0 abc	10 ab	9 a	19.7ab	2181cd	94.1a	8 abc	8 abc	19.3ab	2042d
	50	98.3 ab	10 ab	9 a	20.0a	2610bc	101.2a	10a	9 ab	20.3a	2476c
SE		2.46	0.27	0.20	0.38	92	2.31	0.40	0.39	0.45	73
CV(%)		4.76	5.06	4.06	3.47	7.20	4.19	8.15	8.50	4.07	6.14

Means in the same column for each site followed by a common letter are not significantly different from each other according to Tukey,s Test (P>0.05)

TABLE 6. Germination of *Striga* seed by green manure in the laboratory

Treatment	Germinated *Striga* seed (%)
Ethephone	67a
Zea mays (Staha)	53b
Crotolaria ochroleuca	40c
Cassia obtusifolia	28d
Mimosa invisa	6e
Control (H_2O)	0f
SE	1.94
CV (%)	10.37

Means in the same column followed by a common letter are not significantly different from each other according to Tukey's Test ($P\geq0.05$)

TABLE 7. Germination of *Striga* seed (%) by green manure in the field in Tanzania

Green manure	Itope mean	Kilasilo (%)
C. ochroleuca	28.3a	30a
C. obtusifolia	23.0b	23.3b
M. invisa	4.3c	4.6c
Control	0d	0d
SE	1.15	0.93
CV(%)	14.42	11.20

Means in the same column for each site followed by a common letter are not significantly different from each other according to Tukey's Test ($P\geq0.05$)

TABLE 8. The Benefit: Cost ratio of the effect of green manure and fertilizer on rice yield in Tanzania

Treatment	Fertiliser rate (kg N ha^{-1})	Kilasilo	Itope
Control	0	1.7g	1.8h
	25	3.0f	2.5g
	50	3.6ef	3.2f
C. ochruleuca	0	9.5b	10.2a
	25	9.2b	9.5b
	50	10.1a	9.1b
M. invisa	0	7.6c	6.3c
	25	7.3c	6.1c
	50	7.7c	6.5c
C. obtusifolia	0	3.8e	4.2e
	25	5.9d	5.5d
	50	6.5d	6.1c
SE		0.31	0.25
CV(%)		8.5	7.45

Means in the same column for each site followed by a common letter are not significantly different from each other according to Tukey's Test ($P\geq0.05$)

(0.1 – 0.2 %). This shows that the soils from both sites need to be supplied with organic matter and nitrogen in order to improve the N reserve in the soil. Both sites have less than 50% base saturation, indicating that these soils are of very poor fertility. Soils with such low fertility are susceptible to *Striga* infestation because *Striga* grows well in soils of low fertility. Farmers are aware of this and use *Striga* as a bio-indicator of low soil fertility (Sauerborn, 1996).

Generally, green manure treatments reduced weed prevalence. Both the weed density and weed dry biomass were significantly ($P\leq0.05$) reduced when green manure was added in both sites. In both sites, reduction in total weed number was 50.5 to 32% (m^2) whereas reduction in weed dry biomass was 54.6 to 51.4 % (m^2). This indicates that green manure has the potential to reduce weed infestation in upland rice fields. However, the potential of the green manure to reduce weed prevalence varied with the species used. The results indicated that grass weeds resisted the effect of green manure, hence, more grasses were recorded in green manure plots than broadleaf weeds. The resistance of grasses probably is a result of aggressiveness (Akobundu, 1987).

On the contrary, green manures reduced *Striga* infestation in upland rice soils by reducing *Striga* number, *Striga* height and number of seed produced (number of capsules). The reduction in infestation was the result of the potential of the green manure to induce germination of *Striga* seed to cause suicidal germination, like other trap crops differ in their ability to stimulate germination of *Striga* (Parker and Reid, 1979). The potential of green manure to stimulate *Striga* seed germination is controlled genetically (Bebawi and Michael, 1991) and environmentally (Odhiambo and Ransom, 1996). There was a difference in percentage germination between the laboratory and field experiments probably due to variations in soil factors like inherent soil N, pH and soil water. Green manure also reduces *Striga* by release of nitrogen during decomposition. Nitrogen has a negative effect to the *Stirga* seeds germination and growth in the soil, at the same time enables the susceptible host to tolerate or avoid the effect of *Striga*.

The application of green manure species and nitrogen (25 kg ha^{-1}, 50 kg ha^{-1}) reduced the number of *Striga* by 100% in the 6 and 12^{th} weeks. Green manure and fertiliser enabled the host to avoid the effect of *Striga* probably by poor production of germination stimulants and delayed haustorium attachment. In addition, under good supply of N a host grew vigorously and created unfavourable environment for *Striga* germination and development hence short *Striga* plants. Competing tall S*triga* plants were found to have few capsules per plant. The low number of capsule was the result of the *Striga* like other plants to compensate reproduction on the excessive vegetative growth resulting from the competition. By inhibiting *Striga* growth, green manure application improved rice growth and yield. Application of green manure upon decomposition released nitrogen for the rice plants (Nitrogen supplied by *C. ochroleuca* and *M. invisa* was equivalent to about 50 kg ha^{-1}). This increased the number of tillers per plant, number of panicles per plant panicle length and the grain yield (Murata, 1982). Another contributing factor to the yield of rice probably was the organic phosphorous supplied by green manure. The amount of phosphorous in the initial chemical composition (roots and shoots) was *C. ochroleuca* 0.66%, *M. invisa* 0.66% and *C. obtusifolia* 0.74%.

The benefit per unit cost incurred was higher when green manure was applied than when there was no green manure. This means green manure have a good potential in improving soil fertility and the costs involved in inorganic fertilisers are detrimental to the benefit realised.

CONCLUSIONS

The application of green manure and fertiliser urea improved rice yield and reduced *Striga* population. In particular, *Crotalaria ochroleuca*, offer potential for the control of *S. asiatica* and improve upland rice yield through reduced *Striga* seed population in the soil, and reduced *Striga* growth and development; and reduced infestation of weeds other than *Striga*.

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REFERENCES

Akobundu, O.I. 1987. Weed Science in the Tropics Principles and Practices. John Wiley and Sons. Norwich. 522 pp.

Anderson, J. M. and Ingram, J. S. I. 1993. Tropical Soil Biology and Fertility. A Hand Book of Methods. CABI Publishing, Willingford. 221pp.

Buresh, R. J. and Tian, G. 1997. Soil Improvement by trees in Sub-Saharan Africa. *Agroforestry Systems* 38:51 – 76.

Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic and available forms of phosphorous in soils. *Soil Science* 59:39 – 45.

Brenmer, J. M. and Mulvaney, C. S. 1982. Total nitrogen. In: *Methods of Soil Analysis Part 2 2nd Edition*. Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), pp. 595 – 624. American Society of Agronomy, Madison, Winsconsin.

CIMMYT, 1988. From Agronomic data to farmers' recommendation. An Economics Training Manual. CIMMYT, 79 pp.

Gee, G..W. and Bauder, J.W. 1986. Physical and mineralogical methods. In: *Methods of Soil Analysis, Part 1 2nd Edition* . Kilute, A (Eds.), pp. 383 – 412. American Society of Agronomy, Mdison, Wisconsin.

Giller, K. E. and Wilson K. J. 1993. *Nitrogen Fixation in Tropical Cropping Systems*. Redwood Press Ltd., Melksham, 313 pp.

Gomez, K. A. and Gomez, A. A. 1984. *Statistical Procedure for Agricultural Research* (2nd Edition). John Wiley and Sons New York. 680 pp.

IITA, 1997. Striga Research Methods – A Manual. Barner, D. K., Winslow, M.D., Awad, A. E., Cardwell, K. F., Mohan Raj, D. R. and Kim, S. K. (Eds.), 81 pp. IITA, Ibadan, Nigeria.

Johnson, D.E. 1997. Weeds of Rice in West Africa. WARDA, Bouake. 312pp.

Lameck, P., Mbwaga, A.M. and Riches, C. R. 2003. Context analysis for four villages in Kyela and two villages in Matombo, Mororgoro rural districts. Enhancing productivity of upland rice on Striga infested soils – Project. Project Working Paper No. 2. 44 pp.

Lindsay, W.O. and Norvell, W.A.1978. Development of a DTPA soil test for Zinc, Iron, Manganese and Copper. *Soil Science Society of America Journal* 42 :421-428.

McLean, E. O. 1982. Soil pH and lime requirement. In: *Methods of Soil Analysis Part 2nd Edition.* Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), pp. 199– 224. American Society of Agronomy, Madison, Wnsconsin.

Ministry of Agriculture and Cooperatives, 1998. Basic data, Agriculture and Livestock sector. Dar es Salaam, 50 pp.

Murata, Y. 1982. Physiological Response to Nitrogen in Plants. In: *Physiological Aspect of Crop Yield*. Eastin, J. D.; Haskins, F. A., Sullivan C. Y. and Van Bavel, C. H. M. (Eds.), pp. 235 – 259. American Society of Agronomy, Crop Science Society of America, Wisconsin.

Mussei, A.N., Mbwile, R.P., Kamasho, J.K., Mayona, C.M., Ley, G.J. and Mghogho, R.M. 1999. *Agroecological Zones and Farming Systems of the Southern Highlands of Tanzania*. ARI Uyole, Mbeya. 50 pp.

National Soil Services, 1993. Review of fertiliser recommendations in Tanzania. Mowo, J.G., Floor, J., Kaihura,F.B.S. and Magongo, J.P. (Eds.), 61 pp. M.A.C. Tanga.

National Soil Services, 1987. *Laboratory Procedures for Routine Analysis, 3rd Edition*. TARO. Agricultural Research Station Mlingano, Tanga, pp.150.

Nelson, D.W. and Sommer, L.E. 1982. Total organic carbon and organic matter. In: *Methods of Soil Analysis Part 2 2nd Edition.* Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), pp. 539 – 579. American Society of Agronomy, Madison, Wnsconsin.

Okalebo, R. J. and Galhua, K. W. 1993. Laboratory Methods of Soil and Plant Analysis. *A Working Manual. Soil Science Society of East Africa*. *Technical Publication* No 1. Nairobi, 88 pp.

Smalling, E. 1993. Soil nutrition depletion in sub-Saharan Africa. In: *The Role of Plant Nutrients for Sustainable Food Crop Production in Sub Saharan Africa*. Van Reuler and Prins, W. (Eds.), pp. 53 – 68. V.K.P. Leidschendam.

Thomas, G. W. 1982. Exchangeable cations. In: *Methods of Soil Analysis Part 2 2nd Edition.* Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), pp.159-165. American Society of Agronomy, Madison, Winsconsin.