EVALUATION OF THE POTENTIAL OF GREEN MANURE AND PLANT EXTRACTS FOR THE CONTROL OF WITCHWEED (*Striga asiatica* L. Kuntze) IN UPLAND RICE (*Oryza sativa* L.) IN KYELA, TANZANIA

BY

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ABSTRACT

Striga asiatica is a serious problem in upland rice in Kyela Tanzania. The use of inorganic nitrogen fertilizer urea assures control of the weed. Resource poor farmers cannot adopt the technology due to unavailability and higher prices of inorganic fertilizers. Therefore, the use of green manure available in upland rice fields will be a plausable alternative. Three experiments were conducted to evaluate the potential of green manure and plant extracts for the control of *Striga asiatica* (L.) Kuntze on upland rice (*Oryza sativa* L). These experiments aimed at evaluating the decomposition of the green manure, determining the effect of the green manure and inorganic fertilizer on *Striga* and rice yield and determining the influence of green manure and plant extracts on the germination of *Striga*. Decomposition of roots and shoots of *Crotolaria ochlroleuca* G. (sunhemp), *Mimosa invisa* L.(Colla), *and Cassia obtusifolia* L.(Sicklepod) was determined. Results showed that by the 2^{nd} week shoots had lost 51% of the biomass while by the 6^{th} week roots had lost 50% of the biomass. Then inorganic fertilizer urea at 0 N, 25 kg N ha^{-1} and 50 kg N ha^{-1} was superimposed in green manure plots. Generally, it was found that *Striga* infestation was reduced by 100% while the yield of rice increased from 1238 kg ha^{-1} to 2846 kg ha^{-1}. However, the residual effect of green manures did not reduce *Striga* but increased rice yield. High benefit per unit cost was realised on when *C. ochlroleuca* was combined with 50 kg N ha^{-1}). Green manure application methods (ploughing under, mulch) was also superimposed with inorganic fertiliser urea (0 N, 25 kg N ha^{-1} and 50 kg N ha^{-1}). Results showed that there was no significant difference between mulch and ploughing under on *Striga* except for rice grain yield. Mulch was found to be more economical than ploughing under. The potential of green manure to stimulate *Striga* germination, plant extracts to suppress *Striga* germination and application methods was also determined in the laboratory and field. *Striga* germination was found to be in the order *C. ochroleuca* > *C. obtusifolia* > *M. invisa* (both field and laboratory). Plant extracts were collected from *C. ochroleuca, M. invisa, C. obtusifolia, Vernonia amygdalina* Del. (bitter leaf), *Neuritania mitis, Dolichos kilimandcharis* and *Gnidia kraussiana* Meisn. (yellow heads). It was found that *Striga* seed germination was reduced where *D. kilimandcharis* and *G. kraussiana* were found to be effective in suppressing *Striga* seeds germination. Seed hardening was selected as a good application method. *Crotalaria ochroleuca* and *C. obtusifolia* were recommended for *Striga* control and improvement of soil fertility in Kyela.

DECLARATION

I, Mohamed, Juma Kayeke do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and that it has neither been submitted nor is it being concurrently submitted for a degree award in any other University.

Signature..

Date.......19th November 2004.......

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LIST OF ABBREVIATIONS

AICAF	Association for International Co-operation of Agriculture and Forestry,
Al	Aluminium
ARI	Agricultural Research Institute
CIMMYT	International Maize and Wheat improvement Centre (Centro Internacional de Mejoramiento de Maiz y Ttrigo)
Ca	Calcium
Cu	Copper
FAO	Food and agriculture Organisation of the United Nations
Fe	Iron
ICRA	International Centre for development oriented Research in Agriculture
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crop Research Institute for Sem – Arid Tropics
IITA	International Institute of Tropical Agriculture
IRRI	International Rice Research Institute
LITI	Livestock Training Institute
MAC	Ministry of Agriculture and Co-operatives
Mg	Magnesium
Mn	Manganese
MPa	Mega Pasclas
NaOcl	Sodium hypochlorite
SUA	Sokoine University of Agriculture

TOSCA	Tanzania Official Seed Certification Agency
WARDA	West African Rice Development Association

CHAPTER 1

1.0 INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereals grown almost in all regions of Tanzania (Ministry of Agriculture and Co-operatives, 1998). It is second to maize (*Zea mays*) in terms of consumers' preferences. In Tanzania major rice production systems are lowland (flooded and irrigated), and upland (rain-fed). Rice production in these systems is affected by a number of constraints that make the national average production to be low at 1.5 t ha^{-1} (Ministry of Agriculture and Cooperatives, 1998). The constraints include low soil fertility, poor water management, weed infestation, diseases, and insects.

Kyela district is one of the potential producers of lowland and upland rice in Mbeya region. In this district, small-scale farmers grow rice mainly for food and cash. The district average yield is 1.7 t ha^{-1} (District Agriculture Office, Unpulished). According to International Centre for Development Oriented Research in Agriculture (1994), weed infestation was identified as a major constraint in upland rice production in Kyela. The presence of the parasitic *Striga asiatica* L. Kuntze in upland rice in Kyela magnified the weed problem in upland rice production. *Striga* was identified as the most serious weed in upland rice (ICRA, 1994). Its presence in upland rice fields has forced some farmers to abandon their fields and resort to growing less profitable crops such as cassava (*Manihot esculenta*) and sweet potato (*Ipomea batata*).

There are two species of *Striga* found in Kyela, *Striga forbesii* (Benth.) found in maize fields and *Striga asiatica* found in rice and maize fields. *S. asiatica* is a dominant species in Kyela (Plate 1) Locally *Striga* is known as "kyumika" which means something that dries up the crops. Striga is normally found on dry soils with low soil fertility.

Plate 1: *Striga asiatica* (with red flowers) in Upland rice in Kyela, Tanzania (2002 cropping season)

This has made Kyela farmers to use *Striga* infestation as a bio-indicator for decreasing soil fertility as reported by Kroschel and Sauerborn (1996). *Striga asiatica* is an obligate root parasitic weed that belongs to the Scrophulariaceae family. It requires stimulants for its seeds to germinate. Attachment to the roots of the host is facilitated by haustoria for drawing water and nutrients (Parker and Riches, 1993; Doggett, 1984). The success of *Striga* is due to the small size of the its seed, high number of seeds per plant and long time seed viability of up to 20 years (Parker and Riches, 1993; Doggett, 1984). *Striga* reduces photosynthesis in the field (Gurney *et al.*, 1995), delays maturity, reduces panicle size, plant height, dry matter production and weakens the root system (Parker and Riches, 1993). In doing so, *Striga* infestation causes reduction of yield that can vary between 10% to total loss depending on the intensity of infestation (Parker and Riches, 1993; Mbwaga *et al.*, 2000).

For sustainable control of *Striga*, measures taken must consider reduction of the seed population in the soil and improvement of soil fertility to discourage *Striga* growth without acidifying the soil (Doggett, 1984). Other alternatives include improving soil physical characteristics by the addition of organic matter (Pieterse *et al.*, 1996) and destruction of emerged *Striga* plants so that they cannot seed (Doggett, 1984; Parker and Riches, 1993).

The current recommendation for *Striga* management in Kyela is the application of inorganic nitrogen fertilizers to reduce infestation and to improve rice yields. Many farmers have limited resources and therefore cannot afford high prices of fertilisers.

The use of green manure that reduces *Striga* seed population in the soil by suicidal germination and supply of nitrogen to the soil can be of benefit to farmers who cannot afford inorganic fertilizers.

Farmers are aware of the problem of soil fertility depletion but they rarely use fertilizers (organic and or inorganic). Major limitations include lack of knowledge, unavailability of fertilizers, high costs involved and low profits realised. Therefore, poor resource farmers have to practice sustainable production systems that can be affordable under the situation of decreasing purchasing power. The use of green manure will assist in improving soil fertility by providing plant nutrients and improving soil structure. This improvement will be enhanced by the increase in soil organic matter that is very important for the nitrogen stock in the soil. Apart from these benefits, the use of green manure may be a better choice for farmers because the technology of using green manure is simple to put into practice and at the same time environmentally acceptable.

In Kyela District where rice is grown as a food and cash crop, production has dropped from the average yield of 700 kg to 140 per acre due to depletion of soil fertility and *Striga* infestation (Lameck *et al.*, 2003). On the other hand, the district is densely populated with about 210 person per km^2 and a population growth rate of 4.3 per year (Tanzania Government, 2002). Therefore, farmers need to improve productivity of the available land in order to feed an ever-growing population. Under the pressure on land, poor soil fertility, *Striga* infestation, ever-increasing population and lack of purchasing power, the use of green manure is a plausible alternative as it can be used for soil fertility improvement and consequently control of *Striga* infestation.

A variety of plants which can be used as green manure are locally available and adapted to the ecological conditions of Kyela. These include *Chrotalaria ochroleuca* (G.) (sunhemp), *Mimosa invisa* (L.) (Colla) and *Cassia obtusifolia* (L.) (Sickle pod), where the last two are described as weeds in upland rice production (Johnson, 1997). However, the potential of green plants for soil fertility improvement has been tested mostly in maize production (Lyimo and Temu, 1992). As such, the role of green manure in rice production in Tanzania is largely undocumented despite its potential.

The main objective of this study was to evaluate the potential of green manure and plant extracts in the control of *Striga* in upland rice. The specific objectives were as follows:

i. To assess the role of green manure in improving soil fertility in upland rice ecosystem

ii. To determine the effect of green manure with or without inorganic fertilizer on the yield of upland rice under natural infestation of *Striga asiatica*.

iii To determine the influence of green manure and plant extracts on the germination of S*triga asiatica.*

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 *Striga* species

Striga is an obligate parasitic weed that belongs to the Scrophulariaceae family. In the world, *Striga* is found in Africa, North America, Asia, Australia and New Zealand. Raynal-Roque (1991) reported that there were 35 species of *Striga*, of which 11 were of economic importance in agriculture. These include *S. angustifolia* (Don.), *S. aspera* (Willd.), *S. densiflora* (Benth.), *S. forbesii* (Benth.), *S. lateriaceae* (Vatke), *S. multiflora* (Benth.), *S. parviflora* (Benth.), *and S. parsagei* (Engl.) which attack maize (*Zea mays*), millet (*Pennisetun glaucum*), rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor*), sugar cane (*Sucharrum officinarum*) and *Digitaria sp.* Another group includes *S. asiatica* (L.), S. *hermonthica* (Benth.) and *S. gesnerioides* (Benth.). The first two infest maize, millet, oats, rice, sorghum, and sugar cane while the third one attacks cow peas (*Pisum sativum*), sweet potato (*Ipomea batat*) and tobacco (*Solanum tabbacum*). Raynal-Roque (1996) grouped *Striga* species into three groups, minor pest on crop, major pest on crops and the most important pests on crops. Minor pests on crops are those which are wide spread in native vegetation and their distribution as crop parasite is restricted to patches. These are *S. angustifolia, S. aspera, S. densiflora, S. multiflora, S. parviflora and S. parsegei.* Major pests on crops are *S. gesneriodes* and *S. asiatica.* Their distribution as pests is wider than their natural zone. The most important crop pest is *S. hermonthica*, which is widely distributed in crops but localised in native vegetation.

Striga species which are found in Tanzania are *S. asiatica, S. aspera, S. elegans, S.*

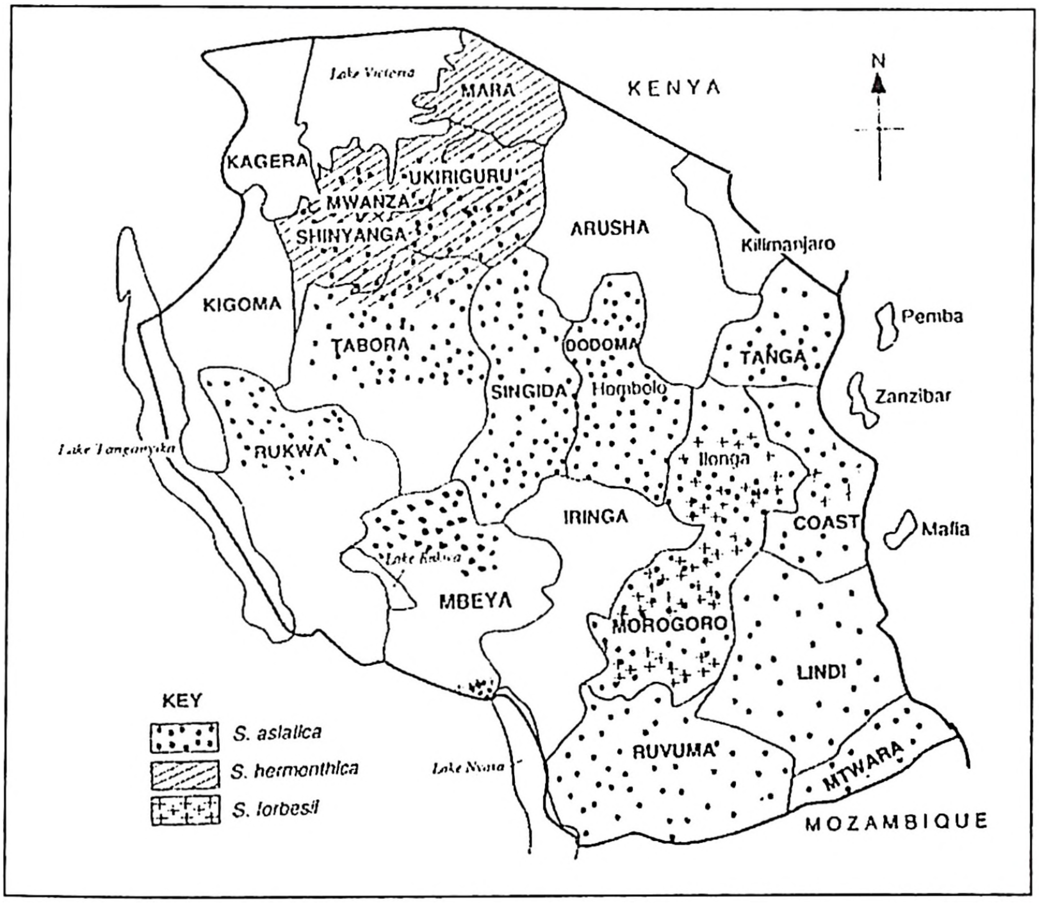
euphrasioides, *S. forbesii*, *S. fulgens*, *S. gesneroides* and *S. hermonthica* (Mbwaga *et al.*, 2000). Among these, important species are *S. asiatica*, *S. forbesii*, and *S. hermonthica* (Mbwaga *et al.*, 2000). According to Sauerborn (1991) distribution of *Striga* species depends on the distribution and movement of hosts. A survey conducted in Tanzania showed the occurrence of only one *Striga* species in some areas and more than one species in others (Mbwaga *et al.*, 2000) (Figure 1). *Striga asiatica* and *S. hermonthica* are found mostly around Lake Victoria area in Mwanza, Musoma and Shinyanga regions. *Striga asiatica* and *S. forbesii* are found in some parts of Morogoro in Eastern Tanzania and Kyela district in Mbeya region the Southern part of the country. In Mtwara, Songea and Tabora regions only *S. asiatica* is found.

The importance of *Striga* species depends on the importance of the attacked crops, the crop loss caused, the intensity of infestation in the fields and the area under infestation. On the other hand, distribution of *Striga* species does not depend only on the distribution and movement of hosts but also the movement of animals, movement of human beings and sometimes floods or surface water run off.

2.2 *Striga* growth and development

Striga develops from seeds in the presence of a germination stimulant. Sauerborn (1991) reported that *Striga* seed can maintain viability for 6 up to 14 years. However, in a study which *Striga* seeds were buried in the soil at different depths different results were obtained. Okonkwo (1991a) reported that *Striga* seed survived 6 years in the laboratory, 9 years in the field buried not more than 30 cm deep and 14 years buried at 152 cm deep in the soil. *Striga* seed buried near the soil surface at 30 cm deep could not survive more than 9 years because of micro-organism activities in the upper layers of the soil (Okonkwo, 1991a). Therefore, the viability of *Striga* seed is determined by host plant, the ecology of the host and storage conditions.

When mature, *Striga* seeds are in a state of innate dormancy. The dormancy period varies with species. The dormancy period for *S. asiatica* is six months (Okonkwo, 1991a) after maturity. *Striga* seed need conditioning before germination. The conditioning process is very important because it makes *Striga* seed ready to germinate. During this process the permeability of the seed coat increases and there is a synthesis of some stimulant co-factors and reduction of germination inhibitors (Sauerborn, 1999). Normally this period takes 1 to 3 weeks at a temperature of 20 ^{0}C to 30 ^{0}C. When temperatures are low, the conditioning period takes long but with high germination percentage. When temperatures are high the conditioning period takes short but with reduced germination percentage (Okonkwo, 1991a). If the conditioning period continues for more than 28 days the seed enters the secondary dormancy or wet dormancy which can be broken down by drying and conditioning again (Parker and Riches, 1993). After the conditioning period, *Striga* seed will germinate when supplied with a germination stimulant. These stimulants are produced by susceptible hosts, trap crops like cotton (*Gossypium hirsutum*) (Cook *et al.*, 1972) and artificially for example G.Rosebery compounds (Johnson *et al.*, 1976). According to Parker and Riches (1993), the G.Rosebery compounds are strigol analogues named after the chemist involved in the identification of the compounds Dr. G. Rosebery.



Source: (Mbwaga *et al.*, 2000)
Figure 1: Distribution of *Striga* species in surveyed areas of Tanzania

Striga seeds can start to germinate after being incubated for 24 hours at 30 ^{0}C (Parker and Reid, 1979). During germination light is not required because of phytochrome control of the germination process (Okonkwo, 1991a). The radicle of the germinated *Striga* seed will respond to the direction of the host by chemotrophic response which is influenced by the pH around the host root (Parker and Riches, 1993). If there is no proper host, a germinated seed can survive for 5 days independently (Sauerborn, 1999). After germination, there is formation of haustorium, a xylem bridge connecting the parasite to the host. Its main functions are attachment, penetration, water and solute acquisition. A chemical agent is responsible for the initiation of the haustorium. The haustorium of *S. asiatica* is initiated by 2,6 dimethoxy-p-benzoquinone (2,6-DMBQ) (Smith *et al.*, 1990).

After emergence, *Striga* can grow up to 15 to 50 cm high depending on the species and adaptation. Seed production varies with species, but it can range from 25 000 to 200 000 per plant (Parker and Riches, 1993). Other variations within species have been observed in *S. asiatica* whereby plant vigour, leaf size and colour of flowers differ due to the influence of growing conditions and type of host (Ralston *et al.*, 1987).

Striga seed dormancy and conditioning period are very important for the adaptability of the S*triga* in its environment. Dormancy under natural infestation enables *Striga* to germinate during cropping season so that it can find a host in the field while conditioning gives time for the host to grow and be ready to support the parasite. In the laboratory conditioning can take about 7 days while in the field takes up to 21 days. On the other hand, growth and development of *Striga* is influenced by species, hosts and environmental conditions.

2.3 Ecology of *Striga*

2.3.1 Temperature

A temperature of 30 ^{0}C has been reported by Petterson (1990) to be conducive for germination and conditioning of *S. hermonthica*, but temperatures of 20 to 26 ^{0}C are reported to be more favourable (Okonkwo, 1991a). It has further been reported that *Striga* seed maintained viability at low temperatures of -7 to –15 ^{0}C for 49 days (Parker and Riches, 1993). This showed that *Striga* is able to survive under a wide range of temperatures that contributes to its ability to maintain viability and its adaptation to the growth conditions of the host.

2.3.2 Light

Striga asiatica does not need light for germination therefore, it avoids germination at the soil surface. According to Parker and Riches (1993) *Striga* is a non-photoperiodic or day neutral plant, and there is evidence that *S. asiatica* can mature in total darkness provided that the host supplies photosynthesis products. However, Sauerborn (1991) reported that light was not a prerequisite for development of the parasite; this was demonstrated by the presence of albino plants in the field. Being non-photoperiodic, *Striga* managed to spread over vast areas in the world (Doggett, 1984). Apart from being a non-photoperiodic plant, *Striga* is a photosynthetically active plant, meaning that it has chlorophyll and thus can carry out photosynthesis and grow well in full sunlight. The rate of photosynthesis in *Striga* is very low at about 20 to 30% of the requirement of a non-parasitic plant and therefore the supplement carbon is obtained from the host. Being a non-photoperiodc plant and its ability to carry photosynthesis enables *Striga* to perform well in a wide range of environment.

2.3.3 Moisture

Soil moisture is very important in germination and development of *Striga* directly and indirectly through host growth and development. Generally, high moisture levels in the soil are unfavourable for *Striga* germination and development although there is no exact data for the amount or limits that are favourable (Pieterse and Verkleij, 1991). Observation of Sauerborn, (1991) showed that germination of *Striga* occurred between zero to –1.29 MPa. This means *Striga* germination takes place when the soil is wet enough to favour growth to reach hosts' root for attachment. According to Dzomeku and Murdoch (1999), *Striga* germination was higher when conditioning was done at zero MPa water potential and temperature range of 25 ^{0}C to 35 ^{0}C. When water potential decreased to -2 MPa at 25 ^{0}C *Striga* germination dropped from 77 to 8 %. By these results, it was concluded that water stress during conditioning reduced seed germination percentage. At higher and medium water stress *Striga* seed germination became insensitive to temperature. Too much soil moisture resulted into lack of oxygen, leaching and dilution of the germination stimulants, and reduced soil temperature (Parker and Riches 1993). Low soil temperature reduces exudation of germination stimulant and increases susceptibility of the germinated *Striga* to soil-borne pathogens.

Humidity is also an important factor in transpiration. High humidity results into low transpiration rate that lowers the amount of water and nutrient taken by *Striga* from the host. Low humidity increases transpiration rate and hence increases the amount of water and nutrient taken from the host plant.

Therefore, management of soil moisture can be used effectively in the control of *Striga*. Under heavy irrigation *Striga* germination is reduced or checked completely. On the other hand, any measure that can affect the transpiration rate of the parasite stands a good chance of killing the parasite or affecting its growth and development.

2.3.4 Soils

The spread of *Striga* species in various agro-ecological conditions has enabled it to establish itself in a wide range of soil types. However, there are some restrictions among species. For example, *S. asiatica* is found on sandy and heavy soils (Pieterse and Verkleij, 1991). Soil type can have a direct or indirect effect on *Striga* growth and survival. It has been reported that soil type played a role in moisture holding capacity, soil temperature and occurrence of microorganism. In heavy soils temperatures were low and caused low *Striga* seed germination while light soils were said to have higher temperatures and resulted into higher *Striga* seed germination (Okonkwo, 1991a; Parker and Riches, 1993). In addition, light soils were prone to leaching, therefore *Striga* germination stimulants were easily leached and lowered the germination of *Striga* and hence low *Striga* number in the field. Nitrogen can also be leached in light soils, and cause high infestation due to low levels of nitrogen in the soil. Another soil factor that favours *Striga* growth is low water holding capacity.

Therefore, heavy soils with high water holding capacity are not preferred by *Striga*. Under water-logging conditions some hosts, such as maize cannot survive, therefore there is no chance for *Striga* survival.

Soil microorganisms infect *Striga* seed in the soil. A good example is *Drechslera longilostrata* (Subram) (hyphomycetes) a seed infesting fungus found in Sudan (Sauerborn, 1991). On the other hand, microorganisms produced ethylene (a natural stimulant) as by-product of their activities in the soil (Pieterse *et al.*, 1996). Therefore, ethylene stimulates *Striga* seed germination in the absence of the host hence death of the germinated seed.

Striga infestation is reported to be associated with low soil nitrogen (Parker and Riches, 1993; Sauerborn, 1991). Through application of nitrogen (50 kg ha^{-1}) in the form of urea 46 % N or ammonium sulphate 21 % N, *Striga* infestation can be reduced. Nitrogen fertilizer has a direct effect on *Striga* and an indirect effect to the host plant. Germination is inhibited and the growth of the haustoria is reduced (Sauerborn, 1991). There is also a possibility of toxicity effect on the developing *Striga* (Parker and Riches, 1993). The extent of inhibition and toxicity of nitrogen fertilizers to *Striga* depends on the form of nitrogen fertilizer and the concentration (Sauerborn, 1991; Parker and Riches, 1993). The effective forms of nitrogen are urea 46 % N and sulphate of ammonia 21 % N but the concentration vary with soil, crop and cropping system. The effects of nitrogen fertilizer to the host are delayed or reduced production of germination stimulant, modification of the ratio of root:shoot balance in favour of shoots which oppose the effect of *Striga* (Parker and Riches, 1993). Other effects are the increase in the potential difference of the host roots that reduces the flow of water and nutrients from the host to the parasite (Sauerbon, 1991; Parker and Riches, 1993). In addition, there is a change of the microclimate resulting from a well-developed host canopy. The change caused an increase of air humidity, reduced light and lowering of the temperature of the host and the parasite. In order to have an effective control of *Striga* by nitrogen fertiliser the time of application is very important. Pieterse and Verkleij (1991) reported that nitrogen fertiliser reduced *Striga* infestation when applied at the time *Striga* started to attach itself to the host root. When applied early or late nitrogen did not affect *Striga* adversely. Under alkaline conditions germination of *Striga* was inhibited, because the germination stimulant became inactive (Okonkwo, 1991b), but no specific pH range has been given as conducive for *Striga* germination. *Striga* can grow under acidic conditions like that of Kyela where the pH is 4.5 to 5.5

Soil is a very important area of consideration when planning a *Striga* control activity because it harbours the host and the parasite and it provides moisture and nutrients. Soil can be manipulated to create unfavourable conditions for *Striga* growth and development. This can be done by improving soil nitrogen to the levels that control *Striga*. Also increasing soil organic matter that improves nitrogen pool in the soil, water holding capacity and increasing microorganism activities that produce ethylene as well as attracting other micro-organisms which attack *Striga* seed in the soil.

2.4 *Striga* – host relationship

The relationship starts when a host produces *Striga* germination stimulants (Parker and Riches, 1993; Doggett, 1984; Sauerborn, 1999). If the stimulant is from a proper host, and the parasite manages to attach itself to the host the association is successful. If the stimulant is from a non-host be it a trap crop or other sources, the association will be unsuccessful leading to suicidal germination. The relationship depends on species of *Striga*, the type of host, susceptibility of the host and environmental conditions. Successful association is very important for *Striga* development, reproduction and regeneration.

On the root of a susceptible host the parasite glues and penetrates the root creating a xylem bridge, called haustorium (Kuijt, 1991). The haustoruim is responsible for the flow of water and minerals from the host into the parasite. Another important function of the haustorium is to play an active metabolic role in the nutrition of the parasite (Stewart and Press, 1990). When solute passes through the haustorium it undergoes biochemical changes, where carbon and nitrogen compounds entering the haustorium are mostly targeted for metabolization. According to Stewart and Press (1990) the carbohydrates, amino acids and organic acids in the xylem sap of *Striga* were different from those in the host (sorghum). In the xylem sap, carbohydrates concentration was five times more compared to the host and its major component was manitol which was not in the host. The nitrogen solute was citrulline in the parasite and asparagine in the host. Organic acid composition was malate and citrate in the host while malate and shikimic acids were found in the parasite.

The flow of water and minerals from the host to the parasite is facilitated by parasites' high transpiration rates (Press *et al.*, 1988). Higher transpiration rates results into lowering the potential of parasites and develops a hydrostatic gradient. The gradient facilitates the movement of the solute from the host to the parasite. Another source of potential difference is the resistance across host and parasite interface resulting from biochemical activity of the haustorium (Stewart and Press, 1990).

Obligate parasites have the ability to assimilate carbon dioxide because they have chlorophyll. Therefore, they rely on their hosts for water and mineral elements. Due to low rates of photosynthesis (0.5 - 5.0 μmol m^{-2} which is about 20-30 % of a non-parasitic plant), and higher rates of respiration they have little net carbon gain which cannot support growth (Stewart and Press, 1990). Therefore, parasites get supplemental carbon from the host when nitrogen moves in the form of organic compounds (Shah *et al.*, 1987). In other studies, it was reported that about 42 % of carbon in the parasite was obtained from hosts' photosynthesis (Graves *et al.*, 1989). There is no evidence that obligate parasites rely on their hosts for growth regulators (Stewart and Press, 1990).

The reaction of the infected host differs with crop, variety and environmental condition affecting the crop. Some of these reactions for susceptible varieties include changes in the ratio of root to shoot balance. The root system of the infected plant is stimulated while the shoot is stunted, for example in sorghum, the ratio was 0.25 and 0.61 for uninfected and infected respectively (Parker and Riches, 1993). Another reaction was reduction in photosynthesis capacity (Gurney *et al.*, 1995). This was the result of an increased absisic acid to the xylem stream of the plant that affect photosynthesis through suppression of ribulose bi-phosphate carboxylation and not through stomatal limitation (Press and Stewart, 1987; Grave *et al.*, 1989). Some susceptible crops showed reduced root development and increased transpiration ratio (Boukar *et al.*, 1996). Generally, growth was reduced due to reduced photosynthesis from 85% to 20% by actual removal of carbon by the parasite (Stewart *et al.*, 1991).

Resistant varieties react in different ways that include avoidance of the parasite by root growth habit like having fewer roots in the upper 15 to 20 cm (Heller and Wegmann, 2000) or reducing root length (Cherif-Ari, *et al.*, 1990). Sometimes, there is lack or insufficient production of germination stimulants (Oliver *et al.*, 1991, Heller and Wegmann, 2000) and mechanical barrier like strengthening of the hosts' root wall structure to stop penetration (Oliver *et al.*, 1991, Heller and Wegmann, 2000). Other resistant varieties produce germination inhibitors and sometimes inhibit radicle exoenzymes (enzyme which enable penetration of the haustorium) while other resistant varieties lack haustorium initiators. However, others resist by post attachment hypersensitive reaction or incompatibility and antibiosis. This is done by reduced *Striga* growth through unfavourable supply of the phytohormone by the host (Heller and Wegmann, 2000; Hausmann *et al.*, 2000).

The relationship between *Striga* and its host is of vital importance especially when planning control measures by using catch crops, trap crops or resistant varieties. It also provides knowledge of the mechanism of resistance or susceptibility of the variety, which is also important in the breeding for resistance.

2.5 *Striga* control strategies

Striga control measures can be grouped into four major categories. These measures include: reduction of seed bank in the soil, limitation of *Striga* seed production, reduced parasitism and prevention of *Striga* seed dissemination to *Striga* free fields (Dashiell *et al.*, 2000; Hausmann *et al.*, 2000). These control measures can be attained by various methods including cultural, mechanical, chemical and biological.

2.5.1 Hand pulling and hand hoeing

These are the most common operations done by small-scale farmers, although they are labour intensive and tedious (Ogborn, 1984). Since these methods act on emerged parasites then the effect of the parasite on the crop is not controlled. These methods only assist in reducing the population build up of *Striga* seeds in the soil. Hand pulling must be done with care before *Striga* set seeds, or else uprooted *Striga* must be destroyed carefully otherwise the operation will assist in the spread of seeds, hence negative results of the control.

2.5.2 Catch crops

Catch crops are highly susceptible varieties of crops such as sorghum and maize. Catch crops can be used to control *Striga* in the field. In order to control *Striga* infestation, the catch crop is grown early in the season so that *Striga* seeds are stimulated to germinate and attach to the catch crop. After reaching a certain stage of growth before flowering of *Striga*, the catch crop is ploughed-under together with the attached *Striga*. Then the crop of the season is planted. In doing so, the population of *Striga* seed in the soil can be depleted over time if the catch crop is grown over a number of seasons. High population density of the catch crop is needed to ensure higher *Striga* seed germination. It was reported by Parker and Riches (1993) that catch crops were economical for large-scale farming but not for small-scale farming because of higher costs associated with the purchase of seed of the catch crop and ploughing under. Another pre-requisite is that rainfall must be favourable to allow growth of the catch crop and then the main crop.

2.5.3 Trap crops

Trap crops also known as false hosts, are plants that can produce *Striga* germination stimulants while they are not proper hosts hence facilitating suicidal germination of *Striga* seeds. Trap crops differ in their ability to stimulate *Striga* germination (Parker and Reid, 1979). This variation is influenced genetically (Bebawi and Michael, 1991) or environmentally (Odhiambo and Ransom, 1996). For example, cotton needed to be supplied with nitrogen fertilizers in order to have effective root exudates to induce *Striga* germination. The effectiveness of trap crops to influence *Striga* germination depended on the potential and or compatibility of the produced stimulants because the response of *Striga* to trap crops is specific (Parker and Riches, 1993). The development of the root system to reach more *Striga* seeds in the soil is also an important factor. On the other hand, effectiveness can depend on soil fertility improvement since *Striga* development is negatively correlated to higher levels of nitrogen in the soil. In addition, a trap crop inter-cropped with susceptible variety can affect *Striga* by shading. Shading increases the relative humidity around the plant and lowers the temperature of the surroundings. In doing so, evapo-transpiration from the *Striga* is lowered and growth and development of the parasite is retarded. Advantages of using trap crops in the field are reduction of *Striga* seed population in the soil, reduced *Striga* parasitism, improved tolerance of the crop to *Striga*, and improved soil fertility when trap crops are legumes.

Trap crops can be used effectively in the control of *Striga* when they are used in inter-cropping, as green manure or in crop rotation. In inter-cropping, trap crops reduced *Striga* incidence and increased the yield of susceptible crops (Parker and Riches, 1993). They ameliorated the microclimate in the field hence reduced the transpiration rate of the parasite that resulted in the reduction of the uptake of water and minerals from the host (Parker and Riches, 1993). Other advantages of inter-cropping are increased land equivalent ratio compared to sole crop and reduced total loss of crop in case of calamities (Giller and Wilson, 1993). In terms of soil fertility, a mixture of legume and cereal improves nitrogen economy by contributing nitrogen to the soil for cereals nutrient uptake (nitrogen transfer) or by taking less nitrogen from the soil (sparing effect).

Different spatial arrangements have been tested in the control of *Striga* by inter-cropping, these included inter-row and intra-row arrangements. Parker and Riches (1993) and Mbwaga *et al.* (2000) reported that intra-row arrangement is more effective than inter-row arrangements. This may be due to root distribution and root density (length per volume of soil) of the legume. The root density is determined by variety of the plant, and influenced by soil type, soil moisture, nutrient availability and soil management practices (Myers *et al.*, 1994). It was reported by Parker and Riches (1993) and Mbwaga *et al.*, (2000) that the level of *Striga* infestation was higher in sole crop than in inter-row arrangement. In intra-row arrangement, the level of *Striga* infestation was very low while in the sole crop the level of infestation was high. On the other hand, the yield of the host increased in the opposite way that is more yields in the intra-row arrangement followed by inter-row arrangement and sole crop.

In rotation, trap crops need different rotation sequences in order to optimise the benefit of *Striga* control. This is due to the variation in their ability to stimulate *Striga* germination. A plant species which can stimulate higher number of *Striga* seed than others stand a better chance of reducing *Striga* seed population in the soil faster than others. Parker and Riches (1993) reported that soy bean (*Glycine max* L.) and pea (*Pisum sativum* (L.) needed four years to reduce *Striga* infestation in the field which could be reduced by pearl millet (*Pennisetum glaucum* L.) in three years. It is possible to find varieties of the same crop differing in their capacity to induce *Striga* germination. This can be the result of different ability to produce stimulants, rooting density and compatibility with the *Striga* species (Sauerborn, 1991). When a legume is used in the rotation sequence, there will be an improvement in the soil nitrogen.

Other trap crops can also be used as green manure. Green manure is known to involve growing of succulent plants, normally legumes, for the purpose of incorporation in the soil to improve soil fertility (Muller-Samann and Koschi, 1994).

Some green manures are suspected to produce *Striga* germination inhibitors and/or interfere with the production of *Striga* germination stimulants. In order to improve soil fertility, green manures have to decompose to make nutrients available for plant uptake. According to House and Stinner (1987), decomposition is the decrease in the mass of the material that results from leaching soluble material, catabolism and oxidation of organic matter and physical break down. The rate of decomposition is highly influenced by the quality of the plant material in terms of lignin, polyphenols and C: N ratio (Palm and Sanchez, 1991). These can enable one to predict decomposition of plant residue because when plant materials with high levels of lignin and polyphenol tend to resist decay (Giller and Wilson, 1993).

Lignin influences decomposition by reducing availability of carbohydrates and proteins by forming complexes hence resistance to decomposition (Swain, 1979). Polyphenols are phenolic compounds that bind plant proteins to form complexes. In the process of binding protein amount of nitrogen became unavailable for decomposition because nitrogen is a major component of protein (Giller and Wilson, 1993). According to Giller and Wilson (1993), C: N ratio is the proportion of nitrogen relative to dry weight which indicates how rapid a plant material is likely to decompose. Myer *et al.* (1994) reported that when a concentration of nitrogen in a plant material was less than 2% or C: N ratio greater than 25:1, this favoured immobilisation of nitrogen. This means nitrogen was utilised by microorganism hence not available for plant uptake. When the concentration of nitrogen was higher than 2% or C: N ratio less than 25, mineralisation was favoured, that means, nitrogen was available for plant uptake. Observation by Giller and Wilson (1993) showed that legumes tend to decompose faster and release about 40 % nitrogen in less than 2 weeks. Under rice ecosystems the decomposition of green manure is faster in upland ecosystem than lowland ecosystem, also utilisation of nitrogen from green manure is efficient in upland ecosystem than lowland ecosystem (Sisworo *et al.*, 1990). The effectiveness of green manure decomposition and nitrogen utilisation in the upland condition is governed by availability of oxygen in the soil (De Datta, 1981). When soil is submerged, water replaces air in the pore spaces hence no oxygen available for microbial activities. In addition, in the absence of oxygen, substances that interfere with nutrient uptake or poison the plant are produced (De Datta, 1981).

In order to determine the suitability of tropical legumes for green manure, screening can be done based on amount of nitrogen accumulated and estimation of the amount of mineral nitrogen in the soil after incorporation. Other methods of screening are determination of the amount of nitrogen released when dried sample of green manure are incubated under aerobic condition and nitrogen released under buried bags incubated in situ (Giller and Wilson, 1993).

The use of trap crops or false hosts is one of the potential *Striga* control measures. Therefore, in order to use trap crops screening must be done to know their effectiveness in inducing *Striga* seeds germination in the field. On the other hand, it is important to know the cropping system that is compatible to the farming system. In addition, the knowledge of other parasitic weeds in the Schrophulariaceae family which attack some trap crops like *Striga gesneroides* and *Alectra vogelii* will assist in the planning for an effective control programme.

2.5.4 Nitrogen fertilizers

Nitrogen in the soil is an important factor in the control of *Striga* because normally *Striga* infestation is found on soils with low nitrogen levels. The application of nitrogen fertilizers has proved to reduce *Striga* number and crop loss. The inhibition effect of nitrogen to *Striga* depends on the form and concentration of nitrogen. Effective forms of nitrogen are ammonia and urea (Sauerborn, 1991, Okonkwo, 1991b, Parker and Riches, 1993), but among the two, urea is more effective than ammonia (Okonkwo, 1991b). It was reported by Okonkwo (1991b) that Nitrogen fertilizer in the form of urea at the concentration between 100 and 1600 mg l^{-1} inhibited *Striga* seed germination and development. Main effects of nitrogen to *Striga* include reduction and/or delayed production of germination stimulants (Cechin and Press, 1993), damaged seed and seedlings in the soil by toxic effects. In addition, slowed-down attachment processes by reducing germ tube growth (Parker and Riches, 1993). Other direct effects of nitrogen fertilizer to *Striga* are the alteration of the host root balance in favour of shoots that oppose the effect of *Striga* to the host (Parker and Riches, 1993). Also the alteration of osmotic pressure in the parasite relative to the host that reduces the flow of water and nutrients from the host to the parasite (Sauerbon, 1991; Parker and Riches, 1993).

Nitrogen reduces incidence of *Striga* and increases crop yields when applied at the appropriate time. If nitrogen is applied early in the season *Striga* will emerge late in the season (Pieterse *et al.*, 1996) because of nitrogen depletion leaving healthy roots prone to *Striga* attack. This means nitrogen fertilizer will improve root system by increasing root density in the topsoil which will lead to success of the parasite. When applied late there will be an increase in *Striga* number late in the season as observed by Pieterse *et al.* (1996). The reason is that nitrogen will improve already infested root system. Therefore, the source of nitrogen fertilizer, time of application of nitrogen fertilizer and the rate of application are very important factors in the control of *Striga* and improvement of the host yield. It is important to ensure that the time of fertilizer application coincides with the time of *Striga* germination and attachment to the host (Pieterse *et al.*, 1996).

2.5.5 Resistant/tolerant varieties

Crops that resist the effect of *Striga* have long been identified. Resistant varieties are those which can germinate and support fewer *Striga* plants when grown on *Striga* infested area, at the same time they produces satisfactory grain yield. Varieties that can germinate and support a high number of *Striga* and produce low yields are called tolerant. Examples of resistant varieties of sorghum are, Framida, Dobbs and N13 (Doggett, 1984), SRN39, SAR29, P9405, and Serena (Mbwaga *et al.*, 2000). Resistant rice varieties include Mwangulu (Mbwaga *et al.*, 2000), ACC102196, Makassa, and IG10 (Riches *et al.*, 1996). There are different mechanisms of resistance as shown by parasite-host relationship, these mechanism vary with crop, variety, and the environment.

Resistant varieties are reported to react in different ways that include avoidance of the parasite. This could be fewer roots in the upper 15 to 20 cm like sorghum variety P-967083 (Heller and Wegmann, 2000) or reduced root length (Cherif-Ari *et al.*, 1990). Other varieties showed insufficient production of germination stimulants, for example sorghum varieties Framida, IS-1073 and IS-9830 (Oliver *et al.*, 1991; Heller and Wegmann, 2000). Whereas in some cases there was a mechanical barrier which strengthens host's root wall structures to stop penetration as shown by sorghum SRN 39 (Oliver *et al.*, 1991; Heller and Wegmann, 2000). Other resistant varieties like sorghum variety called Seredo produced germination inhibitors and sometimes inhibited radicle exoenzymes (enzyme which enable penetration of the haustorium). However, other resistant varieties like Framida, Dobbs and Seredo resisted by post attachment hypersensitive reaction or incompatibility and antibiosis (Heller and Wegmann, 2000). Antibiosis is shown by reduced *Striga* growth through unfavourable supply of the phytohormone by the host (Heller and Wegmann, 2000; Hausmann *et al.*, 2000).

The mechanism of resistance is very important in identifying the gene of resistance and in the planning for *Striga* control. By knowing the mechanism of resistance one can determine the variety to be grown or a variety to be used in intercropping or sequential cropping. On the other hand, the use of resistant varieties must be accompanied with other control measures because these varieties can support parasites to grow and produce seeds, hence increased seed population in the soil.

2.5.6 Chemical control

The important area to focus when considering *Striga* control strategy is the seed population in the soil. Egley (1999) suggested the best time to apply chemicals is when seeds are ready to germinate, at this time the chemical will be effective to reduce seed in the soil and prevent attachment to the hosts. However, soil can affect the efficacy of the herbicide.

When a herbicide is applied to the soil, it undergoes some processes that affect its efficacy. These processes are grouped into physical, biological and non-biological (Akobundu, 1987). Physical processes include leaching, and volatilisation, while biological processes include microbial decomposition, and non-biological processes are adsorption, chemical and photo-decomposition. Leaching is the movement of chemical from upper layer of the soil to lower layers. The movement of chemical is affected by water in the soil, soil texture, chemical properties of the herbicide and its solubility. Examples of highly leachable herbicides are those in the Uracil group. Volatilisation is the process of changing from liquid state to gaseous state depending on volatility of the herbicide and the soil moisture status during application of herbicide. If herbicide is applied on dry soil, there are high chances of volatilisation than when applied on moist soil. Microbial decomposition takes place when micro-organism breakdown organic compounds in order to get energy, for example 2,4-D can be broken down into Cl, CO_2 and water (Akobundu, 1987). Non biological processes can occur when there is chemical decomposition due to soil moisture, ions in the soil, soil temperature, pH and adsorption (herbicide attached to the surface of the soil particles). Dinitroaniline (Pendimethalin) and propharm (Chloprophan) are examples of herbicides that are unstable and can decompose when left on the soil for a period (Akobundu, 1987).

An effective herbicide for the control of *Striga* should control before or immediately after attachment to the host, this can prevent damages to the host (Parker and Riches, 1993). Some pre-emergence herbicides were screened for the control of *Striga*, imazapyr (imazaquin) was reported to be effective (Kanampiu *et al.*, 1997).

Germination stimulant is another group of effective chemicals that can control *Striga*. These included ethylene (glycomonobutyl ether - C_2H^4) (Egley *et al.*, 1990), ethephon (2 chloroethyl phosphonic acid – $C_2H_6ClO_3P$) (Parker and Riches, 1993) and strigol analogues, GR24, GR7, GR5 (Okonkwo, 1991b; Sauerborn, 1991; Parker and Riches, 1993). These were reported to show variable results in the field. However, because of being unstable and insoluble in the soil, and due to high production costs it was uneconomic to produce large quantities to be used in fields (Parker and Riches, 1993).

Another group of chemicals is anti-transpirants like wiltpruf (di-1-p methene). These are applied post-emergence and they can control emerged *Striga* effectively in sorghum where there is higher transpiration rates and air temperature ranging from 37.2 ^{0}C to 40.1 ^{0}C, the optimal temperature for host-parasite association (Press *et al.*, 1989). Application of anti-transpirants impedes foliar loss of water in the air and in doing so reduces transpiration and stomatal conductance by 40 to 57%. The reduction in transpiration causes the temperature of *Striga* leaf to rise to 42.6 ^{0}C. This temperature kills a parasite after 4 hours (Press *et al.*, 1989). Normally the leaf temperature of the *Striga* is below that of the air. For example if the air temperature is 40 ^{0}C, then that of *Striga* is 7 ^{0}C less due to higher transpiration and consequent evaporative cooling.

Chemical control is an important and effective control measure, but due to the associated costs and expertise, small-scale farmers cannot afford. Therefore, it is important to use the right chemical, to apply the right rates at right time in order to benefit from its efficacy and to avoid unnecessary hazards to living organisms and the environment.

2.5.7 Allelochemicals

Rice (1974) defined allelopathy as a direct or indirect harmful effect by one plant on another caused by production of chemical compounds that escape into the environment. Rice (1974) categorised potential allelochemicals in agriculture as terpenoids and steroids, phenolic and their derivatives, coumarins, flavonoids, tannins, alkaloids and cynohydrins.

Allelochemicals are water-soluble compounds that are leached from the foliage, litter, root exudates or volatile substances that diffuse from foliage into the soil. Allelochemicals have allelopathic effects. The amount released depends on the biomass and density of the plants as well as concentration and solubility of the chemical (Weidenhamer, 1996). In the soil, allelochemicals are affected like other herbicides but they are continually added (to the soil) and their toxicity depends on concentration and flux rate (Weidenhamer, 1996). Allellopathy can be autotoxicity or heterotoxicity (Miller 1996). Autotoxicity occurs when a plant produced toxic substances that inhibit germination and development of plants of the same specie. This was observed in *Medicago sativa* L. (alfa alfa). Whereas heterotoxicity occurred when a plant produced toxic materials that affected growth and development of plants of another specie for example *Abutilon theophrasti* L. (Velvet-leaf) and

Chenopodium album L. (lamb quarter) extracts on the germination of *M. sativa.* Patrick *et al.* (1963) as quoted by Miller, (1996) showed that many legumes contain substances with allellopathic potential. Plants with allelopathic potential can be useful in crop production for the control of weeds when used in rotation, intercropping or as cover crops. The potential of these plants differ with species and type of use (Weston, 1996). The effectiveness of the potential to control weeds is highly affected by environmental conditions that interfere with allelopathic effect (Wenston, 1996). Einhelling (1996) reported that allelochemicals are normally found in combination, that means several one allellochemicals are found in the site of action.

Ariga (1997) indicated the possibility of using allelopathic crops in weed management. He used plant extracts of *Avena fatua* L. (Wild oats), *Bidens pilosa* L. (Black jack), *Cynodon dactylon* L. (Couch grass), *Datura stramonium* L., and *Helianthus annus* L. and found that they had an inhibitory effect to the seed of crop plants. Al Menouf *et al.* (1996) reported that extracts of fungreek (*Trigonella foenum graecum* L.), lupin (*Lupinus termis* L.), coriander (*Corrandrum sativum* L.) and turnip (*Brassica rapa* L.) reduced the stimulatory effect of GR24. Based on these results he recommended these plants to be used in intercropping to reduce the infestation of *Orobanche crenata* (L.) and *O. ramosa* (L.) in the field.

Other allelochemical potential was reported by Friesen and Korwar (1991) who found that aqueous extracts of *Euphorbia acalyphoides* (L.) and *E. pilulifera* (L.) which produce phenolic acids reduced *Striga* infestation when sorghum seed was hardened pre-sowing. Allelochemical which show good potential in the control of *Striga* can be considered in the control programme because no single control measure has proved to be 100% efficient.

2.5.8 Biological control

Parker and Riches (1993) and Sauerborn (1991) have documented a number of insects that are natural enemies to *Striga*. The potential ones include *Smicronyx albovariegatus* (Faust), *Junonia orithya* (L.), *Ophyomia strigalis* (Spencer.), *Eutocastra argentisparsa* (Hamps.), *E. undalata* (Snellen), and *Stenophilodes taprobanes* (Feld.). These insects attack *Striga* by feeding on flowers, fruits, stems, roots and leaves, so they kill *Striga* plants or reduce seed production. Sauerborn (1991) documented potential insects in Tanzania. They include *Stenophilia spp* which feed on flower and fruits while *Junonia oenone* (L.), *Diachrisia investigatorum* (Karsch.) are defoliators, *Melanogromyza spp* (Spencer.), *Ophiomia strigalis* (Spencer.) mine stem and roots, *Smicronyx spp* (Haustache) mine fruits. Since they cause little damage to *Striga* population in the field then they cannot be used alone in the control of *Striga* (Parker and Riches, 1993).

Pathogens also have shown potential in the control of *Striga*. These include: *Sphaerotheca fuliginen* (Schltdl.), *Phoma spp* (Sacc.), *Cercospora spp* (Freesen), *Fusarium aquuiseti* (Corda), *Drechstera longirostrata* (Subram) and *Microphomina phaseoline* (Tassi). These have shown a negative effect on *Striga* growth and development by inhibiting *Striga* seed germination and causing wilting and girdling of *Striga* stems. Coitola *et al.* (1996) used a bioherbicide *Fusarium oxysporum*

(Sneyder and Hansen) to inhibit and suppress the germination of *S. hermonthica*. He found that the bioherbicide was very effective at early stages of *Striga* development. *Azospirillium brasilense* (Tarran and Kreig) strains isolated from soil under *S. hermonthica* significantly inhibited the growth of *S. hermonthica* (Abbasher *et al*., 1996). Abbasher, (1994) reported that *Fusarium nygamai* (Burgess and trimboli) and *F. semitectum var majus* were effective in the control of *Striga* from seed to flowering stage. Young *Striga* plants were more susceptible and they died shortly after infection compared to old plants. *Fusarium nygamai* and *Fusarium semitectum var majus* (Schlecht. Emend.) were applied by incorporation in the soil before planting and they attack *Striga* seeds at early stages of growth. After a period of 12 months the concentration of the inoculum was not sufficient to cause disease for *Fusarium spp*, but other species showed 95 to 100% efficiency in the following season (Abbasher, 1994).

2.6 Green manure

Green manures are young tender plants incorporated in the soil in order to improve soil fertility status. High soil nitrogen can control *Striga* in the field because nitrogen reduce production of germination stimulant from the host, enable the host to grow faster to create unfavourable condition for *Striga* growth and development (Parker and Riches, 1993). Therefore, *Striga* infestation in the field is highly favoured by low soil nitrogen. Low nitrogen status can result from depletion of soil nitrogen that is caused by continuous cultivation of the land, changes in the farming practices like shorter or lack of fallow and lack of crop rotation. In the control of *Striga*, green manures play a very important role, they reduce *Striga* seed bank in the soil and improve soil fertility status. The improvement of soil fertility results into increasing yield of the host crop, at the same time reduce *Striga* population.

Soil fertility depletion can occur where the land is under continuous cultivation. It was reported by Smalling (1993) that under continuous cultivation of the land there is an estimated negative nutrient balance approaching 20 to 60 kg N ha^{-1} and 5 to 15 kg P ha^{-1} annually. In order to avoid this situation soil fertility can be improved by addition of soil nutrients using organic and or inorganic fertilizers. Buresh and Tian (1997) reported that in a long-term process, the application of inorganic and readily decomposed organic fertilizers does not replenish soil nitrogen stock, unless there is an increase in soil organic matter. The reason behind is that, the building up of soil nitrogen stock is facilitated by the increase in soil organic matter (Buresh and Tian, 1997). Organic matter is obtained from organic fertilisers which include animal manure, green manure, crop residues and agro-forestry leguminous pruning. In order to replenish soil nitrogen by green manure Rao *et al.* (1998b) suggested the use of short cycle fast growing trees, use of shrub fallow or use of green manure grown elsewhere. The use of green manure is more beneficial because it improves soil fertility in a sustainable way, reduces weed problem and conserves the environment. According to ICRAF (1997), improved fallow is promoted as a promising technology for soil improvement in nitrogen deficient soils of Africa because the technology is affordable and easily incorporated in the farming system.

2.6.1 Green manure and soil fertility

Green manure are plants used as organic fertilizers when applied to the soil, they normally include legumes. In the field, green manure can be obtained from hedgerow intercropping pruning or improved fallow with herbaceous species. In the process of improving soil fertility, incorporated green manure has to decompose to make nutrients available for plant uptake. The amount of nitrogen recovered or available to the plant depends on the rate of organic matter decomposition (Nair *et al.*, 1999). House and Stinner (1987) defined decomposition as the decrease in the mass of the material that results from leaching soluble materials, catabolism, and oxidation of organic matter and physical breakdown. The rate of decomposition is highly influenced by the interaction of environment, soil organisms, quality of the plant material and its management (Anderson and Ingram, 1993).

According to Myers *et al*, (1994) Synchronisation is very important to ensure that crops benefit from nutrients obtained after decomposition of the applied green manure. By synchronisation, plant nutrients from the decomposed green manure are made available to the plants at a period of high demand. This reduces nutrient losses by fast decomposing plant materials.

The general purpose of using green manure is to improve soil fertility in order to discourage *Striga* infestation. In order to understand the effect of green manure on soil fertility, the fertility must be looked into in terms of chemical, physical and biological

2.6.1.1 Chemical soil fertility

The application of green manure has short-term and long-term benefits both of which influence chemical fertility. The short-term benefits involve nutrient release through decomposition of recently added green manure. However long-term benefits influence sustainable production of crops by influencing nutrient stock that occur over years from regular addition of pruned materials and root turnover. This increases the dynamic pool of soil organic matter and plant available nutrients (nitrogen, phosphorus and exchangeable cations). Management and source of green manure may affect the time taken to improve soil fertility. However the magnitude of soil fertility improvement depends on the species, length of fallow and soil condition (Rao *et al.*, 1998a). Species differ because of their adaptation to soil and climatic conditions, rooting characteristics, biological nitrogen fixation and ability to establish mycorrhizal association (Rao *et al.*, 1998a).

Rao *et al.* (1998a) reported that pH affected soil fertility through reallocation of basic cations in the soil profile. Therefore, the decrease in pH during fallow phase was related to the leaching of basic cations, hydrogen released during biological nitrogen fixation and uptake of cation from low layers of soil and stored in a standing biomass. The increase of pH was related to recycled cations from lower layer brought to the surface after litter fall. According to Rao *et al.* (1998a) the change in pH caused by leaf fall varied with plant species. The pH decreased under *Acacia auriculiformis*, (Benth.) pH remained unaffected under *Leucaena spp* (L.) and it increased under *Azadirachta indica* (A. Juss), *Sesbania sesban* (L.), *Cajanus cajan* (L.) and *Senna siamea* (Lam.). This ability of the green manure to alter the pH of the soil enable green manure to renovate acidic, saline and alkali soils to make them better for other crops. In the control of *Striga*, chemical fertility plays an important role because it affects conditions favourable for *Striga* growth and development. It improves soil nitrogen that has the negative effect on the growth of the parasite at the same time enable the host to avoid the effect of the parasite.

2.6.1.2 Physical soil fertility

The physical condition of the soil can be improved by green manure through the increase of organic matter in the soil and consequently increase soil biological activities (Rao *et al.*, 1998). Therefore, there will be better soil aggregation, lower bulk density, lower resistance to penetration and improved porosity. This will result into increased water infiltration and water holding capacity. Under good water holding capacity, the growth of *Striga* is limited due to long conditioning period and dilution of germination stimulants from the host. Therefore the improvement of the physical conditions of the soil will favour the host and discourage the parasite.

2.6.1.3 Biological soil fertility

Soil flora and soil fauna play a major role in soil biological activity, the microbial biomass and earthworm activity were reported to increase when organic matter is added to the soil (Rao *et al.* 1998a). Soil micro fauna play a significant role in improving soil fertility by decomposition of organic matter to improve nutrient status of the soil, and improving soil structure. Hence good soil – water relation and nutrient availability (Rao *et al.*, 1998a). Biological activity in the soil results in the production of ethylene a by-product, this chemical is a natural germination stimulant therefore it can cause suicidal germination of *Striga* seeds hence reduced *Striga* seed in the soil (Parker and Riches, 1993).

Rao *et al*, (1998a) reported that when green manure was used as mulch or fallow it reduced weed infestation in the field. The potential to reduce weed was the result of pruning provided a ground cover, shading effect, and sometimes allelopathy. According to Kang (1993), seed bank of weeds in the soil is reduced by prevention of further seeding (above ground growth) and prevention of germination. The ability of the species to control weeds depended on biomass production, decomposition rate of the litter and the size of the canopy (Rao *et al.*, 1998a). In special cases where there is witchweed green manure have a greater potential in the control of the *Striga*. Green manure improves nitrogen status of the soil that has a negative effect to *Striga* germination and development. Green manure also produces germination stimulants or inhibitors in doing so reduce *Striga* seed by suicidal germination or prevent germination in the case of inhibitors.

2.6.2 Decomposition

Decomposition is a process whereby organic matter is broken-down by microbial enzymes to release soluble and insoluble products. These products are separated from the parent material by leaching, physical fragmentation and activities of macro and micro- organisms in the soil. In crop production, decomposition process takes place in order to release nutrients from the organic material depending on the quality of the plant material, environment and the available decomposer organisms (Nair *et al.*, 1999). The process of decomposition is affected by chemical, biological and physical factors.

2.6.2.1 Chemical and biological factors affecting decomposition

The rate of decomposition is highly influenced by the quality of the plant material in terms of lignin, polyphenols and C: N ratio (Palm and Sanchez, 1991). These factors can enable prediction of the rate of decomposition, because high levels of lignin and polyphenols make plant materials to resist decay (Giller and Wilson, 1993). Nutrient content of plant materials depends on species, plant part, relative proportion of the leaves and twigs, age of tissue, frequency of pruning, soil and climatic factors (Palm 1995). Therefore, in the control of *Striga* factors affecting decomposition must favour decomposition. This will make nutrients to be released at critical time of requirement; for example, the 5th week after rice germination is a critical time for the control of *Striga* in Kyela.

Lignin

In Agroforestry trees lignin ranges between 5 to 20% of dry weight in green foliage but 15 % was reported to be critical (Mafongonya *et al.*, 1997a). Lignin can be used to predict decomposition of plant materials because it affects the rate of decomposition. The ratio of L: N is useful in determining decomposition for litter material that has low percent nitrogen and high amount of lignin (Mafongonya *et al.*, 1998a). Lignin influences decomposition by reducing available carbohydrates and proteins by forming complexes in cell walls that resisted decomposition (Swain, 1979). However, lignin also makes carbohydrate unavailable to the decomposers hence low energy supplied to decomposers. Therefore plant materials with narrow L: N ratios are preferred for the control of *Striga*.

C: N ratio

Giller and_Wilson (1993) defined C: N ratio as the proportion of nitrogen relative to dry weight which indicates how rapid a plant material is likely to decompose. Myers *et al.* (1994) reported that when a concentration of nitrogen in a plant material is less than 2 % or C:N ratio greater than 25:1 it favours immobilisation of nitrogen. If the concentration of nitrogen is higher than 2% or C: N ratio less than 25:1 mineralisation will be favoured. Observation by Giller and Wilson (1993) showed that legumes have low C: N ratio, therefore they tend to decompose faster and release about 40% nitrogen in less than 2 weeks. Therefore, legumes are favourable green manures in the control of *Striga* because apart from narrow C: N ratio some of them can be trap crops.

Polyphenols

Polyphenols are phenollic compounds that differ in size, solubility and reactivity. Polyphenols bind plant protein to form complexes that reduce release of nitrogen in the decomposition process (Giller and Wilson, 1993). Polyphenols have the ability to supply carbon to decomposers at the same time they inhibit growth and reactivity of decomposers and other organisms. Therefore the factor for plant material to resist decomposition is not the amount of polyphenols it has but rather the type or their protein binding capacity called reactivity (Mafongonya *et al.*, 1998a).

Quality of plant materials

The quality of the plant materials is normally measured in terms of Nitrogen (N) and Phosphorus (P) minerilazation pattern. According to Mafongonya *et al.* (1998b) plant materials of high quality are those with 20 mg g^{-1} N and 2.5 mg g^{-1} P (0.02 % N and 0.025% P). In addition, the quality of the plant material was referred to according to its carbon constituent and nitrogen content. This involved soluble carbon, cellulose, hemicellulose, lignin, polyphenols and nitrogen, (Mafongonya *et al.*, 1998a). The amount of carbon and soluble carbon is very important for microorganism decomposers because that is their major source of energy for growth and decomposition process in the soil (Mafongonya *et al.*, 1998a). Therefore, Mafongonya *et al.* (1998a) regarded lignin as an important factor determining the rate of decomposition because of its low quality in terms of energy provided to the decomposer microorganism and its resistance against microbial degradation. However it was suggested that (lignin + polyphenol): N was an excellent predictor of decomposition because that ratio showed a close relationship to the rate of nitrogen mineralisation.

Soil pH

Another factor affecting decomposition of the plant materials is the pH of the soil. Soil pH is affected by water regime, concentration of salts, exchangeable cations and CO_2 in the soil. The soil pH determines the type of microorganism that take part in the decomposition of the green manure in the soil. On the other hand, it determines the type of chemical reactions and the rates of reactions in the soil. Soil pH also has a direct effect on growth and development of the host plant therefore it affects the growth and development of *Striga*.

2.6.2.2 Physical factors affecting decomposition

Water and air

Water is a very important input affecting microbial activity in the soil. Under water logged conditions microbial activities are restricted because of absence of air. Therefore, high moisture levels and extreme low levels can lower the rate of decomposition. Oxygen in the soil determined the type of decomposers and its absence lowered the rate of decomposition (Palm and Sanchez, 1991). The presence of carbon dioxide in the soil influenced microhabitat and inhibited growth of some organisms (Dickinson, 1974).

Water has direct effect on microorganism in the soil. Scholes *et al.* (1994) reported that activity and mobility of bacteria in the soil was restricted at –1.5 MPa while fungi were active up to –15 Mpa. At the same time when the water potential was –1.5 to –3.0 Mpa water and nutrient uptake seized and decomposition stopped.

Soil temperature

Organisms can tolerate different levels of temperature in the environment they are living in. Therefore soil temperature dictates the type of organism to decompose plant material in the soil (Alexander, 1987) and the rate of decomposition (Palm and Sanchez, 1991). Temperature also determines growth and activity of microorganisms when interacted with other factors like water. In a study by Scholes *et al.* (1994), the rate of decomposition increased with increase in temperature between 10 to 30^{0}C. The temperature of 30^{0}C was the maximum for respiration, above 30^{0}C respiration and activities of the organisms in the soil started to decline. When temperature reached 40^{0}C the decomposition decreased significantly (Scholes *et. al.* 1994). Temperatures that are conducive for decomposition process are also appropriate for *Striga* conditioning and germination therefore by-product of decomposition like ethylene gas stands a better chance of causing suicidal germination of the parasite.

Soil structure

Soil structure has an indirect effect on the decomposition process. It determines water movement, aeration and temperature in the soil (Dickinson, 1974). It has direct effect on the growth and movement of organisms and spread of microbial propagules. On the other hand, it determines the growth and development of the host as well as *Striga*.

Factors affecting decomposition depends on each other and sometimes act together to accomplish decomposition of the plant materials in the soil. The same factors have direct and indirect effects on growth and development of the host plant and *Striga*.

2.6.3 Synchrony

Synchronisation of the nutrient released and plant uptake implies that the rate of nutrient released during decomposition is closely related to the rate at which it is needed by the plant (Myers *et al.*, 1994). Synchronisation is very important because it ensures efficient use of nutrients and minimises nutrient losses. Mafongonya *et al.* (1998 a) suggested two ways to improve synchrony of plant nutrient released from decomposition and crop nutrient demand. One way was to regulate the rate at which nutrients are release. Another way was to provide more favourable environment for plant growth, like improvement of nutrient capture through extensive roots. In order to regulate nutrient release rate, plant shoots of varied rates of decomposition could be used. On the other hand, the use of fresh litter, reduced size litter materials and incorporation of the litter material in the soil increases the rate at which nutrients are released from the litter material (Mafongonya *et al.*, 1997b).

Under *Striga* infestation synchronisation of the nutrients released and plant uptake is very important. It enables the host plant to withstand the effect of the parasite by efficient acquisition and utilisation of the plant nutrient obtained from decomposition. It also suppresses *Striga* under the negative effect of soil nitrogen.

The witch weed (*Striga spp*) will continue to threaten cereal production since the farming system continues to provide favourable reproduction conditions for *Striga*. The conditions include depletion of soil fertility caused by continuous cultivation of the land, poor agronomic practices and poor *Striga* control measures. In order to avoid *Striga* problem deliberate effort should be geared towards reducing *Striga* seed population in the soil and improvement of soil fertility to reduce *Striga* growth and development. When measures to reduce *Striga* or improve soil fertility are employed, care must be taken to minimise environmental degradation, a challenge for the 21st Century (Sibuga, 1997). In addition, control measures to be employed must enable farmers to control *Striga* and find it worthwhile to do so in the farming system.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 EXPERIMENT 1: Decomposition of green manure in upland rice soils of Kyela, Tanzania

3.1.1 Justification

There are several problems affecting rice production in Tanzania. Depletion of soil fertility is one among the major problems hindering rice production, making the national average production to be low at 1.5 t ha^{-1} (Ministry of Agriculture and Co operatives, 1998). The problem of poor soil fertility in upland rice soils of Kyela District is associated with the infestation of a parasitic weed *S. asiatica. Striga* reduces yield of rice from 10 % to total loss depending on the level of infestation (Parker and Riches, 1993; Mbwaga *et al.*, 2000).

Striga is controlled by application of inorganic nitrogen fertilizer at the rate of 50 kg N ha^{-1}. Higher prices and unavailability of inorganic fertilizers make resource poor farmers fail to afford this technology and therefore turn to a alternative source of fertilizer the green manure. Green manures can undergo mineralization to improve soil nitrogen that has a negative effect on *Striga* growth and development. In addition, green manure can reduce *Striga* seed population in the soil by behaving as a trap plant.

Therefore, the study was carried out with the specific objective of determining the rate of decomposition of green manure *C. ochroleuca*, *C. obtusifollia* and *M. invisa.* These are used as green manure in order to improve soil fertility as a strategy to control *S. asiatica* in upland-rice soils.

3.1.2 Description of the experimental site

Location

The experiment was conducted in Kyela district which lies between 30^0 40' and 30^0 00' longitudes East and 9^0 25' and 9^0 40' latitudes South. Most of the district lies on the floor of the West arm of African rift valley at the tip of lake Malawi, with an altitude of 400 to 500 m a.s.l. Two experimental sites were chosen these are located in Kilasilo and Itope villages (Figure 2). Kilasilo was selected for having been under continuous cultivation for 5 years while Itope was under fallow for 3 years.

Climate

Kyela receives 1000 mm to 2600 mm of rainfall per year, is under a monomodal rainfall system with the growing season starting from November to June. During this study period, the following climatic data were collected: rainfall, soil temperature at 10 cm and 20 cm depth, minimum and maximum air temperature (Appendix 1).

Soils

The landform of Kyela is described as flat lacustrine plain with alluvial fans, while the soils are described as Alluvial fine sands and clay loams (Mussei *et al.*, 1999). Upland rice soils of Kyela are dominated by Chromic Gleysols. These are imperfectly drained greyish sand loam to clay with moderate fertility (National Soil Services, 1993).

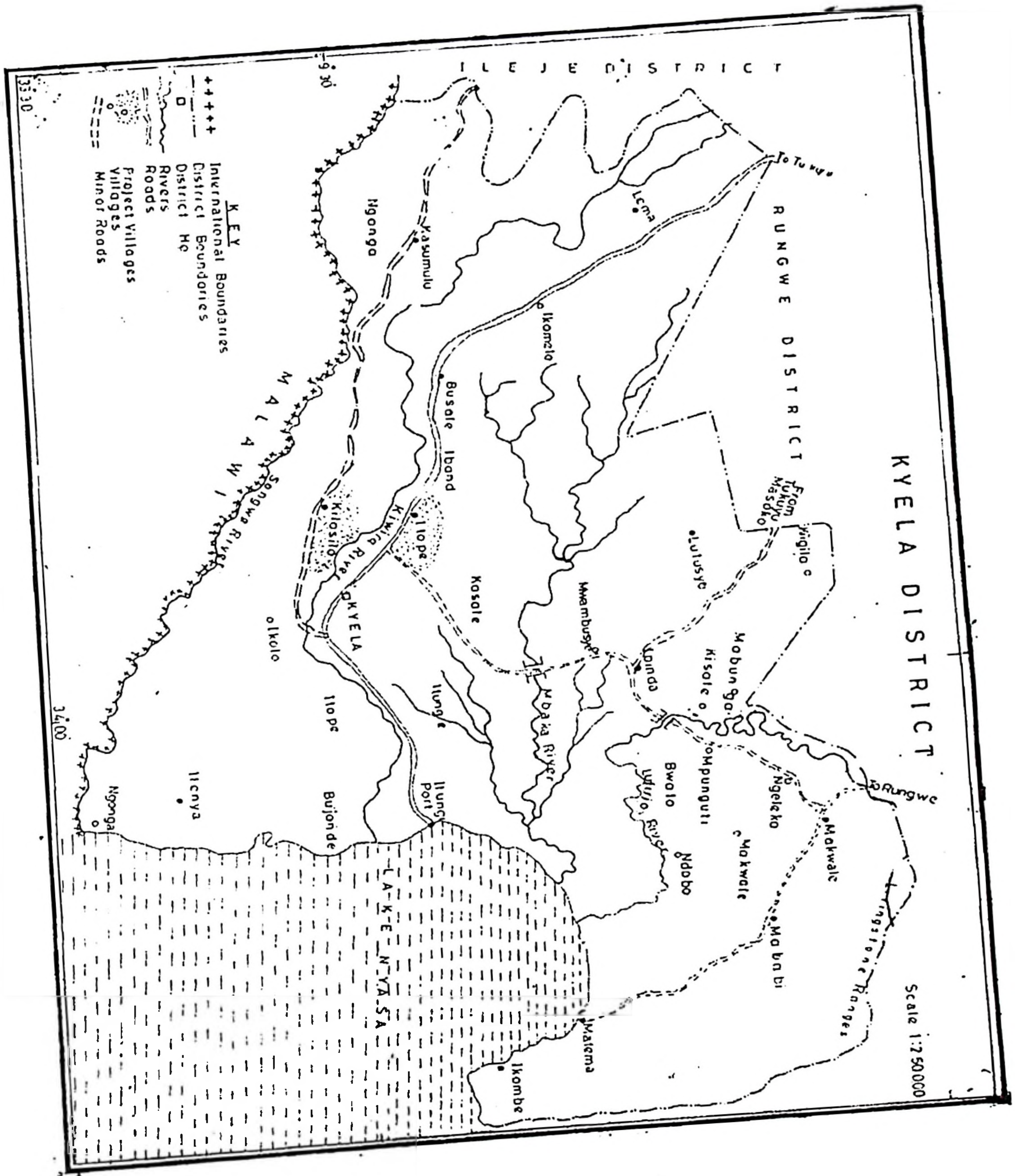


Figure 2: A map of Kyela district showing experimental site

Before setting the experiments, composite soil samples were collected from each site and analysed for their physical and chemical characteristics. 8 soil samples were collected randomly from each site at a depth of 0 to 20 cm. Samples were then mixed to make a composite sample for each site, weighing 4 kg.

Soil samples were analysed for their physical and chemical properties as follows: Soil pH was measured by using a ratio of (1:2.5) soil: water using the method described by McLean (1982). Nitrogen was determined by micro-Kjedahl digestion method (Bremner and Mulvaney, 1982) while organic carbon was determined by wet digestion method of Walkley and Black according to Nelson and Sommers (1982). Available P was extracted by Bray and Kurtz-1 method and determined spectrophotometrically according to the procedure described by Murphy and Relay (1962). Cation Exchange Capacity was determined by neutral ammonium acetate saturation method (National Soil Service, 1987). The amount of exchangeable bases in the NH_4Oac extract was determined using atomic absorption spectrophotometer (Thomas, 1982). Soil particle analysis was carried out by the hydrometer method (Gee and Bauder, 1986). Micronutrients were extracted by Diethylene triamine pentaacetic acid (DTPA) and determined by atomic absorption spectrophotometer according to the method described by Lindsay and Norvell (1978).

3.1.4 Experiment lay out and management

The experiment was set to determine decomposition pattern of shoots and roots of *C. ochroleuca*, *M. invisa* and *C. obtusifolia* by the litterbag method as described by Anderson and Ingram (1993). Litterbags were made of black nylon mesh. The size of one litterbag was 30 cm x 30 cm with mesh size of 4 mm. Inside each litterbag, another nylon mesh material (mosquito gauze) was fitted to prevent macro-fauna to enter and reach plant materials in the litterbags. It also prevents small leaves of *M. invisa* from falling out. Plant shoots and roots of green manure used in this experiment were sun-dried separately for 2 days. Then 20 g of air-dried shoots or roots were weighed and put into separate litterbags. The litterbags were buried at 20 cm depth (the rooting depth for rice plant). The litterbags with shoots were separated from those with root and were all located away from plots with rice plants.

A Randomised Complete Block Design with three replications was used to test the treatments. There were seven treatments. These included three treatments with green manure shoots (three species), three treatments with green manure roots (three species) and one control (without litterbag). Plot size was 1 m x 1 m where four litterbags were kept 40 cm apart in each plot. In each plot all the four litterbags contained a single species of green manure (shoots or roots). Litter- bags for plant shoots and those for roots were sampled once after every 2 weeks over a period of 8 weeks.

Sampling

Litterbags were retrieved from the soil by digging out the soil using a small garden shovel and then each litterbag was taken out of the soil by hand. Materials from the litterbag (while still in the mosquito gauze) were separated carefully from unwanted materials like plant roots and soil attached to the surface and put into a paper bag. These were taken to the laboratory where they were cleaned thoroughly by using a fine brush to remove sand and roots of other plants. The retrieved materials were taken out of the mosquito gauze and put in paper bags and oven dried at 60^0 C for 72 hours.

Another batch of air-dried green manure shoots and roots were ground by a power sample grinder to pass through a 1 mm sieve. The sieved samples were used for determination of initial chemical characteristics. Nitrogen, phosphorus, carbon, soluble polyphenols and lignin were determined. Nitrogen was determined by the micro-Kjedahl digestion method (Bremner and Mulvanay, 1982) while determination of total organic carbon was carried out by wet digestion method of Walkley and Black was done according to Nelson and Sommers (1982). Total P was determined according to Okalebo and Galhua (1993) where samples were dry ashed and P determined spectrophotometrically. Soluble polyphenols and lignin were determined by acid detergent fibre (ADF) method as outlined by Anderson and Ingram (1993).

Soluble polyphenols and lignin of the roots and shoots were determined as follows:
A sample of the material weighing 0.2 g was put into a 50 ml beaker, 20 ml 50% methanol were added in the beaker, covered with para-film and placed in a water bath at 77 to 80 ^{0}C for 1 hour. An extract was then obtained by filtration using Whatman No 1 filter paper into a 50 ml volumetric flask; 50% aqueous methanol was used to rinse, and filled to the mark with distilled water. After thorough mixing, 1 ml of the sample was pippeted into a 50 ml volumetric flask, 20 ml of water, 2.5 ml Follin-Denis reagent and 10 ml sodium 17% carbonate were added. Then distilled water was added to the mark and left to stand for 20 minutes. The same was repeated

for the standard solutions. After 20 minutes, the standard and sample absorbencies were read at 760 nm and a graph of absorbencies against standard concentration was then plotted. Then concentration for each sample and the blanks was determined. In order to get the value for the correct concentration the mean blank value was subtracted from the sample value. Total extractable polyphenols (P) were calculated using the formula: P (%) = (C x 5) / W, Where C = concentration of sample and W = weight of sample

Lignin was determined by the acid detergent fibre (ADF) method as follows:

An air-dry plant material weighing 0.5 g was put into a 250 ml wide neck conical flask. 100 ml sulphuric acid were added, then the flask was gently refluxed for 1 hour on a hot plate. Then it was filtered hot through pre-ignited sinter of a known weight (W2) under gentle suction. The residue was washed with 3 x 50 ml aliquots of boiling water. Washing was continued using acetone until no more colour could be removed, and then the fibre was sucked dry. Drying continued in an oven at 105 ^{0}C for 2 hours, then cooled in a dessicator and weighed again (W3).

Ash containing ADF (%) = {(W3 – W2)/W1} x 100 x {100/100 – (%) water content}. Then the sinter containing the ADF was half filled with 72 % sulphuric acid and cooled to 15 ^{0}C. Stirring was done with a glass rod to produce a smooth paste and then the sinter was placed in a suitable vessel to catch the waste acid as it drains away. The sinter was refilled with sulphuric acid at hourly intervals. After 3 hours, the acid was filtered off under vacuum and then the residue was washed with hot water until the filtrate was free of acid. The lignin and ash product was rinsed with acetone, dried at 105 ^{0}C for 2 hours and cooled in a desiccator and weighed

(W4). Then the sinter was ignited at 550 ^{0}C for 2 hours; cooled in a desiccator and weighed (W5): The amount of lignin was then calculated as follows:

Lignin (%) = {(W4 - W5) / W1} x 100 x {100/100 - % water content}

Data collection

Percent mass loss

Residual weight of the retrieved sample was determined and percent mass loss was calculated and recorded.

Data analysis

The percentage mass loss was subjected to analysis of variance (SAS/STAT, 1988). Treatment means were separated by the procedure of Duncan Multiple Range Test and were declared significant at $P \leq 0.05$.

3.2 EXPERIMENT 2: The Influence of green manure and inorganic fertilizer on *Striga* population and yield of upland rice in Kyela, Tanzania

3.2.1 Justification

Efforts by small-scale farmers to feed an increasing population have resulted into continuous cultivation of the land and change of farming practices like abandoning crop rotation, intercropping and fallowing. This has led to a poor balance of soil nutrients. Depletion of nutrient and hence soil fertility favours the *Striga* attack which is a serious weed in upland rice. Farmers are aware of the problem of low soil fertility but they rarely use fertilizers because of unavailability, high costs involved and low profits realised (Lameck *et al.*, 2003). This has made farmers to consider using alternative sources of nutrients that are cheap and available in the farming system. The use of green manure is a plausable alternative to resource poor farmers. Application of green manures and inorganic fertilizers increases organic matter in the soil and build up nitogen stock in the long term compared to application of inorganic fertilizer alone and readily decomposed organic fertilizers (Buresh and Tian, 1997).

The ability of green manure to improve soil fertility by improving soil nitrogen, plays an important role in the control of *Striga* because *Striga* infestation is favoured by poor soil fertility. In addition, where green manure fallow is used, there is a possibility of reducing *Striga* seed bank in the soil by suicidal germination.

Therefore, experiments were set to determine the influence of *C. ochroleuca*, *C. obtusifolia* and *M. invisa* used as green manure supplemented with inorganic nitrogen fertilizer in the control of *S. asiatica* and improvement of upland rice yield.

3.2.2 Site characterisation

Site description

The experiments were conducted in the same areas and sites as described in section 3.1.3

Vegetation

In Kilasilo site the area was clear of trees and bushes and had been under rice cultivation for more than 5 years. Prior to the setting of the experiment, the weeds in the experimental site were identified with the help of a field guide (Johnson, 1997) and they are listed in Table 1.

Table 1: Weeds found in the experimental site – Kilasilo.

Family	Scientific name	Common name
Commelinaceae	*Commelina benghalensis* L.	Wandering jew
Cyperaceae	*Cyperus sphacelatus* Rottb.	Nut sedge
	Fimbristylis ferruginea (L.)Vahl	Globe fingerush
Poaceae	*Digitaria horizontalis* Willd	Couch grass
	*Sacciolepsis africana*C.E.Hubb& Snowden	Sacciolepsis
Rubiaceae	*Oldenlandia herbaceae* (L) Roxb	Oldenlandia
	Spermacoce ocymoides Burm.F.	Borreria
Tiliaceae	*Corchorus olitorius* L.	Jute mallow
Euphorbiaceae	*Croton hirtus* L.	Tropical croton
Pedaliaceae	*Ceratotheca sesamoides* Endl.	False sesame

The plot at Itope was clear of trees and bushes and had been under fallow for 5 years. Prior to the setting of the experiment, the weeds in the experiment site were identified with the help of a field guide (Johnson, 1997), they are listed in Table 2.

Table 2: Weeds found in the experimental site – Itope.

Family	Scientific name	Common name
Tilliacea	*Triumphetta rhomboidea* Jacq	Paroquet bur
Rubiaceae	*Spermacoce acymoides* Burm.F.	Borreria
	Odenlandia herbacea (L) Roxb	Oldenlandia
Papilionoideae	*Calopogonium mucunoides* Desv	Calopo
Poaceae	*Rhynchelytrum repens* Willd.	Redtop
	Eleusine indica (L.) Gaetrtner	Goose-grass
	Cynodon dactylon L.	Bermuda grass
	Chloris pycnothrix Trin	False star grass
Cyperaceae	*Pycreus macrostachyos* (Lam)	Field segde
	Rynchospora corymbosa(L.) Britton	Golden beak sedge
Pedaliaceae	*Ceratotheca sesamoides* Endl.	False sesame
Mimosoideae	*Mimosa invisa* L.	Colla
Asteraceae	*Vernonia glabra* (Steetz)Vatke	Vernonia(Bitter leaf)
	Ageratum conyzoides L.	Billy goat weed

Among the weed species, broadleaf weeds were dominant in terms of coverage.

Rice varieties

A wide range of rice varieties are grown in Kyela. These include Supa India (Kilombero), Zambia, Faya, Rangi mbili, Kihogo, Mwangulu, Mwasungo, IR54 and IR64. The preferred varieties are Supa India and Zambia because of good cooking quality, aroma, grain size and colour. Supa India was used in this experiment because, it is planted by about 95% of farmers in the upland ecosystem and it is highly susceptible to *Striga* attack. Rice seeds for the experiment were bought from one farmer in Kyela.

Green manures used in this experiment were *C. ochroleuca* (sunhemp) Plate 2, *M. invisa* (Colla) Plate 3 and *C. obtusifolia* (Sickle pod) Plate 4. The latter two are locally available and are regarded as weeds in upland rice (Johnson, 1997). The photographs were taken from experimental plots in year 2001.

Plate 2: *Chrotalaria ochroleuca*

Plate 3: *Mimosa invisa*

Plate 4: *Cassia obtusifolia*

Soils

The soils are the same as described in section 3.1.3

3.2.3 Experiment layout and management

In this experiment, green manure was grown and ploughed under at the stage of 50 % flowering. Rice was sown in the plots the same season 2 days after the green manure was ploughed under. This was done based on the results of the decomposition experiment where it was found that green manure shoots lost about 40 % of their mass in 2 weeks time.

Three green manure plant species were used: *C. ochroleuca*, *C. obtusifolia*, *M. invisa*. Green manure plants species were planted in their respective plots of 6 m x 5 m at seeding rate of 25 kg ha^{-1}. After 2 months (flowering period), the green manure plants were ploughed under in their respective plots, but before planting rice each plot was divided into 3 sub plots of 2 m x 5 m each. These sub plots were partitioned by a polythene sheet of 5 m x 0.3 m where 0.25 m as placed under the soil to prevent roots and fertilizer from crossing to an adjacent plot. Two days after ploughing under Supa India rice variety was sown in each plot at 0.2 m x 0.2 m spacing. In the 5^{th} week after germination of rice three rates of fertilizer urea (F1 = 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1} and F3 = 50 kg N ha^{-1}) were superimposed to sub plots. The treatments are shown in Table 3. These treatments were tested in Randomised Complete Block Design replicated three times. Inorganic fertilizer in the form of urea was applied as a blanket recommendation for the control of *Striga* at the rate of 50 kg N ha^{-1} during the 5^{th} week after planting rice (Kayeke, 1999).

Table 3: Experimental treatments.

Treatments	Fertilizer(urea) rate N kg/ha
1.*Crotolaria ochroleuca* + Fertilizer	0
2.*Crotolaria ochroleuca* + Fertilizer	25
3.*Crotolaria ochroleuca* + Fertilizer	50
4.*Mimosa invisa* + Fertilizer	0
5. *Mimosa invisa* + Fertilizer	25
6. *Mimosa invisa* + Fertilizer	50
7.*Cassia obtusifolia* + Fertilizer	0
8. *Cassia obtusifolia* + Fertilizer	25
9. *Cassia obtusifolia* + Fertilizer	50
10.Control + Fertilizer	0
11. Control + Fertilizer	25
12. Control + Fertilizer	50

A separate experiment was also laid nearby where three green manure plots of *C. ochroleuca*, *C. obtusifolia* and *M. invisa* were left to reach flowering stage, rice was planted in the following season (2001/02). Green manure were sown in separate plots of 6 m x 5 m using a seeding rate of 25 kg ha^{-1} and were left to reach flowering before either ploughing under or cut as mulch. After reaching flowering stage, the green manure plants were ploughed under and cut as mulch in their respective plots and left until the following season. The following season (2001/02), before planting rice each plot was divided into 3 sub plots of 2 m x 5 m each. These sub plots were partitioned by a polythene sheet of 5 m x 0.3 m where 0.25 m as placed under the soil to prevent roots and fertiliser from crossing to an adjacent plot. Supa India rice variety was sown in each plot at 0.2 m x 0.2 m spacing. In the 5^{th} week after germination of rice three rates of fertiliser urea (F1= 0 kg N ha^{-1}, F2= 25 kg N ha^{-1} and F3= 50 kg N ha^{-1}) were superimposed to sub plots. The treatment combinations are shown in Table 4.

Table 4: Experimental treatments.

Treatments	Green manure application method	Urea rate N kg ha^{-1}
1.*Crotolaria ochroleuca* + Fertilizer	Mulch	0
2. *Crotolaria ochroleuca* + Fertilizer	Mulch	25
3. *Crotolaria ochroleuca* + Fertilizer	Mulch	50
4. *Crotolaria ochroleuca* + Fertilizer	Plough under	0
5. *Crotolaria ochroleuca* + Fertilizer	Plough under	25
6. *Crotolaria ochroleuca* + Fertilizer	Plough under	50
7.*Mimosa invisa* + Fertilizer	Mulch	0
8. *Mimosa invisa* + Fertilizer	Mulch	25
9. *Mimosa invisa* + Fertilizer	Mulch	50
10. *Mimosa invisa* + Fertilizer	Plough under	0
11. *Mimosa invisa* + Fertilizer	Plough under	25
12. *Mimosa invisa* + Fertilizer	Plough under	50
13. *Cassia obtusifolia* + Fertilizer	Mulch	0
14. *Cassia obtusifolia* + Fertilizer	Mulch	25
15. *Cassia obtusifolia* + Fertilizer	Mulch	50
16. *Cassia obtusifolia* + Fertilizer	Plough under	0
17. *Cassia obtusifolia* + Fertilizer	Plough under	25
18. *Cassia obtusifolia* + Fertilizer	Plough under	50
19. Control + Fertilizer	-	0
20. Control + Fertilizer	-	25
21. Control + Fertilizer	-	50

Randomised Complete Block Design with three replications was used to test the treatments.

The same experimental plots were used for planting rice in the 2002/03 season without planting green manure. Inorganic fertilizer urea was applied as in the previous season. This was meant to assess the residual effect of green manure and green manure application methods, on the yield of rice and *Striga* population in the field.

Sampling area

Each plot measured 2 m x 5 m and comprised of 10 rows of rice plants. One row of rice was left from both sides of the plots as border rows. 8 rows of rice remained in the net area of 4.6 x 1.6m (Figure 3), and these rows were used for data collection.

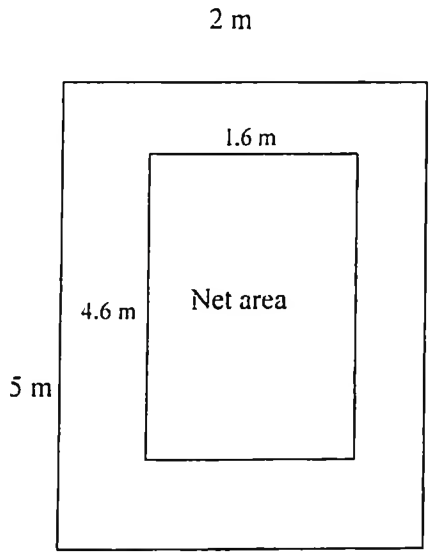


Figure 3: Experimental plot showing a net area

3.2.4 Data collection

Number of tillers per plant

The number of tillers was counted from 5 plants picked randomly in the net area. The average number of tillers per plant was recorded. Tiller counts were recorded when rice plants reached physiological maturity stage.

Number of panicles per plant, (effective tillers)

The panicles of 5 plants picked randomly in the net area were counted at physiological maturity of the rice plants and the mean recorded as the number of panicles per plant.

Panicle length

Panicle length was measured at maturity of the rice plants where 5 rice plants were picked randomly in the net area. Then 4 panicles were measured from each plant using a 30 cm rule (the average of the four panicle lengths gave the panicle length of a plant). Then the total panicle length from 5 plants was used to determine the average panicle length per plant. The panicle length in cm was recorded.

Plant height

This was measured just before harvesting. The measurements were done by using a demarcated 2 m rule to measure the height reached by the longest panicle of the plant after lifting up the panicle. Five plants were picked randomly in the net area. Then the average plant height in cm was determined and recorded.

Nitrogen concentration

This was determined just before booting. Two plants were picked randomly uprooted and roots were separated from the rest of the plant by cutting at soil level. Samples were oven dried at 60 ^{0}C until constant weight was obtained, then ground to pass through 1mm mesh. Finally, nitrogen was determined using the micro Kjcdhal digestion method as described by Brenmer and Mulvaney (1982). The percent nitrogen was recorded.

Grain yield

This was determined by harvesting all plants in the inner plot. Grains were threshed and winnowed to remove trash and unfilled grains. Fully filled grains were weighed.

The weight was adjusted to 14 % moisture content according to Gomez (1972). Adjusted grain weight = (A x W) where A - the adjustment coefficient; W - the weight of the harvested grain; A coefficient is computed as follows A = (100- M/86) where M is the percent moisture content of the grain. The grain yield was expressed in kg ha^{-1}.

Weed counts (weeds other than *Striga*)

The number of weeds was determined by counting the number of broadleaf weeds, grass weeds separately. Counting was done by using a 0.25 m^2 quadrant where the average of 4 quadrants was recorded.

Weed dry weight (weeds other than *Striga*)

The weight of weeds was obtained by uprooting weeds in two quadrants. The uprooted weeds were cut at soil level to remove the roots. Then the shoots were oven-dried for 72 hours at 60 ^{0}C and weighed to get the total weed dry weight.

***Striga* count**

The number of *Striga* plants in the 6^{th} and 9^{th} weeks after rice germination were counted and recorded. The method used was to count all *Striga* plants per hill in the plot of 10 m^2. The large area was used instead of net area to avoid uneven distribution of *Striga* in a plot

***Striga* plant height**

In the 9^{th} week after rice germination, 5 mature *Striga* plants were sampled randomly and their heights were measured by using a 50 cm rule. Then the average plant height was determined and recorded.

Striga seed production (number of capsules per plant)

Capsule numbers were counted from 5 mature plants, the same plants used to measure height in each plot. The average number of capsule per plant was calculated and recorded.

Data analysis

The collected data were subjected to analysis of variance using (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 wher x is the number of *Striga*) because there were plots with zero *Striga*, while for other weeds was by square root (Gomez and Gomez, 1984). After analysis treatment means were separated by the procedure of Duncan Multiple Range Test/Tukey's Test and were judged significant at $P \leq 0.05$. In the presentation of the results, the original means were used.

Economic analysis

Economic analysis was done to asssess the green manure technology. The analysis was done by using cost: benefit ratio as described by CIMMYT (1988). Costs were determined by variable costs where the gain or revenue was determined by considereing the average farm price per bag of 70 kg to be 18,000 Tshs. The benefit or loss was abtained by the difference between costs and revenue, When the difference was positive it was a profit, but when negative it was considered a loss.

The benefit: cost ratios obtained were subjected to analysis of variance. Then means were separated by the procedure of Duncan Multiple Range Test/Tukey's Test and were judged significant at $P \leq 0.05$. The components benefit and cost ratio are shown below

Without green manure	Green manure plough under	Green manure mulch
Costs	**Costs**	**Costs**
Cultivation	Cultivation	Cultivation
1st harrow	1st harrow	1st harrow
2nd harrow	2nd harrow	2nd harrow
Planting rice	Planting green manure	Planting green manure
1st weeding	Plough under green manure	Slashing green manure
2nd weeding	Planting rice	Planting rice
3rd weeding	Weeding	Weeding
Inorganic fertilizer	Inorganic fertilizer	Inorganic fertilizer
application	application	application
Harvesting-	Harvesting-	Harvesting-
Cutting	cutting	cutting
Shelling/winnowing	shelling/winnowing	shelling/winnowing
Transporting	transporting	transporting
Gains	**Gains**	**Gains**
Selling paddy	Selling paddy	Selling paddy

Statistical model (RCB Design)

$$Y_{ijkl} = \mu + \rho_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijkl}$$

Where Y_{ijkl} = Response j^{th} level of factor A, k^{th} level of factor B in the i^{th} block

μ = General mean

ρ_i = Effect of the i^{th} block

α_j = Added effect of the j^{th} level of factor A, measured as a deviation from μ

β_k = Added effect of the k^{th} level of factor B, measured as a deviation of factor μ

$(\alpha\beta)_{jk}$ = Added effect of the combination of the jth level of factor A with the kth level of factor B; the $(\alpha_j \times \beta_k)$ interaction effect

ε_{ijkl} = Random error

3.3 EXPERIMENT 3: The influence of green manure and plant extracts on the germination of *Striga asiatica* (L.) Kuntze in upland rice in Kyela, Tanzania

3.3.1 Justification

Striga asiatica (L.) Kuntze was identified as the most serious weed in upland rice in Kyela, Tanzania (ICRA, 1994). *Striga* affects crops by reducing growth and development; where yield reduction can range from 10% to total loss (Parker and Riches, 1993; Mbwaga *et al.*, 2000).

The current recommendation for *Striga* control in Kyela is the use of urea fertilizer to reduce infestation. Farmers with limited resources cannot afford high prices of inorganic fertilizers. Alternative control measures like the use of green manure mulch or other plant extracts can be of benefit to farmers.

Plant extracts and mulch materials can provide allelochemicals. Results from weed management studies have shown that different types of allelochemicals have shown potential in the control of weed (Yoshida *et al*, 1993, Chanyowedza *et al*, 1997; Friesen and Korwar, 1991). Apart from using plant extracts to suppress *Striga* growth, trap crops can be used to stimulate *Striga* germination thus reduce *Striga* seed population in the soil by suicidal germination.

Therefore, the objective of the experiment was to determine the potential of trap crops to stimulate germination of *Striga* seed and to evaluate the ability of plant extracts to suppress *Striga* seed germination as a strategy to control *Striga* in upland rice.

In thisstudy, three experiments were conducted to determine the potential of trap crops to stimulate *Striga* seed germination, evaluate application rates of the plant extracts and determine appropriate application methods under controlled conditions in the field.

3.3.1.1 Study I: Determination of the potential of trap crops to stimulate *Striga* germination

Seed collection

Seeds for 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 during the 2000/01 cropping season. The 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 the 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 taped gently on a polythene sheet to shed seeds after which the floral heads were burnt to ensure no risk of dispersing remained *Striga* seeds. After threshing, seeds were sieved using sieves with mesh sizes 250, 150, 100, 90 microns to remove plant trashes. *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.

Experiment layout and design

Completely Randomised Design replicated three times was used to test the treatments. There were six treatments, these included root exudates from *C. ochroleuca*, *M. invisa*, *C. obtusifolia*, *Zea mays* (Staha variety-highly susceptible to *S. asiatica*), Ethephone 50 ppm as a standard germination stimulant and distilled water.

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

Where Y_{ijk} = k^{th} observation in the i^{th} level of factor A, j^{th} level of factor B

μ = General mean of observation

α_i = Added effect of the i^{th} level of factor A, measured as a deviation from μ

βj = Added effect of the j^{th} level of factor B, measured as a deviation of factor μ

ε_{ijkl} = Random error

Laboratory experiment

Germination stimulants were extracted from growing roots of the green manure plants and maize. The root exudate was obtained by growing the green manure and maize 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. The clean plants were suspended in bottles containing 100 ml of distilled water in the manner that the roots in water and the shoot above the water level for 24 hours. After removal of plants water from the bottles was used as germination stimulants according to the procedures described by 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 before setting the experiment. Conditioning was done as follows, *Striga* seed were put 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 by lid. Carefully the covered petri-dishes were wrapped in parafilm to prevent moisture loss and wrapped in aluminium foil to exclude light. The covered petri-dishes were placed in an incubator to maintain the temperature of 30 ^{0}C for 2 weeks. After conditioning period, the petri-dishes were removed from the incubator, opened and the moisture inside was dried up by using bloating papers. Wet seeds on the paper discs 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 the count of germinated *Striga* seed under microscope (X 40 magnification).

Field experiment

Striga seeds were put in small bags (Eplee bags) made of nylon cloth. The size of the bags was 3 cm x 3 cm with an opening on one end. On the opening end, a manila string was fitted to tie the opening end when burying the bag in the soil and 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 green manure *C. ochroleuca*, *M. invisa* and *C. obtusifolia*, a control plot was included. 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. This experiment was conducted in two sites for one season. Treatments were green manure species *C. ochroleuca, M. invisa, C. obtusifolia* and control. Randomised Complete Block design with three replications was used to test the treatments in two sites.

Data collection

Number of germinated *Striga* seeds were counted, expressed in percentage and recorded.

Data analysis

Data were subjected to analysis of variance by SAS/STAT (1988), after analysis treatment means were separated by the procedures of Duncan Multiple Range Test and were declared significantly different at $P \leq 0.05$.

3.3.1.2 Study II: Determination of appropriate application rates of plant extracts for suppression of *Striga* seed germination

***Striga* seed**

Collection and storage of *Striga* seeds up to the time of use was done as in 3.3.1.1

Plant extracts

There were two groups of plant extracts, the first group was from green manure used to improve soil fertility *C. ochroleuca*, *M. invisa* and *C. obtusifolia*, another group was obtained from the following species

Specie	Family	Active part
1. *Vernonia amygdalina* (Del.)	Leguminoceae	Leaves
2. *Neuritania mitis*	Leguminoceae	Tubers
3. *Dolichos kilimandscharis*	Leguminoceae	Tubers
4. *Gnidia kraussiana*(Meisn.)	Thymelaeae	Tuber

These plant materials were obtained from The Agricultural Research Institute Uyole collection of botanicals with potential in agriculture.

Plant extracts were prepared by mashing the active part of the plant. The mashed plant materials were air-dried and ground using a powered sample grinder, and sieved to pass through a 1 mm sieve. The sieved plant materials were used in the preparation of the plant extracts. 3 concentration of the extracts were prepared by using 10 g, 20 g, and 30 g of plant materials in 100 ml of distilled water. The soaked plant materials were left to stand for 24 hours and sieved with a cotton cloth to remain with a liquid prepared with 10 g in100 ml, 20 g in 100 ml and 30 g in 100 ml. Another group of extracts was collected from the three green manure plant species used in experiment (I), *C. ochroleuca, M. invisa* and *C. obtusifolia*. The plant materials were collected and soaked in distilled water following the procedure of Yoshida *et al.* (1993). However soaking time was lengthened to improve extracts' concentration. Ten grams of dry leaves (dried at flowering stage) were soaked in 100 ml distilled water for 36 hrs. Only 10 g in 100 ml were used because it was assumed that in the field the extracts will be obtained from rain water when raining, rain-water will be washing mulch material hence one level of concentration.

Experiment layout and design

This was a laboratory experiment whereby Complete Randomised Design replicated four times was used. The treatments consisted of 4 plant species each of them was used to prepare three levels of plant extracts to make 12 treatments. In addition, there was one concentration of each of the three green manures, and the control consisted of distilled water and Ethephone. Therefore, the total number of treatments was 17. In this experiment *Striga* seeds were germinated in petri-dishes.

Experiment management

Striga seeds were conditioned for 12 days at 30 ^{0}C according to the procedure described by IITA (1997). After conditioning, water in the petri dishes was dried using a bloating paper and wet seeds were left to air dry. The air-dried seeds were taken back to the petri dishes and supplied with 2 ml of germination stimulant Ethephone and 2 ml of the plant extracts. They were incubated again for 24 hours at 30 ^{0}C, petri dishes were taken out of the incubator for counting germinated *Striga* seed under microscope (with a magnification of x 40).

Viability test for *Striga* seeds

Striga seeds that did not germinate in experiment II were subjected to viability test as outlined by (IITA, 1997). One gram (1gm) of 2,3-5 triphenly chloride salt was dissolved in 100 ml of distilled water, and the pH of the solution was adjusted to 7 using sodium hydroxide salt. The solution was put in bottles wrapped in aluminium foil to avoid deterioration of the solution by light and then stored in a refrigerator. All un-germinated seeds were placed in petri dishes containing tetrazonium solution to cover *Striga* seeds. Petri-dishes were wrapped in aluminium foil to exclude light. *Striga* seeds in the petri dishes were incubated at 40 ^{0}C for 48 hrs in order to stain seeds. After incubation, the solution was poured off through a filter paper leaving *Striga* seeds behind in the petri dishes. These seeds were placed in another petri-dish where (Sodium hypochlorite) NaOCl was added to bleach the seed coat leaving a stained endosperm beneath to be seen. Observation for seed viability was done under the microscope where a red stained endosperm indicated viable seeds.

Data collection

The number of viable *Striga* seeds was counted, and the percentage germination was determined and recorded.

Data analysis

Collected data were subjected to analysis of variance (SAS/STAT, 1988) and means were separated according to Duncan multiple Range Test and were declared significant at $P \leq 0.05$.

3.3.1.3 Study III: Evaluation of application methods of plant materials

After the identification of plant extracts with potential to suppress germination of *Striga* seeds in experiment II, 2 species namely *D. kilimansdcharis* and *G.*

kraussiana were chosen for evaluation of application methods. The active ingredients of the used plant extracts are saponin for *G. kraussiana* (Matorofa and Nyazema, 1988) and coumarin for *D. kilimandscharis* (Kambewa *et al.*,1988).

This study was aimed at evaluating the application methods of plant materials to suppress germination of *S. asiatica* seeds.

Experiment layout and design

Randomised complete block design replicated four times was used in this experiment. There were eight treatments included two plant species, three application methods and 2 controls. There were two plant species namely *D. kilimansdcharis* and *G. kraussiana*. The application methods were used namely seed hardening, seed coating and application of the powder of the plant materials in planting holes (2 g per hole). Two control treatments were included. These were *Striga* infested pots without plant extracts and another with neither *Striga* nor plant extracts (rice was planted free of plant extracts and *Striga*). This experiment was conducted under controlled conditions (pot experiment) and was modified in the field by reducing the one treatment to suit natural *Striga* infestation.

In the field, Randomised complete block design replicated four times was also used. There were seven treatments including two plant species, three application methods and one control. The 2 plant species were *D. kilimansdcharis* and *G. kraussiana*. Three application methods were used namely seed hardening, seed coating and application of the powder of the plant materials in the planting hole. The control treatment was without plant extracts. In the field, natural *Striga* infestation was used instead of artificial innoculation. Each plot measured 2.4 m x 3 m and comprised of 12 rows of rice plants. One row of rice was left from both sides of the plots as border rows. Ten rows of rice remained in the net area of 2 m x 2.8 m these rows were used for data collection.

The plant extracts were prepared by using 30 g of powdered plant material in 100 mls of distilled water for 24 hours. Seed hardening was done by soaking rice seeds in the respective extract for four hours and air-dried to the original weight as explained by Freisen and Korwar (1991). Seed coating was done by mixing 30 g of plant material (in a powder form) with 100 ml of sucrose liquid. Rice seeds (500 g) were added and mixed until all rice seed were coated. Treated rice seeds were air dried to let the plant extract stick on rice seed coat. Seed treatment was prepared using 30 g of plat material in 100 ml of water that was effective in the suppressing *Striga* germination (results from Study I).

Before setting the experiment, rice seeds treated with plant extracts were subjected to a seed germination test, this was meant to test whether plant extracts can affect germination. A simple experiment was set. Sets of twenty healthy rice seeds were selected and treated with each plant extract. Treated rice seeds were placed in petri-dishes containing wet filter paper soaked by distilled water. After 9 days, germinated rice seeds were counted from each petri-dish.

Pot experiment

Seeds of rice variety Supa-India were sown in 10 l buckets. Every 3 buckets represented a plot (1 treatment). Each bucket was filled with 15 kg soil at a ratio of 45:55 sandy:clay to make a composition of Kyela soils, Nitrogen level was 0.15%. *Striga* inoculation was done artificially before sowing rice seeds. The inoculum was prepared by mixing 3.3 g of *Striga* seed in 1 kg of clean fine sand. About 2 g of the inoculum was applied in the planting hole at a depth of 0 to 5 cm during planting according to the procedures of Ransom *et al.* (1990). There were 4 hills per bucket, where 4 rice seeds were sown per hill. After 2 weeks, thinning was done to retain a plant per hill.

Data collection

Plant height

At maturity stage, rice plant height was measured by a wooden 2 m rule. The height was measured from the soil surface to the tip of the longest panicle after lifting up the panicle. The average plant height was obtained by dividing the total number of plant length to the number of plants in the pots (plots).

Number of tillers per plant

This was recorded at grain filling stage, number of tillers in a plot was counted and divided by the number of plants to get the average number of tillers per plant.

Number of panicles per plant

At maturity stage, panicles were counted from plants in the pots of each plot and then the average was determined to get the number of panicles per plant.

Panicle length per plant

The length of the panicle was determined at maturity stage using a 30 cm rule where panicles in the pots were measured. The total panicle length was divided by the number of plants in the pots to obtain the panicle length per plant.

Grain yield

The grain yield was determined by weighing the grains after harvesting and winnowing to remove unfilled grains and other trash. The grain yield was expressed in gm/pot. The weight was adjusted to 14 % moisture content. Adjustment was done according to Gomez (1972).

***Striga* count**

Number of *Striga* shoots in pots was counted on the 6th, 9th and the 12th week after rice germination, *Striga* number per pot was determined by dividing the number by 3. The average number of *Striga* per pot was recorded while in the field *Striga* number in 6 m^2 was recorded.

***Striga* height**

In the 12th week the average height of flowered *striga* plant was determined using a 50 cm rule. Six *Striga* plants (2 plants from each pot) were picked randomly and their height measured. Then the total height was divided by 6 and the average *Striga* plant height was recorded.

Striga dry weight and capsule number

A sample of 10 full grown *Striga* plants were uprooted in the 12th week and the number of capsules per plant was recorded. The plant dry weight after air drying for 2 weeks was measured by a laboratory sample balance and recorded.

Data analysis

Collected data were subjected to analysis of variance by using (SAS/STAT. 1988) and means were separated according to Duncan Multiple Range Test and judged significant at $P \leq 0.05$.

4.0 CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 EXPERIMENT I

Results

Physical and chemical properties of the soils

The results showing the physical and chemical properties of the soils are indicated in Tables 4 and 5.

Table 4: Some physical properties of experimental soils.

Site	% Sand		Clay (%)	Silt (%)	Textural class
	Coarse	Fine			
Kilasilo	38	5	40	17	Sandy clay
Itope	40	5	35	20	Sandy clay

Table 5: Some chemical properties of experimental soils.

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

Initial chemical characteristics of the green manure

The results on the chemical characteristics of the green manure shoots and roots are shown in Table 6.

Table 6: Initial chemical characteristics of the three green manure species.

	Crotolaria oclureca		*Cassia obtusfolia*		*Mimosa invisa*	
Parameters	**Roots**	**Shoots**	**Roots**	**Shoots**	**Roots**	**Shoots**
Total N (%)	1.3	3.4	1.0	2.4	2.0	3.4
Organic C (%)	39.4	39.2	39.3	39.3	39.5	39.3
Total P (%)	0.2	0.4	0.4	0.4	0.3	0.4
Polyphenols %)	2.5	6.9	12.5	30.0	7.5	26.3
Lignin (%)	5.6	3.7	6.4	5.7	7.8	5.8
C:N ratio	30.3	11.5	39.3	16.4	19.8	11.6
Lignin : N ratio	4.3	1.1	6.4	2.4	3.8	1.7
Polyphenol:N ratio	1.9	2.0	12.5	12.5	3.9	7.7
Polyphenol+ Lignin : N ratio	6.2	3.1	18.9	14.9	7.7	9.4

Decomposition

The results indicating the decomposition pattern of green manure species are shown in Figure 3, 4 and 5. The rate of decomposition was higher in shoots than in the roots. By the fourth week 75% of *C. ochroleuca* shoots had decomposed whereas for *M. invisa* shoots 60% and 56% for *C. obtusifolia* shoots. Therefore, maximum release of nutrients occurred during the first 4 weeks. On average 48% of the roots had decomposed by the 6^{th} week and average of 59% by the 8^{th} week. Therefore, maximum release of nutrients from the roots occurred after 8 weeks.

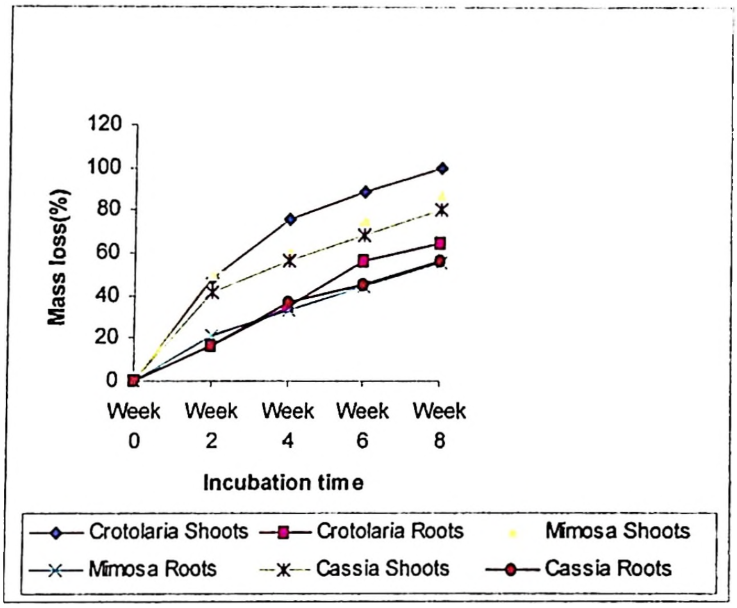


Figure 3: Decomposition pattern of green manure shoots and roots at Kilasilo village

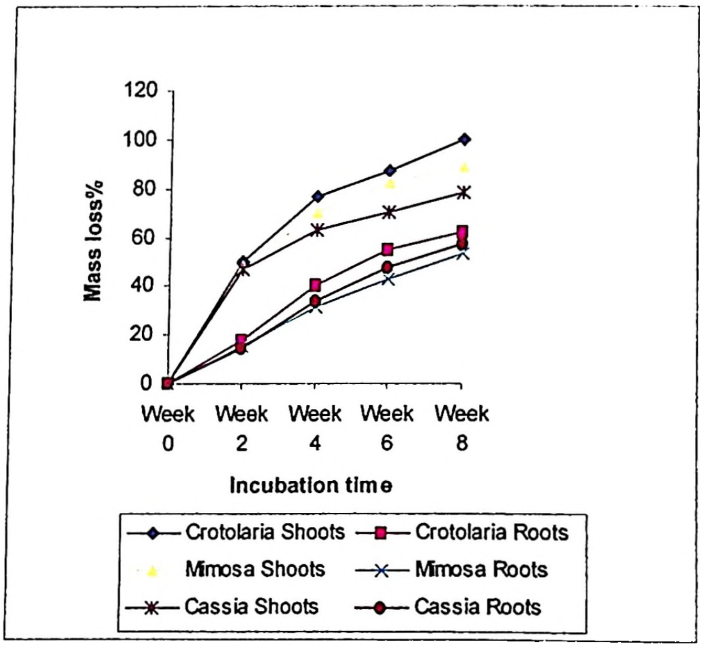


Figure 4: Decomposition pattern of green manure shoots and roots at Itope village

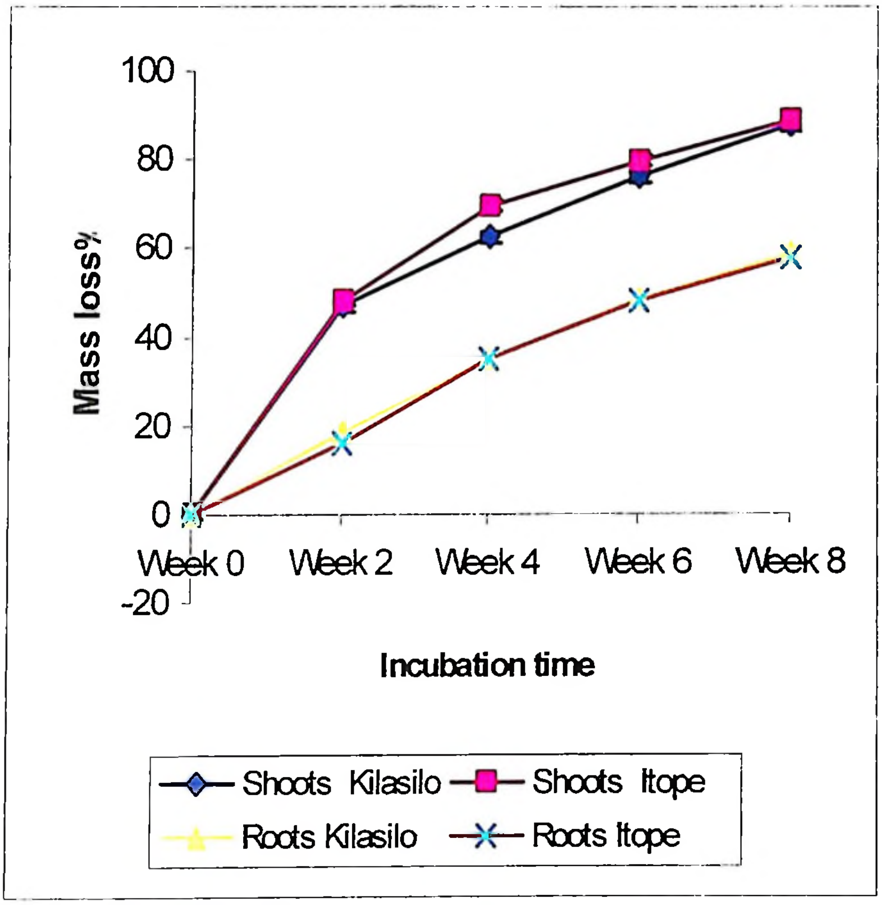


Figure 5: Decomposition pattern of green manure shoots and roots across sites

In figure, 4 results show that the rate of decomposition of the shoots was higher than that of the roots at Itope. By the 4th week 76% of *C. ochroleuca* shoots had decomposed whereas *M. invisa* and *C. obtusifolia* shoots had lost 60% and 56% respectively. These results show that the maximum release of the nutrients occurred during the first 4 weeks. The roots decomposition showed that the average of 48% of the root mass had decomposed by the 6th week and 57.5% by the 8th week.

Results in Figure 5 show that there were slight differences among sites that influenced the decomposition pattern of green manure shoots and roots. The green manure shoots showed a higher mass loss than the roots. On the other hand, at Itope shoots had a significant higher (P□ 0.05) mass loss in the 4^{th} week and 6^{th} week than Kilasilo while the roots had about the same mass loss in both sites.

Discussion

Physical and chemical properties of the soils

The textural class of both sites is suitable for upland rice production, but due to poor fertility status application of organic/inorganic fertilizer is important to improve rice yield. On the other hand, the textural class for both sites also favours the growth of *Striga* because they are sandy clay and are well drained. 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 is highly soluble and can be toxic to the plants. On the contrary the levels of Al in all sites are very low (trace). Probably the amount of Al in the soil combined with phosphates to form insoluble compounds hence low levels of Al. 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 condition 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 as shown in the following equations:

1. $Al^{3+} + 2H_2O + H_2PO_4^- \rightarrow Al(OH)_2 H_2PO_4 + 2H^+$

2. $Fe^{3+} + 2H_2O + H_2PO_4^- \rightarrow Fe(OH)_2 H_2PO_4 + 2H^+$

3. $Al(OH)_3 + 3H_2PO_4^- \rightarrow Al(H_2PO_4)_3 + 3OH^-$

4. $Fe(OH)_2 + 2H_2PO_4^- \rightarrow Fe(H_2PO_4)_2 + 2OH^-$

Organic carbon of soils at both sites is very low (less than 2 %), while nitrogen levels are also low (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 nitrogen reserve in the soil. The levels of CEC are medium and satisfactory for retention of cationic nutrients. The percent base saturation is 26 % for Kilasilo and 25 % for Itope. Both sites have percent base saturation less than 50 indicating that these soils are of very poor fertility. Soils with such a 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). Low nitrogen levels and low organic carbon levels also contribute to the poor soil fertility that encourages *Striga* growth.

The blanket recommendation for fertilizer in rice soils of the Southern Highlands of Tanzania is 40 kg P_2O_5 ha^{-1} and 60 kg N ha^{-1} (NSS, 1993). This recommendation caters for both improved and local varieties. Local varieties with low yield potential are prone to lodging under heavy application of nitrogen fertilizers. The soils in both sites are not ideal for upland rice production. They need amendments through the application of organic and inorganic fertilizers. The use of both organic and inorganic fertilizers is very important, because inorganic fertilizer provides nutrients for immediate use by the plant while application of organic fertilizer improves soil organic matter and nitrogen reserve for long time use. In addition, organic matter improves soil structure and physical properties like water holding capacity that has a negative effect on *Striga* infestation.

Initial chemical characteristics of the green manure

Nitrogen is higher in shoots than in roots hence upon decomposition shoots will release more nitrogen and the potential to suppress *Striga* is more in shoots than in roots. Likewise, accumulation of nitrogen in *C. ochroleuca* is not different from that of *M. invisa* so their decomposition pattern is the predicted to be the same. The amount of total carbon in the shoots and the roots almost similar indicating that the have a similar contribution of organic carbon in the soil carbon pool. The levels of polyphenols in the shoots were higher than in the roots for all three species of green manure This suggest that roots can decompose fastre than shoots. On the other hand, the level of lignin for the roots were higher than the shoots in all green manure species indicating that roots will have slow decomposition than shoots. Plant materials with high levels of lignin and polyphenols tend to resist decomposition.

Ratios of some chemical properties were calculated in order to assist in explaining the decomposition rate of plant materials. These are carbon to nitrogen ratio (C:N), lignin to nitrogen ratio (Lignin:N), Polyphenol to Nitrogen ratio (Polyphenols:N) and Polyphenols + Lignin to Nitrogen ratio (Polyphenols + Lignin:N). The three green mnure species showed higher C:N ratio in roots than shoots indicating that roots will have a slower decomposition rate than shoots. From the results (Table 6) the decomposition pattern of the shoots was predicted to follow the trend *C. ochroleuca* > *M. invisa* > *C. obtusifolia*, while the roots decomposed in the following trend: *M. invisa* > *C. ochroleuca* > *C. obtusifolia.* The release of nitrogen in a *Striga* infested soil is important for the control of *Striga* and enhanced growth of susceptible crop.

Decomposition

The results on decomposition indicated that by the 4th week and 6th week the average mass loss was about 63 %. At the same time, week 5 is the recommended time for fertilizer application for the control of *Striga* in Kyela because that is the time of haustorium initiation, development and contact (Press and Cechin, 1994). The same authors reported by application of ammonium fertilizer inhibited attachment of the parasite and its early development. Therefore, by having more than 63% of the nutrients released by the 4th week, nitrogen released is available for the control of *Striga* and the growth of rice. Since upland rice in Kyela is sown directly in the main field then the proper time of green manure incorporation is immediately before sowing rice seeds. This ensures nitrogen for the control of *Striga* that is needed in the 5th week after germination of rice seeds.

Roots lost an average of 48 % of its mass by the 4th week, and by the 6th week mass loss was 58 %, This means that more than 50 % of the nutrients were already released and made available to the rice plants. As for the plant shoots, the decomposition pattern of the roots was related to the C: N ratio and Polyphenol: N ratio. These predicted the root mass loss trend to be *M. invisa* > *C. ochroleuca* > *C. obtusifolia*. Late release of nutrients by roots can benefit late maturing varieties like Supa india grown by small scale-farmers in upland areas of Kyela. Supa india takes 120 days to mature, with the reproductive phase taking 30 days, and the ripening phase 35 days. This suggests that a rice plant (Supa India) at the 6^{th} week will be maximizing utilization of plant nutrients released by the decomposed green manure roots. In addition, late release of nutrients can contribute to the plant nutrients in the coming cropping season. Therefore, synchronozation is important so that the rice plant can maximize the utilization of the released nutrients, while at the same time suppressing *Striga* infestation.

Conclusions

- Decomposition pattern of the tested green manures in Kyela soils indicated that *C. ochroleuca* decomposed faster than *M. invisa* and *C. obtusifolia*. The trend was *C. ochroleuca* > *M. invisa* > *C. obtusifolia*
- Decomposition of *C. ochroleuca* lost (about 75 %) of its mass in the first 4 weeks of rice growth in Kyela, while *M. invisa* and *C. obtusifolia* lost about 65 % and 60 % of the mass, respectively, during the same time.
- The release of more than 50 % of the nutrients in the first 4 weeks suggested that these green manures may be suitable for the control of *Striga asiatica* in Kyela. The 4^{th} week is the time the parasite attaches itself to the host, therefore optimum suppression of *Striga* is expected if incorporation of green manure and nutrient

release is synchronised with rice growth.

- Decomposition of roots released 50 % of the nutrients after 8 weeks therefore the released nutrients can be available to long maturing varieties like Supa india that take 120 days to attain maturity.

4.2 EXPERIMENT II

Results

The effect of green manure on weed (other than *Striga*) intensity

The results on the effect of green manure on weed other than *Striga* are presented in Table 7. Grass weeds and broadleaf weed counts, total weed count and total weed dry weight decreased significantly with the application of green manure in both sites. *Mimosa invisa* and *C. obtusifolia* had significantly more grasses in Kilasilo and Itope respectively (18, 18.1 and 21.1, 18.6) than *C. ochroleuca* (12.5, 12.9). *Crotalaria ochroleuca* (24.8, 24.2) and *M. invsa* (19.9, 33.4) had significantly fewer weed total count compared to *C. obtusifolia* (33.4, 39.9) in Kilasilo and Itope respectively. The potential of green manure to supress weeds was in the order *C. ochroleuca* >*M. invisa* > *C. obtusifolia.*

Table 7: The effect of green manure on Weed density.

	Weeds in m^{-2}							
	Kilasilo				Itope			
Treatments	Grasses	Broad leaf	Total count	Total dry wt (gm)	Grasses	Broad leaf	Total count	Total dry wt (gm)
Control	43.3a	37.0a	81.1a	120.0a	18.3a	33.8a	52.9a	126.3a
C. ochroleuca	12.5b	12.2b	24.8b	24.0d	12.9b	9.5d	24.2d	29.8d
M. invisa	18.0c	11.6b	19.9b	46.5c	18.1c	15.3c	33.4c	51.8c
C. obtusifolia	21.1c	12.3b	33.4c	56.9b	18.6c	21.0b	39.9b	66.6b
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 Duncan Multiple Range Test ($P \leq 0.05$)

The effect of green manure on *Striga* growth and development

The results show that all green manure significantly reduced *Striga* ($P \leq 0.05$) in both sites. The control plots had significantly more numbers of *Striga* than green manure plots in the 6^{th} and 12^{th} week after rice germination. The green manure plots had no *Striga* at all. The green manure species suppressed *Striga* equally effectively in both sites.

The effect of green manure on growth and yield of rice

The results on growth and yield of rice are presented in Table 8. The height of rice plants, number of tillers, panicle per plant and grain yield increased significantly with application of green manure in both sites. The yield varied significantly with the type of green manure. In Kilasilo, rice plots applied with *C. ochroleuca* had fewer plant tillers 9.1 than other green manure, but it had significant higher number of panicle per plant than other green manure. In both sites, rice plots applied with *C. ochroleuca* had significantly higher yield than other green manure. In Kilasilo, rice plots applied with *C. ochroleuca* (2846 kg ha^{-1}), rice plots applied with *M. invisa* (2626kg ha^{-1}) and rice plots applied with *C. obtusifolia* (2010 kg ha^{-1}). While the yield in Itope site was rice plots applied with *C. ochroleuca* (2818 kg ha^{-1}) > rice plots applied with *M. invisa* (2252 kg ha^{-1}) > rice plots applied with *C. obtusifolia* (1960 kg ha^{-1}).

Table 8: The effect of green manure on growth and yield of rice.

	Kilasilo					Itope				
Tre	Plant height (cm)	Tillers/plant	Panicles/ Plant	Panicle length	Yield $kgha^{-1}$	Plant height (cm)	Tillers/ plant	Pani./ plant	Panicle length	Yield $kgha^{-1}$
1	85.0b	8.5c	8.4b	18.7b	1335d	90.0c	8.1b	7.1b	18.4c	1238d
2	91.1a	9.1a	8.8a	19.3a	2846a	98.7a	9.1a	8.7a	19.8a	2818a
3	89.9a	9.8b	8.8a	18.9b	2626b	97.6ab	8.7a	8.3a	19.1b	2252b
4	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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochroleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*

The effect of green manure and fertilizer on *Striga* growth and development

Results in table 9 show that in both sites control plots had significant high ($P \leq 0.05$) number of *Striga* in 10 m^2 in the 6^{th} and 12^{th} 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 fertilizer and green manure. In the sixth week, the number of *Striga* shoots was significantly highest in the control without inorganic fertilizer 167 and 126 for Kilasilo and Itope, respectively. Nitrogen application at 25 kg Nha^{-1} and 50 kg Nha^{-1} also reduced *Striga* number 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 Nha^{-1}. All combination of green manure and inorganic nitrogen fertilizer suppressed *Striga* germination comletely.

Table 9: The effect of green manure and fertilizer on *Striga* growth and development.

Treat.	Fert	Kilasilo *Striga* count in 10 m² 6 wks	Kilasilo *Striga* count in 10 m² 12 wks	Kilasilo *Striga* height	Kilasilo Capsules/plant	Itope *Striga* count in 10 m² 6 wks	Itope *Striga* count in 10 m² 12 wks	Itope *Striga* height	Itope Capsules/plant
1	F1	167.0 a	27.9a	22.8a	16.3a	126.1a	126.1a	27.9a	18.6a
	F2	30.4b	15.3b	25.9a	15.5a	12.9b	25.1b	15.3b	9.0b
	F3	6.89c	15.3b	15.3b	6.4b	4.1c	9.29c	15.3b	8.8b
2	F1	0d	0c	-	-	0d	0d	-	-
	F2	0d	0c	-	-	0d	0d	-	-
	F3	0d	0c	-	-	0d	0d	-	-
3	F1	0d	0c	-	-	0d	0d	-	-
	F2	0d	0c	-	-	0d	0d	-	-
	F3	0d	0c	-	-	0d	0d	-	-
4	F1	0d	0c	-	-	0d	0d	-	-
	F2	0d	0c	-	-	0d	0d	-	-
	F3	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 Duncan Multiple Range Test ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, F1 = 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The effect of green manure and inorganic nitrogen fertilizer on growth and yield of rice

The results in Table 10 indicate an increase in yield and yield components when green manure and inorganic fertilizer were applied in both sites. Plant height increased significantly ($P \leq 0.05$) with the application of green manure and nitrogen fertilizer 50 kg Nha^{-1} under all green manure species in Kilasilo and Itope. When green manure and nitrogen fertilizer were applied at 25kg Nha^{-1} the plant height for *M. invisa* (86.7 cm) and *C. ochroleuca* (88.5 cm) did not show significant variation but varied significantly ($P \leq 0.05$) with *C. obtusifolia* (92 cm) in Kilasilo. The use of green manure and fertilizer N 50 kg Nha^{-1}at Kilasilo, resulted in higher ($P \leq 0.05$) number of tillers per plant (10 cm, 10.7 cm and 10.3 cm) than with 25 kg Nha^{-1}

except *M invisa* at 25 kg N ha^{-1}and 50 kg N ha^{-1}. The number of panicles per plant showed no significant difference among green manure when 50 kg Nha^{-1} was applied in Kilasilo. In Itope *M. invisa* and *C. obtusifolia* showed no significant ($P \leq 0.05$) variation between 0 Nha^{-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 kg N ha^{-1}, 50 kg N ha^{-1}were applied the grain yields varied significantly ($P \leq 0.05$) with each other. *Crotalaria ochroleuca* had the highest yield (2798 kg ha^{-1} and 3442 kg ha^{-1}) followed by *M. invisa* (2592 kg ha^{-1} and 3059 kg ha^{-1}) and *C. obtusifolia* (2181 kg ha^{-1} and 2610 kg ha^{-1}) the last. In Itope, the grain yield in all green manure and fertilizer, 0 kg N ha^{-1}, 25 kg N ha^{-1} and 50 kg N ha^{-1} varried significantly ($P \leq 0.05$) from each other except *C. ochroleuca* with 0 kg Nha^{-1} (2458 kg ha^{-1}) and *C. obtusifolia* with 50 kg N ha^{-1} (2476 kg ha^{-1}), that were similar.

Table 10: The effect of green manure and inorganic fertilizer on growth and yield of rice.

Treatments	F	Kilasiko					Itope				
		Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length	Grain yield in Kg ha^{-1}	Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length	Grain yield in Kg ha^{-1}
1	F1	77.7a	7.3a	7.3a	17.9a	815a	78.7a	6.7a	6.0a	17.3a	825a
	F2	86.5bc	9.0cd	8.6b	18.6b	1406b	93.5bc	7.3ac	6.7a	19.0bc	1230b
	F3	90.8cd	9.7def	9.0c	19.7cd	1784c	97.7cde	10.3f	8.7c	19.0bc	1633c
2	F1	84.2b	8.0b	8.3b	18.7b	2300c	96.7cd	8.0cd	7.3b	18.7b	2458g
	F2	88.5cd	9.3cd	9.0c	19.0bc	2798e	96.5cd	9.3e	9.0cd	19.7c	2870l
	F3	100.7g	10.0ef	9.3c	20.3d	3442g	103.0f	10.0fe	9.7d	21.0e	3126j
3	F1	86.0bc	8.7cb	8.0b	17.7a	2227c	92.1b	7.7bd	7.3b	18.7b	1894d
	F2	86.7bc	10.0e	9.0c	19.0bc	2592d	99.7de	8.3d	8.0b	19.0bc	2238f
	F3	95.2ef	10.7e	9.3c	20.0d	3059f	101.1ef	10.0fe	9.7d	19.7cd	2623h
4	F1	85.7bc	9.0cd	8.0b	18.7b	1238b	92.7b	7.6bd	7.7b	18.7b	1363b
	F2	92.0de	9.7df	9.0c	19.7cd	2181c	94.1b	8.3d	8.0b	19.3cb	2042e
	F3	98.3fg	10.3e	9.3c	20.0d	2610d	101.2ef	10.3f	9.0cd	20.3de	2476g
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 Duncan Multiple RangeTest($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}.

The effect of green manure application methods on weed intensity

Results in table 11 show the effect of green manure application methods on weed intensity. These indicate that the number of broadleaf weeds, total number of weeds and total weed dry weight were decreasing with green manure in both sites. In Kilasilo the number of grasses showed significant (P≤0.05) difference among application methods of green manure treatments under *C. ochroleuca* plough under (11.2) which vary significantly (P≤0.05) by having fewer grass weeds than mulch (16.4). The weed intensity did not vary significantly (P≤0.05) on the application methods of all other green manure species in both sites.

Table 11: The effect of green manure application methods on weed infestation.

	Weeds m⁻²							
Treat	Kilasilo				Itope			
	Grasses	Broadleaf	Total count	Total dry wt (gm)	Grasses	Broad leaf	Total count	Total dry wt (gm)
1	17.5a	31.0a	49.3a	30.7a	19.3a	34.7a	54.5a	52.7a
2(Mulch)	16.4a	11.2bc	27.7b	20.3bc	19.0a	15.1b	34.2b	33.2cd
2(Plu)	11.2b	6.9c	18.2b	14.4c	18.6a	11.2b	31.2b	30.9d
3 (Mulch)	21.4a	11.3bc	32.7b	24.8b	18.1a	15.2b	33.6b	29.4d
3(Plu)	17.5a	16.0b	33.9b	27.2b	16.4a	15.1b	33.3b	33.5cd
4(Mulch)	16.7a	13.1bc	29.8b	28.5b	19.8a	16.9b	36.8b	40.6b
4(Plu)	18.6a	11.0bc	29.5b	26.2b	19.2a	16.6b	35.9b	37.6bc
SE	0.36	0.56	0.61	0.43	0.37	0.35	0.35	0.24
CV (%)	15.58	26.62	19.07	15.06	15.01	14.87	10.25	6.98

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)

Key 1= Control, 2 = *C. ochroleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The effect of green manure application methods on *Striga* infestation

The results in table 12 show that *Striga* count in the 6th and 12th week after germination of rice in both sites was significantly higher in the control plots compared to green manure applied plots. The number of *Striga*, *Striga* plant height and capsule number did not vary significantly (P≤0.05) on the application methods in all green manure species except *M. invisa* under mulch in the 6[th] week were significantly lower compared to ploughing under. However, in Itope *M. invisa* ploughing under reduced *Striga* plant height and capsule number significantly (P≤0.05).

Table 12: The effect of green manure application methods on *Striga* growth and development.

Treat	Kilasilo				Itope			
	Mean number of *Striga* in 10 m^2		*Striga* height (cm)	*Striga* capsules per plant	Mean number of *Striga* in 10 m^2		*Striga* height (cm)	*Striga* capsules per plant
	6wks	12 wks			6 wks	12 wks		
1	26.5a	30.5a	23.4a	14.3a	23.20a	27.3a	29.15a	16.9a
2(Mulch)	0.4c	3.0c	10.9bc	6.0b	0b	0.5b	2.8b	2.2b
2(Plu)	0.4c	1.3c	7.1c	4.1b	0b	0.3b	2.4b	1.7b
3 (Mulch)	0.7c	8.9b	22.0a	14.9a	0b	0b	-	-
3 (Plu.	2.4b	8.5b	22.8a	14.9a	0b	0b	-	-
4 (Mulch)	2.4b	9.9b	21.7a	13.8a	0b	0.2b	1.3bc	1.3bc
4 (Plu)	3.3b	7.9b	11.4b	14.0a	0b	0.2b	0.3c	1.7b
SE	0.17	0.19	0.32	0.26	0.45	0.10	0.36	0.29
CV (%)	25.88	19.93	23.93	23.79	10.54	22.56	21	28

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)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The effect of green manure application methods on growth and yield of rice

Results in Table 13 show that application methods of green manure significantly (P≤0.05) increased rice grain yield and yield components in both sites. The control plots in both sites had shorter plants, fewer tillers per plant, shorter panicles and lower grain yield than green manure plots. In Kilasilo *C. ochroleuca* mulch and *M. invisa* plough-under promoted significant (P≤0.05) taller plants (100.7 cm and 102.6 cm) than the control (89.5 cm). In Kilasilo *C. ochroleuca* mulch promoted significantly taller plants, more panicles per plant, longer panicles and higher grain yield than other treatments. In Kilasilo plant height, vary significantly with application methods of green manure. Application methods of *M. invisa* did not significantly (P≤0.05) influence the number of tillers, panicle length, and yield. On the other hand, *C. obtusifolia* did not have an influence on panicle length and yield. High yield was recorded under *C. ochroleuca* mulch (3403 kg ha^{-1}) followed by plough under (3214 kg ha^{-1}), control which had significantly (P≤0.05) low yield.

Crotalaria ochroleuca and *M. invisa* showed a significant (P≤0.05) difference in plant height between mulch and plough under. The plant heights for *C. ochroleuca* were 102.7 cm and 107.2 cm while those of *M. invisa* were 103.1 cm and 107.7 cm. The number of tillers varied significantly (P≤0.05) under *M. invisa* where ploughing under had more tillers (11.7) than mulch (10.1). Application methods of green manure did not significantly influence the number of tillers, panicle length and yield under *C. ochroleuca*.

Table 13: The effect of green manure application methods on growth and yield of rice.

	Kilasilo					Itope				
	Plant ht (cm)	Tillers/ plant	Panicles/ plant	Panicle length (cm)	Yield kgha^{-1}	Plant ht (cm)	Tillers/ plant	Pani./ plant	Panicle length (cm)	Yield kgha^{-1}
1	89.5d	7.6d	6.8d	17.6d	1767d	93.5d	9.2c	8.2d	18.0d	1597f
2(Mulch)	100.8a	10.0a	9.3a	21.1a	3403a	102.8b	11.7a	11.4a	21.1a	3061b
2(Plu)	96.6b	9.0b	8.9b	18.6c	3214b	107.2a	11.7a	11.4a	21.1a	3061b
3(Mulch)	94.2c	9.1b	8.6b	17.8d	2537c	103.1b	10.1b	9.4c	20.9a	2827c
3(Plu)	102.6a	9.4b	8.3b	19.3b	2667c	107.7a	11.9a	10.8a	18.2c	3285a
4(Mulch)	93.6c	7.9d	7.3c	17.9d	2532c	95.6cd	10.7b	10.0b	18.8c	2284e
4(Plu)	97.0b	8.6c	8.4b	17.6d	2607c	97.3c	10.8b	10.0b	20.2b	2553d
SE	1.30	0.20	0.21	0.30	55	1.35	0.26	0.23	0.35	55
CV (%)	4.07	6.87	8.09	4.91	6.16	4.02	7.33	7.09	5.49	6.08

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)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The effect of green manure application methods and fertilizer on *Striga* growth and development

Results in Table 14 show that the control plots had high ($P \leq 0.05$) number of *Striga* at 6 and 12 weeks after rice germination in both sites. However, the number of *Striga* decreased when green manure application methods were superimposed with fertilizer in both sites. The number of *Striga* was higher in the control plots than other treatments in Itope than Kilasilo. In addition, *Striga* number increased in the 12th week in both sites. There was a reduction of *Striga* to zero in some plots at Itope under the influence of green manure application methods. The reduction of *Striga* height and number of capsules per plant in Kilasilo showed some variations. For example under *C. obtusifolia* (mulch) there was an increase in *Striga* height and capsule numbers per plant while under *C. ochroleuca* (mulch) there was a decrease in plant height and capsule number.

Table 14: The effect of green manure application methods and fertilizer on *Striga* growth and development.

	Fert	Kilasilo *Striga* count in 10 m^{-2} 6 wks	Kilasilo *Striga* count in 10 m^{-2} 12 wks	Kilasilo *Striga* height (cm)	Kilasilo Capsules /plant	Itope *Striga* count in 10 m^{-2} 6 wks	Itope *Striga* count in 10 m^{-2} 12 wks	Itope *Striga* heigh t (cm)	Itope Caps ules/p lant
1	F1	29.3a	61.1a	19.5bcde	15.3abc	27.7a	46.0a	26.5a	15.2d
	F2	29.3a	24.2b	24.6abc	11.6cd	21.6b	27.2b	28.9a	17.2d
	F3	22.5b	14.2c	25.2ab	14.5abc	20.3c	13.5c	30.2a	16.9d
2(Mulch)	F1	0.5gh	4.7hij	13.8ef	8.3de	0d	1.0d	3.7c	2.8c
	F2	0.5fgh	3.1jk	14.1ef	6.4e	0d	0.7de	4.8c	3.1bc
	F3	0.2gh	1.5lm	4.8g	3.7f	0d	0f	-	-
2(Plu)	F1	1.0fg	2.6kl	11.2f	7.1e	0dd	1.1d	10.0b	5.8b
	F2	0.9fg	1.2mn	4.8g	2.6f	0d	0f	-	-
	F3	0.9fg	0.5n	4.5g	1.9f	0d	0f	-	-
3(Mulch)	F1	1.2f	10.5de	17.1de	13.1bc	0d	0f	-	-
	F2	0h	7.7fg	22.1abcd	15.6abc	0d	0f	-	-
	F3	1.0fg	5.8ghi	26.2a	14.6abc	0d	0f	-	-
3(Plu)	F1	5.2c	10.8de	20.8abcd	13.8abc	0d	1.0	3.7c	2.6c
	F2	3.4de	9.2ef	21.5abcd	13.2bc	0d	0f	-	-
	F3	4.7cd	5.9gh	24.7abc	16.4ab	0d	0f	-	-
4(Mulch)	F1	3.4de	14.6c	17.1de	11.8cd	0d	1.1de	5.1c	3.4bc
	F2	3.8cde	10.1def	23.1abcd	14.9abc	0d	0f	-	-
	F3	0.7fg	5.9ghi	23.9abc	13.9abc	0d	0f	-	-
4(Plu)	F1	3.2de	12.5cd	16.9dc	15.8abc	0d	0f	-	-
	F2	3.1e	8.2ef	18.2cde	17.8a	0d	0f	-	-
	F3	3.5de	4.0ijk	10.4f	7.66e	0d	0f	-	-
SE		0.66	0.74	0.12	0.1	0.16	0.04	0.14	0.11
CV(%)		25.88	19.93	23.93	23.79	10.54	25.56	61	68

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 ($P \leq 0.05$)
Key 1 = Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1 = 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The effect of green manure application methods and fertiliser on growth and yield of rice

Application of inorganic nitrogen fertilizer 50 kg N ha^{-1} resulted into taller plants than 0 and 25 kg N ha^{-1} in Kilasilo (Table 14). The number of tillers per plant increased under the influence of application methods of green manure and inorganic fertilizer where 50 kg N ha^{-1} had more ($P \leq 0.05$) tillers than 0 kg N ha^{-1}. However, when 50 kg N ha^{-1} were applied with *C. ochroleuca* (mulch), *C. obtussifolia* plough under and *M. invisa,* both mulch and plough under promoted higher number of tiller per plant ($P \leq 0.05$) 11.7 cm, 10.7 cm, 10.7.cm and 10.3 cm respectively than other treatments. The increase in panicle number ($P \leq 0.05$) was the result of the influence green manure and nitrogen application at 50kg N ha^{-1} and green manure application methods. The number of panicles showed a significant difference ($P \leq 0.05$) with application methods under *C. ochroleuca* where mulch had 10.7 panicles, and *C. obtusifolia* where ploughed under had 10.3 panicles. The panicle lengths in all treatments at 50 kg N ha^{-1} were significantly ($P \leq 0.05$) high except *C. obtusifolia*. Panicle showed a significantly difference ($P \leq 0.05$) in green manure application methods under *C. ochroleuca,* mulch had (23.7 cm) while *M. invisa* and *C. obtusifolia* plough under had 20.6 cm and 18.3 cm panicle lengths respectively. Green manure and fertilizer rate 50 kg N ha^{-1} promoted more grain yield than 0 kg N ha^{-1} and 25 kg N ha^{-1}. The grain yield showed a significant difference under *C. ochroleuca* at 25 kg N ha^{-1} where mulch promoted high grain yield (3368 kg ha^{-1}). On the other hand, plough under promoted high grain yield under *C. obtusifolia* 25 kg N ha^{-1} 2653 kg ha^{-1} and 50kg N ha^{-1} 3118 kg ha^{-1}.

In Itope green manure application methods and fertilizer showed an increase in plant height at 25kg N ha^{-1} and 50 kg N ha^{-1} in *M. invisa*. A significant difference ($P \leq 0.05$) within green manure application methods was observed under *M. invisa* 25kg N ha^{-1} where plough under was superior to mulch. On the other hand, a significant ($P \leq 0.05$) difference in green manure application methods was expressed on *M. invisa* and *C. obtusifolia* 0kg N ha^{-1} where plough under had more panicles than mulch. The length of the panicles was significantly ($P \leq 0.05$) influenced by green manure application methods as observed under *C. ochroleuca* and *M. invisa* where mulch had shorter panicle length than ploughed under. The application of green manure and fertilizer increased grain yield significantly at 50 kg N ha^{-1}. On the other hand, yield in green manure application methods significantly ($P \leq 0.05$) differed under all green manure species where plough under was superior to mulch.

Table 15: The effect of green manure application methods and fertilizer on growth and yield of rice.

Treatments	F.	Kilasiko					Itope				
		Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length (cm)	Grain yield in Kg ha^{-1}	Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length (cm)	Grain yield in Kg ha^{-1}
1	F1	77.8k	6..3h	5.7j	16.66h	1018m	85.01	7.7i	6.7k	16.7j	876p
	F2	90.8gh	7.76g	6.7l	17.1gh	2036k	96.4jk	9.0h	7.7j	17.8bhi	1533o
	F3	100.0cd	8.7de	8.0fg	19.0c	2246j	99.0hi	11.0de	10.3ef	19.4ef	2383j
2(Mulch	F1	96.0f	9.0cd	8.3ef	19.0c	2585l	100.0gh	11.3cd	11.0cd	20.5c	2483i
	F2	99.3cde	9.3c	9.0cd	20.7a	3368n	104.7def	11.3cd	11.3bc	20.0cde	3000f
	F3	106.7a	11.7a	10.7a	23.7b	3959a	103.0	12.3a	12.0a	22.7a	3700c
2(Plu)	F1	90.7ghi	8.3cf	8.0fg	18.3de	2716g	104.7def	11.3cd	10.7de	19.3ef	3000f
	F2	96.0f	9.3c	9.3c	18.7cd	3078d	106.7cde	11.3cd	11.0cd	19.7de	3068e
	F3	103.0b	9.3c	9.3c	19.0c	3846b	110.3ab	12.3a	11.3bc	20.3cd	3933a
3(Mulch)	F1	89.3hi	8.0fg	7.3h	17.0gh	1808l	98.3hij	9.3gh	8.3i	20.0cde	1950h
	F2	92.7g	9.0cd	8.3ef	17.5fg	2766f	103.3f	9.3gh	9.3h	19.7de	3066e
	F3	100.76bc	10.3b	10.0b	19.0c	3036e	107.7bc	11.7bc	10.7de	23.0a	3466d
3(Plu)	F1	97.7def	8.7de	7.7gh	18.3de	2276j	104.3ef	11.0de	10.0fg	16.8j	2650h
	F2	102.0bc	9.0cd	8.0fg	19.0c	2696g	107.3cd	12.0ab	10.7de	18.5gh	3873b
	F3	108.0a	10.7b	9.3c	20.7b	3027e	111.3a	12.0ab	11.7ab	19.3ef	3839b
4(Mulch)	F1	84.5j	6.7h	6.0j	16.7h	2241j	87.01	9.7g	8.7i	17.3ij	1803h
	F2	96.0f	8.3ef	7.3h	18.0ef	2253j	97.3hij	10.7ef	10.3ef	18.3gh	2066l
	F3	100.3bcd	8.7de	8.7de	19.1c	2800f	102.3fg	11.7bc	11.0cd	20.7c	2983f
4(Plu)	F1	88.01	6.7h	6.7l	17.0gh	2050k	94.0k	10.3f	9.7gh	18.7fg	2133k
	F2	96.8ef	8.3ef	8.7de	17.5fg	2653h	96.0jk	11.0de	10.3ef	20.3cd	2633h
	F3	106.2a	10.7b	10.3ab	18.3de	3118c	102.0fg	11.0c	10.0fg	21.7b	2893g
SE		0.49	0.07	0.08	0.11	6.57	0.51	0.1	0.09	0.13	6.51
CV(%)		4.07	6.87	8.09	4.01	6.24	4.02	7.33	7.09	5.49	6.08

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu – Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The residual effect of green manure on weed intensity

Results in the table 16 show that the suppression of weeds other than *Striga* by the residual effect of green manure was not effective. Under *C. ochroleuca* and *C. obtusifolia* in Kilasilo and all green manure species in Itope, the reduction of weed infestation was not significant (P≤0.05). In Kilasilo the number of broadleaf weeds was low (P≤0.05) under *M. invisa* (14.3) and *C. obtusifolia* (23.1). Total number of weeds was significantly low (P≤0.05) under *M invisa* (30.6), resulting in reduced dry weight compared to the control. Results in Itope show that *M. invisa* plots had significantly low (P≤0.05) number of grass weeds (15.3) compared to the control plot (25.5). Total number of weeds was significantly low (P≤0.05) under *M invisa.*

Table 16: The residual effect of green manure on weed intensity.

Treat	Weeds m^{-2}							
	Kilasilo				Itope			
	Grasses	Broadleaf	Total count	Total dry wt (gm)	Grasses	Broadleaf	Total count	Total dry wt (gm)
1	20.1ab	29.4a	49.8ab	59.0a	25.5a	21.4a	47.9a	42.6a
2	22.4a	31.2a	54.4a	47.1ab	18.1ab	19.6a	38.3ab	41.6a
3	15.9b	14.3c	30.6c	41.9b	15.3b	17.9a	34.2b	43.0a
4	16.6ab	23.1b	41.1b	48.0ab	22.1ab	17.4a	40.3ab	38.2a
SE	0.32	0.23	0.27	0.27	0.44	0.25	0.39	0.22
CV (%)	22.33	14.10	12.29	11.88	29.84	17.72	18.85	10.26

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)
Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*

The residual effect of green manure on *Striga* growth and development

The results in Table 17 show that in both sites the number of *Striga* decreased significantly (P≤0.05) with the residual effect of green manure in the 6^{th} and 12^{th} week after rice germination in both sites. At Kilasilo, all plots with residual effect of green manure had significantly (P≤0.05) reduced *Striga* number. The *Striga* plant height increased with the residual effect of green manure while number of capsule per plant significantly increased (P≤0.05) under *M. invisa* (23.1) and *C. obtusifolia* (22.3). *Striga* plant height and number of capsule per plant are significantly low (P≤0.05) under the residue effect of *M. invisa* 23.8 cm and 21.8 cm in Itope respectively. In Kilasilo *Striga* plant height and capsule number were low under the control plots.

Table 17: The residual effect of green manure on *Striga* growth and development.

Treat	Kilasilo				Itope			
	Mean number of *Striga* in 10m²		*Striga* height (cm)	*Striga* capsules per plant	Mean number of *Striga* in 10m²		*Striga* height (cm)	*Striga* capsules per plant
	6wks	12 wks			6wks	12 wks		
1	77.6a	134.1a	20.93b	18.0b	96.7a	158.5a	25.7a	25.9a
2	41.0	60.3d	22.34a	19.0b	33.7c	6.5b	28.3a	25.5a
3	48.1c	75.9c	23.80a	23.1a	55.5b	71.1b	23.8b	21.8b
4	62.3b	95.0b	23.21a	22.3a	36.8c	53.1b	27.3a	25.9a
SE	0.27	0.38	0.07	0.09	0.39	0.47	0.08	0.08
CV (%)	11.02	12.07	4.61	6.16	16.30	15.99	4.96	5.04

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)
Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*

The residual effect of green manure on growth and yield of rice

The results in Table 18 show that the rice grain yield increased significantly (P≤0.05) under the influence of the residual effect of green manure in both sites. *Crotalaria ochroleuca* had significant (P≤0.05) taller plants than other treatments in both sites. Panicle count also increased under the residual effect of green manure in both sites. However, panicles were long under in plots applied with *C. ochroleuca* 21.6 cm, 21.7 cm followed by plots applied with *M. invisa* 19.9 cm, 20.3 cm and those applied with *C. obtusifolia* 19.0 cm, 20.1 cm in Kilasilo and Itope respectively. The yield under the residual effect of green manure was significantly higher (P≤0.05) than the control. In both sites *C. ochroleuca* promoted significantly higher yields than both *M. invisa* and *C. obtusifolia* in Kilasilo (1034 kg ha^{-1}) and Itope (1259 kg ha^{-1}) respectively.

Table 18: The residual effect of green manure on growth and yield of rice.

	Kilasilo					Itope				
Treat	Plant ht (cm)	Tillers /plant	Panicles/plant	Panicle length (cm)	Yield kgha^{-1}	Plant ht (cm)	Tillers /plant	Pani./ plant	Panicle length (cm)	Yield kgha^{-1}
1	82.2c	7.3a	7.0b	18.2d	799c	85.3c	7.3c	6.9b	18.2c	881c
2	95.8a	7.7a	7.7a	21.5a	1034a	98.8a	8.8b	8.6a	21.7a	1259a
3	89.1b	7.6a	7.6a	19.9b	918b	95.1b	8.6b	8.4a	20.3b	1134b
4	90.0b	7.9a	7.9a	19.0c	918b	93.3b	9.2a	8.8a	20.1b	1123b
SE	1.39	0.21	0.20	0.25	24	1.42	0.16	0.17	0.26	61
CV (%)	4.6	8.6	8.2	3.9	7.98	4.59	5.90	6.45	4.06	16.67

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)
Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*

The residual effect of green manure and fertilizer on *Striga* growth and development

There were few *Striga* in the 6th week after rice germination. In the 12th week, the number of *Striga* increased in both sites. *Striga* number varied significantly with green manure treatments at 50 kg ha^{-1} in Kilasilo. The same situation was observed in the 12th week but the number of *Striga* increased in the same manner as the 6th week. *Striga* height was increased independently of the influence of either fertiliser or the residual effect of the green manure. *Striga* capsule number showed a significant (P≤0.05) decrease at when inorganic fertilizer was applied at 50 kg ha^{-1}.

Table 19: The residual effect of green manure and fertilizer on *Striga* growth and development.

		Kilasilo				Itope			
Treat.	Fert	*Striga* count in 10m^{-2}		*Striga* height (cm)	Capsules/plant	*Striga* count in 10m^{-2}		*Striga* height (cm)	Capsules/plant
		6wks	12wks			6wks	12wks		
1	F1	103.9a	182.1a	19.3d	18.5cd	153.0a	247.8a	24.6cd	28.4bc
	F2	72.6cd	125.2b	20.2c	15.9d	100.7b	143.5b	27.0abc	27.3bcd
	F3	58.2d	100.7b	22.6abc	19.2b	50.3dc	101.1c	25.6bcd	22.3c
2	F1	69.05bcd	110.4b	22.7c	18.5cd	51.6de	89.9cd	27.0abc	29.3ab
	F2	42.5c	61.1d	22.6abc	19.9b	32.7fg	63.5de	29.3a	27.6b
	F3	19.2f	26.9f	23.9ab	18.6cd	30.5g	26.0g	29.9a	20.1e
3	F1	75.7c	115.2b	22.5abc	25.2a	97.9bc	131.5b	23.6d	25.2d
	F2	47.8c	88.8c	23.9ab	19.6ab	46.1ef	59.9ef	23.9d	22.3e
	F3	26.7f	35.6cf	24.8a	21.3bc	32.0fg	38.9fg	23.9d	18.2f
4	F1	85.1ab	131.7b	22.3b	20.6bc	69.6cd	98.7cd	25.5bcd	31.9a
	F2	65.9cd	110.6	22.5bc	24.7a	26.7g	49.1e	28.8a	25.8cd
	F3	41.2e	52.5de	24.9a	21.8b	22.1g	24.0g	27.6ab	20.7e
SE		0.48	0.66	0.12	0.16	0.68	0.83	0.14	0.14
CV (%)		11.02	12.07	4.61	6.16	16.30	15.99	4.96	5.04

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The residual effect of green manure and fertilizer on growth and yield of rice

The results in table 20 show that application of inorganic fertilizer improved the residual effect of the green manure. Plant height, number of tillers, panicle length and grain yield increased significantly ($P \leq 0.05$) with application of inorganic fertilizer under the residual effect of green manure. On the other hand, the residual effect of green manure and fertilizer influenced the number of tillers per plant. The number of panicles per plant and panicle length increased with the residual effect of green manure and fertilizer 50 kg ha^{-1}. The grain yield in all plots that had received green manure during previous season increased significantly ($P \leq 0.05$) when nitrogen was applied at 25 and 50 kg ha^{-1}. In Itope, rice plant height showed a significant ($P \leq 0.05$) increase with the residual effect of green manure and fertilizer. On the other hand, the residual effect of green manure and fertilizer increased panicle number per plant and panicle length significantly ($P \leq 0.05$). The grain yield in all treatments showed a significant increase ($P \leq 0.05$) at 25 kg $ha^{-1}$and 50 kg ha^{-1}.

The Benefit: Cost of application of green manure and fertiliser on rice yield.

The results in table 21 show that benefit per unit cost incurred increased ($P \leq 0.05$) significantly in plots where green manure and inorganic fertilizer were applied in both sites. However, the following year when green manure was not applied (residual effect) the benefit dropped in both sites. Among the green manures application *C. ochroleuca* gave more ($P \leq 0.05$) benefit per unit cost incurred followed by *M. invisa* and *C. btusifolia.* In Itope the benefit from 25 kg N ha^{-1} and 50 kg N ha^{-1} did not vary significantly ($P \leq 0.05$) under *C. ochroleuca* (9.5:1 and 9.1:1) and *M. invisa* (2 .6:1 and 6.5:1). In year 2002/03 (Kilasilo) the benefit per unit cost, in the control treatment was realised at 50 kg ha^{-1} (2.3:1). In the residual effect of *C. ochroleuca* there was no improvement in the benefit per unit cost when inorganic fertilizer was added, 0 kg N ha^{-1} (3.4:1) was similar to 50 kg N ha^{-1} (3.3:1) while 25 kg N ha^{-1} was (2.9:1). Under the residual effect of *M invisa* there was a drop in the benefit when inorganic fertilizer was applied. The same was observed under *C. obtusifolia.* At Itope, there was no benefit realised from residual effect.

Table 20: The residual effect of green manure and fertilizer on growth and yield of rice.

Treat		Kilasiko Plant height (cm)	Kilasiko Tillers per plant	Kilasiko Panicle counts/ plant	Kilasiko Panicle length (cm)	Kilasiko Grain yield in $Kgha^{-1}$	Itope Plant height (cm)	Itope Tillers per plant	Itope Panicle counts/ plant	Itope Panicle length (cm)	Itope Grain yield in $Kgha^{-1}$
1	F1	77.5e	6.7d	6.3f	17.5f	666g	82.7e	6.7e	6.0h	17.2d	679f
	F2	80.0d	7.3bd	7.0def	18.2ef	784f	82.3e	7.0e	6.7g	18.3c	826ef
	F3	89.0c	8.0ab	7.7cd	19.0de	948de	91.0d	8.3c	8.0de	19.0bc	1138c
2.	F1	88.16c	6.7d	6.7ef	20.9bc	874e	92.3cd	7.7d	7.7ef	19.3b	1023cd
	F2	95.8b	8.0ab	8.0abc	21.7ab	988cd	100.3ab	8.7c	8.3dc	21.0a	1220bc
	F3	103.5a	8.3a	8.3a	22.1a	1240a	103.7a	10.0a	9.7a	21.7a	1534a
3	F1	86.3c	7.0cd	7.0def	18.5e	761f	88.6d	7.7d	7.3f	19.7b	889def
	F2	86.5c	7.3bcd	7.3cde	19.7d	929de	95.5bc	8.7c	8.7c	19.7b	1077cd
	F3	97.0b	8.3a	8.3a	21.3ab	1066bc	101.3a	9.3b	9.3ab	21.4a	1437a
4	F1	86.3c	7.0cd	7.0def	18.8e	785f	88.4d	8.3c	7.7ef	19.7b	878def
	F2	89.3c	8.0ab	8.0abc	17.8f	941de	91.7cd	9.0b	9.0bc	19.7b	1137c
	F3	94.3b	8.7a	8.7a	20.5c	1029bc	99.7ab	10.3a	9.7a	21.1a	1354ab
SE		2.41	0.37	0.36	0.44	42	2.46	0.28	0.30	0.46	105
CV(%)		4.61	8.6	8.2	3.9	7.98	5.59	5.90	6.45	4.06	61

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C.obtusifolia*, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

Table 21: The Benefit: Cost ratio of the effect of green manure and fertilizer on rice yield.

Treat	Fert	Kilasilo		Itope	
		2001/02	2002/03	2001/02	2002/03
1	F1	1.7g	1.3e	1.8h	1.3c
	F2	3.0f	1.5e	2.5g	1.3c
	F3	3.6ef	2.3d	3.2f	1.9c
2	F1	9.5b	3.4a	10.2a	4.1a
	F2	9.2b	2.9b	9.5b	3.8a
	F3	10.1a	3.3ab	9.1b	4.3a
3	F1	7.6c	2.8ab	6.3c	3.5ab
	F2	7.3c	2.7cd	6.1c	3.2b
	F3	7.7c	2.7cd	6.5c	4.0a
4	F1	3.8e	3.4a	4.2e	3.4b
	F2	5.9d	3.0abc	5.5d	3.5ab
	F3	6.5d	2.8b	6.1c	3.4b
SE		0.31	0.23	0.25	0.40
CV(%)		8.5	14.72	7.45	2.61

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)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The residual effect of green manure application methods on weed intensity.

It is shown in Table 22 that the residual effect of green manure application methods reduced the total number of weeds other than *Striga* and total weed dry weight in both sites. In Kilasilo *M. invisa* 13.9 and 15.9 and *C. obtusifolia* 15.9 and 15.1 had significant low (P≤0.05) number of grasses in both mulch and plough under. Broadleaf weeds were significantly few (P≤0.05) under *C. ochroleuca* (mulch) 14.3, *M. invisa* (plough under) 17.4, and *C. obtusifolia* (mulch) 13.8. Total number of weeds was significantly high (P≤0.05) except under *C. ochroleuca* mulch 32.8, *M invisa* mulch 35.5 and *C. obtusifolia* plough under 32.0, while the dry weight was also significantly high (P≤0.05) except *C. ochroleuca* mulch 24.4 g. The results in Itope indicate that the number of broadleaf weeds was not affected by residual effect of green manure application methods while grasses showed significant (P≤0.05) difference, under *C. ochroleuca*, mulch had fewer grasses 10.4 than plough under 18.1. On the other hand, in *C. obtusifolia* plough under, few grasses were found 10.8 while in mulch there were 15.4. Weed dry weight showed a significant ($P \leq 0.05$) difference in green manure application methods on *C. ochroleuca* and *M. invisa*.

Table 22: The residual effect of green manure application methods on weed infestation.

	Weeds m^{-2}							
Treat	Kilasilo				Itope			
	Grasses	Broadleaf	Total count	Total dry wt (gm)	Grasses	Broadleaf	Total count	Total dry wt (gm)
1	18.8a	22.3a	41.9a	39.2a	16.6ab	21.5a	38.3a	44.2a
2(Mulch)	18.0a	14.3b	32.8c	24.4c	10.4c	18.7ab	29.8c	22.1cd
2(Plu)	16.4ab	22.8a	39.6ab	37.1a	18.1a	17.6b	35.9ab	32.4b
3(Mulch)	13.9b	20.3a	35.5bc	30.1b	17.2a	15.5b	33.1bc	25.4c
3(Plu)	15.9b	17.4b	34.0c	30.5bc	16.9a	15.8b	32.9bc	30.5b
4(Mulch)	11.5b	13.8b	25.4d	27.4bc	15.4b	17.6b	33.8bc	22.3cd
4(Plu)	15.5b	16.4ab	32.0c	36.6a	10.8c	17.1b	28.2c	18.1d
SE	0.21	0.24	0.19	0.22	0.23	0.19	0.20	0.29
CV (%)	16.29	17.44	10.20	12.13	17.89	14.13	10.55	17.18

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochroleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The residual effect of green manure application methods on *Striga* growth and development

The results indicate that *Striga* plant height and the number of capsules per plant were not affected by the residual effect of green manure application methods in Itope while in Kilasilo there was an increase more than the control. Plants were taller in mulch than in plough under while the number of capsules was higher in plough under than mulch. There were significantly low ($P \leq 0.05$) few *Striga* in the 6th week except under *C. obtusifolia* plough under in Kilasilo. *Striga* plants in all treatments were taller than the control except *M. invisa* plough under and *C. obtusifolia* mulch while the number of *Striga* capsules in the control plots was significantly (P≤0.05) low. The results show that in Itope site, *Striga* count in the 6th week was significant (P≤0.05) low under *C. obtusifolia* mulch (9.3). In the 12th week *C. ochroleuca* (mulch) (39.9), *M. invisa* plough under (37.2), and *C. obtusifolia* (plough under and mulch) had significant (P≤0.05) few *Striga* (40.1 and 23.7 respectively).

Table 23:The residual effect of green manure application methods on *Striga* growth and development.

	Kilasilo				Itope			
	Mean number of *Striga* in 10 m²		*Striga* height (cm)	*Striga* capsules per plant	Mean number of *Striga* in 10 m²		*Striga* height (cm)	*Striga* capsules per plant
Treat	6wks	12 wks			6 wks	12 wks		
1	82.5a	94.0a	20.8c	15.7d	41.9a	81.6a	19.8a	18.6a
2 (Mulch)	44.9	65.9b	22.1b	18.3c	31.0ab	39.9b	24.7a	19.2a
2 (Plu)	42.3b	72.6ab	23.9a	21.2b	38.8a	67.9a	18.2a	20.8a
3(Mulch)	45.3b	64.6bc	23.6ab	23.1a	38.2a	68.9a	20.4a	20.8a
3(Plu.	27.7c	96.4c	20.4c	18.3c	25.2b	37.9b	18.6a	13.3a
4(Mulch)	34.1bc	51.6bc	22.3bc	20.6b	9.3c	23.7c	18.9a	15.4a
4(Plu)	65.4a	90.9a	18.6d	17.1bc	27.5ab	40.1b	22.3a	18.8a
SE	0.37	0.62	0.08	0.08	0.38	0.42	1.10	1.15
CV (%)	16.04	22.56	5.20	5.48	20.99	18.12	7.14	10.87

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)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The residual effect of green manure application methods on growth and yield of rice

The results in table 24 (Kilasilo) indicate that rice plants grown under the residual effect of green manure application methods were significantly taller (P≤0.05) than the control in Kilasilo. *Cassia obtusifolia* plough under had significant higher (P≤0.05) number of tillers than other treatments. Panicle number per plant was significant high (P≤0.05) under *C. ochroleuca* (plough-under 7.8), *M. invisa* (mulch 7.9) and *C. obtusifolia* mulch and plough under. The results indicate that in Itope the residual effect of green manure application methods increased plant height significantly ($P \leq 0.05$) A significant variation ($P \leq 0.05$) on green manure application methods was shown by *C. ochroleuca* and *M. invisa*. *Crotolaria ochroleuca* mulch indicates significant high ($P \leq 0.05$) number of tillers (10). *Crotolaria ochroleuca* mulch also had significant more ($P \leq 0.05$) panicles per plant, panicle length per plant and grain yield than other treatments.

Table 24: The residual effect of green manure application methods on growth and yield of rice.

	Kilasilo					Itope				
Treat	Plant ht (cm)	Tillers /plant	Panicles/plant	Panicle length (cm)	Yield $kgha^{-1}$	Plant ht (cm)	Tillers /plant	Pani./ plant	Panicl length (cm)	Yield $kgha^{-1}$
1	85.2b	7.3bc	7.2b	18.6c	972c	83.7c	7.6e	7.3f	18.1c	782f
2(Mulch)	94.4a	7.4bc	7.3b	20.7a	1006bc	101.9a	10.0a	10.0a	21.8a	1677a
2(Plu)	91.9a	7.8bc	7.8a	20.3ab	985bc	92.1b	8.6c	8.3dc	19.2b	1175d
3(Mulch)	91.7a	8.0ab	7.9a	20.6a	1124a	90.7b	9.1bc	8.9c	19.5b	1052e
3(Plu)	92.8a	7.2c	7.2b	19.8b	1082ab	98.7a	9.4b	9.4ab	21.2a	1443b
4(Mulch)	93.0a	7.9ab	7.9a	19.7b	1085ab	92.8b	8.3d	8.1e	19.9b	1363c
4(Plu)	92.4a	8.2a	7.9a	19.7b	994bc	92.1b	8.8c	8.7cd	19.6b	1130d
SE	1.46	0.22	0.22	0.22	34	1.62	0.18	0.19	0.28	37
CV (%)	4.89	8.58	8.84	3.34	9.91	5.24	6.14	6.88	4.23	9.23

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under

The residual effect of green manure application methods and inorganic fertilizer on *Striga* growth and development

The residual effect of green manure application methods and inorganic fertilizer is shown in Table 25. The results indicate that the number of *Striga* plants in the 6^{th} and 12^{th} week decreased when fertilizer urea was applied in both sites. *Striga* plant height and the number of capsules per plant were not affected by green manure application methods and inorganic fertilizer. There was a significant variation ($P \leq 0.05$) on the number of *Striga* under the residual effect of green manure application methods and urea in Itope. *Striga* plant height was decreasing with the application of urea also under *C. ochroleuca* plough under *Striga* plant were shorter than in mulch. The application of nitrogen fertilizer and residual effect of *C. ochroleuca* mulch, *C. obtusifolia* mulch reduced the number of capsules per plant.

Table 25: The residual effect of green manure application methods and fertilizer on *Striga* growth and development.

Treat	Fert	Kilasilo *Striga* count in 10m² 6wks	Kilasilo *Striga* count in 10m² 12wks	Kilasilo *Striga* height	Kilasilo Capsules/plant	Itope *Striga* count in 10m² 6wks	Itope *Striga* count in 10m² 12wks	Itope *Striga* height	Itope Capsules/plant
1	F1	103.5a	125.4b	21.2g	15.2j	69.9a	117.2a	19.3fgh	19.2cdef
	F2	83.6b	98.5bcde	20.8gh	15.2j	32.6efg	85.2bc	19.3fgh	17.9efg
	F3	63.2cd	63.7ghi	20.7ghi	16.6hi	28.4fghi	49.5f	20.7def	18.6cdef
2Mulch)	F1	0.5cde	112.9bc	24.9abc	22.5abc	37.8def	46.4fg	26.1a	21.6abc
	F2	40.2gh	64.5fghi	23.6bcd	21.3cd	31.2efghi	44.9fg	24.2ab	16.8fghi
	F3	28.9ij	47.7ij	23.3cd	18.2efg	24.5hij	29.8hi	23.8abc	17.2efgh
2(Plu)	F1	71.2bc	104.4bcd	20.8gh	19.0ef	60.8ab	114.2a	18.5ghi	23.9a
	F2	39.3gh	62.7hi	19.2hij	17.3gh	44.3cd	74.7cd	17.8hij	19.3bcdef
	F3	28.9ij	38.9jk	26.6a	17.2ghi	17.8j	29.0hi	18.4ghi	19.3bcdef
3(Mulch)	F1	54.6de	87.5cdef	19.1ij	19.7de	53.8bc	94.6b	21.6cde	21.5abc
	F2	23.0j	40.2jk	20.3ghi	17.9fgh	41.0de	71.9cd	18.2ghi	19.9bcde
	F3	12.4k	22.3l	21.6efg	15.2ij	23.0ij	44.7fg	21.4def	20.3abcd
3(Plu)	F1	55.0de	80.5defg	21.5fg	23.3a	33.5ij	54.0ef	19.9efg	14.4ij
	F2	54.7de	62.4hi	25.3ab	21.4c	24.2hij	36.5gh	22.5bcd	14.2ij
	F3	29.1ij	52.4ij	24.1bcd	23.1ab	19.0j	26.0ij	16.6ij	11.2k
4(Mulch)	F1	104.9a	170.6a	19.3hij	21.6bc	18.1j	52.9ef	20.9def	17.2efgh
	F2	55.6de	76.6efgh	18.6j	18.9ef	3.9k	18.2j	19.9efg	15.3hij
	F3	43.2fg	46.0ij	17.9j	16.6hij	8.1k	9.7k	16.0j	13.7j
4(Plu)	F1	51.2ef	85.6defg	20.4ghi	20.9cd	36.8defg	64.3de	21.3def	18.4defg
	F2	31.8hi	47.5ij	23.1def	22.4abc	27.8ghi	36.3gh	21.87cde	22.3ab
	F3	22,3j	29.4kl	23.2cde	17.2ghi	19.1j	24.3ij	24.1ab	16.0ghij
SE		0.14	0.23	0.03	0.03	0.14	0.16	0.04	0.5
CV(%)		16.04	22.56	5.20	5.48	20.99	18.12	7.14	10.87

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

The residual effect of green manure application methods and inorganic fertilizer on growth and yield of rice

The results in Table 26 indicated that when inorganic fertilizer was applied there was an increase in plant height, number of tillers, panicle number, panicle length, and grain yield in both sites. The number of tillers and the number of panicles showed that the residual effect of the green manure showed no significant difference except under *M. invisa* where plough under had more tillers ($P \leq 0.05$) than mulch. The number of panicles increased with the application of inorganic fertilizer urea except under *M invisa* mulch where it dropped. The panicle length showed significant ($P \leq 0.05$) difference from the residual effect of the green manure *M. invisa* when inorganic fertilizer was applied (25 kg N ha^{-1} was 21.2 cm and 50 kg N ha^{-1} was 21.2 cm). *C. obtusifolia* with 25 kg N ha^{-1} panicle length was 20.8 cm where plough under had long panicles. The residual effect of green manure application methods on grain yield showed a difference under *C. ochroleuca*. Under *M. invisa* the difference was observed when 25 kg N ha^{-1} was applied, mulch had higher yield 969 kg ha^{-1} than plough under 1189 kg ha^{-1}.

The results in Itope indicate that plant height, number of tillers per plant, panicle numbers, panicle length and grain yield increased when inorganic nitrogen fertilizer was applied. The residual effect of the green manure application methods showed significant difference ($P \leq 0.05$) when fertilizer was applied. *Crotalaria ochroleuca* mulch showed high grain yield, long panicles, high number of panicles, high number of tillers and tall plants compared to plough under.

The Benefit: Cost ratio of the residual effect of green manure application methods and inorganic fertilizer on growth and yield of rice

The results in Table 27 show that in the first season (2001/02) there was an increase ($P \leq 0.05$) in the benefit where green manure and inorganic fertilizer urea were applied. The highest benefit per unit cost incurred was realised when *C. ochroleuca* mulch was applied without inorganic nitrogen fertilizer. There were few cases where no significant response ($P \leq 0.05$) was observed when fertiliser was applied. For example *M. invisa* plough under in Kilasilo and *C. ochroleuca* mulch in Itope where 0kg N $ha^{-1}$and 25 kg N ha^{-1} did not vary significantly ($P \leq 0.05$). The residual effect (2002/03) at Kilasilo sites showed that the benefit per unit cost decreased when fertilizer was applied in *C. ochroleuca* plots. In Itope there was no benefit realised per unit cost invested when fertilizer was applied. In both site under the control treatments there was an improvement in the benefit per unit cost invested except at Itope in year 2002/03. Among the application methods mulch showed high benefit per unit cost incurred compared to plough under.

Table 26: The residual effect of green manure application methods and fertiliser on growth and yield of rice.

		Kilasiko					Itope				
Treat	F.	Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length (cm)	Grain yield in $Kgha^{-1}$	Plant height (cm)	Tillers per plant	Panicle counts/ plant	Panicle length (cm)	Grain yield in $Kgha^{-1}$
1	F1	81.5h	6.3h	6.3h	18.3i	733j	79.0i	7.0i	6.7j	17.7k	657l
	F2	82.66h	7.0fg	7.0fg	17.9i	892h	79.8i	7.7gh	7.7hi	18.2jk	793k
	F3	91.4def	8.7ab	8.3bc	19.7ef	1293b	92.0f	8.0fg	7.7hi	18.3j	895ij
2(Mulch)	F1	89.3ef	7.0fg	7.0fg	20.3cd	869hi	98.7cd	9.3c	9.3d	21.0c	1466d
	F2	91.0def	7.7de	7.7de	20.0de	1012ef	103.0ab	10.0b	10.0a	21.6b	1633c
	F3	95.3abc	8.7ab	8.7ab	20.7bc	1076e	104.0a	10.7a	10.7b	22.6a	1933a
2(Plu)	F1	92.4cde	6.7gh	6.7gh	20.7bc	777j	88.0g	8.3ef	8.0gh	18.6ij	951i
	F2	93.3bcd	7.3ef	7.3ef	20.7bc	1014ef	92.0f	8.3ef	8.0gh	19.3gh	1183fg
	F3	97.3a	8.3bc	8.0cd	208ab	1233bc	96.3de	9.0cd	9.0de	19.6fg	1390de
3Mulch)	F1	88.3fg	6.7gh	7.3ef	19.7ef	910gh	84.0h	9.0cd	8.3fg	18.7ij	850jk
	F2	95.0abc	7.3ef	7.7de	19.8ef	969fg	91.7f	9.0cd	9.0de	20.0ef	1055h
	F3	95.0abc	7.7e	6.7gh	20.1de	1360a	96.3de	9.3c	9.3d	19.9efg	1252f
3(Plu)	F1	86.0g	7.0fg	6.7gh	19.3fgh	890h	93.0ef	9.0cd	9.0de	20.8cd	1121gh
	F2	93.3bcd	8.0cd	8.0cd	21.2a	1189cd	100.0bc	9.0cd	9.0de	21.0c	1437de
	F3	95.7ab	9.0a	9.0a	21.2a	1294b	103.0ab	10.3ab	10.3bc	21.6b	1771b
4(Mulch)	F1	89.7ef	7.3ef	6.7gh	18.9h	802.0ij	86.5gh	8.3ef	7.7hi	19.3gh	1088h
	F2	91.3def	8.3bc	8.3bc	19.3fgh	1024ef	93.9ef	8.0fg	8.0gh	20.0ef	1381e
	F3	96.4ab	9.0a	8.7b	20.9ab	1156d	98.0cd	8.7de	8.7ef	20.3de	1620c
4(Plu)	F1	92.3cde	7.0fg	7.0fg	19.0gh	9320gh	84.8gh	7.3hi	7.3l	20.0ef	951 l
	F2	90.3def	7.7de	7.7de	20.7bc	1081e	92.1f	9.0cd	8.7ef	19.00hi	1053h
	F3	96.3ab	9.0a	9.0a	19.5fg	1242bc	99.3cd	10.0b	10.0c	19.7fg	1386de
SE		0.55	0.08	0.08	12.94	61	0.06	0.06	0.07	0.01	14.3
CV(%)		4.89	8.58	8.84	3.34	9.91	5.24	6.14	6.88	4.23	9.23

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under,F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

Table 27: The Benefit: Cost ratio of the residual effect of green manure application methods and fertilizer on growth and yield of rice.

Treatments	Fert	Kilasilo		Itope	
		2001/02	2002/03	2001/02	2002/03
1	F1	1.7m	1.5j	1.4o	1.2i
	F2	3.8l	1.5j	2.6n	1.2i
	F3	3.8l	2.3hi	4.1m	1.3i
2 (Mulch)	F1	13.4a	3.8a	11.4b	7.1a
	F2	12.7b	3.3b	11.2b	6.0b
	F3	12.7b	3.0bcdc	11.7a	6.2b
2(Plough under)	F1	9.4d	2.9cdef	10.4c	3.8c
	F2	9.0dc	3.0bcde	8.9f	3.6cd
	F3	9.9c	3.3bc	10.1d	3.8c
3(Mulch)	F1	6.6j	2.7defgh	7.2l	2.4h
	F2	8.8ef	2.2l	9.8e	2.4h
	F3	8.3gh	3.0bcd	9.6e	2.7gh
3(Plough under)	F1	6.7j	2.6fghi	7.8h	3.5cd
	F2	6.8j	2.9cdef	8.7f	3.5cd
	F3	6.8j	2.8def	8.9f	3.8c
4(Mulch)	F1	8.5fg	2.2hi	6.6j	3.4de
	F2	8.0h	2.3hi	6.3kl	3.5cd
	F3	7.5l	2.4ghi	8.1g	3.8c
4(Plough under)	F1	5.8k	2.7defg	6.1l	2.8fg
	F2	6.7j	2.6fghi	6.6j	2.4h
	F3	7.0j	2.6efgh	6.4jk	3.1ef
SE		0.07	0.07	0.43	0.05
CV(%)		7.32	13.03	7.12	13.69

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N ha^{-1}

Nitrogen concentration in rice shoots

The results in Table 28 (2001/02) show that the percentage nitrogen accumulated in rice shoots in Kilasilo was significantly ($P \leq 0.05$) high in all green manure treatments. *C. ochroleuca* mulch had 0.745%, 0.82%, 1.01% higher levels of nitrogen than plough under 0.67%, 0.71%, 0.76%, the same was observed under *M. invisa* mulch and plough under. The situation observed in Itope was similar to Kilasilo that rice shoots from green manure had high nitrogen percent at all fertilizer levels compared to control. Under the residual effect (2002/03) there were significant

($P \leq 0.05$) differences in benefit:cost ratio in green manure application methods were superimposed with inorganic fertilizer urea. In Kilasilo site there was no significant difference ($P \leq 0.05$) between mulch and plough under, while in Itope *C. obtusifolia* mulch with 0 kg N ha^{-1} and 25 kg ha^{-1} had higher nitrogen than plough under. When 50 kg N ha^{-1} was applied in *M. invisa* plots plough under 0.88 % was significantly higher than mulch 0.78 %.

The application of green manure and inorganic nitrogen fertilizer significantly ($P \leq 0.05$) increased the amount of nitrogen accumulated from rice shoots in both sites in (2001/02) Table 29. The percent nitrogen concentration among green manure species was *C. ochroleuca* > *M. invisa* > *C. obtusifolia*. The application of green manure and inorganic nitrogen fertilizer showed an increase in the percent nitrogen concentration in both sites in (2001/02). Under the residual effect (2003/03), percent nitrogen concentration in all green manure plots increased with application of inorganic fertiliser urea but under control plot the 25 kg N ha^{-1} did not vary significantly with 50kg N ha^{-1}.

Table 28: Percent nitrogen accumulation in rice shoots under green manure application methods and fertilizer.

Treat	Fert	Kilasilo		Itope	
		2001/02	2002/03	2001/02	2002/03
		Nitrogen concentration at booting satge			
1	F1	0.54m	0.59 j	0.54 k	0.64 jk
	F2	0.57lm	0.72 ghi	0.59 j	0.64 jk
	F3	0.60kl	0.82cde	0.68 gh	0.77 def
2 (Mu)	F1	0.74de	0.68I	0.76 e	0.67 hij
	F2	0.82c	0.82cde	0.86 c	0.82 cd
	F3	1.01a	0.96a	0.96 a	0.94 ab
2 (Plu)	F1	0.67hi	0.68I	0.70 fg	0.68 efgh
	F2	0.71fg	0.76efgh	0.75 e	0.74 efg
	F3	0.76d	0.91a	0.79 d	0.98 a
3 (Mu)	F1	0.66I	0.67I	0.63 i	0.65 ijk
	F2	0.76d	0.75fghi	0.70 fg	0.71 fghi
	F3	0.80c	0.87bc	0.81 d	0.78 de
3 (Plu)	F1	0.61j	0.69I	0.70 fg	0.69 ghij
	F2	0.60kl	0.78defg	0.71 f	0.73 efg
	F3	0.86b	0.93ab	0.91 b	0.88 bc
4 (Mu)	F1	0.61j	0.71hi	0.72 f	0.71 fghi
	F2	0.70fgh	0.75fgi	0.79 d	0.76 def
	F3	0.74d	0.85bc	0.86 c	0.86 cd
4 (Plu)	F1	0.61j	0.73ghi	0.54 k	0.60 k
	F2	0.68ghi	0.73I	0.67 h	0.65I jk
	F3	0.70fgh	0.86bc	0.79 d	0.78 de
SE		0.015	0.032	0.012	0.030
CV(%)		3.74	7.24	3.00	6.77

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N h^{-1}

Table 28: Percent nitrogen accumulation in rice shoots under green manure application methods and fertilizer.

Treat	Fert	Kilasilo		Itope	
		2001/02	2002/03	2001/02	2002/03
		Nitrogen concentration at booting satge			
1	F1	0.54m	0.59 j	0.54 k	0.64 jk
	F2	0.57lm	0.72 ghi	0.59 j	0.64 jk
	F3	0.60kl	0.82cde	0.68 gh	0.77 def
2 (Mu)	F1	0.74de	0.68I	0.76 e	0.67 hij
	F2	0.82c	0.82cde	0.86 c	0.82 cd
	F3	1.01a	0.96a	0.96 a	0.94 ab
2 (Plu)	F1	0.67hi	0.68I	0.70 fg	0.68 efgh
	F2	0.71fg	0.76efgh	0.75 e	0.74 efg
	F3	0.76d	0.91a	0.79 d	0.98 a
3 (Mu)	F1	0.66I	0.67I	0.63 i	0.65 ijk
	F2	0.76d	0.75fghi	0.70 fg	0.71 fghi
	F3	0.80c	0.87bc	0.81 d	0.78 de
3 (Plu)	F1	0.61j	0.69I	0.70 fg	0.69 ghij
	F2	0.60kl	0.78defg	0.71 f	0.73 efg
	F3	0.86b	0.93ab	0.91 b	0.88 bc
4 (Mu)	F1	0.61j	0.71hi	0.72 f	0.71 fghi
	F2	0.70fgh	0.75fgi	0.79 d	0.76 def
	F3	0.74d	0.85bc	0.86 c	0.86 cd
4 (Plu)	F1	0.61j	0.73ghi	0.54 k	0.60 k
	F2	0.68ghi	0.73I	0.67 h	0.65I jk
	F3	0.70fgh	0.86bc	0.79 d	0.78 de
SE		0.015	0.032	0.012	0.030
CV(%)		3.74	7.24	3.00	6.77

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N h^{-1}

Table 29: Percent nitrogen accumulation in rice shoots when green manure and fertilizers were applied.

		Nitrogen concentration in rice shoots at booting stage			
Treat	Fert	Kilasilo		Itope	
		2001/02	2002/03	2001/02	2002/03
1	F1	0.59I	0.61h	0.61e	0.64h
	F2	0.70h	0.72ef	0.81d	0.79de
	F3	0.84e	0.77e	0.91b	0.92a
2	F1	0.84e	0.81cd	0.86c	0.77e
	F2	0.94b	0.90b	0.94b	0.86bc
	F3	1.01a	0.96a	1.00a	0.92a
3	F1	0.75g	0.69f	0.72e	0.67gh
	F2	0.79f	0.79d	0.82d	0.79de
	F3	0.92c	0.86bc	0.94b	0.88ab
4	F1	0.68d	0.62g	0.82d	0.71fg
	F2	0.76c	0.73ef	0.86c	0.75ef
	F3	0.88b	0.85c	0.91b	0.83cd
SE		0.017	0.025	0.017	0.020
CV(%)		3.76	5.63	3.5	4.39

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 ($P \leq 0.05$)

Key 1= Control, 2 = *C. ochruleuca*, 3 = *M. invisa*, 4 = *C. obtusifolia*, Plu = Plough under, F1= 0 kg N ha^{-1}, F2 = 25 kg N ha^{-1}, F3 = 50 kg N h^{-1}

Discussion

Weed infestation

Generally, green manure treatments reduced weed prevalence. Both the weed density and weed dry biomass were significantly ($P \leq 0.05$) reduced when green manure was added in both sites. In Kilasilo, total number of weeds was reduced from 81.2 to 19.9 (m^2) while weed dry biomass was reduced from 120.3g to 24.8g (m^2). In Itope the reduction of total number of weeds was from 52.9 to 24.2 (m^2); weed dry biomass was reduced from 126.3g to 29.8 (m^2). Generally in both sites, the reduction of 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 growing canopy of the green manure plants probably lowered the temperature and light reaching the soil surface which in turn suppressed weed seed germination. Green manure species *C. ochroleuca*, *M. invisa*, *C. obtusifolia* had an allellopathic effect to the weeds due to the levels of polyphenols found in green manure species. The presence of polyphenol compounds found in the green manure species (Roots ÷ shoots) were *C. ochroleuca* 9.35%, *M. invisa* 42.5% *C. obtusifolia* 33.75%. According to Rice (1974) phenolics and their derivatives are potential allellochemicals in agriculture. The important factor in weed control is the amount and the type of phenollics compounds released from the green manure species to the environment (Rice, 1974; Friesen and Korwar, 1991; Mafongonya *et al.,* 1998a). In this experiment, the both the amount and type were considered important. The results indicated that grass weeds resisted the effect of green manure hence more grasses were recorded in green manure plots than broadleaf weeds. For instance in both sites *C. ochroleuca* plots had 8% more grasses than broadleaf weeds, while *M. invisa* and *C. obtusifolia* had 14% and 10% respectively more grasses than broadleaf weeds. The resistance of grasses probably is a result of aggressiveness (Akobundu, 1987). Aggressive weeds are those with rapid seedling growth and wide tolerance to edaphic and environmental factors.

Weed number and weed dry weight were not reduced by green manure application methods (plough-under and mulch) in both sites. In both sites, there was no significant difference ($P \leq 0.05$) in total number of weeds and weed dry weight between plough under and mulch in all green manure species. This indicated that weed control is the result of the effect of green manure specie and not the application method of the green manure species. Under the residual effect of green manure, the reduction of total weed number and weed dry weight was from 49.8 g to 30.6 g (m^{-2}) and 59 g to 41.9 g (m^{-2}) in Kilasilo. In Itope total weed number was reduced from 47.9 to 34.2 (m^{-2}) but there was no reduction in weed dry weight. On the other hand, the green manure species showed no significant variation ($P \leq 0.05$) on weed dry weight in both sites and total weed number in Itope, while in Kilasilo there was a significant difference ($P \leq 0.05$) among the green manure species. There was a reduction in weed number and weed dry weight under the residual effect of green manure application methods. Also there were cases where plough under had more weeds than mulch for example, under *C. ochroleuca* and *C. obtusifolia* in Kilasilo. In Itope weed dry weight was reduced under *M. invisa* and *C. ochroleuca*. These results suggested that the type of green manure was responsible for the reduction in weed infestation in the field and not the application methods. Weed prevalence observed under the residual effect of type of green manure and green manure application methods was the result of the remaining viable weed seeds. It is also supposed that application of green manure improved soil organic matter that in turn could have an effect on the factors affecting seed germination like the temperature, moisture, alternate wetting and drying of soil.

Striga growth and development

Green manures reduced *Striga* infestation in upland rice soils by reducing *Striga* number, *Striga* height and number of seed produced (number of capsules). In Kilasilo, *Striga* number was reduced by 100% in the 6^{th} and 12^{th} week in both sites. The reduction in infestation was the result of the potential of the green manure to induce germination of *Striga* seed to cause suicidal germination hence low *Striga* seed population in the soil. Decomposition of green manure in the soil caused by microbial activities resulted in the production of ethylene gas as a by-product. This gas is a natural germination stimulant of *Striga*. Probably in the course of decomposition of green manure ethylene gas contributed in stimulation of germination hence suicidal germination. Another effect of green manure in the control of *Striga* was the release of nitrogen during decomposition. Nitrogen has a toxic effect to the *Stirga* seeds in the soil at the same time enables the susceptible host to tolerate or avoid the effect of *Striga*. In addition, it was found in the results of experiment iii that *C. ochroleuca*, *M. invisa* and *C. obtusifolia* released potential extracts. These extracts had the ability to reduce stimulatory effect of the germination stimulants from the host hence reduced the number of germinated *Striga* seeds by allelopathy.

In Kilasilo, 25 kg N ha^{-1} reduced the number of *Striga* by 82% and 46% in the 6^{th} and 12^{th} week respectively. On the other hand, 50 kg N ha^{-1} reduced the number of *Striga* by 97% and 46% in the 6^{th} and 12^{th} week. The *Striga* plant height and the number of capsules were reduced by 33% and 5% when 25 kg N ha^{-1} was applied, but when 50 kg N ha^{-1} was applied the reduction was 33% and 58%. In Itope, the number of *Striga* was reduced by 89% and 80% when 25 kg N ha^{-1} was applied while 96% and 92% when 50 kg N ha^{-1} was applied in the 6^{th} and 12^{th} week. In addition, when 50kg N/ha was applied *Striga* plant heights, and the number of capsules per plant were reduced by 45% and 52% respectively in the 6^{th} and 12^{th} week. The application of green manure and fertilizer urea was very effective in the control of *Striga.* The application of green manure species and nitrogen (25 kg ha^{-1}, 50kg ha^{-1}) reduced the number of *Striga* by 100% in the 6th and 12th week. The same treatments in Itope reduced the number of *Striga* by 100%. On the other hand, green manure and fertilizer 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 nitrogen a host grew vigorously and created unfavourable environment for *Striga* germination and development.

The height of *Striga* decreased with the application of green manure probably due to the late attachment, which caused *Striga* plant to emerge late to unfavourable microclimate created by the growth of the host. There were situations where *Striga* plants were tall under green manure treatment probably that was resulted from competition for light and air. 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 resulted from the competition.

Under green manure application methods, the number of *Striga* was reduced from 27.0 to 0.4 in the 6th week and 30.5 to 1.3 in the 12th week. *Striga* height was reduced from 23.4 cm to 10.9 cm. The number of capsules was not influenced (Kilasilo). While in Itope the reduction number of *Striga* was 23.0 to 0 and 22.3 to 0 in the 6th and 12th weeks after rice germination. The individual application methods of green manure did not show a significant reduction ($P \leq 0.05$) in *Striga* growth and development. This indicated that the specie of the green manure were responsible with *Striga* reduction in the field.

The residual effect of the green manure and green manure application methods did not reduce *Striga* infestation, but when each of the two is superimposed with fertilizer *Striga* infestation was reduced. *Striga* population observed under residual effect of green manure probably was due to low fertility status because of absence of green manure. Therefore, there was no reduction in seed population in the soil, no nitrogen added to the soil from decomposition and no organic matter to maintain the nitrogen pool in the soil. High coefficient of variation (CV) (%) values in *Striga* infestation was caused by the observation in green manure plots where some plots had no *Striga* completely.

Rice growth and yield.

Green manure application improved rice growth and yield. In Kilasilo the yield increased from 1335 to 2846 kg ha^{-1}, the green manure species showed significance difference in the yield. The yield components also increased, plant height increased from 85 cm to 92 cm, number of tillers from 8.7 to 9.8, number of panicles 8.4 to 8.8 and panicle length from 18.7 cm to 19.4 cm. In Itope the grain yield increased from1238 to 2818 kg ha^{-1}, plant height increased from 90.0 cm to 97.6 cm, number of tillers from 8.7 to 9.8, panicle number 8.4 to 8.8 and panicle length 18.4 cm to 19.8 cm. Application of green manure upon decomposition released nitrogen for the rice plants. This increased the number of tillers per plant, number of panicles per plant panicle length and the grain yield (Murata, 1982). The improvement of yield was the result of nitrogen supplied by the green manure and the control of *Striga* in the field. Nitrogen supplied by *C. ochroleuca* and *M. invisa* was equivalent to about 50 kg ha^{-1}. 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 application of green manure and fertilizer urea also improved yield and the yield components of rice. Yield increase was from 815 kg ha^{-1} to 3442 kg ha^{-1}. In green manure species, the grain yield showed a significant variation in fertilizer rates. For example in *C. ochrolueca* the yield was (0 kg N ha^{-1}) 2300 kg ha^{-1}, (25 kg N ha^{-1}) 2798 kg ha^{-1} and (50 kg N ha^{-1}) 3442 kg ha^{-1} in Kilasilo. While in Itope the yield was (0 kg ha^{-1}) 2458 kg ha^{-1}, (25 kg N ha^{-1}) 2870 kg ha^{-1}, (50 kg N ha^{-1}) 3126 kg/ha. The application of inorganic fertilizer and green manure improved rice yield, by providing plant nutrients to the rice plants. Healthy plant is less susceptible produce less stimulants and thus lower germination of *Striga* in addition of creating cooler microclimate unfavourable to *Striga*.

Under green manure application methods rice yield was improved from 1767 kg ha^{-1} to 3403 kg ha^{-1} in Kilasilo. There was a significance difference between mulch and plough under in yield where, *C. ochroleuca* mulch (3403 kg ha^{-1}) appeared to be better than plough under (3214 kg ha^{-1}) in Kilasilo while other green manure species were not. In Itope also the yield increased from 1597 kg ha^{-1} to 3285 kg ha^{-1}. It was *M. invisa* and *C. obtusifolia* that showed a significant difference between mulch and plough under, where plough under was better than mulch. Generally, the yield showed significance difference in green manure application methods except some few mentioned cases. This variation could be related to different processes in the soil. These include leaching of nutrients, nutrient mobility and decomposition of green manure roots which had a slow decomposition rate in the soil in both mulch and plough under plots. When fertilizer at the rate of 25 and 50kg N ha^{-1} was applied the yield improved but the difference between plough under and mulch didn't show a specific trend.

The residual effect of green manure showed that the level of fertility fell drastically after one season, although the yield in green manure residual plots was higher than the control but it was lower than the previous season. Yield components showed poor response on the residual effect. The application of fertilier and the residual effect of green manure improved the yields and yield components. On the other hand, the residual effect of green manure application methods was also poor it was improved when fertilizer urea was added. Therefore, the residual effect of green manure and green manure application methods are not effective in *Striga* infested soils of Kyela.

Nitrogen concentration in rice shoots

Nitrogen recovered from rice shoots showed an increase with the application of inorganic fertiliser. All green manure species and the application of green manure and inorganic fertilizer resulted in significant differences in percent nitrogen concentration in rice shoots. The percent of nitrogen accumulated from the residual effect was less than the percent accumulated in the first year. For example in *C. ochroleuca* (Kilasilo) the drop in nitrogen concentration in rice shoots between year

1 and year 2 was (0 kg N ha^{-1}) 4%, (25 kg N ha^{-1}) 4%, (50 kg N ha^{-1}) 5% while in Itope it was (0 kg N ha^{-1}) 10%, (25 kg N ha^{-1}) 8.5%, (50 kg N ha^{-1}) 8%. The variation in the percentage drop in nitrogen concentration probably is influenced by the inherent nitrogen status of the soil (0.16% Kilasilo and 0.2% in Itope). The differences in year 1 and year 2 indicated that fertility dropped due to absence of green manure application, that means green manure species improved the nitrogen status of the soil in the first year. The difference of nitrogen concentration in 0 kg N ha^{-1} to 50 kg N ha^{-1} did not show a specified trend for example in *C. ochroleuca* in Kilasilo 0 kg N ha^{-1} to 25 kg N ha^{-1} varied by 11% and 25 kg N ha^{-1} to 50 kg N ha^{-1} by 7%. In year 2 the difference was 10% and 6.25%. In Itope the difference was 8.5% and 10.5% in year 1 and 6% and 6.5% in year 2. The lack of specified trend perhaps is the result of the low potential of nutrient use efficiency of the rice variety since crops and varieties have shown variation in nutrient use efficiency (acquisition, transport and utilisation) (Rautio, 1992).

Benefit: Cost of the technology

The benefit per unit cost incurred was higher when green manure was applied than when there was no green manure, the increase in benefit was 82% at each site, Kilasilo and Itope. When fertilizer was applied, the application of inorganic fertiliser increased the benefit realised by 65% at each site. Among the green manure *C. ochroleuca* showed a significant higher benefit per cost incurred than *M. invisa* and *C. obtusifolia* in Kilasilo and Itope, respectively. The application of green manure in the form of mulch increased the benefit by 30% and 9% (*C. ochroleuca* in Kilasilo and Itope, respectively) compared to the control. The results indicated that the application of green manure in form of mulch was more profitable than ploughing under due to labour involved in the field operation, slashing was cheaper than ploughing under. In Kilasilo the profit was higher than Itope because of inherent fertility level in the soil was low (percent base saturation was 26 and 25 respectively) therefore application of green manure improved yield. Under the residual effect of green manure the benefit obtained dropped by 21.5% in Kilasilo and 12.5% in Itope, this is associated to the inherent soil fertility in the site. The residual effect of green manure application methods showed that the benefit to the cost incurred was very low in both sites. It was found that the benefits observed under the residual effect of green manure was less than the benefit in the season when green manure was applied. This means the costs of production were higher under residual effects compared to previous season. Therefore, application of green manure must be a continous practice in the upland rice soils of Kyela.

Conclusions

- *Crotalaria ochroleuca*, *M. invisa*, and *C. obtusifolia* offer potential for the control of *S. asiatica* and improve upland rice yield by the following ways
  - They reduced *Striga* seed population in the soil, and reduced *Striga* growth and development
  - They reduced stimulatory effect of germination stimulant produced by the host plant
  - They reduced infestation of weeds other than *Striga*
  - They improved soil fertility and improved rice yield where *C. ochroleuca* and *M. invisa* improved rice yield equivalent to 50 kg N ha^{-1}.

- The application of green manure and fertilizer urea improved rice yield and reduced *Striga* population.
- Green manure application by ploughing under or mulching had no effect on *Striga* infestation but improved rice yield.
- One-year application of green manure had a poor residual effect on rice yield and *Striga* infestation, the same applies for green manure application methods. Therefore, green manure application should be a continous farm practice to ensure soil fertility improvement.

4.3 EXPERIMENT III

4.3.1 Study I

Results

Ethephone (an artificial stimulant) applied at the rate of 50 ppm resulted in the highest ($P \leq 0.05$) germination percentage (67%) followed by Staha (53%) a susceptible maize variety. The green manure species showed a significant difference ($P \leq 0.05$), among themselves in the ability to stimulate germination. *Crotalaria ochroleuca, C. obtusifolia, and M.invisa* stimulated 40%, 28%, and 6%, respectively (Table 30).

From retrieved Eplee bags in Itope (Table 31) *C. ochroleuca* stimulated the highest ($P \leq 0.05$) germination percent of *Striga* seed, (28.3%) compared to *M. invisa* (4.3%) and *C. obtusifolia* (23%). In Kilasilo the percent *Striga* seed germination was higher than Itope. *Crotolaria ochroleuca* stimulated significantly high percent (30%) of *Striga* seeds germination followed by *C. obtusifolia*, (23.3%) and *M. invisa* (4.6%).

In both sites Itope and Kilasilo control treatment did not stimulate *Striga* germination. The trend of seed germination across sites was *C. ochroleucca* > *C. obtusifolia* > *M.invisa* (Table 31).

Table 30: 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 Duncan Multiple Range Test ($P \leq 0.05$)

Table 31: Germination of *Striga* seed (%) by green manure in the field.

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 Duncan Multiple Range Test ($P \leq 0.05$)

Discussion

Ethephone and maize (Staha variety) germinated 67% and 53% of the *Striga* seed while high germination from the green manure was 40% *C. ochroleuca*. This has shown that Ethephone and maize (Staha) had higher ability to stimulate *Striga* germination than green manure. Probably the effectiveness of the stimulant and its compatibility to *S. asiatica* are factors contributed to higher *Striga* germination. Among the tested green manures the ability to stimulate *Striga* germination was in the order *C. ochroleuca* (40%) > *C. obtusifolia* (28%) > *M. invisa* (6%). Trap crops differ in their ability to stimulate germination of *Striga* (Parker and Reid, 1979). It has been explained that the potential of green manure to stimulate *Striga* seed germination is controlled genetically (Bebawi and Michael, 1991) and environmentally (Odhiambo and Ransom, 1996). However, the green manures were subjected under the same environment, therefore, the factor affecting the potential to stimulate germination was genetically controlled.

There was a difference in percentage germination between laboratory and the field. In the laboratory the germination was 40% for *C. ochroleuca*, 28% *C. obtusifolia* and 6% *M. invisa* but in the field the germination was 29% *C. ochroleuca*, 23% *C. obtusifolia*; 4.5% *M. invisa*. The difference was probably contributed by soil factors like soil pH and soil water which affected germination stimulant concentration, the movement of germination stimulant in the soil, and lowering soil temperature hence poor production of stimulants. In the field green manure species differed in the production of stimulants, effectiveness of the stimulant and the ability to reach many *Striga* seed in the soil by their roots. This is supported by the field observation that *Crotolaria ochroleuca* grew faster than other species. *Mimosa invisa* had a slow growth rate at early stages of development compared to other green manure. *Cassia obtusifolia* had poor growth at early stages of development especially at Kilasilo site, this was associated with low levels of soil nitrogen. In Kilasilo *Striga* seeds germination percentage was higher than Itope this was associated with low soil nitrogen. The level of nitrogen in Kilasilo was 0.16% this was lower than Itope which was 0.21%. Low level of nitrogen has been found to improve production of germination stimulants (IITA, 1997).

Conclusions

From the results it was concluded that *C. ochroleuca*, *C. obtusifolia* have a potential to stimulate *Striga* germination, where *C. ochroleuca* stimulated more *Striga* seeds than *C. obtusifolia*.

4.3.2 Study II

Results

The extracts collected from 30 g in 100 ml in every plant species had significantly ($P \leq 0.05$) low number of germinated *Striga* seeds ranging from 0 to 31%. On the other hand, the extracts from 20g in 100 ml reduced *Striga* germination significantly from 100% to 48%. The extract made by 10g in 100 ml showed significantly high number ($P \leq 0.05$) of germinated *Striga* seeds ranging from 18% to 55%, while the green manure extracts reduced *Striga* germination by 58% to 54%. The results from green manure species were not significantly different ($P \leq 0.05$) from each other. Ethephone recorded significantly highest ($P \leq 0.05$) number of germinated *Striga* seed (65%). The control that had distilled water alone showed a mean germination percent of less than 1% (Table 32).

Table 32: The effect of plant extracts on the germination of *Striga* seed.

Treatment Plant spp	Germinated *Striga* seed (%)
1.*Neuritania mitis* 30	31 f
2.*N euritania mitis* 20	38 e
3.*N euritania mitis* 10	55 b
4.*Vernonia amygdalina* 30	16 g
5.*Vernonia amygdalina* 20	48 c
6.*Vernonia amygdalina* 10	52 cb
7.*Gnidia kraussiana* 30	0 h
8.*Gnidia kraussiana* 20	0 h
9.*Gnidia kraussiana* 10	18 g
10.*Dolichus kilimandscharis* 30	1 h
11.*Dolichus kilimandscharis* 20	18 g
12.*Dolichus kilimandscharis* 10	28 f
13.*Cassia obtusifolia*	42 cd
14.*Mimosa invisa*	43 d
15.*Crotalaria ochroleuca*	46 cd
16.Ethephone	65 a
17.Distilled water	0.3 h
SE	2.02
CV (%)	11.66

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

Discussion

The results indicate that the potential of plant extracts to suppress *Striga* germination varied with plant species. *Neuritania mitis* (30 g) germinated 31%, *V. amygdalina* (30 g) 16% germinated, *G. kraussiana* (30 g) no germination observed and *D. kilimandcharis* (30 g) only 1% germinated. The extracts from green manure leaves also showed an inhibitory effect on the germination of *Striga* seed. The germination of less than 1% observed in the control is the result of spontaneous germination of *Striga* seed as found in other studies by Maass (2001).

The results from *Striga* seed viability test showed that plant extracts tested did not damage *Striga* seeds, since un-germinated seeds were found to be alive (viable) after the experiment. Probably, the effect of plant extracts on the germination of *Striga* seed was the reduction of the stimulatory effect of the germination stimulant used in the experiment. From the results of this experiment two plant species extracts *D. kilimansdcharis* and *G. kraussiana* were chosen for evaluation of application methods because of their potential to suppress *Striga* germination.

Conclusions

From the results, it was concluded that *Dolichos kilimansdcharis* and *Gnidia kraussiana* applied at the rate of 30 g in 100 ml indicated good potential to reduce germination of *Striga* seeds. *Dolichus kilimansdcharis* and *G. kraussiana* are recommended for further experiment to evaluate application methods of the plant materials to control *Striga*.

4.3.3 Study III

4.3.3.1 Pot experiment

Results

The results in Table 33 show that there was no significant difference ($P \leq 0.05$) in the number of germinated *Striga* seed six weeks after rice germination except for *G. kraussiana* powder in the soil which had significantly ($P \leq 0.05$) few *Striga* plants (1.27) per pot. In the 9th and 12th week after rice germination plant extracts reduced the number of *Striga* plants significantly ($P \leq 0.05$), where all treatments had fewer *Striga* than the control. Where no extract was added to *Striga*, a high ($P \leq 0.05$) number of *Striga* (5.04 and 5.64) was observed. *Striga* shoot height and *Striga* shoot dry weight were not affected by the application of the extracts, except *G. kraussiana* hardening which had (4.96) height and (0.09) dry weight. However, the number of capsules per *Striga* plant was reduced significantly (P≤0.05) by the application of plant extracts except for the *G. kraussiana* (hardening) (4.01). The application methods did not vary significantly (P≤0.05) in the number of capsules. *Striga* height, dry weight and number in the 9th week. *Gnidia kraussiana* powder in the soil and seed coat were effective than other in the 6th and 9th week.

The results in table 34 show that rice plants in the control treatment (without *Striga* + without plant extracts) were significantly taller (P≤0.05) than those treated *Striga* without plant extracts 88.4 cm and *G. kraussiana* seed coat 88.8 cm. The number of tillers and panicle number per plant were improved significantly (P≤0.05) compared to *Striga* seed alone and *D. kilimandcharis* (seed coat and hardening). However, rice straw biomass in all treatments were significantly higher (P≤0.05) than *Striga* seed alone (74.4 g), except *G. kraussiana* (hardening and seed coat) 72.5 g. Plant extract treatments had significantly more (P≤0.05) grain yield than *Striga* seed alone except *G. kraussiana* (powder in the soil).

Table 33: The effect of plant extracts on the growth and development of *Striga*.

Treatments	*Striga* number per pot			Capsule number per plant	*Striga* height (cm)	*Striga* weight (gm)
	6th week	9th week	12th week			
G. kraussiana (hardening)	1.96a	3.4b	4.3b	4.0ab	5.0b	0.1b
G. kraussiana (seed coated)	1.90ab	3.7b	3.4c	3.7b	4.7ab	0.2ab
G. kraussiana (powder in soil)	1.27b	3.3b	3.7bc	3.8b	4.8ab	0.3ab
D. kilimandscharis(hardening)	2.42a	4.0b	4.3b	3.7b	4.5ac	0.4ab
D. kilimandscharis (seed coated)	2.24a	4.0b	4.6b	3.6b	4.5ac	0.4ab
D. kilimandscharis(powder in soil)	1.81ab	3.0b	4.0bc	3.2b	4.4c	0.3ab
Control (Without extracts)	2.58a	5.0c	5.6a	4.4a	4.5ac	0.5a
SE	0.34	0.33	0.39	0.26	0.18	0.12
CV(%)	36.78	20.04	20.70	15.73	8.93	9.14

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

Table 34: The effect of plant extracts on growth and yield of rice.

Treatments	Plant height (cm)	Tillers per plant	Panicle number per plant	Panicle length (cm)	Straw biomass gm/plant	Yield (gm)
G. kraussiana (hardening)	90.8ab	11.5c	10.8b	20.2ab	79.9bc	73.9b
G. kraussiana (seed coated)	88.8b	10.7c	10.1b	18.8bc	72.5c	71.4b
G. kraussiana (powder in soil)	95.3a	12.0bc	11.3b	19.7ab	83.1b	69.1bc
D kilimandscharis (hardening)	93.4ab	14.5ab	12.9a	20.1ab	87.9b	75.0b
D. kilimandscharis (seed coated)	95.9a	13.5b	12.8a	19.2bc	83.8b	77.0b
D.kilimandscharis (powder in soil)	93.4ab	12.6bc	11.4b	21.5a	89.9b	75.7b
Striga seed without extract	88.4b	11.5c	10.0b	17.3c	74.4c	67.4c
Control (No *Striga*)	96.0a	15.3a	14.2a	20.4ab	112.9a	90.7a
SE	3.03	0.87	0.93	0.64	4.05	2.67
CV(%)	6.54	13.76	16.05	6.55	9.47	7.13

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

4.3.3.2 Field experiment

Results

Results in Table 35 show that in the sixth week, control treatment and *G. kraussiana* coated had significantly high (P≤0.05) number of *Striga* (11.2) while other treatments had no significant difference in the number of *Striga*. *Striga* height did not respond to the effect of plant extracts. The number of capsules per *Striga* plant was significantly high (P≤0.05) in the control treatments while *D. kilimandcharis* coated and *G. kraussiana* in soil had significantly low (P≤0.05) number of capsule per *Striga* plant 3.9 and 3.6 respectively. *G. krausiana* in soil had significant low (P≤0.05) *Striga* dry weight than other treatments

Results in Table 36, indicate that plant height in *G. kraussiana* hardening did not differ significantly with control, while other plant extracts differed significantly (P≤0.05) with control in plant height. On the other hand, *D. kilimandcharis* in the soil had significantly high (P≤0.05) number of tillers (7.0) while other treatments were similar to the control. The *D. kilimandcharis* in the soil showed significantly high (P≤0.05) number of panicles per plant (7.0) compared to other treatments which had low (P≤0.05) number of panicles per plant. All treatments showed significantly longer (P≤0.05) panicles than the control, while the grain yield, did not show any significanct difference between control and plant extracts. Plant biomass in *G. kraussiana* powder in the soil and *D. kilimancharis* powder in the soil had significantly high (P≤0.05) biomass 0.4 gm and 0.4 gm compared to the control.

Table 35: The effect of plant extracts on the growth and development of *Striga*.

Treatments	*Striga* number in 6m²		Capsule count per plant	*Striga* height (cm)
	6th week	12th week		
G. kraussiana (hardening)	8.5b	10.0d	4.2b.	5.0a
G. kraussiana (seed coated)	11.2a	14.2b	4.4b	4.8ab
G. kraussiana (powder in soil)	8.7b	11.6bcd	3.6c	4.2b
D. kilimandscharis(hardening)	7.4b	9.6d	4.4b	4.7ab
D. kilimandscharis (seed coated)	7.8b	12.1bcd	3.9c	4.4ab
D.kilimandscharis (powder in soil)	8.4b	12.4bcd	4.2b	4.6ab
Control (no extracts)	11.9a	16.5b	5.1a	4.7ab
SE	0.67	1.71	0.28	0.27
CV(%)	14.72	27.55	13.29	11.73

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

Table36: The effect of plant extracts on growth and yield of rice.

Treatments	Plant height (cm)	Tillers per plant	Panicle number per plant	Panicle length (cm)	Straw biomass gm/plant	Yield kgha⁻¹
G. kraussiana (hardening)	83.5c	6.0b	6.3bc	17.7b	0.49ab	815ab
G. kraussiana (seed coated)	86.6b	6.5ab	6.5b	17.9b	0.33b	649b
G. kraussiana (powder in soil)	87.8ab	6.0b	6.0bc	18.4ab	0.41a	658b
D kilimandscharis (hardening)	86.1ab	6.3b	6.3bc	18.1ab	0.39ab	843ab
D. kilimandscharis (seed coated)	87.5ab	6.5ab	6.5b	17.9b	0.35b	679ab
D.kilimandscharis (powder in soil)	89.8a	7.0a	7.0a	18.7a	0.42a	869a
Control (no extracts)	80.2c	6.0b	5.8c	16.7c	0.35b	713ab
SE	2.41	0.36	0.32	0.39	0.02	96
CV(%)	5.61	11.23	10.25	4.44	12.83	25.75

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

Discussion

The plant extracts in all application methods reduced *Striga* infestation in the 9^{th} and 12^{th} week. Application of plant extracts generally reduced the number of capsules from 5.1 to 3.6 therefore fewer seeds for regeneration were formed. By reducing the number of seed produced in the soil the level of infestation in subsequent cropping seasons is reduced. *Striga* height was not affected by the extracts because the extracts were not effective in reducing plant height, also *Striga* as a photosynthetic plant competed for air and light (Parker and Riches, 1993). Therefore, its height increased when there was competition for air and light. *Striga* dry weight was not affected by extracts because it is an independent factor that doesn't correlate with change in the biomass of the infested host plant like other parasitic weeds like *Orobanche spp* (Graves *et al.*, 1989).

There was an effect of the plant extracts on rice plant. It improved plant height (80.2 to 90.0), number of effective tillers (5.8 to 7.0) and panicle length (16.7 cm to 18.7 cm). This can be due to the negative effect of plant extracts on *Striga* that reduced the effectiveness of the infestation. The results in the pot experiment differed with the field results indicating that field conditions like excess moisture during rains/excess draought during interfered with the activity of plant extracts and favoured *Striga* infestation. All application methods resulted in low grain yield and low straw biomass. This indicated that the plant extracts were not effective enough to reduce *Striga* infestation and improve grain yield under field conditions. On the other hand, the results indicated that hardening is a good application method since it improveded the yield components of rice plants.

Conclusions

- *Dolichos kilimandcharis*, *G. kraussiana* have shown a poor inhibitory effect on the germination of *Striga* in the field but they are recommended to be applied as seed hardening to be incorporated with other control methods.

CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS

From the results it is concluded that:

- Decomposition of *C. ochroleuca* released (about 75%) of its mass in the first 4 weeks while *M. invisa* and *C. obtusifolia* released about 65% and 60% of the mass, respectively during the same time. The trend of the decomposition was *C. ochroleuca* > *M. invisa* > *C. obtusifolia*
- Since more than 50% of the released nutrients occurred in the first 4 weeks then these green manures are suitable for the control of *Striga asiatica* in Kyela because that is the time the parasite attaches itself to the host. Maximum suppression of the weed is therefore expected if incorporation of green manure is synchronised with rice growth.
- Decomposition of roots released 50% of the nutrients after 8 weeks therefore the released nutrients can be available to long maturing varieties like Supa india that takes 120 days to attain maturity.
- *Crotalaria ochureca, M. invisa*, and *C. obtusifolia* are potentially effective in the control of *Striga asiatica* and improved upland rice yield by the following ways:
  - They reduced *Striga* seed population in the soil by suicidal germination and reduced *Striga* growth and development.
  - They reduced stimulatory effect of germination stimulant produced by the host plant.
  - They reduced infestation of weeds other than *Striga.*
  - They improved soil fertility and improved rice yields where *C. ochroleuca* and *M. invisa* improved rice yield equivalent to 50 kg N/ha.
- The application of green manure and fertilizer urea improved rice yield and

reduced *Striga* population.

- Green manure application methods, plough under and mulch had no effect on rice yield and *Striga* infestation.
- One-year application of green manure had a poor residual effect on rice yield and *Striga* infestation. The same applies for green manure application methods. Therefore, green manure application should be a continous farm practice to ensure soil fertility improvement.
- *Dolichos kilimansdcharis* and *Gnidia kraussiana* applied at the rate of 30 g in 100 ml showed good potential to reduce germination of *Striga* seeds when host seeds are hardened before sowing.

From the conclusions it is recommended that

- Improvement of rice soils of Kyela should be done by the use of green manure of *C. ochroleuca*. Since the nutrients released by *C. ochroleuca* are not adequate then a supplement of other nutrients should be added. Inorganic nitrogen can be applied in the 5^{th} week. Other nutrients like P can be applied to balance the nutrient in the soil and improve on the nutritional status of the soil.

* In order to reduce *Striga* seed population density in the soil *C. ochroleuca* and C. obtusifolia are recommended for use in Kyela.
* Green manure can be incorporated in the soil or left as mulch in rice fields of Kyela.
* When varieties of low yield potential like Supa India are grown, nitrogen should be applied with inorganic fertilizer at the rate of 25kg N ha^{-1} with green manure to improve rice yield and control *Striga*.

* Green manure application should be a continuous practice in *Striga* infested areas of Kyela.
* *Dolichos kilimansdcharis* and *Gnidia kraussiana* at the rate of 30 g in 100 ml should be used to treat rice seed before sowing as component in *Striga* control.

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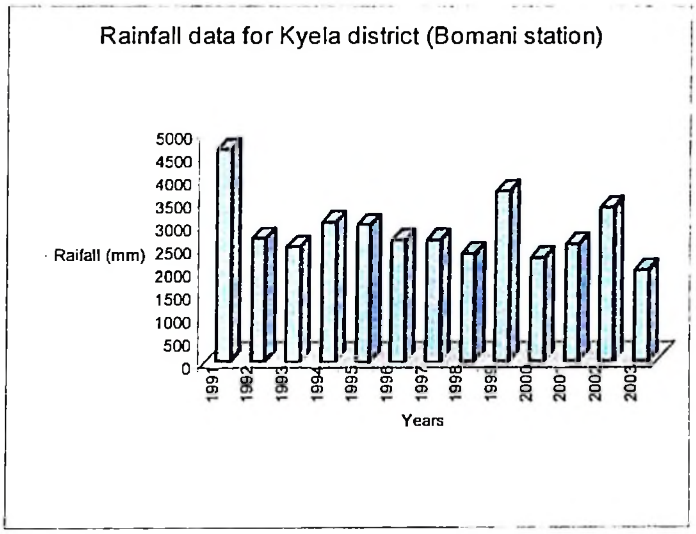
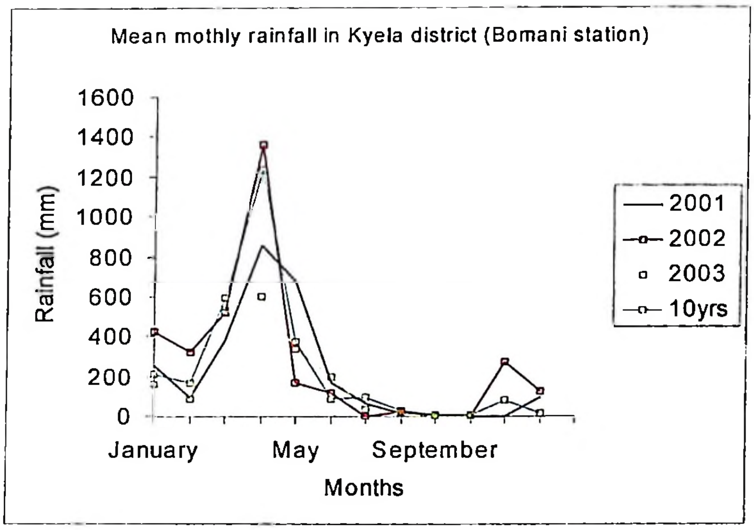
APPENDICES

Appendix 1:Climatic Data



Annual rainfall for 13years



Mean monthly rainfall for three season and average of 10 years

Mean monthly temperature ^{0}C (air)

Year	Jan	Febr	Marc	April	May	June	July	Augu	Sept	Oct	Nov	Dec
2000												
2001						28.45	27.29	26.56	28.94	31.06	32.85	32.44
2002	30.29	31.82	31.79	35.22	30.55	28.62	28.85	28.11	30	32.25	32.18	31.73
2003	31.88	32.1	33.07	31.6	30.89	29	27.55					

Mean monthly soil temperature at 20 cm (^{0}C)

Year	Jan	Feb	Marc	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2000												
2001						2.45	2.38	2.44	2.61	2.99	3.24	3.09
2002	2.71	2.88	2.74	2.64	2.69	2.48	2.46	2.56	2.9	3.2	3.01	2.91
2003	2.79	2.9	2.92	2.71	2.61	2.49	2.35					

Mean monthly soil temperature 10 cm (^{0}C)

Year	Jan	Feb	Marc	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2000												
2001						2.3	2.24	2.19	2.4	2.77	3.02	2.79
2002	2.56	2.66	2.65	2.49	2.43	2.29	2.22	2.34	2.6	2.9	2.75	2.67
2003	2.57	2.67	2.68	2.54	2.43	2.33	2.18					

Appendix 2: Green manure biomass accumulated before application

	Kilasilo		Itope	
Green manure specie	Shoots wt(t/ha)	Roots wt (t/ha)	Shoots wt(t/ha)	Roots wt (t/ha)
C.oclureca	4.30	0.34	4.40	0.35
M. invisa	4.25	0.29	4.35	0.30
C.obtusifolia	4.20	0.29	4.33	0.32

Appendix 3: Green manure decomposition pattern

Table 1:Decomposition of plant shoots at Kilasilo

	Mass loss (gm) 2 WAI	Mass loss (gm) 4 WAI	Mass loss (gm) 6 WAI	Mass loss (gm) 8 WAI
C. ochroeuca	47.91a	74.46a	89.11a	100a
M. invisa	50.00a	59.73b	74.86b	87.16b
C. obtusifolia	41.53b	56.30b	68.00b	80.48c
SE	1.94	1.74	2.09	1.05
CV (%)	7.23	4.74	4.68	2.05

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

Table 2:Decomposition of plant roots at Kilasilo

	Mass loss (gm) 2 WAI	Mass loss (gm) 4 WAI	Mass loss (gm) 6 WAI	Mass loss (gm) 8 WAI
C. ochroleuca	16.40a	35.07a	55.98a	64.48a
M. invisa	21.48a	33.46a	44.18b	55.48b
C. obtusifolia	17.05a	36.90a	44.98b	55.90b
SE	2.65	3.76	1.23	2.06
CV (%)	25.10	18.54	4.40	6.06

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

Table 3:Decomposition of plant shoots at Itope

	Mass loss (gm) 2 WAI	Mass loss (gm) 4 WAI	Mass loss (gm) 6 WAI	Mass loss (gm) 8 WAI
C. ochroleuca	49.95a	76.28a	87.31a	100a
M. invisa	47.72a	69.86b	81.98b	88.56b
C.obtusifolia	46.68a	62.56c	69.83c	77.93c
SE	1.79	1.05	1.6	1.11
CV (%)	6.45	4.12	3.41	5.26

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

Table 4:Decomposition of plant roots at Itope

	Mass loss (gm) 2 WAI	Mass loss (gm) 4 WAI	Mass loss (gm) 6 WAI	Mass loss (gm) 8 WAI
C. ochroleuca	17.88a	40.11a	54.49a	62.23a
M. invisa	15.58a	31.13b	42.53c	53.06c
C.obtusifolia	14.40a	33.46b	47.31b	57.28b
SE	1.45	1.75	1.95	1.88
CV (%)	15.81	8.71	7.04	5.66

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

Table 5:Decomposition of plant shoots across sites

	Roots				Shoots			
	2WAI	4WAI	6WAI	8WAI	2WAI	4WAI	6WAI	8WAI
Kilasilo	18.31a	35.12a	48.71a	58.86a	46.82a	62.37a	76.05b	87.86a
Itope	15.97a	34.90a	48.13a	57.52a	48.05a	69.43b	79.71a	88.83a
SE	1.23	1.69	0.94	1.13	1.04	0.74	0.94	0.74
CV(%)	21.63	14.51	5.85	5.87	6.41	4.23	3.25	2.27