UNIVERSITY OF CAPE COAST

CAPE COAST

MANAGEMENT OF THE NOXIOUS WEED SPEARGRASS (*IMPERATA CYLINDRICA* (L.) BEAUV.) IN THE FOREST AND FOREST- SAVANNA TRANSITION AGRO-ECOLOGICAL ZONES OF GHANA

BY:

GRACE ESI-KYIREM BOLFREY-ARKU

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MAY, 2004

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

.... DATE: 10/11/04 ....

GRACE ESI-KYIREM BOLFREY-ARKU
(STUDENT)

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

.... DATE: 10/11/04 ....

PROF. A. G. CARSON
(PRINCIPAL SUPERVISOR)

.... DATE: 15/11/04 ....

PROF E.C. QUAYE
(CO-SUPERVISOR)

.... DATE: 29/11/04 ....

DR. J.N. NELSON-BUAH
(CO-SUPERVISOR)

ABSTRACT

Field and screen house studies were conducted to: 1) investigate farmers' perception of speargrass (*Imperata cylindrica* (L.) Beauv.) and existing management practices, 2) recommend a legume cover to control speargrass and improve soil fertility, 3) determine the effect of integration of land preparation, chemical application and cover crop on growth and survival of speargrass and 4) evaluate the growth and yield of maize and yam on speargrass managed fallow. The studies involved a 3 x 3 factorial arrangement of land preparation and cover crop laid as a split plot design and a 2^3 factorial arrangement in a split-split –plot design of land preparation, chemical application and cover crop at Mampong and Wenchi in the forest and forest-savanna transition zones. The mean fallow or crop length was 4.7 and 4.5 years respectively. Speargrass was ranked the most noxious weed because of its deleterious effect on crops through competition and piercing nature of emerging shoots from rhizomes on crops. It becomes a problem after three years cropping and was present on 94% of the fields surveyed with high incidence (86%) on those burnt at time of land preparation. Farmers perceived yield losses due to speargrass was <30 to >80 % ($326 - $869/ha). In the field studies ploughing delayed the regrowth of speargrass up to 8 weeks while *Mucuna* suppressed growth up to 32 weeks. *Stylosanthes* reduced speargrass dry weight by 77 % relative to natural fallow and 55 % relative to *Mucuna* while *Mucuna* reduced weight by 48 % relative to the natural fallow at 44 weeks. The legume fallow reduced speargrass rhizome dry weight by 69-77 % compared to the natural fallow and suppressed shoot regrowth > 50 % on following crop. *Stylosanthes* or *Mucuna* fallow increased maize grain yield by 62 and 98 % respectively over the natural fallow. The marginal rate of return (MRR) of changing from natural fallow to *Stylosanthes* or *Mucuna* fallow was 113 and 153 % respectively. Soil analysis showed an increase in organic C and available K and a decrease in available P, Ca and Mg. Total N was medium for all cover (0.10 – 0.17 %) at Mampong but low at Wenchi (0.04 – 0.13 %). Glyphosate application after land preparation increased effectiveness of control by 61 % up to 3 months, while planting *Mucuna* after glyphosate effected speargrass control beyond 6 months. Glyphosate-*Mucuna* combination reduced the incidence of speargrass by 50 % and rhizome dry weight by 81 % while glyphosate or *Mucuna* reduced weight by 64 and 60 % respectively over the natural fallow. Speargrass rhizomes pierced 1% of harvested yam tubers where glyphosate was applied, 7 % from non-glyphosate plots, 15% from burned plots and 9 % from ploughed plots. The fungus *Colletotrichum gloeosporiodes*, which causes anthracnose, was isolated from the leaves of yam and *Mucuna*. In the screen house, 5 % of the rhizomes from legume fallow sprouted against 18 % from the natural fallow. Speargrass management through integration of land preparation method, chemical or legume cover is economically viable.

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DEDICATION

This dissertation is dedicated to my late father, Mr. Austin Adjin Bolfrey who did not live long enough to see his and his darling daughter's dream come true. It is also dedicated to my mother, Madam Rose Akua Asuantsewa Ehun; husband Nanabanyin; kids, Jason, Michael, Kevin and Caleb; and siblings who lived through to see a dream realized.

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CHAPTER ONE

INTRODUCTION

Weeds constitute one of the major constraints to crop production. Akobundu (1991), reported that weeds absorb approximately 40% of the total available farm labour in sub-Saharan Africa. Weeds were of minor importance when long fallows (≥ 10 years) were possible but scarcity of land imposed by increasing human population with its attendant development has led to intensive land cultivation and a reduction in fallow period (≤ 5 years). The consequence is an increase in weed pressure and the prevalence of noxious weeds, for example, *Striga spp*, speargrass, and nutsedge. Various studies have shown that these noxious weeds become significant when soil fertility declines (Akobundu, 1993; Moody, 1975). In an Integrated Weed Management (IWM) workshop by weed scientists from the Eco-regional Program for the Humid and Sub humid Tropics of Africa (EPHTA) in 1997, speargrass was reported as a noxious weed in about 60 % of the country reports. The scientists restated the seriousness of speargrass and called for the development of a comprehensive management strategy.

Speargrass (*Imperata cylindrica* (L.) Beauv.), ranked the world's 7th most troublesome weed (Holm *et al.*, 1977), is an invasive perennial plant widespread in most tropical and subtropical zones of the world. It is reported in 73 countries as a weed in 35 crops (Holm *et al.*, 1977). It is estimated to cover ≥18 million ha of potentially arable land in Indonesia, 5 million ha in Papua New Guinea and 0.3 million ha in Fiji (Brook 1989; Sukama, 1986). Survey report from West Africa revealed that speargrass could be found from Senegal, Benin, Ghana, and Nigeria to the Cameroon (Chikoye *et al.*, 1999; Ivens, 1980) with coverage ranging from 9 to 97 % of farmer's fields. In Nigeria, it has been reported that, it has the potential to invade 260 million hectares of land and negatively affect nearly 80 million people residing in intensively cultivated areas of the moist savanna and humid forest zones (Chikoye *et al.*, 1999; Anoka, 1995; Jagtap, 1995). Speargrass with its high nutrient uptake offers serious competition to cereals, grain legumes, vegetables and root and tuber crops (Saxena and Ramakrishnan, 1983) and apart from direct yield losses, the rhizomes cause physical injury to tuber crops, predisposing them to attack by insect pests and disease pathogens. Evidence of allelopathic effect on other crops has been also reported by Eussen (1979, 1978). It has therefore received extensive research effort elsewhere because of its agricultural, economic and social importance in a wide variety of habitats, climates and cultures.

In Ghana the weed has infested over 70 % of fields in the Forest, Transition and Coastal Savannah zones of Ghana and can be found in cereals, legumes and root and tuber crops. A study on yam production by Anchirinah *et al.*, (1996) in Brong Ahafo Region of Ghana mentioned speargrass as one of the most difficult to control weeds. Ghanaian farmers consider the weed as noxious because of its rapid regeneration capacity, competitiveness, and difficulty to control with the hoe and cutlass and high weeding frequency (five times in a cropping season). The most popular local Akan name "Eto" (you'll meet me) or "Seregogoro" (pierces like needle) shows how farmers perceive speargrass in the affected areas. Thus, farmers abandon infested fields after three years cropping; not only because of its rapid growth and competitiveness, but also, that the sharp points of the emerging shoots from the rhizomes pierce their feet. The weed thus exerts detrimental effects on crops and humans yet its distribution and management in Ghana has not received the expected research attention. The affected crops, roots and tubers, cereals and legumes are important national commodities with the roots and tubers also as major export crops.

The recent introduction of the President's Special Initiative (PSI) on cassava (*Manihot esculenta*) coupled with the fact that Ghana is the second producer and number one exporter of yam (*Dioscorea spp*) in the world (Otoo, 2001; GYPEA, 2000) has made the management of speargrass more imperative than ever. Unfortunately most crop farmers are smallholders without adequate resources to effectively control the weed often by the hoe and commenced after weeds had begun to exert a depressive effect on yields. Increasing labour costs and its unavailability at critical times make hand hoeing untimely and expensive. The lack of consistent management practices for speargrass and the inherent low soil fertility has promoted the opening up of virgin lands since the hitherto long fallows for natural vegetation to smother or out-compete the weed is untenable.

As scarcity of land has progressively forced farmers to shorten the fallow period, the emphasis in weed management has shifted from forest fallow to beneficial cover crops. Hence, alternative management methods that are inexpensive, environmentally safe, less time consuming and sustainable for reduction of the fallow period or sedentarization is essential especially in the aforementioned areas considered part of the "bread basket' zones of Ghana. According to Chikoye *et al*., (1999) the development of a comprehensive management strategy for speargrass and other weeds should be a priority research because the weed threatens the livelihood of > 200 million people in West Africa. By not addressing this problem, there could be a potential yield reduction of over 50% i.e. $543 for yam, $166 for cassava and $83 for maize per hectare annually from competition to speargrass alone and a substantial decline in soil fertility with the subsequent opening up of virgin lands. Improper management of speargrass in particular would lead to increase in production costs and a reduction in tuber quality as a result of weed pressure and increase in pests and disease incidence. Women and children who could have invested their time and energy in other useful ventures, including schooling for the children would have to provide labour for frequent weeding.

Combining different weed control options (IWM) would tackle the problem of speargrass invasion and infestation in a holistic manner than a single control method. The strategy, which aims at the adaptation and improvement of existing technology, would lead to the documentation of currently available management options and areas of serious infestation. The cover crops would improve soil fertility for the subsequent crop in a rotation.

General Objective

This research aims at addressing problems of the infestation and invasion of farmlands by speargrass, decline in soil fertility and crop yield by developing low input technologies to manage speargrass.

The specific objectives are to:

- Gather baseline information on farmers' perception of speargrass, the incidence and the current control practices in the forest and transition zones of Ghana
- Identify and recommend an effective legume cover crop to control speargrass and improve soil fertility
- Determine the effect of the integration of land preparation method, chemical application and cover crops on growth and survival of speargrass
- Evaluate the growth and yield of maize and yam, grown on *Imperata cylindrica* managed fallow field

NULL HYPOTHESES

Land preparation method, chemical application and cover crop can:

- Reduce the long fallow period of speargrass infested field and is economically viable
- Lower rhizome viability
- Enhance soil fertility
- Improve tuber quality

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Biology of Speargrass

Speargrass (*Imperata cylindrica* (L.) Beauv.), also called alang-alang in Malaysia, cogongrass in the United States, bladygrass in Australia, silverspike in South Africa and swordgrass in Eastern Africa, is an invasive perennial plant ranked the 7th most troublesome weed in the world (Holm *et al*, 1977). The genus *Imperata* was named after Ferrante Imperato, an Italian apothecary who lived in the early 17th century (Hubbard *et al.*, 1944). The genus *Imperata*, family Poaceae, is from the subfamily Panicoideae of the tribe Andropogoneae (Watson and Dallwitz, 1992; Gabel, 1982) and subtribe Saccharinae (Campbell, 1985; Clayton, 1972). Hubbard *et al.*, (1944) divided *I. cylindrica* into 5 groups based on morphological characters, geographical distribution and ecological forms. These are vars. *major*, *africana*, *europa*, *condensata* and *latifolia*. The varieties *major* and *africana* are abundant and very persistent with var. *major* extending from Japan and southern China to the Pacific Islands, through to Australia, India and eastern Africa. The var. *africana* found from Senegal and Sudan southward through Africa is approximately 76-117 cm tall with leaves 3-11 cm long and 0.7 – 1.3 cm wide (Sharma and Okafor, 1988) though generally speargrass can be as tall as 2 m (Tjitrosoedirdjo, 1993). The bulk of the rhizomes of var *africana* occur at a soil depth of 10-20 cm and it does not penetrate more than 30 cm of alfisol soil (Anoka, 1995; Sharma and Okafor, 1988; Ivens, 1975).

Speargrass reproduces copious amount of seeds (3,000 seeds per plant) sexually which, may colonize cleared or non-infested land by wind dispersal over long distances of an average of 15 metres (Holm *et al.*, 1977) to 100 metres (Shilling *et al.*, 1997) and become viable only when cross-pollinated (McDonald *et al.*, 1996) often with low success rate (Shilling *et al.*, 1997). It has been observed that 95 % of the seeds can germinate within a week of harvesting (Santiago, 1980, 1965) and can retain their viability for at least one year, with highest viability from those less than three months old (Shilling *et al.*, 1997). It usually flowers under stress such as burning, cutting, or drought (Kushawa *et al.*, 1983; Santiago, 1980). The prevention of seed production is difficult because of the widespread stress-induced practices of cutting for thatch and burning which has been observed to stimulate seed production (Tjitrosoedirdjo, 1993).

Asexual reproduction by rhizomes is the main means of propagation which can reach soil depths of one metre or more ((Terry *et al*, 1997). Vegetative reproduction from rhizomes is a significant factor in human spread of the species because these are often found in dirt moved as fill (Shilling *et al.*, 1997; Willard, 1988; Ayeni and Duke, 1985). Speargrass can reach a population density of 450 shoots/m^2, with 11.5 and 7 tons of shoot and rhizome respectively (Soerjani, 1970). It assimilates carbon dioxide by the C_4 photosynthetic pathway (Paul and Elmore, 1984), which gives it a competitive advantage over C_3 plants in tropical conditions.

2.2 Distribution

The genus occurs in south Asia, the Pacific Islands, Australia, Argentina, Chile, Columbia, the West Indies and Africa though it is also present but not serious around the Mediterranean and parts of Southern Europe (Turvey, 1994; Al-Juboory and Hassaway, 1980). In Japan and New Zealand, it is found above latitudes 45^0 north and south (Holm *et al*., 1977). It is also present in North Florida and the Gulf Coast States of the United States (Onokpise *et al*., 1999; Shilling *et al*., 1995; Shilling, 1988; Elmore, 1986). Holm *et al*., (1977) estimated that over 500 million ha of land have been infested with speargrass worldwide with 200 million ha in Asia, and 100,000 ha in the United States mainly from Alabama, Florida, and Mississippi (Schmitz and Brown, 1994; Dickens, 1974). In Africa, it can be found in North Africa, Senegal through to Ghana and all the way to Nigeria and Sudan extending to South Africa and Madagascar (Garrity *et al*., 1997; Aken'Ova and Atta-Krah, 1986 and Ivens, 1980). The areas of occurrence are said to be heterogenous with respect to climate, vegetation, soils, farmer resources and infrastructure (Manyong *et al*., 1996b).

2.3 Ecology

Speargrass grows in areas with 500 to 5000 mm rainfall annually at altitudes of up to 2700 m and can thrive in all soil types whether clayey or water-logged (Holm *et al*., 1977; Ivens, 1975). The weed's tolerance of water-logging is due to its higher gas-filled root porosity. This is an important adaptation, especially where the infiltration capacity of the soil has been affected by physical soil degradation. It can even survive on infertile soils (Suryatna and McIntosh, 1980) but is a poor competitor, which is easily suppressed by other species when found on fertile soils (Eussen and Wirjahardja, 1973). The weed has a low nutrient demand per unit of dry matter production and a high efficiency of nutrient uptake (Saxena and Ramakrishna, 1983), this coupled with its ability to extract soil water from shallow soil layers makes it able to invade areas that will not support other grasses. Repeated logging and fire are reported to be primary agents of succession leading to speargrass domination (Tjitrosoedirdjo, 1993; Ivens, 1975). Speargrass is a fire climax species whose presence is associated with frequent occurrence of bush fires. The aggressive and invasive nature of speargrass is mostly attributed to its extensive rhizome system, which is concentrated in the upper 20 cm of soil (Tjitrosemito, 1991; Soerjani, 1970) but the restriction of axillary bud formation to the apical region and apical dominance plays a major role in slowing down the spread of the weed (English, 1998; Wilcut *et al*., 1988). However, the weed cannot survive in areas where the ground is frequently cultivated but thrives on roadways, pastures, fallow lands, parks etc (Onokpise *et al*., 1999; Coile and Shilling, 1993; Willard *et al*., 1990). The rhizomes have a lot of vesicular-arbuscular mycorrhizal fungi around the rhizosphere (Widiastuti and Kramadibatra, 1992) which helps it to utilise available phosphorous to the disadvantage of other plants in areas where phosphate is limiting.

2.4 Utilization

The shoot of speargrass is used for thatch, mulch or protection of seedlings from direct sunlight (Mitrosuhardjo *et al.* 1989) though, when used as mulch, only 37% of the shoot decomposed compared to 63% decomposition of *Chromolaena odorata* (Agbim, 1987). It is also used for erosion control (Suryatna and McIntosh, 1980). Johannes (1980) demonstrated the use of speargrass shoot for energy-rich coal brickets. Townson's (1991) review on utilization of speargrass included grazing, paper production and packing materials. Holm *et al.* (1977) reported that the older leaves of speargrass have low nutritive value and animals that fed on them tended to develop sore mouths; even though they have high levels of calcium (Sharma and Okafor, 1988). Townson's list also included medicinal use as sedative, tonic, antipyretic, diuretic, fumigation of haemorrhoids, treatment for venereal diseases, high blood pressure and the extracts as aphrodisiac among others. Attempts have also been made to make sugar and alcohol.

2.5 Agricultural Importance

Harper (1960) defined weed interference as the detrimental effects of one plant species on another resulting from their interactions with each other, which includes both competition and allelopathy usually when they are in close contact. Competition is defined by Aldrich (1984) as the relationship between two or more plants in which the supply of growth factors fall below their combined demands.

2.5.1 Speargrass - Crop Interactions

Plants interfere usually with each other by competing for light, nutrients, water, oxygen, carbon dioxide and space (root and tuber crops). The survival mechanisms and persistence of speargrass seems to be favoured by its biological attributes ie genetic variability, dual reproductive mechanisms, vigorous underground rhizomes, carbon assimilation pathway, ability to grow on degraded soil, and allelopathy; and past field management practices such as shortened fallow length in intensively cropped areas and burning. These attributes have made the weed more competitive for environmental resources and space than most crops (Grooves, 1991; Inderjit and Dakshin, 1991; Tjitrosemito *et al.*, 1990; Eussen, 1981; Ivens, 1980; Holm *et al.*, 1977; Soerjani, 1970). In Asia, infestation had been increasing at a rate of 150,000 ha annually (Soerjani, 1970).

Speargrass is not crop specific and it is reported to infest about 35 crops with different cropping systems but is a principal weed in coconut, oil palm, rubber, citrus, cassava, yam, sweet potatoes, maize, rice, and groundnut (Chikoye *et al.*, 2000; Al-Juboory and Hassaway, 1980; Holm *et al.*, 1977). The devastating effects on crop production are well documented (Akobundu and Ekeleme, 2000; Chikoye *et al.*, 2000; Garrity *et al.*, 1997; Lagoke and Fayemi, 1981; Eussen *et al.*, 1976). Severe infestations damage crops through competition, which suppresses growth resulting in significant yield losses, increases investment in labour for weeding and may delay harvests. Direct crop yield reduction from competition to speargrass has been estimated at 76-80% in cassava, 78% in yam and 50 % in maize (Chikoye *et al.*, 2001;

Udensi *et al.*, 1999; Koch *et al.*, 1990). Reduced yield have also been reported in oil palm and coffee (Brook, 1989).

The rhizomes of speargrass have been reported to physically injure other plants and appear to be allelopathic (Bryson and Carter, 1993; Brook, 1989). In root and tuber crops such as cassava, yam and sweet potato and groundnut, apart from direct yield losses, the emerging shoots from rhizomes, pierce the tubers and pods, which pave way for secondary infection by disease pathogens. In a survey, Chikoye *et al.* (2000) reported that farmers felt the presence of speargrass limits field size, increases labour for weeding, causes physical injury to skin, reduces quality of tuber crops and increases the occurrence of bush-fires and the incidence of insects and pathogens. Farmers mostly affected by speargrass in Sub-Saharan Africa are peasants who mostly rely on manual control, which is time and labour consuming. A report from IITA (1977), indicated that weeding twice in a speargrass infested maize and cowpea field consumed 54 % of total labour. In Nigeria, according to Akobundu *et al.* (2000), four weedings are required to prevent maize yield reduction in the derived savanna. Holm *et al.*, (1977) and Oritsejafor (1986) indicated that speargrass (*I. cylindrica* var. *africana*) is a host to *Fusarium oxysporum* and could also provide breeding grounds for the locust (*Zonocerus variegatus*).

2.5.2 Allelopathy

Eussen (1979) and Eussen *et al*. (1981a; 1976; 1973) confirmed that allelopathic properties were partly responsible for the competitiveness of speargrass and its ability to dominate extensive areas. Shoot, rhizome and root extracts from speargrass delayed the germination and inhibited shoot length of tomatoes (*Lycopersicon esculentum*) and cucumber (*Cucumis sativus*). The rhizomes had the most potent extract and the biologically active substance was vanillic acid. Tjitrosemito *et al*. (1990) also reported the accumulation of phenolic substances in speargrass when treated with glyphosate. In a study, to establish whether allelopathic compounds were present in the rhizosphere of speargrass, Inderjit and Dakshin (1991) confirmed the presence of higher concentrations of phenolic compounds from or near the rhizosphere and therefore concluded that the weed succeeds through allelochemicals in the rhizosphere. Also the reduction in the nodule characteristics and thus N fixation capacity of the legume plant *Melilotus parviflora* in association with speargrass is indicative of the efficiency of the allelopathic effect. Mulching with speargrass also delayed the emergence of *Abelmoshus esculentus* and *Corchorus olitorius* compared with unmulched plots (Fasheun, 1988). This inhibitory effect was also reported by Singh *et al*., (1989), who observed that 10% conc. (w/v) of aqueous extract of speargrass inhibited germination of soybean and maize seeds. Akobundu and Ekeleme (1995) also associated yield reduction in maize to the allelopathic effects of speargrass rhizomes on maize. However, Lippincott (1997) suggests that other explanations may exist for the competitive success of speargrass and that the existence of allelopathy is not certain.

2.6 Rhizome Regenerative Capacity

The rhizomes are perenniating organs with extended capacity for vegetative regeneration with a lot of vesicular-arbuscular mycorrhizal fungi around the rhizosphere (Widiastuti and Kramadibatra, 1992). Regeneration increases in the presence of oxygen at the rhizosphere (Wilcut *et al*., 1983). Light favours rhizome bud germination and it has been proved that rhizomes which develop during the rainy season do not regenerate as well as those formed in the dry season (Soerjani, 1970). The lateral buds can remain dormant for long periods and a bud from a single rhizome node can produce 350 shoots in 6 weeks to cover up to 4 m^2 in 11 weeks (Eussen, 1980). Longer or larger rhizomes have a greater probability to sprout (Ivens, 1975; Soerjani and Soermarwoto, 1969) while mature buds closest to the apex sprout earlier than the others (Soerjani, 1970). Wilcutt *et al*. (1983) reported rhizome length of 2.73m in 109 days while Lee (1977) observed that a 15cm length rhizome produced 181 shoots/m^2 in 6½ months. Age also affects the regenerative capacity of speargrass rhizomes with older rhizomes regenerating better than the younger ones (Ayeni and Duke, 1985). The nodes along the first 10 cm of the rhizomes do not have buds but they occur irregularly along the rest of the rhizome; this coupled with the inability of the terminal rhizome fragments to grow if buried deeper than 4cm, explain the success of mechanical control or cultivation (Widyatmoko and Ryanto, 1986; Peng, 1984; Ivens, 1980) because regeneration decreases with increased depth. The rhizomes have modifications in the central cylinder, which helps in water conservation to resist breaking up and disruption when disturbed or trampled (Holm *et al*., 1977). However, cultivation, which is used for exposing rhizomes to desiccation if not properly done, can stimulate bud growth by fragmentation of the rhizomes and through aeration of the soil.

2.7 Effect of Light on Growth of Speargrass

Monteith (1977) observed that dry matter production of a plant canopy is directly related to the amount of photosynthetically active radiation (PAR) intercepted by the canopy. Light is important for the growth of speargrass although there are contradictory reports on the production of shoots versus rhizomes under different light intensities. Eussen (1981b) showed that after 6 months growth, speargrass had more rhizomes than shoot biomass at 20-100 % light intensity while, Soerjani (1970) had more shoots (11.5 t ha^{-1}) than rhizomes (7.0 t ha^{-1}). An 80% decrease in incident light was observed to decrease the relative growth rate by 50% in both shoots and rhizomes (Eussen, 1981a). Under insufficient soil moisture but abundant solar energy, Tjitrosemito (1991) showed that speargrass sacrifices shoot growth to maintain assimilate in the rhizome which it uses under favourable soil moisture conditions. The total plant dry weight, leaf area, dry weights of roots, stems, leaves, and rhizomes, and numbers of rhizomes and leaves were significantly reduced under shading when grown from stem and rhizome propagules (Patterson, 1980). The rhizomes are also affected by dessication hence the common practice of its exposure to the sun as a control measure (Sherman, 1980).

This feature of intolerance is exploited in the choice of cover crop to be grown in association with speargrass as a control measure. Plant canopy characteristics affect the amount and manner of light interception, and are important factors in determining the level of efficiency in the utilization of PAR since they affect light distribution to individual leaves. Low levels generally result in decreased photosynthesis, biomass accumulation and yield. In a study, the quantity of shoots and rhizomes negatively correlated with the infestation of associated vegetation especially *Chromolaena odorata* (Eussen and Wirjahardja, 1973) as a result of competition for light.

2.8. Use of Shade as a Speargrass Management Strategy.

As scarcity of land progressively forces farmers to shorten the fallow period, the emphasis in weed management has shifted from forest fallow to beneficial cover crops, which can retard the succession to speargrass. In general, cover crops are best used to prevent speargrass infestation and the mechanism for speargrass suppression with cover crops is through shading by limiting the available solar radiation for its growth and may be through allelopathy (Eussen 1981b). Most cover reach full canopy cover earlier than speargrass reducing the photosynthetically active radiation (PAR) reaching the weed and thereby reducing their competitive ability (Benvenuti *et al.*, 1994). Thus the management of shade is critical to the successful conversion of speargrass dominated vegetation. To control speargrass successfully, it is essential to reduce the number of viable buds and prevent them from forming new aerial shoots. Several studies have demonstrated shade- induced changes in speargrass biomass dry weight, partitioning and plant morphology. Eussen (1978) found that the relative growth rates (RGR) of speargrass shoots and rhizomes over a period of two to six months were reduced by 50% and 80% in reduced light intensity. Soerjani (1970) found that 50% shade caused shallower rhizome depth than found in unshaded plants.

In an experiment, Moosavi-Nia and Dore (1979) found reductions in shoot dry weight, rhizome dry weight and total carbohydrate content of speargrass rhizomes of plants grown in 75 % shade. They also reported significant reductions in rhizome and tuber-bulb productions compared with plants grown in normal daylight. The susceptibility of speargrass to the herbicides dalapon (Sukartaamadja and Siregar, 1971) and glyphosphate (Moosavi-Nia and Dore, 1979) was greater in plants grown under shade as a result of the depletion of carbohydrates in the roots and rhizomes.

2.9 Management of Speargrass

A successful control demands the destruction of the capacity of the speargrass to regrow through physical damage, burial or physiological damage, by inhibiting growth such that, speargrass ceases to be a problem under field or fallow situations since complete removal is impossible and uneconomical. The control methods to achieve this feat have been varied but the main methods are physical (manual and mechanical), cultural, biological, chemical and integrated weed management (IWM).

2.9.1 Cultural Control

Traditionally, farmers in the tropics remove their crop residues and prepare land for cropping by burning which is considered a labour-saving device. Since most of the resource-poor farmers of the tropics cannot purchase fertilizer, they burn to replenish the soil mainly with potash (Safo *et al.*, 1990) but this stimulates the growth of speargrass and enhances seed production. Shifting cultivation continues to be a primary means of livelihood for millions of farm families throughout the tropics.

Fallows, or the period of regeneration between cropping periods, are an integral part of shifting cultivation systems and serve the functions of soil improvement and weed suppression. If crops no longer give adequate economic returns for labour expended due to increased weed pressure and a decline in soil fertility farmers returned their lands to fallow (Brook, 1989). The determination of fallow lengths is often a function of weed competition and the amount of labour required to maintain crop yields – i.e., a field may be allowed to go into fallow when the labour required to keep it free of weeds exceeds the labour needed to clear a new site (Greenland, 1974). Farmers usually use long fallows to manage natural succession processes and according to Brubacher *et al.* (1989), competition allows farmers to replace unmanageable weed species with more easily prepared secondary forest. The length of time needed to shade and displace speargrass under natural fallow may be 12-15 years (Ahn, 1978). However, the frequent burning and the scarcity of land as a result of population pressure has shortened the fallow period therefore preventing the regrowth of forest vegetation to levels that eventually shade and displace speargrass (De Rouw, 1995). Thus this traditional cropping system has been reported by several scientists to be no longer practicable (Turvey, 1994; Saka, 1992; Akobundu, 1991; Alimi, 1991; Okigbo, 1989; Stifel, 1989).

2.9.2 Manual Control

Speargrass is controlled predominantly by manual weeding which usually involves slashing, burning, hand weeding, and hoeing or a combination (Ivens, 1980). Manual methods do not disrupt the rhizomes of speargrass; thus sprouting of new shoots is not prevented and therefore does not offer seasonal control. Long lasting control, need to be repeated 3-5 times to get reasonable control, and yield reduction often occurs despite the control measures (Townson, 1991). Hoe-tillage on burnt land reduced infestation by 63 % and increased crop yield by 449 % (Anoka, 1995). This method besides not being effective becomes more tedious under severe infestations and does not allow for cropping of large tracts of land. Terry *et al.* (1997) report that it can take 85 man-days to open up a hectare of land in Indonesia. Mounding or ridging which are popular land preparation methods if properly constructed could bury rhizomes to depths >15 cm to delay sprouting and emergence of speargrass (Ivens, 1980).

2.9.3 Mechanical Control

Deep tillage offers effective control of speargrass (Shilling and Gaffney, 1995; Townson, 1991; Ivens, 1980). Ivens (1975) recommends that for effective control of speargrass tractor ploughing should be done during the dry season, given that one or two days exposure on the soil surface are sufficient for the rhizomes to lose their viability. A single plough alone is not enough to effectively control subsequent speargrass regrowth due to large rhizome reserves, thus Shilling and Gaffney, (1995) suggested three ploughings in a year to depths > 15 cm for 3 years to effectively deplete rhizome reserves for long lasting control. Willard *et al.*, (1996) reported speargrass shoot and rhizome biomass reduction of 73 and 66 % for two discings respectively. In West Africa, the disc plough is rarely operated deep enough to break up sizeable proportions of the rhizome system for lasting control. Thus any control achieved is short lived because it is only the upper rhizomes that are disturbed. Ivens (1980) reported a loss of viability with increasing depth and that only 20 % of rhizomes that emerged from 7.5 cm succeeded in reaching the surface but reduced their viability quickly due to dessication.

2.9.4 Biological Control

The use of cover crops for speargrass control is widespread in southern Benin (Manyong *et al.*, 1996a). Cover crop interferes with weeds through allelopathy and competition for light. A significant 50 – 80 % reduction of speargrass rhizome dry matter was enough to return the fields to cropping again within 2-3 years with cover crop fallow (Chikoye *et al.*, 2002; Akobundu *et al.*, 2000; Udensi *et al.*, 1999; Versteeg and Koudokpon, 1990). *Stylosanthes guainensis* (Aubl) Sw, *Desmodium intortum*, *Crotalaria spp*., *Lablab spp*., and *Pueraria phaseoloides* are some of the recommended cover crops for speargrass suppression (Sajise, 1980). Chikoye *et al.*, (2001) in their studies showed that cover crops reduced speargrass biomass by ≥ 52 % 12 months after planting compared to plots without cover crop and that the best cover was *Mucuna* (velvetbean). Plots without cover crops had 2–11 times higher shoot dry matter while plots with cover crops reduced rhizome dry matter by 55–100 % (Chikoye *et al.*, 2002). Akobundu (1993) in his studies reported speargrass density of

19 plt/m^2 on *Stylosanthes* fallow and 56 plt/m^2 on *Mucuna* fallow at 39 months after planting and then increased to 28 plt/m^2 and 55 plt/m^2 respectively by 52 months.

Most cover crops are very toxic due to high concentrations of phytochemicals significant to allelopathy. Although Lorenzetti *et al.* (1998) reports that phytochemicals constrain the use of some cover crops for food value or forage, they may provide farmers with a new opportunity of value-added phytochemical products. *Mucuna*, for example has biologically active natural products that make it an effective cover for speargrass control. However, *Crotolaria* though very effective for speargrass suppression, inhibits subsequent maize germination (van Noordwijk, 1995, quoted by Macdicken *et al.*, 1997) because of the release of allelopathic substances from the above-ground biomass and/or from decaying roots (Hairiah *et al.*, 1992).

2.9.4.1 Use of *Mucuna* Cover for Weed Control

Mucuna spp (Velvet bean), a vigorous annual climbing non-stinging legume from the family Fabaceae originally from China, Malaysia or India has successfully been used since time immemorial for weed control and restoration of soil fertility (Wilmot-Dear, 1984; Duke, 1981; CSIR, 1962). The most common are *Mucuna deeringiana*, *M. utilis*, *M. pruriens*, *M. cochichinensis*, *M. capitata* and *M. aterrina* (Duke, 1981; Tanaka, 1976; IIA, 1936). *Mucuna* has few insect problems and it is immune to wilt and rootknot caused by nematodes through damage by the soil-borne pathogen *Macrophomina phaseolina* has been reported (Bell and Jeffers 1992; Berner *et al.*, 1992). Versteeg and Koudokpon (1990) used *Mucuna spp.* as live mulch to suppress speargrass. Udensi *et al.* (1999) reported that *Mucuna spp*. was as effective as herbicides in suppressing speargrass.

A survey at Atebubu in the Brong Ahafo Region of Ghana showed that 73 % of the farmers were aware that *Mucuna* can suppress weeds and may hence be their main motivation for its adoption (Anthofer, 1999). In a survey at Benin, there were thrice more farmers who used mucuna for speargrass control than for soil fertility restoration (Versteeg *et al*., 1998). According to Akobundu and Poku, (1984) *Mucuna* can be an effective short duration (3-4 months) cover for speargrass suppression. It has also been reported to be effective in Columbia (van Eyk-Bos, 1986) and even on an acid soil in Lampung, Indonesia (Guritno *et al*., 1992; Hairiah *et al*., 1992). In the Mono province of Benin, Versteeg and Koudokpon (1990) indicated that *Mucuna* reduced speargrass to less than 10% of its initial density on farmer's fields. Dovonou (1994) also reported a reduction of speargrass density from 270 to 32 shoots/m^2 while other farmers working with SG 2000 reported complete elimination after two to three consecutive *Mucuna* crops (Galiba *et al*.,cited by Vissoh *et al*., 1998). In a researcher-managed trial in Nigeria *Mucuna* was the most efficient among other covers for speargrass control (Akobundu and Poku 1984; Akobundu and Udensi, 1984). Speargrass density was 1 shoot/m^2 from an initial density of 100 shoot/m^2 while rhizome fresh weight was 2 kg for *Mucuna* compared to 36 shoot/m^2 with 5 kg rhizome weight or 58 shoot/m2 and 6 kg rhizome weight for *Centrosema* or *Psophocarpus* cover respectively after 15 months. However, it has been reported that because of the high Al tolerance of speargrass reclamation by *Mucuna* is less effective if the topsoil has been eroded (Hairiah *et al*., 1993).

2.9.4.2. Use of *Stylosanthes* Cover for Weed control

Stylosanthes a leguminous shrub from the subfamily Papilioniodae and family Leguminosae occurs naturally in the tropics, subtropics and temperate regions of the Americas, Africa and Southeast Asia (t'Mannetje, 1984). It has been used quite a lot for the rehabilitation of speargrass grassland for tropical pasture legume and as a cover in plantations (Tarawali, 1991; McCowan *et al*., 1986). It performs well under both drought and waterlogged conditions (Edye and Grof, 1984) and in areas of low soil fertility, especially where the soil has a low P content and acidic, although forms adapted to alkaline soils are common in the Caribbean, Central America and Mexico. However, it is susceptible to anthracnose caused by *Colletotrichum gloeosporioides* (Daroesman, 1981). *Stylosanthes* established well in a study by Bustami *et al*., (1982) on speargrass infested plots that had either been treated with herbicide or cultivated but moderately on plots that had been burned or ploughed. According to Sajise and Lales (1975) dual allelopathy between *Stylosanthes* and speargrass enable the legume cover to compete successfully. In a potted replacement series experiment with *Stylosanthes* and speargrass, *Stylosanthes* was more competitive than the weed up to the end of the experiment, which was about five months (Tjitrosoedirdjo *et al*., 1981).

2.9.5 Chemical Control

Chemical control is particularly important in areas where large tracts of land have been infested, cultivation is difficult, manual labour for weeding is difficult to hire and expensive. It also becomes an option when one wants to avoid the drudgery of farming. Over 30 herbicides with different combinations have been evaluated and reported for speargrass control (SEAWIC, 1988; Bacon, 1986; Dickens and Buchanan, 1975) with varied results depending on the climate, soil type and rate of application (Willard *et al.*, 1997, 1996; Akobundu, 1991; Townson, 1991; Ivens, 1980). Some of these herbicides are TCA (trichloroacetic acid), dalapon, amitrole, sulfometuron., paraquat, glyphosate and imazapyr. The use of fluaziflop (fusillade 2000) and glufosinate (Ignite) in the United States suppressed growth for three months (Shilling and Gaffney, 1995). Of the many herbicides only a few have been found suitable and the availability of these systemic herbicides with the ability to translocate to underground rhizomes make chemical control an attractive option for managing speargrass (Udensi *et al.*, 1999; Akobundu, 1991; Ivens, 1980). However, for speargrass control the efficacy of penetration and translocation of most of these herbicides are affected more by the biological state of the weed. Tjitrosemito (1991) showed that the penetration and translocation of glyphosate and imazapyr in speargrass was greatly reduced when the leaf was dead.

Dalapon is a systemic herbicide absorbed by both leaves and roots which interferes with the biosynthesis of panthotenic acid, a precursor of CoA (Hilton *et al.*, 1954, cited by Tjitrosoedirdjo, 1993). It accumulates in young leaves, thus must be sprayed on actively growing shoots but requires repeated applications and not less than 2 years to reduce speargrass population to a negligible level. Dalapon when applied on speargrass under 3- year –old rubber at 2 – 2.5 kg a.e./ha effectively controlled speargrass within 7 days with little regrowth but at < 2 kg a.e./ha the rhizomes rapidly regenerated. From this it was implied that dalapon was more effective for shaded speargrass.

Glyphosate (N-phosphonomethyl-glycine) is a systemic herbicide and an inhibitor of 5-enolpyruvyl-shikimic acid 3-phosphate (EPSP synthase) an enzyme of the shikimic acid pathway (Amrhein *et al.*, 1980). The efficacy of glyphosate is dependent on the climate, age of speargrass and the shade on it. Thus the recommended rates range from 1.8 – 4.0 kg a.e./ha. It is very popular in West Africa for both small and large scale farmers because of its relatively affordable price, inactivation in the soil and non–toxic effect on following crop. The use of glyphosate for speargrass control led to 54 % speargrass biomass reduction in Ghana (Adu-Tutu *et al.*, 1995). Chikoye *et al.* (2002) reported about 51 % less shoot dry matter on glyphosate–treated plots compared to plots weeded twice. In the same study rhizome dry matter was 2-3 times higher on plots weeded twice than the glyphosate treatments.

Imazapyr is systemic and requires 3-4 months for its effectiveness to show on speargrass. It is persistent in the soil and will damage subsequent crops following application in the dry season but is leached out when applied in the wet season with minimal effect on following crops (Tjitrosemito, 1991) but the persistence varies with the soil physical properties and moisture. Even though it provides excellent control with long term efficacy than glyphosate it exposes crops to phytotoxic residues, which is a risk to crop production. Ahrens (1994) reported weed control of up to 2 years. Studies in Nigeria showed that plots treated to imazapyr at 1.0-1.5 kg a.e/ha needed only two weedings for maximum maize yield in the second year after control (Terry *et al.*, 1997) but Onyia (1997) revealed that maize cannot be planted before 8 weeks after application which invariably may delay planting with a consequent yield reduction.

The residual effects of imazapyr and glyphosate reduced weed density by 21 and 15 % in following cropping (Udensi *et al.*, 1999). Glyphosate at 3.4 kg ae/ha and imazapyr at 0.8 kg ae/ha reduced speargrass rhizome infestation by 43 and 51 % respectively about 2 years after application (Willard *et al.*, 1996).

Complete control by these herbicides requires repeated applications to kill or deplete rhizomes, a prerequisite for achieving long-term control, which, can be very costly (Willard *et al.*, 1997). A single herbicide application can cost as much as $400/ha (Shilling and Gaffney, 1995) as a result of repeated applications besides the often severe impact on non-target species, which creates disturbances that allow for the re-invasion by speargrass or secondary invasion by other weedy species (Gaffney and Shilling, 1996). The apical dominance exhibited by speargrass has been shown to reduce the efficacy of herbicidal control due to sub-lethal herbicide sink activity in dormant axillary buds (English, 1998; Shilling *et al.*, 1997). Thus for both economical and environmental reasons, the currently recommended herbicides except glyphosate may be unacceptable in Ghana and elsewhere in West Africa due to the complex cropping systems.

2.9.6 Integrated Speargrass Management

Integrated control which, was first suggested by Tjitrosemito *et al.* (1985) consists of the integration of chemical or mechanical methods followed by the establishment of cover crops or annual crops. Effective management of speargrass with adequate supply of labour, machinery and herbicides have also been reported. (Cox and Johnson, 1993). The adaptability of speargrass to all forms of stress, mainly environmental and ecological conditions and the genetic variations within the five major varieties has aided its survival in natural and man-made ecosystems and hence the need to employ different management practices to tackle the weed. This necessitates the integration of different control practices since various studies have shown that a single control method is insufficient for a lasting control. Cultivation, which is used for exposing rhizomes to desiccation when not properly done, can stimulate bud growth hence the need to apply translocated herbicides, which acts on the sites of action to combat the growth. It is known that residual herbicides persist longer in some soils than others, cultivation is more effective on some soils and even biological control of speargrass can be constrained by genetic variability. Tjitrosemito *et al*. (1994) observed that some clones of speargrass in certain parts of Indonesia were more sensitive to glyphosate than clones from other parts. In Nigeria, Holm *et al.* (1977) reported of ecotypes of speargrass with higher shade tolerance. Speargrass is not completely eradicated with legume cover and rhizomes under the ground must be eliminated by weeding or herbicide before cropping to avoid rapid reinfestation. Thus a successful control must aim to destroy the rhizomes, which propagates and preserve the weed.

A continuous cropping system is often imperative to prevent the establishment of speargrass or to control it in early stages (Suryatna and McIntosh, 1982) and Shilling and Gaffney (1995) believed that the ultimate is to follow an integrated approach. They suggested burning followed by tilling and herbicide application and the establishment of a cover that would out compete speargrass over a long term. The integration of competition provided by desirable species after initial suppression with glyphosate or imazapyr provided the most sustained control of speargrass (Gaffney and Shilling, 1996). *Mucuna* plus glyphosate or imazapyr reduced speargrass density (Udensi *et al*., 1999). Adegbola *et al*. (1970) recorded 95 % speargrass control after 12 months when they ploughed to 15 cm depth and followed it by seeding *Andropogon gayanus* after a dry season fallow.

Willard *et al*. (1996) reported accepted control of > 80 % in speargrass rhizome biomass only when dalapon, glyphosate or imazapyr was preceeded and followed by discing. This is because long-term control of speargrass is dependent upon the elimination of rhizomes and not only on shoot response, which most often is an overestimation of a treatment efficacy.

2.10 Cover Crop for Soil Improvement

During the fallow period, available soil nutrients are extracted from deeper layers of soil and brought to the top soil by plants for their regrowth (Bandy, 1994). While fallowing previously cropped lands, farmers clear primary forests to crop on fertile lands which often guarantee 2-4 years of continuous cropping before poor fertility forced them to return the land to fallow again (Eussen and Wirjahardja, 1973). Legumes have been known to contribute significantly to maintaining nitrogen (N) levels, organic matter, physical and microbiological properties of soils (COMBS, 1993; Buresh and De Datta, 1991; Dakora *et al*., 1987) in cereals.

Stylosanthes usually exhibits a high N content, combined with a very low P content, which decreases as the plant ages, especially under water stress. The advantages of *Stylosanthes* include the ease of nodulation with local *Rhizobium spp.*

The response to inoculation with *Rhizobium* varies largely among and within species; the N-fixation efficiency presumably depends on the environmental conditions of the collection sites. The N contribution of *Stylosanthes* is reported to be a function of species and length of fallow. *Stylosanthes* has been reported to improve soil fertility faster than a natural fallow. Maize yields at three levels of applied N (0, 60, or 120 kg/ha) was 1700 kg/ha on plots that had 3 years *Stylosanthes* cover with no fertilizer-N additions and 800 kg/ha on plots under 4 years natural fallow without (Tarawali 1991). In another study in the Cameroun, *Stylosanthes* provided excellent weed control and highest maize grain yield of 2.25 t/ha on unfertilized plots and 4.40 t/ha with fertilization among *Calopogonium mucunoides* and *Canavalia ensiformis* (Sanginga *et al.*, 1996). Farmers normally introduce crops into *Stylosanthes* fallow after three years because of the legume's soil improving characteristics (Tarawali *et al.*, 1998). Maize grain yield following 3 year *Stylosanthes* fallow was higher than on continuously cropped or natural fallow fields. Grain yield after 3 years *Verano Stylosanthes* or 2 years *Cook Stylosanthes* was equivalent to 90 and 110 kg N/ha respectively from 3 year cropped field.

In Sunyani district of Ghana, 92 % of the farmers' motivation for using *Mucuna* was for soil fertility enhancement, in contrast to Atebubu, where speargrass suppression was the farmers' motivation (Anthofer, 1999). Maize grain yield increases on farmer's fields of about 500 kg/ha for a local maize variety and about 800 kg/ha for an improved variety was reported, after one year *Mucuna* fallow and also improved maize grain yield of 70 % over continuously cropped fields (Versteeg and Koudokpon, 1990; Versteeg, 1993). Maize grain yield increased from 480 to 1140 kg/ha in very depleted soils after what is known in Benin as 'the *Mucuna* shock treatment for comatose soils' (Versteeg *et al.*, 1998).

Osei-Bonsu and Buckles (1993) observed that the average maize-grain yields of 3- 4 kg/ha on fields previously planted to *Mucuna* without N- fertilizer was similar to that normally obtained with recommended levels of fertilizer (130 kg/N). Their estimate of an equivalent of more than 100 kg N/ha from Mucuna to the following maize was very near to that of Sanginga *et al.* (1996) for southwestern Nigeria. *Mucuna* fallowing has additional benefits, such as erosion control and the maintenance or improvement of the soil's physical, chemical, and biological properties. Hulugalle *et al.* (1986) reported increases in porosity and infiltration rates and a decrease in penetrometer resistance with increased *Mucuna* biomass at the International Institute of Agriculture (IITA) in Ibadan. Losses of 3-7.5 t soil/ha were observed on maize-*Mucuna* plot, compared with 30 t soil/ha on sole-maize plot (Azontonde, 1993). Osei-Bonsu (unpublished data), found that 13.8 t/ha of dry mulch (12.6cm thick) and an estimated 4.1million earthworm casts/ha (21.6 t/ha) after 2 season's *Mucuna* fallow compared to 1.3 million casts/ha (3.6 t/ha) for plots planted to cowpea.

2.11. On-Farm Economic Analysis

Farmers are usually interested in economic returns and tend to consider the costs of changing from one practice to another and the economic benefits resulting from that change and in doing so they take risks into account in stepwise fashion (CIMMYT, 1988). Thus on-farm research interventions must be subjected to economic analysis in the context of farmer circumstances in order to provide sound recommendations, which would be adopted.

Partial Budgeting

Partial budgeting according to CIMMYT (1988) is explained as a method of organizing experimental data and information about the costs and benefits of various alternative treatments. The components are:

The total costs that vary is the sum of all the costs that vary for a particular treatment which usually includes inputs such as seed, fertilizer, herbicides etc, labour, and machinery if necessary; the average yield of each treatment and the adjusted yield for a treatment which is the average yield usually reduced by 10 % to reflect the difference between the experimental and farmer yields of the same treatment. The reasons adduced for this are that of precise and timely management of experimental variables with overestimated yields from uniformly small plots, harvesting at the optimum time and in some cases heavier losses from farmers' harvest methods (CIMMYT, 1988). The other components are the field price of crops, the gross field benefits for each treatment and the net benefits.

Marginal Analysis

The marginal analysis is a method used to compare total costs that varies (TCV) with the net benefits. This is best represented by plotting the net benefits of each treatment against the TCV to give a visual presentation of the changes in costs and benefits in changing from one treatment to the other. It also helps to clarify the reasoning behind the calculation of marginal rates of return (MRR), which compares the increments in costs and benefits between pairs of treatments (CIMMYT, 1988) usually expressed as percentage.

Acceptable Minimum Rates of Return

The estimation of the acceptable minimum rate of return has been found to be particularly useful in situations where the farmer has to make an additional investment in his normal farming practices as a result of an additional recommendation. For the majority of situations the minimum rate of return acceptable to farmers is estimated at 50% and above (CIMMYT, 1988).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Farmer Practices, Perception and Incidence of Speargrass in the Forest, and Forest-Savanna Transition Ecological Zones.

The specific objectives of this study were to:

(1) Characterize the cropping systems of speargrass infested areas

(2) Determine the incidence and spread of speargrass

(3) Document farmers' perception of speargrass in relation to other weeds

(4) Find out farmers' quantification of yield losses attributable to speargrass

(5) Determine the existing weed management interventions.

An informal survey including field observations that facilitated the collection of preliminary information was used to design questionnaires for the two surveys conducted in October 1996 and June 2000 respectively.

Selection of Study Areas

The survey was conducted in two phases (1996 and 2000) in the Ashanti and Brong Ahafo regions of Ghana in areas that fall in the forest and forest-savanna transition ecological zones of Ghana. The areas were purposively selected on the basis of the importance of the weed problem. The selected districts were Wenchi, and Techiman districts (Brong Ahafo Region), Ejura-Sekyidumase (Ashanti Region) in the forest-transition and Sekyere West (Ashanti Region) in the forest zones. The towns and their locations are presented as Appendices 1 and 2 respectively. Farmers in the selected areas are engaged in intensive agriculture and the fields are known to be infested with speargrass. The area has a bimodal rainfall system, which allows for two cropping seasons within a year and are located between latitudes 7^0 and 8^0 N.

Selection of Farmers and Locations

The sample consisted of 62 males and 19 females who were randomly selected from the two regions. The study locations in each district were selected within 50 km radius of the district capitals due to financial constraints.

Questionnaire Design

The results of an informal survey were used to design the questionnaire for the selected districts (Appendix 3).

Data Collection

The data was collected randomly through individual, household and group interviews, with some of the interviews being conducted on the field. The criterion for selection was willingness to be interviewed. Weed assessment was through field sampling. Five quadrats of 1 m^2 were randomly placed in surveyed fields and number of speargrass shoots/quadrat recorded. The assessment of speargrass infestation based on percentage cover was visually obtained by the use of discrete classes where 0-25 % was considered as low, 26-50 % as moderate, 51-75 % as heavy and > 75 % as very heavy. Noxious weeds were assigned numbers on a scale of 1-4, 1 being the most noxious and 4 the least noxious. Weeds were identified by local and scientific names.

Data Analysis

The data was analyzed with SPSS 8.0 for Windows and the most important crop and weeds were ranked by frequency of occurrence. Cropping intensity factor for each district was computed as:

$$\text{Cropping Intensity Factor (CIF)} = \frac{C}{C+F} \times 100$$

Where C = length of cropping; F = fallow period

3.2. FIELD EXPERIMENTS

3.2.1 Experimental Sites

Field experiments were carried out at Kyiremfaso near Mampong (Ashanti Region) in the Forest and Wenchi (Brong Ahafo Region) in the Forest–Savanna Transition ecological zones. Both zones have a bimodal rainfall pattern with an annual mean of 1500 mm in the Forest and 1300 mm in the Forest–Savanna Transition.

The Kyiremfaso site which was a farmer's field until over 48 years ago was a forest with a closed canopy but was practically a monotypic stand of speargrass with leaves well over 1 m in height at the time of site selection. Adu and Mensah-Ansah (1995), described the soils in the Mampong area as a Bediesi series (Rhodi-Profondic-lixisol) which is a dark gray-brown loamy topsoil 15 to 30 cm thick overlying a reddish-brown to red sandy clay loam to sandy clay subsoil on coarse-grained Voltaian sandstone.

At Wenchi the experimental field located at the Wenchi Farm Institute had been used for crop production research for over 20 years. Thus speargrass was not as dense or vigorous as at Mampong, and was interspersed with several species of broad-leafed weeds. The Wenchi area is classed as a Damongo-Techiman-Tanoso compound association (Coultas, 1959). The Techiman series also known as Episkeleti-Ferrick-Acrisol (WRB, 1998) is described as a brown sandy loam surface over reddish brown gravelly clay loam subsoil developed on Voltaian sandstones. Both sites had been abandoned and left to fallow due to the menace of speargrass.

3.2.2. The Effect of Land Preparation Methods and Cover Crop on the Regrowth of Speargrass (*Imperata cylindrica* (L.) Beauv.).

A split-plot design with four replications was used. The main plot treatment was land preparation methods and the subplot units were cover crops randomized within each whole plot. The land preparation methods were slash-burn, slash-mulch or plough while the cover crops included *Stylosanthes guianensis, Mucuna pruriens* (black coloured velvet bean) and *Canavalia ensiformis* (Jack bean). A no cover crop (natural fallow) was included for comparison. At both locations in the first year, the tractor was used for ploughing and the cutlass was used for slashing. In the second year (1997), since farmers' intimated that it would be unwise and not economical to plough a fallow field for a second time with no food crop the ploughed plots were hoed instead. The plot size was 6 x 6 m with 1m alleys between plots and 2m alleys between main plot treatments and replicates at both locations. This layout was to reduce cover crop encroachment from adjacent borders. However in 1997, only *Mucuna* was replanted because *Stylosanthes* is a perennial crop while the Jack bean was excluded because it was not competitive to speargrass. *Stylosanthes* was drilled into the soil with inter-row spacing of 50 cm. *Mucuna* and *Canavalia* were planted at two seeds/hole with inter and intra row spacing of 50 cm. In 1996, the cover crops were planted on June 21st and July 19th whereas for 1997 it was on May 2nd and June 12th at Mampong and Wenchi respectively. Alleys were cultivated as needed to prevent rhizome spread between adjacent treatments.

3.2.3. The Effect of Land Preparation Methods, Chemical Application and Cover Cropping on Speargrass (*Imperata cylindrica* (L.) Beauv.) Control.

The experiment located at Mampong was designed as a split-split-plot with treatments randomized within blocks in four replications. The plot size was 8 x 8 m with 1m between plots and 2 m between replications. The alleys were cultivated as and when necessary. The objectives were to: 1) evaluate the effect of glyphosate (round up) application on ploughed or slashed–burned fields on the control of speargrass, 2) determine the influence of *Mucuna pruriens* planted after round up application on speargrass regrowth and 3) determine the interactive effect of land preparation method, chemical application and legume cover crop on speargrass management in a fallow situation. Chemical application was split on the land preparation while cover crop was split on chemical application.

The treatments were as follows:

1. Land Preparation
   - Slash-burn only and Plough only
2. Chemical application
   - Glyphosate and No Glyphosate
3. Cover crop
   - *Mucuna pruriens* and No *Mucuna pruriens*

Glyphosate was applied 2-3 weeks after land preparation and mucuna was planted on August 8 and April 28 for 1996 and 1997 respectively.

The following data were collected for both experiments (3.2.2 and 3.2.3):

- Visual estimation of speargrass control (scored as percentage where 100 % was complete speargrass cover and 0 % no speargrass coverage)
- Weed stand count by species (density)
- Speargrass shoot and rhizome biomass
- Photosynthetic active radiation (PAR) Interception
- *Mucuna* and *Canavalia* seed yield were also collected.

Data on speargrass and other weeds were collected at monthly intervals with quadrat sizes of 1x1m thrown randomly three times in a plot. Weeds were counted by species in the quadrat to measure density. At each sampling time, the weed shoots were sorted out by species within quadrat on the field, cut at ground level and subsequently oven dried at 60^0C for 72 –96 hrs to a constant weight in the laboratory to obtain weed biomass. A bucket augur was used to sample soil for rhizome biomass at the end of each year. Rhizomes were sampled to a depth of 30 cm in 15-cm layers. The samples from each plot were bulked and bagged separately on the field. To recover the rhizomes 350 cm^3 of the soil was washed under running water using a very fine sieve of mesh size 5 mm and the rhizomes oven dried at 60^0C for 48 h and weighed. Light interception by the plants was measured with the sunfleck ceptometer (1989, Deagon Devices Inc.) at 8, 16 and 20 weeks after planting.

3.2.4 Growth and Yield of Maize following Two Years Legume Fallow

After two years of cover cropping, the fields were cleared, soil samples taken for determination of soil nutrients and then planted to maize varieties Dorke and Obatanpa on July 25 at Mampong and May 29 (1998) at Wenchi. Plant spacing was 80 x 50 cm. A blanket application of Phosphorous (P) and Potassium (K) were applied to all plants at 60 kg/ha as single super phosphate (SSP) and muriate of potash respectively. Nitrogen was not applied to the maize. Weeding was as and when necessary. Data on maize establishment, plant height, percent maize tassel by 8 WAP, and maize plant population at harvest were collected. Weed data were on speargrass density and shoot biomass and other weed biomass. Grain yield and moisture were recorded at harvest. The grain yield was converted at 13.5% moisture. The study at Wenchi was destroyed by cattle thus no yield data were recorded.

Economic Analysis of Maize Grain Yield

The partial budget analysis method by CIMMYT (1988) was used to determine the net returns of the treatments employed to manage speargrass. The marginal rate of return (MRR) was used to calculate the returns to investment. All costs were obtained at farm gate or the local market. The components used for the analysis are presented below:

i) Average yield (kg/ha) from natural fallow, *Stylosanthes* and *Mucuna* treated plots

ii) Adjusted yield (average yield reduced by 10 %)

iii) Gross field benefits: price/100kg x adjusted yield

iv) Total costs that vary (TCV) included:

- Costs of legume cover seed
- Cost of planting the various legume covers
- Cost of weeding after planting maize

v) Net benefits (Gross benefits – TCV)

vi) Net benefit curve: Each of the treatments was plotted according to the net benefit and TCV.

vii) The MRR was calculated by the following formula:

$$MRR = \frac{\text{Net benefit (a) - Net benefit (b)}}{\text{TCV (a) - TCV (b)}} \times 100$$

Since, the statistical analysis was significant for maize grain yield from the main effect of cover crop, maize grain yield used for the assessment was from those plots. It was also assumed that farmers borrowed from the informal market at 50 %.

3.2.5. Residual Effect of Preceeding Land Preparation, Chemical Application and Cover Crop on Speargrass and Yam growth

Yam was planted on April 28, 1998 at Mampong and April 30, 1998 at Wenchi two years after Experiment 3.2.3. Soil samples were taken for the determination of soil nutrients before planting yam. The Denta variety of White yam was planted on mounds at inter and intra row spacing of 1 m. Weeding was as and when necessary.

The field was also scouted for diseases and *Mucuna*, yam (*Dioscorea spp*) or siam weed (*Chromolaena odorata)* leaves with disease symptoms were picked and sent to the laboratory for analysis. Pieces of *Mucuna* and leaf tissues taken from leaf areas with lesions were separately surface sterilized in sodium hypochlorite solution (5 %), dried and plated on moistened filter paper in a petri dish. Tissues were incubated at 28 ^{0}C under a twelve hour UV light regime. After 4 days, filter papers with growths were examined under a stereomicroscope and the pigmentation and spore characteristics were used to identify the fungal isolates.

Data on yam establishment, number of tubers harvested, tubers with holes, tubers with rhizomes and tuber yield at harvest were collected. Frequency and time of weeding, density and biomass of speargrass and other weeds were also recorded.

Field Data Analysis

Statistical analysis was carried out with the Statistical Analysis System (SAS, version 8, 1999) using the Mixed procedure. Data were subjected to the analysis of variance (ANOVA) and correlation analysis and means separated at $p<0.05$. The data were not pooled over years or site because land preparation method differed in the second year and also the initial speargrass population at Mampong was different from Wenchi. Besides, Wenchi and Mampong are in two different ecological zones.

3.3 SCREEN HOUSE STUDIES AND LABORATORY ANALYSIS

3.3.1 Preceeding Land Preparation, Chemical Application and Legume Cover on Speargrass Rhizome Viability

A screen house study on speargrass rhizome viability for both experiments was initiated in 1999 at the Crops Research Institute in Fumesua. A bucket augur was used to sample soil to a depth of 30 cm in 15-cm layers after the two years cover cropping. The samples were bagged separately on the field and taken to the station where the soil was divided into two parts of 350 cm^3 each for the rhizome viability test and soil nutrient analysis. The same procedure used for recovering speargrass rhizomes outlined above was used. Rhizomes were cut into segments of two buds and planted by hand in plastic cups filled with sandy loam soil with drainage holes at the bottom. Each pot had 5 segments planted to a depth of 2-5 cm. and rhizomes were covered with about 2.5 cm of sandy loam soil. All pots were watered as needed to maintain moisture level at or near field capacity. The study was run for three months. Percent sprouting and shoot height data were recorded. Percent emergence was calculated based on number of emergent shoots over the total rhizomes in a cup.

3.3.2 Effect of Legume Cover on Soil Fertility Improvement

At the initiation of the studies, soils from the selected sites were sampled with a bucket augur and examined for its nutrient status and described from pits following soil survey staff (1993) procedures at depths of 0-10, 10-28, 28-46, 46-68, 68-91 and 91-117 cm. The pH was measured on both 1:1 (by weight) soil/water and a 1:2.5 KCL suspension (Jackson, 1958). The Walkley-Black procedure (Jackson 1958) was used for organic C. Exchangeable cations were extracted using 1 M NH_4OAc (Jackson, 1958) while the elements were determined using a Thermal Jarrel-Ash Model 9000 ICP spectrophotometer (Jarrel-Ash, Boston, Ma). Particle size analysis was determined using the hydrometer method (Day, 1965) for silt and clay. Sands and gravel were determined gravimetrically after dry sieving. Mineralogy of the clay fraction was determined using a GE X-ray diffractometer (General Electric Corp.). The Mehlich 3 method of extraction was used for determining available nutrients.

The soils at both sites were sampled again after two years of cover cropping for its nutrient with a bucket auger in October 1998. Three cores were dug per plot per replication after which similar treatments from our replications were bulked for analysis. Soil pH was determined in a 1:1 suspension of soil and water using a pH meter (Jackson, 1969). Organic carbon was determined by the modified Walkley and Black procedure as described by Nelson and Sommers (1982). Total nitrogen (N) was determined by the Kjeldahl digestion and distillation procedure as described in Soil Laboratory Staff (1984). Exchangeable cations (calcium, magnesium, potassium) in the soil were determined in normal ammonium acetate extract (Black, 1965). Bray's No1 Phosphorus method was used to extract available phosphorus. The readily acid – soluble forms of P were extracted by an HCl/NH_4F mixture. Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent.

CHAPTER FOUR

RESULTS

4.1. FARMER PRACTICES, PERCEPTION AND THE INCIDENCE OF SPEARGRASS IN THE FOREST AND FOREST-SAVANNA TRANSITION ZONES

Farmer and Cropping Characteristics

The characteristics of farmers who were interviewed in 1996 and 2000 and the cropping characteristics are summarized in Tables 4.1.1 and 4.1.2. The sample consisted of 77 % males and 23 % females (Table 4.1.1). Fifty two percent of the farmers were aged between 41 and 60 years but the age ranged from 20 to over 60 years. The mean farm size across ecological zones was 1.2 ha with 83 % of the farmers having farm sizes of up to 2 ha. Farmers however, practised crop rotation on the same field. Mixed cropping was observed on 74 % of the fields and monocropping on 24 % (Table 4.1.1). Yam and cassava based systems dominated the intercropped fields, with yam/maize/cassava alone accounting for 24.4 % of the fields and Yam/Maize/Cassava/Vegetable/Cowpea on 16.7 % of all fields (Fig. 4.1.1). Groundnut or cowpea was almost always grown in association with maize, millet, yam or cassava. Maize or vegetable as a monocrop was observed in Wenchi, Ejura and Sekyere West districts while yam/maize/cassava mixtures were practised in all districts with the highest incidence at Sekyere West (Table 4.1.2). Across ecological zones 54 % of the fields had been in fallow for at most five years, while 68 % had been continuously cropped for three years or more (Table 4.1.3). The mean cropping intensity factor (CIF) was 48.9% (Table 4.1.4). The most intensively cropped district (CIF = 67.4 %) was Techiman followed by Wenchi.

Table 4.1.1 Farmer Characteristics

Characteristic	Description	% of Farmers across ecological zone
Sex	Male	77.1
	Female	22.9
Age (Years)	20 - 40	33.3
	41- 60	51.9
	>60	14.8
Farm size (ha)	<0.4	2.4
	0.41- 0.8	19.7
	0.81 - 1.2	22.4
	1.5 - 2	18.4
	>2	17.1
Cropping system	Monocropped	26.3
	Mixcropped	73.7

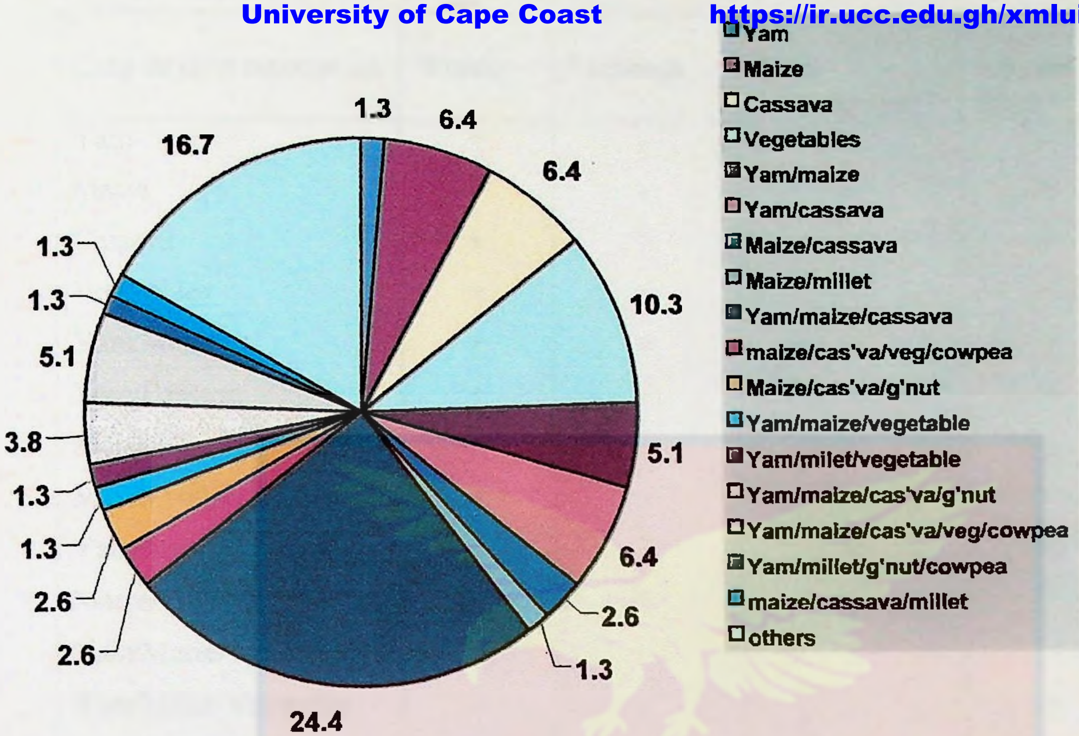


Figure 4.4.1. Frequency of crops and crop associations in the forest and forest-savanna-transition ecological zones

Table 4.1.2. Crop and Crop Associations on Speargrass Infested fields

Crop or crop association	Wenchi	Techiman	Ejura Sekyedumase	Sekyere West
Yam	+	-	-	-
Maize	+	-	+	+
Cassava	+	-	+	-
Vegetables	+	-	+	+
Yam/Maize	+	+	-	+
Yam/Cassava	+	-	+	+
Maize/Cassava	+	-	+	-
Maize/Millet	-	-	-	+
Yam/Maize/Cassava	+	+	+	+
Maize/Cassava/G'nut*	-	+	+	-
Yam/Maize/Vegetable	-	-	-	+
Yam/Millet/Vegetable	-	-	-	+
Maize/Cassava/Millet	+	-	-	-
Yam/Maize/Cassava /G'nut	-	-	+	+
Maize/Cassava/Cowpea/ Veg**	-	+	+	-
Yam/Millet/Cowpea /G'nut	-	-	-	+
Yam/Maize/Cassava/ Cowpea/Veg	+	-	+	-
Other	+	-	+	+

*=Groundnut; **= Vegetable

Table 4.1.3. Cropping Characteristics

Characteristic	Mean (Year)	Description (Year)	% Fields across ecological zone
Fallow	4.7	1	5.4
		2	8.1
		3	16.2
		4	10.8
		5	13.5
		6 - 10	31.1
		> 10	14.9
Length of cropping	4.5	From fallow	4.5
		1	13.4
		2	13.4
		3	25.4
		4	11.9
		5	9.0
		6 - 10	19.4
		> 10	3.0

Table 4.1.4. Mean Fallow years and Cropping Intensity for the Selected Districts

District	Fallow length	Cropping length	Cropping Intensity (%)
	---------------- Years	------------------	
Wenchi	3.88 ± 0.35	4.25 ± 0.46	52.30
Techiman	3.20 ± 0.86	6.60 ± 1.47	67.35
Ejura-Sekyedumase	5.33 ± 0.35	4.10 ± 0.65	43.50
Sekyere West	5.52 ± 0.30	4.90 ± 0.61	47.02
Across Region	4.72 ± 0.21	4.52 ± 0.32	48.92

Speargrass Duration, Distribution and Degree of Infestation

The common names for speargrass and their meanings are presented in Table 4.1.5. The weed has several local names but "eto" or "seregogoro" is the most common because it is the language of the dominant tribe (Twi) in the surveyed area and these names show how it is perceived. Forty percent of the farmers reported the presence of speargrass from 20 to over 60 years and 21 % for ≤ 10 years (Table 4.1. 6). The duration of speargrass as presented indicates that the weed had been at the forest –savanna-transition zone for a longer period than the Forest.

The degree of infestation and its relationship with cultural practices is shown in Table 4.1.7 and Figure 4.1.3. Speargrass was present in 94% of the fields with higher incidence (86%) on the fields that were burnt at time of land preparation (Table 4.1.7). Across zones, 60% of fields had heavy infestations (> 50%) and 39% showed infestations below 50%. Densities ranged from 20 – 100 plt/m^2 with a mean of 33 plt/m^2 and shoot heights of 15-300 cm. At Techiman 83 % of fields had speargrass infestation of >80 % compared to about 30 % in the other districts (Fig. 4.1.2). Generally, the severity of speargrass infestation increased with increasing crop length with low incidence (12 %) on fields cropped from fallow (Fig. 4.1.3). The incidence was high (80 %) on the fields that had been cropped for over 4 years with heavy infestations of > 50 %.

The weed was found on farmlands, marginal lands, along highways, roads, footpaths, backyards, disturbed fields, wetlands and was observed to thrive on all kinds of soils whether well or poorly drained.

Table 4.1.5. Local names of *Imperata cylindrica* with some meanings in Forest/Forest-Savanna-Transition zones of Ghana

Name	Language	Meaning
Eto	Twi	you will meet me
Seregogoro	Twi	pierces like needle
Tomini/Tome		
Moprouma	Frafra	pierces
Tofa	Sissala	
Srelale	Wangara	
Poloi	Dagare	

Table 4.1.6. Farmer Perception of Duration of Speargrass by District

District	------ Farmers' perception of speargrass duration ------				
	0 -10 yr	11- 20 yr	21- 40 yr	Over 40 yr	Can't tell
Wenchi	27.3	15.2	6.1	51.5	3.0
Techiman	0.0	0.0	0.0	100.0	0.0
Nkoranza	0.0	0.0	0.0	100.0	0.0
Ejura-Sekyedumase	12.5	37.5	18.8	25.0	6.3
Sekyere-West	24.0	32.0	24.0	16.0	4.0
Mean	21.0	23.5	13.6	39.5	2.5

Table 4.1.7. Speargrass Distribution and its relation to cultural practices

Speargrass	Description	--% Fields across ecological zone --		
			Burn	No Burning
Present	Yes	94.0	85.9	14.1
	No	6.0	100.0	0.0
			Mean density	Height
Density	20 plt/m^2	56.7		
	21–40 plt/m^2	26.7	33 plt/m2	15 – 300 cm
	41–100 plt/m^2	10.0		
	100 plt/m^2	6.7		
Infestation	≤ 50 %	39.1		
	51 – 80 %	30.1		
	>80 %	30.1		

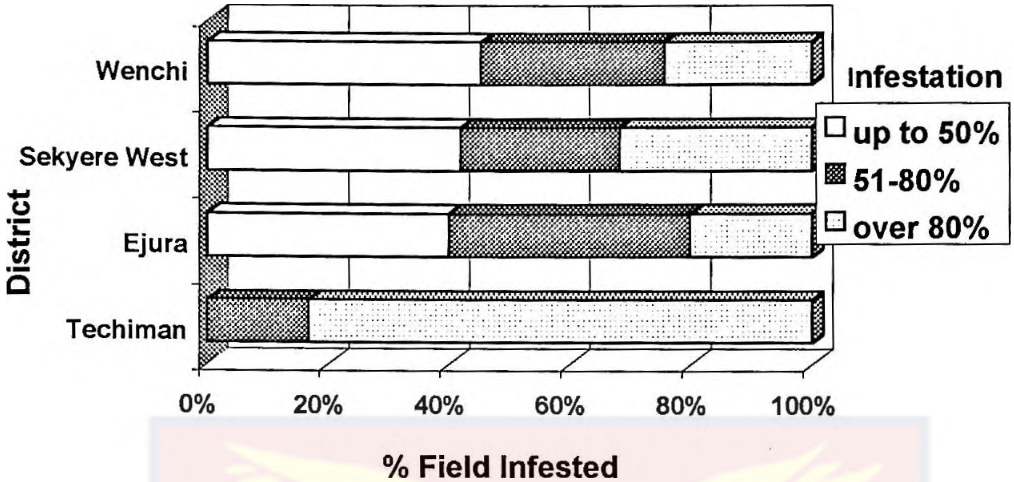


Figure 4.1.2 Percent speargrass infestation by district

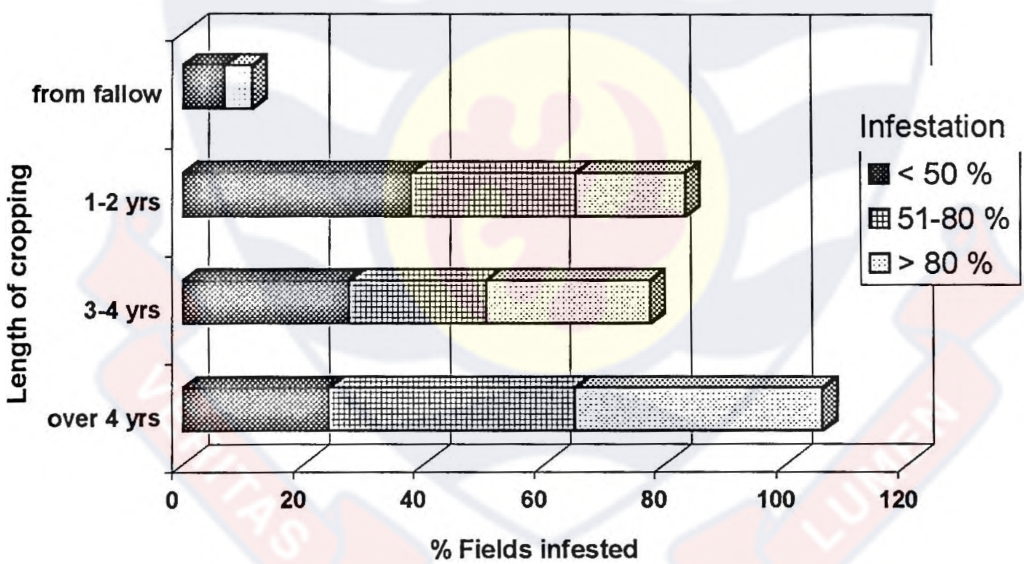


Figure 4.1.3 Relationship between cropping length and speargrass infestation

Farmer Perception of Speargrass and Other Weeds

Speargrass was ranked as the most noxious among other weeds by 80 % of the farmers and not noxious by 1% across the ecological zones (Table 4.1.8). However, all females perceived the weed as noxious. All the farmers at Techiman ranked it as the most noxious weed. From Wenchi district 27 % of farmers perceived it as a worse weed compared to 8 or 14 % from Ejura Sekyedumase and Sekyere West districts. It is notable that it was only at Sekyere West that 5 % of the farmers ranked speargrass as not important. In this district, *Euphorbia heterophylla*, *Panicum maximum* and *Cyperus rotundus* were ranked as important weeds. The reasons assigned for the ranking are listed below:

- Difficult to control manually and labour is expensive
- Its deleterious effect on crops through competition for nutrients
- Sharp growing tip of the rhizome pierces crops (groundnut, yam, cassava) affecting quality of product
- Sharp point of the emerging shoots from the rhizomes pierce their feet
- Dominance over other weeds and crops so they do not grow well
- Adaptation to all types of soil
- Presence results in reduction of cultivable land
- Rough edges of shoot can cause abrasions on human and animal skin
- Shoots dry up fast which constitute fire hazard in the dry season
- Permanent reaction to human skin on contact in certain cases

Other weeds also present were *Chromolaena odorata*, *Spigelia anthelmia*, *Ageratum conyzoides*, *Centrosema pubescens*, *Commelina spp*, *Rottboellia cochinchinensis*, *Digitaria spp* and *Chrysopogon aciculatus*. *C. rotundus* (nut sedge) was the second worst weed followed by *E. heterophylla*. *C. pubescens* known as 'bankye wire' (cassava wire) in the Akan language was also considered a troublesome weed.

Sixty-eight percent of the farmers mentioned that speargrass first became a problem after three years cropping from fallow, 22.2 % said after 4 years and 11.1 % could not tell when. In the Ejura-Sekyedumase district, 63 % of farmers reported that speargrass became a problem after continuously cropping a piece of land for three years. The figures for the other districts were 61 % for Wenchi and 84 % for Sekyere West districts This was however, dependent on the length of fallow period and also previous history of the field as the field could be infested even after a year's cropping. Even though, speargrass has a deleterious effect on crops and humans 87.8 % of the farmers reported it as a readily available source of roofing material, 8.7 % for medicinal use and 2.4 % for livestock feeding. Ironically, most of those who acclaimed the benefits of speargrass ranked it as the most noxious weed. Farmers mentioned though that there are other plant sources of roofing materials.

Table 4.1.8. Farmers' Ranking of Speargrass among Other Weeds

Character	% Farmers			
	Worst weed	Worse weed	Bad weed	Not important
<u>Sex</u>				
Male	81.3	15.6	1.6	1.6
Female	78.9	15.8	5.3	0.0
<u>District</u>				
Wenchi	69.7	27.3	3.0	0.0
Techiman	100.0	0.0	0.0	0.0
Ejura-Sekyedumase	93.8	6.3	0.0	0.0
Sekyere West	80.0	12.0	4.0	4.0
Mean	80.2	16.0	2.5	1.2

Table 4.1.9. Farmers Perception of Time Speargrass Become a Problem after Cropping from Fallow on District Level

District	% Farmers		
	First 3 years	After 4 years	Can't tell
Wenchi	60.6	24.2	15.2
Techiman	42.9	42.9	14.3
Ejura-Sekyedumase	62.5	31.3	6.3
Sekyere West	84.0	8.0	8.0
Mean	66.7	22.2	11.1

Land Preparation and Weed Control

Most of the farmers (86.7 %) slash-burn at land preparation. Out of those who burn, 76.9% follow it up with the hoe, 16.9 % use herbicide (glyphosate) while 6.2 % plough with the tractor. For those who did not burn at land preparation, 70 % used the hoe, 10 % applied herbicide and 20 % used the tractor to plough (Table 4.1.11). Herbicides were mainly used at Ejura Sekyedumase and Sekyere West districts. Of those who use herbicide (glyphosate), 85.7 % do so on fields with > 50 % speargrass infestation.

Follow-up weed control is mostly with the hoe or cutlass and farmers could weed as many as 3-6 times per season depending on type of crop and level of infestation. Most farmers (63 %) usually do the first follow-up at 3 or 4 weeks after planting (WAP) depending on the crop with only 3.8 % weeding at 6 weeks (Tab. 4.1.12). According to the farmers, it takes about 8-10 man days to weed an acre of infested field. For speargrass infested field, the cost of weeding per acre could range from ¢60,000.00 to ¢120,000.00 compared to ¢50,000.00 to ¢75,000.00 per acre on non-infested field.

All farmers who planted sole yam first weeded at 3 WAP, while follow-up weeding on farms with only maize or cassava was at 3 or 4 and 2 or 3 WAP respectively (Table 4.1.13). For Yam/maize/cassava associations most farmers tended to weed between 2 through 4 WAP compared to 4 weeks for millet-based associations. Under severe speargrass infestation almost all the farmers abandon fields to natural fallow while 13 % use glyphosate because they could not afford to fallow the fields and these are those who rotated their crops. None of the farmers mentioned the use of cover crop fallow for reclaiming fields abandoned to speargrass in the survey areas. The abandoned fields are however returned to cropping when there is a dense growth of *C. odorata*, which is used as an indicator of a matured field, freed from speargrass infestation.

Table 4.1.10. Land Preparation Methods used by Farmers

Characteristics	Description	---% of Farmers across ecological zone ---			
			Hoeing	Herbicide	Plough
Burn at Land preparation	Yes	86.7	76.9	16.9	6.2
	No	13.3	70.0	10.0	20.0
Herbicide (Glyphosate) use	≤ 50 %	14.3			
	51-80 %	50.0			
	> 80 %	35.7			

Table 4.1.11 Level of Speargrass Control as perceived by Farmers and Time of Follow-up Weeding

Characteristics	Description	----% of Farmers across ecological zone ---		
			Herbicide	Non-Herbicide
Level of control	Excellent	7.2	6.7	4.9
	Adequate	39.8	53.3	35.8
	Inadequate	48.2	26.7	53.7
	Very poor	2.4	6.7	1.5
	Can't tell	2.4	6.7	1.5
Time of weeding	≤ 2 weeks	21.7		
	3 weeks	32.5		
	4 weeks	31.3		
	3-4 weeks	1.2		
	> 6 weeks	3.6		
	Can't tell	9.6		

Table 4.1.10 Influence of Crop Associations on Follow-up Weeding

Cropping system	---------------Time of Follow-up Weeding--------------					
	2 wk	3 wk	4 wk	3-4 wk	6 wk	Can't tell
Yam	0	100	0	0	0	0
Maize	20	40	40	0	0	0
Cassava	20	20	20	0	20	0
Vegetables	25	25	0	0	0	50
Yam/Maize	25	50	25	0	0	0
Yam/Cassava	20	20	60	0	0	0
Maize/Cassava	0	0	100	0	0	0
Maize/Millet	0	0	100	0	0	0
Yam/Maize/Cassava	30	21.1	36.8	0	5.3	5.3
Maize/Cassava/G'nut*	50	0	0	0	0	0
Yam/maize/Vegetable	0	100	0	0	0	0
Yam/Millet/Vegetable	0	0	100	0	0	0
Maize/Cassava/Millet	0	100	0	0	0	0
Yam/Millet/G'nut/beans	0	0	100	0	0	0
Maize/Cassava/Veg** /cowpea	0	50	50	0	0	0
Yam/Maize/Cassava /G,nut	33.3	33.3	33.3	0	0	0
Yam/Maize/Cassava/ Veg/beans	0	75	0	25	0	0
Other Combination	15.4	30.8	30.8	0	7.7	15.4
Mean	20.5	30.8	32.1	1.3	3.8	9.0

Yield Reduction Attributable to Speargrass

Farmers perceived that crop yield could be reduced from >80 % to < 30 % when speargrass is not controlled on time or appropriately. Forty-six percent of the farmers reported losses of greater than 80 %, 43 % reported losses of 31 to 80 % and 11 % for losses of less than 30 %. For yam or yam based systems yield losses due to late weeding of speargrass could range from 31 to over 80%, maize or its associations 51-80 % and cassava based systems < 30 % to 98 % (Tab.

4.1.14). Most of the respondents however had observed that very good crop yields are realized on relatively fertile speargrass infested fields if there is good and timely control. They believed the rhizomes improve water infiltration to the soil by opening up the pores due to its piercing nature.

Table 4.1.13. Farmers' Perception of Crop Yield Loss due to Speargrass

Cropping system	% Farmers' Assessment of Yield Loss			
	< 30%	31-50%	51-80%	> 80%
Yam				7.7
Cassava	33.3	16.7		15.4
Vegetables		16.7	16.7	
Yam/Maize				7.7
Yam/cassava		33.3	16.7	7.7
Maize/Millet				7.7
Yam/Maize/Cassava	66.7		16.7	23.1
Maize/Cassava/Groundnut			16.7	
Yam/Maize/Vegetable				7.7
Yam/Millet/Vegetable		16.7		
Maize/Cassava/Vegetable/Cowpea				7.7
Yam/Maize/ vegetable/cowpea			16.7	15.4
Yam/Maize/cassava/Groundnut		16.7		
Yam/Millet/Groundnut/Cowpea			16.7	

4.2. EFFECT OF LAND PREPARATION METHODS AND COVER CROP ON *Imperata cylindrica* (SPEARGRASS) REGROWTH

Speargrass Shoot Density

Speargrass shoot density was influenced by land preparation method up to 8 weeks after planting (WAP) in 1996 at Wenchi. Speargrass shoot regrowth was faster when the field was burnt than when ploughed or slash-mulched. Ploughing and slashing as land preparation methods effectively reduced speargrass shoot density by 33 % compared to burning (Table 4.2.1) but ploughing was similar to slashing.

At Mampong, land preparation method significantly reduced percent spear grass infestation and shoot density at 4 weeks. Visual estimation of infestation indicated a significant 66 % reduction by ploughing compared to slash-burning or slashing alone (Table 4.2.2). Shoot density was reduced by 53 and 37 % when ploughed or slashed respectively, relative to the slash-burned. At 8 WAP, it was the interaction of land preparation method and cover crop that rather influenced the density of spear grass (Fig. 4.2.1). The slashed or ploughed plots with or without legume fallow significantly reduced speargrass shoot density by 44 – 47 % over the burn-natural fallow (no cover crop). Similarly, a significantly low density range of 28 – 34 plt/m^2 was recorded on the plough-legume fallow plots compared to 64 - 70 plt/m^2 on the burn – legume combinations. Within the ploughed block, *Stylosanthes* or *Mucuna* fallow was more effective in reducing shoot density than the natural fallow while similar densities were recorded among the plough-*Canavalia*, plough-natural fallow and slash with or without any of the legume fallows. Ploughing followed by *Mucuna* fallow reduced speargrass density better than slashing followed by stylosanthes or natural fallow. The density of speargrass on the plough-*Canavalia* treatment (33.8 plt/m^2) was lower relative to slashing with *Stylosanthes* or natural fallow (63.8 and 68.3 plt/m^2). Land preparation or legume cover did not affect speargrass shoot density in 1997 at both sites.

Table 4.2.1. Effect of land preparation methods on speargrass density and dry weight 8 WAP. Wenchi – 1996

Land Preparation	Density plt/m^2	Dry weight g/m^2
Burn	6.28	24.7
Plough	4.19	12.1
Slash	4.92	20.3
SE (p=0.05)	0.76	3.6

Table 4.2.2. Effect of land preparation methods on speargrass infestation and shoot density, 4WAP. Mampong – 1996

Land	% Infestation	Density (plt/m^2)
Burn	90.3	94.7
Plough	66.0	44.3
Slash	72.8	60.0
SE (p=0.05)	3.4	10.0

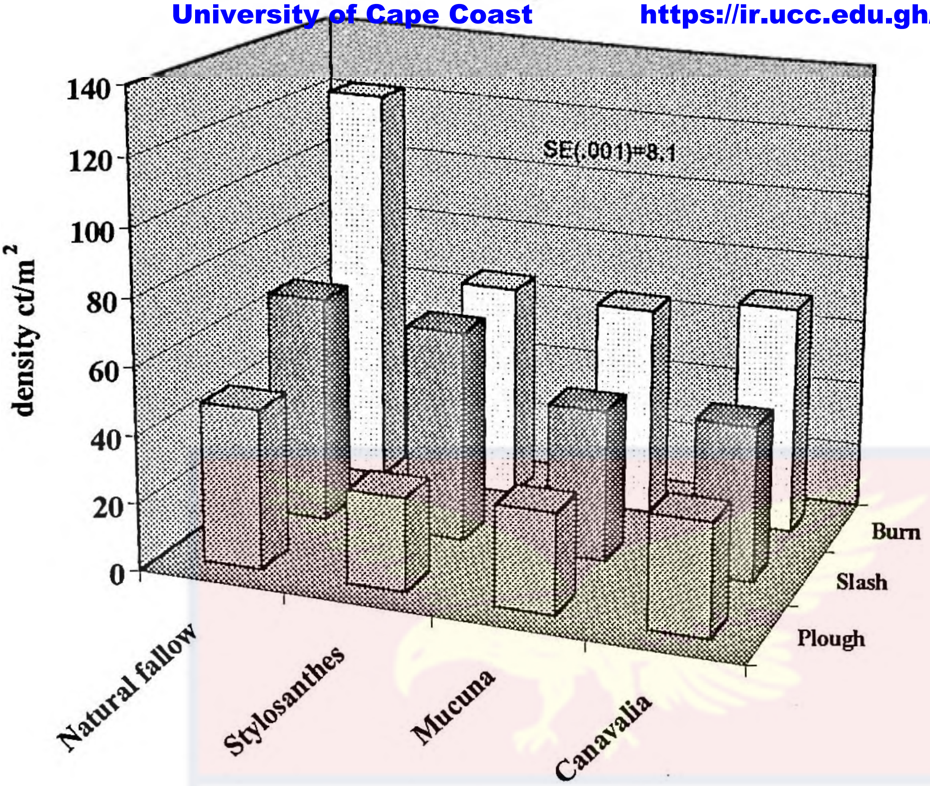


Fig. 4.2.1 Land preparation method and cover crop on spear grass shoot density 8 WAP, Mampong- 1996

Speargrass Shoot Dry Weight

At Wenchi, ploughing reduced shoot dry weight of speargrass by 51 and 41 % compared to burning or slashing respectively at 8 WAP in 1996 (Table 4.2.1). However, by 16 weeks, *Mucuna* as a cover effectively reduced speargrass shoot dry weight by 47 %, relative to those under natural fallow (Table 4.2.4).

Speargrass shoot dry weight at Mampong was affected by land preparation method from 4 through 16 WAP (Table 4.2.3). At 4 WAP, ploughing or slashing had reduced shoot dry weight of speargrass 39 and 31 % respectively over burning but by 8 weeks the effect of either method of land preparation on shoot dry weight had become similar while at 16 weeks, ploughing was over 40 % superior to burning or slashing. The type of cover crop also influenced spear grass shoot dry weight from 8 through 32 WAP, with *Mucuna* being the most effective in weed suppression (Tab.4.2.5). At 8 weeks, shoot dry weight was 129.2 g/m^2 on *Mucuna*, 143.8 g/m^2 on *Stylosanthes* and 208.3 g/m^2 on *Canavalia* treatments and 249.3 g/m^2 under natural fallow. *Stylosanthes* or *Mucuna* was more effective in smothering speargrass shoot regrowth than *Canavalia*. By 16 weeks, shoot dry weight had reduced by 64 % under natural fallow, 62 % on the *Canavalia* cover, 55 % under *Stylosanthes* and 47 % under *Mucuna* cover. However, the three leguminous cover crops were significantly better on dry weight basis than the natural fallow through 32 weeks. Among the three legume cover crops, *Mucuna* was very effective in reducing spear grass shoot dry weight. The effect of legume cover on weed suppression is presented as Appendix 4.

In 1997 at Wenchi, the trend in shoot weight reduction was similar to that observed in 1996. The legume cover crops significantly reduced weight from 8 through 44 weeks (Fig. 4.2.2) compared to the natural fallow. Both *Mucuna* and *Stylosanthes* significantly reduced shoot dry weight of speargrass but the difference between them was not significant.

At Mampong, the effect of initial land preparation method on speargrass growth was evident in the first four weeks. The ploughed or slash-burned plots reduced speargrass shoot dry weight by 30 % over the slashed plots (Table 4.2.3). *Mucuna* and *Stylosanthes* significantly reduced spear grass shoot weight from 8 through 44 weeks (Fig. 4.2.3) compared to the natural fallow. The trend was similar to the 1996 observation. *Stylosanthes* consistently had the least shoot dry weight (40 to 72 g/m^2) throughout the period of observation. *Stylosanthes* was superior to mucuna in suppressing speargrass from 8 – 16 weeks, but by 32 weeks the *Mucuna* had suppressed speargrass to the same level as *Stylosanthes*. It is worth noting that, beyond 32 weeks there was an increase in shoot dry weight for all cover. However, there was a distinct change in performance between the two legume cover crops with *Stylosanthes* being significantly more effective in suppressing speargrass regrowth. While the percentage increase in speargrass shoot dry weight from 32 wk to 44 wk by *Stylosanthes* was 45 %, *Mucuna* increased it by 268 %. Cover crop negatively correlated with speargrass shoot dry weight at p=0.0001 and r = -0.60 to -0.83 throughout the period of observation.

Photosynthetic Active Radiation (PAR) Interception

At Wenchi, the amount of PAR intercepted by the legume and natural fallow was about the same at 8 weeks in 1996. However, by 16 weeks *Mucuna* and *Canavalia* had significantly intercepted 78 and 74 % respectively of the PAR compared to 63 % by the natural fallow and 62 % by *Stylosanthes* (Table 4.2.4). In 1997, the PAR intercepted by *Stylosanthes* or *Mucuna* was similar (> 90 %) but significantly greater r than the amount intercepted by the natural fallow (82 %) at 20 WAP.

Light interception by *Stylosanthes* at Mampong for 1996 was a low 44 % compared to 74 and 65 % by *Mucuna* or *Canavalia* while in 1997, *Stylosanthes* intercepted 98 % and *Mucuna* 97 % of the PAR compared to 91 % by the natural fallow.

Other Weed Growth

There was also > 40 % reduction in shoot dry weight of other grass weeds on *Stylosanthes* cover than *Mucuna* or the natural fallow at 32 weeks at Wenchi during the second year. At Mampong, by 44 weeks, there were virtually no broadleaf weeds on the natural fallow while the *Stylosanthes* or *Mucuna* treatments recorded 17.3 and 76.6 g/m^2 respectively.

Table 4.2.3. Effect of land preparation methods on speargrass shoot dry weight (g/m^2), Mampong – 1996 and 1997

	---------------- 1996	----------------------		1997
Land Preparation	4 WAP	8 WAP	16 WAP	4WAP
Burn	70.41	205.88	90.88	58.51
Plough	43.22	142.13	52.13	59.31
Slash	48.28	200.00	83.00	84.33
SE (p=0.05)	7.69	NS	9.66	7.81

Table 4.2.4. Effect of cover crops on speargrass shoot dry weight and PAR interception - Wenchi 1996

	------- weight (g/m^2) ------		--------- %PAR --------	
Cover crop	8 WAP	16 WAP	8 WAP	16 WAP
Natural fallow	22.02	52.92	50.99	62.80
Stylosanthes	21.57	38.75	41.91	61.53
Mucuna	15.21	27.91	57.88	78.45
Canavalia	17.28	40.42	55.95	74.01
SE (p=0.05)	NS	7.85	3.31	3.14

Table 4.2.5. Effect of cover crops on speargrass shoot dry weight (g/m²) Mampong -1996

	8 WAP	16 WAP	32 WAP
Natural Fallow	249.33	89.30	280.50
Stylosanthes	143.83	65.30	185.90
Mucuna	129.17	68.20	158.00
Canavalia	208.33	78.50	199.50
SE (p=0.05)	18.70	7.69	19.19

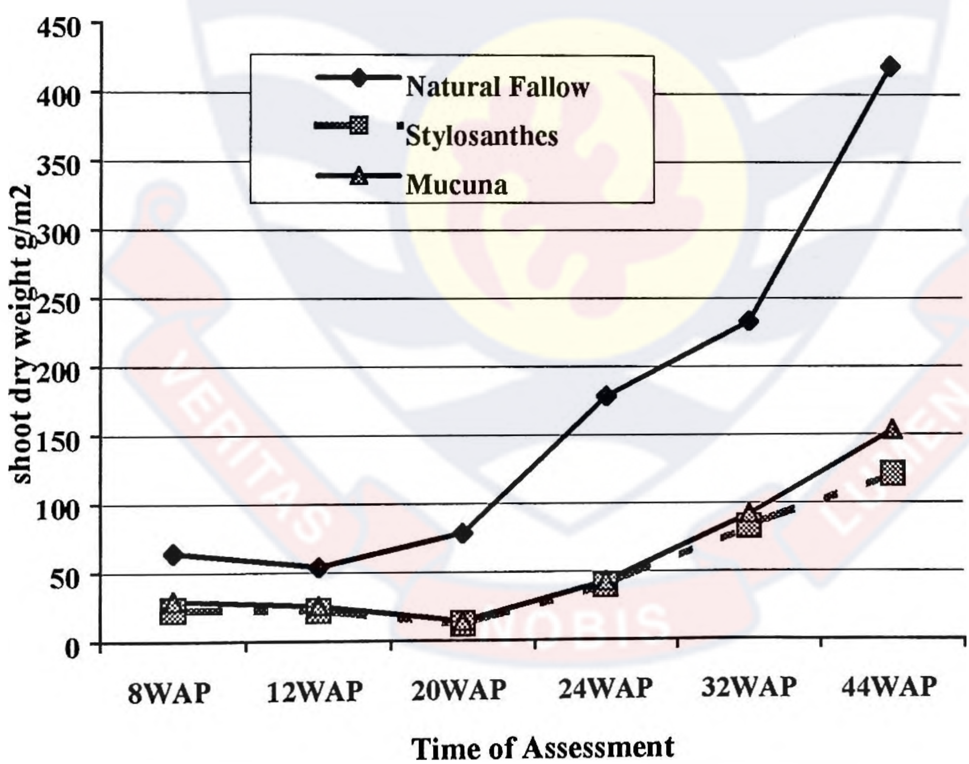


Fig. 4.2.2. Effect of 2 years Legume Cover on Speargrass Shoot Dry Weight at Wenchi

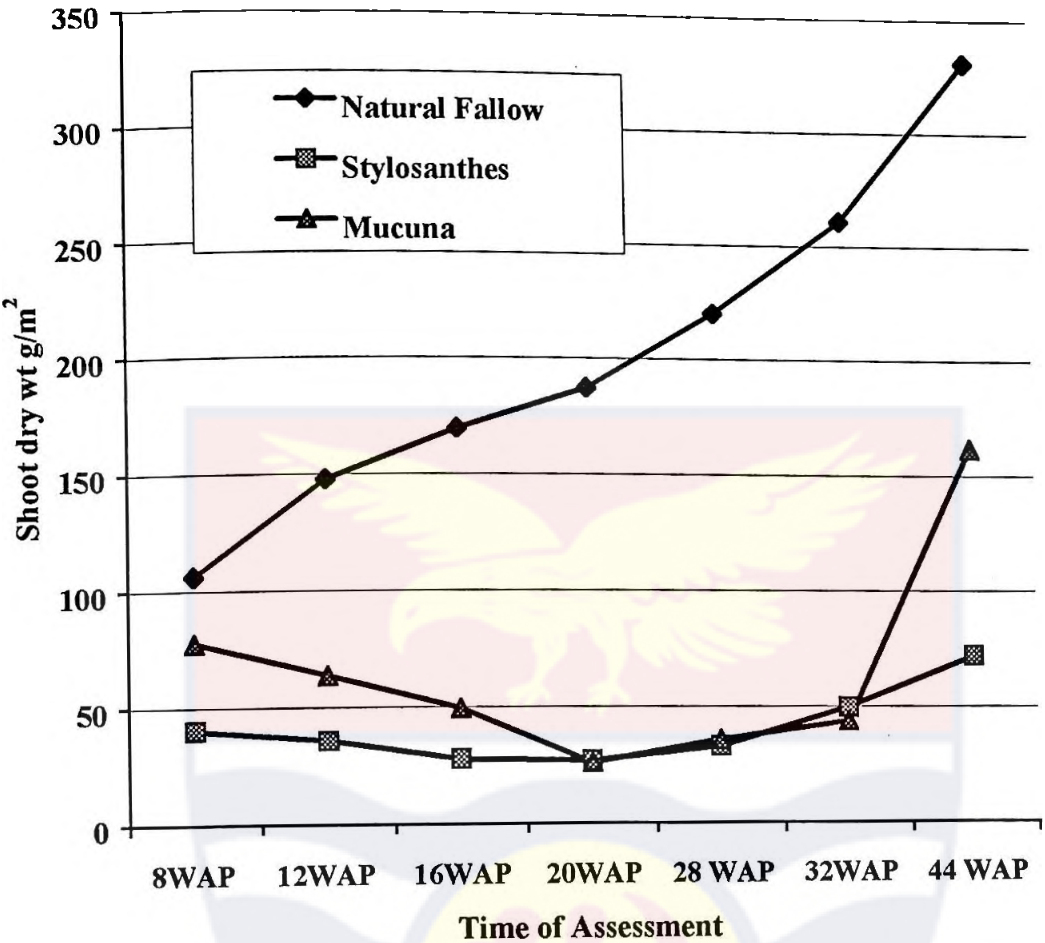


Fig. 4.2.3. Effet of 2 years Legume Cover on Speargrass Shoot Dry Weight - Mampong

Table 4.2.6 Effect of 2 years legume cover on the growth of other weeds at Wenchi – 32 WAP

	Grass	Broadleaf
	----------dry wt g/m^2-----------	
Natural Fallow	65.63	12.55
Stylosanthes	34.82	19.51
Mucuna	78.6	3.48
SE(p=0.05)	2.20	ns

Rhizome Dry Weight

The trend of speargrass rhizome dry weight is presented in Fig. 4.2.4. All the three legume covers significantly reduced rhizome dry weight by (45 - 56 %, $p > 0.05$) compared to the natural fallow at soil depth of 0-15 cm at Wenchi after the first year. After 2 years, *Mucuna* or *Stylosanthes* had reduced rhizome weight by 69 and 77 % respectively compared to the natural fallow. At Mampong, *Stylosanthes* or *Mucuna* reduced rhizome weight by 51 and 57 % over the natural fallow but 68 and 73 % in relation to *Canivalia* respectively at $p = 0.05$. Generally, there was a reduction in rhizome dry weight with increasing depth. Correlation analysis was positive ($r = 0.584$, $p = 0.0001$) between rhizome and shoot dry weights from 16 weeks with correlation coefficient decreasing with depth.

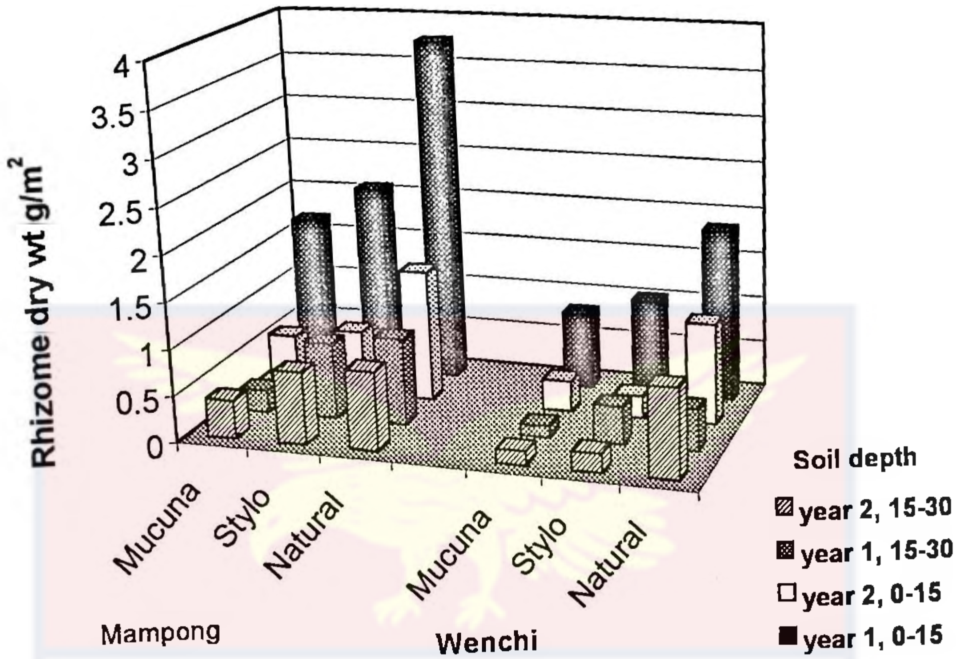


Fig. 4.2.4. Effect of 2 years Legume Cover on Speargrass Rhizome Dry Weight

4.3 IMPROVEMENT OF SOIL FERTILITY THROUGH LEGUME COVER CROPPING

4.3.1 Growth and Yield Performance of Maize Succeeding Two Year Legume Fallow

Wenchi

The residual effect of two years of cover cropping influenced the shoot density and dry weight of speargrass, maize plant height, % tassel and stalk weight 8 weeks after planting maize (Table 4.3.1). Lower densities of 3.4 and 3.5 plt/m^2 were observed in plots previously planted to *Stylosanthes* or *Mucuna* respectively compared to 5.2 plt/m^2 from the natural fallow. Similarly, *Stylosanthes* or *Mucuna* effectively reduced speargrass shoot dry weight by 43 % relative to the natural fallow. There were also 57 % more broadleaf weeds on the *Stylosanthes* treated plots than the *Mucuna* or natural fallow treatments. Very vigorous maize plants were observed on *Stylosanthes* cropped plots in terms of height (60 cm), plant tassel (24 %) and dry stalk weight (1.2 g/plt). There was a positive correlation of 0.57 ($p = 0.01$) and 0.71 ($p = 0.001$) between cover crops and maize plant height or % plant tassel respectively.

Mampong

Previous land preparation and cover crop reduced speargrass shoot dry weight, broadleaf weed dry weight and increased maize population while previous cover increased maize plant height and grain yield (Table 4.3.2). At 12 weeks, *Stylosanthes* or *Mucuna* fallow with either land preparation method were 51 – 90 % more effective in suppressing speargrass shoot regrowth than burning under natural fallow. The slash-*Stylosanthes* combination also reduced speargrass shoot dry weight by 53 % relative to burn- natural fallow. *Mucuna* whether on ploughed or burned plot suppressed speargrass shoot growth similarly, while shoot dry weight was reduced by > 80 % on the burn-legume fallows compared to the plough or slash -natural fallow combinations, or slash-*Mucuna* fallow. Broadleaf weed dry weight at 12 weeks was as low as 3.5 g/m^2 compared to 57g/m^2 on the burn-*Stylosanthes* treatment which was the heaviest. Maize population ranged from 3.6 – 5.7 plt/m^2 with the lowest on the slash-natural fallow treatment.

Maize grown on *Mucuna* fallow was 29 cm taller than that grown on *Stylosanthes* fallow and 39 cm ($p<0.05$) taller than that on natural fallow (Table 4.3.3). Maize grown on *Stylosanthes* or *Mucuna* fallow out yielded those on the natural fallow by 62 and 98 % respectively. Correlation analysis indicated a positive coefficient of 0.596 ($p = 0.001$) and 0.455 ($p = 0.001$) between cover crops and maize plant height or grain yield respectively.

Table 4.3.1. Influence of two-year cover cropping on speargrass regrowth and maize performance 8 WAP - Wenchi

Cover crop	Speargrass Density plt/m^2	Maize: Height cm	Maize: Tassel %	Maize: Stalk wt g/plt
No cover	14.2	37.3	2.8	0.8
Stylosanthes	15.3	59.8	23.7	1.2
Mucuna	14.4	50.6	5.8	0.9
SE (P =0.05)	ns	4.4***	5.8**	0.1**

ns=non significant; **, ***=significant at 0.001 and 0.0001 probability level

Table 4.3.2. Influence of previous land preparation and legume cover on speargrass shoot and broadleaf weed dry weight (g/m^2), and maize population (plt/m^2)

	Speargrass 12 WAM*	Broadleaf weed 12 WAM	Maize population 8 WAM
	------------ dry wt g/m^2	----------	plt/m^2
Burn-natural fallow	56.0	3.5	4.3
Burn-*Stylosanthes*	6.5	57.0	4.5
Burn-*Mucuna*	5.5	26.5	4.7
Plough-natural fallow	33.5	26.0	5.3
Plough-*Stylosanthes*	27.3	17.5	5.1
Plough-*Mucuna*	12.0	27.5	4.4
Slash-natural fallow	36.0	20.5	3.6
Slash-*Stylosanthes*	26.5	18.5	5.2
Slash-*Mucuna*	35.0	26.0	5.7
SE (p = 0.05)	11.3	14.8	0.5

*=weeks after maize

Table 4.3.3 Effect of 2 years preceeding legume fallow on maize height and grain yield - Mampong

Cover	Height (cm)	Yield (kg/ha)
Natural fallow	104.8	712.1
Stylosanthes	120.0 (14.5%)*	1156.5 (62.4%)
Mucuna	149.1 (42.3%)	1411.6 (98.2 %)
SE (p = 0.05)	10.5	183.9

* = % reduction

4.3.2 Soil Nutrient Analysis

Baseline analysis presented as Appendix 5, indicated that the soil at Wenchi had a considerably more organic C throughout than that at Mampong. The Mampong soil was low in available P whereas that of Wenchi was medium. Both soils were medium in available K and medium in Ca and Mg (standard from Soil Research Institute Lab. Manual, 1978). Nitrate and ammonium were not found in any soil. Available Mn was high or medium while Zn was low in both soils (Appendix 6).

Generally, organic C and available K increased while soil pH became moderately acidic at Mampong after the two-year fallow. Available P decreased at both sites, with not much improvement in organic C level and soil acidity at Wenchi (Table 4.3.4). The legume fallows increased soil OM content slightly over the natural fallow. At Mampong, organic matter content in the topsoil was moderate (> 1.5 %) but decreased with increasing depth (Appendix 7). OM content of the top and subsoils from *Stylosanthes* cover were 1.6 – 2.4 and 1.3 – 1.5 % respectively compared with 1.6 – 2.0 and 1.2 – 1.3 % for *Mucuna*. The total

N from plots under natural or leguminous fallows was medium (0.10 - 0.17 %) with *Stylosanthes* plots having a significantly higher (16.7 %) total N than the *Mucuna* or natural fallow (Table 4.3.5). The Wenchi site had a generally low available total N range of 0.04 – 0.13 % in the top 15 cm layer (Appendix 8). The organic matter content of 1.5 – 1.9 % was moderate for all type of cover (Table 4.3.5).

Available P (Table 4.3.5) was generally low for both sites <10 mg/kg, and Ca levels were almost the same at both sites under the natural fallow (2.67 and 2.99) but was higher for the *Stylosanthes* or *Mucuna* treatment at Mampong compared to Wenchi (2.93 and 3.04 vs. 1.98 and 2.59 respectively). At Mampong, levels of exchangeable K did not differ much among fallow treatments but at Wenchi the legume fallows increased the level by 56-71 % over the natural fallow. Exchangeable Ca was low at both sites. It was (2.72 – 3.36 me/100 at Mampong and 1.12 – 4.32 me/100 at Wenchi. Levels of exchangeable Mg were about the same for both sites. Topsoil acidity levels were moderate (5.6 – 6.0) with pH values decreasing with depth at both sites.

Table 4.3.4 Comparative analysis of soil nutrients before and after cover cropping at soil depth 0 – 30 cm

	Mampong		Wenchi	
	Before	After	Before	After
Organic C (%)	0.48	0.81	0.82	0.83
Available P (ppm)	3.91	1.22	14.46	2.66
Available K (ppm)	53.71	60.95	56.41	78.10
Soil pH (1:1 H_2O)	4.97	5.47	4.80	5.18
Ca (me/100g)	3.05	2.25	7.90	2.23
Mg (me/100g)	1.00	0.87	1.95	0.91

Table 4.3.5 The influence of 2 years legume cover on soil nutrients at soil depth 0-15 cm

	pH	Organic matter %	total N %	Avail P mg/kg	Avail K mg/kg	Ca me/100g
Mampong						
Natural fallow	5.9	1.80	0.12	2.08	66.17	2.99
Stylosanthes	5.8	2.96	0.14	2.58	66.83	2.93
Mucuna	5.7	1.80	0.12	2.62	67.8	3.04
Wenchi						
Natural fallow	5.2	1.7	0.093	2.87	57.1	2.67
Stylosanthes	5.2	1.5	0.083	2.8	89.3	1.97
Mucuna	5.2	1.9	0.09	1.9	91	2.19

4. 3. 3. Economic Analysis – The Partial Budget Analysis for Maize following 2 years Legume Fallow at Mampong

Table 4.3.6 shows the summation of all the costs that vary for each of the cover treatments since maize grain yield was significant for cover treatment. The least and highest variable costs of production of ¢275,000.00/ha and ¢307,500.00/ha was from the slash-*Stylosanthes* or *Mucuna* fallows respectively.

The components of the partial budget for each of the treatment which includes the average and adjusted yield, gross field benefits, total costs that vary and net benefits is presented in Table 4.3.7. The lowest net benefit of ¢237,640.00 was from the natural fallow and the highest of ¢708,820.00 was from the *Mucuna* fallow. Figure 4.3.1 shows the net benefit curves of the treatments. The marginal rate of return (MRR) of changing from natural fallow to *Stylosanthes* fallow or *Mucuna* fallow was 112.5 % and 153.2 % respectively while switching from *Stylosanthes* fallow to *Mucuna* was 50.8 %.

Table 4.3.6. Land preparation and legume fallow on speargrass control – total costs that vary (TCV)

Treatment	Seed	Seed Planting	Weeding	Cost/ha
	¢			
Natural fallow	0.00	0.00	275,000.00	275,000.00
Stylosanthes	80,000.00	62,500.00	137,500.00	280,000.00
Mucuna	120,000.00	50,000.00	137,500.00	307,500.00

Table 4.3.7 Partial Budget Components for Maize following 2-year Legume fallow – Mampong

	Natural fallow	*Stylosanthes*	*Mucuna*
Average Yield (kg/ha)	712.0	1156.5	1411.6
Adjusted Yield (kg/ha)	640.8	1040.9	1270.4
Cost/100 kg (¢)	80,000.00	80,000.00	80,000.00
Gross benefits (¢)	512,640.00	832,720.00	1,016,320.00
Total Costs that Vary (¢/ha)	275,000.00	280,000.00	307,500.00
Net benefits (¢/ha)	237,640.00	552,720.00	708,820.00

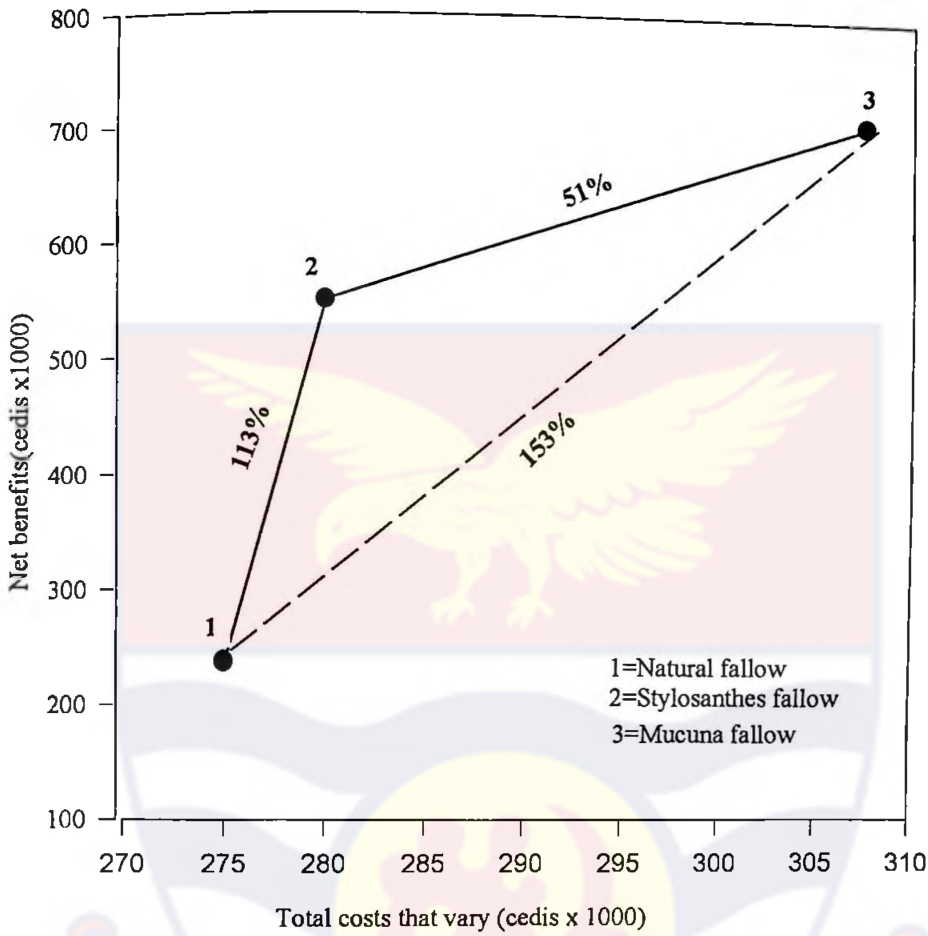


Fig. 4.3.1. Net benefit curve and MRR (%) for Maize following 2 -year legume fallow

4.4. LAND PREPARATION, CHEMICAL APPLICATION AND COVER CROPPING AND THE INCIDENCE OF SPEARGRASS

Speargrass Shoot Density

Mampong

The interaction of land preparation method and chemical application significantly decreased speargrass shoot density. By 4 WAP there was hardly any speargrass regrowth (< 1.2 plt/m^2) on plots that were either ploughed or burned and glyphosate treated while 3.84 and 6.43 plt/m^2 was recorded on the ploughed or burned non-glyphosate treatments respectively. Applying glyphosate after burning or ploughing was 81 % more effective in reducing speargrass density than burning without chemical application. The application of glyphosate on the ploughed plots significantly reduced speargrass shoot density by 68 % compared to ploughing. Also, ploughing without glyphosate treatment was 40 % more effective in reducing speargrass density than burning without chemical application.. At 8 WAP there was a significant interaction of land preparation method, chemical application and cover crop on shoot density (Table 4.4.1). Similar shoot densities of < 1.5 plt/m^2 were recorded on burn or plough-glyphosate treated plots with or without *Mucuna* cover, 5.8 plt/m^2 on the ploughed and 8.1 plt/m^2 on the burned-non glyphosate–natural fallow. Burning significantly increased speargrass shoot density by 28 % over ploughing on non glyphosate treated-natural fallow plots. Glyphosate–*Mucuna* treatment with either type of land preparation method reduced the incidence of speargrass by 50 % compared to the non glyphosate-treated plots with similar land preparation. Appendix 9 shows the visual effect of the interaction of speargrass and chemical application at 12 weeks.

For 1997, *Mucuna* reduced shoot density by 37 % (p=0.01) over natural fallow at 4 weeks while glyphosate application reduced density by 78 % (p = 0.0001) decreasing to 61 % by 8 weeks relative to non chemical application. Glyphosate treatment also reduced the density of other weeds by 42 %. The interaction of land preparation method and cover crop also influenced speargrass shoot density at 8 weeks (Fig. 4.4.2). *Mucuna* cover preceeded by ploughing or burning reduced shoot density similarly (3-4plt/m^2) and significantly lowered density (≤ 51 %) compared to either land preparation method without *Mucuna* cover.

Wenchi

The results as presented in Fig. 4.4.1 showed a significant chemical application and cover crop effect on speargrass shoot density up to 12 weeks after treatment. At 4 weeks, glyphosate-*Mucuna* combination produced the lowest density of 1.04 plt/m^2 among the four treatment combinations. By 12 weeks shoot densities were low (1.43 – 3.00 plt/m^2) and about the same among glyphosate-treated plots with or without *Mucuna* cover .or *Mucuna* cover alone. Twenty weeks after treatment application, the emergence of broadleaf weeds was influenced by the interaction of chemical application and cover crop. Percent broadleaf weed cover was high (< 39 %) for glyphosate or *Mucuna* treatment alone compared to < 8 % for glyphosate-*Mucuna* combination or the natural fallow.

Table 4.4.1. Interaction of land preparation method, chemical application and cover crop on speargrass shoot density at 8 WAT, 1996, Mampong

Land Prep.	Chemical	*Mucuna*	Natural fallow
		----------- plt/m^2 ------------	
Burn	Glyphosate	1.19	1.43
	No glyphosate	2.59	8.06
Plough	Glyphosate	1.13	1.41
	No glyphosate	2.12	5.83
SE (p = 0.05)		0.33	

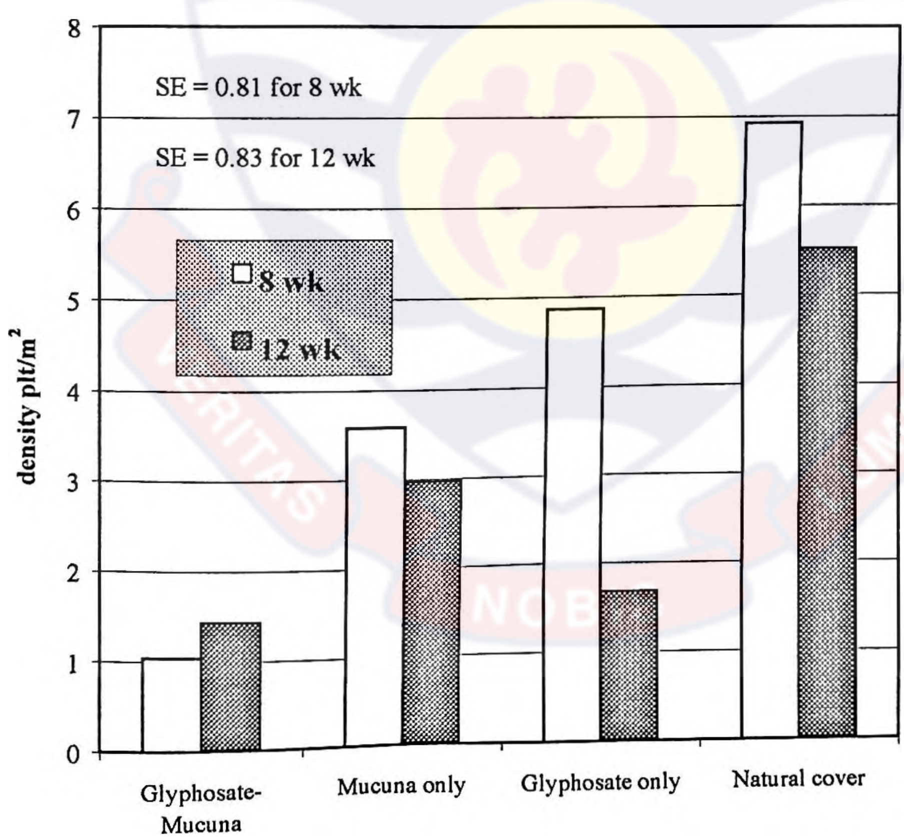


Fig. 4.4.1. Interaction of chemical application and cover crop on speargrass shoot density - Wenchi

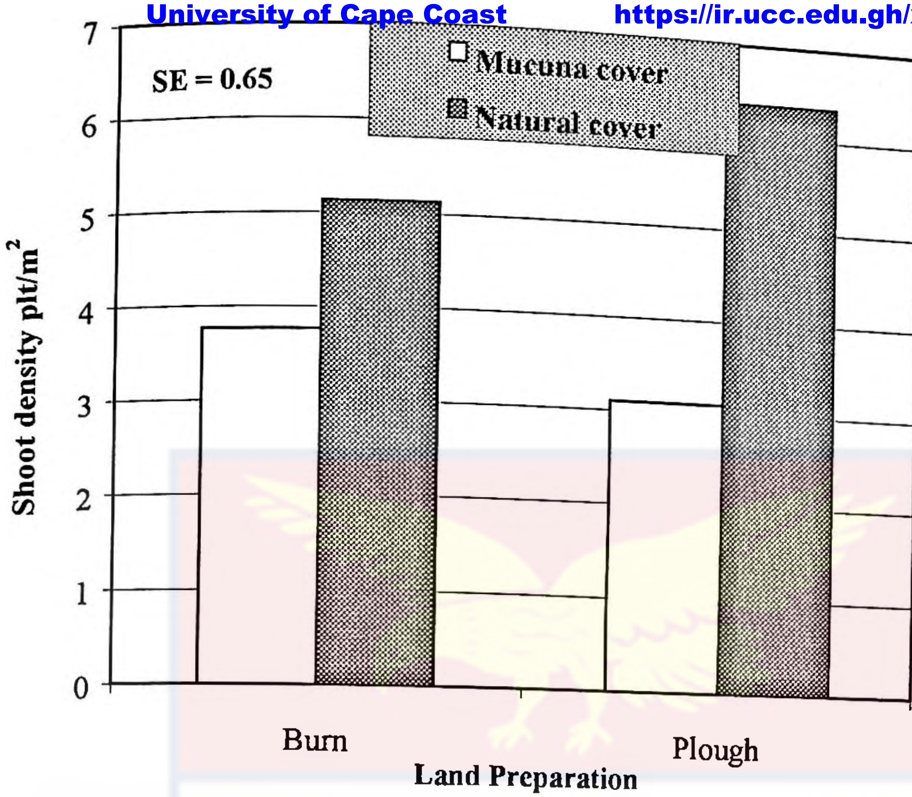


Fig. 4.4.2. Shoot density of speargrass under different land preparation methods and *Mucuna* cover 8 WAT - Mampong , 1997

Speargrass Shoot Dry Weight

<u>Mampong</u>

The interaction of chemical application and cover crop on speargrass shoot dry weight was significant ($p<0.01$) from 8 through 12 WAP in 1996. At 8 weeks shoot dry weight on glyphosate-*Mucuna* treatment was reduced by 92 % compared to the non glyphosate-natural cover treatment (Table 4.4.2). *Mucuna* alone reduced dry weight by 177 % compared to the natural fallow. The reduction in shoot dry weight at 12 weeks followed a similar pattern to that at 8 weeks, except there was also an interaction between land preparation method and the type of cover. The heaviest dry weight of 176 g/m^2 was recorded under natural fallow. Speargrass shoot dry weight was lower (20-78 g/m^2) on the ploughed plots with or without *Mucuna* cover compared to the burned plots (22-153 g/m^2) with similar follow-up treatments. The level of speargrass suppression through burning or ploughing followed by *Mucuna* was almost the same. There was a 66 % reduction in shoot dry weight on the ploughed only plots compared to those that were just burned.

In 1997, glyphosate - *Mucuna* combination effectively reduced speargrass shoot dry weight compared to the other treatment from 8 through 40 WAP (Fig. 4.4.3). Speargrass shoot dry weight from glyphosate-*Mucuna* combination at 8 weeks was significantly lower by 81 % relative to that on *Mucuna* cover alone or the natural cover but was about the same as that from glyphosate application alone. Glyphosate–*Mucuna* treatment or *Mucuna* alone effectively reduced shoot dry weight by 90 % and 54 % at 20 weeks. By 40 weeks, speargrass dry weight reduction was 53 % for the glyphosate-*Mucuna* combination while *Mucuna* increased dry weight by 55 %. Glyphosate was effective in suppressing speargrass regrowth up to 12 weeks but by 40 weeks the effectiveness had reduced drastically by > 300 %. However, glyphosate was 69 % more effective in suppressing shoot regrowth compared to the natural cover. By 40 weeks, all the other three treatments were superior in delaying shoot regrowth relative to the natural cover. Shoot dry weight was 17 g./m^2 for glyphosate-*Mucuna* treatments, 114 g/m^2 for glyphosate treatments, 65 g/m^2 for *Mucuna* treatment and 371 g/m^2 for the natural cover. Leaving the plot under natural fallow consistently increased speargrass shoot dry weight over the period by 183 %.

<u>Wenchi</u>

The results were similar to those obtained at Mampong with glyphosate-*Mucuna* treatment combination being the most effective on speargrass regrowth from 8 through 32 WAP (Fig. 4.3.4). At 8 wk, dry weight for glyphosate with or without *Mucuna* or *Mucuna* alone was $\leq$ 12 g/m^2 compared to 150 g/m^2 for the latter but by

32 wk, speargrass dry weight from glyphosate-*Mucuna* combination or *Mucuna* alone had increased to ≤ 24 g/m^2, glyphosate alone was 63 g/m^2 and natural cover was 226 g/m^2.

Table 4.4.2. Effect of chemical application and legume cover on speargrass shoot dry weight (g/m^2) , Mampong. 1996

Treatment	8WAT	12 WAT
Glyphosate-*Mucuna*	9.73	10.63
Glyphosate-only	18.13	55.00
Mucuna only	45.50	32.43
Natural fallow	125.88	176.00
SE (p = 0.05)	10.97	15.05

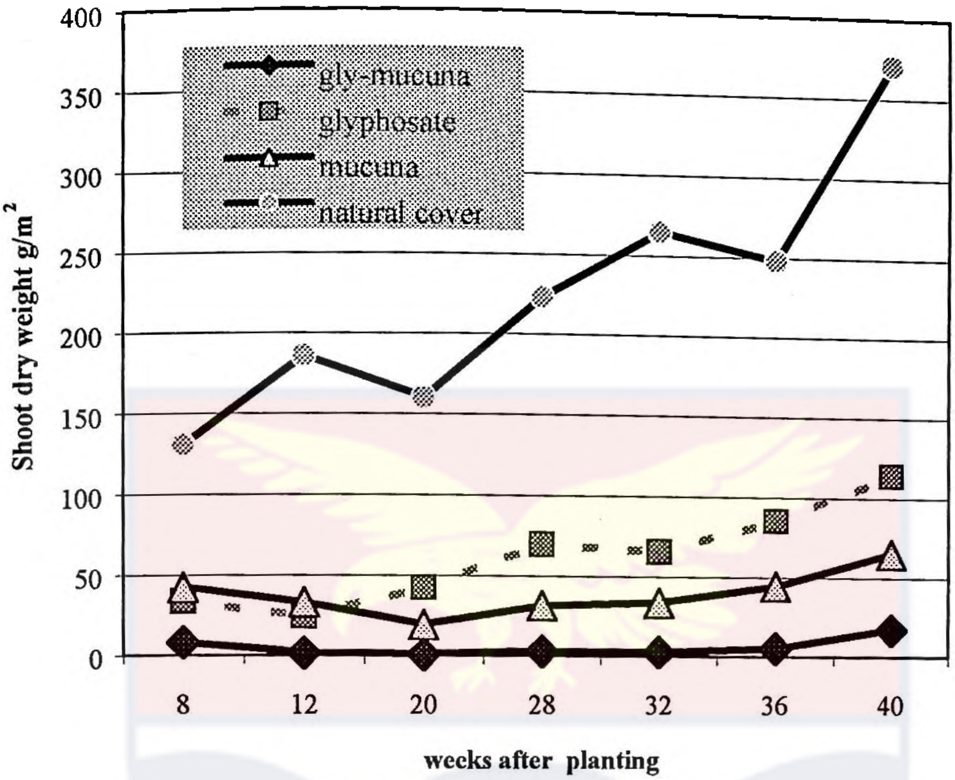


Fig. 4.4.3. The response of speargrass to the interaction of chemical application and legume cover - Mampong, 1997

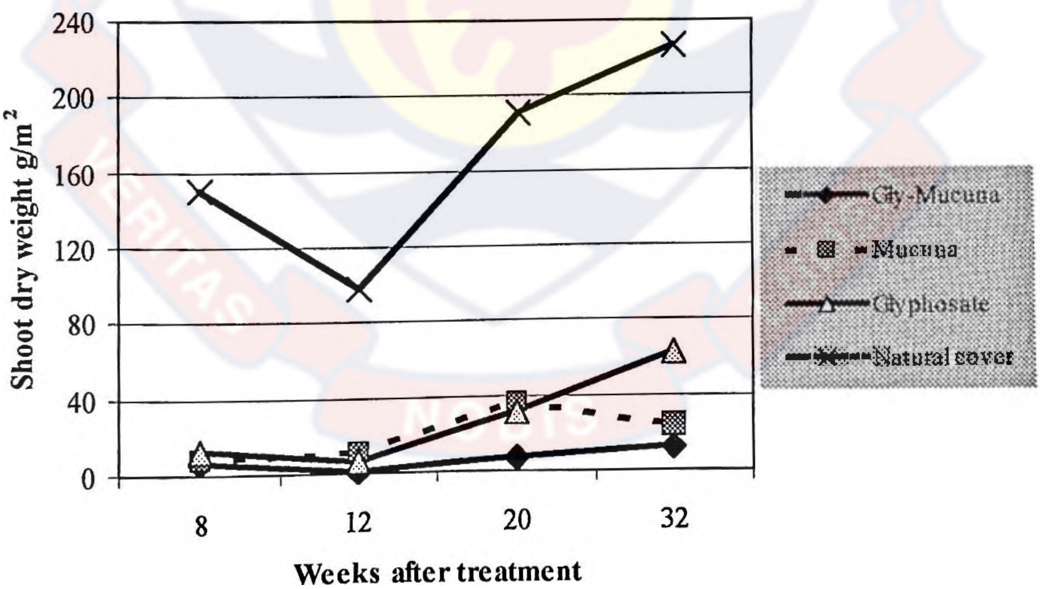
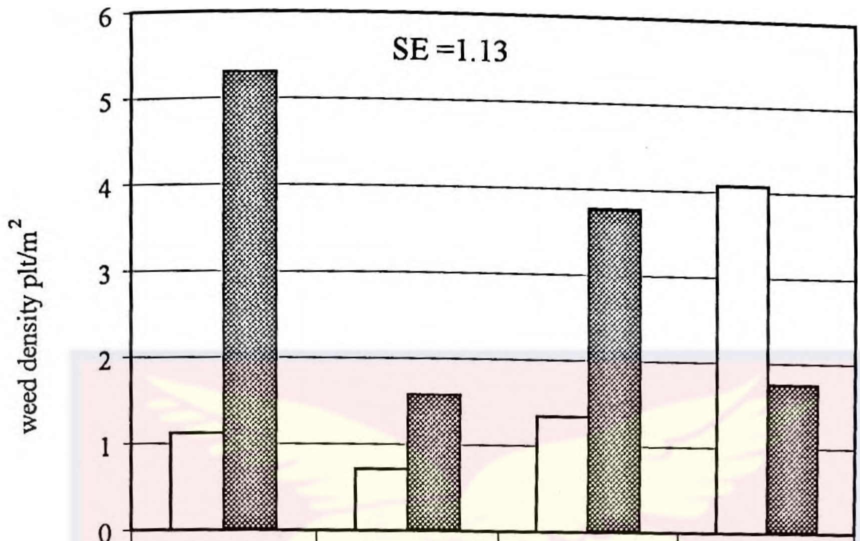


Fig. 4.4.4. Interaction of glyphosate-*Mucuna* treatment on speargrass shoot dry weight over time - Wenchi

Weed Succession

Application of glyphosate reduced the density of other weed density ($p = 0.01$) by 42 % 4 weeks after treatment in 1997. Weed succession at 8 weeks was characterized by the presence of *Spigelia anthelmia*, *Talinum triangulare*, *Cyperus spp*, *Phyllantus amarus*, *Chromolaena odorata*, *Tridax procumbens*, *Commelina sp*, seedling grasses and other broadleaves with *C. odorata* being the dominant. Weed density was high under plough-no glyphosate-natural fallow compared to burn with similar follow-up treatments. Similar densities were recorded on plough-*Mucuna*, plough or burn-glyphosate-*Mucuna* or burn-natural fallow plots (Fig. 4. 4.5). At 36 weeks, the least broadleaf dry weight of 16.8 g/m^2 was from the natural cover.



	Burn-glyphosate	Plough-glyphosate	Plough only	Burn only
Mucuna	1.12	0.71	1.34	4.07
No Mucuna	5.3	1.58	3.77	1.75

Fig. 4.4.5. Land preparation, chemical application and cover crop on weed density 8 WAP - Mampong, 1997

Rhizome Dry Weight

In 1996, *Mucuna* cover reduced rhizome dry weight by 64 % and 57 % at 0-15 and 15-30 cm soil depth respectively relative to the natural cover at Mampong but in 1997 dry weight at 15 cm depth was reduced by 59 % (Table 4.2.3). Beyond this depth there was no significant effect of treatment on rhizome dry weight. Glyphosate application also reduced weight by 59 % at 15-30 cm and 83 % at 30-45 cm depth compared to the non-chemical treatment in 1996.

At Wenchi, *Mucuna* cover reduced rhizome dry weight by 57 % at 15 cm depth (Table 4.2.4), while dry weight at 15-30 cm depth was affected by glyphosate-*Mucuna* interaction. Rhizome dry weight from glyphosate-*Mucuna* treatment was a low of 0.43 g/kg soil and 2.31 g/kg soil under natural fallow.

Mucuna Growth Parameters

Ploughing or burning with or without glyphosate application did not show any real difference in *Mucuna* establishment or dry weight at 4 and 14 weeks after planting respectively.

Table 4.4.3. Effect of Mucuna cover or glyphosate application on speargrass rhizome dry weight (g/kg soil) - Mampong

	Soil depth in cm				
	1996			1997	
	0-15	15-30	30-45	0-15	15-30
	g/kg soil				
Mampong					
Mucuna	0.18	0.15		0.11	
Natural cover	0.5	0.35		0.27	
SE	0.13	0.05	NS	0.07	NS
Glyphosate		0.14	0.02		
No glyphosate		0.4	0.12		
SE	NS	0.07	0.03	NS	NS

Table 4.4.4 Effect of *Mucuna* cover and glyphosate application on speargrass rhizome dry weight (g/kg soil) – Wenchi

	Soil depth (cm)	
	0-15	15 – 30
Mucuna	0.76	
Natural cover	1.75	
SE	0.30	NS
Glyphosate-*Mucuna*		0.43
Glyphosate-natural cover		0.83
Noglyphosate-*Mucuna*		0.93
Noglyphosate-natural cover		0.41
SE		0.41

4.5. THE EFFECT OF PRECEEDING LAND PREPARATION, CHEMICAL APPLICATION AND COVER CROP ON SPEARGRASS REGROWTH AND YAM TUBER QUALITY

4.5.1 Speargrass Regrowth

Previous glyphosate-treated plots had by 12 weeks reduced speargrass shoot dry weight by 68 % (Table 4.5.1). Shoot dry weight was lowest (4.3 g/m^2) for glyphosate-*Mucuna* and highest (21.1 g/m^2) for the natural cover treatments at 10 % level of probability in Wenchi. For Mampong, speargrass density was 33 % lower (p =0.0001) on the glyphosate-treated plots compared to the non-glyphosate treated (Table 4.5.2). Burn or plough–*Mucuna* combinations reduced density similarly but were 4 weeks after planting yam, 29 and 36 % significantly more efficient than burn - natural cover. Glyphosate-*Mucuna* treatments consistently had the smallest shoot dry weight of 8.63 g/m^2 by 20 weeks while the heaviest weight of 56.26 g/m^2 was from plots under natural cover (Table 4.5.3). At 8 weeks speargrass shoot dry weight on glyphosate-*Mucuna* plots was significantly lower compared to glyphosate treatment alone. There was no difference in the growth of speargrass between plots with glyphosate application or *Mucuna* cover alone. The trend continued through 20 weeks except for gyphosate-*Mucuna* treated plots which proved superior to glyphosate application alone. Speargrass shoot dry weight was at 24 weeks after planting yam 28.3 g/m^2 and 51.6 g/m^2 on the *Mucuna* or natural cover respectively.

Weed succession was affected by the residual effect of chemical application or cover at 4 weeks. Broadleaf weed density was < 1 plt/m^2 on non-glyphosate-treated plots and 2 plt/m^2 on *Mucuna*–treated plots (Table 4.5.2 and Table 4.5.4). Broadleaf dry weight was 3 times smaller on the natural cover compared to *Mucuna* cover from 16 to 24 weeks (Table 4.5.4).

4.5.2 Yam Tuber Quality and Yield

Appendix 10 shows yam tubers pierced by speargrass rhizomes. Land preparation method or the type of cover did not significantly improve yam tuber quality at the 5 or 10 % probability level at both sites. At Mampong, the number of tubers pierced by rhizomes or tuber yield was statistically similar for all treatments though, there was slightly higher tubers with rhizomes on the plots that were burned (15%) compared to the ploughed (9 %). However, the quality of yam was improved by previous glyphosate treatment at the 10% probability level at Wenchi (Table 4.5.1). Of the harvested tubers from glyphosate treated plots 1% was pierced by speargrass rhizomes compared to 7 % from the non-glyphosate treated.

Similarly tuber yield was 1.38 kg/m^2 on plots planted to *Mucuna* and 1.11 kg/m^2 on the natural cover ($p=0.05$) at Wenchi while that yield on the ploughed or burned plots was 1.2 kg/m^2 and 0.9 kg/m^2 respectively at Mampong.

4.5.3 Rhizome Growth

Glyphosate-*Mucuna* treatment reduced rhizome dry weight by 93 % compared to the natural cover two years after treatment application (Table 4.5.3). However, pretreatment with either *Mucuna* or glyphosate reduced dry weight similarly by 80 % over the natural cover ($p < 0.05$).

Table 4.5.1 Effect of two-year chemical application on speargrass shoot regrowth and yam tuber quality - Wenchi

	-- dry weight (g/m²) --		Rhizome pierced tubers (%)
Chemical	8 wk	12 wk	Harvest
Glyphosate	1.5	3.3	1.3
No-glyphosate	4.9	10.6	7.2
SE (0.1)	1.7	3.3	2.7

Table 4.5.2. Residual effect of two years chemical application on weed growth, (4 wk) and speargrass regrowth (24 wk) - Mampong

Chemical application	Speargrass ------- Density	Other weeds (plt/m²) -----------	Speargrass Dry wt (g/m²)
Glyphosate	9.7	4.4	29.4
No glyphosate	14.5	0.9	50.5
SE (0.05)	0.7	0.9	4.3

Table 4.5.3. Residual effect of two years chemical application and legume cover on speargrass shoot and rhizome growth – Mampong

Treatment	Shoot dry weight (g/m²) 8 wk*	16 wk	20 wk	Rhizome dry weight (g/kg soil) At yam harvest
Gly**- *Mucuna*	8.96	2.04	8.63	0.08
Mucuna only	18.14	6.22	26.09	0.21
Glyphosate	24.28	8.03	27.29	0.24
Natural cover	49.84	52.05	56.26	1.20
SE	5.22	2.60	4.13	0.09

*=weeks; **=glypgosate

Table 4.5.4. Residual effect of 2 years legume cover on broadleaf weed growth - Mampong

Cover crop	Density (plt/m²) 4 wk	Dry wt (g/m²) 16 wk	24 wk
Mucuna	3.5	0.8	16.7
No *Mucuna*	1.9	0.2	4.7
SE	0.7	0.2	2.7

4.5.4. Incidence of Disease

Laboratory analyses revealed the presence of pathogens listed in Table 4.5.5. Four disease pathogens including *Colletotrichum gloeosporiodes* which causes anthracnose in yam was common in isolates from *Mucuna*, *Chromolaena odorata* and yam leaves from Mampong while at Wenchi, 3 disease pathogens which also included *C. gloeosporiodes* were common to *Mucuna* and yam leaves. Again at Mampong, 5 pathogens common to *Mucuna* and *C. odorata* were observed.

Table 4.5.5. Laboratory analysis of disease pathogens isolated from *Mucuna*, yam and *C. odorata* leaves

Disease Pathogen	Yam	Mucuna	*C. odorata*
Mampong			
Fusarium semitectum	+	+	+
Fusarium. monilifome,	-	+	-
Bipolaris sp,	-	+	+
Cercospora sp	+	+	+
Phoma sp	-	+	-
Colletotrichum gloeosporiodes	+	+	+
Periconia sp	+	+	-
Cladosporium sp	+	+	-
Nigrospora sp	+	+	-
Corynespora sp	-	+	-
curvularia sp	+	+	+
Alternaria alternata	-	-	+
Wenchi			
C. gloeosporiodes	+	+	
Cladosporium herbarum	+	+	
Corynespora sp	+	+	
Phoma sp,	+	-	
Nigrospora sp	+	-	
Myrothecium sp	+	-	
A. alternata	+	-	
Curvularia sp		+	

4.6. PRECEEDING LAND PREPARATION, CHEMICAL APPLICATION AND LEGUME COVER ON SPEARGRASS RHIZOME VIABILITY

4.6.1 The Effect of Land Preparation and Cover Crop

At Wenchi, the type of cover crop fallow influenced the viability of the rhizomes at the 5% significant level (Table 4.6.1). The shoot height of sprouted rhizomes from *Stylosanthes* treatment was 52% shorter than those from the natural cover at soil depth of 15 cm. Generally, sprouting of rhizomes at 15-30 cm depth from the *Stylosanthes* or *Mucuna* fallow was 47 and 64 % lower than the natural fallow. Shoot height of sprouted rhizome at soil depth of 15 – 30 cm was 1.6 cm from the natural fallow, 0.5 cm from the *Stylosanthes* fallow and 0.3 cm from the *Mucuna* fallow respectively. Correlation analysis of cover cropping to sprouting or height of sprouted rhizomes at depth of 15 –30 cm was negative (r = 0.45 and 0.52 for height at p =0.001).

Either land preparation method or the type of cover at Mampong did not significantly affect rhizome growth from soil depth of 15 cm but rather at 15-30 cm depth (Table 4.6.2). The shoots from plots that were under natural fallow were more vigorous than those from *Stylosanthes* or *Mucuna* fallow. Sprouting of rhizomes under natural fallow was 17 % compared to 7.5 % under *Mucuna* fallow while shoot height was reduced by 51 % and 81 % under *Stylosanthes* or *Mucuna* fallow respectively compared to the natural fallow. Correlation analysis between cover crop and sprouting or shoot height at 15-30 cm depth was negative (r = -0.43 at p=0.01 for sprouting and -0.53 at p =0.001 for height).

4.6.2. The Effect of Land preparation, Chemical application and Cover Crop

At Mampong, preceeding cover crop or chemical application affected the growth of rhizomes at 15cm depth and 15-30 cm depth respectively at the 10% level of probability. At 0-15 cm depth 5% and 17.5 % of the rhizomes from *Mucuna* or natural cover respectively sprouted whilst 2.8 % from glyphosate treatment also sprouted against 15 % from non chemically treated at 15-30 cm depth. There was however no treatment effect on sprouted rhizome height. There was a strong correlation between sprouting and height (r = 0.712, p = <.0001).

Table 4.6.1 The effect of preceeding legume cover on speargrass rhizome viability from different depths– Wenchi

	Sprouting (%)		Height (cm)	
Type of cover	0-15cm	15-30cm	0-15cm	15-30cm
Natural fallow	23.5	17.3	2.1	1.6
Stylosanthes	15.8	9.2	1.0	0.5
Mucuna	16.9	6.3	1.5	0.3
SE	NS	0.4	3.2	0.3

Table 4.6.2 The effect of preceding legume cover on speargrass rhizome viability from different depths– Mampong

	Sprouting (%)		Height (cm)	
Type of cover	0-15cm	15-30cm	0-15cm	15-30cm
Natural fallow	13.9	17.2	0.7	1.7
Stylosanthes	9.9	11.3	0.5	0.8
Mucuna	6.3	7.5	0.3	0.3
SE	NS	3.8	NS	0.4

CHAPTER FIVE

DISCUSSION

5.1 FARMER PRACTICES, PERCEPTION AND THE INCIDENCE OF SPEARGRASS IN FOREST AND FOREST-SAVANNA-TRANSITION ZONES

Cropping Characteristics

The mean farm size and the crop combinations observed across the two ecological zones are consistent with reports from other studies in Ghana (Anchirinah *et al.*, 1996; Marfo *et al.*, 1994). Chikoye *et al*, (2000) also reported similar farm holding size and crop combinations of 2-6 crops in speargrass dominated fields in West Africa. Manyong *et al.* (1996) similarly in his characterization of major crops of the savanna. The fact that most farmlands are < 2 ha is because farming is mostly by peasants who rely on manual methods of weed control using family labour mainly by women which is confirmed by Akobundu (1991).

The prevalence of intercropping was also due to the fact that most farmers rented the land and thus need security. Intercropping is popular in resource-poor communities because it, among other reasons, diversifies and stabilizes crop production and economic returns, distributes farm labour more uniformly and often gives better control of weeds than sole cropping (Midmore, 1993). Intercrops of contrasting phenology maintain complete canopy cover over the ground for a relatively longer time thereby preventing weed seed germination through reduced soil temperature and changes in spectral light quality to non-optimal levels.

The mean crop intensity factor (CIF) of 49 % is an indicator of the ratio between length of cropping and fallow. The implication is that the lands are not being intensively cropped yet in certain areas as shown by mean cropping length of 3.5 years and a fallow of 5 years. The fact that the abandoned fields are returned to cropping when there is a dense growth of *Chromolaena odorata* which is used as an indicator of a mature field probably explains why the fallow periods are quite long in certain districts contrary to the general belief that the average fallow periods in the two ecological zones are 3 –5 years (Anchirinah *et al.,* 1996). In a study, the density of speargrass negatively correlated with *Chromolaena odorata* infestation (Eussen and Wirjahardja, 1973).

The CIF was high at Techiman district because the area has a major market linking the northern and southern parts of the country and thus a higher population growth in the district. This is explained by Boserup's (1987; 1965) evolution of farming systems and agricultural change. Boserup hypothesized that the evolution of farming systems in many African countries is determined by population growth, which influences agricultural change, rather than agricultural production determining population growth. The evolutionary path followed is as follows: forest fallow; bush fallow; short fallow; annual cultivation and multiple cropping. Successive stages are associated with more intense use of the land through higher levels of technology, labour and capital investment in the land.

Ranking of speargrass and other weeds

The general perception of speargrass as the most troublesome weed by the farmers confirms reports from Africa and elsewhere (Chikoye *et al.*, 2000; Anchirinah *et al.*, 1996; Anoka, 1995; Boonitee and Ritdhit, 1984). All the women perceived it as noxious probably because they do the weeding. The other major weeds were *E. heterophylla* and *C. benghalensis*. *E. heterophylla* has been reported as a very competitive weed in cowpea and soybean (Akobundu *et. al.*, 1988) and yam (Anchirinah *et al.*, 1996) and

C. benghalensis was identified as a major weed in cotton and cereals (Ahanchede and Gasquez, 1997; Ahanchede, 1994). Farmers assertion that crops grown on speargrass infested fields especially maize gives high grain yield provided the weed is well controlled is corraborated by Soepardi, (1980). Speargrass is said to improve soil physical properties and hence allow freer access for water and fertility by extracting nutrients from deep down the soil profile. The use of speargrass for erosion control was not mentioned by any of the farmers (Suryatna *et al.*, 1980 and Rajaratna, 1978).

Speargrass Incidence and Distribution

Speargrass was observed throughout the surveyed area and seemed to have been with the farmers for over forty years with higher incidence on fields that were burned compared to the non-burned fields. Since most farmers practice slash and burn agriculture the results are not surprising for a lot of studies have confirmed that fires induce flowering and seeding, reduce competition from other plants, and create openings for seedling establishment (Dozier *et al*., 1998; Shilling *et al*., 1995; Bryson and Carter, 1993).

Shallow cultivation performed in the rainy season mostly with the hoe usually breaks rhizomes into small pieces, and inadvertently eliminates apical dominance resulting in increased sprouting of buds and subsequent shoot growth. The widespread distribution and incidence may be attributed to the activities of timber firms and burning charcoal which has opened up the forest areas, the movement of soil for road construction and for building houses and the use of shoots as thatch. Some farmers believed that the practice of shifting cultivation, which opens up the place, has also contributed to the spread because speargrass cannot survive very well under shade. This is supported by its ranking in Mampong. It was not the most noxious weed because speargrass appeared to be more of a problem in areas that had been opened up for example logging and where charcoal burning was rife. This is in agreement with Ivens (1980) studies in Nigeria. According to Tjitrosoedirdjo (1993), repeated logging and fire are primary contributors to succession leading to speargrass domination. Suryatna and McIntosh, (1980) have also reported the loss of the forests in Indonesia to shifting cultivation and logging. Techiman had the highest infestation because of the high cropping intensity.

Weed Control

Apart from manual weeding mostly with the hoe, herbicides were mainly used at Ejura Sekyedumase and Sekyere West districts apparently because of the promotion of glyphosate to control speargrass by the Crops Research Institute concentrated in those areas. None of the farmers mentioned the use of cover crop fallow for reclaiming fields abandoned due to speargrass using *Mucuna* to control speargrass had been initiated in the Ejura Sekyedumase district for a while.

Crop Yield Loss

Crop yield reduction of 30 to 80 % perceived by the farmers confirms reported observations. Crop yield reduction from competition to speargrass in cassava has been estimated at 76-80%, 78% in yam and 50 % in maize (Chikoye *et al.*, 2000; Udensi *et al.*, 1999; Akobundu and Ekeleme, 1995; Koch *et al.*, 1990). Most of the respondents however had observed that very good crop yields are realized on relatively fertile speargrass infested fields if there is good and timely control. They believed the rhizomes improve infiltration of water to the soil by opening up the pores. Similarly, Soepardi (1980) indicated that speargrass improves soil physical properties, which allow free access to water, and fertility by extracting nutrients from deep in the soil profile.

5.2 LAND PREPARATION, CHEMICAL APPLICATION AND COVER CROP ON SPEARGRASS CONTROL

The choice of land preparation method, chemical and cover crop was informed by the land tenure system gathered from the survey and reports by others. The emphasis for using cover crops in this study was to reclaim speargrass infested fields within a shorter time instead of the usually long fallow.

5.2.1 Land Preparation Methods and Control of Speargrass

Burning, ploughing, or slashing alone could not suppress speargrass beyond 8 weeks at both sites though ploughing was the most effective in suppressing speargrass regrowth while burning enhanced it. This implies that with appropriate land preparation, early interference from speargrass with other crops could be delayed within the first 2 months which could give the farmer more respite in the case of a delay in first follow-up weed control considering that most farmers have more than one piece of land. Burning is believed to stimulate the growth of speargrass, which allows for greater interception of PAR for it to flower. Anoka (1995) similarly reported speargrass having a rapid vegetative growth under burning. It has also been established that fire activates the axilliary buds of the rhizomes, which are well adapted and fire-resistant, resulting in vigorous shoot growth and tillering (Holm *et al.*, 1977; Soerjani, 1970).

A major problem with speargrass growth is the persistence of its extensive rhizomes that spread in the topsoil and the subsoil. Thus land preparation methods that do not remove these rhizomes would lead to the regrowth of speargrass. This may explain why the traditional manual methods such as slashing, burning and hoeing have proved ineffective in controlling speargrass over the years (Chikoye *et al.*, 1999; Ivens, 1980) because they do not disrupt the rhizomes of speargrass; thus sprouting of new shoots is not prevented. Ploughing was superior to the other forms of land preparation method at both Mampong and Wenchi probably because it breaks up the rhizomes and brings them up for desiccation though it did not influence rhizome dry weight. It could be that ploughing was not deep enough since the rhizomes could reach depths of 45 cm and beyond. The fact that none of the land preparation methods affected the dry weight of speargrass rhizomes corroborates work by other scientists. According to Willard (1988) and Gaffney (1996), disking (ploughing) alone is not effective for speargrass control although some reduction of biomass occurs. Dozier *et al.* (1998), reported that shallow-tillage fragmented rhizomes causing short-term growth reduction and subsequent shoot growth. Long lasting control, need to be repeated 3-5 times to get reasonable control, and yield reduction often occurs despite the control measures (Townson, 1991).

5.2.2 The Effect of Cover Crops on Speargrass Control

Mucuna and *Stylosanthes* out-performed *Canavalia* at both locations in reducing speargrass regrowth in 1996. However, *Mucuna* reduced speargrass regrowth better than *Stylosanthes*. As an annual *Mucuna* establishes faster than *Stylosanthes*, and with its broadleaf characteristics is able to shade out speargrass with a consequent reduction in growth whereas stylosanthes is perennial and thus slow to establish. The poor control by *Canavalia* could be attributed to the lower percent ground cover.

Chikoye *et al*., (2002) explained the poor control by cowpea and egusi melon on speargrass by their shorter duration of shading and poor ground cover. According to them these cover crops are short-season crops, which does not leave much litter after senescence. This could be the reason for the widespread use of *Mucuna* for weed control and green manure in many parts of the tropics (Coultas *et al*., 1996; Versteeg and Koudokpon, 1990). *Mucuna* reduced the density of speargrass from 270 to 32 plants/m^2 so that fields that needed an estimated 60-80-man days/ha to weed were freed with a fraction of the labour effort (Dovonou, 1994 reported by Versteeg *et al*., 1993). Manyong *et al* (1996) concluded that the adoption of *Mucuna* by smallholder farmers was primarily to control speargrass, which acted as a window for the acceptability of *Mucuna* for soil improvement. Chikoye *et al.* (2001) also reported > 50 % reduction in speargrass biomass with *Mucuna* cover.

For 1997, the performance of *Mucuna* and *Stylosanthes* on speargrass shoot dry weight was similar at Wenchi throughout the observational period (44 weeks) whereas at Mampong, it was similar up to 32 weeks and thereafter *Stylosanthes* suppressed speargrass better than *Mucuna*. This is because *Stylosanthes* as a perennial was still actively growing ad very competitive to speargrass. Also, beyond 32 weeks it could be that *Mucuna* was about senescing thus was not very competitive with the speargrass that had emerged in the mixture at that time implying that *Stylosanthes* would be a better cover for long-term control than *Mucuna*.

5.2.3 The Effect of PAR on Speargrass and other Weed regrowth

Mucuna and *Stylosanthes* because of their high interception of PAR might have forced speargrass in the mixture to draw on the food reserves in the rhizomes for growth without it being replenished efficiently from photosynthesis, as its rate of photosynthesis was low. Teasdale and Mohler, (1993) suggested that light transmittance maybe a good indicator of the capacity of mulches to suppress weed emergence. Percent light interception is a good indicator of the efficiency of canopy development and therefore a determinant in smothering weeds. Herbaceous cover crops suppress speargrass by limiting the available solar radiation for its growth and possibly through allelopathic interactions (Eussen, 1981). The cover crops and speargrass fallow intercepted similar amount of PAR at 8 weeks because the canopies of the legume covers had not fully developed. *Mucuna* takes at least 6 weeks before its effect on speargrass is visible (Macdicken *et al.*, 1997). Thus the advantages of *Mucuna* cover on weed growth were not reflected in reduction of speargrass shoot dry weight. Full canopy cover also reduces the PAR reaching weeds under the crop thereby reducing their competitive ability (Benvenuti *et al.*, 1994)

However beyond 16 weeks, the differences between PAR intercepted by *Mucuna*, *Canavalia*, *Stylosanthes* and the natural fallow dominated by speargrass reduced dry weight of speargrass shoot and other weeds. Cover negatively correlated to speargrass shoot dry weight ($r = -0.73288$; $p = 0.001$; $r^2 = 0.537$) implying that 54 % of the variation in speargrass dry weight is explained by relationship between type of cover crop and speargrass dry weight. Speargrass is sensitive to shading and a weak competitor in fertile soils (Ivens 1980). *Mucuna* is aggressive and *Stylosanthes* spreads so their canopies intercepted more light for vegetative growth preventing much light to go through the canopy to the speargrass.

The basis of crop production is radiation interception by the crop and where competing weed or crops intercept more light than its component crop, the growth of the component is impaired. When a weed like spear grass colonizes a field it can negatively affect the growth of the associated crop or crops based on total radiation capture. Where cover crops are efficient in radiation capture, they become more efficient etiolators hence effectively suppressing speargrass shoot regrowth as was reflected in the weed dry weight. Hopkins (1970) in his studies in Nigeria suggested that low levels of solar radiation intercepted by speargrass in the legume covers might be responsible for the cessation or slowing down of shoot regrowth during the apparently favourable wet season. Speargrass being a C4 plant was able to use the light intercepted under natural fallow for photosynthesis thus the high shoot dry weight.

The emergence of other weeds is consistent with Chikoye *et al.* (2002) who also reported that reductions in speargrass dry matter led to the emergence of annual weeds not initially present. Udensi *et al.*, (1999) and Anoka (1991) have reported of changes in weed composition after effective control of speargrass. Literature also abounds of allelopathic effect of speargrass on other plants, which might have accounted for the virtually non-existent weeds in the natural fallow plots (Singh *et al.*, 1989; Fashuen, 1988).

5.2.4. Chemical Application and Speargrass Control

The application of glyphosate reduced speargrass density up to 12 weeks. Glyphosate has been reported to suppress speargrass for at least 16 weeks after treatment (Udensi *et al.*, 1999). Studies by Adu-Tutu *et al*, (1995) also reported that glyphosate controlled speargrass up to 12 weeks. Glyphosate interferes with amino acid metabolism (Jaworski, 1972) specifically the formation of phenylalanine, tyrosine and tryptophan (Townson and Butler, 1990) and could have been more rapidly incorporated into metabolic processes as a substitute for amino acids. It was also revealed that glyphosate application was as effective as *Mucuna* treatment up to 20 wk beyond that *Mucuna* was better at weed suppression. Chikoye *et al.*, (2002) reported of low weed dry matter on glyphosate treated plots.

5.2.5 The Interaction of Land Preparation Methods and Chemical Application on Speargrass Regrowth

The interaction of land preparation and chemical application reduced the density of speargrass only at Mampong probably because the land was from a long fallow whereas at Wenchi the site had been used for crop production research for over 20 years. From the results it could be inferred that burning or ploughing followed by glyphosate application was more efficient in reducing speargrass shoot density or dry weight (biomass) than burning or ploughing alone. It is possible that reducing the rhizome system through ploughing or removing dead biomass through burning improved the effectiveness of glyphosate application on the regrowth. Burning or ploughing may have forced the rhizomes to reallocate carbohydrate reserves to produce new shoot, thereby weakening the rhizomes (Richards *et al.*, 1995). Furthermore the greater demand for energy resulting from breaking of apical dominance along the rhizome after ploughing may have allowed more herbicide to be absorbed and translocated by the actively growing shoots resulting in greater concentration in the rhizome buds. Willard *et al.*, (1996) reported of improved speargrass control with glyphosate followed by mowing based on reductions in shoot biomass. Cultivation when not done properly has been established to stimulate bud growth by fragmentation of the rhizomes and through aeration of the soil (Sherman, 1980); hence the inclusion of glyphosate resulted in better weed suppression.

5.2.6 Interaction of Chemical Application and Cover Crop on Speargrass Shoot and Rhizome Dry weight

The positive correlation (r = 0.64) between speargrass rhizome and shoot dry weight indicate that any control measure that does not affect the rhizomes would be ineffective. The biological success of speargrass to colonise farmlands depends on the ability of its rhizomes to regenerate. As a result, management practices for speargrass should aim at strategies that would reduce or eliminate the rhizomes. *Mucuna* and glyphosate application impacted negatively on rhizome growth reducing weight by 50 to 67 % after 2 years. Chikoye *et al.* (2002) showed that *Mucuna* interference nearly eliminated rhizomes of speargrass within two years of growing cover crops while other studies also reported a 50 to 80 % reduction in rhizome dry matter in 2 to 3 years of growing cover crops (Akobundu *et al.*, 2000; Chikoye *et al.*, 2000; Udensi *et al.*, 1999). The fact that speargrass control was better under glyphosate-*Mucuna* combination than glyphosate or *Mucuna* alone may imply that the combination was complimentary. Initial weed emergence and therefore competition between *Mucuna* and speargrass was virtually non existent due to control by glyphosate which allowed *Mucuna* to grow without much interference as shown by the amount of PAR intercepted. *Mucuna* cover intercepted 92 % of the photosynthetically active radiation compared to 81 % under the natural cover. Sukartaamadja and Siregar, (1971) and Moosavi-Nia and Dore, (1979) explained that the susceptibility of speargrass to dalapon or glyphosate was greater under shade due, to the depletion of carbohydrates in the roots and rhizomes in plants. Alternatively, it could be due to morphological changes in the nature of leaves due to shading. This assertion needs to be confirmed in further studies, i.e. whether the enhanced activity of glyphosate-*Mucuna* combination is due to biochemical interference or changes in leaf morphology. Glyphosate or imazapyr followed by *Mucuna* has been reported to reduce speargrass density (Udensi *et al.*, 1999).

At both sites *Mucuna* significantly reduced rhizome dry weight up to 30 cm depth. Chikoye *et al.*, (2001) reported that *Mucuna* nearly eliminated speargrass rhizomes in an intercrop within two years of application. A reduction in natural light is an important factor in the growth of speargrass and Soerjani (1970) found that light directly affects rhizome production and caused a shallower mean depth of rhizomes than under the natural cover. Shading increased speargrass shoot to rhizome ratio and reduced the total rhizome production as confirmed by Moosavi-nia and Dore, (1979).

5.2.7 Interaction of Land Preparation Method, Chemical Application and Cover Crop on Weed Succession

Effective control of speargrass with herbicides or *Mucuna* cover has been known to change weed floral composition to mostly annuals (Udensi *et al*., 1999, Bacon, 1986) due to the removal of the dominance effect of speargrass through allelopathy and competition. Shading by *Mucuna* may also have prevented other weed seeds from germination by reducing the amount of light required to induce weed seed to germinate, thereby reducing the growth of annual weeds. Control of speargrass by glyphosate provided an advantage for other weeds to invade the freed space for effective growth in the presence of light and absence of initial competition from speargrass. As explained earlier burning stimulated the growth of speargrass and the absence of any control measures thereafter enhanced the dominance of speargrass hence the low weed growth under burn-natural cover treatment.

5.2.8 Land preparation Method and Chemical Application on Legume Cover Growth

Slashing as a land preparation method affected the initial establishment of *Stylosanthes* due to its tiny seed and the heavy mulch under slashing. Hence it was not effective on speargrass density. The partial budget analysis indicated that for land reclamation with legume fallow beyond a year there is no need for any elaborate land preparation method. Glyphosate application alone increased the yield of *Mucuna* by 44 % implying that for better establishment of *Mucuna* for a short fallow, it would be better to apply chemical perhaps after slashing.

5.3 LAND PREPARATION, CHEMICAL APPLICATION AND COVER CROP ON SPEARGRASS RHIZOME VIABILITY

The fact that combinations of land preparation method and cover crop, chemical application or cover crop alone had a significant negative effect on sprouting of speargrass rhizomes may imply that the treatments did have some deleterious effect on the propagative capacity of the rhizomes. Even though ploughing delayed the regrowth of speargrass in the field studies it did not have an effect on rhizome viability probably due to the extensive rhizome reserve and single treatment. Shilling and Gaffney (1995), have suggested ploughing thrice in a year. The type of preceeding plant fallow at both Mampong and Wenchi affected rhizome viability. This is supported by the significant correlation coefficient (r = - 0.40) between cover and sprouting or height of sprouted rhizomes. The low correlation may be because treatment effect of legume fallow affected rhizomes from only 0-15 cm depth or other factors, e.g. age of rhizome, soil moisture etc.

Glyphosate because of its systemic action was able to impact beyond 15 cm depth at 10 % level of significance while the interaction of land preparation and cover crop also impacted beyond 15 cm (p = 0.01). Plough –legume cover combination was the most effective in inhibiting rhizome growth because of the complimentary effects of the combination in depleting rhizome reserves. Fragmentation of speargrass rhizomes system and the turning action, which tends to bury some of the fragments deeper into the soil by ploughing, reduced the ability of the terminal bud to grow (Peng, 1984). This coupled with shading effect of the legume covers in depleting carbohydrate reserve of the rhizomes drastically reduced the regrowth potential of the rhizomes.

It could be inferred from this that the integration of different control methods would be more reliable and effective in delaying/preventing the regrowth of speargrass than a single control method. From the result more treatment interactions were expected on rhizome viability but it was not so probably because there are other factors that also affect rhizome viability. It has been reported by Ayeni and Duke (1985) in growth-chamber studies that the stage of growth and its weight were the main features that determine the regenerative capacity of the propagule. In this study, the age of the rhizomes were not considered due to logistic problems. Wilcut *et al.* (1988) also in his study concluded that the regenerative capacity of the rhizomes is also dependant on the portion of rhizomes used and that the apical portion has the highest regenerative capacity.

5.4 PRECEDING CHEMICAL APPLICATION AND LEGUME COVER ON SPEARGRASS REGROWTH AND YAM TUBER QUALITY

5.4.1 Follow-up Weed Control

At Mampong, between 3 to 5 months after planting yam, there was no weeding on plots previously under glyphosate-*Mucuna* or *Mucuna* cover irrespective of land preparation method, there was one weeding under glyphosate treatment and two weedings under natural cover. The avoidance of early weed competition and reduction in weeding frequency implies lower costs of weeding, and more time to engage in other activities that would enhance farmers' socio-economic status. It could be postulated from the results that leaving the land under two year natural fallow may not be long enough to return the land to cropping again especially for root and tuber crops.

5.4.2 Yam Tuber Quality

The low percentage of tubers (1 %) pierced by speargrass rhizomes from glyphosate treatment could be attributed to effective suppression of shoot and rhizome growth as shown by the low rhizome dry weight on glyphosate alone or in combination with mucuna. The higher yield on plots previously cropped to mucuna may also be explained by effective weed control as reflected in the reduced weeding frequency. Thus interference between crop and weed was greatly minimized.

5.4.3 Incidence of Disease

The isolation of *C. gloeosporiodes, Cercospora spp* and *Curvularia spp* from leaf lesions of yam and *Mucuna* could be significant. *C. gloeosporiodes* has a wide host range including legumes and root and tuber crops. The species has been isolated from infections in pawpaw, mango, soya bean and avocado (Dodd *et al*., 1992). Moses (1997) showed that C. *gloeosporiodes* isolated from stem tip dieback tissues of cassava when inoculated into fruits of banana, avocado, tomato and pepper caused lesions characteristic of this anthracnose causing organism. *Cercospora spp* and *Curvularia spp* have been isolated from yam and cassava leaf and stem diseases. Could *Curvularia* isolate from *Mucuna* cause infections in cassava and yam? These questions and others will be worth answering. Once such an association has been identified then it would be prudent to look at the system very well because the general belief is that mucuna is usually free from pests and diseases in West Africa (Bunch and Buckles, 1998). Berner *et al*. (1992) had identified *Macrophomia phaseolina* in a disease outbreak on a mucuna field in southwestern Nigeria though this was not so in this study. Since, *C. gloeosporiodes* can cause considerable yield losses and it can be transferred from leaf to tuber, then the use of mucuna especially in endemic areas must be carefully looked in the context of Integrated Pest Management (IPM).

5.5 PREVIOUS LEGUME COVER ON SPEARGRASS REGROWTH, FOLLOWING MAIZE PERFORMANCE AND SOIL FERTILITY

5.5.1 Follow-up Weed Control

The first follow-up weeding in maize was skipped in *Stylosanthes* or *Mucuna* fallow due to effective suppression of speargrass by these legume covers at both sites. It has been reported by others that the principal means of weed suppression by cover crops is through shading and allelopathy (Macdicken *et al.*, 1997; Fuji, 1991). It is thus possible that the residual effect of allelopathy was at play here. The influence of preceding land preparation and cover on speargrass dry weight was evident 12 WAP on the field at Mampong. The effective control of speargrass on the burn-*Stylosanthes* or *Mucuna* plots resulted in high incidence of mostly broadleaf weeds. Udensi *et al.* (1999) and Nancy *et al.* (1996) reported that cover crop residue could modify weed seed germination by altering the seed environment and through other interference as allelopathy.

5.5.2 Maize Grain Yield

The fact that the dominance of speargrass had been considerably reduced by the cover crops previously minimized the competition between maize and speargrass. This could account for the vigorous maize plants on the *Stylosanthes* and *Mucuna* fallows. The low plant population on the natural fallow treatments and the positive correlation between cover crops and maize plant height or grain yield confirms this. Maize grain yield increase of 62 and 98 % from the *Stylosanthes* or *Mucuna* fallows over the natural fallow, coupled with taller maize plant and higher plant population seem to suggest that there must have been some other contributing factors besides minimizing weed interference.

Legume covers apart from their weed suppression ability have been known to improve soil fertility, which must have contributed to the increase in yield. Codjia (1996) observed a 98 % increase in maize grain yields without chemical fertilizer in his study on the response of maize to *Mucuna*. *Mucuna*'s ability to restore soil fertility resulted in 70 % greater maize yields than on continuously cropped fields in Benin (Versteeg *et al.*, 1998). In another study, maize grain yield on plots preceded by 3 years *Stylosanthes* fallow increased by 112 % over that from 4 years natural fallow (Tarawali, 1991). Cover crops have been reported to have a positive effect on subsequent maize growth by increasing water storage in the soil and by improving root development of maize (Hairiah and van Noordwijk, 1989). *Stylosanthes* is known to improve the soil's physical and chemical porosity. Tarawali and Ikwuegbu (1993), reported that *Stylosanthes* decreased the soil's bulk density and increased its porosity. It is possible that these could have contributed to the increased yield from the *Stylosanthes* fallow.

5.5.3 Soil Fertility Improvement

Even though, the % total soil N was higher under the *Stylosanthes* than *Mucuna* this difference did not translate into yield. Bouldin (1988) and Handayanto (1992) in their studies reported that the residual effects of legume cover crops on subsequent crops are less certain and depend on quality and soil conditions influencing N mineralization rates from soil organic inputs. It could be that delayed release of N from *Stylosanthes* as a result of higher lignin and polyphenol might be a contributory factor (Fox *et al.*, 1990). It is also possible that *Stylosanthes* produced smaller biomass than *Mucuna*; hence the difference in maize grain yields between the two legume covers. Vallis and

Gardener, (1984) and Oikeh *et al.* (1998) also reported that the effect of legume on subsequent crop is dependent on species capacity to fix atmospheric nitrogen, biomass production, strain of rhizobium, nutrient recycling due to death or decay of soil vegetative cover.

From the soil analysis, the initial pH ranged from 4-5 and since *Mucuna* is reported to perform best on soils with pH of 5.0 - 6.5 (Kretschmer, 1989) it could account for its low N contribution. Generally, it appears the increase in maize grain yield under legume fallow compared to the natural fallow apart from reduced weed competition could have been through accumulation of N in the soil over time or through improvement of soil physical properties.

5.5.4 Economic Analysis On Maize Following 2 Years Legume Fallow

The highest net benefit was from maize grown on *Mucuna* fallow irrespective of land preparation method implying that *Mucuna* is the most promising option for speargrass fallow management. For a farmer to be willing to change from one treatment to the other, the MRR of the change should be greater than the acceptable minimum rate of return. The MRR of 153 % in switching from natural fallow to *Mucuna* indicates that every ¢100 invested in planting mucuna, the farmer can expect to recover the ¢100 and obtain an additional ¢153.00. Similarly in switching to *Stylosanthes* fallow, the farmer tends to gain ¢113.00. However, with *Stylosanthes* fallow, the benefit to the farmer is not only weed control but also fodder for his animals. The MRR of 51 % in switching from *Stylosanthes* fallow to *Mucuna* cover makes it unacceptable. This falls below the acceptable minimum rate of return of 50 - 100% (CIMMYT, 1988). Thus a farmer is well off with the *Stylosanthes* fallow. Thus any serious and business-oriented farmer would choose the *Mucuna* or Stylosanthes fallow to the natural fallow. However, for short term weed control then the option would be for *Mucuna* fallow.

Stylosanthes is a fodder crop and in the transition zones where some farmers practice mixed farming, the option of using *Stylosanthes* fallow to suppress speargrass, while at the same time providing food for livestock should be considered in such situations. *Stylosanthes* can thrive in soils with low P and low fertility, *Mucuna* on the other hand has a high P requirement and contains substantial amount of L-Dopa which can intoxicate if consumed in large quantities thus it is not suitable for fodder.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Speargrass was ranked the most noxious weed and was known locally as 'eto' meaning "you will meet me" or 'seregogoro' which means "piecing like needle". It was present in 94% of the fields surveyed with high incidence (86%) on fields burnt at time of land preparation. Techiman was the most intensively cropped district with the highest incidence of speargrass. Speargrass first becomes a problem after three years cropping from fallow and fields are abandoned under severe infestation. A dense growth of *Chromolaena odorata* was used as an indicator of a field matured from speargrass infestation. Weed control was mainly with the hoe and done manually while glyphosate was used mainly on fields with > 50 % speargrass infestation. The cost/ha of control for an infested field within a crop situation could be ≤ ¢600,000.00/ha ($71) in a growing season and 20-60 % greater than non-speargrass infested field. From the farmer perception losses due to untimely and improper control ranged from <30 to 80 % (¢2.7 to ¢7.4 million or $326 - $869) of yield depending on the cropping system and level of infestation.

Field studies revealed that land preparation method alone could not suppress speargrass beyond 8 weeks. Burning promoted the incidence of speargrass, while ploughing delayed its growth. For *Stylosanthes* to be effective on speargrass, the best option is to plough the field before planting. *Stylosanthes* effectively suppressed the growth of speargrass better than *Mucuna* over a longer period. *Mucuna* was effective up to 32 weeks but *Canavalia* was not. *Mucuna* or

Stylosanthes fallow can be used to reduce the traditional long fallow system for speargrass infested fields to two years. Initial land preparation is important for the establishment of the legume cover to avoid early competition. Weed succession was mainly broadleaf weeds such as *Ageratum conyzoides, C. odorata and Tridax procumbens.*

Soil nutrient analysis after 2 years showed an increase in organic C and available K while available P, Ca and Mg decreased at both sites. Total N was medium for all types of cover (0.10 – 0.17 %) at Mampong but low at Wenchi (0.04 – 0.13 %). *Stylosanthes* and *Mucuna* fallow enhanced the vigour and growth of maize plants and increased grain yield by 62 and 98 % respectively over the natural fallow.

Glyphosate application after burning or ploughing was more effective (61%) than either land preparation alone. Glyphosate was effective up to 3 months, while the inclusion of *Mucuna* extended control beyond 6 months. Glyphosate-*Mucuna* combination reduced rhizome dry weight to a greater depth than glyphosate or *Mucuna* alone.

For a sustainable long-term management of speargrass the integration of land preparation, chemical application and cover crop to prevent re-infestation is important. *Mucuna* can be integrated for short-term fallow management and *Stylosanthes* for long term fallow. The economic sustainability of using legume cover fallow for speargrass management has been firmly established for maize production.

Controlling speargrass with glyphosate improved yam quality by reducing the number of tubers pierced by rhizomes while burning the land reduced quality by increasing number of tubers with by rhizomes. The fungus *Colletotrichum gloeosporiodes*, which causes anthracnose, was isolated from the leaves of both yam and *Mucuna*. Since, *C. gloeosporiodes* can cause considerable yield losses and can be transferred from leaf to tuber, the fungus has to be monitored when using *Mucuna* to manage speargrass in root and tuber production

6.2 RECOMMENDATIONS

The quality of this study would have been enhanced if:

1. The soil analysis had been analysed on plot-by-plot basis within each replication instead of bulking similar treatments together before the analysis.
2. The legume cover biomass had been collected to determine C; N ratio
3. Data Collection could have been fortnightly
4. The incidence and severity of disease on both legume covers and yam had been scouted for and scored
5. The fungal isolate had been cultured in the laboratory and tested on test crops
6. Different parts of the rhizomes had been considered in the viability studies
7. The survey had included a larger area and more people.
8. There were no variations in the seed yam used for planting as these were bought in the open market thus its uniformity and viability could not be ensured.

Future Research

a. It would be worth looking at the effect of grazing on speargrass, the growth of *Stylosanthes* and speargrass control.

b. Could *Curvularia spp* and *C. gloeosporiodes* isolates from *Mucuna* cause infections in cassava and yam?

c. Is the enhanced activity of glyphosate-*Mucuna* combination due to biochemical interference or changes in leaf morphology?.

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Appendix 1 List of towns selected for the survey

TECHIMAN DISTRICT

Kuntunsu
Oforikrom

WENCHI DISTRICT

Akrobi Old Town
Amponsakrom
Awisa
Kwankunumkrom
Yankadi / Eha ye de
Koaze
Namesa
Boasu
Wugatu

NKORANZA DISTRICT

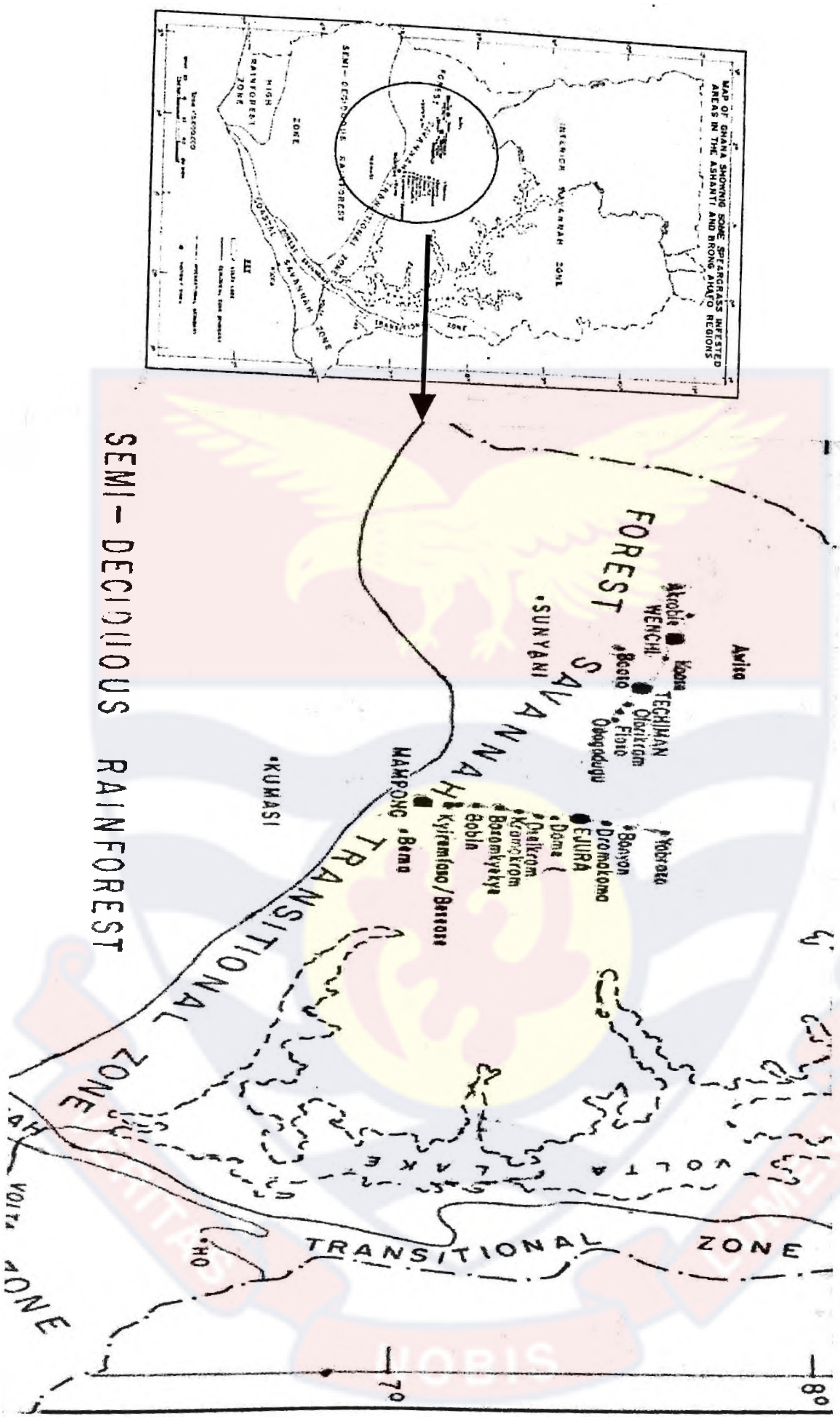
Ouagadogou
Fiaso

EJURA DISTRICT

Yabraso
Krobite
Kwaadjei / Adjeikrom
Dromankuma
Hiawoanwu
Bonyon

SEKYERE WEST DISTRICT

Bobin
Dome
Beemah / Bimma
Bosomkyekye
Kyeremfaso / Besease



Appendix 2. Location of survey areas

Appendix 3. Questionnaire for survey

Farmer practices, perception and incidence of speargrass in the forest, and forest-savanna transition zones - Survey questionaire

Name of village/town ....

District/Region ....

Language of area ....

Sex of Farmer: F = 1 M = 2

Age of Farmer ....

Name of Interviewer ....

Date of Visit ....

A. Cropping History of land

1.1 How many fields do you have?
(i) 1 (ii) 2 (iii) 3 (iv) 4 (v) 5

1.2 What is the size of the field?
(i) Field 1 = ... (ii) Field 2 = ... (iii) Field 3 = ...
(iv) Field 4 = ... (v) Field 5 = ...

1.3 How long has this field been in fallow before it was cleared for cropping
(i) 1 yr (ii) 2 yrs (iii) 3 yrs (iv) 4 yrs (v) 5 yrs (vi) over 5 yrs (vii) over 10 yrs
(viii) don't know (ix) 0 if cropped last year

1.4 What crops were grown on this piece of land?
last year ....
last 2 years ....
last 3 years ....
last 4 years ....
1 = cassava 2 = yam 3 = maize 4 = beans 5 = vegetable, specify
= other, specify

1.5 How long has this land been continously farmed?
(i) 1 yr (ii) 2 yr (iii) 3 yr (iv) 4 yrs (v) don't know (vi) 0, if from fallow

1.6 List crops being grown on this farm this year
1 = cassava 2 = yam 3 = maize 4 = beans
5 = vegetable, specify .... 6= other, specify

1.7 What is the size of this field? ....

1.8 Which of the following terms apply to this farm?
(i) large-scale mechanized (ii) shifting cultivation (iii) rain-fed
(iv) irrigated (v)mixed cropping (vi) monocropping

1.8 Does farmer use fire in land preparation every year?
(i) Yes (ii) No

B. Soil Characteristics

2.1. The soil on this farm is best described as
(i) Sandy (ii) loam (iii) Sandy loam (iv) Clay (v) Clay loam

2.2. Drainage on the farm is: (i) Poor (ii) fair (iii) Good

C. Husbandry Practices

3.1. When was this crop planted (weeks)?
....

3.2. When was the first follow-up weeding done?
....

3.3. How do you control weeds on the farm?
(i) Cutlass and/or hoe (ii) Interrow cultivation with tractor (iii) Herbicide

3.4. If herbicide, list name. ....

3.5. Did farmer use fertilizer on the farm? (i) Yes (ii) No.

3.6. What was the rate of fertilizer used per acre?
(i) 1 bag (ii) 2 bags (iii) 3 bags (iv) 4 bags (v) 5 bags.

D. Speargrass (*Imperata Cylindrica*)

4.1. Is speargrass present on the farm or not? (i) Yes (ii) No

4.2. What is the local name of speargrass?

....

4.3. What is the meaning of the local name? ....

4.4. How long have you known speargrass in this district.

(i) 0-5 years (ii) 6-10 years (iii) 11-15 years iv) 16-20 years

(iv) 21-30 years (vi) 30-40 years (vii) over 40 yrs or since childhood

4.5. How does farmer rate speargrass among other weeds on the farm?

(i) worst weed (ii) worse weed (iii) bad weed (iv) not important weed

state reason for ranking ....

....

4.6. Is present weed control practice enough to control speargrass?

(i) Excellent control (ii) Adequate control (iii) Inadequate control

(iv) very poor control

4.7. How is speargrass controlled? ....

....

4.8. What are the uses of speargrass?

(i) Medicinal (ii) Roofing (iii) Livestock feed

(iv) Others (state)..............................

4.9. When does speargrass become a problem after first clearing of land from fallow?

(i) 1st yr (ii) 2nd yr (iii) 3rd yr (iv) 4th yr (v) 5th yr

(vi) 6th yr (vii) after 6th yr

4.10. What is the height of speargrass?

(i) Nil (ii) 0-15cm (iii) 15-30cm (iv) 30-60cm (v) 60-100 cm

(vi) 100-150cm (vii) 150-200 cm (viii) 200-300 cm.

4.11. How much area does speargrass cover on this farm?

(i) Nil (ii) 0-5% (iii) 6-10% (iv) 11-20% (v) 21-30%

(vi) 31-40% (vii) 41-50% (viii) 51-60%.

4.12. Has speargrass flowered or not? Yes = 1 No = 2

4.13. Estimate randomly with a quadrat the density of speargrass.

(i)..................... (vi) ....
(ii).................... . (vii) ....
(iii)................... (viii).........................
(iv).................... (ix) ....
(v)..................... (x)............................

4.14. Name some of the common weeds on the farm

(i)...........................
(ii)..........................
(iii).........................
(iv)..........................

4.15. Name the worst weed on the farm

....

4.16. How do you rate chemical control against manual control?

(i) same (ii) better (iii) poorer (iv) can't tell

4.17. What is the yield reduction associated with speargrass?

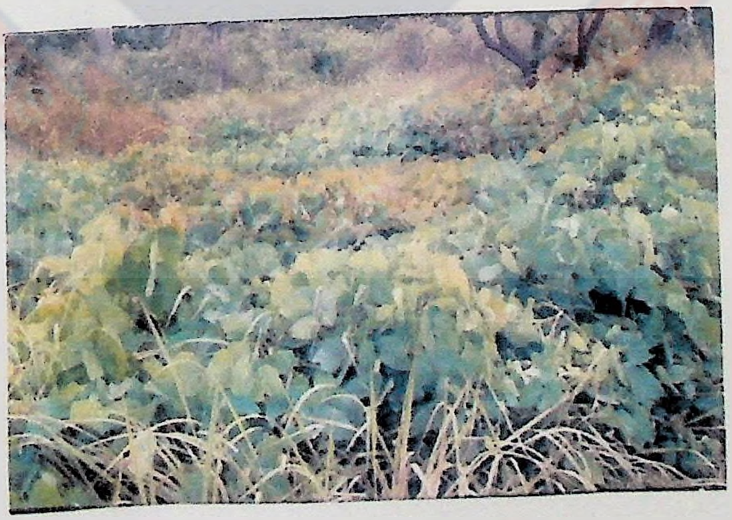
a) If controlled on time ....
b) If controlled late ....

4.18. Is there a difference in cost of controlling speargrass infested fields?

If yes, state price for normal weeds ....

Price for speargrass infested fields ....

Appendix 4. Effect of land preparation and cover crop on speargras control 14 WAP.



Appendix 5. Some chemical characteristics of soils at Mampong and Wenchi sites before legume cover fallow

Depth (cm)	pH 1:1 H_2O	pH 1.25 KCl	Org. C	Extractable cations Ca	Mg	K	Na
Mampong			%	meq//100g			
0-10	5.6	5.0	0.72	4.5	1.4	3.0	0.5
10-28	4.7	4.1	0.42	1.6	0.6	0.6	0.0
28-46	4.6	4.0	0.29	1.0	0.9	0.1	0.4
46-68	4.5	3.9	0.31	0.7	0.9	0.0	0.2
68-91	4.3	3.9	0.16	0.9	0.3	0.1	0.2
91-117	4.2	4.0	0.24	0.9	0.5	0.0	0.5
Wenchi							
0-18	5.2	4.9	0.91	7.7	2.0	0.4	0.4
18-30	4.8	4.5	0.85	8.1	1.9	0.0	0.3
30-46	4.4	4.2	0.71	5.8	0.5	0.0	0.0
46-66	4.4	4.3	0.66	7.2	1.2	0.7	0.3
66-86	4.3	4.3	--	8.3	0.2	0.0	0.0
86-117	4.4	4.5	0.60	3.4	0.9	0.0	0.0

Appendix 6. Available nutrients in surface soils of the two sites – Mehlich 3 extraction method

P	K	Ca	Mg	Mn	B	Cu	Zn
ppm							
Mampong							
2.0 l	61.2 l	1124 m	158 m	63.8 h	3.2 h	0.5 l	0.6 l
5.7 l	60.4 l	829 m	217 m	42.8 m	0.5 l	0.3 l	0.5 l
4.2 l	52.2 l	770 m	128 m	58.2 h	0.1 l	0.2 l	0.5 l
3.7 l	41.8 l	766 m	147 m	44.5 m	0.1 l	0.4 l	0.5 l
Wenchi							
26.1	63.4 l	805 m	140 m	59.7 h	0.1 l	1.2 m	0.5 l
2.8 l	49.4 l	826 m	205 m	135.6 h	0.1 l	1.5 m	0.6 l

L = low; m = medium; h = high; Nitrate and ammonim were not found

Appendix 7 --. Available nutrients in Mampong site after two years cover cropping at different soil depths

0 - 15 cm

Treatment	Org. C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	1.11	0.13	1.90	2.00	68.50	3.20	1.60	5.90
PNF	1.07	0.11	1.80	2.75	58.50	2.72	1.28	5.80
SNF	0.98	0.13	1.70	1.50	71.50	3.04	0.80	6.00
B-*Stylo*	0.94	0.13	1.60	2.87	66.50	2.72	1.12	5.60
P-*Stylo*	1.37	0.17	2.40	2.62	63.50	2.72	1.28	5.80
S-*Stylo*	1.09	0.11	1.90	2.25	68.50	3.36	0.64	5.90
B-*Mucuna*	1.11	0.13	1.90	2.00	66.50	2.88	1.12	5.70
P-*Mucuna*	1.19	0.14	2.00	2.00	68.50	3.36	1.44	5.90
S-*Mucuna*	0.92	0.10	1.60	2.50	68.50	2.88	1.12	5.60

15 - 30 cm

Treatment	Org. C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	0.72	0.08	1.20	0.62	58.50	2.24	0.64	5.70
PNF	0.66	0.08	1.10	0.75	60.00	1.92	0.80	5.40
SNF	0.98	0.13	1.70	0.12	56.50	2.72	0.80	6.00
B-*Stylo*	0.76	0.13	1.30	1.00	53.50	1.92	1.12	5.30
P-*Stylo*	0.80	0.11	1.40	1.25	55.00	1.60	0.96	5.50
S-*Stylo*	0.86	0.11	1.50	0.75	56.50	3.04	0.48	5.70
B-*Mucuna*	0.72	0.09	1.20	1.12	56.50	2.24	0.80	5.30
P-*Mucuna*	0.68	0.11	1.20	0.62	56.50	2.56	0.96	5.90
S-*Mucuna*	0.76	0.09	1.30	0.75	55.00	1.76	0.96	5.50

30 -45 cm

Treatment	Org. C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	0.56	0.07	1.00	2.00	68.50	1.92	0.32	4.90
PNF	0.56	0.07	1.00	0.37	86.50	1.12	0.48	4.90
SNF	0.64	0.08	1.10	trace	60.00	1.12	0.48	4.90
B-*Stylo*	0.64	0.10	1.10	0.12	51.30	1.60	0.64	5.40
P-*Stylo*	0.68	0.07	1.20	0.37	56.50	1.44	0.80	4.90
S-*Stylo*	0.56	0.07	1.00	0.37	56.50	2.24	0.48	5.00
B-*Mucuna*	0.56	0.07	1.00	0.12	50.00	1.28	0.80	4.70
P-*Mucuna*	0.46	0.08	0.80	0.37	51.30	1.60	0.96	5.70
S-*Mucuna*	0.60	0.06	1.00	0.50	56.50	1.44	0.48	4.90

B= Burn; P= Plough; S= Slash; NF= natural fallow; *Stylo*= *Stylosanthes*; OM= Org. matter

Appendix 8 --. Available nutrients in Wenchi site after two years cover cropping at different soil depths

0 - 15 cm

Treatment	Org. C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	0.86	0.08	1.50	5.75	48.50	2.56	0.80	5.40
PNF	1.48	0.13	2.60	2.12	71.50	4.32	1.60	5.40
SNF	0.59	0.07	1.00	0.75	51.30	1.12	0.96	4.80
B-*Stylo*	0.78	0.11	1.30	2.75	46.50	1.92	0.80	5.00
P-*Stylo*	0.92	0.10	1.60	trace	195.00	2.56	1.28	5.30
S-*Stylo*	0.86	0.04	1.50	5.75	26.50	1.44	0.96	5.40
B-*Mucuna*	1.56	0.11	2.70	12.62	91.50	2.24	1.44	5.30
P-*Mucuna*	1.17	0.10	2.00	2.87	61.50	2.88	0.96	5.40
S-*Mucuna*	0.55	0.06	1.00	0.12	120.00	1.44	0.64	5.00

15-30 cm

Treatment	Organic C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	0.90	0.12	1.60	1.25	46.50	2.88	0.64	5.10
PNF	1.05	0.10	1.80	0.37	35.00	3.66	1.44	4.90
SNF	0.59	0.07	1.00	2.87	55.00	0.96	0.48	4.70
B-*Stylo*	0.66	0.08	1.10	0.75	41.50	2.40	0.64	5.10
P-*Stylo*	0.96	0.04	1.70	trace	128.50	3.20	1.60	5.00
S-*Stylo*	0.76	0.07	1.30	3.75	141.50	1.76	0.64	5.30
B-*Mucuna*	1.21	0.10	2.10	8.25	65.00	2.24	1.76	5.30
P-*Mucuna*	0.74	0.10	1.30	1.12	45.00	3.52	0.64	5.30
S-*Mucuna*	0.49	0.06	0.80	1.12	78.50	1.28	0.48	5.10

30 - 45 cm

Treatment	Organic C (%)	Total N (%)	OM (%)	P (mg/kg)	K (mg/kg)	Ca (me/100g)	Mg (me/100g)	pH
BNF	0.67	0.07	1.20	0.50	195.00	1.76	0.96	5.60
PNF	0.78	0.11	1.30	0.12	26.50	2.40	0.80	5.40
SNF	0.59	0.06	1.00	2.87	55.00	0.96	0.48	5.10
B-*Stylo*	0.62	0.08	1.00	0.75	56.50	2.72	1.12	5.00
P-*Stylo*	0.86	0.10	1.50	trace	133.50	2.56	0.96	5.30
S-*Stylo*	0.53	0.04	0.90	0.62	75.00	1.60	0.48	5.20
B-*Mucuna*	0.98	0.08	1.70	4.00	48.50	2.40	0.48	5.20
P-*Mucuna*	0.69	0.03	1.20	trace	86.50	2.40	1.12	5.00
S-*Mucuna*	0.45	0.04	0.80	0.12	83.50	1.12	0.48	5.20

B= Burn; P= Plough; S= Slash; NF= natural fallow; *Stylo*= *Stylosanthes;* OM= Org. matter

Appendix 9 Interaction of glyphosate and mucuna cover on speargrass regrowth – 12WAT.

A=Plough-glyphosate; B=Plough only; C=Plough-glyphosate-mucuna; D=Plough-mucuna

Appendix 10: Yam tubers pierced by speargrass rhizomes.