KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

EFFECT OF *Gliricidia sepium* AND *Senna siamea* PRUNINGS ON THE GROWTH AND ROOT YIELD OF CASSAVA

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE MASTER OF PHILOSOPHY IN AGROFORESTRY

BY

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JUNE 2009

DECLARATION

I declare that except references to other people's research work to which due acknowledgement has been given, this thesis submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi for the Master of Philosophy in Agroforestry the results of this project are my own and have not been submitted in any thesis for any award.

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ACKNOWLEDGEMENT

My sincerest gratitude goes to my project supervisor Dr. J.J. Afuakwa, Lecturer, Agroforestry Department, KNUST for his constructive criticisms, guidance and patience and for his constant attention during the write-up of this work for it to become real in spite of his heavy schedule.

I would like to give special recognition and appreciation to the late Dr. Charles Adu-Anning, who was my first supervisor until his untimely death. He gave me a lot of support and encouragement during the period I worked under him. May His Soul Rest In Perfect Peace.

I would like to express my profound gratitude to all the lecturers and staff of the Agroforestry Department.

A special acknowledgement is extended to Drs Francis Tetteh and Roland Nuhu Issaka of the CSIR-Soil Research Institute (SRI), Kumasi, Dr Harrison Dapaah (CSIR-Crops Research Institute, Kumasi), and Mr E. K. Asiedu, Head of Crops Department, University of Education, Mampong Campus. They gave excellent guidance, supervision, constructive criticism, suggestions and contribution which helped to make this work a success. I am also greatly indebted to Mr T. Abotiatey, Mr Frimpong and all laboratory technicians of CSIR-Soil Research Institute for their active assistance in all stages of the field work and data analysis. I cannot forget my parents Mr and Mrs Acquaah and my husband, Mr Ayirebi Dansoh for care, as well as spiritual and moral support during the period of this study.

ABSTRACT

Cassava is grown mainly on impoverished soils with no soil amendments such as fertilizers. Continuous cropping of cassava without adequate maintenance of soil fertility could lead to soil and environmental degradation. With high root yields and as an efficient soil nutrients miner, cassava removes large quantities on N, P, K and Mg. Organic mulches particularly of leguminous plants provide considerable quantities of plant nutrients. Mulching as an agricultural technique is a useful and affordable tool in adapting low external input cropping systems to local economic and environmental conditions. Pruning of plants provides the biomass for use as soil amendment. Field and laboratory studies were conducted at Kwadaso (Kumasi) from April 2005 - Dec 2006 to evaluate the potentials of *Gliricidia sepium* and *Senna siamea* prunings for soil fertility improvement in Ghana. A randomised complete block design (RCBD) was used. Six treatments used were: *Gliricidia sepuim*, *Senna siamea*, ½ *Gliricidia sepium* + ½ fertilizer, ½ *Senna siamea* + ½ fertilizer, control and fertilizer (NPK). Fresh root yield ranged from 11.8 t/ha for Control to 31.0 t/ha for ½ *Gliricidia sepuim* + ½ fertilizer. The *G. sepuim* treatment produced the second highest cassava yield of 24.9 t/ha, while *Senna siamea* and Fertilizer treatment (NPK) treatments gave intermediate cassava fresh root yields of 24.7 and 24.1 t/ha respectively. The highest nitrogen content in cassava leaves was obtained in the Fertilizer treatment and *Gliricidia sepuim* (3.31-3.33 %). The highest leaf phosphorus content was observed in the *Gliricidia sepuim* and *Senna siamea* treatments, while the control, *G. sepuim* and *Senna siamea* had the highest leaf potassium content. The cassava starch content for the sole treatments (sole Gliricidia, Senna, mineral fertilizer) were lower than the combined application of prunings and mineral fertilizer.

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CHAPTER ONE

INTRODUCTION AND BACKGROUND

The genus *Manihot* is a member of the economically important family Euphorbiacea. With several thousand species cassava *(Manihot esculenta* Crantz*)* is the most important species of this genus (Microsoft Encarta Encyclopaedia 2003). Cassava roots mature between 6-18 months depending on cultivar but can remain in the soil for two years after maturation.

Cassava is a perennial, woody shrub with an edible root that grows in tropical and sub – tropical areas of the world. Cassava is an important food in the tropical areas of Africa and Latin America. It is estimated that the crop provides about 41% of all calories consumed in Africa. (Aromolavan, 2004) Cassava is grown almost exclusively as food in 39 African countries, stretching in a wide belt from Madagascar in the Southeast to Senegal in the North–West (Hahn and Keyser, 1985). This crop accounts for approximately a third of the total staples produced in sub – Saharan Africa (FAO, 1986).

Whereas cereals and other crops do not grow well on marginal lands cassava has the ability to grow on marginal lands. It can tolerate drought and can grow in low nutrient soils. Cassava roots can be stored in the soil up to 24 months, and in some varieties up to 36 months. Harvest may be delayed until market, processing, or other conditions are favourable.

CASSAVA IN GHANA

Cassava was introduced from Brazil, its country of origin, to the tropical areas of Africa, the Far East and the Caribean Islands by the Portuguese during the 16th and 17th centuries (Jones, 1959). In the Gold Coast (now Ghana), the Portuguese grew the crop around their trading ports, forts and castles and it was a principal food eaten by both the Portuguese and slaves. By the second half of the 18th century, cassava had become the most widely grown and used crop of the people of the coastal plains (Adams, 1957). The Akan name for cassava 'Bankye' could most probably be a contraction of 'Aban kye' – Gift from the Castle. Cassava is an important crop to Ghana. Although attempts were made to develop cassava in the 1930s after its introduction from Brazil in the 16th century, past government policies marginalized the crop in favour of export crops. Serious research on the crop started in the late 1980's and focussing on the selection for high yields, low hydrocyanic acid (HCN) content, cooking qualities and pest and disease resistance.

The spread of cassava from the coast into the hinterland was very slow. It reached the Akans -Ashanti and Brong Ahafo areas and Northern Ghana, mainly around Tamale, in 1930 (Ofori *et al*., 1997). The Akans of the forest belt preferred plantain and cocoyams, whereas the people of the north preferred sorghum and millet. Despite the introduction of cassava to Ghana in the 16th century and its substantial contributions to the livelihood of the populace the crop remained in obscurity and neglect. Cassava became firmly established in most areas after the serious drought of 1982/83 when all other crops completely failed (Korang – Amoakoh *et al*., 1987). Cassava and its various preparations including fufu, gari and konkonte are now very popular foods throughout Ghana and not only in the coastal regions, as was the case some 20 years ago.

According to Hahn *et al*. (1986), the crop was rapidly adopted by farmers and integrated into the traditional farming and food systems of Africa because of the following factors:

- Adaptability to traditional farming and food systems;
- Relative ease of cultivation and processing;
- Year – round availability and insurance against crop failure;
- Low input or resource requirements;
- Relatively high yield of food energy (calories).

Further more cassava does well in an area where the annual rainfall exceeds 900 mm, with rainy period over 120 – 150 days, and the altitude ranges from sea level to 2000 m above sea level.

The interest in the crop in recent times results from the realization of the potential of cassava as food security and emergence crop which could generate employment for the rural poor and foreign exchange for the country.

Cassava has a comparatively high biological efficiency of food – energy production because of rapid and prolonged crop growth and produces 2.2 times more calories per hectare than maize (FAO, 1986), with a lower resource cost (Hahn *et al*., 1979; Ikepi *et al*., 1986). Cassava's virtue as a human food item is that it is a cheap and abundant source of energy (Ikepi *et al*., 1986). The stability of cassava production (measured using the yearly coefficient of yield variation from 1966 to 1986-cassava 4.3%; maize 36.2%), is the highest among the major world food crops (TAC, 1985). Cassava is predominantly grown on Ultisols and Oxisols in lowland, humid areas of tropical Africa. These soils have low inherent fertilities and are difficult to manage. In these areas of Africa, increasing population pressures have drastically reduced the length of fallow periods leading to poorer soils and low productivity (Hartmans, 1981), and greater vulnerability of crops to drought and acid infertility soils and low cost of carbohydrate (Hillocks, 2003).

In Ghana and most parts of Africa cassava is normally not fertilized. The crop is mostly intercropped with maize or the last crop in most rotation systems. Cassava may benefit

from residual effect under intercropped environment when the maize crop is fertilized. The crop is an efficient soil nutrient extractor and continuous cropping without proper nutrient replacement could deplete the soil nutrient reserves.

The introduction of the Presidential Special Initiative (PSI) on cassava in 2001, which besides other benefits, resulted in the establishment of the Ayensu Starch Company at Bawjiase and the need for more cassava to feed the growing population, underline the need to improve on cassava production per unit area. The use of available and cheaper soil improvement materials may help resource-poor farmers to improve on the production since most farmers are not able to purchase inorganic fertilizers due to their relatively high cost. Fast growing leguminous trees play a significant role in improving soil productivity and can therefore be used to improve cassava production. It is expected that when prunings of *Gliricidia sepium* and *Senna siamea* are used to fertilize the soil, they will significantly increase the yield of cassava. Data are abound on the effect of inorganic fertilizer on cassava. Issaka *et al.* (2007) and Howeler (1987) however reported the effect of organic materials on the growth and yield of cassava as well as the impact of root formation on soil nutrient stores are inadequate or lacking.

The objectives of this study were therefore to:

- Determine the effect of prunings of *Gliricidia sepium, Senna siamea* and inorganic fertilizer on the growth, development and root yield of cassava.
- Evaluate the effect of integrating *Gliricidia sepium* and *Senna siamea* prunings with mineral fertilizer on the growth and yield of cassava.
- Estimate the impact of cassava production on soil N, P and K.

CHAPTER TWO

LITERATURE REVIEW

2.0 Farmers' Cropping Systems

Farmers in Ghana evolved cropping systems in the form of rotations and crop mixtures suitable for various agro- ecological zones in which they operate, generally in the following sequence; maize-legume (cowpea) maize/cassava – fallow (Doku,1967). With fallow periods drastically decreasing in the wake of population pressure on farm land, agronomic investigations are urgently needed to develop appropriate systems of soil fertility maintenance. Farmers do not apply fertilizers owing to high cost and cassava yields vary from 5 tonnes/ha to 25 tonnes/ha or more depending on soil fertility.

2.1 Growth Requirements

Cassava grows well on sandy and loamy soils of reasonable fertility. It can grow on almost all soil types provided they are not waterlogged, too shallow or too stony, since these conditions prevent the formation of roots. Cassava is very resistant to drought and it is one crop that provides food security in drought - stricken areas. It loses its leaves but quickly re –grows them with the first rains after the drought period. Cassava will produce an economic crop on exhausted soils unsuitable for growing other crops and consequently, it is the last crop taken in rotation in shifting cultivation. If soil fertility is too high, there is excessive vegetative growth at the expense of root and starch formation (Purseglove, 1968). Cassava can tolerate pH of 5.5-8.0. It has unsatisfactory growth at low temperatures such as less than 16 ^{o}C; since it cannot withstand chills and frost. It is purely a tropical crop. Long periods of exposure to drought, increase cyanide

accumulation in roots (Githunguri *et al.*, 1998). Cassava does not usually require irrigation, but occasional irrigation during drought is helpful.

Cassava is a crop of the lowland and tropics. Growth is resumed at the onset of the rain. It can be grown in areas where the annual rainfall is as low as 500 mm, provided that there is sufficient water available at planting so that the crop may become established. During periods of drought, the cassava plant sheds its older leaves and becomes almost dormant. Stands of cassava may be left to grow for several years. Roots produced under such conditions show a series of short and long sections, corresponding to dry and rainy season growth.

Land preparation begins with land clearing after which the field is burned to increase the mineral content in the soil. If fertilizer is to be applied, it is advisable to do so in the first and third months of planting. Small-scale farmers hardly apply fertilizer due to its high cost or non- availability in some instances.

2.2 Effect of Fertilizers on the Growth and Root Yield of Cassava

Cassava requires considerable amounts of nitrogen, phosphorus and potassium. Nitrogen application increases the number of tuberous roots formed (Kasele *et al.*, 1984; Odwukwe and Oji, 1984). Nitrogen deficiency can be easily recognized by stunted growth and leaf discoloration. Excessive application of nitrogen without simultaneous application of phosphate or potash may enhance vegetative growth at the expense of root yield (Githunguri *et al.*, 1998). Phosphorus is important for the development of the root system and its deficiency is recognized by stunted growth and violet discolouration of the leaves. Although cassava removes large quantities of potassium from the soil, an adequate supply of nitrogen and phosphorus seems to be more important in producing good yield than is a large supply of potassium. Symptoms of

potash deficiency begin with stunted growth, followed by development of dry, brown spots at the tips and margins of the leaves. Potash deficiency may also affect root quality, increases HCN., decreases starch content (IITA, 1990). If applied correctly, however, it results in significant increase in tuberization, root diameter and weight, storage cell size and number, and dry-matter of roots.

However, at the peasant level of production, fertilizers are not used in the cultivation of cassava, even though application of NPK fertilizers and farmyard manure give positive results (Cong, 2001, Lahai *et al*., 1992, Odwukwe and Oji, 1984). Lahai *et al*.,*(*1992*)* obtained 27 – 36 % increase in root yield due to fertilization while Osiname and Landu (1989) observed reduction in root loss due to leaf harvest when fertilizer was applied at 50 -50-50 NPK/ha. In Vietnam, Cong (2001) obtained maximum root yield when fertilizer was applied at 60-60-120 NPK kg/ha. Even though cassava is an efficient soil extractor of minerals, continuous cropping without proper nutrient replacement could deplete the soil nutrient reserves. Howeler (1987) reported that with respect to P, K and Mg, large amounts are extracted from the soil by cassava compared to other tropical crops. In addition, harvested products have high K/N ratios. Therefore, loss of soil nutrients, particularly K, often results from long-term cultivation of cassava under poor soil management practices and could cause yield decline. Continuous cassava cultivation could also lead to reduction in soil pH through depletion of nutrients, but good soil nutrient management practices like fertilization and inclusion of legume crops in rotation may reverse the resulting yield decline**.** Sasidher and Sadadaddan (1976) found that growing cassava after cowpea on a loam acid soil with pH 5.8 was more profitable than any other sequences without legume-based rotation. The yield of cassava is affected by variety and fertilization (Issaka *et al*., 2007); the authors observed a significant increase in tuber yield when cassava was fertilized. Nitrogen application increased the number of

tuberous roots formed (Kasele *et al*., 1984; Odwukwe and Oji, 1984). Cassava yield after 15 years of continuous cultivation without fertilization dropped from an initial level of 30 t ha^{1-} to 17 t ha^{1-} (Sittibusaya and Kurmarohita, 1978). When fertilizer was later on applied at 375 kg N, 164 kg P_20_5, and 312 kg K_20 ha^{-1}, yields increased from 22 t ha^{-1} to 41t ha^{-1} (Sittibusaya and Kurmarohita, 1978).

2.3 Effect of Leguminous Trees on Soil Fertility Dynamics

Crop yields in large parts of Kenya are low (ICRAF, 1994; ICRAF, 1997) due to declining soil fertility as a result of continuous cropping and non-application of fertilizers by farmers. For example, soils (Acrisols, Ferralsols and Nitisols,) in western Kenya, are poor in organic matter content and have low reserves of nitrogen , phosphorus , and some trace elements (ISSS/ISRIC/FAO.1998) (Mwiinga *et al.*, 1994; Mugendi, 1996; Sanchez *et al*., 1997; Rao *et al.*, 1998). In addition the soils are easily compacted and are prone to erosion. As soon as the vegetative cover is removed and land intensely cropped with grain crops, the soil's physical, chemical and biological properties are readily degraded (ICRAF, 1993; Sanchez *et al.*, 1997).

In Ghana with the liberalization of trade and introduction of structural adjustment programmes (SAP), fertilizer costs have increased to a level unaffordable to small-scale farmers. To increase and maintain crop yields to meet the needs of the growing population has become a major national problem.

Agroforestry technologies such as short duration planted tree fallows and green manuring (biomass transfer) with tree residues have been demonstrated to increase crop yields (Niang *et al*., 1996; ICRAF, 1997). These technologies have also been found to be economically attractive to farmers (Sanchez *et al*., 1997). In the absence of fertilizers, crop production relies largely on nutrient management through organic residues (Vanlauwe *et al*., 1996; Rao *et al.*, 1998).

In western Kenya, farmers have live fences around their farms and grow shrub and tree hedges on contours, but rarely use the biomass from these trees and shrubs for soil fertility improvement. Several studies have shown that tree residues can be used as a source of nutrients to crops (Niang *et al.*, 1996; Palm, 1996; ICRAF, 1997). The residues serve mainly as source of organic matter and nitrogen, but may also contribute significant amounts of other essential nutrients. These residues upon incorporation into the soil can help increase crop yields. For example, experiments conducted in western Kenya, have demonstrated that higher yields of cassava can be obtained with leaf biomass of *Tithonia diversifolia* than even with commercial urea fertilizer (ICRAF, 1996; ICRAF, 1997; Rao *et al.*, 1998). *Tithonia diversifolia* is a soft and succulent shrub belonging to the family Asteraceae and is commonly referred to as wild sunflower. Application of *Tithonia diversifolia* at 5 t ha^{-1} (fresh weight) increased maize grain yield about one and half times higher than fields without soil amendments (Chris *et al*., 2008).

The capacity of any agroforestry system to enhance nutrient cycling depends both on soil fauna, environmental conditions (e.g. temperature, moisture, and aeration) and on management factors. Management aspects include the selection of tree species with appropriate phenology, rooting patterns and litter quality. However, scientists need to understand the complex interactions among the above in order to realize the potential benefits of introducing agroforestry in a given environment (ICRAF, 1993).

2.3.1 *Gliricidia sepium*

Since different legumes may fix different quantities of nitrogen and produce various quantities of biomass, there is the need to select suitable leguminous trees which can significantly affect soil productivity. *Senna siamea* and *Gliricidia sepium* provide a source of renewable organic fertilizer, feed for livestock, and firewood.

Investigations on Alfisols and Entisols in Southern Nigeria have shown that cropping maize and cowpeas sequentially with either *Leucaena* or *Gliricidia* is a promising alley cropping system. Studies conducted on Alfisols at Ilene and at Ibadan with maize alley cropped with *Gliricidia* showed that, at both locations, *Gliricidia* prunings met the nitrogen requirement of maize. Evans (1986) reported that in general *Gliricidia* coppice yield was greatest when coppice numbers were two to three shoots per stool.

2.3.2 Environmental Adaptation of *Gliricidia sepium*.

The tree grows well in acidic soils with a pH of 4.5-6.2. The tree is found on volcanic soils in its native range in Central America and Mexico. However, it can also grow on sandy, clay and limestone soils.

Picture 1: Pictures of *Gliricidia sepium*

2.3.3 *Senna siamea*

Senna siamea is commonly used in hedgerow, intercropping trials for improving soil fertility. It holds large amounts of nitrogen in its foliage. It has high biomass production which can serve as soil fertility improvement plant. It has coppicing ability with termite resistance and serves as windrows, for fuelwood, post and poles, timber, mulch, and supplies food for human consumption. It does well at altitude 0- 1700 m and above 600 mm rainfall.

2.4 Environmental Adaptation of *Senna siamea*.

Senna siamea thrives in the tropical heat. It is most prevalent in areas where annual rainfall is 1000 mm or above and the dry season is less than 4 or 5 months; it grows best in deep, well drained relatively rich soils.

Picture 2: Pictures of *Senna siamea*

2.5 Agroforestry potential of *Senna siamea*

Senna siamea is a fast growing, medium sized tree and it coppices well. It is not good for intercropping, but important due to its fast growth and effective weed control. *Senna siamea* can attain heights of 5 m in 3 years and 15 m in 10 years. It can be planted direct or with seedlings. The seeds may be scarified or soaked in warm water to aid in germination. The fodder is not very palatable, but can be eaten, though leaves may be poisonous to livestock.

2.6 Mulch / Organic Matter

FAO (19) describes soil organic matter as any material produce originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process.

Senna siamea is lopped for mulch and green manure in agroforestry applications. The mulch improves the soil moisture and keeps the soil warm. Organic matter resulting from the mulch stabilizes the soil by improving the structure of the soil. It is used due to its

rapid growth, ability to biologically accumulate atmospheric nitrogen, ease of establishment, adaptability to many different site conditions, and the ability to regrow vigorously after pruning. The amount of pruning applied as mulch has been reported to be positively and significantly related to the amount of moisture in the soil (Banful *et al.*, 2000). Reynolds and Jabbar (1995) showed that the yield of maize was highly correlated with the percentage of *L. leucocephala* and *Gliricidia sepium* prunings produced. Maize yield was also found to be highly correlated to nitrogen content of prunings and rainfall (Vanlauwe *et al.*, 1999). The amount of nutrients recycled through hedgerow prunings varied with location, season, species and hedgerow management (Duguma *et al*., 1985; Van der Meersch, 1992; Ruhigwa *et al*., 1995; Sanginga *et al*., 1995; Kang *et al*., 1999; Tossah *et al*., 1999). Duguma *et al*. (1985) indicated that frequent pruning and lower pruning height lowered biomass and nutrient yields of prunings.

Pruning management and environmental factors also influenced nitrogen fixation rates (Sanginga *et al*., 1995). Nitrogen fixation rates were suppressed by 21% and 19% in *L. leucocephala* and *G. sepium* respectively when prunings were incorporated instead of mulched (Kadiata *et al*., 1997). Generally however, *L. leucocephala* can fix 73% of its nitrogen requirement (Kadiata *et al*., 1997) while 44 to 58% of *G. sepium* nitrogen requirement can be provided through fixation (Rowe *et al*., 1999).

Nutrient yield from prunings is also greatly affected by specie adaptability and biomass yield although N_2-fixing legumes tend to have a high nitrogen yield (Kang and Shannon, 2001). On an acid soil in Sierra Leone, Amara *et al*., (1996) reported average nitrogen yield to be 524, 370 and 297 kg ha^{-1} for *Gmelina arborea* Roxb, *G. sepium* and *Senna siamea* (Lamk) Irwin & Barneby, respectively. On the other hand, higher nitrogen yields were obtained with *S. siamea* and *Albizia lebbeck* (L.) Benth than in *G. sepium* in Southern Togo (Tossah *et al*., 1999). Akonde' *et al*. (1997) reported 253 kg ha^{-1} yr^{-1} of

recycled nitrogen for *L. leucocephala* hedgerows and 131 kg N ha^{-1} yr^{-1} for *Cajanus cajan*. The difference could be due to varying decomposition rates of prunings which is specie-dependent (Issaka *et al*., 2007). Tian *et al*. (1995) indicated that the chemical quality of the prunings in terms of nitrogen, lignin and polyphenol contents affected decomposition and mineralization rates. To enhance decomposition, Read *et al*. (1985) suggested the incorporation of prunings in the soil.

2.7 Nitrogen release and uptake.

In spite of the high nitrogen content of leguminous hedgerow species, there is growing concern on low recovery rates of nitrogen from prunings and on the synchrony of nitrogen use by crops (Sanginga *et al*., 1995; Amara *et al*., 1996). Mulongoy and van de Meersch (1988) reported very low recovery rate of 5 to 10% nitrogen from applied *L. leucocephala* prunings. Similar results by Vanlauwe *et al.* (2001) indicated that only 10% of residue-derived nitrogen from applied *L. leucocephala* prunings was recovered 471 days after application. Van de Meersch (1992) also reported low recovery of nitrogen from *L. leucocephala* and *S. siamea* mulch, contributing about 20 to 30% of nitrogen release to the companion crop. Similarly, Mulongoy and van de Mersch (1988) indicated that in a *L. leucocephala* hedgerow intercropping system, only 20% of released nutrients could be recovered by the adjacent crop. Several other authors have indicated that some plant residues release less N than expected (Vallis and Jones, 1973; Read *et al*., 1985; Sandhu *et al*., 1990; Xu, 1991). As a general rule, Myers *et al.* (1994) stated that the N-use efficiency of plant residues by a first crop was about 15% for legume residues and 5% for cereal straw residues, but there was much variation. For instance, higher nitrogen uptake and recovery were obtained from low quality *C. cajan* prunings (Mafongoya *et al*., 1997b) as a result of its greater contribution to soil organic matter and

hence to particulate organic matter nitrogen than high quality litter that decomposed rapidly (Campbell *et al*., 1994). Vanlauwe *et al.* (1999) stressed that particulate organic matter nitrogen in soil was a better predictor of crop nitrogen uptake. To improve nitrogen recovery in crops, Sanginga *et al*. (1995) advocated mixing high and low quality prunings. Mafongoya *et al*. (1997a) however, observed no improvement in nitrogen recovery from mixing prunings of *L. leucocephala* and *Calliandra calothursus*.

In recent times attention has been drawn to the potential of nutrient contribution from roots of the hedgerow species. Sanginga *et al*. (1990) estimated that about half of the total nitrogen in *L. leucocephala* is found in the roots. Also Kang and Mulongoy (1992) observed that *G. sepium* had almost half of the fixed N in stems and 40% in roots and only a small proportion found in leaves.

2.8 Decomposition of hedgerow prunings and earthworm activity

Plant residue is the external main source of nutrient supply in low input agricultural systems. Nutrient release from residue such as prunings is determined by decomposition rate which is largely regulated by soil fauna (Tian and Badejo, 2001). Earthworms facilitate the decomposition processes of mulch and play an important role in soil fertility through nutrient cycling and the formation of organic matter (Bargali *et al*., 1993). Earthworms increased the breakdown of prunings of *Dactyladenia barteri* (Hook. f. ex Oliver) G.T., a low quality residue, by 27% and *Gliricidia*, a high quality residue by 1.4% (Tian *et al*., 1995). In a study of natural and planted fallows, Tian *et al.* (2000) indicated that the decomposition rate of leaf litter was correlated with the number of earthworms under the fallow. Henrot and Brussaard (1997) reported that soil macrofauna contributed between 30 and 40% of mulch decomposition over the period of approximately 50% disappearance of the original materials on an acid soil. Soil

macrofauna, particularly, earthworms, were also found to contribute to the breakdown of tannin-protein complexes accumulated during decomposition of residue (Lavelle *et al*., 1993).

Tian and Badejo (2001) reported that when earthworms consumed organic compounds, nitrogen tied up in the food was released due to their efficient carbon utilization and less efficient nitrogen utilization. According to Asawalam (1997), total nitrogen and organic carbon contents of earthworm casts were 2-3 times higher than in soil. Lopez-Hernandez *et al*. (1993) also found that earthworms enhanced release of phosphorus through earthworm phosphateases. Gilot (1997) noted that in the presence of earthworm, soil carbon mineralization decreased by 5% after three years. Martin (1991) and Blanchart *et al.* (1993) also made similar observations and ascribed the reduction to the physical protection offered by the compact nature of the casts and a protective hydrophobic impermeable cortex layer. Lavelle (1994) hypothesized that the presence of earthworms could limit the loss of organic matter in disturbed systems such as annual crops and modify the quality of soil organic matter by the protection of young organic matter. Gilot (1997) confirmed the hypothesis in a three-year study.

Improvement in soil physical condition could also be attributed to increased earthworm activity under alley cropping (Kang *et al*., 1990; Hauser *et al*., 1998). Earthworm activity improved soil porosity while decomposing plant residue (Kang and Shannon, 2001). Aina (1984) indicated that high infiltrability associated with tropical soil under forest cover was largely due to earthworm activity. Similarly, Cogle *et al.,* (1994) reported that earthworm activity significantly enhanced water infiltration and reduced soil erosion in an Alfisol. Intense earthworm activity was observed to transform a compact soil to a porous structure (Chauvel *et al.,* 1999) by increasing the proportion of large aggregates

through casting (Gilot, 1997). Casting led to the stability of aggregates (Blanchart, 1992).

2.9 Effect of hedgerow prunings on soil physical properties and conservation

Prunings from hedgerow species have been shown to improve the soil physical conditions of an Alfisol (Hulugalle and Kang, 1990). Prunings of *G. sepium* or *C. cajan* increased size and water stability of soil aggregates and reduced soil bulk density within three years of hedgerow establishment (Mapa and Gunasena, 1995). Salako and Hauser (2001) reported that *S. siamea*, *L. leucocephala*, *A. leptocarpa* and *A. auriculiformis* significantly improved soil bulk density better than *Pueraria phaseoloides* cover crop in a planted fallow system. Further, soil aggregate stability was greater for *L. leucocephala* than for *P. phaseoloides*.

Flemingia macrophylla [(Willd.) Merrill] and *L. leucocephala* prunings also increased soil moisture and reduced soil temperature in an alley cropping system (Banful *et al*., 2000). Hulugalle and Ndi (1993) reported a decrease in dry season soil temperature and an increase in water infiltration rate of an Ultisol. The high infiltration rate contributed to reduced water runoff and soil erosion (Kang and Ghuman, 1991). In a study in Nigeria, Lal and Dick (1997) stated that alley cropping reduced concentrations of sediment and nutrients in runoff on slopes of 2-8%.

2.10 Effect of hedgerow prunings on soil nutrient status.

Application of hedgerow prunings resulted in higher soil organic carbon, sulphur, exchangeable calcium, magnesium and potassium and a decreasing C/N ratio (Jones *et al*. 1996). Kang *et al* (1999) indicated that prunings led to higher organic carbon, phosphorus, potassium and calcium contents but lower magnesium content.

Application of two or more prunings of *L. leucocephala* resulted in positive net balances between mineralized nitrogen, potassium and calcium and nutrients removed in the crop but led to a negative net balance for phosphorus and magnesium (Lupwayi and Haque, 1999). Schroth *et al* (1995b) also indicated that alley cropping with *G. sepium* reduced nitrogen and magnesium losses from a Ferralic Cambisol. Contrary to the results above, Akonde *et al* (1997) observed net losses of nitrogen, potassium, calcium and magnesium in an alley cropping system on an Acrisol. However, compared to natural regrowth, decline in nutrients was less with alley cropping and stabilized at a higher level (Kang and Ghuman, 1991; Van der Meersch, 1992; Kang *et al*., 1999). Continuous application of prunings with high nitrogen content also tended to lower soil pH (Kang *et al*., 1999).

There was evidence that organic amendments could decrease phosphorus absorption and increase its availability to crops (Dick *et al*., 2001). This could be attributed to mechanisms such as complexation of aluminium and iron by organic acids or other organic compounds (Iyamuremye and Dick, 1996). Kumwenda *et al.* (1998) reported that *C. cajan* had been found to produce root exudates containing piscidic acid (phenolic compound) which could chelate iron to free phosphorus from iron phosphates in soils. The exudates could also dissolve rock phosphate to make phosphorus available for crop use.

Alley cropping affects the nutrient distribution within the soil profile. Hauser (1990) reported that nitrogen, calcium and magnesium concentrations were higher in the surface soil under *L. leucocephala* hedgerows than in the alleys or in no-tree control plot. The higher nutrient concentration in the hedgerows was from litter fall and earthworm casts. Although alley cropping was compared to a forest system, the presence of deep rooting woody species provided a better safety net for the recapture of leached nutrients than a monocrop system (Douthwaite *et al*., 2002; IITA, 1993). Horst *et al* (1995) reported that

alley cropping with *L. leucocephala* reduced nitrate leaching below 150-cm depth compared to the no-tree control. These observations indicate that soil under alley cropping could provide a better dynamic sink and source of plant nutrients than soil under no-tree (Kang and Shannon, 2001).

2.11 Effect of hedgerow prunings on crop production.

Different responses of food crops to alley cropping have been reported in the humid and sub-humid zones. The responses of maize, rainfed rice and grain legumes to alley cropping have consistently been positive (Kang *et al*., 1995). Budelman (1990) also showed a positive benefit from alley cropping yam (*Dioscorea rotundata* (L.) Poir) with *G. sepium* in Ivory Coast. Ruhigwa *et al* (1995) reported that plantain (*Musa* spp.) grown on an Acrisol performed well in alley cropping with *D. barteri*. However in a previous study, Swennen and Wilson (1985) reported that mulch of *F. macrophylla* decreased yield of plantain relative to the control.

Positive yield results of a variety of vegetable crops alley cropped with *L. leucocephala* have been reported (Palada *et al*., 1992). Hauser (1990) reported that *F. macrophylla* alley cropping produced the highest cumulative maize grain and cassava tuber yields which were 42% to 67% more than the no-tree control. Consequently they recommended *F. macrophylla* for continuous alley cropping of maize/cassava intercrop. However, Meregini *et al.,* (1995) did not find a yield advantage when alley cropped with cassava, while, Kang *et al*., (1995) reported a reduction in yield of cassava. Shading related to inappropriate hedgerow management was suggested to have accounted for the low cassava yields (Welke *et al*., 1995; Kang *et al*., 1998). Versteeg *et al.* (1998) also observed decreased maize yield from 1200 to 500 kg ha^{-1} in the absence of timely pruning in the derived savanna in Benin. Sanginga *et al*. (1995) and Amara *et al.* (1996)

stressed the need to modify hedgerow management to better synchronize nutrient release from biomass and crop uptake. Van der Meer (1998) indicated the need to manipulate the crop-hedgerow interrelationships to render alley cropping more effective.

In a maize alley cropping study with *G. sepium* and *L. leucocephala*, prunings showed the most benefit to the maize and when applied at four weeks before planting than at four weeks and six weeks after planting of maize (Mulongoy *et al*., 1993). Read *et al*. (1985) reported a higher maize yield and nitrogen uptake with incorporation of *L.leucocephala* prunings in the soil compared to their application as mulch. However, Mulongoy *et al*., (1993) did not observe any difference in maize nitrogen uptake between mulching and soil incorporation of prunings of *F.macrophylla, G. sepium, L.leucocephala* and *S. siamea.*

On sustainability of the system, long-term studies have shown that yields under continuous cropping could be maintained at moderate levels by alley cropping without nitrogen fertilizer input, and at higher yield levels with only moderate rates of fertilizer (van der Meersch, 1992; Kang *et al*., 1999). Vanlauwe *et al*., (2001) reported that yields in long-term alley cropping systems without fertilizer were sustained at 1061 kg ha^{-1} (*L. leucocephala*) and 1849 kg ha^{-1} (*S. siamea*) relative to control yields of 934 kg ha^{-1}. Long term data also showed that occasional tillage of the alleys could increase crop yield (Kang *et al*., 1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description

The experiment was conducted at Central Agricultural Station (CAS), Kwadaso, at the CSIR-Soil Research Institute experimental fields which lie (06^0 43' N, 01^0 36' W), between the periods of April 2005 – December 2006. The area has an altitude of 28.71m above sea level and bimodal rainfall with major and minor seasons in March to July and September to November respectively. The mean annual rainfall is 1100 mm. The mean temperature ranges between 24 ^oC and 27 ^oC. The soils in the area belong to the Kumasi-Asuansi Soil Association (Ghana Soils Classification) or Ferric Acrisol-Dystic Fluvisol (FAO/ UNESCO Soil Classification, 1998).

3.2 Soil Sampling.

Initial soil samples were taken from 20 points covering the whole field layout at 0-20 cm. For each depth the soil was well mixed and composite sample taken and labeled. Composite soil samples were again taken after harvest according to treatments.

3.3 Laboratory analysis.

Soil samples were sent to Soil Research Institute for analysis. Soil samples were first dried, ground, and passed through a 2 mm mesh sieve. Soil pH (H_2O) was measured with a pH meter (glass electrode) according to the method recommended by McLean (1982). Organic matter and total carbon were determined by wet combustion (Walkley and Black, 1934), total nitrogen content by the macro-Kjeldahl method as described by Bremner (1965). Exchangeable cations were first extracted with ammonium acetate and

the various cations determined by atomic absorption spectrophotometry (Thomas 1982). Potassium was determined by a Flame Photometer. Available phosphorus content was determined by the method of Bray and Kurtz (1945).

Prunings of *Senna siamea* and *Gliricidia sepium* were analysed for the levels of Nitrogen, Phosphorus, Potassium, Carbon and Carbon: Nitrogen ratio.

3.4 Experimental design and treatments

A Randomized Complete Block Design with four replications was used. Six treatments were used viz:

T1: Control (no soil amendment applied)

T2*: Gliricidia sepium* pruning: 5 tons per hectare dry matter

T3*: Senna siamea* pruning : 5 tons per hectare dry matter

T4: Mineral fertilizer: N-P_2O_5-K_2O kg per hectare (90-60-60)

T5 *Gliricidia sepium* pruning (2.5 t/ha dry matter) + N-P_2O_5-K_2O kg per hectare (45-30-30)

T6: *Senna siamea* pruning (2.5 t/ha dry matter) + N-P_2O_5-K_2O kg per hectare (45-30-30)

3.5 Agronomic practices

Cassava variety, *Afisiafi* was used as the test crop and planted on plots 6.0 m x 5.0 m at a planting distance of 1 m x 1 m.

Prunings were broadcast and incorporated using a hoe one week to planting. Prunings were applied fresh. Mineral fertilizer was split applied. Half of the mineral fertilizer was applied 4 weeks after planting and the other half 12 weeks after planting by side banding and buried.

3.6 Estimation of quantity of fresh prunings required for application.

The dry matter equivalent of the fresh prunings was estimated by first determining the dry matter of *Senna siamea* (36%) and *Gliricidia sepium* (30%).

The quantity of fresh prunings (X) that is equivalent to a known amount of dry matter (Y) is given by;

$X = 100/Z \times Y$

Where Z is the % dry matter of the fresh prunings

For *Senna siamea* the quantity of fresh prunings equivalent of 5.0 t dry matter per 1 ha was 13,889 kg (41.7 kg/plot of 30 m^2)

For *Gliricidia sepium* the quantity of fresh prunings equivalent of 5.0 t dry matter per ha was 16,667 kg (50.0 kg/plot of 30 m^2)

3.7 Data collection

Data were collected for the following parameters:

- Number of plants per plot
- Number of roots per plot
- Weight of roots per plot
- Above ground biomass
- Percent dry matter of roots, stem and leaves
- Starch content of root

The above ground biomass was separated into stems and leaves and weighed. Sub samples (3 replications) of the various parts were taken, weighed fresh and then oven dried at 60^oC for two days and weighed. Separate sub samples were taken again, oven dried at 60 ^oC for two days and ground. These were used for analysis.

3.8 Statistical Analysis.

Statistical software, Statistix 7, was used for statistical analysis.

3.9 Detailed procedures for soil analysis.

3.9.1 Soil Analytical methods.

The chemical and physical properties of the soil were determined in the laboratory of Soil Research Institute, Kwadaso-Kumasi. The soil samples were air-dried, ground and passed through a 2-mm mesh sieve before analysis.

3.9.2 Soil pH.

Soil pH was determined in a 1:2.5 suspension of soil and water using a HI 9017 Micro-processor pH meter. A 20 g soil sample was weighed into 100 ml polythene bottle. 50 ml distilled water was added and the bottle capped. The solution was shaken on a reciprocating shaker for two hours. After calibrating the pH meter with buffer solutions at pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

3.9.3 Soil organic carbon.

Organic carbon was determined by a modified Walkley and Black procedure as described by Nelson and Sommers (1982). This procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After reaction, the excess dichromate is titrated against ferrous sulphate. One gram of soil sample was weighed into an Erlenmeyer flask. A reference sample and a blank were included. Ten millilitres of 1.0 N (0.1667 M) potassium dichromate solution was added to the soil and the blank flask. 20 ml of concentrated sulphuric acid was carefully added from a flat bottom flask, swirled and allowed to stand for 30 minutes in a fume cupboard.

250ml distilled water and 10 ml concentrated orthophosphoric acid were added and allowed to cool. One millilitre of diphenylamine indicator was added and titrated with 1.0 M ferrous sulphate solution.

Calculation

The organic carbon content of soil was calculated as,

$$\% \text{ Organic C} = \frac{M \times 0.39 \times mcf \ (V_1 - V_2)}{s}$$

where;

M = molarity of ferrous sulphate solution

V_1 = ml ferrous sulphate solution required for blank

V_2 = ml ferrous sulphate solution required for sample

s = weight of air-dry soil sample in gram

mcf = moisture correcting factor (100 +% moisture) / 100)

0.39 = 3 x 0.001 x 100% x 1.3 (3 = equivalent weight of C).

1.3 = a compensation factor for the incomplete combustion of the organic matter.

3.9.4 Total Nitrogen

Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described in Soil Laboratory Staff (1984). A 0.5 g soil sample was put in a Kjeldahl digestion flask and 5.0 ml distilled water added to it. After 30 minutes, 5.0 ml concentrated sulphuric acid and selenium mixture were added and mixed carefully. The sample was placed on a Kjeldahl digestion apparatus for 3 hours until a clear digest was obtained. The digest was diluted with 50.0 ml distilled water and mixed well until no more sediment dissolved and allowed to cool. The volume of the solution was made to 100 ml with water and mixed well. A 25 ml aliquot of the solution was transferred to the

reaction chamber and 10.0 ml of 40% NaOH solution was added followed by distillation. The distillate was collected in 2% boric acid. The distillate was titrated with 0.02 N HCl solution with bromocresol green as indicator. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

Calculation:

The % N in the sample was expressed as:

$$\%N = \frac{N \times (a - b) \times 1.4 \times mcf}{s}$$

where:

N = concentration of HCl used in titration.
a = ml HCl used in sample titration
b = ml HCl used in blank titration
s = weight of air-dry soil sample in gram.
mcf = moisture correcting factor (100 +%moisture)/100
1.4 = 14 x 0.001 x 100% (14 =atomic weight of nitrogen*)* (14.0067)

3.9.5 Bray's No1 Phosphorus (Available phosphorus).

The readily acid – soluble forms of P were extracted with HCl: NH_4F mixture called the Bray's No. 1 method as described by Bray and Kurtz (1945) and Olsen and Sommers (1982). Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent.

A 2.0 g soil sample was weighed into a shaking bottle (50 ml) and 20 ml of extracting solution of Bray-1 (0.03 M NH_4F and 0.025 M HCl) was added. The sample was shaken for one minute by hand and then immediately filtered through a fine filter (Whatman No. 42). One ml of the standard series, the blank and the extract, 2 ml boric acid and 3 ml of the coloring reagent (ammonium molybdate and antimony tartarate solution) were pipetted into a test tube and homogenized. The solution was allowed to stand for 15

minutes for the blue colour to develop to its maximum. The absorbance was measured on a spectronic 21D spectrophotometer at 660nm wavelength.

A standard series of 0, 1.2, 2.4, 3.6, 4.8, and 6 mg P/l was prepared from a 12-mg/l stock solution by diluting 0, 10, 20, 30, 40, and 50 ml of 12 mg P/l in 100 ml volumetric flask and made to volume with distilled water. Aliquots of 0, 1, 2, 4, 5 and 6 ml of the 100 mg P/l of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

Calculations:

$$P\ (mg/kg) = \frac{(a - b)\ x\ 20\ x\ 6\ x\ mcf}{s}$$

where

a = mg/l P in sample extract
b = mg/l P in blank
s = sample weight in gram
mcf = moisture correcting factor
20 = ml extracting solution
6 = ml final sample solution

3.9.6 Exchangeable cations.

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate (NH_4OAc) extract (Black, 1965) and the exchangeable acidity (hydrogen and aluminum) was determined in 1.0 M KCl extract as described by Page (1982).

3.9.7 Extraction of the exchangeable bases.

A 10 g sample was transferred into a leaching tube and leached with 250 ml of buffered 1.0 M ammonium acetate (NH_4OAc) solution at pH 7.

3.9.8 Determination of calcium and magnesium.

For the determination of the calcium plus magnesium, a 25 ml portion of the extract was transferred into an Erlenmeyer flask and the volume made to 50 ml with distilled water. A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 per cent potassium cyanide (from a burette), 1.0 ml of 2.0 per cent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01 M EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour. A 20 ml 0.01 M magnesium chloride solution was also titrated with 0.01 M EDTA in the presence of 25 ml of 1.0 M ammonium acetate solution to provide a standard blue colour for the titration.

3.9.9 Determination of Calcium only.

A 25 ml portion of the extract was transferred to a 250 ml Erlenmeyer flask and the volume made to 50 ml with distilled water. Hydroxylamine hydrochloride (1.0 ml), potassium cyanide (1.0 ml of 2% solution) and potassium ferrocyanide (1.0 ml of 2%) were added. After a few minutes, 4 ml of 8 M potassium hydroxide and a spatula of murexide indicator were added. The solution obtained was titrated with 0.01 M EDTA solution to a pure blue colour. Twenty millilitres of 0.01 M calcium chloride solution was titrated with 0.01 M EDTA in the presence of 25 ml 1.0 M ammonium acetate solution to provide a standard pure blue colour standard.

Calculations:

The calculation of the concentration of calcium + magnesium or calcium follows the equation:

$$\text{Ca + Mg (or Ca) (cmol/kg soil)} = \frac{0.01x(Va - Vb)x1000}{0.1xW}$$

where

W = weight in grams of oven – dry soil extracted

V_a = ml of 0.01 M EDTA used in the titration

V_b = ml of 0.01 M EDTA used in blank tritration.

0.01 = concentration of EDTA used

$$Ca = Mg \text{ (or Ca) (cmol/kg soil)} = \frac{0.01x(Va - Vb)x1000}{0.1xW}$$

3.9.10 Exchangeable potassium and sodium determination.

Potassium and sodium in the percolate were determined by flame photometry.

A standard series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l. This was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15, and 20 ml of the 100 mg/l standard solution were put into 200 ml volumetric flasks respectively. One hundred millilitres of 1.0 M NH_4OAc solution was added to each flask and made to volume with distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelengths of 766.5 and 589.0 nm respectively.

$$\text{Exchangeable K (cmol/kg soil)} = \frac{(a - b) \text{ x } 250 \text{ x } mcf}{10 \text{ x } 39.1 \text{ x } s}$$

$$\text{Exchangeable Na (cmol/kg soil)} = \frac{(a - b) \text{ x } 250 \text{ x } mcf}{10 \text{ x } 23 \text{ x } s}$$

where

a = mg/l K or Na in the diluted sample percolate

b = mg/l K or Na in the diluted blank percolate

s = air –dried sample weight of soil in gram

mcf = moisture correcting factor

3.9.11 Exchangeable acidity.

Exchangeable acidity is defined as the sum of Al and H. The soil sample was extracted with unbuffered 1.0 M KCl, and the sum of Al and H was determined by titration. Fifty grams of soil sample was put in a 200 ml plastic bottle and 100 ml of 1.0 M KCl solution added. The bottle was capped and shaken for 2.0 hours and then filtered. Fifty millilitres portion of the filtrate was taken with a pipette into a 250 ml erlenmeyer flask and 2 – 3 drops of phenolphthalein indicator solution added. The solution was titrated with 0.1 M NaOH until the colour just turned permanently pink. A blank was included in the titration.

$$\text{Exchangeable acidity (cmol/kg soil)} = \frac{(a - b) \times M \times 2 \times 100 \times mcf}{s}$$

where:

a = ml NaOH used to titrate with blank

b = ml NaOH used to titrate with blank

M = molarity of NaOH solution.

s = air – dried soil sample weight in gram

2 = 100/50 (fitrate / pipetted volume)

mcf = moisture correction factor ((100 + % moisture) /100)

3.9.12 Effective cation exchange capacity (ECEC).

Effective cation exchange capacity was determined by the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) and exchangeable acidity (Al^{3+}+H^{+})

3.10 Detailed procedures for Plant analysis.

3.10.1 Plant sampling and preparation.

Leaves of *Senna siamea* and *Gliricidia sepium* sampled at harvest were kept in paper envelopes and oven-dried at 80 ^{0}C for 48 hours after which they were milled to pass through 20 mesh sieve.

3.10.2 Nitrogen.

Total nitrogen was determined by the Kjeldahl method in which plant material was oxidized by sulphuric acid and hydrogen peroxide with selenium as catalyst. The N present was converted into NH_4^{+}. The ammonium ion, which reacts with the excess of sulphuric acid to form ammonium sulphate, was distilled off in an alkaline medium into boric acid.

$$NH_3 + H_3BO_3 \rightarrow NH_4^{+} + H_2BO_3^{-}$$

The $H_2BO_3^{-}$ that was formed was titrated with standard hydrochloric acid back to H_3BO_3. 20.0 g oven-dried plant materials was ground in a stainless steel hammer mill with a sieve mesh of 1 mm, and mixed well to ensure homogeneity. 0.2 g of the plant material was weighed into a Kjeldahl flask, a tablet of selenium catalyst was added and 5 ml of concentrated H_2SO_4 was also added to the mixture. This was digested on the Electrothermal Kjeldahl apparatus for three hours. After the clear digest had cooled, 20 ml of distilled water was poured into the Kjeldahl flask containing the digested material before it was transferred into a 100 ml distillation tube. In the distillation tube another 20

ml distilled water was added plus 20 ml 40 % NaOH and then distilled for 4 minutes. The distillate was received in a conical flask containing 20 ml of 4 % boric acid with PT5 indicator (methyl red and bromocresol green indicators). The received greenish solution was titrated against 0.1 M HCl dispensed from a burette. Percent N was calculated from the volume of HCl used to attain end-point (Soil Laboratory Staff, 1984).

Calculation:

$$\% \text{ N DM}^{-1} = \frac{(a - b) \times M \times 1.4 \times mcf}{s}$$

where

a = volume of 0.1 M HCl used for sample titration

b = volume of 0.1 M HCl used for blank titration

M = molarity of HCl

1.4 = 14 x 0.001 x 100 % (14 = atomic weight of N)

s = weight of sample in milligrams

3.10.3 Organic carbon.

Organic carbon content of organic material was determined using the dichromate-acid oxidation method. To 0.5 g of organic material in an Erlenmeyer flask was added 10 ml concentrated sulphuric acid, 10 ml 0.1667 M $K_2Cr_2O_7$ and 10 ml of concentrated orthophosphoric acid. After the addition of water, the solution was allowed to stand for 30 minutes and back titrated with 1.0 M $FeSO_4$ solutions with diphenylamine indicator.

The organic carbon content was calculated from the following equation:

$$\% \text{ C} = \frac{M \times 0.39 \times 10^{-3}}{s} \times (a - b)$$

where

M = molarity of $FeSO_4$

a = volume of $FeSO_4$ solution required for blank titration

b = volume of $FeSO_4$ solution required for sample titration

s = weight of oven-dried sample in grams

0.39 = 3 x 0.001 x 100 % x 1.3 (3 = equivalent weight of carbon).

1.3 = compensation factor allowing for incomplete combustion

3.10.4 Determination of phosphorus and potassium.

Phosphorus and potassium were determined in plant ash using the Vanado-Molybdenum method. 0.5 g of the plant material was weighed into a porcelain crucible and ashed in a muffle oven at a temperature of 450 – 500 ^{0}C. The ashed sample was removed from the oven after cooling and then made wet with 1–2 drops of distilled water and 10 ml of 1:2 dilute HNO_3 added. The crucible was then heated on a water bath until the first sign of boiling was observed. The crucible was removed and allowed to cool. The content was filtered into a 100 ml volumetric flask using a no. 540 filter paper. The crucible was washed two times with 5 ml distilled water followed by the filter which was also washed two times with 20 ml distilled water. After, 10 ml each of ammonium vanadate and ammonium molybdate solutions were added and shaken thoroughly. The solution was allowed to stand for 10 minutes for full colour development and then filled to the 100 ml mark. A standard curve was also developed concurrently with P concentrations ranging from 0, 1, 2, 5, 10, and 15 to 20 µg P per litre of solution. The absorbance of the sample and standard solutions were read on the spectrophotometer (spectronic 21D) at a wavelength of 470 nm. A standard curve was obtained by plotting the absorbance values of the standard solutions against their concentrations. Phosphorus concentration of the samples was determined from the standard curve. Potassium in the ash solution was determined using a Gallenkamp flame analyser. Potassium standard solutions were

prepared with the following concentration: 0, 10, 20, 40, 60 and 100 µg K per litre of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission values against their respective concentrations.

3.10.5 Harvest Index Calculation

$$\frac{\text{Root yield per plot}}{\text{Total biomass per plot}} \quad \text{or} \quad \frac{\text{Root yield per hectare}}{\text{Total biomass per hectare}}$$

3.10.6 Biomass Calculation

Weight of dry leaves + weight of dry stem + weight of dry roots = Total dry matter

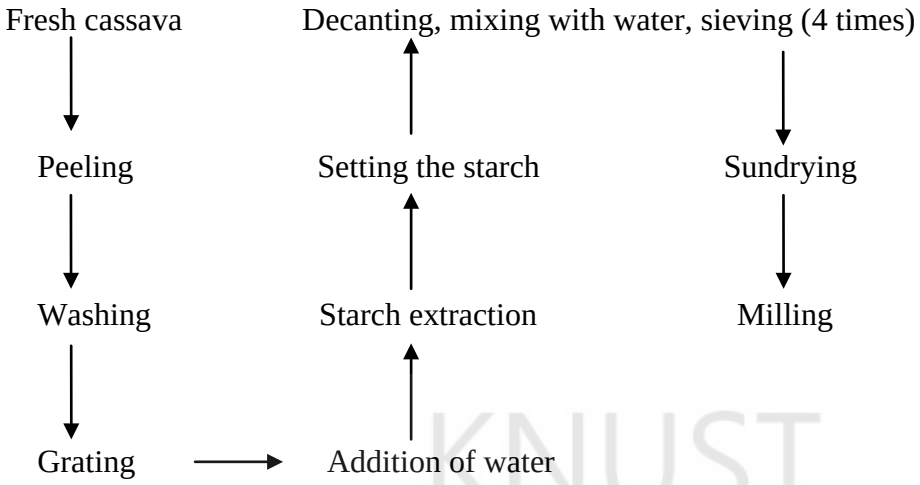
3.10.7 Starch Exraction.

Starch was extracted using the wet extraction method. The harvested cassava roots were selected at random, washed and peeled with a knife. The peeled roots were further washed under tap water to remove dirt. They were cut into pieces with sizes ranging from 2cm - 3 cm and 1 kg of these chunks ground into a slurry using a blender (model 32 BL 80 (8011)

The blender was then switched on at low speed for 60 seconds. Starch was obtained from the resultant slurry by filtering through clean cheese cloth. The residue was further mixed with 200 ml of water and starch extracted from the slurry, by filtering through cheese cloth. This cycle was repeated several times until little or no starch was present in the filtrate. The filtrate was allowed to stand for 3 hours and then the supernatant decanted.

500 ml of water was added to resuspend the starch and supernatant decanted after 3 hours. The wet starch obtained was dried in a solar tent dryer for 48 hours. The extraction process is summarized in the flow chart below.

Flow chart for the process



Cassava starch content Calculation:

$$X = \frac{(a \times 100)}{b}$$

where

a = wt of dry root starch (kg)

b = wt of fresh cassava root (kg)

3.10.8 Economic importance of starch

Starch provides calories and also is slow to metabolise so it gives you energy for longer. That means it's good for eating before physical activities like running or playing football. it can be found in potatoes and other root vegetables. Starch is one of the most important plant products to man. It is an essential component of food providing a large proportion of the daily calorific intake and is important in non-food uses such as in adhesives. The amylose and amylopectin granules in starch contains small amounts of lipid and phosphate. Starch is important energy source in baby foods because it has a low fermentability. It is estimated that 70% of the starch produced is converted into syrups for food use . Modified waxy maize starch is important in processed meat products

where its gelling properties are useful as a binder to maintain the texture and stability of the processed product. Food is not the only use of starch, industrial uses are also very important. Starch is used as an additive in cement to improve the setting time and it is used to improve the viscosity of drilling muds in oil wells and so seal the walls of bore holes and prevent fluid loss. In paper-making, starch is used for several purposes. As a filler it bonds the cellulose fibres together and improves the strength of the product. It is used as an adhesive in paper bags. It is also used as a coating to improve writing and erasing properties and to improve the finish quality. One particular use is in carbonless copy papers.

CHAPTER FOUR

RESULTS

4.1 Chemical Properties of Soil, *Gliricidia sepium* and *Senna siamea* Biomass

Initial soil properties are presented in Table 4.1. The soil was acidic and low in total nitrogen, available phosphorus and exchangeable Ca and Mg. Exchangeable K was moderate.

Table 4.1 Initial soil chemical properties of the study site (0-20 cm) and soil chemical properties at harvest.

Treatment	Soil pH (H2O 1:1)	Total N (%)	Org M	Exchangeable Cations (cmol (+) kg^{-1})					Bray No 2 P ($mg\ kg^{-1}$)	Bray Extractable K ($mg\ kg^{-1}$)
				Ca	Mg	K	Na	ECEC		
Initial soil sample	5.94	0.11	2.14	4.96	0.96	0.32	0.99	7.23	4.20	108.60
G. sepium	4.50	0.11	2.41	5.12	0.93	0.28	0.04	6.44	9.26	142.50
Senna siamea(ss)	4.49	0.15	3.08	5.38	0.96	0.31	0.03	6.68	8.70	140.50
Full Fertilizer	4.60	0.12	2.63	4.92	0.99	0.32	0.05	6.27	2.69	172.00
½ Gli+½ Fert	5.09	0.15	3.06	6.84	0.80	0.32	0.04	7.36	2.95	135.30
½ SS+½ Fert	5.71	0.13	2.79	5.24	0.90	0.25	0.03	6.43	7.73	148.90
Control	4.46	0.12	2.51	6.36	0.96	0.34	0.02	7.17	8.29	164.20
Mean	5.03	0.13	2.66	5.55	0.93	0.31	0.19	6.87	6.64	144.60
Standard error	0.22	0.01	0.13	0.28	0.02	0.12	0.04	0.17	3.37	7.80

Soil chemical properties at harvest are presented in Table 4.1. Soil pH was strongly acidic for all the treatments except for ½ SS+½ Fertilizer which was acidic. Exchangeable Ca was highest for the ½ Gli+½ Fertilizer and Control treatments while the Fertilizer (NPK) treatment gave the lowest value. Exchangeable K was similar for all the treatments. The *Senna siamea* and ½ Gli+½ Fertilizer treatments gave the highest values for both organic matter and nitrogen. Available P was highest for G. *sepium*,

Senna siamea, ½ SS+½ Fert and Control. Very low values of available P were observed under Full Fertilizer and ½ Gli+½ Fertilizer treatments.

Table 4.2. Nutrient composition of *Gliricidia sepium* and *Senna siamea*

Plant material	N	P	K	C	C/N
			%		
Gliricidia sepium prunings	2.85	0.31	1.19	46.5	16
Senna siamea prunings	2.04	0.22	0.44	45.5	22

Selected nutrient content and Carbon Nitrogen ratio of *Gliricidia sepium* and *Senna siamea* prunings are presented in Table 4.2. *Gliricidia sepium* showed higher values for N P and K than *Senna siamea* prunings.

Table 4.3 Plant biomass and inorganic fertilizer application and their effect on cassava root N, P, K and starch content.

Treatment	Nitrogen(N)	Phosphorus (P)	Potassium(K)	Starch content
		%		
Gliricidia sepium	3.31	0.34	0.83	22.2
Senna siamea	2.82	0.34	0.84	22.6
Fertilizer (NPK)	3.33	0.28	0.67	23.9
½ *Gliricidia* + ½ Fertilizer	3.29	0.26	0.73	27.9
½ *Senna siamea* + ½ Fertilizer	3.19	0.28	0.68	25.2
Control	3.10	0.29	0.82	22.2
Mean	3.17	0.30	0.71	24.0
LSD	0.98	0.09	0.28	0.8
CV (%)	20.5	20.2	26.3	3.3

Nitrogen content of cassava roots ranged from 2.82 % to 3.33% and the differences among treatments were not significant (Table 4.3). Phosphorus contents of the roots were also similar. Fertilizer (NPK) treatment gave the lowest significant K content (0.67%), all the other treatments gave similar values. ½ *G. sepium* + ½ Fertilizer gave the highest

starch content followed by ½ *S.siamea* + ½ Fertilizer and Full Fertilizer. The other treatments gave similar values (Table 4.3).

Except for *S. siamea* all the soil amendments resulted in significantly larger number of cassava stands per hectare than the control (Table 4.4). Fertilizer (NPK) (51,167) and *G. sepium* (56,667) gave significantly higher numbers p=0.05 of roots ha^{-1} than control (36,458). Root weight was similar for *G. sepium, S. siamea, and* ½ *G. sepium* + ½ Fertilizer and which were significantly higher (p=0.05) than the Control. Addition of plant biomass or application of mineral fertilizer resulted in higher root yield than the control. ½ *G. sepium* + ½ Fertilizer (31.0 t ha^{-1}) gave significantly higher root yield than ½ *S. siamea* + ½ Fertilizer (21.9 t ha^{-1}).

Table 4.4 Effect of *G. sepium, S. siamea* and inorganic fertilizer on fresh root yield and yield components of cassava.

Treatments	Number of Stand ha^{-1}	Number of Roots ha^{-1}	Average Root weight (g)	Root yield (t ha^{-1})
Control	6458	36,458	338	11.8
Fertilizer (NPK)	7083	54,167	449	24.1
G. sepium (G)	7708	56,667	482	24.9
S. siamea. (S)	6667	42,292	587	24.7
½ G+ ½ F	7292	49,792	651	31.0
½ S + ½ F	7500	45,208	484	21.9
LSD (5%)	650	10,778	105	6.3

Table 4.5 Effect of *G. sepium, S. siamea* and inorganic fertilizer on dry matter of cassava plant parts and harvest index.

Treatments	Leaves dry wt (t ha^{-1})	Stems dry Wt (t ha^{-1})	Roots dry wt (t ha^{-1})	Total dry matter (t ha^{-1})	Harvest Index
Control	2.69	8.64	4.01	15.3	29.5
Fertilizer (F)	3.28	10.44	8.19	21.9	37.5
Gliricidia sp. (G)	3.58	11.76	8.48	23.8	35.8
Senna sp. (S)	3.44	10.73	8.40	22.6	37.4
½ G + ½ F	4.20	14.38	10.52	29.1	36.0
½ S + 1/2 F	3.14	10.19	7.43	20.8	35.8
LSD (5%)	1.55	4.03	2.13	7.0	7.1

Table 4.5 shows the effects of application of soil amendments and mineral fertilizer on the dry matter yield of cassava plant parts and harvest index. Leaf dry weight was significantly higher for Full Fertilizer, *G. sepium, S. siamea,* and ½ *G. sepium* + ½ Fertilizer than the Control but similar to ½ *S. siamea* + 1/2 Fertilizer . Stem dry weight was significantly higher for ½ *G. sepium* + 1/2 Fertilizer (14.38 t ha^{-1}) than ½ *S. siamea* +1/2 Fertilizer (10.19 t ha^{-1}) and Control (8.64 t ha^{-1}), stem dry weight for all the other treatments were similar. Cassava root dry weight was significantly higher for all the soil amendments and mineral fertilizer treatments than the control (4.01 t ha^{-1}). Application of *S. siamea* prunings gave root dry weight of 8.40 t ha^{-1} which was significantly higher than Full Fertilizer (8.19 t ha^{-1}) and ½ *G. sepium* + ½ Fertilizer (10.52 t ha^{-1}). *G. sepium, S. siamea* and ½ *G. sepium* + ½ Fertilizer gave significant higher total dry matter than Control (15.3 t ha^{-1}). ½ *G. sepium* + ½ Fertilizer (29.1 t ha^{-1}) gave the highest total dry matter which was significantly higher than Full Fertilizer (21.9 t ha^{-1}) and ½ *S. siamea* +1/2 Fertilizer (20.8 t ha^{-1}). Harvest index was significantly higher for S. *siamea* (37.4) and Full Fertilizer (37.5) treatments than the control (29.5). Harvest index was similar for all the other treatments.

Table 4.6 Uptake of NPK by cassava roots under the various treatments

Treatments	N	P	K
		Kg ha^{-1}	
Control	124.3 (5.4)	11.6 (0.5)	32.9 (1.1)
Fertilizer (F)	272.7 (11.9)	22.9 (1.0)	54.9 (1.8)
Gliricidia sp. (G)	280.7 (12.2)	28.8 1.3)	70.4 (2.3)
Senna sp. (S)	296.7 (12.9)	35.8 (1.6)	88.4 (2.9)
½ G + ½ F	244.4 (10.6)	19.3 (0.9)	54.2 (1.8)
½ S + ½ F	262.9 (11.2)	23.5 (1.0)	57.1 (1.9)
LSD (5%)	95.6	7.3	14.5

Number of bags of urea (46% N), TSP (45% P) and Muriate of Potash (60% K) in parenthesis. A bag weighs 50 kg.

Table 4.6 shows quantities of N, P and K in cassava roots and estimation of these amounts in 50 kg bags of urea, triple superphosphate and muriate of potash. When the fertility of the soil was improved through fertilization more nutrients were taken by the plant. Table 4.7 shows that large amounts of N, P and K were taken by the roots. Uptakes of these nutrients were significantly higher for the fertilized treatments than the Control.

Dry root yield correlated positively and highly significant with most of the selected parameters (Table 4.7). Dry root yield did not correlate with number of stands or harvest index.

Table 4.7. Correlation between dry root yield and selected parameters

Parameter	Fresh root yield
Number of stands	0.2107
Number of roots	0.6231**
Stem dry wt	0.8124***
Leaves dry wt	0.6328**
Dry root wt	0.7584***
Total dry matter	0.9865***
Harvest index	0.2832

*** p≤ 0.01; *** p≤ 0.001.*

CHAPTER FIVE

DISCUSSION

5.1 Effect of plant biomass and inorganic fertilizer on soil chemical properties

The initial soil pH was acidic becoming strongly acidic under all the treatments except the ½ Gli + Fert. and ½ SS + Fert, at harvest. The presence of organic acids during decomposition partly explains the strongly acidic conditions of soils on which prunings were applied. According to Tan (1994) and Schnitzer (1986) fulvic and humic acids are produced during decomposition and act as weak acids, this may have influenced the pH of the soil environment.

Decomposition of organic materials results in the release of nitrogen, phosphorus, sulphur and improves the CEC of the soil (Tan, 1994 and Schnitzer, 1986). Despite large uptake of nutrients (Table 4.7) soil nutrient levels at harvest were similar to the initial levels. Application of organic and mineral fertilizer and their combination ensured high nutrient build up. Nutrient uptake under Control was lower. Generally improving the fertility of the soil reflects in crop yield and less in soil properties after harvest. This is normally due to large uptake of nutrients which reflect in yield. This explains why nutrient levels after harvest had fallen to similar levels and to initial levels.

5.2 Effect of organic and inorganic sources of nutrients on cassava yields

Yield parameters that determine fresh root yield include number of roots/plant and root weight. Fresh root yield correlated significantly with number of roots, root weight, stem weight and leaf weight (Table 4.8). Number of roots was significantly affected by the various treatments. Number of roots were significantly higher under sole pruning, mineral fertilizer and their combinations than the control. These observations support the

findings of several authors (Kasele *et al*., 1984; Issaka *et al*, 2007; Odwukwe and Oji, 1984) who reported that increasing the nutrient level of the soil increased the number of roots formed. Release of nitrogen from the mineral fertilizer or from decomposing prunings supported the formation of more roots than the Control. At Manga in the Upper East Region of Ghana, Issaka *et al*, (2002) observed that phosphorus deficiency reduced the number of tubers produced by sweet potato. Root initiation takes place under favourable edaphic conditions and normally exert strong influences on the final root yield.

Root weight was also affected by the various treatments (Table 4.5). It was significantly lower under the control treatment than all the other treatments. Higher nutrition under sole pruning, mineral fertilizer and their combinations resulted in bigger roots than those obtained from the control. This observation supports the findings of many authors (Cong, 2001; Issaka *et al*, 2007; Sittibusaya and Kurmarohita, 1978 and Niang *et al*., 1996). Among the sole pruning, mineral fertilizer and their combinations ½ G + ½ F combination gave significantly bigger roots than the other treatments except SS.

Fresh root yield was significantly affected by the various treatments (Table 4.5). It yield was significantly lower under Control (11.8 t ha^{-1}) compared to all the other treatments. Improved nutrient level due to the application of prunings, mineral fertilizer or their combinations largely explains the observed difference in fresh root yield. Improving the soil fertility levels resulted in the production of more roots which were also bigger than those produced under the control treatments. Issaka *et al* (2007) observed that yield of fresh cassava roots increased with increasing fertilization to 60-60-60 kg N: P2O5:K2O/ha and remained constant up to 120-120-120 kg N: P2O5:K2O/ha. They attributed the increase in fresh root yield to improved nutrient availability. Many other authors (Howeler, 1987; Kasele *et al*., 1984; Odwukwe and Oji, 1984; Githunguri *et al*.,

1998; Cong, 2001; Lahai *et al* 1992; Osiname and Landu, 1989 and Sittibusaya and Kurmarohita, 1978) support the findings of this study. ½ G + ½ F gave the highest fresh root yield (31.0 tha^{-1}) which was significantly higher than that for ½ S + ½ F (21.0 tha^{-1}) and Full mineral Fertilizer (24.1 tha^{-1}) but similar to G and S.

5.3 Nutrient uptake by fresh root

Uptake of N, P and K by cassava roots showed that in most cases uptake of these nutrients are larger that the amount applied. Application of 3 bags of urea, 2 bags of TSP and 2 bags of muriate of potash (MOP) is equivalent applying 69- 45- 60 kg NPK/ha. Under the Control treatment about 124 kg N ha^{-1} was taken by the roots.

Treatments that received prunings, mineral fertilizer or their combinations produced more roots/ha resulting in high and significant uptake of N, P and K (Table 4.7). These large uptakes of nutrients also explain why soil fertility levels after harvest were similar to the initial levels despite the applications of organic, mineral fertilizers and their combinations.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This study was conducted for only one year (2004) and it is recommended that the trial should be repeated for two or more years to allow for a comprehensive conclusion to be made. However, tentatively the following conclusions can be suggested;

- Use of *G. sepium* and *S. siamea* prunnings applied at 5 t/ha significantly improved root yield of cassava.
- Application of *G. sepium* and *S. siamea* prunnings produced similar root yield as mineral fertilizer.
- Combination of 2.5 t/ha *G. sepium* and *S. siamea* prunnings + half rate of mineral fertilizer gave comparable root yield as sole prunings of *G. sepium* and *S. siamea* and mineral fertilizer.
- Large amounts of nutrients (especially nitrogen) is taken up by cassava roots.
- The soil fertility level will decline significantly if cassava is cultivated without any inputs.

With reference to the above it is recommended that organic, mineral or the combinations of these two sources of nutrients can be used for profitable and sustainable cassava cultivation.

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