EFFECTIVENESS OF *Moringa oleifera* LAM. AS SOIL AMENDMENT ON GROWTH AND YIELD OF *Amaranthus caudatus* L. AND *Abelmoschus esculentus* (L.) MOENCH

BY

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ABSTRACT

Soil acidity and pollution of underground water resulting from the use of mineral fertilisers for crop production are major challenges in sub-saharan Africa. Organic fertilisers from plant sources such as moringa leaf extract and seed cake are environment friendly and have been used for vegetable production. However, little is known about the efficacy of powdered forms of Moringa Leaf Blade (MLB) and Leaf Petiole (MLP) as soil amendment for amaranth and okra production. Hence, the effectiveness of powdered MLB and MLP on growth and yield of amaranth and okra were evaluated.

An incubation experiment involving MLB (2.8% N), MLP (2.1% N), "Sunshine" Organic Fertiliser - SOF (1.4% N) and NPK 20:10:10 each at 100 kg N/ha as well as control (No fertiliser amendment) was conducted using 50 g soil weighed into extraction cups. The treatments were arranged in a completely randomised design with three replicates. Nitrogen release was monitored for 12 weeks at 4 weeks interval using standard procedure. On the field, the fertiliser treatments at the rate of 100 kg N/ha were evaluated for their effect on the growth and yield of amaranth and okra. Experiments were laid in randomised complete block design with three replicates. Data collected on amaranth include number of leaves and leaf area at 4 Weeks After Sowing (WAS) and on okra number of leaves and leaf area at 8 WAS. The total amaranth shoot yield (ASY) was recorded as the sum of the weight of shoot harvest at 4, 8 and 12 WAS, while total okra pod yield (OPY) was recorded as the sum of the weight of fruits harvested at five days intervals over 30 days. Data were analysed using descriptive statistics, linear correlation and ANOVA at 5 % probability level.

Nitrogen (g/kg) release differed significantly among the fertiliser sources and was in the order; control (0.5±0.01) < SOF (1.3±0.05) < MLP (1.4±0.06) < MLB (1.7±0.01) < NPK (5.1±0.06). Number of leaves and leaf area of amaranth ranged from 8.9±0.3 (control) to 14.9±0.7 (MLB) and 14.9±0.1 (control) to 53.4±2.0 cm^2 (MLB), respectively. For okra, number of leaves and leaf area ranged from 20.8±0.2(control) to 37.8±0.5 (MLB) and 338.7±17.0 (control) to 657.9±21.2 cm^2 (MLB). The ASY from plots treated with MLB (9.9±0.2 t/ha) and NPK (9.2±0.3 t/ha) were similar and significantly ($p<0.05$) higher than MLP (7.8±0.1 t/ha), SOF (6.6±0.2 t/ha) and control (3.7±0.2 t/ha). Similarly,

OPY from plots treated with MLB (6.0±0.3 t/ha) and NPK (5.9±0.2 t/ha) were comparable and significantly ($p<0.05$) higher than MLP (5.1±0.2 t/ha), SOF (4.5±0.1 t/ha) and control (2.6±0.1 t/ha). Nitrogen release was significantly ($p<0.05$) and positively correlated with ASY ($r = 0.58$) and OPY ($r = 0.63$).

Moringa leaf blade powder at the rate of 100 kg N/ha improved growth and yield of amaranth and okra. Hence, it could be used as an alternative soil amendment to NPK fertiliser in amaranth and okra production.

Key words: Moringa leaf blade, Moringa leaf petiole, nitrogen release, amaranth shoot yield, okra pod yield

Word count: 475

CERTIFICATION

I certify that this work was carried out by Abdulkareem Babatunde OSUMAH, in the Department of Agronomy, University of Ibadan.

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DEDICATION

This work is dedicated to Almighty God, the Alpha and Omega, who has guided me thus far.

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CHAPTER 1

INTRODUCTION

Most developing countries have constraints of mineral fertiliser and most importantly, high cost, pollution of underground water and soil acidification pose limitation to its uses. Efforts to use *moringa oleifera* plant parts as sustainable organic fertiliser have not received much attention. It has been observed that during harvesting the leftover leaves on moringa stem will become waste if not used (Foidl *et al.,* 2001). Use of plant residue for crop production has many advantages. Foidl *et al.*(2001) noted that collection of moringa leftover for agricultural use will prevent waste in every year production and its conversion to animal feeds will improve the quality of the feed. Therefore, one of the solutions to wastage is to consider the material as resources to be reused.

Fuglie (2001) reported that *Moringa oleifera* could be propagated from seed and stem–cutting, and the biomass produced from moringa planting materials have potential mineral elements (macro and micro elements) which have been reported for improving the nutritional quality of leaf vegetable and pepper (Busani *et al*., 2011). According to Foidl *et al*. (2001), use of moringa plant parts as soil amendment has positive effects on soil fertility by adding organic matter into the soil. Furthermore, Foidl *et al*. (2001) reported that moringa plant parts do not pollute environment and fast decomposition of moringa plant parts resulting to high nutrient release for plant uptake, which lead to increase in crop yield.

Moringa plant parts have been considered as fertiliser for use in food crop agriculture in few developing countries (Anjorin *et al*., 2010). Researchers in Senegal, Tanzania and Kenya have used moringa plant parts as soil amendment and as plant growth enhancer to raise agricultural crops such as black beans, tomatoes, leaf vegetables and pepper. Makker and Bekker (1997) reported that moringa leaf extract used as plant growth enhancer significantly increased the yield of black beans, pepper and tomato by 39, 48 and 52% respectively. Fuglie (2001) also reported more favourable results in nutrient uptake, growth and yield of soya bean and pepper when applied moringa seed cake as fertiliser.

Growing of vegetables is a major aspect of horticulture in view of the value of its products. According to Gupta *et al*. (1989), amaranth and okra are among the best vegetables in term of their chemical composition and nutritional status. Traditionally, amaranth and okra are grown either as mono crop or in a mixed cropping system through seed propagation (Osumah, 2010). They are tropical plants which grow well in warm climate with their determinate attribute (Obigbesan, 2015). Furthermore, most amaranth plant are grown as leafy vegetable that could be harvested within four weeks after sowing of seed (Martineau, 2005), while okra plants are cultivated in Southwest Nigeria for their fresh pod (Akanbi *et al*., 2005), and could be harvested at five days interval when the pods have attained maturity (Tindall, 1991). Several researchers have obtained significant increase in the yield of vegetable with the application of mineral fertiliser and organic nutrient sources as soil amendment (Akanbi and Togun, 2002). However, one of the major constraints to vegetable production is the inadequate supply of mineral fertilisers coupled with the frequent increase in the price of these `fertilisers (Elbehri *et al*., 1993; Akanbi *et al.,* 2005). As a result of this constraint and adverse effect of mineral fertiliser on tropical soil, there is need for farmers to focus on the use of organic materials as soil amendments. *Moringa oleifera*leaf parts as organic fertiliser (Foidl *et al*., 2001) can be used in the tropical environment where scarcity and high cost of chemical fertilisers is prevalent (Yinda and Adeoye, 1994).

Moringa oleifera plant parts can serve as an alternative because of its availability, environment friendliness and documented information on its use asfoliar organic fertiliser and soil amendment for vegetable production (Foidl *et al*., 2001; Anjorin *et al*., 2010). Similarly, Gliricidia leaf decomposed rapidly when applied as manure to improve soil fertility (Morafa, 2007). However, Gliricidia leaf had been used by farmers to grow leafy vegetables (Obigbesan, 2015), while its efficacy can be seen on plant height and leaf development of crop like amaranth (Morafa, 2007) as a result of its effective nitrogen release into the soil with better nitrogen uptake of test crops (Kamara *et al*., 2000).

Hence, this work investigated the potential of moringa plant parts that could be used as substitute for expensive mineral fertiliser in amaranth and okra production. Therefore, the objectives of this study were to:

i. Evaluate the N, P and K release from different soil amendments: powdered moringa (leaf blade and leaf petiole), powdered gliricidia whole leaf, “Sunshine” organic fertiliser and N.P.K 20:10:10,

ii. Determine the growth performance, biomass yield and uptake of nitrogen, phosphorus and potassium in the screeenhouse by amaranth and okra as affected by different soil amendments,

iii. Determine the effect of different soil amendments on amaranth shoot yield and okra pod yield.

CHAPTER 2

LITERATURE REVIEW

2.1 Description of *Moringa oleifera*

Moringa (*Moringa oleifera* Lam.) is a native of northern India and has become naturalized in the tropical and sub-tropical areas of Africa, Asia and Latin America (Busani *et al.,* 2011). The Moringa tree is known by such regional names as Horseradish tree, Murunga, Marango, Mulangay and Malunkai (Tagwira, 2011). In Nigeria, it is called by various names as drum stick in English, Zogale in Hausa, Okwe in Igbo and Ewe ile in Yoruba language (Kand, 2011). It is considered as one of the world's most useful trees, as almost every part of the plant can be used for food, medication and industrial purposes (Gidamis *et al.,* 2003).

Moringa oleifera is the most common among the 14 known species of family Moringaceae (Hartwell, 1971), and it is fast growing and drought resistant. It is a perennial tree which is slender and deciduous, and grows to about 10 m in height (Fuglie, 2001). The color of the flower is white or creamy white, and has a fragrant odour. The pod contains about 20 seeds embedded in the pith with pod that tappers at both ends (Foidl *et al*., 2001). However, the pod may develop only in certain flowers while the rest of the flowers may fall off (Anjorin, 2010).

The plant grows in a variety of climate and sub-standard soils (Busani *et al*., 2010) but it does not grow well in a cold environment and loses it leaves during winter (Fuglie, 2001). It has a very deep tap root (Foidl *et al*., 2001), which continues until enough moisture is reached even when not growing the trunk or leaves. When young moringa shoot is visible, it needs direct sunlight to grow well, and it is one of the fastest growing biomasses on the planet when properly nourished (Tagwira, 2011). It has been noticed that normal growth of Moringa ranges from 3 to 5 meters in a year if left uncropped (Kand, 2011) while a full mature Moringa tree can grow to 12 meters (Broin, 2006).

2.2.0 Agronomy of *Moringa oleifera*

Agronomy of *Moringa oleifera* is based on the production of moringa plant on small and large scale which depend on land preparation, propagation, planting and

maintenance of the tree (Tagwira, 2011). Hsu (2006) stated that factors considered in the production of the plant lie on the intention of the grower either for leaf production or seed production, which depends on several options during planting and this could affect plant spacing in intensive and semi-intensive productions. Therefore, hindrance to moringa production could be affected by undesirable sites such as water logged sites, termite infested soils and animal grazing fields (Hsu, 2006).

Moringa can be propagated from seeds and stem cuttings (Foidl *et al*., 2001). According to Tagwira (2011), moringa seeds have no dormancy periods and can be planted as soon as they are mature. He stated further that it is best to sow the seeds where tree is intended to grow and not transplant the seedling because the young seedlings are fragile and there is high risk of damaging the tap root. However, the seeds must be relatively fresh, viable and disease free to give a good germination (Anjorin *et al*., 2010). One or two seeds per hole can be sown at a maximum depth of 2cm and germination could take place within 7 to 12 days (Tagwira, 2011). If the two seeds germinate, the weaker plant can be removed after they reach the height of 30cm (Hartwell, 1971; Kand, 2011), and it could be done carefully to avoid damaging the root system of the remaining plant. As the shoot becomes visible after the daily slightly watering of the plant, the plant needs direct sunlight to grow well (Foidl *et al*., 2001) and the tree often grows up to 5 m in the first year (Kand, 2011).

Hartwell (1971) reported that after the moringa tree had stopped producing fruits each year, stems need to be cut back into different sizes so that fresh growth may take place. These cut-back stems are excellent for growing new trees for subsequent season (Tagwira, 2011), and hard wood cuttings of 50cm long and at least 4 to 5cm in diameter can be used for propagation (Tagwira, 2011). When planted, one third of the stem must be buried in the soil. Fungli (2001) stated that plants produced with cuttings will not have a deep root system and will be more sensitive to wind and drought. Cuttings are also more sensitive to terminate attacks but it can be prevented by putting cow dung on top of the open end of the cuttings (Tagwira, 2011). Spacing of moringa plant depends on the type of production system adopted by the grower (Anjorin *et al*., 2010). Anjorin *et al*. (2010) stated that moringa plants spaced at 0.5to 1m apart in a small-scale production gives good results with less maintenance. Moringa trees can be grown in alleys and

associated with other crops (Hartwell, 1971). The distance between moringa rows must be 2 to 4 m, and they must be oriented East-West to ensure that inter crops receive enough solar radiation (Foidl *et al*., 2001). It is better to intercrop with crops that can enrich the soil in minerals, especially in nitrogen like leguminous plants such as groundnut, beans or soybean (Ebiere, 2005). However, for leaf production only, spacing of moringa plants should be 50 by 50cm but spacing must be much wider for seed production (Tagwira, 2011). Therefore, spacing of about 1m apart has been recommended for seed production (Foidl *et al.,* 2001).

Moringa trees will generally grow well with fertiliser (Kand, 2011). Fertiliser application must be done during land preparation before planting. Instead of mineral fertiliser, farmyard manure or compost can provide the necessary nutrients as well as improve the soil structure (Yinda and Adeoye, 1994). When it receives enough organic supplements, moringa can produce large quantities of leaves (Broin, 2006). Its leaves are rich in proteins and minerals (Busani *et al*., 2011), which means that the soil needs to provide enough nitrogen and minerals to the plant (Anjorin *etal*., 2010). Phosphorus can also be added at planting time to enhance root development (Ebiere, 2005). However, research carried out showed that yearly applications of 10t/ha manure and 40kg/ha ammonium sulphate to *Moringa oleifera* increased yield as much as threefold (Tagwira, 2011). Also, application of 60 kg P/ha significantly improved the growth and yield of *Moringa oleifera* (Anjorin *et al.*, 2010). It is important to apply fertiliser at least once in a year when the plant is about to start an intense vegetative growth within 4 to 6 weeks after planting (Tagwira, 2011).

Weeding should be done regularly to avoid competition for nutrients especially for nitrogen (Akobundu, 1993) and the weeding must be more frequent when the plantation is young. A good option is to leave the weeds on the soil surface as a mulch to reduce evaporation and enrich the soil (Obigbesan, 2015), while burying the weed is not necessary as tropical soils have a very low capacity to retain minerals over time (Sanchez, 1986). It is advisable to weed an adult plantation at least four times in a year with a higher frequency during rainy seasons (Akobundu, 1993).

Maintenance pruning is required at each harvest by removing the leaves and cutting the stems above a certain height (Tagwira, 2011). However, if the Moringa trees

are left unpruned during the dry season, then a good pruning must be done at early rainy season (Tagwira, 2011). It is important to cut just above a node to reduce rooting of terminal branches (Foidl *et al*., 2001). Therefore, it has been reported that pruning helps induce more fruits, as well as larger fruits, in seed producing farm of *Moringa oleifera* (Ebiere, 2005).

2.2.1 Soil/Land preparation

The ease with which the root spreads is a necessary condition in plant growth and development. Moringa requires a well-drained loamy or sandy soil for optimal growth (Anjorin *et al*., 2010). The land should be slashed where necessary and all unwanted materials removed from the field. The land must be ploughed and harrowed to a maximum depth of 30cm if the plant density is high (Tagwira, 2011) but it is better to dig pits and refill them with the soil if the planting density is low. In this case, the pits must be 30 to 50cm deep and 20 to 40 cm wide. This will ensure good root system penetration without causing too much soil erosion than ploughing which could be risky in tropical environment due to heavy rainfall, wind and slope of the land (Sanchez, 1986).

2.3.0 Organic Fertiliser

The physical and chemical properties of tropical soil make it imperative for soil amendment with fertiliser sources in crop production. However, the adverse effect of chemical fertiliser on tropical soil and its high cost make the introduction of organic fertiliser to farming a welcome development and its use to rehabilitate marginal soils is not toxic to the environment (Agboola, 1990). Therefore, nutrient elements in organic fertiliser are mainly in organic form and these have to be mineralized before the nutrient become available to plant.

According to Ojo *et al.* (2008), use of organic fertiliser on tropical soil has several benefits such as:

1. It contributes to the maintenance of physical soil fertility resulting in a better soil moisture status through addition of new organic matter.
2. It improves soil fertility and increases crop production.
3. It minimizes surface and underground water pollution.
4. It improves the water holding capacity of the soil.

5. It has effect on nutrient availability.

However, an efficient and effective use of organic fertiliser ensures crop productivity by immobilizing nutrients that are highly susceptible to leaching and enhancing soil microbial activity (Agboola, 1990). Organic fertiliser constitutes mainly of the plant and animal waste, and these include poultry manure, cow dung, compost, urine and plant residues from farm and forest. Application of organic wastes obtained from different sources for crop production has two advantages namely: prevents the accumulation of wastes in the environment and provides organic matter and nutrients for soil and it also gives a number of nutritive elements to crop with little added cost. Ojo *et al.* (2008) stated that recycling wastes and manure through organic waste management is the main factor that can control long term micro-nutrient balance of the soil.

Organic materials are vital natural resources for sustaining soil productivity. Not only do these organic sources replenish soil organic matter, which is a key factor of soil quality, but also supply essential nutrients for plant (Obigbesan, 2015). The growing need for sustainable agriculture has brought vast interest in reusing organic waste materials to solve the problems of soil fertility in relation to crop growth, yield and quality (Idowu and Akinyemi, 2015). Effort to develop the use of crop residues and other organic material as fertiliser have received much attention in the recent years because of their improvement on soil physical, chemical and biological properties (Morafa, 2007). However, the limitations to the use of organic fertilisers are due to their inherent slow release of nutrient elements and large quantity needed to apply (Giller, 2002).

The beneficial effects of organic materials have been studied by many researchers. A short and long term experiment on two different sandy loam Alfisol: Typic Paleudalf in Abeokuta and Oxic Paleustalf in Zaria, conducted by Akinrinde and Okeleye (2005) showed that addition of organic materials: Ogun and Sokoto rock phosphate significantly increased the relative agronomic efficiency of the soils, which are considered very important in yield, than the mineral single super phosphate. Use of maize-stover compost in soil for growing vegetable crop has helped in maintenance of soil structure with improvement of soil organic matter and pH (Akanbi and Togun, 2002). He and Traina (1992) reported that city refuse compost (CRC) improve certain important

physical and chemical properties, macro aggregates and cation exchange capacity of marginal soils. They also reported that negative effects had been associated with the use of non-mature CRC, which was not biologically stabilized and sparingly humified, that normally causes high concentration of heavy metals in the soil. According to Monzote (2006), agrochemicals were expensive and therefore unsustainable from economic point of view in Cuba's commercial agriculture. Most of the bio-fertilisers developed were bacteria such as rhizobium, azotebacter and azospirillium which fix nitrogen in association with legumes and they could replace inorganic nitrogen.

Hsu, (2006) reported that use of crop residues as mulch improved soil structure in tropical soils where the soil texture were mostly loam and having organic matter within a critical level of 1.5-2.0%. However, the effect of the mulch was attributed to its ability to prevent soil erosion and increase in the activities of macro and micro fauna present in the soil (Hsu, 2006). Hsu, (2006) stated further that aggregate stability are more in soils that contained high polysaccharides. Diaz *et al*. (1994) discovered a significant increase in average percentage of aggregate stability with increased level of urban refuse incorporated in the soil and the beneficial effect remained for two years after application. Significant increase in fungi and bacteria populations and a reduction in extractable organic carbon were observed where urban refuse was applied. They concluded that the actions of microbiological activity coupled with the release of polysaccharides from the urban refuse were responsible for the initial formation of soil aggregates which improved soil structure, porosity and hydraulic properties of the soil.

2.3.1 Moringa Plant Parts as Organic Fertiliser

Potential mineral elements (both macro and micro elements) have been found in all the plant parts of *Moringa oleifera* and these nutrient elements have been reported in improving the nutritional quality of leaf vegetable and pepper (Busani *et al*., 2011). For instance, Makkar and Becker (1997) reported that moringa was used as plant growth enhancer, which significantly increase yield of black bean, tomato, bell pepper, onion and corn by 39, 52, 48, 44 and 35% respectively. It also produced some effects such as heavier roots, stems and leaves, with bigger fruits and higher sugar levels. However,

Foidl *et al.*(2001) reported on nutrient uptake, growth and yield of soya bean, corn and pepper when applied moringa seed cake as protein-rich fertiliser.

Moringa oleifera leaves have been reported to have high nitrogen content (Anjorin *et al.,* 2010), and this makes moringa leaves to be a good source of supplementary organic matter in the soil. According to Ahn (1979), nitrogen content in most tropical soils is usually directly proportional to the organic matter content except soil where plant materials have recently been ploughed in. Moringa leaves could be used as mulch and could also be incorporated in the soil for plant uptake (Broin, 2006). The nitrogen release by moringa leaves can aid plant growth since it has been reported that nitrogen is required by plants for vegetative growth and that the amount of vegetative growth is proportional to the amount of nitrogen taken up by the plant (Mengel and Kirkby, 1998).

However, addition of moringa leaves as manure may correct soil degradation resulting from continuous cultivation and it may also increase efficiency of fertiliser use (Foidl *et al.,* 2001). Foidl *etal*. (2001) also stated that use of adequate amount of moringa leaves with the petiole as mulch cover helped to maintain high soil nutrients status and high biological activity.

Suppression of weeds by mulch application is more effective in the presence of mulch that decomposes slowly. Kang *et al,* (1990) reported that high nitrogen and low lignin and polyphenol contents lead to fast mulch decomposition. He then concluded that *Gliricidia sepium* and *Leucena leucocephala* mulch cannot control weeds because of their fast decomposition rate. Moringa leaves with petiole could serve as a replacement for fast decomposing mulch material since moringa petiole could persist for more than a week (Foidl *et al*, 2001). Akobundu and Palms (1987) stated that in addition to physical suppression of weeds, the decomposing plant residue can also release phytotoxic compounds that inhibit crop and weed growth. However, according to Foidl *et al*. (2001), moringa mulch had no allelopathic effect on crop but it could rather suppress weed biomass.

2.4.0 Soil fertility and its constraint

Fertility is the ability of soil to provide required nutrients both in quality and quantity. Organic matter improves soil fertility and productivity, and all life in the soil depends on organic matter for nutrient and energy (Agboola, 1990). However, the health of a soil not only has implication on soil fertility but also on the crop, animal and man, which obtain their sustenance from it (Nikolas, 1997).

Major problem facing tropical agriculture is the inherently low fertility status of most of the soils because of the predominant low activity clay minerals (Agboola, 1990) and loss of eroded top soil with its organic matter and nutrients (Batiano and Mokwunye, 1991). However, agricultural practices such as tillage affect soil organic matter stability by altering above and below ground organic matter inputs and decomposition rates. Therefore, soil fertility is highly affected by soil erosion, leaching, soil structure instability and environmental pollution (Ojo *et al.,* 2008).

Nutrient depletion and soil degradation have become a major threat to agricultural productivity in Nigeria (Ojo *et al.,* 2008). However, Doran *et al.* (1996) reported that soil chemical degradation is always associated with a decline in the organic matter content. He also reported that loss of organic matter is generally associated with decline in a certain soil chemical and physical properties such as soil porosity, soil aggregate stability and increase in soil strength indices.

Most soils contain an abundance of elements necessary for the growth of plants but most of these elements are not available for plant use due to leaching, antagonistic effect of nutrient and unfavourable environmental condition (Halliday *et al.,* 1992). Halliday *et al*. (1992) also reported that over exploitation of natural resources through permanent depletion of soil – borne nutrients resulted to yield reduction, loss of soil fertility and eventually desertification of the soil. In order to arrest the above situation nutrient balances (nutrient applied minus nutrient loss) and use of organic fertiliser as a source of nutrient for low fertility soil could be adopted (Ojo *et al.,* 2008).

When a cropping system such as a mono crop with annual crop is adopted, soil aggregate stability reduces rapidly as a result of little supply of residue to replenish the soil organic reserves (Batiano and Mokwunye, 1991). It also leads to an increase in the

amount of dispersed clay as a result of the increasing proportion of fluvic and oxidation of organic bonding agents (Fagbenro, 1979).

Fertile soil contains large number of living organisms (micro-flora and micro fauna), which vary greatly in size and function (Doran *et al.,* 1996). For instance, mulching with plant residues favour the development of mycorrhizal fungi which take carbon compounds fixed by photosynthesis in the leaves from the host plant and, in return, supply the host plant with phosphorus and micronutrient which they take up from the soil solution (Li *et al.,* 2001). Therefore fertility of the soil can be affected when the efficiency of the mycorrhizal fungi is constrained by low temperature, water stress and soil pH less than 5.0 (Li *et al.,* 2001) as well as by salinity, toxic concentration of Al, Fe, and Mn, and by large additions of soluble phosphorus fertilisers (Amberger, 1992).

The cation exchange capacity (CEC) is an important factor in soil fertility (Agboola, 1990), and availability of nutrients to plant depends on soil pH (soil acidity) and the redox-potential (Ojo *et al.,* 2008). Nutrient adsorption and release are related to the amount and type of clay minerals and their ability to hold and exchange cations or anions (Marschner, 1995). Marschner (1995) further stated that crops do not respond to nitrogen when phosphorus (P) is deficient in the soil. Plant available P are frequently deficient in tropical soils when P is chemically bond as Fe or Al phosphate, and when the capacity of Fe and Al oxides and some clay minerals adsorp P added in water soluble forms (Amberger, 1992). However, base cations such as potassium, calcium and magnesium become deficient or imbalance in the acid soils of humid tropics due to small cation exchange capacity to retain them against leaching, poor parent materials and growing of cash crops that have a large requirement for these nutrients (Ojo *et al.,* 2008).

2.5.0 Plant residue application

Fertilisers are substances which are added to the soil to supply nutrient elements required in the nutrition of plants. However, methods of fertiliser application depend on type of fertiliser used (liquid or solid form), crop involved, soil characteristics and climatic condition (Mengel and Kirkby, 1998). Mengel and Kirkby (1998) stated further that timing of fertiliser application is usually connected with the method chosen and the fertiliser being used. Therefore, fertiliser can be applied before planting, at planting and

later after planting using broadcasting, side dressing and band placement method (Morafa, 2007).

The most common organic fertiliser used in sub-saharan Africais residue burning, residue incorporation and mulching (Agboola and Unamma, 1991). Agboola and Unamma (1991) reported that residue burning is the traditional method of getting rid of thrash or waste organic residue from the farm and this method is mostly practiced by subsistence farmers in South Western Nigeria. Residue incorporation provides good contact and mixing with soil to maintain good soil moisture conditions and rapid nitrification (Morafa, 2007). Morafa (2007) stated that this method should be practiced in areas less prone to erosion.

Mulching is the most practiced method of crop residue or fertiliser material management. Agboola and Unamma (1991) stated that residue mulch has contributed immensely to physical, chemical and biological properties of soil. They described it as an important strategic way to minimize soil erosion as it reduces raindrop impact; retards run off velocity, reduce evaporation and increases soil water storage in the root zone. Kamara *et al.* (2000) investigated the effects of mulch from *Gliricidia sepium*, *Leucaena leucocephala* and *Senna siamea* on weed composition, biomass and maize grain yield. They discovered that *Gliricidia sepium* and *Senna siamea* plots recorded lower weed density and biomass than the control plot. The use of mulch reduces the herbicide quantity needed to provide lasting weed control in crop production (Akobundu and Palms, 1987).

2.6.0 Amaranth

2.6.1 History and Origin

Amaranth with genus *Amaranthus* from the family Amaranthaceae is a widely distributed, short-lived herb. It occurs mostly in temperate and tropical regions. It was discovered in Mexico from wide varieties and is now commercially cultivated (Duperiez and Deleener, 2004). Amaranthus could be called pigweed, African spinach, bush green, spinach, spinach green, “tete” varieties, “Olorungbin” etc. Most amaranths are cultivated as leaf vegetables, cereals or ornamental plants. Amaranths have many species and some species are not easily identified they cross-fertilize readily (Martineau, 2005).

Amaranth began attracting research interests in 1972 when Australian plant physiologist John Downton found that the seed also contains protein of unusual quality (Grubben, 1976).

2.6.2 Botany

Amaranth (*Amaranthus caudatus* L.) belongs to the genus *Amaranthus* which contains more than 50 species (Tindall, 1983).

Amaranth is herbaceous, upright predominantly self-pollinated annual plant which grows from less than 1m to more than 2 m (Martineau, 2005). The root system is a modified tap root which though is deeper than those of most grasses but is not as deep as those of other tap root crops (*Elbehri et al.,* 1993). Leaves are arranged spirally but leaves which have no venation are broad and arranged alternatively on the stem (Tindall, 1983). Amaranths have brilliantly coloured petioles, stem and flowers which may be red, purple, green or a mixture of these colours, and the inflorescence is a panicle and may be as long as 50cm. while the seeds may be brown, translucent or cream coloured (Martineau, 2005). The seeds are tiny, with 1000 seeds weighing between 0.57 g to 0.69 g (Tindall, 1983).

2.6.3 Agronomic Requirements

Amaranth is a quantitative short-day plant and grows well at day temperature above 25^{o}C (Elbehri *et al.,* 1993). Traditionally, it is grown either as mono-crop or in mixed cropping system by broadcasting the seed directly or by transplanting vigorous seedlings raised in a nursery (Tindall, 1983). The seed requires shallow planting depth. A depth of 1.2cm was found adequate for amaranths (Martineau, 2005).

Field experiments have shown that amaranths can be maintained at a density of 100 plants per square metre which gives a plant population of 1,000,000 plants per hectare (Elbehri *et al.,* 1993). High density is associated with amaranths established by the directly seeded method as it ensures rapid ground cover, thus enhancing weed control. However, Akanbi and Togun (2002) maintained a spacing of 20 x 20cm for amaranth that could be harvested two to three times by cutting the plant at 10cm above soil level, since amaranth is a determinate plant (Obigbesan, 2015). Amaranths are known to respond to

fertiliser in particular nitrogen at the rate of 100kgN/ha (Osumah, 2010), especially in soils that are deficient of nitrogen (Elbehri *et al.,* 1993).

Because of the strong growth of amaranth, weeds do not adversely affect it, except nut grass (*Cyperus rotundus* L.) and weeding can be done by appropriate application of herbicide or by hand weeding (Akobundu, 1993).

2.6.4 Uses of Amaranth

Amaranth species are cultivated and consumed as a leafy vegetable in many parts of the world. Grupta and Sehgal (1992) stated that amaranth is a good ornamental plant due to its brilliantly colored, bright golden seed head, brightly coloured stems and leaves that are of great importance to floriculturist. Traditionally, in arid regime, the leaves are dried and the leaf powder is used in sauces during the dry season. However, green amaranth is of great nutritional value, being composed of high nitrogen. It is cooked and consumed as a vegetable dish or as an ingredient in sauces (Gupta *et al.,* 1989).

2.7.0 Okra

2.7.1 History and Origin

Okra is believed to originate somewhere around Ethiopia and was cultivated by the ancient Egyptians in the 12th century, and is now popular in Africa and other parts of the world (James, 2001).

Okra has been in existence in Africa for a very long time and as a result, it has acquired so many local names among which are Tsan, Kwai (China), Guibombo (Spanish), Gombo (France), Bhindi (India), Okro and ladies finger (England).

2.7.2 Botany

Okra [*Abelmoschus esculentus* (L.) Moench] is a tropical annul herb growing up to 120 cm tall. It has heart shaped leaves, which are, alternate and up to 30 cm in length. They have 3 to 5 lobes and the upper leaves are more deeply lobed than the lower ones.

Flowers are large, yellows and hibiscus – like (James, 2001). James (2001) also reported that flowers are self-fertile, auxiliary, solitary, short pedicels, 5 mm in diameter and conspicuously attractive. The fruits are 2.15cm in length, 2 to 3 cm in diameter, with upward pointing hairs in young age. The capsules are in different colours which range

from white, dark green or red colour with ridged, round and short or pointed pyramidal shape (Tindall, 1991).

The pod colour can range from brilliant red to green, gold and nearly white and each pod usually contains 30 to 80 seeds (U.S. Dept., 1992). The seeds are round and they are usually approximately 20 seeds/g.

2.7.3 Economic Importance of Okra

Okra is an important crop across the globe. It is cultivated in the tropical regions mainly for its pod yield, which is being used in form of relish (Tindall, 1991). It is a good source of vitamins, iron, calcium, mineral and protein (James, 2001). James (2001) also reported that mature okra plants is used to make rope and paper while the very young, tender pods can be sliced, dipped in egg, breaded with corn meal and fried with corn kernels, onion and sweet peppers.

The plant is highly flavoured because of its mucilaginous property, which gives a slippery texture on cooking. It can be served with stew to accompany other food materials. The mucilaginous preparation from the pod can be used as a blood plasma replacement (Tindall, 1991). The consumption of okra's edible parts such as young pods and leaves to promote digestion, prevent constipation and medicine for peptic ulcer.

2.7.4 Climatic and Soil Requirements

Okra is a tropical plant, which grows best in warm climate (James, 2001). It is adapted to a wide range of soil, as it can be grown in the gardens, small farms, flat land, heaps or beds, and it requires less fertile soil relative to other horticultural crops (Tindall, 1991). It also thrives well on well-drained sandy loam to loamy soil (Komolafe *et al.*, 1999).

Okra can tolerate a wide range of climate for its germination. It is a good crop for rotation with a winter cover crop, and the seed is sown between April and July but it can grow throughout the year under irrigation. Its growth is highly influenced by day-length as it flowers early in long day length (Tindall, 1991).

2.7.5 Propagation

Okra is generally propagated by seed. Two to three seeds are either sown on ridge, bed or on the flat at depth of 1 – 2cm (Komolafe *et al.,* 1999). Okra seeds are directly sown into the soil and seedlings are later thinned to one per stand.

Akanbi *et al.* (2005) suggested a spacing of 60 cm apart between rows and 30 cm within rows to give a population density of about 55,555 plants per hectare. He suggested that one of the ways of increasing the economic yield of the crop is planting at high plant density. However Komolafe *et al.* (1999) stated that for large canopy formation of okra plant, spacing of 50 x 50 cm to give okra plant population of 40,000 plants per hectare can be adopted.

2.7.6 Weed Management

The effects of weeds on crops are of great significance. It was reported by Akobundu (1993) that weeds caused the greatest yield reduction in fruit vegetable crops such as tomato, pepper and okra by competing for moisture, nutrients and light. Different methods are used to control weeds in okra field. According to the experiment conducted by Akobundu (1993), he stated that application of herbicides followed by hand weeding was found to be significantly superior to herbicides alone while uncontrolled weed growth reduced okra pod yield by about 50%. He also reported that Mulching of okra plant is another method of weed control and management which reduces weed growth and weed competition.

2.7.7 Fertiliser Requirement

Most researchers had reported significant okra yields to fertiliser application. Minerals and organic elements play important roles in the physiological growth and development of okra plant, most especially for major metabolic activities of the plant.

Different nitrogen rates were reported by researchers for okra production in southwest Nigeria (Omotoso and shittu, 2007). However, nitrogen at 100 kg N/ha significantly improved okra yield when grown in sandy loam Alfisol (Osumah, 2010), while Omotoso and Shittu, (2007) in their work reported that 150 kg N/ha NPK fertiliser applied by ring method of application gave okra optimum yield. Akanbi *et al.* (2005)

reported okra growth and yield were increased when used the combination of inorganic and organic fertiliser.

2.7.8 Harvesting

Okra flowers about 60days after seed germination. Once flowering starts, pods must be harvested at five days interval because within 10 to 12 days of flower opening, the pods of most cultivars become woody and inedible (Tindall,1991). Almost, all harvesting is done by hand because pods are tender and knife can also be used to cut the fruit stalk.

CHAPTER 3

MATERIALS AND METHODS

3.1 Evaluation of the comparative nutrient release from soil mixed with moringa leaf blade, moringa leaf petiole, gliricidia leaf, "Sunshine" organic fertriliser and N.P.K 20:10:10 in incubation study

Incubation experiment was conducted in Plant Nutrition laboratory, Department of Agronomy, University of Ibadan, Ibadan in March, 2014 to evaluate N, P and K release from powdered moringa leaf blade and moringa leaf petiole in comparison with powdered gliricidia leaf, "Sunshine" organic fertiliser and N.P.K 20:10:10. The experimental soil was collected at 15 cm depth from the experimental field at Parry Road (7^0 26'N and 3^0 54'E), University of Ibadan. The soil of the experimental site is Alfisol (NFC, 1988) with low organic matter, high percentage base saturation and low cation exchange capacity. The soil is dark brown, well drained loamy sand, and it is represented by Ibadan and Egbeda series (Smyth and Montgomery, 1962).

The composite soil sample collected was air dried and sieved before cropping with pearl millet for 12 weeks to deplete the soil of its native nutrients to help determine the level of response to added soil amendments. The depleted soil was analysed for pH, N, P, K, Ca and Mg before the experiment commenced while percentage N, P, K, Ca and Mg contentsof moringa leaf blade, moringa leaf petiole, gliricidia whole leaf and "Sunshine" organic fertiliser were also analysed using the method described by Udo and Ogunwale (1986) respectively. Results of chemical analysis on soil pH (1:1 soil/water ratio), N, P and K were recorded before incubation commenced (Table 4.1).

The incubation method described by Quitanon *et al.* (1988) was used and described as follows; 90 mg powdered moringa leaf blade, 119 mg powdered moringa leaf petiole, 91 mg powdered gliricidia whole leaf, 177 mg "Sunshine" organic fertiliser, 12.5 mg N.P.K 20:10:10 and distilled water only (control) were applied to 50 g soil weighed into each 70 ml extraction cup and mixed thoroughly with stirring rod. The quantity of fertiliser materials reported above was equivalent to 100 kg N/ha nitrogen requirement of amaranth and okra (Osumah, 2010). The extraction cups were arranged in a completely randomized design (CRD) with three replications. Ten millimeter (ml) of distilled water was added to each extraction cup and stirred thoroughly, and then covered with filter paper. The incubation was at room temperature and moisture loss was

replenished by adding distilled water at seven days intervals. The incubation experiment was carried out for 16 weeks during which the soils were sampled at 4 weeks intervals.

The soil chemical properties determined on each sample were pH (1:1 soil/water ratio), total N (g/kg), available P (mg/kg) and exchangeable K (cmol/kg). For each nutrient source, optimum N, P and K release was observed. All the data collected were subjected to analysis of variance and significant treatment means were separated using Duncan's Multiple Range Test at 5% probability.

3.2 Effect of soil amendment with moringa leaf blade and petiole on growth, biomass yield and nutrient uptake of amaranth and okra in pot experiment

Pot experiment was carried out in the screenhouse of the Department of Agronomy, University of Ibadan in August 2014 to determine the effect of moringa leaf blade and moringa leaf petiole on amaranth and okra production. The same soil used in experiment 1 was used for this study. Five kilogram soil was weighed into six pots replicated five times in a completely randomized design. Ten amaranth and two okra seeds were sown separately in each pot per replicate, and were later thinned to four plants amaranth and one plant of okra per pot at two weeks after sowing (WAS). Quantity of moringa leaf blade and moringa leaf petiole equivalent to 100kgN/ha (Nitrogen requirement of the test crops) was applied to 5 kg soil as listed below:

T_1: Control (No moringa treatment)

T_2: 9.0 g powdered moringa leaf blade

T_3: 11.9 g powdered moringa leaf petiole

Powdered moringa leaf blade and leaf petiole were applied at two weeks before sowing of the test crops and the experimental soil was watered to 60% field capacity. Data were collected at 3, 4 and 5 WAS on plant height (cm)(using graduated meter rule), number of leaves(by counting), stem girth (cm)(using vernier caliper at 5 cm above soil level) and leaf area (cm^2) (using LI-COR, model LI-3100Cleaf area meter). Biomass yield (fresh and dry in g/plant) and nutrient uptake (g/plant of N, P and K) were determined by standard methods of Udo and Ogunwale (1986) after the termination of the experiment at 5 WAS. All data collected were subjected to analysis of variance and significant treatments were separated using the least significant difference (LSD) at 5%.

3.3 Growth and yield responses of amaranth and okra to moringa leaf blade and petiole compared with some nutrient sources on the field

An experiment was conducted at Parry Road experimental field, University of Ibadan in the early season of 2015. This experimental field was where the soil used for Experiment 1 and 2 were collected. Before the establishment of this experiment, composite soil samples were randomly taken and analysed for chemical properties and particle size distribution. The experimental field was cropped with maize in the early season of 2014 to exhaust the native nutrient of the soil. After the maize cobs were harvested, the experimental plot was cleared to remove the maize stover and other plant residues. The experimental plot was ploughed and harrowed at one week interval after which a second composite soil sample was collected for chemical analysis.

The experimental plot was divided into two field experiments where *Amaranthus caudatus* (amaranth) and *Abelmoschus esculentus* (okra) were cropped separately on the field (Figure 3.1). Figure 3.1 comprises of six treatments replicated three times in a randomized complete block design with two test crops. The six treatments are listed below:

i. Control (unamended soil)
ii. 0.72kg powdered moringa leaf blade
iii. 0.95kg powdered moringa leaf petiole
iv. 0.73kg powdered gliricidia whole leaf
v. 1.42kg “Sunshine” organic fertiliser
vi. 0.10kg N.P.K20:10:10

The quantity of each fertiliser material applied was equivalent to100 kg N/ha (N rate of the test crops).All the organic fertiliser materials were applied a week before sowing of seed, while NPK 20:10:10 was applied by side placement method within the plant row at two weeks after sowing of seeds (Akanbi and Togun, 2002). Seeds of amaranth were drilled in 20 cm rows and thinned to one plant per stand two 2 WAS at 20 cm within row spacing equivalent to 250,000 plants/ha. Two seeds of okra were sown per hole at 50 x50 cm spacing and thinned to one plant per stand at two weeks after sowing, giving 40,000 okra plants per hectare. Weeding of the plots commenced at 2 WAS and

weeding was done at 5, 8 and 11 WAS. Cypermetrin was used at the rate of 5 ml per liter of water to spray okra plants at 4 and 5 WAS to control insect pest.

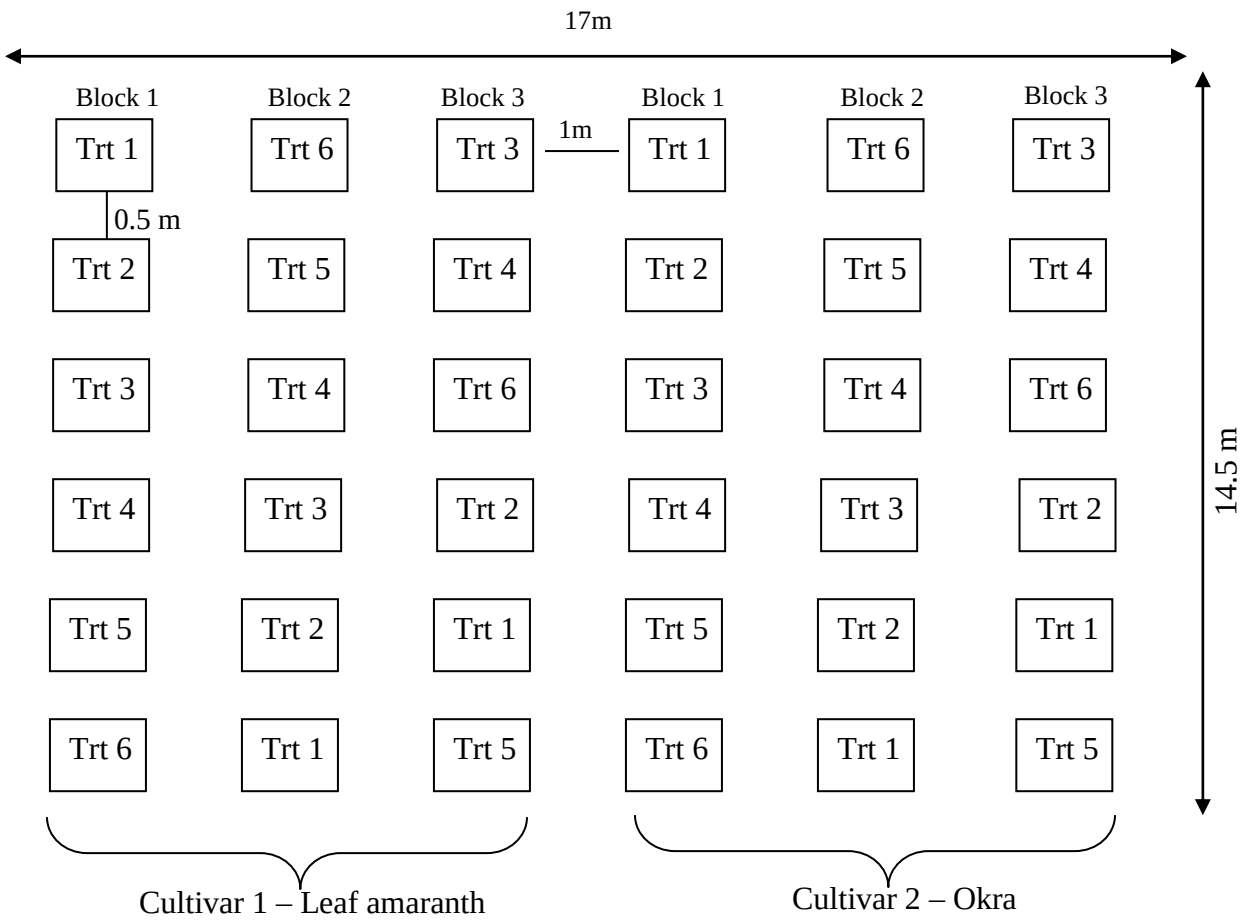
Data on amaranth growth parameters were taken at 4 WAS. Forty-four amaranth plants were selected at random from each plot and the following growth parameters were taken per plant; Plant height (cm), stem girth (cm), leaf area (cm^2) and number of leaves. Fresh shoot yield was determined at harvest (4, 8 and 12 WAS) by cutting the amaranths at 10 cm above the soil level. After the last harvest, the total shoot yield (t/ha) was determined by adding up the three harvests. For dry matter yield and tissue analysis, 54 amaranth plants harvested per plot at 4, 8 and 12 WAS were used. Their fresh shoot weight was measured while the dry shoot weight was measured and recorded in gram per plant after oven drying to constant weight at 80^oC. The dried amaranth shoot were ground and analysed for N, P and K by standard methods of Udo and Ogunwale (1986). Nutrient uptake was calculated as described by Ombod and Isokrari (1994) as:

Nutrient uptake = % nutrient content x sample dry weight

After the last harvest of amaranth at 12 WAS, soil samples were randomly collected from each treatment plot and bulked. Composite soil samples were taken and subjected to chemical analysis to determine the pH, residual N, P, K, Ca and Mg status of the soil using standard methods of Udo and Ogunwale (1986).

Data on growth parameters of okra were collected at 4, 6 and 8 WAS. Nine plants of okra were randomly tagged per plot for data collection on number of leaves per plant(counting the functional leaves), plant height (cm)(measured with a graduated meter rule from ground level to the end of the stem) and stem girth (cm) using vernier caliper at 5cm from ground level. Okra leaf area (cm^2) was determined from sampled leaves removed from tagged plants per plot at 8 WAS and measured with LI-COR, model LI-3100C leaf area meter. Parameters taken at 10 WAS were number of flowers per plant and number of fruit pods per plant which were determined by counting. Data collected on yield parameters of okra at first harvest were number of fresh pods per plant and weight of fresh/dry pods per plant, which were taken by counting and weighing with sensitive electronic scale, respectively. At interval of five days, okra fresh pods were harvested seven times on each plot and using electronic scale. Okra fresh pod yield per hectare was determined by extrapolating the yield per plot to unit land area. At the end of harvesting the okra pods, soil samples were randomly collected from each treatment plot and bulked.

The composite soil samples were analysed for pH, residual N, P, K, Ca and Mg using the standard methods reported above. Data collected were subjected to analysis of variance and means of significant treatments were separated using Duncan's Multiple Range Test and Least Significant Difference at 5% probability level. Relationships between nutrient release from incubation experiment at 4, 8 and 12 weeks of incubation (WOI) and amaranth N, P and K uptake at 4, 8 and 12 WAS were established by correlation at 5 % probability. Furthermore, nutrient release at 12 WOI was correlated at 5 % probability with amaranth shoot yields as well as okra pod yields.



– Cultivar as main plot
– Treatment as sub – plot

Figure 3.1: Experimental field layout

CHAPTER 4

RESULTS

4.0 Evaluation of nutrient release from soil mixed with moringa leaf blade and moringa leaf petiole compared with gliricidia leaf, "Sunshine" organic fertiliser and N.P.K 20:10:10.

4.1 Chemical analysis of experimental soil and organic fertiliser materials

The result of pH (1:1 soil/water ratio), total nitrogen (N), available phosphorus (P) and exchangeable potassium (K) is shown in Table 4.1 after the soil had been exhausted with pearl millet for 12 weeks. The pH (1:1 soil/water ratio) value was 5.10 (acidic). The value of 0.16 g/kg N, 2.10 mg/kg P and 0.05 cmol/kg K were found to be low when compared with their respective critical levels of 1.5 - 2.0 g/kg, 10-15 mg/kg and 0.3-0.5 cmol/kg. Also, calcium (Ca), magnesium (Mg) and sodium (Na) were low in respect to their critical levels of 2-2.6, 0.2-0.9 and 0.2-0.5 cmol/kg.

However, the result obtained from chemical analysis on the fertiliser materials used in this experiment showed that moringa leaf blade contained the highest N, P, K, Ca and Mg contents when compared with gliricidia whole leaf and "Sunshine" organic fertiliser respectively (Table 4.2).

4.2 pH changes at different weeks of incubation (WOI)

In Table 4.3, the pH values at 4WOI for all the treatments were significantly different except for the pH of soil treated with moringa leaf blade (MLB) and gliricidia whole leaf (GWL). At 8WOI, soil treated with moringa leaf petiole (MLP) was found to be significantly higher than other treatments while soil treated with MLB and GWL were significantly higher than soil treated with "Sunshine" organic fertiliser (SOF), NPK 20:10:10 and distilled water only. At 12 WOI, soil treated with MLP and GWL recorded significantly ($p<0.05$) higher pH than other treatments. The pH of soil treated with MLB, MLP and GWL were comparable and they were significantly higher than distilled water only, SOF and NPK 20:10:10.

4.3 Nitrogen release at different weeks of incubation

Nitrogen release from soil treated with NPK 20:10:10 was the highest at all sampling dates and was significantly higher when compared with other treatments at 4, 8, 12 and 16 WOI. At 4 WOI, N release from soil treated with MLB was significantly higher than N release of soil treated with MLP, SOF and distilled water but only the same with N release from soil treated with GWL. Nitrogen release was very low in soil treated with distilled water when compared with other treatments (Figure 4.1). However, the optimum nitrogen release was observed at 16 WOI for MLB, MLP, GWL and SOF, while that of distilled water and NPK 20:10:10 was found at 4 WOI.

4.4 Phosphorus release at different weeks of incubation

Phosphorus release from soil treated with NPK 20:10:10 was significantly higher than P of other treatments from 4, 8, 12 and 16 WOI. At 4 WOI, P release from MLB was significantly ($P<0.05$) higher than P release from GWL, MLP and SOF. Phosphorus release at 8 and 12 WOI from soil treated with MLB was significantly the same with P release from soil with MLP and GWL. At 16 WOI, P release from soil treated with MLB was significantly higher than other treatment except the soil treated with GWL and NPK fertiliser (Figure 4.2). However, the optimum P release from soil treated with distilled water, MLB, SOF and NPK was found at 4 WOI while soil treated with MLP and GWL were optimally released at 12 WOI.

4.5 Potassium release at different weeks of incubation

Optimum K release from soil treated with distilled water, MLP and NPK 20:10:10 was found at 4 WOI while optimum release of K from soil treated with MLB, GWL and SOF was found at 16 WOI. However, K release from soil treated with NPK 20:10:10 was significantly higher than K release from other treatments except for MLB and MLP at 16 WOI (Figure 4.3).

Table 4.1: Soil chemical properties before the incubation experiment

Soil properties	Value
pH (1:1 soil/water ratio)	5.10
Total nitrogen (g/kg)	0.16
Available phosphorus (mg/kg) Bray-P1	2.10
Exchangeable cations (cmol/kg)	
Ca	0.60
Mg	0.10
K	0.05
Na	0.10

Table 4.2: Nutrient composition of organic fertiliser materials used in this study

	Nutrient composition (%)				
Fertiliser sources	N	P	K	Ca	Mg
Moringa leaf blade	2.79	0.42	1.85	1.92	0.19
Moringa leaf petiole	2.10	0.28	2.06	2.23	0.15
Gliricidia whole leaf	2.74	0.36	0.72	1.15	0.17
"Sunshine" organic fertiliser	1.41	0.19	0.44	1.08	0.11

`

Table 4.3: Effects of nutrient sources on soil pH at different weeks of incubation

Treatment	pH (1:1 soil/water ratio) WOI				
	0	4	8	12	16
Distilled water (control)	5.1	5.4e	5.5d	5.5d	5.7c
MLB	5.1	6.6b	6.7b	6.7b	6.8ab
MLP	5.1	7.1a	7.0a	6.9a	6.8ab
GWL	5.1	6.5b	6.7b	6.8ab	6.9a
SOF	5.1	6.2c	6.3c	6.5c	6.7b
N.P.K 20:10:10	5.1	6.0d	5.4d	5.2e	5.0d

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test. WOI= Weeks of Incubation, MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf and SOF = "Sunshine" Organic Fertiliser,.

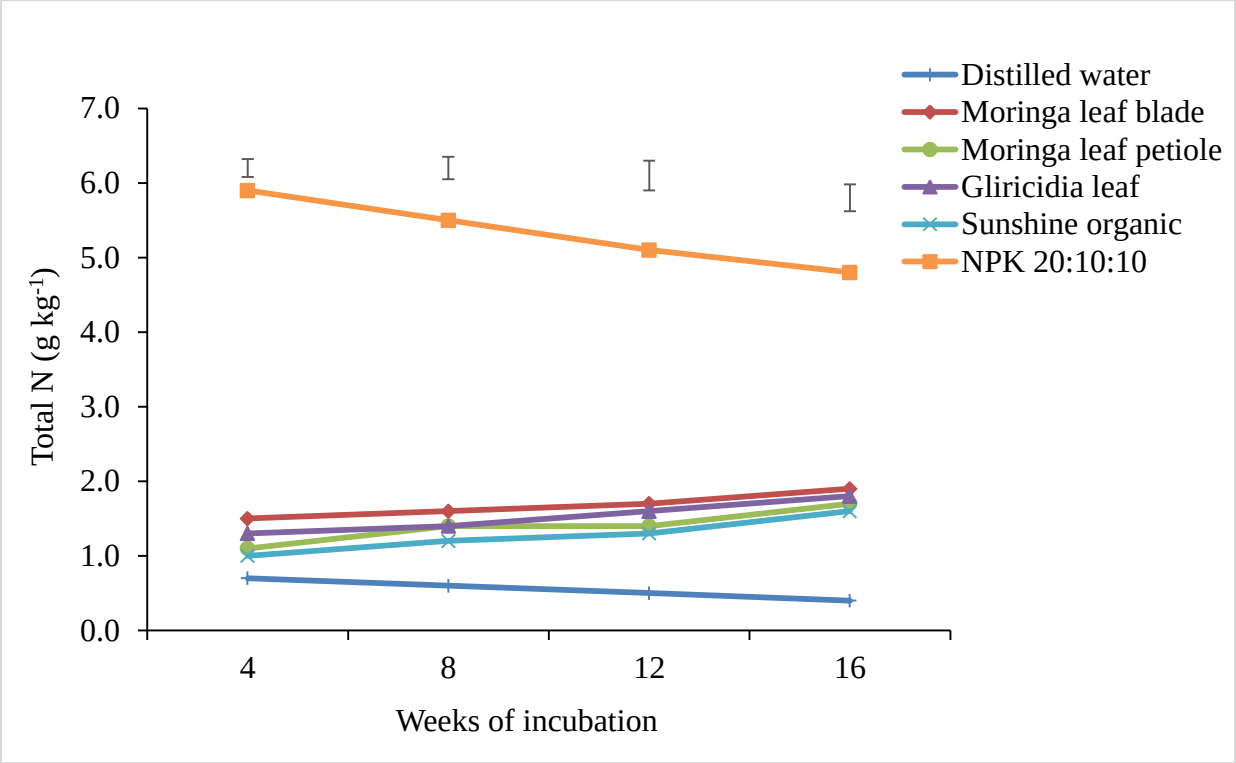


Figure 4.1: Nitrogen release pattern of different fertiliser sources

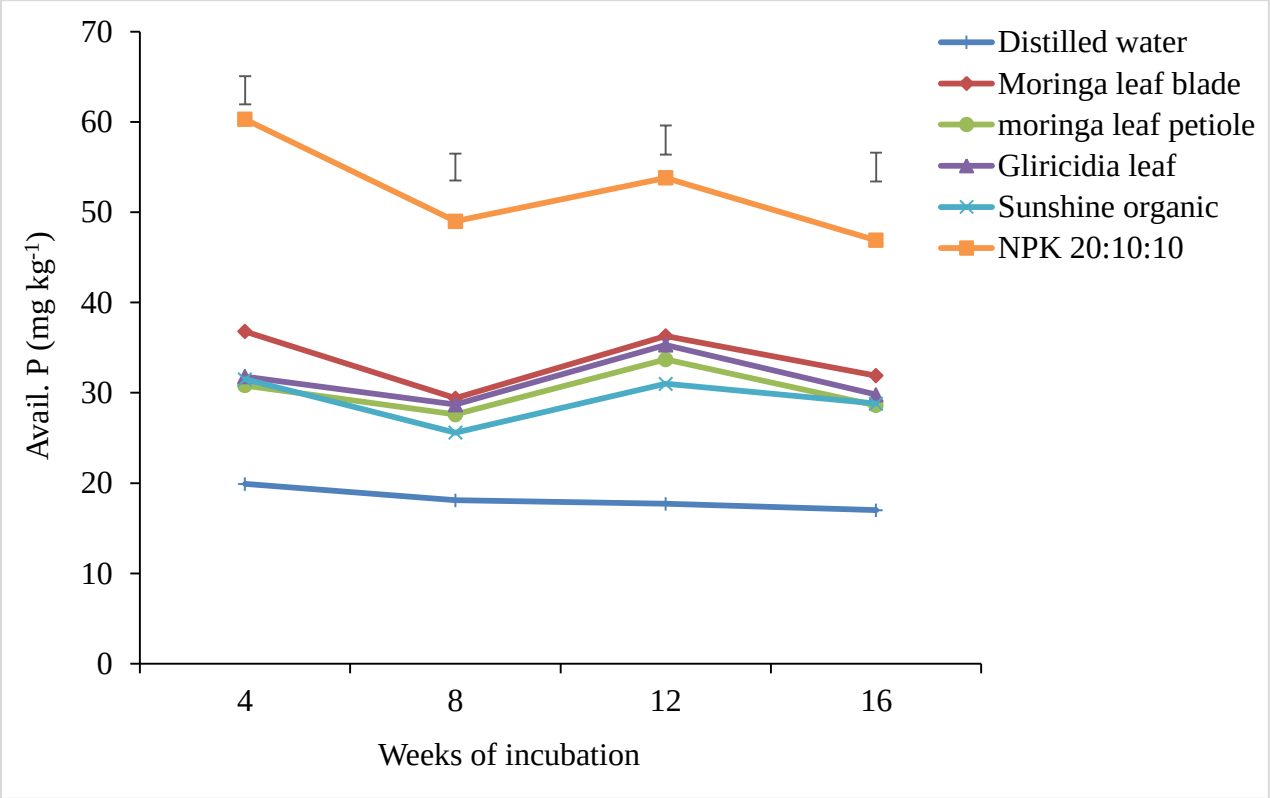


Figure 4.2: Phosphorus release pattern of different fertiliser sources

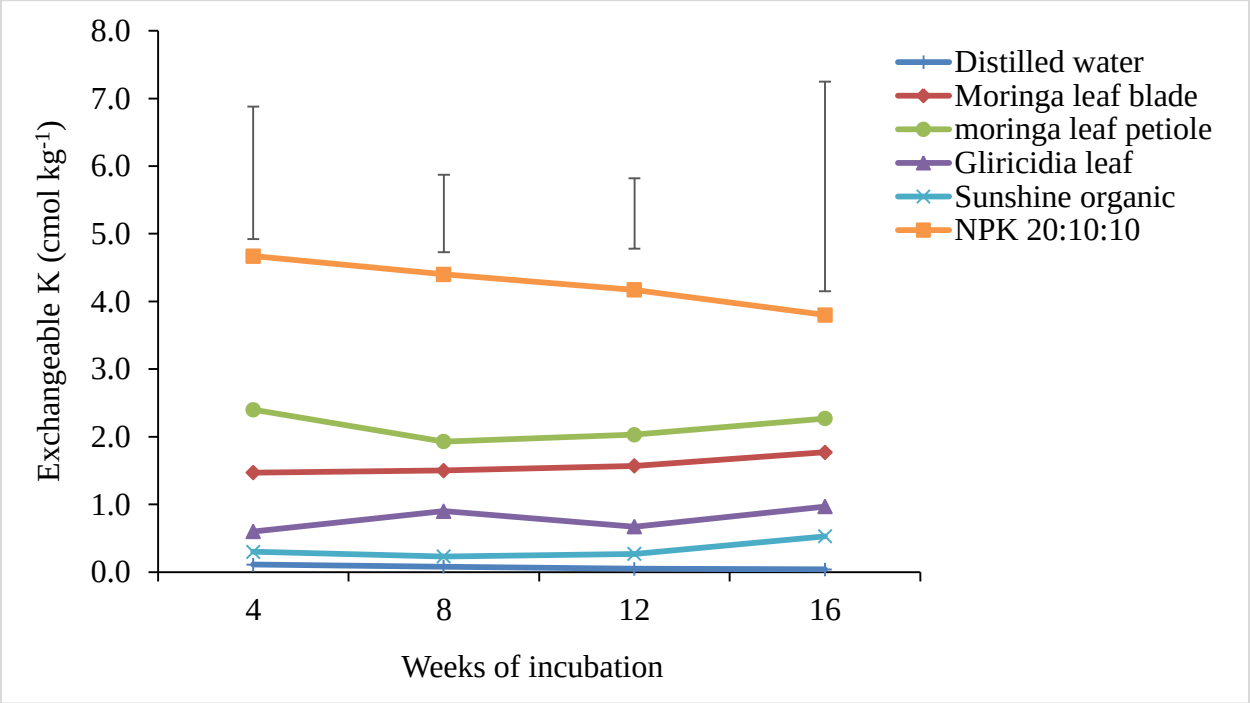


Figure 4.3: Potassium release pattern of different fertiliser sources

4.6 Response of amaranth and okra to nutrient release from moringa leaf blade and petiole for their growth and yield performance

4.7 Chemical properties of experimental soil

The values of pH (1:1 soil/water ratio), total nitrogen, available phosphorus and exchangeable (potassium, calcium, magnesium and sodium) reported in Experiment I was the same for the soil used in this study since the soil was collected after exhaustive cropping with millet.

4.8 Effects of soil amendment with moringa leaf blade and petiole on growth performance and biomass yield of amaranth

The growth data showed that there were significant responses to moringa amendment by amaranth based on plant height, number of leaves, stem girth and leaf area when compared with control (Table 4.4). At 4 and 5 WAS, there were no significant differences between amaranth treated with moringa leaf blade (MLB) and moringa leaf petiole (MLP) in plant height, number of leaves, stem – girth and leaf area. Amaranth grown with MLB was significantly taller than amaranth under control at 3, 4 and 5 WAS in plant height, number of leaves, stem girth and leaf area except for number of leaves at 3 WAS where there was no significant difference (Table 4.4). Amaranth grown with MLP was significantly taller in plant height and wider in stem-girth than amaranth under control at 3, 4 and 5 WAS (Table 4.4).

Amaranth grown with MLB recorded highest fresh biomass weight of 8.15 g/plant and was significantly ($p<0.05$) higher than other treatments while amaranth grown with MLP had fresh biomass weight that was significantly higher than amaranth under control (Table 4.5). Also, amaranth grown with MLB produced the highest dry matter of 0.75 g/plant and it was significantly higher than amaranth under control but not significantly higher than amaranth grown with MLP (Table 4.5).

4.9 Effects of soil amendment with moringa leaf blade and petiole on amaranth nutrient content and nutrient uptake

Nitrogen and phosphorus contents were found to be highest in amaranth grown with MLB while K content was highest in amaranth grown with MLP (Table 4.6). Therefore, there was no significant difference between amaranth grown with MLB and MLP with respect to N, P and K content. N and P contents in amaranth grown with MLB and were significantly different from amaranth grown under control (Table 4.6). However, K content found in amaranth grown with MLB and MLP were significantly higher than amaranth grown under control.

In respect to N and K uptake, amaranth grown with MLB and MLP were not significantly different from each other but significantly different from control. Phosphorus uptake discovered at amaranth grown with MLB and MLP was significantly ($P<0.05$) different from each other while P uptake of the moringa amendments was significantly ($P<0.05$) higher than control (Table 4.6).

Table 4.4: Effects of soil amendment with moringa leaf blade and petiole on growth performance of amaranth at different weeks after planting

Treatment	Plant height (cm)			Number of leaves			Stem girth(cm)			Leaf area (cm^2) at 5 WAS
	WAS									
	3	4	5	3	4	5	3	4	5	
Control	11.4	17.5	20.7	7.8	10.3	12.9	0.3	0.5	0.6	20.1
Moringa leaf blade	22.7	30.3	34.6	9.5	14.8	18.7	1.1	1.3	1.5	56.9
Moringa leaf petiole	21.2	28.1	33.5	8.9	13.6	18.0	1.0	1.2	1.4	49.7
LSD (5%)	2.7	3.3	3.5	NS	1.4	1.9	0.2	0.2	0.2	12.9

NS: Not significant at 5 % probability level, WAS = Weeks After Sowing

Table 4.5: Effects of soil amendment with moringa leaf blade and petiole on biomass yield (g/plant) of amaranth

Treatment	Fresh weight	Dry weight
Control	3.37	0.24
Moringa leaf blade	8.15	0.75
Moringa leaf petiole	6.62	0.69
LSD (5 %)	1.21	0.14

Table 4.6: Effects of soil amendment with moringa leaf blade and petiole on amaranth N, P and K contents and uptake

Treatment	Nutrient content (%)			Nutrient uptake (g/plant)		
	N	P	K	N	P	K
Control	0.89	0.17	0.30	0.21	0.04	0.07
Moringa leaf blade	1.96	0.40	0.68	1.47	0.30	0.51
Moringa leaf petiole	1.78	0.35	0.71	1.23	0.24	0.49
LSD (5 %)	0.39	0.09	0.13	0.29	0.05	0.11

4.10 Effects of soil amendment with moringa leaf blade and petiole on growth performance and biomass yield of okra

Highest mean value in okra growth performance was observed in okra grown with MLB, which was the same with other treatments on stem-girth development at 3, 4 and 5 WAS but was significantly different from okra grown under control at 3, 4 and 5 WAS in okra plant height, number of leaves and leaf area (Table 4.7). From 3, 4 and 5 WAS, it was observed that okra grown with MLB and MLP were not significantly different from each other for okra plant height, number of leaves and leaf area.

On okra fresh and dry biomass yields, there was no significant difference between okra grown with MLB and MLP (Table 4.8). Dry matter produced by okra grown with MLB and MLP were significantly higher than dry matter of okra under control.

4.11 Effects of soil amendment with moringa leaf blade and petiole on okra nutrient content and nutrient uptake

Nitrogen, phosphorus and potassium contents of okra grown with MLB and MLP were statistically the same (Table 4.9). Nitrogen, phosphorus and potassium uptake observed in the tissue of okra grown with MLB and MLP were significantly ($p<0.05$) higher than control.

Table 4.7: Effects of soil amendment with moringa leaf blade and petiole on growth performance of okra

Treatment	Plant height (cm)			Number of leaves			Stem girth(cm)			Leaf area (cm^2)
	WAS			WAS			WAS			WAS
	3	4	5	3	4	5	3	4	5	5
Control	9.7	15.2	23.5	5.0	9.0	11.4	0.8	1.0	1.3	183.1
Moringa leaf blade	14.4	21.5	36.1	6.0	11.7	17.2	1.3	1.5	2.0	324.3
Moringa leaf petiole	13.8	21.1	35.3	5.7	11.2	16.5	1.2	1.4	1.9	307.5
LSD (5 %)	1.3	2.1	3.6	NS	1.1	1.5	NS	NS	NS	50.7

NS: Not significant at 5 % probability; WAS= Weeks After Sowing

Table 4.8: Effects of soil amendment with moringa leaf blade and petiole on biomass yield (g/plant) of okra

Treatment	Fresh weight (g)	Dry weight (g)
Control	5.01	0.58
Moringa leaf blade	9.98	1.37
Moringa leaf petiole	9.25	1.24
LSD (5 %)	1.25	0.22

Table 4.9: Effects of soil amendment with moringa leaf blade and petiole on okra N, P and K contents and uptake

Treatment	Nutrient content (%)			Nutrient uptake (g/plant)		
	N	P	K	N	P	K
Control	0.97	0.24	0.52	0.56	0.14	0.30
Moringa leaf blade	3.10	0.65	1.02	4.25	0.89	1.39
Moringa leaf petiole	2.93	0.58	0.95	3.63	0.72	1.18
LSD (5 %)	0.63	0.12	0.20	1.06	0.15	0.26

4.12 Growth and yield response of amaranth and okra to application of moringa leaf blade, moringa leaf petiole, gliricidia leaf, "Sunshine" organic fertiliser and NPK (20:10:10)

4.13 Soil particle size distribution and chemical properties

The particle size distribution and chemical properties of the soil before cropping to maize in the early wet season of 2014 are shown in Table 4.10, while Table 4.11 contains the nutrient status of the soil in the early wet season of 2015. The soil pH in water and pH in potassium chloride in Table 4.10 was slightly acidic and strongly acidic respectively while Table 4.11 shows that the soil was acidic in water and strongly acidic in potassium chloride. The textural class of the soil was loamy sand (Table 4.10). The N, P, K, Ca, Mg and organic carbon with soil in 2014 were higher than 2015 soils. However, the nutrient elements found in both years were lower than their respective critical nutrient levels as reported in Experiment 1. The extractable micronutrient of the soil in Table 4.10 was high in Cu and Zn when compared with their respective critical level of 1.2 – 2 and 1 – 5 g/kg while Fe and Mn were respectively within their critical level of 5 – 200 and 5 – 100 g/kg.

4.14 Post-planting chemical analysis

At 12 and 16 WAS, composite soil samples were collected at 0 – 15 cm depth from amaranth and okra plots respectively. The pH values recorded on amaranth and okra plots under organic fertiliser treatments showed that the pH was slightly acidic while control and NPK were acidic in water and strongly acidic in potassium chloride (Table 4.12). All the values observed in all the treatment plots for Ca and Mg showed that all the nutrient elements were low compared with their respective critical level as reported in Experiment 1. However, K values obtained at MLB and MLP plots were within the critical level of 0.3 – 0.5 cmol/kg K. Nitrogen and Phosphorus contents under control and NPK 20:10:10 plot were very low while moringa leaf petiole and "Sunshine" organic fertiliser plots contains N and P that were moderately low when compared with N and P critical levels reported in Experiment 1. Under moringa leaf blade plots, N, P, Ca, Mg and K contents were significantly ($p<0.05$) higher than N, P, Ca, Mg and K contents recorded in NPK 20:10:10, Sunshine organic fertiliser and control plots (Table 4.12).

Table 4.10: Physico-chemical properties of soil in experimental field before cropping in year 2014

Soil properties	Values
Particle size distribution (g/kg)	
Sand	880
Silt	72
Clay	48
Textural class	Loamy sand
pH (1:1 H_2O)	5.8
pH(1:1 KCl)	4.0
Total N (g/kg)	0.8
Organic carbon (g/kg)	6.7
Available P (mg/kg) Bray- P1	4.0
Exchangeable cations (cmol/kg)	
Ca	1.8
Mg	0.5
K	0.2
Na	0.1
Extractable Micronutriments (mg/kg)	
Mn	84
Fe	95
Cu	4
Zn	18

Table 4.11: Chemical properties of the experimental field after exhaustive cropping with maize in year 2015

Soil properties	Values
pH (1:1 soil/water ratio)	5.2
pH(1:1soil/KCl ratio)	3.8
Total N (g/kg)	0.2
Organic carbon (g/kg)	3.6
Available P (mg/kg) Bray- P1	2.0
Exchangeable cations (cmol/kg)	
Ca	0.7
Mg	0.2
K	0.04
Na	0.1

Table 4.12: Post-Planting chemical properties of soil collected from amaranth plots at 12 WAS and okra plots at 16 WAS in year 2015

Treatment	pH		N	P	Ca	Mg	K
	(1:1 H_2O)	(1:1 KCl)	(g/kg)	(mg/kg)		(cmol/kg)	
Amaranth plot							
Control	5.60	4.10	0.09	1.20	0.09	0.02	0.02
MLB	6.40	5.70	1.61	14.40	0.22	0.10	0.35
MLP	6.90	6.00	1.37	9.70	0.26	0.07	0.38
GWL	6.50	5.50	1.40	11.50	0.17	0.09	0.24
SOF	6.30	5.50	1.12	8.01	0.11	0.05	0.16
NPK 20:10:10	5.10	3.60	0.59	7.12	0.10	0.03	0.13
LSD (5%)	0.60	1.00	0.57	4.50	0.08	0.03	0.13
Okra plot							
Control	5.40	3.90	0.05	1.04	0.06	0.01	0.01
MLB	6.20	5.80	1.50	12.70	0.14	0.05	0.30
MLP	6.30	5.70	1.10	8.31	0.18	0.04	0.31
GWL	6.20	5.80	1.15	10.40	0.10	0.04	0.20
SOF	6.10	5.60	1.07	6.92	0.09	0.03	0.18
NPK 20:10:10	5.00	3.20	0.48	5.30	0.08	0.01	0.12
LSD (5%)	0.50	1.10	0.52	4.01	0.05	0.01	0.10

MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser, WAS= Weeks After Sowing.

4.15 Growth and yield performance of amaranth under different fertiliser treatments

Applied treatments significantly ($p<0.05$) increased plant height of amaranth (Table 4.13). At 4 WAS, plants under control recorded the least mean plant height and number of leaves which were significantly lower than the others. The highest mean plant height and number of leaves obtained from amaranth plants treated with moringa leaf blade (MLB) were not significantly different from amaranth that received gliricidia whole leaf (GWL) and NPK 20:10:10. Plant height and number of leaves of amaranth plant treated with GGL was similar to amaranth treated with moringa leaf petiole (MLP) and NPK 20:10:10, respectively but significantly lower than amaranth grown with "Sunshine" organic fertiliser (SOF). However, the mean stem girth observed at 4WAS was found to be highest under MLB, which was significantly higher than SOF and control. The trend of amaranth leaf area showed that application of MLB resulted in significantly higher when compared with other treatments while leaf area of amaranth under MLP and SOF were the same.

Dry weight of amaranths obtained from MLB plots at 4, 8 and 12 WAS were found to be significantly ($p<0.05$) higher than other treatments (Table 4.14). Dry weight of amaranths that received GWL plots and NPK fertiliser plots were significantly different from each other. Also, amaranths dry matter obtained from GWL plots were significantly higher than the dry matter produced by amaranth that received MLP plots and SOF plots at 4, 8 and 12 WAS (Table 4.14).

Total amaranth fresh shoot yield obtained after applying MLB (9,900 kg/ha) and NPK 20:10:10(9,200 kg/ha) were the same (Table 4.14). However, 9,900 and 9,200 kg/ha obtained from MLB and NPK 20:10:10 respectively were significantly higher than 8,300, 7,800, 6,600 and 3,700 kg/ha recorded following application of GWL, MLP, SOF and control, respectively.

4.16 Nitrogen, Phosphorus and potassium contents and uptake by amaranth at 4, 8 and 12 weeks after sowing (WAS)

Data on nutrient content and uptake by the amaranth at 4, 8 and 12 WAS are presented in Table 4.15. Amaranth grown with 0.1 kg NPK 20:10:10 recorded the highest N content of 2.00, 2.21 and 2.08 % at 4, 8 and 12 WAS respectively, which were significantly higher than other treatments except for moringa leaf blade (MLB). It was observed that N contents found in amaranth grown with 0.95 kg moringa leaf petiole (MLP) and gliricidia whole leaf (GWL) were the same. Highest P content of 0.43 % recorded from NPK 20:10:10 were significantly higher than P content obtained from other treatments. Also, the K contents in the shoot of amaranth grown with MLB and GWL were not significantly different from each other. Highest K content was obtained from amaranth grown with NPK 20:10:10 and it was significantly higher than K content in the amaranth treated with other treatments.

;With respect to nutrient uptake, amaranth shoot harvested from the plots grown with MLB had highest N uptake. However, this was not significantly different from N uptake in the shoot of amaranth grown with NPK 20:10:10 but significantly ($p<0.05$) different from other treatments. Amaranth grown with NPK 20:10:10 recorded the highest P uptake, and this was significantly higher than amaranth P uptake of other treatments except for P uptake at MLB. The trend in the P uptake from the shoot of amaranth plant showed that there was no significant difference between MLP and GWL. The highest quantity of K absorbed in the shoot was found in amaranth treated with MLB and NPK 20:10:10. However, the highest values of K uptake in amaranth shoot which was similar at MLB and NPK 20:10:10 were significantly ($p<0.05$) higher than other treatments.

Table 4.13: Effects of nutrient sources on some growth parameters of amaranth at 4 WAS

Treatment	Plant height (cm)	Stem-girth	Number of leaves	Leaf area per plant (cm^2)
Control	19.3d	0.3c	8.9d	14.9e
MLB	32.8a	1.2a	14.9a	53.4a
MLP	26.6bc	1.1a	13.9b	35.0d
GWL	29.1ab	1.1a	14.3ab	42.4c
SOF	24.0c	0.7b	12.8c	30.8d
NPK 20:10:10	27.0bc	1.2a	14.4ab	46.9b

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test. MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser, WAS= Weeks Afer Sowing.

Table 4.14: Effects of nutrient sources on amaranth short yield at 4, 8 and 12 WAS and Total amaranth shoot yield

Treatment	Fresh shoot yield (g/plot)			Dry shoot yield (g/plant)			Total fresh shoo yield (kg/ha)	Total fresh shoot yield (t/ha)
	4	8	12	4	8	12		
Control	198.2d	285.8d	256.5d	0.3e	0.5e	0.4e	3,700d	3.7d
MLB	584.9a	759.2a	646.1a	1.0a	1.3a	1.2a	9,900a	9.9a
MLP	440.5b	591.7b	527.8b	0.6d	1.1c	0.8d	7,800b	7.8b
GWL	467.9b	636.4b	555.7b	0.8c	1.1c	0.9c	8,300b	8.3b
SOF	354.8c	509.5c	456.3c	0.6d	0.9d	0.8d	6,600c	6.6c
NPK 20:10:10	576.3a	724.5a	603.1a	0.8b	1.2b	1.0b	9,200a	9.2a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test.

MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser, WAS= Weeks Afer Sowing

Table 4.15: Effects of nutrient sources on amaranth N, P and K contents and uptake at 4, 8 and 12weeks after sowing

Treatment	Nutrient content (%)			Nutrient uptake (g/plant)		
	N	**P**	**K**	**N**	**P**	**K**
At 4 WAS						
Control	0.72d	0.10d	0.21d	0.19d	0.03d	0.06d
MLB	1.81a	0.30b	0.52b	1.82a	0.30a	0.53b
MLP	1.45b	0.22c	0.48b	0.93b	0.14b	0.31b
GWL	1.47b	0.28b	0.49b	1.10b	0.21b	0.37b
SOF	1.20c	0.19c	0.37c	0.71c	0.11c	0.22c
NPK 20:10:10	2.00a	0.41a	0.65a	1.74a	0.37a	0.53a
At 8 WAS						
Control	0.91d	0.17e	0.34e	0.41e	0.08d	0.15e
MLB	2.05a	0.42b	0.80b	2.69a	0.55a	1.05a
MLP	1.66b	0.31cd	0.72c	1.78c	0.33b	0.77c
GWL	1.70b	0.36bc	0.79b	1.87b	0.40b	0.87b
SOF	1.45c	0.28d	0.60d	1.28d	0.25c	0.53d
NPK 20:10:10	2.21a	0.51a	0.88a	2.67a	0.61a	1.06a
At 12 WAS						
Control	0.86d	0.13e	0.26e	0.32e	0.04d	0.10e
MLB	1.85a	0.33b	0.68b	2.13a	0.38a	0.78a
MLP	1.50bc	0.25cd	0.51c	1.20c	0.20b	0.41c
GWL	1.64b	0.29bc	0.67b	1.49b	0.27b	0.61b
SOF	1.36c	0.21d	0.43d	1.03d	0.16c	0.32d
NPK 20:10:10	2.08a	0.43a	0.74a	2.18a	0.45a	0.78a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test, MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser, WAS= Weeks After Sowing.

4.17 Growth performance of okra at 4, 6 and 8 weeks after sowing (WAS)

The trend observed at 4, 6 and 8 WAS with okra plant height showed that there were significant increase in the height of the plant in respect to the treatment applied (Table 4.16). Okra plant grown with NPK 20:10:10 recorded the highest plant height at 4, 6 and 8 WAS respectively, which were significantly ($p<0.05$) higher than other treatments. At 4 and 6 WAS, the plant height of okra were the same under moringa leaf blade (MLB), moringa leaf petiole (MLP) and gliricidia whole leaf (GWL). Also, okra plant height from MLB and MLP were the same at 4, 6 and 8 WAS (Table 4.16).

Highest number of leaves was recorded at MLB at 4, 6 and 8 WAS respectively (Table 4.16). The values were significantly different from other treatments except at 4 WAS when there was no significant difference between the mean values of MLB (13.5) and NPK fertiliser (12.5). At 8 WAS, the leaf area of okra plant was highest at MLB and it was significantly higher than the leaf area of other treatments (Table 4.16 and plate 4.1).

The stem girth of okra plant significantly increased from 4, 6 and 8 WAS (Table 4.17). At 4WAS, there was no significant difference between the stem girth of okra recorded at MLB and NPK 20:10:10 while at 6 and 8 WAS, stem girth at MLB was significantly higher than the stem girth of other treatments.

4.18 Effects of fertiliser treatments on flower and pod formation of okra at 10 WAS

Number of flowers and pods produced at 10 WAS were highest when NPK 20:10:10 and MLB were applied (Table 4.17). The highest number of flowers recorded from NPK 20:10:10 plots were the same with number of flowers in okra recorded from MLB, MLP and GWL plots. The number of flowers produced per plant was the same among MLP, GWL and SOF. However, the highest mean value of 9.2 pods/plant observed at MLB were the same with 8.7 recorded from NPK 20:10:10. The number of pods produced per plant was the same under MLP and GWL, and also between GWL and SOF (Table 4.17).

L-R: Control, Gliricidia Whole Leaf, Moringa LeafBlade and NPKplots

Plate 4.1: Okra biomass formation as influenced by different nutrient sources

4.19 Effect of fertiliser treatment on okra pod yield

At 10 WAS, the highest fresh pod weight of (14.6 g/pod) obtained from okra grown with moringa leaf blade was similar to 14.4 g/pod obtained from NPK 20:10:10, but it was significantly ($p<0.05$) higher than the fresh pod weight of other treatments (Table 4.18). The number of pods and seeds per pod at 10 WAS were highest in okra grown with moringa leaf blade. The highest number of harvested pod per plant and number of seeds per pod obtained from okra plants grown with moringa leaf blade were not significantly different from NPK 20:10:10but significantly ($p<0.05$) higher than other treatments. The number of seeds per pod obtained from moringa leaf petiole, gliricidia whole leaf and "Sunshine" organic fertiliser were similar.

Total fresh pod yield obtained from okra grown with moringa leaf blade (6,000 kg/ha) and NPK 20:10:10 (5,900 kg/ha) respectively were similar, but they were significantly higher than other treatments (Table 4.18).

Table 4.16: Effects of nutrient sources on growth performance of okra at 4, 8 and 12 weeks after sowing

Treatment	Planting height (cm)			Number of leaves WAS			Stem girth (cm)			Leaf area (cm^2) 8 WAS
	4	6	8	4	6	8	4	6	8	
Control	15.6d	36.7e	66.6e	9.2d	14.7e	20.8e	0.9d	1.6e	2.3e	338.7f
MLB	22.7b	59.6b	102.4b	13.5a	24.6a	37.8a	1.7a	2.7a	3.9a	657.9a
MLP	20.7b	57.0bc	98.6bc	11.9b	20.9c	31.1c	1.5bc	2.4bc	3.5bc	549.7c
GWL	21.6b	56.4b	93.3c	11.6bc	20.7c	29.9c	1.5bc	2.3cd	3.4c	524.1d
SOF	18.8c	54.1d	79.8d	10.7c	19.2d	27.6d	1.4c	2.2d	3.2d	474.3e
NPK 20:10:10	26.3a	66.2a	116.7a	12.5ab	22.7b	33.7b	1.6ab	2.5b	3.6b	623.6b

Means with the same letter in the column are not significant ($p<0.05$) using Duncan's Multiple Range Test.

MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF="Sunshine" Organic Fertiliser, WAS= Weeks After Sowing.

Table 4.17: Effect of nutrient sources on number of flowers and fresh pods of okra produced at 10 WAS

Treatment	Number of flowers/plant	Number of pods/plant
Control	1.1c	3.6d
MLB	2.0a	9.2a
MLP	1.8ab	7.1b
GWL	1.7ab	6.5bc
SOF	1.5b	6.0c
NPK 20:10:10	2.1a	8.7a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test. MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser, WAS= Weeks After Sowing.

Table 4.18: Effects of nutrient sources on okra yield at 10 WAS and okra total pod yield

Treatment	Fresh pod weight (g/pod)	Number of harvested pod per plant	Number of seeds per pod	Total pod yield (kg/ha)	Total pod yield (t/ha)
Control	7.9e	1.4d	47.3c	2,600d	2.6d
MLB	14.6a	3.0a	71.5a	6,000a	6.0a
MLP	13.6b	2.5b	59.9b	5,100b	5.1b
GWL	12.5c	2.3bc	57.7b	4,900bc	4.9bc
SOF	11.6d	2.1c	56.2b	4,500c	4.5c
NPK 20:10:10	14.4ab	2.9a	69.6a	5,900a	5.9a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test. MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF = "Sunshine" Organic Fertiliser, WAS= Weeks After Sowing.

4.20: Correlation between N release and amaranth N uptake

In Table 4.19, N release at 4, 8 and 12 weeks of incubation (WOI)from control, “Sunshine” organic fertiliser, moringa leaf petiole, gliricidia whole leaf, moringa leaf blade and NPK 20:10:10 was significantly associated(r=0.601, r= 0.952 and r= 0.748) with amaranth N uptake at 4, 8 and 12 WAS, respectively. There was also significant association between P (r= 0.583, r= 0.775 and r= 0.663) and K (r= 0.524, r= 0.690 and r= 0.617) release at 4, 8 and 12 WOI and P and K uptake at 4, 8 and 12 WAS, respectively.

4.21: Correlation between N release at 12 WOI and amaranth shoot yield

Table 4.20 showed that nitrogen release at 12 WOI from control, “Sunshine” organic fertiliser, moringa leaf petiole, gliricidia whole leaf, moringa leaf blade and NPK 20:10:10 was significantly associated (r= 0.635)with amaranth shoot yield at 12 weeks after sowing (WAS). It also significantly associated (r= 0.578) with total amaranth shoot yield. However, amaranth shoot yield at 12 WAS was significantly associated (r= 0.898) with total amaranth shoot yield.

4.22: Correlation between N release at 12 WOI and okra pod yield

In Table 4.21, there was high significant correlation (r= 0.644) between nitrogen release at 12 WOI obtained from unamended soil (control), “Sunshine” organic fertiliser, moringa leaf petiole, gliricidia whole leaf, moringa leaf blade and NPK 20:10:10 and okra pod yield at 12 WAS. Nitrogen release also associated significantly (r= 0.625) with total okra pod yield. Furthermore, potassium release at 12 WOI was significantly associated (r= 0.662) and (r=0.639) with okra pod yield at 12 WAS and total okra pod yield respectively. Lastly, okra pod yield at 12 WAS had high significant correlation (r= 0.976) with total okra pod yield.

Table 4.19: Correlation Coefficient matrix showing the effect of nutrient sources between N, P and K release at 4, 8 and 12 WOI and amaranth N, P and K uptake at 4, 8 and 12 WAS

Treatment	Nutrient release at 4 WOI			Amaranth nutrient uptake at 4 WAS		
	N	P	K	N	P	K
N-release	1.00					
p-release	0.030	1.00				
K-release	0.025	0.021	1.00			
N-uptake	0.601**	0.007	0.010	1.00		
P uptake	0.011	0.583*	0.012	0.004	1.00	
K uptake	0.014	0.009	0.524*	0.001	0.002	1.00

Treatment	Nutrient release at 8 WOI			Amaranth Nutrient Uptake at 8 WAS		
	N	P	K	N	P	K
N-release	1.00					
p-release	0.041	1.00				
K-release	0.036	0.028	1.00			
N-uptake	0.952**	0.013	0.018	1.00		
P uptake	0.015	0.975**	0.020	0.009	1.00	
K uptake	0.015	0.016	0.690**	0.006	0.008	1.00

Treatment	Nutrient release at 12 WOI			Amaranth Nutrient Uptake at 12 WAS		
	N	P	K	N	P	K
N-release	1.00					
p-release	0.033	1.00				
K-release	0.029	0.024	1.00			
N-uptake	0.748**	0.008	0.012	1.00		
P uptake	0.013	0.663**	0.014	0.007	1.00	
K uptake	0.017	0.011	0.617**	0.003	0.005	1.00

** Correlation is significant at 0.01 level. WOI = Weeks of Incubation, WAS = Weeks After Sowing.

Table 4.20: Correlation coefficient matrix showing the effect of nutrient sources between Nutrient release at 12 WOI and amaranth shoot yield

	N-release	P-release	K-release	ASY at 12 WAS	TASY
N-release	1.00				
P-release	0.058	1.00			
K-release	0.040	0.071	1.00		
ASY at 12 WAS	0.635**	0.582*	0.555*	1.00	
TASY	0.578*	0.531*	0.510*	0.898**	1.00

** Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level.

ASY = Amaranth Shoot Yield, TASY = Total Amaranth Shoot Yield, WOI = Weeks of Incubation, WAS = Weeks After Sowing.

Table 4.21: Correlation coefficient matrix showing the effect of nutrient sources between Nutrient release at 12 WOI and okra pod yield

	N-release	P-release	K-release	OPY at 12 WAS	TOPY
N-release	1.00				
P-release	0.058	1.00			
K-release	0.040	0.071	1.00		
OPY at 12 WAS	0.644**	0.560*	0.662**	1.00	
TOPY	0.625**	0.503*	0.639**	0.976**	1.00

** Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level.

OPY = Okra Pod Yield, TOPY = Total Okra Pod Yield, WOI = Weeks of Incubation, WAS = Weeks After Sowing.

CHAPTER 5

DISCUSSION

High nutrient elements found in moringa leaf blade and moringa leaf petiole corroborates the report of Foidl *et al*. (2001) that moringa plant parts have high macro nutrient elements and could be used as soil amendment for soil fertility improvement. In the incubation study, moringa leaf blade, moringa leaf petiole, gliricidia whole leaf and "Sunshine" organic fertiliser gradually releases their nutrients while NPK 20:10:10 releases its nutrient fast. This explains why the application of NPK 20:10:10 is at two weeks after planting while the organic fertilisers are applied a week before planting on the field (Ojo *et al*., 2008).

It is evident in this work that high nutrient content found in moringa leaf blade contributes to steady increase in N, P and K release during 16 weeks of incubation, higher N, P and K uptake by amaranth at 4, 8 and 12 weeks after sowing and higher residual N, P, K, Ca and Mg in experimental plots. These findings support the result found by Morafa (2007) on performance of gliricidia leaf over *Chromoleana odorata* and mineral fertiliser in cassava-maize intercrop. However, Morafa (2007) reported that gliricidia leaf plots recorded higher nutrient release than *Chromoleana odorata* plots, higher nutrient uptake in maize tissue and higher residual nutrient elements than in mineral fertiliser and *Chromoleana odorata* plots.

High pH of soil incubated with moringa leaf petiole which was neutral (7.0) and near neutral level (7.1) could be as a result of high calcium and potassium content present in moringa leaf petiole (Foidl *et al*., 2001). Soil incubated with moringa leaf blade resulted in improve soil pH while sharp decline in pH of incubated NPK 20:10:10 showed that the soil was tending towards acidity. Makker and Becker (1997) attributed the improvement of moringa leaf on soil pH to increase in soil organic matter and calcium content. Both substances are cementing and stabilizing agents in soil aggregation (Giller, 2002). However, improvement in soil pH and nutrient release by moringa leaf blade observed in this study could be responsible for the increase in growth and yield of amaranth and okra evaluated, and this is in line with the report of Foidl *et al*. (2001) that

soil improvement and nutrient provided by moringa leaf resulted to increase in growth and yield of leafy vegetable.

In the screenhouse, amaranth and okra respond positively to soil amended with moringa leaf blade and leaf petiole, and this was evident on number of leaves, leaf area, fresh biomass yield and N, P and K uptake of the test crops which are significantly higher than control. This finding also confirmed the work of Akinola (1999) and Akanbi and Togun (2002) who found that soil amended with organic materials significantly increased amaranth growth and biomass yield. The significant increase of moringa leaf blade and leaf petiole over control on various growth parameters is an indication that manure is a store house for nutrient elements and organic matter which are essential for plant growth (Ojo *et al.,* 2008). It also confirms the agronomic value and the potential of organic material in soil fertility amendment as reported by Agboola and Obatolu (1990) and Morafa (2007).

High N, P. and K concentration and uptake found in amaranth and okra tissue is a result of abundant release of N, P and K from moringa leaf blade. This finding support the result of Lawal *et al*. (2011) on high nutrient concentration and uptake observed in sunflower tissue as a result of better utilization of N, P. and K in soil solution by sunflower root. Amaranth and okra phosphorus uptake show significant differences between moringa leaf blade and leaf petiole. This observation on phosophorus uptake was in agreement with the report of Idowu and Akinyemi (2015) that plant root can take up phosphorus released to soil from fertiliser sources in different pattern.

On the field, there were significant reduction in amaranth and okra growth parameters such as number of leaves, leaf area and stem girth in control and "Sunshine" organic fertiliser plots. However, this result to low yield recorded in control and "Sunshine" organic fertiliser plots. This agrees with the result obtained by Osumah (2010) in the reduction of amaranth and okra leaf biomass produced with human urine-water dilution ratio (1:6) which resulted to low yield as a result of low nutrient supply from the urine-water dilution ratio. Furthermore, highest amaranth fresh and dry biomass yield were recorded at moringa leaf blade plots. This finding was supported by the result of Akanbi and Togun (2002) on amaranth fresh and dry matter yield recorded from maize-stover compost. However, the high amaranth fresh and dry matter yield obtained could be as a

result of the effects of N, P and K on amaranth nutrient uptake together with efficient use of nutrients and water by amaranth (Osumah, 2010)

Nitrogen effect is expected since nitrogen is an important constituent of leaf formation and development (Hortson, 1996; Osumah *et al.*, 2011). Higher biomass produced could be responsible for the highest pods per plant, fresh pod weight and seeds per pod obtained from okra grown with moringa leaf blade at 10 weeks after sowing. These findings corroborate the report of Osumah *et al*. (2011) that high yield obtained from crop could be as a result of metabolite produced during photosynthesis in the leaf biomass and better translocation of the metabolite from plant tissue to the reproductive site.

High significant correlation recorded between (N and K release) and okra pod yield in this study showed that nitrogen and potassium influence okra pod formation, and this is in line with the report of Akanbi *et al.* (2005) that okra requires nitrogen and potassium for its pod production. Furthermore, high significant relationship was recorded between nitrogen release and amaranth shoot yield. This relationship support the report of Elbehri *et al.* (1993) and Akanbi and Togun, (2002) that increase in nitrogen release in the soil gave higher influence on amaranth shoot yield than phosphorus and potassium. However, nitrogen release from moringa leaf up to 12 weeks of its application to soil will further classify it as a high quality fertiliser material suitable for fast growing shoot duration crops such as garden egg and leafy vegetable (Foidl *et al*., 2001). Moringa leaf could also be used to support long duration crops such as cassava in their early stage of establishment as a result of its fast decomposition with high macronutrient elements and organic matter release into the soil (Fuglie, 2001). The statement of Fuglie (2001) is in accordance with fast decomposition and steady increase of nitrogen, phosphorus and potassium release from moringa leaf blade observed in this study. This is in line with the report of Morafa (2007), which stated that plant materials of high N content such as *Gliricidia sepium* support cassava in their early stages of growth due to its steady decomposition rate and release of nutrient elements into the soil.

Furthermore, moringa leaf blade increased amaranth shoot yield and okra pod yield by over 50%, 25% and 15% when compared with control, “Sunshine” organic fertiliser and gliricidia whole leaf respectively as a result of steady release of nitrogen,

phosphorus and potassium from fast decomposing moringa leaf blade. Similar observations were reported by Makker and Bekker (1997) and Fuglie (2001) on tomato and pepper when moringa leaf extract was used as growth enhancer. Effects of moringa leaf blade on growth and yield of amaranth and okra therefore were significantly superior over commercial "Sunshine" organic fertiliser and gliricidia whole leaf. This confirmed the potential of *Moringa oleifera* as organic fertiliser in amaranth and okra production.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study was carried out to find the more effective material between moringa leaf blade and leaf petiole as a substitute to the expensive and soil acidifying mineral fertiliser in amaranth and okra production.

Nutrient composition of moringa leaf blade and leaf petiole were determined from chemical analysis after air drying for 3 days and later oven drying at 80°C. Other organic fertiliser materials ("Sunshine" organic fertiliser and gliricidia whole leaf) were also subjected to chemical analysis to establish their nutrient composition before starting the incubation experiment. Incubation study was conducted for 16 weeks at four weeks interval. Soil pH, nitrogen (N) phosphorus (P) and potassium (K) were first determined on the experimental soil before the commencement of the incubation. Actual N, P and K release were obtained for each week of incubation by subtracting the initial N, P and K values from N, P and K release at the end of each incubation week.

Moringa leaf blade and leaf petiole at 100 kg N/ha were used as soil amendment to grow amaranth and okra on an infertile soil in screenhouse pot experiment. Growth parameters, biomass yield and nutrient uptake were determined using appropriate methods. Moringa leaf blade and leaf petiole performed significantly better than control in all the parameters considered.

Lastly, field experimentson the same location were carried out involving the cultivation of amaranth and okra grown with 0.72kgmoringa leaf blade, 0.95kgmoringa leaf petiole, 0.75kg gliricidia whole leaf, 1.42kg "Sunshine" organic fertiliser, 0.1kg N.P.K 20:10:10 and no soil amendment (control). Growth parameters of amaranth were taken at 4 weeks after sowing (WAS) on54 tagged amaranths per plot. The 54 tagged amaranths were cut at 10cm above soil level for regeneration to take place. Cuttings were done at 4, 8 and 12WAS. The three cuts gave amaranth total shoot yields. However, the 54 amaranths cut at 4, 8 and 12 WAS were oven drying at 80^{o}C and then analysed for N, P and K. Nitrogen, P and K contents and uptake in amaranth tissue were determined by standard methods. Furthermore, okra growth parameters were determined at 4, 6 and 8 WAS while okra pod yields were determined by weighing fresh pods harvested per plot

at interval of 5 days. Seven harvests were conducted and these gave the total pod yield of okra. At 12 and 16 WAS, composite soil samples were collected on amaranth and okra plots respectively to determine the pH, residual N, P, K, Ca and Mg of the soil. Relationship between nutrient release at 4, 8 and 12 weeks of incubation and amaranth N uptake at 4, 8 and 12 WAS were determined by correlation at 5 % probability. Relationship between nutrient release at 12 weeks of incubation and amaranth shoot yield as well as okra pod yield was established by correlation.

This work has clearly shown that;

1. Moringa leaf blade with over twice as much N (2.79%), four times as much K (1.85%) and P (0.42%) as the commercial "Sunshine" organic fertiliser with 1.41% N, 0.44% K and 0.19% P is a good organic fertiliser for amendment of infertile soils.
2. The incubation experiments over 16 weeks revealed that while NPK fertiliser rapidly lost its nutrients in the soil environment with sharp decline in N, P and K release, moringa leaf blade above all others replenished the soil with increasing nutrients especially N and K.
3. The order of yield performance is moringa leaf blade>NPK fertiliser >gliricidia whole leaf > commercial "Sunshine" organic fertiliser. This confirms the superiority of moringa leaf blade over NPK fertiliser, gliricidia whole leaf and "Sunshine organic fertiliser".
4. The excellent performance of moringa leaf blade was attributed to its inherent high nutrient content and steady increase in N, P and K release when applied as soil amendment. However, there was high residual N, P and K in the plots treated with moringa leaf blade.
5. Significant correlations that existed between nutrient release and amaranth shoot yield as well as okra pod yield indicate that N contributes immensely in amaranth shoot yield while(N and K) in okra pod yield.
6. This work attests that *Moringa oleifera*, also known as miracle tree, providing nutrients for human nutrition, is also a veritable source of plant nutrition. It is easily available and affordable (self-produced by the farmer), harmless to soil ecosystem and enriches the soil with valuable essential nutrients.

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APPENDICES

Appendix 1:Calculation on quantity of fertiliser applied to 50g soil for incubation study.

Required values:

a. Application rats of Nitrogen for amaranth and okra 100kgN/ha
b. Furrow slice in one hectare = 2×10^6kg soil
c. Weight of soil = 50g $\approx$ 0.05kg $\approx$ 0.05kg

Step 1: To calculate the "kgN" that will be found in 50g soil

Since 2×10^6kg soil will required 100kgN

0.05kg soil will required $\frac{100\text{kg N} \times 0.05\text{kg soil}}{2 \times 10^6\text{kg soil}}$

$= 0.0000025\text{kgN} \approx 2.5 \times 10^{-6}\text{kgN}$

$\therefore$ 50g (0.05) soil will require 2.5×10^{-6}kgN:

To calculate the quantity of Moringa leaf to apply

Moringa leaf (having 2.79% N)

Taking "%" to "kg", we have 2.79%N to be 2.79kgN.

$\therefore$ 2.79kgN will be found in 100kg Moringa leaf (ML)

1kgN will be found in $\frac{1\text{kgN} \times 100\text{kgML}}{2.79\text{kgN}} = 35.84\text{kgML}$

$\therefore$ 1kgN will be found in 35.84kgML

Looking for the quantity of Moringa leaf to apply;

Since 1kgN gives to 35.84kgML

Then, 2.5×10^{-6} will give $\frac{2.5 \times 10^{-6} \times 35.84\text{kgML}}{1\text{kgN}} = 89.6 \times 10^{-6}\text{kgML}$

$\therefore$ Convert 89.6×10^{-6}kgML to milligram (multiply by 1,000,000)

$\therefore$ $(89.6 \times 10^{-6} \times 10^6)$g ML = 89.6kg ML

$\therefore$ 89.6g ML $\approx$ 90mg ML.

90mg of Moringa leaf will be required for 50g soil.

(2) Moringa petiole (having 2.10%N)

$\therefore$ 2.10kgN will be found in 100kg Moringa petiole (MP)

1kgN will be found in 100kg Moringa petiole (MP)

$$\text{1kgN will be found in } \frac{\text{1kgN x 100kg MP}}{2.10} = 47.619\text{kgMP}$$

∴ 1kg N will be found in 47.62kgMP

To get the quantity to add to 50g soil

1 kg N gives 7.62kg MP

2.5×10^{-6} kgN (from step 1) will give $\frac{2.5 \times 10^{-6}\ \text{kgN x 47.62kgMP}}{\text{1kgN}}$

$$= 119.05 \times 10^{-6}\ \text{kg MP}$$

∴ Covert 119.05×10^{-6} kgMP to milligram (multiply by 1,000,000) =119.05mgMP

∴ 119mg Moringa petiole will be required for 50g soil.

(3) Gliricidia leaf (having 2.74%N)

2.74kgN will be found in 100kg Gliricidia leaf (GL)

$$\text{1kgN will be found in } \frac{\text{1kgN x 100kg GL}}{\text{2.74kgN}} = 36.496\text{kgGL}$$

∴ 1kgN will be found in 36.496kg GL

To calculate the quantity of Gliricidia leaf to be added to 50g soil,

Since 1kgN gives 52.08kg x 10^{-6}kgGL $\quad \frac{2.5 \times 10^{-6}\text{kgN x 36.496 kgGL}}{\text{1kgN}} = 91.24 \times 10^{-6}$

Then 2.5×10^{-6}KgN (from step 1) will give

∴ Convert 91.24×10^{-6}kg GL to gram (multiply 1,000,000) = 91.24gGL

91mg Gliricidia leaf will be needed to apply to 50g soil.

(4) Sunshine organic fertiliser (having 1.4%N)

1.41kgN will be found in 100kg Sunshine organic fertiliser (SOF)

$$\text{1kgN will be found in } \frac{\text{1kgN x 100kg SOF}}{\text{1.41kgN}} = 70.921\text{kg SOF}$$

∴ 1kgN will be found in 70.921 by SOF

To calculate the quantity of SOF to be added to 50g soil

Since 1kgN gives 70.921kg SOF

Then, 2.5 x 10^{-6} kgN (from step 1) will give $\frac{2.5 \times 10^{-6}\ \text{KgN} \times 70.921\text{kg SOF}}{1\text{kgN}}$

$= 177.30 \times 10^{-6}$kgSOF

∴ Covert 177.30 x 10^{-6}kgSOF to milligram (multiply by 1,000,000) = 177.30mg SOF

∴ 177mg SOF will be added to 50g soil

(5) NPK (20:10:20) contains 20% N

20kgN will be found in 100kg NPK

1kgN will be found in $\frac{1\text{kgN} \times 100\text{kg NPK}}{20\text{kgN}}$ = 5kg NPK (20:10:10)

∴ 1kgN will be found in 5kg NPK (20:10:10)

To calculate the quantity of NPK (20:10:10) to be added to 5kg soil since 1kg N gives 5kg soil

Since 1kgN gives 5kgNPK

Then, 2.5 x 10^{-6} kgN (from step 1) will give $\frac{2.5 \times 10^{-6}\ \text{kgN} \times 5\text{kgNPK}}{1\text{kgN}}$

$= 12.5 \times 10^{-6}$ kg NPK

∴ Convert 12.5 x 10^{-6} kg NPK to milligram (multiply by 1,000,000) = 12.5mg NPK (20:10:10)

∴ 12.5mg NPK (20:10:10) will be added to apply to 50g soil.

Appendix 2: Calculation on quantity of moringa leaf and moringa petiole applied to 5kg soil for screenhouse experiment.

Required values:

a. Application rate of Nitrogen for amaranth and okra = 100kgN/ha

b. Weight of soil used = 5kg

c. Weight of soil in one hectare = 2 x 10^{6}kg

Calculation:

Step 1: To calculate the "kgN" that will be found in 50kg soil

If 2 x 106kg requires 100kgN

5kg will require $\frac{5\text{kg} \times 100\text{kg N}}{2 \times 10^{6}\text{kg}}$ = 250 x 10^{-6} kgN

$\therefore$ 5kg soil will require 250×10^{-6} kgN

(1) To calculate the quantity of ground Moringa leaf to apply

Moringa leaf (2.79%N)

Convert "%" to "kg"; 2.79%N = 2.79kgN

$\therefore$ 2.79kgN will be found in 100kg Moringa leaf (ML)

$$1\text{kgN will be found in } \frac{1\text{kgN} \times 100\text{kg ML}}{2.79\text{kgN}} = 35.84\text{kg ML}$$

$\therefore$ 1kgN will be found in 35.84kgML

Calculating the quantity of Moringa leaf to cover 5kg soil;

Since 1kgN give 35.84kgML

Then, 250 x 10-6kgN will give $\frac{250 \times 10\text{-}6 \text{ kgN} \times 35.84\text{kgML}}{1\text{kgN}} = 8{,}960 \times 10\text{-}6\text{kgML}$

$\therefore$ 250 x 10-6 kgN will give 8,960 x 10-6 kg Moringa leaf

$\therefore$ coverting 8,960 x 10-6 kgML to g (multiply by 1,000)

$\therefore$ (8,960 x 10-6 kgML x 1000)gML = 8.96gML $\approx$ 9.0gML

$\therefore$ 9.0g ground Moringa leaf will be applied to 5kg soil

(2) To calculate the quantity of ground Moringa petiole to apply

Moringa petiole (2.10%N)

Convert "%" to "kg" ; 2.10%N = 2.10kgN

2.10kgN will be found in 100kg Moringa petiole (MP)

$$1\text{kgN will be found in } \frac{1\text{kgN} \times 100\text{kgMP}}{2.10\text{kgN}} = 47.617\text{kgMP}$$

$\therefore$ 1kgN will be found in 47.617kgMP

To find quantity to apply to 5kg soil,

Since 1kgN gives 47.62kg MP

Then, 250×10^{-6} kgN (from step 1) will give $\frac{250 \times 10^{-6} \text{ kgN} \times 47.62\text{kgMP}}{1\text{kgN}}$

$= 11905 \times 10^{-6}$ kgN

$\therefore$ 250×10^{-6} kgN will give $1{,}1905 \times 10^{-6}$ kgN

Converting 1.1905×10^{-6}kgN to g (multiply by 1,000)

$\therefore$ $(1{,}1905 \times 10^{-6}$ kgN x 1000)g MP = 11.905g MP

$\therefore$ 11.9g ground Moringa petiole will be applied to 5kg soil

Appendix 3: Calculation on quantity of fertiliser to apply on 2m2 plot.

Required value:

a. Application rate of nitrogen for amaranth and okra = 1000kgN/ha

b. Area of hectare = $10{,}000m^2$

c. Area of plot to cover = $2m^2$

Step 1: To calculate the 'KgN' that will be found in $2m^2$ plot.

If $10{,}000m^2$ require 100KgN

Then, $2m^2$ will require $\frac{2m^2 \times 100kgN}{10{,}000m^2} = 0.02kgN$

$\therefore$ 0.02 kgN will cover $2m^2$

1. To calculate the quantity of Moringa leaf to apply

Moringa leaf (2.79%N)

Taking % to kg; 2.79%N = 2.79kgN

$\therefore$ 2.79% to kgN will be found in 100kg Moringa leaf (ML)

1kgN will be found in $\frac{1kgN \times 100kg\ ML}{2.79kgN} = 35.84kgML$

$\therefore$ 1kgN will give 35.84kgML

To get the quantity of Moringa leaf to apply to $2m^2$ plot;

Since 1kgN gives 35.84kgML

Then, 0.02kgN will give $\frac{0.02kgN \times 35.84kgML}{1kgN} = 0.72kgML$

$\therefore$ 0.02kgN will give 0.72kg Moringa leaf

$\therefore$ 0.72kg Moringa leaf will be applied to $2m^2$plot

(2) To calculate the quantity of Moringa petiole to apply

Moringa petiole (2.10%N)

Taking % to kg; 2.10%N = 2.10kgN

$\therefore$ 2.10kgN will be found in 100kg Moringa petiole (MP)

1kgN will be found in $\frac{1kgN \times 100kgMP}{2.10kgN} = 47.62kgMP$

$\therefore$1kgN will give 47.62kg Moringa petiole

To get the quantity of Moringa petiole to apply to $2m^2$ plot;

Since 1kgN gives 4762kgMP

Then, 0.02kgN will give $\frac{0.02\text{kgN} \times 47.62\text{kgMP}}{1\text{kgN}} = 0.952\text{kgMP}$

$\therefore$ 0.02kgN will give 0.952kg Moringa petiole

$\therefore$ 0.95kg Moringa petiole will be applied to $2m^2$plot

(3) To calculate the quantity of Gliricidia leaf to apply

Gliricidia leaf (2.74%N)

Taking % to kg; 2.74kgN

$\therefore$ 2.74kgN will be found in 100kg Gliricidia leaf (GL)

1kgN will be found in $\frac{1\text{kgN} \times 100\text{kgGL}}{2.74\text{kgN}} = 36.496\text{kgGL}$

$\therefore$ 1kgN will give 36.496 kg Gliricidia leaf

Getting the quantity of Gliricidia leaf to apply to $2m^2$ plot;

Since 1kgN gives 36.496kgGL

Then, 0.02kgN will give $\frac{0.02\text{kgN} \times 36.496\text{kgGL}}{1\text{kgN}} = 0.73\text{kgGL}$

$\therefore$ 0.02kgN will give 0.73kg Gliricidia leaf

$\therefore$ 0.73kg Gliricidia leaf will be applied to $2m^2$plot

(4) To calculate the quantity of "sunshine" organic fertiliser

Sunshine organic fertiliser (1.41%N)

Taking % to kg; 1.41%N = 1.41kgN

$\therefore$ 1.41kgN will be found in 100kg Sunshine organic fertiliser (SOF)

1kgN will be found in $\frac{1\text{kgn} \times 100\text{kgSOF}}{1.41\text{kgN}} = 70.921\text{kgSOF}$

$\therefore$ 1kgN will give 70.921kg SOF

Getting the quantity of SOF to apply to $2m^2$plot

Since 1kgN gives 70.921kg SOF

Then, 0.02kgN will give $\frac{0.02\text{kgN} \times 70.921\text{kg SOF}}{1\text{kgN}} = 1.418\text{kg SOF}$

$\therefore$ 0.02kgN will give 1.418 kg SOF

$\therefore$ 1.42kg Sunshine organic fertiliser will be applied to $2m^2$ plot

(5) To calculate the quantity of NPK (20:10:10)

NPK (20:10:10) contain 20% N.

Taking % to kg; 20% N= 20kgN

$\therefore$ 20kgN will be found in 100kg NPK (20:10:10)

NPK (20:10:10) contain 20%N

Taking % to kg; 20%N = 20kgN

$\therefore$ 20kgN will be found in 100kg NPK (20:10:10)

1kgN will be found in $\frac{\text{1kgN x 100kg NPK (20:10:10)}}{\text{1kgN}}$ = 5kg NPK (20:10:10)

$\therefore$ 1kg N will give 5kg NPK (20:10:10)

Getting the quantity of NPK (20:10:10) to apply to $2m^2$ plot

Since 1kg gives 5kg NPK (20:10:10)

Then, 0.02kg N will give $\frac{\text{0.02kgN x 5kg NPK (20:10:10)}}{\text{1kg N}}$ = 0.1kg NPK (20:10:10)

$\therefore$ 0.02 kg N will give 0.1kg NPK (20:10:10)

$\therefore$ 0.1kg NPK (20:10:10) will be applied to $2m^2$ plot

Appendix 4: Cumulative shoot weight of 54 amaranths cut above 10cm ground level per $2m^2$ plot

Treatment	1st cut 4 WAP	2nd cut 8WAP	3rd Cut 12WAP	Total shoot weight (g)
Control	198.2d	285.8d	256.5d	740.5d
MLB	584.9a	759.2a	646.1a	1,980.2a
MLP	440.5b	591.7b	527.8b	1.560b
GWL	467.9b	636.4b	555.7b	1,660b
SOF	354.8c	509.5c	456.3c	1,320.6c
NPK (20:10:10)	576.3a	724.5a	603.1a	1,840.9a

MLB = Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser.

Appendix 5: Okra fresh pod yields (g/2m^2) harvested from different fertiliser treated plots

Treatment	5/08/15 1	10/08/15 2	15/08/15 3	20/08/15 4	25/08/15 5	30/08/15 6	04/09/15 7	Total fresh weight(g/2m^2)
Control	62.2d	71.5d	78.1d	109.8d	74.3d	66.9d	58.1e	5,20.9d
MLB	145.8a	163.2a	197.4a	239.1a	172.0a	159.3a	143.2a	1,210a
MLP	131.4b	142.6b	155.2b	184.3b	147.4b	140.1b	129.8b	1,030.8b
GWL	126.1b	134.3bc	151.9bc	177.1b	140.6b	132.7b	118.1c	980.8b
SOF	110.5c	129.0c	142.8c	160.4c	127.1c	115.2c	106.0d	890c
NPK	142.3a	160.7a	193.0a	234.2a	171.3a	157.5a	141.0a	1,200a

MLB = Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf, SOF= "Sunshine" Organic Fertiliser.

Appendix 6: Okra fresh pod yield (g/plot) at 12 WAS

Treatment	Okra pod yield (g/plot)
Control	18.7d
Moringa leaf blade	436.5a
Moringa leaf petiole	339.5bc
Gliricidia whole leaf	329.0 bc
"Sunshine" organic fertiliser	303.2c
NPK 20:10:10	427.2a

Means with the same letter in column are not significantly different ($p<0.05$) using Dunean's Multiple Range Test.

* Okra pod yields at 12 WAS is the summation of third and fourth harvest.

Appendix 7: Nutrient added per $2m^2$ plots

Nutrient sources	Amount of nutrient added ($g/2m^2$)				
	N	P	K	Ca	Mg
0.72kg Moringa leaf blade	20.1	3.0	13.3	13.8	1.4
0.95kg Moringa leaf petiole	20.0	2.7	19.6	21.2	1.4
0.73kg Gliricidia whole leaf	20.0	2.6	5.3	8.4	1.2
1.42kg "Sunshine" organic fertiliser	20.0	2.7	6.2	15.3	1.6
0.10kg NPK (20:10:10)	20.0	10	10	-	-

Appendix 8: Nutrient composition of moringa leaf blade and leaf petiole harvested from moringa plant

Nutrient element	**Leaf blade**	**Leaf petiole**
Macronutrient (%)		
Nitrogen	2.79	2.10
Phosphorus	0.42	0.28
Potassium	1.85	2.06
Calcium	1.92	2.23
Magnesium	0.19	0.15
Micronutrient (mg/kg)		
Iron	52.9	21.0
Manganese	4.4	1.6
Zinc	10.6	8.8
Copper	7.5	5.9

Appendix 9: Monthly rainfall (mm) and mean monthly temperature (^{0}C) of University of Ibadan in the year 2015

Month	Rainfall (mm)	Mean temperature (^{0}C)
January	0.0	26.5
February	14.8	27.2
March	3.0	27.8
April	3.0	27.0
May	106.6	25.4
June	162.8	25.2
July	77.0	24.6
August	63.9	24.8
September	174.7	24.5
October	148.8	25.7
November	_	26.3
December	_	26.8

Source: Department of Geography weather data, University of Ibadan

Appendix 10: Effects of Nitrogen release at different weeks of incubation

Treatment	Total N (g/kg) WOI			
	4	8	12	16
Distilled water (control)	0.7e	0.6d	0.5d	0.4e
MLB	1.5b	1.6b	1.7b	1.9b
MLP	1.1cd	1.4b	1.4bc	1.7cd
GWL	1.3bc	1.4b	1.6b	1.8bcd
SOF	1.0d	1.2c	1.3c	1.6d
N.P.K 20:10:10	5.9a	5.5a	5.1a	4.8a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test.WOI= Weeks of Incubation,MLB= Moringa Leaf Blade, MLP= Moringa Leaf Petiole, GWL= Gliricidia Whole Leaf and SOF = "Sunshine" Organic Fertiliser,.

Appendix 11: Effects of nutrient sources on phosphorus and potassium release at different weeks of incubation

Treatment	Available P (mg/kg)				Exchangeable K (cmol/kg)			
	WOI				WOI			
	4	8	12	16	4	8	12	16
Distilled water (control)	19.9d	18.1d	17.7d	17.0d	0.11c	0.08d	0.05c	0.04c
MLB	36.8b	29.4b	36.3b	31.9b	1.47b	1.50b	1.57b	1.77ab
MLP	30.8c	27.6b	33.7bc	28.6c	2.40b	1.93.b	2.03b	2.27ab
GWL	31.8c	28.7b	35.3b	29.8bc	0.60c	0.90c	0.67c	0.97bc
SOF	31.5c	25.6c	31.0c	28.8c	0.30c	0.23c	0.27c	0.53bc
N.P.K 20:10:10	60.3a	49.0a	53.8a	46.9a	4.67a	4.40a	4.17a	3.80a

Means with the same letter in the column are not significantly different ($p<0.05$) using Duncan's Multiple Range Test. WOI= Weeks of Incubation,MLB= Moringa Leaf Blade, MLP=Moringa Leaf Petiole, GWL=Gliricidia Whole Leaf and SOF= "Sunshine"Organic Fertiliser.