RESPONSE OF CASSAVA-MELON INTERCROP TO ARBUSCULAR MYCORRHIZAL INOCULATION AND FERTILISERS IN IBADAN, NIGERIA

BY

Peter Wusu OLUGBEMI

Matric No: 72785

B.Sc. (Hons.), M. Sc. Agronomy, (Soil Science) Ibadan

A Thesis in the Department of Agronomy

Submitted to the Faculty of Agriculture and Forestry

in partial fulfillment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

AUGUST 2019

ABSTRACT

Sustainable crop production is hampered by declining soil fertility. Application of fertilisers and nutrient mobilising microbes such as Arbuscular Mycorrhizae (AM) could improve nutrient uptake and yield of crops like cassava and melon. However, there is insufficient information on the use of fertilizers and AM in cassava-melon intercrop. Hence, effects of fertilisers and AM on the yield of cassava (*Manihot esculenta* Crantz) and melon (*Citrullus lanatus* Thumb Mansf) intercropped in Ibadan were investigated.

In the screenhouse, responses of two melon cultivars (*Bara* and *Sewere*) to four fertiliser treatments with (+AM) or without (-AM) inoculation were investigated using 4×2×2 factorial arrangements. Melons were grown at one plant per 5 kg soil. Treatments were Organomineral Fertiliser-OF, Almond leaf Compost-AC, and NPK 15-15-15-(inorganic), all at 60 kgN/ha and No Fertiliser Application-NFA in a completely randomised design with three replicates. Data collected were Crop Biomass-CB (g/pot) and Fruit Yield-FY (g/pot). On the field, AM inoculation (+AM, -AM), fertiliser treatments (NFA, OF and NPK) and two cropping systems (sole and intercrop) were investigated. The experiment was in randomised complete block design, replicated thrice with *Sewere*-melon and cassava (TME-7) as test crops. Investigation on residual effects was also conducted. Data collected were Melon Seed Yield-MSY (kg/ha) and Cassava Storage Root Yield-CSRY (t/ha). Nitrogen uptake (g/kg), AM Cassava Root Colonisation-AMCRC (%) and AM Spore Count-AMSC (100g per soil) were determined. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

Bara and *Sewere* CB ranged from 48.8±8.0 (NFA-AM) to 168.3±4.0 (NPK+AM) and 90.0±3.2 (NFA-AM) to 213.3±4.2 (NPK+AM), respectively. *Bara* FY under AC+AM was 20.6±2.1 but increased significantly under OF+AM (48.3±2.4) and NPK+AM (161.7±4.0). Cultivars, AM and fertilisers significantly influenced FY and followed the order: *Sewere* (171.7±3.0; OF+AM) > (166.7±3.5; NPK+AM) >*Bara* (161.7±3.4; NPK+AM) > (20.6±2.2; AC+AM). On the field, MSY under sole was 122.0±16.4 (NFA-AM) and 499.5±25.8 (OF+AM) under intercrop. The residual effects of fertilisers and AM inoculation were significant on MSY with 178.8±22.4 under OF+AM and sole cropping followed by 159.0±15.2 under (NPK+AM) with intercrop. There was significant difference in CSRY among treatments. The CSRY ranged from 9.6±2.4 (NFA+AM) to 22.3±2.5 (OF+AM). However, interaction

between fertilisers, AM and cropping systems at residual showed no significant difference among OF and NPK application without AM inoculation. The CSRY ranged from 5.4±1.3 (NFA-AM) to 11.9±2.4 (OF+AM) under sole crop. Nitrogen uptake under sole cropping ranged from 0.28±0.01 (NFA-AM) to 0.71±0.03 (OF+AM) and under intercrop, it was 0.29±0.01 (NFA+AM) to 0.42±0.02 (OF+AM). The AMCRC ranged from 35.3±0.9 (NFA–AM) to 45.0±1.6 (NPK–AM) under sole cropping system. The NFA+AM had 21.3% increase in AMSC compared to that of (NPK+AM). The interaction of fertilisers and AM had significant effect on AMSC and was in the order 35.0±1.2 (NPK+AM) < 40.0±1.3 (OF+AM) < 52.0±2.2 (NFA-AM).

Organomineral fertiliser at 60 kgN/ha and mycorrhizal inoculation improved melon and cassava yields. Inorganic fertiliser reduced yield, arbuscular mycorrhizal cassava root colonisation and mycorrhizal spores under residual cropping and was therefore not sustainable.

Keywords: Soil fertility management, Organomineral fertiliser, Root colonisation, Mycorrhizal inoculation

Word count: 486

ACKNOWLEDGEMENTS

I give thanks and praises to God Almighty who gave me grace that is ever sufficient and guidance to finish this work.

My sincere gratitude and appreciation goes to my supervisor, Professor O. Fagbola whose patience, understanding and exemplary lifestyle is worthy to emulate.

I am highly indebted to Professor E. A. Akinrinde, (Head, Department of Agronomy) for his contributions towards the success of this work. I must also express my gratitude to all members of my supervisory committee: Professor J. A. I. Omueti, Professor E.O Aiyelari, Professor Hassan Tijani-Eniola, (Department of Agronomy) and Professor O. J. Oyetunji (Department of Botany, University of Ibadan). I am also thankful to Professor O J. Babayemi (Animal Science Department).

My profound gratitude goes to Mrs. E.T. Giwa., Mr. S.A. Omoshuli, and all staff of Department of Agronomy for their contributions at each stage of this work. Specially, my gratitude goes to Dr. T.B. Akinrinola (Agronomy Teaching and Research Farm manager).

I am particularly grateful to my wife, Mrs. E. Florence Olugbemi, for her understanding, patience, support, prayers and encouragement all along. I also thank my dear children John, Joshua, Josiah and Joseph for their love and support. I need to thank all members of my extended family, Mrs. T. Ogungbe, my brothers and sisters for their contributions.

I must also thank the Management and all staff members of Michael Otedola College of Primary Education (MOCPED) particularly, those in the Department of Agricultural Education, Mr. E.O. Ola, Mr. K. Akano, Dr. W.G. Adebosin and other well-wishers.

I thank all my beloved Pastors; S. Alaka, J. Adekoya, J., Abobade, D. Jonathan and others for their contributions. I appreciate the contributions of Mrs. F. Lawal, Mr. O. G. Ali-Ben, Olusola Ojugbele, Adetola Ayokunle, Sanni Christiana and all members of Deeper Life Campus Fellowship (DLCF) of Michael Otedola College of Primary Education Noforija Epe. I thank you all for your contributions.

God bless you all.

CERTIFICATION

I certify that this work was carried out by Mr. Peter Wusu Olugbemi, Matriculation number 72785 of Department of Agronomy, University of Ibadan.

Supervisor

O. Fagbola

B.Sc. (Ibadan) M.Sc. (Ibadan), Dip (Copenhagen)

M. Phil. (Cantab), Ph. D. (Ibadan).

Professor of Molecular & Environmental Microbiology

DEDICATION

This thesis is dedicated to God Almighty, the Father of our Lord Jesus Christ, the Author and Finisher of our faith, for His guidance, protection and provision throughout the course of study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is an enduring shrub that can be harvested within twelve months after planting. It belongs to Euphorbiaceae family which is prevalently planted for its tuberous root with about 15% peel and 85% flesh (IITA, 2004). It is the most generally conveyed tropical tuber crop discovered growing between latitude 30^{o}N and longitude 30^{o}S in regions where yearly precipitation is more prominent than 500 mm and mean temperature is above 25^{o}C (FIIRO, 2006). As indicated by Yusuf *et al.* (2008), cassava based cropping frameworks are more common than other cropping systems in many sub-Saharan Africa countries. Normally, cassava is usually left to continue growing after the other arable crops such as maize, cowpea, melon, and soybean have been harvested in the early cropping season.

Cassava is a popular tuber crop that is compatible with other arable crops particularly maize for intercropping, for both early and late planting seasons (Ijoyah *et al.*, 2012). Legumes crops like cowpea or soybean are planted in the late season with cassava in view of their natural favourable feature of short germination period, low shelter structure, dry spell resilience and capacity to fix nitrogen and to stifle weeds (Ayoola and Makinde, 2007; Olorunda, 2010; Nair, 2014). As a staple crop, cassava has certain inalienable attributes that have made its farming appealing to smallholder farmers, for example, its capacity to flourish with soils where other crops fizzled and requires generally low resources for cultivation. In addition, cassava can withstand dry spell, can be accessible throughout the year, inexpensive to farm and brings high profit to farmers, along these lines giving family means of livelihood. Thus, cassava is viewed as a starvation reserve crop (Okon *et al.*, 2010).

Cassava assumes significant role in mitigating the issue of food insecurity resulting from spontaneous population expansion in sub-Saharan Africa (Adeola, 2007; Beader, 2013). Nigeria is the most astounding cultivator of cassava in the planet earth, trailed by nations including Zaire, Tanzania, Ghana, Mozambique, Uganda, Madagascar, Angola, Cameroon, Cote d'Ivoire and Benin (FAO, 2014). Cassava is

used in the production of by-products such as, starch, dried cassava "garri," fermented and dried cassava pulp, wet pulp, smoked cassava balls, cassava bread to mention but few of the products that can be produce from cassava (FIIRO, 2006; Muoneke and Mbah, 2007). In addition, cassava is compatible with melon for intercropping in conventional cultivation system. Intercropping is a cultivation system which guarantees adequate food supply against crop failure with the aim of expanding return and benefit by utilizing the same manpower and other resources (Adeola, 2007; Oluleye and Akinrinde, 2011).

Melon (*Citrullus lanatus* (Thumb) Mansf) 'Egusi' originates from the family Cucurbitaceae including cucumber, horned melon, musk melon, canary melon, water melon and pumpkin. Melon has fleshy pulp with different pulp colour that differentiates it from water melon (Ugwumba, 2010). Sadiq *et al.* (2013) and in Protabase, melon comes from the tropical and sub-tropical Africa and is a local of West Africa, where it was disseminated and cultivated throughout the Mediterranean. As opined by Adewusi *et al.* (2000), melon is famous in Nigeria for its edible seeds, which are utilized in cooking of local soups and snacks such as fried melon seed ball known as 'robo' in South West Nigeria.

The principal parts of seeds of melon include: oil (50%) and protein (38%). The oil content is similar to those of other oil plants. Moreover, it contains water, nutrients and considerable measure of minerals like potassium, phosphorus, magnesium, calcium, zinc and iron. It responds well to manures applied at 25– 30 t/ha like other arable crops (Ugwumba, 2010). Likewise, melon is a significant part of conventional copping systems in Nigeria. It can be intercropped with some staple crops, for example, cassava, maize and sorghum. The potential of melon to cover the ground makes it valuable to control weeds and lessen soil run off under intercropping. Melon is cultivated at times as sole crop in large field, market garden near urban area or backyard (Sri Budiastuti *et al*., 2012).

Among impediments to crop cultivation in Nigeria, supplement exhaustion in soils and yield decrease have turned out to be a severe obstacle. The fundamental driver of soil fertility issues in crop cultivation is the reduced length of fallow due to human population pressure and other formative needs on land (Faujdar *et al.*, 2014; Gilley and Rise, 2000). The short length of fallow of the available farmlands result in low fertility of soil, when nutrients removed in the past cultivations is not completely

replenished (Nair, 2014). Consequently, alternative techniques such as intercropping are carried out on limited accessible land for cultivation (Ayoola and Adeniyan, 2006).

The management and conservation of the soil to prevent reduced harvest under intensive cultivation have turned out to be significant area of agronomic research (Ayoola and Adeniyan, 2006). However, when manure is efficiently and viably utilized it guarantees economical harvest by immobilising nutrients that are vulnerable to leaching (Omueti *et al*., 2000; Fagbola and Ogungbe, 2009).

Manure application assumes important position in replenishing soil fertility for cultivation particularly where bush fallowing is no more in existing. Soumare *et al*. (2003) showed that crop yields from plots with manure application are normally higher contrasted than crop yields obtained from plots that were under shrub fallowing for long period. Be that as it may, the utilization of manure in cassava and melon intercropping is definitely not a typical practice among Nigeria peasants' farmers (Kiani *et al.,* 2005). Despite all the potentials of mineral composts in crop cultivation, there are issues, for example, accessibility to famers, cost, natural issues and underground water contamination (Castillo *et al.*, 2003; Gilley and Risse, 2000; Jadoon *et al.*, 2003; Irwin, 2010).

Since use of inorganic fertilizers had been a common method of adding nutrients to improve soil fertility, organic method is gradually becoming more adopted due to its affordability and ecosystem friendly. Mycorrhiza beneficial interaction is a very much recognised biological system that enhances nutrient acquisition by most plants growing on nutrients deficient soils (Schuessler *et al*., 2001; Fagbola *et al.*, 2001; Dalpe and Monreal, 2004). Additionally, from these associations the plants gain the followings: improved water and nutrients uptake, improved phosphorus uptake, drought and disease resistance. Advantages of the organisms are the provision of photosynthates to the parasitic system situated in the cortical cells of the plant and the encompassing soil (Dania *et al*., 2014).

Besides, water, nutrients, and photosynthates transfers happen through the parasitic filament network that bridges plant rhizosphere and plant roots (Fagbola *et al.*, 2001). Subsequently, mycorrhiza can be utilized to improve the use of organic fertilisers within the structure of sustainable agriculture. Sustainable crop cultivation in traditional farming systems incorporate intercropping with the utilization of organic fertilisers, for example, (organomineral compost) and additionally bio fertiliser (Mahmood and Rizvi, 2010; Dania *et al.*, 2013).

Mycorrhizal usage in farming will assist in reduction of problems of nutrient acquisition particularly on degraded soils. Short-fallow farming systems appear to be a typical practice for cassava and melon farming. Consequently, more studies are required for sustainable growth in productivity in the intercropping of cassava and melon. In spite of the fact that, intercropping is a method for crop cultivation, yet there are insufficient data on nutrients demand which is additionally imposed by sole utilization of inorganic fertilisers. The utilisation of organomineral fertilizers can be enhanced with mycorrhizal inoculation to improve nutrient uptake and crop productivity. The development and yield of cassava and melon under intercropping with consolidated utilisation of organomineral fertiliser and mycorrhizal inoculation have received little attention. This work was carried out with the main objective of intercropping cassava and melon with Arbuscular Mycorrhizal Fungi (AMF), organic and inorganic fertilisers on an Alfisol. Consequently, the specific objectives of this study were to:

i. assess the response of two cultivars of melon to organomineral fertiliser, NPK and compost under pot trial;
ii. evaluate the response of melon and cassava as sole or intercrop to NPK, organomineral fertiliser and arbuscular mycorrhizal inoculation in field trials;
iii. determine the influence of arbuscular mycorrhiza fungi on the uptake of nutrient by cassava plant;
iv. evaluate the land equivalent ratio (LER) for both cassava and melon;
v. determine the effect of OF and NPK application on arbuscular mycorrhiza fungi spore and cassava roots colonisation under the two cropping systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Agronomy and distribution of cassava crop

Cassava (*Manihot esculenta* Crantz*)* is an important economic crop cultivated in many tropical countries, spreading all over West African countries. Cassava plant is classified as a perennial semi-shrub, with large palmate leaves having 5 or 7 lobes and a slender petiole. The stem is interspersed with nodes by which the plant reproduces vegetatively (FIIRO, 2006; Olorunda, 2010).

The size of cassava storage roots decrease gradually beginning from the stem as they run into the ground ending with thin universal robust fibrous starchy roots. The starchy roots comprise of two portions, an external cortex, which is corky, and an internal fleshy part which can be processed into different consumable carbohydrates or modern starches. The external cortex likewise has two layers. The cortex is known as the 'peel' and conventionally evacuated by a procedure called "stripping" to have access to the inward starchy delicate flesh (Beader, 2013; Kunji, 2013).

The cassava plant can stay alive in harsh tropical atmospheres even in poor soils without enough water supply. It adjusts to a wide range of climatic and natural conditions; growing between 30^{o}N and 30^{o}S of the Equator. Cassava endures temperatures somewhere in the range 25^{o}C and 35^{o}C with a normal precipitation of 500 mm to 5000 mm per annum and a soil pH of 4 to 9 (Alves, 2002). Notwithstanding, for ideal growth performance, it needs a warm, moist atmosphere and well distributed yearly precipitation. Root development in cassava plant is photo periodic; thus it is improved by short days and delayed by long days that surpass 10 to 12 hours. Onwueme and Sinha (2002) and Beader, (2013), revealed that poor yearly precipitation distribution in cassava growing season can be activated if there is good soil texture, and drainage (Okon, 2011).

2.2 Cassava production in Nigeria

As indicated by Food and Agriculture Organization report (FAO, 2014), Nigeria is the largest cassava producer on the planet; a third extra than cultivation in

Brazil and practically twofold the production of Indonesia and Thailand. Cassava cultivation in other African nations, like Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda seems small in contrast with Nigeria's significant yield FAO (2014). Thus, Nigeria was positioned first among the twenty cassava producing countries on the planet with the yearly output of around 54 million metric tonnes in the year 2012 (Table 2.1). Be that as it may, as indicated by FIIRO, (2006) and Agahiu *et al.* (2012), out of the thirty-six states, seventeen southern states that are within the humid tropics accounted for about 66% of the national output of cassava.

2.3 Cassava Energy Conversion ratios

The two kinds of cassava, bitter and sweet are great calorie yielding crops. FIIRO (2006) stated that cassava calories per hectare per day is more than other crops. In particular, cassava plant yield 250,000 calories for each day per hectare, while other plants calories yield are: maize, 209,000 cal/ha/day; rice is 176,000 cal/ha/day; and wheat is around 114,000 cal/ha/day (Beader, 2013). Hillocks (2002), observed that the cassava storage roots are the least expensive root crop in terms of cost per kilogram. In Nigeria, for example, cost of yam, sweet potato, irish potato and cocoyam were 1.9, 2.0, 2.6, and 2.5 respectively contrasted with that of cassava (FIIRO, 2006). From the study, cassava storage roots, (which can be processed into various food products) is a renowned staple among many southern Nigerians; hence, cassava is produced in large amount (Hillocks, 2002; Ijoyah *et al.*, 2012).

Cassava storage roots, however, high in energy conversion is however, low in riboflavin, and have practically zero niacin and nutrient as detailed by FIIRO (2006). The poor nutritive value of cassava required nutrients supplement if used as a staple food. Tare (2009), revealed a development in the wholesome worth of a cassava nutrition which is enhanced by methionine. The leaves when consumed as a vegetable, supply nutrients and basic minerals and are valuable as domesticated animals feed supplements (Ukpabi and Ejiofor, 1997 cited in FIIRO, 2006). However, the majority of the items from cassava are used domestically, yet sizeable parts of the produce are being exported with a thriving local demand (IITA, 2004). Wide assortments of products can be obtained from different processing methods of cassava storage roots. In spite of the fact that there might be slight distinction in names given to the products,

Table 2.1: Cassava producing countries in the world as at 2012

Rank	Area/Country	Production ($1000)	Production * (Metric tonnes)
1	Nigeria	5,641,002	54,000,000
3	Thailand	2,212,526	29,848,000
2	Indonesia	2,448,829	24,177,372
6	Brazil	1,203,651	23,044,557
4	Democratic Republic of the Congo	1,654,693	16,000,000
5	Ghana	1,519,652	14,547,279
7	Angola	1,111,110	10,636,400
8	Mozambique	1,049,995	10,051,364
9	Vietnam	1,018,048	9,745,545
10	India	848,239	8,746,500
11	Cambodia	795,349	7,613,697
12	United Republic of Tanzania	570,624	5,462,454
13	Uganda	514,434	4,924,560
14	Malawi	490,161	4,692,202
15	China, mainland	428,716	4,560,000
16	Cameroon	394,870	4,287,177
18	Madagascar	365,620	3,621,309
17	Sierra Leone	367,709	3,520,000
19	Benin	344,287	3,295,785
20	Rwanda	283,765	2,716,421

Source: FAO, 2014

* Other countries not listed are producing at values below those highlighted.

yet similar basic units of operations are engaged in the processing. Distinctive products acquired from cassava are fermented cassava flour, fermented cassava and corn meal, (garri and lafun, separately), fermented cassava mash, fermented cassava and steamed chips of cassava tuber, fermented mist cassava grits, fermented and smoked cassava balls (FIIRO, 2006; Salami, 2014).

Notwithstanding, the sweet cassava assortments of the above products are prepared and eaten as major meals, as it contains low amount of cyanide, so that non fermented tubers of such varieties can be eaten as bubbled grits (Agahiu *et al*., 2012; Salami, 2014). Presently, use of cassava for starch, liquor, adhesive and animals feed is not uncommon in Nigeria. In spite of the fact that, it has the potential, cassava has only contributed little to international trade profit and import substitution. Major problems are labour cost and soil fertility status among other factors (Nweke *et al*., 2002; FIIRO, 2006; Pukwu, 2013).

2.4. Cassava and Cropping Systems in Nigeria

Cassava is reputed to have large ecological amplitude with regards to tolerance of poor soils and harsh climatic conditions (FIIRO, 2006). Moreover, cassava formed the elementary component of cropping systems in various areas in Nigeria where it forms the main component up to 50% in intercropped farmland (Nair, 2014). Cassava cultivation in traditional Agriculture has received attention from various researchers. The major crops grown in association with cassava in West Africa include: yam, maize, plantain, cocoyam and pigeon peas. While in East Africa, cassava is commonly intercropped in various combinations with plantain, beans, sweet potato, maize and groundnut. Cassava is often intercropped with principal staple crops such as yam, maize, cocoyam and subsidiary crops such as grain legumes, okra and fluted pumpkin (Carretero *et al.*, 2009; Agahiu *et al*., 2012; Ijoyah *et al*., 2012; Pukwu, 2013).

Ezulike *et al.* (2006) and IITA (2012) observed that up to 50% of cassava grown in Southern Nigerian for instance, is intercropped with grain legumes or arable crops like, maize, melon, and leafy - vegetables. The cultivation of cassava under oil palm and other economic trees constitutes the agro-forestry system in some parts of Nigeria. Cassava is usually planted on mounds, ridges or flats. When planted on mounds, it is positioned on the side, while yam occupies the top and upland rice is sown in the furrow. Cassava may be cultivated as a relay crop or at the same time with component crops (Kunji, 2013).

2.4.1 Intercropping cassava with other staple crops

Cassava is not grown only as a mono crop but often cultivated along with one or more different staples on the same field with no distinct row arrangement. This mean it is, been grown with one or more different crops at the same time during part of the life cycle of other crops. According to IITA (2004) and FAO (2012), statistics on intercropped cassava tend to be underestimated especially if the shorter term annuals planted with cassava have been harvested before the data have been collected. The number of plants in the intercrop is highly changeable. On many family farms, sole cropping is dominant in the outer fields, while intercropping reaches its maximum complexity in the compound garden where cassava and other annual staples, vegetables, and perennial fruit trees are intercropped. Farm size tends to vary between 1 and 4 hectares in both the rain forest and savannah areas. Although there is a prevalence of bigger farms in the savannah zone, the number of plants in cassava mixed cropping tends to decline. Despite the fact that intercropping is generally practiced, the examples are area explicit, particularly in the scope of staples species that might be intercropped (IITA, 2012).

Higher yields were observed in sole cropping over intercropped plants according to report from Michael *et al*. (2012). From their report also, intercropping cassava with maize and *egusi* melon reduced cassava storage root yield. The intercropped cassava storage root yield in earlier planting season was compared with when cassava was sole cropped. This confirmed the shading effect of taller maize plants that reduced the photosynthetic absorption rate of egusi melon (a lower developing plant). The growth and yield of egusi melon was reduced when intercropped with cassava and maize contrasted with those obtained from sole cropped *egusi* melon and this further negatively affected the yields of the two crops.

As an advantage of intercropping, total intercrop yield was greater than the component crop yields. Intercropping cassava, maize and egusi melon gave higher land equivalent ratio (LER) values indicating that higher productivity per unit area was achieved by growing the three crops together than by growing them separately (Pukwu, 2013).

2.5 Cassava Production, Agronomic Practices and Utilization

2.5.1 Ecology of cassava

Cassava is a tropical root crop, requiring at least eight months of warm weather to mature. It is traditionally grown in the forest and savanna climate, but can be grown in extremes of rainfall. In most cases, it does not tolerate flooding. In droughty areas, it loses its leaves to conserve moisture, producing new leaves when rains resume. It takes 18 or more months to produce a crop under adverse conditions such as cool or dry weather. Cassava does not tolerate freezing conditions, but tolerates a soil pH of between 4.0 to 8.0 and more productive in full sun (Tare, 2009; Osundare, 2015).

2.5.2 Cassava cultivars and recommended varieties

A yield of 10 - 15 tonnes per hectare is possible in Nigeria, in farmers' field, while research farm yields up to 25- 40 tonnes per hectare (Ezulike *et al.,* 2006; FIIRO, 2006). This is possible on research farms due to; good planting materials (stem cuttings from plants 8 - 12 months old), adequate weed control measures, planting in well drained deep rich soils and with the use of improved cassava varieties (Ezulike *et al*., 2006). However, an average yield of 8.9 metric tonnes per hectare is obtainable in Africa while 11.1 and 13.3 metric tonnes per hectare are obtainable in Central and South America respectively (Hillocks, 2002; IITA, 2012).

In spite of numerous high yielding varieties in Nigeria, many farmers still grow local cassavas landraces. Among the promising varieties released earlier are: NR4 41044, TMS 82/00661, TMS 30572, TM 30555, TMS 8537, TMS 550395, and TMS 3000 (IITA, 2012). These varieties are adapted to about 80% of Nigerian agro-ecological zones; however, cultivars TMS 30572, TMS 4(2) 1425 and NR 8082 seem to enjoy wide spread cropping in the farmers' fields, while some of the earlier released varieties are reported to be losing some of the desirable breeding characteristics mentioned above (FIIRO, 2006; IITA, 2013).

The following cassava varieties were further released for their high yielding and processing quality: TMS 30572, NR 8082, NR8083, TMS 4(2) 1425, TMS 81/00110 and TMS 92/0326 (Ugwu and Ukpabi, 2002; IITA, 2012). Besides these, UMUCASS42 and UMUCASS43 (initially known as IITA –TMS – I982132 and IITA – TMS – I011206 respectively) cultivars, were also released as they are of good high quality cassava flour, high dry matter which is positively related to starch quantity,

high leaf retention and moderate levels of beta-carotene for enhancing nutrition (IITA, 2013).

According to report from IITA (2015), few cassava cultivars were available until the time national and international cassava breeding programs were established. This is obvious because, cassava propagation is through stem cuttings for cloning. The breeding programs released cassava clones that are resistance to various several pests and diseases. Mostly, cassava varieties' names reflect their regions except those that were developed and released from international research centres. Those from such centres have an official code, which is often reserved as the appellation of such cassava cultivars (IITA, 2015). Usually, grouping of cassava cultivar is centered on character of the leaves, the pigment, the shoots and storage root. It is common characteristics that cassava cultivars vary in storage roots length and diameter, yield as well as resistance levels to pests and disease. Other features that vary from cultivar to cultivar: are time of harvest, cooking and process quality, and temperature adaption (FIIRO, 2006; IITA, 2013).

2.5.3 Planting, planting material and cultural practices in cassava production

The shoot is the developed portion of cassava plant that serves as the planting material. Planting of cassava can be done by the use of matured stem cut at a length of about 10 to 30 cm. The choice of planting material for cassava is based on cutting from healthy stock of propagule. The cuttings are placed uprightly or at tilted position in an orderly pattern either on mounds, beds, ridges or flat prepared land and the lower half of the cuttings are covered with soil (Hillocks, 2002; IITA, 2013). At the point if soils are too shallow for planting cuttings, then cuttings are put in an upstanding or inclined position; or laid parallel to the ground to secure a depth of about 2-3 cm layer of soil. Cassava planter has been developed in certain zones to reduce work inputs. The cassava cuttings are placed at recommended plant spacing of 100 cm by 100 cm (1.0 m^2). Cuttings produce roots within a couple of days and new shoot soon appear at the old leaf petiole axis on the stem. Cassava plant seeds are only utilized for stems multiplication purposes. Considering the extremity of the cutting, it is basic foundation of successful establishment of the cassava plant (IITA, 2015).

Cassava growth is fairly moderate at beginning; consequently, weeds must be controlled amid the initial couple of months. Although, cassava can produce tuber with minimum inputs, the best yield in cassava is only possible with average soil fertility

levels and steady moisture availability. The optimal growth and yield ability of cassava plant is expressed as the ratio of its harvest index and storage roots weight to total plant weight. Typically, these desirable indexes of cassava ranged from 0.5 – 0.7. Cassava response to macro-nutrients such as P and K vary, however, cassava response positively to P and K fertiliser application. Arbuscular Mycorrhizae (AM) benefits cassava by scavenging for phosphorus and supplying it to the roots (Ayoola and Adeniyan, 2006; Ijoyah *et al.*, 2012).

According to Olurunda (2010) and Salami (2014), nitrogen fertilizer application at more than 100 kg ha^{-1} of actual N/ha may result in excessive foliage production at the expense of storage root development and a low harvest index. Fertilizer is only applied during the first few months of growth. Cassava plants are ready for harvest as soon as there are storage roots large enough to meet the requirements of the consumer. Under the most favorable conditions, yields of fresh roots can reach 9.0 t/ha while average world yields from mostly subsistence agricultural systems are 9.8 t/ha (Pukwu, 2013). Typically, harvesting can begin as soon as eight months after planting. In the tropics, cassava plants can stay on farm for more than one growing season, allowing the storage roots to enlarge further. However, as the roots age, the central portion becomes woody and inedible (FIIRO, 2006).

2.5.4 Imperatives to cassava cultivation

Cassava basic insect pests in Africa include green bug of cassava, the cassava coarse bug, multicolored grasshopper and termites. The primary diseases influencing cassava include; cassava mosaic, root rot, bacteria blight, and cassava anthracnose. Poor agronomic practices, pests, disease and other edaphic combined with other biotic factors cause yield decline that may be as high as half of the total yield in Africa (IITA, 2013). Cassava establishment relies upon availability and supply of valuable stem cuttings. The multiplication rate of these vegetative planting materials is very low compared to grain crops, which are propagated by true seeds. Furthermore, cassava stem cuttings are cumbersome and exceedingly short-lived as stems dehydrate within some of days (Muoneke and Mba, 2007; IITA, 2013).

Like other root crops, cassava storage roots harvest period should be accomplished within a short period of time to avoid the tuber going bad. Hence, storage roots must be prepared into a storable produce before long harvesting finish.

Numerous cassava cultivars contain cyanogenic glycosides, and insufficient processing can prompt interminable poisonous quality. Different processing techniques, for example, sun drying, grinding or grating, and fermenting can be utilised to decrease the cyanide content of cassava (FIIRO, 2006; IITA, 2013).

2.5.5 Mineral fertilisers and its effects on cassava production

According to Aden (2013), cassava storage roots yields could be increased significantly when farmers apply chemical fertilisers at the recommended rate. The utilisation of improved cassava cultivars and mineral fertilisers, encouraged increase in cassava storage roots yield. In the production of cassava, fertilisers' application ought to be done with about equivalent measures of the three principal elements namely nitrogen, phosphorus and potassium. If good yield must be maintained over a period of time, N-P-K fertiliser must be added to make up for the removed nutrient elements, particularly potassium. This is should be done possibly by the use of compound fertilisers that are high in K and N, and moderately low in P (Beader, 2013). To reduce the costs of production, farmers ought to moderate volatilization of nitrogen and the problems of the P and K overflowing and disintegrating continually by covering the inorganic forms of these fertiliser sources during application (Adios, 2014).

The source of other nutrient elements and nitrogen from mineral fertilisers or manure can likewise be upgraded with urea compacted into super granules or urea pills covered with cake produced from neem seed oil. The two advances moderate significantly the nitrification of urea, decreasing nitrogen volitilisation into the air and to surface water. Though, the use of chemical fertilisers alone can support cassava root storage yields, but they cannot withstand continuous crop production for long time on degraded land, hence for cassava production sustainability especially on nutrient depleted soil, the combined usage of organic and inorganic fertilisers is essential (Olorunda, 2010).

2.5.6 Fertiliser use: Types and rates for cassava production

According to Irwin (2010) and Beader (2013); continuous cultivation of tuber and root crops for example; yam (*Dioscorea spp*), cassava (*Manihot esculenta* Crantz) and sweet potato (*Ipomoea batatas*) result in high exploitation of plant nutrients, especially, nitrogen, phosphorus and potassium (Adaso, 2014; Aweto, 2014). Therefore, constant husbandry of these crops thus resulting in soil nutrient diminution where there are inadequate soil fertility maintenance practices, but with an appropriate fertiliser package, which include; application of organic and or inorganic fertilisers (Aden, 2013; Osundare, 2015).

Normally, fertilizer recommendations should be based on soil analysis but where this is not available, the land history and vegetation of such land may be used as a guide. Under continuous cultivation in the forest, a first dose of 200 kg (4 bags) of N. P. K 15.15.15 per hectare or a full small matchbox per plant at 4-6 weeks after planting is ideal (Daukan, 2012; Aweto, 2014). The second dose of 100 kg of Murate of Potash (MOP) or a half-full small matchbox per plant at 14-16 weeks after planting should also be applied (Kunji, 2013; Aden, 2013). In the savanna zone, 100 to 200 kg (2 - 4 bags) of N. P. K 15.15.15 per hectare or a full small matchbox per plant at 4 - 6 weeks after planting cassava and the second dose of 50 kg of Murate of Potash (MOP) per hectare is recommended (Beader, 2013).

2.5.7 Weeds control in cassava production

In cassava production, weeds can be controlled using either chemical or mechanical measures or both. When cassava is planted it is advisable to apply pre emergency (weed killers) herbicides for example, primextra at the rate of 5 litres /ha three days after planting provided if no herbicide was applied before land preparation and planting, depending on the level of weed infestation. Manual hoeing as mechanical method is also effective especially at the beginning of dry season before cassava is harvested (Olorunmaiye, 2010; Bilalis *et al*., 2010).

2.5.8 Harvesting, processing and utilisation of cassava

The procedures for harvesting cassava are removal of upper parts of cassava plant (cutting off the stems and the leaves), by uprooting; which is the lifting up of the underground portion of the shoot and dragging the storage roots out of the ground. Next to this is the removal of the storage roots (tubers) by cutting the storage roots off

the cassava plant base with either hands or cutlass. Attention must be on the storage roots during harvesting and processing to reduce level of damage to the produce, as damaged storage roots seriously reduce shelf life (FIIRO, 2006). Following the harvesting of cassava, the stems for the following planting are chosen. According to Ugwu and Ukpabi (2002), such chosen cuttings must be kept in a secured area to avert drying up. The period of cassava storage roots is just a couple of days except if the roots get special treatments. Conventional techniques incorporate pressing the storage roots in wet mulch to prolong its shelf life (IITA, 2004).

Growing cassava plant is for the enlarged starchy storage roots, which contain about the most extreme hypothetical accumulated starch on a dry weight basis among stable crops. Fresh cassava storage roots have about 30% starch; the thin layer round the storage roots can be stripped and bubbled, prepared, sun dried. On health basis, the storage roots should not be eaten raw, because of the harmful effects of the cyanogenic glycosides. However, these cyanogenic glycosides are reduced to harmless proportions through cooking (Salami, 2014). In normal settings, cassava storage roots or tubers are ground before sap is separated by pressing or squeezing it. The grated storage roots are also dried over a flame to make a product or cure, season and cooked. This can further be rehydrated with water or added to soups or stews (FIIRO, 2006).

In Africa, tubers are prepared in a few unique ways. Cassava storage roots can be allowed to ferment in water, and later either is sun dried for storing or ground or made into mixture to be cooked. Mixed refreshments (alcoholic beverages) can be produced using the tubers. Young delicate leaves can be exploited as a potherb, which contains large amounts of protein (8-10% FW). This can be prepared similarly like spinach, but care must be taken to kill lethal mixes amid the cooking procedure (Hillocks, 2002). Dried cassava storage roots or tubers can be processed to flour. Corn might be included amid the processing procedure for nearby utilisation, while the cassava flour can be used for bread production. Fresh storage roots can be cut meagerly and pan fried to make an item like chips of potato. The cassava tubers may be sliced into bigger lance pieces for preparing a consumable item (Ezulike *et al.*, 2006).

2.6 Melon *Citrullus lanatus* (Thumb) Mansf Production

2.6.1 Description and distribution of Melon *Citrullus lanatus* (Thumb) Mansf

Citrullus lanatus (Thumb) Mansf belongs to the tribe *Benincaseae* of the subfamily *Cucurbitaceae*. "*Egusi"* Melon *Citrullus lanatus* is a native of tropical Africa and a member of the *Cucurbitaceae* family. It is widely cultivated for its edible seeds which are used as condiment in enriching the taste and appearance of local stew (Denton and Olufolaji, 2000; Abiola and Daniel, 2014). According to Adewusi *et al*. (2000), the genus *Citrullus* and *Cucumeropsis* belong to the family *Cucurbitaceae*, which consists of various climbing, crawling and trailing herbaceous plants (Onuh *et al.,* 2011).

The seeds of "*egusi"* are nutrient-rich in protein, crude fibre and ash at about 34%, 5% and 12% respectively. The oil obtained from the seeds is of high quality, often used for cooking and other industrial products, such as soap making, medicine, and illuminant (Adewusi *et al.*, 2000). The two different kinds of melon seed in Nigeria are differentiated mainly by using the seed edge that is either presence or absence on the seed (Denton and Olufolaji, 2000; Olaniyi and Tella, 2011). The two types are referred to as *bara* (with prominent thick seed edge with black or white colour) and *serewe* (without pronounced seed edge).

2.6.2 Ecology of melon

According to Ayoola and Makinde (2007), naturally, *Citrullus lanatus* have preference to a well-drained soil of moderately flat or on fairly undulating land high in soil organic matter. It is also found naturally in disturbed areas or as a weed in cultivated land. It is day length neutral. "*Egusi"* melon is cultivated in tropical lowlands up to 1000 m altitude. Both perform better in the savanna region than in the wet forest zone (Ayoola and Makinde, 2007). In West African, melon cultivation normal yearly precipitation between 700 mm to 1000 mm and a daytime temperature of 28– 35ºC are required. Too much rainfall and excessive humidity result to extreme melon biomass and increase disease infestation, for examples; fruit rot and leaf rot diseases, consequentially; this result to reduction in seed yields (Ornella *et al.*, 2011). Despite the fact that dry season melon production gives high seed yields, peasant farmers prefer rainy season melon production since they cannot afford irrigation facilities due to unavailability of fund. According to Adewusi *et al. (*2000), the

savanna zone melon seed yields are up to three times the recorded seed yields in the forest zone (Abiola and Daniel, 2014).

2.6.3 Some valuable common melon cultivars among farmers in Nigeria

The small monetary gain of a few varieties of Cucurbitaceae, cultivated broadly among the smallholder peasant farmers in Nigeria, is melon *egusi* seed (Abiola and Daniel, 2014). *Egusi* melon (*Colocynthis citrullus* L.) has significant yield in Nigeria. The familiar types are *egusi* melon (*Cucumeropsis edulis*, Hook; C. *mannii*, Naudin), gourd melons (wind gourd and container gourd, Lagenaria siceraria, Molina, Standley) and watermelon (*Citrullus lanatus*, Thunb, Matsum and Natai). *Egusi* varies from the decisively related watermelon (C. *lanatus* ssp. vulgarris) by the white, unpleasant and unappetizing pulp and seeds, which have delicate testa coat that can be effectively evacuated (Yusuf *et al*., 2008). The seed nature and coat shading are common tools used for describing *egusi* as *Bara* (huge darker seeds with dark edges), *Serewe* (smooth dark colored seeds without unmistakable edges), The *Bara* melon has wider distribution due to the preference to it by the consumers across the geographical zone. The cross breeding capacity between *egusi* melon and water melon was carried out by NIHORT to developed new cultivars with palatable seeds (Sadiq, 2015).

In Nigeria cropping practices, *egusi* melon is typically compatible with different staple crops such as yam, cassava, maize, and found suitable for mixed cropping and intercropping systems in most Nigerian farmers' cropping system. Melon plant in mixed cropping acts as lively mulching material to conserve soil moisture and control weeds. However, it cultivation is primarily for the seed which is utilised in preparation of different local soups (Adewusi *et al.,* 2000). The cultivation of melon is increasingly famous in the northern parts of Nigeria where there is expanded cultivable land which has made sole melon cropping promising amidst other crops that are common and constantly grown (Yusuf *et al*., 2008). Despite the fact that melon production increases the farmers' income substantially, melon (*egusi)* farming faces a lot of challenges that result to yield reduction (Sadiq, 2015).

2.6.4 Soil requirements and propagation of melon.

Egusi melon thrive well in a fertile soil (sandy loam soil) with a soil pH range of 6 – 7; but acidic soil or soil pH below 6 encourages high proliferation of soil borne diseases such as *Fusarium* among others which becomes a severe problem. Poorly drained soil or flooded farmland provides a suitable medium for melon crop to be attacked by fruit rot and anthracnose disease. Melon requires moderately fertile soil for early and close vegetative cover, which is suitable for weeds and erosion control (Ekwere *et al*., 2013).

There is retardation of germination in *"egusi"* melon when sown in soil with high temperature, but no seed dormancy. Germination of melon seed take place when temperatures are about 17°C at night, couple with constant daytime temperatures of 32°C. Melon seed is sown directly on ridges or in flat plots after land preparation as best sowing medium.

Melon is compatible for either sole cropping, and can be intercropped or as mixed cropping with cassava and other crops such as; millet or sorghum and maize are common cereal. It is sown at planting distance of 1 metre by 1 metre to give a plant population of 10,000 plants pet hectare at two seedlings per planting stand and latter thin to one seedling per stand; which is optional. However, in traditional growing setting, two to four seeds are grown per stand given total plant population ranging from 20,000 to 40,000 plants per hectare (Carretero *et al*., 2009 and Sadiq *et al*., 2013).

2.6.5 Effects of fertilizers on melon yield

Applications of fertilizers to melon play an important role in the yield potential of melon. Compound fertilizers such as NPK 15-15-15 at range of 60 – 80 N kg ha^{-1}has been reported to increase melon seeds yield (Olaniyi, 2006). Olaniyi and Tella (2011) reported that the growth, yield and nutritional values of melon were more influenced by increased rates of potassium application up to 30 kg K_2O ha^{-1} and decline at 40 kg K_2O ha^{-1}. It was also reported that sole application of nitrogen and potassium at 60 kg and 30 kg ha^{-1} respectively gave the highest yield of melon seeds in Ogbomoso in Nigeria (Olaniyi, 2006; Olaniyi and Tella 2011).

2.7 Types of Intercropping Systems

Intercropping involves the growing of two or more crops simultaneously in the same piece of land while the practice of growing one type of crop variety alone in pure

stands on a field is referred to as sole cropping. According to Onwueme and Sinha (1999) and Berry *et al*. (2009) four types of intercropping can be identified. Row, patch, mixed and relay intercropping.

Row intercropping: Is the cultivation of two or more crops simultaneously on the same field with a row management; or the growing of two or more crops planted in rows.

Patch intercropping: This is when each of the various crops on the field is grown in several small patches inter-spread with similar patches of other crops.

Mixed intercropping: When the various crops are grown intermingled more or less at random with each other.

Relay intercropping. This involves growing of two or more crops simultaneously during part of each one's life cycle, that is, the second crop is planted after the first crop has reached a reproductive growth stage but before harvest. This situation could also be seen as a case of overlapping crop rotation (Adeola, 2007; Ijoyah *et al*., 2012).

With traditional Agricultural set-up, intercropping is very common and suitable for food crop production. According to Ayoola and Adeniyan (2006) and Bilalis *et al.* (2010) the suitable land for food production is fixed and diminished, yet farmers are faced with the difficulty of increasing productivity to meet the food demand of the teaming population (Ayoola and Makinde, 2007). Hence, a system integrating different practice of soil fertility maintenance, which will include the use of mineral fertiliser, organic manure and intercropping which provides fast and good ground covers, should be developed (Schulthess *et al*., 2004; Ekwere *et al*., 2013).

In line with the above, successful crop mixtures in the intercrop have the capacity of sharing available resources over time and space of cultivation till harvesting. The predominance of this practice of intercropping among peasant farmers can be attributed to low resource, the advantage in reducing crop failure and demand of such crops components within such locality. According to Tijani-Eniola and Akinifesi (1996) and Adeola (2007), cassava and soybean were least competitive with each other when cassava was intercropped at six weeks after sowing soybean compared to simultaneous sowing.

2.7.1 Crop yield, land use efficiency and related concepts in intercropping systems

Different workers have suggested various means to evaluate crop mixture productivity and efficiency such as; Relative Yield Total (RYT) and Land Equivalent Ratio (LER). The sole crop yields have always been used as standard for comparison of relative yield in assessing combined yields from intercropping practice. Due to fluctuations in the prices of crops, differences in arrangement and worth of crop product, growth duration and energy content in the component crop, hence the joined yields are of slight value (Beets, 1982 cited by Adeola, 2007; Onu *et al*., 2011).

Land Equivalent Ratio (LER) is an index of combined yield for evaluating the effectiveness of all forms of intercropping. It is the sum of the ratio of yields from intercrops relative to the optimum sole crop yield for the land area occupied by both intercrops. Generally, LER has been a single index widely used for evaluating the yield advantage of intercropping systems (Onwueme and Sinha, 1999). It can be expressed as.

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of crop A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of crop B}}$$

An LER greater than one implies that the intercropping is beneficial than sole cropping of that crop combination, when it is less than one, it means the intercropping was less than beneficial than sole cropping (Onwuene and Sinha, 1999; Adeola, 2007; Berry *et al*., 2009). 'Yield' can be measured as dry matter production, grain yield, nutrient uptake, energy, or protein production as well as the market value of the crops.

This LER prevents the overestimation of mixture productivity relative to the sole crop. Mead and Willey (1980) (cited by Adeola, 2007), however, argued against the use of Relative Yield Total (RYT) because they considered the objectives of intercropping as to finding the best ways of growing two or more crops together. Relative Yield Total (RYT) is identical to Land Equivalent Ratio (LER) except that the yield is expressed on per plant basis rather than per unit of land area as in the case of Land Equivalent Ratio (LER). The main advantage of the use of LER as index to evaluate crop yield in intercropping is attributed to its provision of a standardized basis that allows the "addition" of crops to obtain "combined yields" so that comparison between individual LERs can indicate competitive effects and the total LER can be taken as a measure of the relative yield advantage (Mead and Willey, 1980). However,

the main limitation of LER is non-component crops with varying maturities as it is based on land area only.

2.8 Soil Fertility Problems and Crop Production

Soil is the principal factor of crop production among others, hence; all other factors revolve round soil for Agriculture. Williams *et al.* (2014), stated that soil is the product of the weathering of rocks (parent materials), as predisposed by living things, topography, climate and the drive of materials into and from the soil system. Vegetation usually depends on the soil systems in interacting ways. Roots of plant enter and go into the soil in order to obtain oxygen, nutrients, water and structural backing for general plants and other materials on the earth surface (Ation, 2013; Irwin, 2010). However, not all soils can meet these requirements for food production; hence such soils are considered to be constrained or infertile (Osiname, 2000). The primary constraints of soil may be classified into nutrient toxicities, nutrient accessibility and preservation, physical degradation and water availability due to erosion (Nyle and Ray, 2014). In the constrained soils, the inborn fertility of soil is connected with mineralisation of organic matter in the soil (Lege, 2012; Agegnehu, 2014).

Some backlog of improved soil management technologies which aimed at increasing the productivity levels of crop include the use of organic fertilisers in blend with inorganic fertilisers, the use of inorganic fertilisers based on soil test values to avoid nutrients imbalance and abuse, the use of light implements for land preparation or bush slashing and manual removal of the total plant weight to avoid soil compaction (Singh, 2008). Besides, the use of zero tillage and multiple cropping through inclusion of legumes and appropriate use of crop rotation is very promising (Nottidge *et al*., 2010).

Deterioration in total organic materials in the soil may often be a core cause of nutrient use up, and nutrient unavailability and retention for farming systems. This can be amended with external nutrient inputs. Ation (2013) asserted that soil fertility can be improved through application of organic and inorganic fertilisers. However, application of organic residues is an important management practice that plays important roles in regaining the lost plant nutrients and soil organic matter (Osiname, 2000; Ogungbe and Fagbola, 2008). Gilley and Risse (2000) and Anthony and Akinrinde (2011) stated that many physical, chemical and biological soil properties of surface horizon (soil) depend largely on the soil organic matter.

2.8.1. Soil and crop production problems

The soil is an important factor in food production and the central problem of tropical agriculture is the inability of the land to sustain annual food crop for more than a few years at a time. Agegnehu (2014) asserted that the soil is a medium and source of nutrition for both plant and animal life, therefore the neglect of managing soil fertility will eventually lead to food crisis. Many efforts to achieve self-sufficiency in food production failed due to minor consideration given to the role of soil in crop production. Nair (2014) enumerated the following as soil constraints: erosion, poor maintenance of soil fertility and lack of data on soil tests. However, there was emphasis on increasing land area under cultivation with the noticeable actions taken on soil in programs such as National Accelerated Food Production Program of 1972, Operation Feed the Nation of 1976 and Green Revolution program of 1980 to boost crop production with supply of fertilisers at subsidized prices (Aweto, 2014). This may even be more harmful to crop production in the absence of relevant information about the soil.

Principally, Nigerian farmlands (soils) are full of low activity clay, such as in Alfisols and Ultisols. They are so called low activity clay because of their limitations, unique management requirements and other distinctive feature that adversely affect their potential for crop production. These limitations include acidity and Al toxicity, low nutrient reserves, nutrient imbalance and multiple nutrient deficiencies (Ogunkunle, 1995; Ation, 2013).

2.9. Overcoming Soil Constraints to intensified Crop Production

According to Nyle and Ray (2014), the following recommendations are essential to increase agricultural productivity: Firstly, fertiliser policy; which can be sustained through judicious use of the fertilisers that is, the application of nutrient-rich organic resources. These fertilisers must be provided at sensible cost and presented in quantities appropriate for use by peasant farmers. Secondly, improved nutrient use efficiency; this may be achieved by ascertaining the rate of application, form of fertilisers and time and places that offer the highest rate of economic return to the users. Thirdly, effective soil conservation techniques should be intensified to reduce soil erosion and increase productive capacity of agriculture (Belay *et al.*, 2001; Lege, 2012). Besides, the maintenance of the key resource to soil productivity; which is the soil organic matter because of its ameliorative effect on nutrient supply, detoxification

of harmful soil constituents, moisture and nutrient retention and its role in soil structure formation. Hence, the level of organic matter within a soil must be increased and maintained (Kunji, 2013; Osundare, 2015).

2.10. Description of Arbuscular Mycorrhizal

Arbuscular Mycorrhizal Fungi (AMF) are obligate symbionts that inhabit roots of a wide range of host plants beside their function in providing nutritional benefits to their hosts (Wagg *et al*., 2011a). These soil fungi are sturdily involved in plant's tolerance to a diversity of other biotic and abiotic stresses (Bennett *et al*., 2009); they influence composition and variety groups of plant (Wagg *et al*., 2011b) and play role in stabilisation of soil aggregates (Rillig and Mummey, 2006). Diverse of AMF species separates largely vary with respect to their growth and physiological characteristics as well as their nutritional benefits granted unto them by their host plants (Lendenmann *et al*., 2011). This occurrence is usually known as functional diversity (Feddermann *et al*., 2010).

Mycorrhiza is soil fungi that live in and around the roots of plants. The fungi and the plants form mutually beneficial associations in which the fungi receive carbohydrates from the plants and the plants receive nutrients from the fungi. The most common mycorrhizal association is the Arbuscular Mycorrhiza (AM) type. This type of association is also described as highly specialized which cause no damage to their hosts but leads to a mutual benefit from the association by the host and fungal component (Dalpe and Monreal, 2004; Duhamel and Beesetty, 2011). External appearances of fungi are dimorphic and are composing of coarse, thick walled, irregular non-septate hyphae with smaller thin-walled lateral branches. These branches are short-lived and become septate as they die. Hyphae produced appressorior on the root surface prior to penetration (Jansa *et al.,* 2008).

AM fungi colonisation produces either very little or no modification on the external morphology of roots. In some species such as maize and tomatoes, mycorrhizae can be recognized by their bright yellow colour which contrasts sharply with the white non-mycorrhizal roots. The colour, however, disappears rapidly on exposure to light; hence the colour is not apparent in species with thick root (Feddermann *et al.,* 2010; Munkemuller *et al.,* 2012). Through low power compound microscope, AM fungi internal morphology can be examined. The hyphae penetrate the epidermal cells of young roots behind the meristematic region. Penetration

through root hairs is common in some host species. After colonisation, AM fungi forming arbuscle within cortical cell; the arbuscles are usually terminal, but in some hosts, they form laterally or hyphae that grow from cell to cell (Schuessler *et al*., 2001; Lendenmann *et al.,* 2011; Dania *et al.,* 2013).

2.10.1. Classification of mycorrhizal fungi

There are two main types of mycorrhizal fungi; Ectomycorrhiza and Endomycorrhiza (Okon *et al*., 2010).

Ectomycorrhizae: The indicative feature of these groups of soil fungi is the existence of hyphae between root cortical cells; many have a sheet or mantle of fungal tissue that may completely cover the absorbing root. The mantle can vary widely in thickness, colour, and texture depending on the particular plant fungus combination (Verbruggen *et al*., 2012). These groups of soil fungi are present on tree plants ranging from forest trees to shrubs. Numerous of the host plants fit into the families *Pinaceae, Butulaceae, Myrtaceae* and *Fagaceae* (Verbruggen *et al*., 2012). This fungus often forms thick hyphal mantle round the feeder roots and these roots are morphologically altered but some ectomycorrhizae do not present a hyphal mantle as other subtypes of endomycorrhizae (Carretero *et al*., 2009). Ectomycorrhizae are very important for forest nutrition and nutrients recycling processes in forest ecosystems. According to reports, several tropical tree species were also found to be ectomycorrhizal but majority of these trees are endomycorrhizal of vesicular – arbuscular mycorrhizal type (Wagg *et al*., 2011a).

Endomycorrhizal fungi: The growth of an exceedingly branched arbuscle within cortical cells of root is the major feature that differentiates these fungi from ectomycorrhizal fungi. At the initial stage, the fungus develops between the cortical cells of the host plant's roots and rapidly enters the root cell wall of the host plants (Okon *et al*., 2010; Wagg *et al*., 2011b). As the fungus develops, the membrane of the host cell invaginates and envelopes the fungus, to create a new structure called vesicle, where substance of great molecular complexity is dumped (Bennett *et al*., 2009). Other structures formed by some Arbuscular Mycorrhizal (AM) fungi include auxiliary cells, vesicles and asexual spore. The thin walled structure filled with lipid that is usually formed within the intercellular gaps of root cells are called vesicles (Wagg *et al*., 2011a).

Vesicles serve primarily as a storage structure; however, vesicles function also as reproductive material or material for propagating fungus. Commonly found cells in the soil are the auxiliary cells which can be coiled or knobby. Reproductive spore can be produced either in the soil or in the root but it is more usually in the soil. Spores formed by fungi producing arbuscular mycorrhizal associations are vegetative, forming by the variation of asexual hyphae (Lendenmann *et al.*, 2011).

Endomycorrhizae are only structurally differentiated from ectomycorrhizae but not functionally. Arbutoid mycorrhiza, monotropoid mycorrhiza, ericoid and orchid mycorrhizae are regionally important for some specific plants, that is, species of the ericales, monotropaceae and orchidaceae (Okon *et al*., 2010).

2.10.2 Importance of AM fungi in soil fertility and crop production

The extent to which a plant depends on mycorrhizae varies from species to species. There are groups of plants that are virtually non-mycorrhizae. According to Mahmood and Rizvi (2010), though not all, but these include. species belonging to the families *Chenopodiaceae, Cruziferecae* and *Juncaceae, Amarantaceae, Caryophyllace ae, Fumariaceae, Phytolaccaceae, Polygonaceae* and *Urticaceae*
(Lendenmann *et al.*, 2011).

However, majority of plants enter a loose symbiosis with mycorrhizal fungi. The extent to which the roots are colonized depends partly on the amount of fungal material in the soil and partly on soil conditions. The phosphorus (P) content of soil plays an important role. Plant's dependency on mycorrhizal is determined in large part by the extent of its root system. Plant with a system of well developed fine dense, roots, such as many cereals are dependent on mycorrhizae only in nutrient – poor soils, these are known as optimal mycotropic plants. Plant with a weakly developed, coarse root system and few root hairs are dependent on mycorrhizae under all conditions; these are obligatory mycotropic plants (Gao *et al.,* 2001; Lendenmann *et al.,* 2011).

2.10.3 Interaction of AM fungi with soil and crops

The enhanced ability of crop roots for water and vitamin consumption from the soil when dominated by AM fungi is the major method proposed to clarify the implication of AM fungi plant performance. The behaviour mainly seems with soil minerals that cannot be easily move such as P, Zn and Cu. Enhanced P vitamin when dominated with AM fungi has been shown for hundreds of grown plants (Munkemuller

et al. 2012). Going beyond the P-depletion zone formed round about the root systems of crop, the fungal soil system is allowed to retain P- transport to plant for substantial duration of time (Hodge, 2000; Verbruggen *et al*., 2012). In high P soil environment, AM fungi ineffectiveness for plants and symbiosis associations are for the short term repressed. Therefore, a fall in P application is suggested to be able to arouse and preserve symbiosis effectiveness (Duhamel and Beesetty, 2011). According to Mahmood and Rizvi (2011), a good number of crops such as maize, sorghum, wheat, potatoes, and sunflower are able to benefit from mycorrhizal connection, while plant belonging to families *Crucifereae, Rassicaeae,Chenopodiaceae* and *Caryophyllaceae* do not benefit from AM fungi symbiosis (Jimin, *et al*, 2013).

2.10.4 Effects of AM fungi colonisation on crop growth and yield

Mycorrhizal colonisation is found to be limited to the cortical layers of root of the host plant. Infection of crop roots occur with fungal hyphae, infected root fragments and AM fungi spore in the soils. The AM fungi lack host specificity, but many show some preferences for plant species (Duhamel and Beesetty, 2011). However, the rate of infection is inhibited by some physical factors such as soil temperature, soil pH, water stress or drought among others (Verbruggen *et al*., 2012).

Carretero *et al*. (2009), found out in a growth chamber studies that P absorption and the intensities of AM fungi colonisation were higher in maize grown in undisturbed soil from three zero-tilled field sites, then in maize grown in similar but disturbed soil. Jimin, *et al*. (2013) and Dania *et al*. (2013) reports showed that inoculating of host plant with appropriate strain of arbuscular mycorrhizal fungi, increased yields, even in ordinary conditions without additives. The increased in yield were comparable to the one obtained when 30 kg phosphorus ha^{-1} was applied to maize, rice using 56 kg phosphorus ha^{-1}, cassava using 160 kg, and bitter orange with 556 kg of phosphorus per hectare (Bilalis *et al*., 2011; Obaba, 2013).

2.10.5 Arbuscular mycorrhizal P and N mobilisation and uptake

The impacts of mycorrhizal mycelia on the uptake of broke down mineral nutrients are all around reported. In ectomycorrhizal and arbuscular mycorrhizal relationship in any event, the mycorrhizal mycelium gives an expanded surface region to nutrient uptake and improves the nutrient securing of the host plants. The hyphae

are likewise ready to enter little microsites that are unavailable to a lot coarser plant roots (Utobo*et al.*, 2011). Dynamic use of ineffectively versatile nutrients, for example, phosphorus prompts the development of nutrient drained volumes of soil around roots, which the mycorrhizal hyphae can connect, providing nutrients from increasingly removed soil. In some ectomycorrhizal parasitic species, separated structures, for example, contagious rhizomorphs encourage translocation of nutrients over long separations. In spite of the fact that it is very much acknowledged that mycorrhiza aid procurement of mineral nutrients as of now in the soil

However, for many years, increasing accentuation has been set upon the capacity of mycorrhizal growths to trigger N and P from natural polymers. The likelihood that the supply of N and P to plants is absolutely subject to the nutrient preparing exercises of decomposers has been progressively tested by perceptions of the capacity of mycorrhizal parasites to separate N and P from a progression of organically significant substrates, for example, dust, dead nematodes and soil smaller scale arthropods just as saprotrophic mycelia (Sturmer and Siqueira, 2011). Association of various gatherings of mycorrhizal fungi in microbial activation and nutrient cycles, bringing about assembly of N and P from microbial, reduced level of faunal, meso-faunal and plant litter, has consequently empowered the advancement of unique plant networks along altitudinal or latitudinal slopes. This plant network is clearly observed in the ericoid mycorrhizal fungi that colonise uncultivated land and in ectomycorrhizal fungi colonizing agro ecosystems. In these biological systems, where N and P are isolated from natural structures that are not promptly accessible to autotrophs, the predominant plant species are exceedingly subject to mycorrhizal symbionts for their nutrient supply. AMF may be associated with decaying of plants and animals remains in certain biological systems purposefully for mobilisation of N and P in such organic materials (Thonar *et al.,* 2013).

2.10.6 Effect of arbscular mycorrhizal fungi on plant nutrients uptake

Whenever nutrient is missing from the soil medium, the limiting factor controlling uptake of nutrient is the root surface area. Root structures like (hyphae) of mycorrhiza fungi possess the ability to greatly escalate the absorbing structural area of the root. Gao *et al.* (2001) and Jansa *et al.* (2008) found that while extra-matrix mycelia accounted for less than 20% of the total nutrient absorbing surface mass, they contributed nearly 80% of the absorbing surface area of pine seedlings. Among the

features contributing to the effectiveness of nutrient absorption by mycorrhiza is the hyphae, which is distributed beyond the nutrient depletion zone that develops around the crop root (Duhamel and Beesetty, 2011).

Beside this, there is a relatively narrow diameter structure of the hyphae that has access to even where the host roots cannot penetrate to. This is because these narrow hyphae can grow into the small soil pores where the roots or even root hairs access (Feddermann *et al.,* 2010). Another merit accredited to AM fungi is ability to access pools of P that is not available to the plant. According to Munkemuller *et al.* (2012), one mean for this access is the physical and chemical inorganic and organic phosphorus that are released through organic acids plus the action of low molecular organic anions, for example; oxalate which can be replaced by the absorbed phosphorus at the metal-hydroxide surfaces through reactions of ligand exchange. Secondly, the dissolve metal-oxide surfaces release phosphorus, and thirdly, producing complex metallic compounds in solution whereby preventing precipitation of metal-phosphate compounds to occur in soil system (Utobo *et al.*, 2011).

Munkemuller *et al.* (2012) observed from their works that some AM fungi release large amount of acid called oxalic acid. This acid helps in the mechanism of releasing mineral phosphorus through mineralisation of plant and animal remains. There has been an affirmative report of the connection between phosphatase enzyme activity and the extent of fungal hyphae associated with AM fungi soil.

According to Duhamel and Beesetty (2011), arbuscular mycorrhizal associations influence nitrogen concentration in mycorrhizal plants, which tend to have high nitrogen uptake than in non-mycorrhizal plants. Fungi colonisation increases the rate of nodulation and nitrogen fixation by rhizobium in leguminous plants. Although there is indirect effect of AM fungi in nitrogen fixation resulting from improved P nutrition and growth at low P level (Sturmer and Siqueira, 2011). Similarly, nutrients such as Ca, Mg and Zn uptakes were increased by AM fungi inoculated plants according to Straker *et al.* (2010).

Evidences abound that AM fungi increases plant-water relations through flow in inoculated plant roots. Also, some agricultural crops are found to have higher transpiration rate due to AM fungi activities. Fagbola *et al.* (2001) and Dania *et al.* (2013) reported that AM fungi inoculation significantly increased stem girth and leaf

dry weight of hedgerow trees under adequate watering conditions and significantly increased root length under drought conditions.

2.10.7 Agronomic practices that boost or depress AM fungi levels in farmland

Almost all cultivation measures affect the occurrence and activity of AM fungi. Many of the effects on plant growth achieved through tillage and crop rotation are partially due to changes in mycorrhizal colonisation. Cultivation methods can be used to promote mycorrhizal fungi population in the soil, but Sturmer and Siqueira (2011), reported that land clearing and burning can lead to reduction in the natural mycorrhizal population in the soil. Duhamel and Beesetty (2011) observed reduction in AM fungi development which resulted in reduced P uptake by maize seedlings in tilled field compared to P uptake in non-tilled arable field; it was then concluded that soil disturbance reduced the effectiveness of the AM fungi symbiosis.

Similarly, crop rotation and fallow systems can affect the diversity and function of AM fungi. Verbruggen *et al*. (2012) described the role of AM fungi in a long-fallow disorder of field crops in the state of Queensland, Australia. Also in field trials carried out at CIAT in Colombia, the mycorrhizal activity of cassava planted in rotation with legumes (*Vigna unguiculata*, *Vigna radiate* and groundnut) was markedly higher than in cassava planted in monoculture. The stimulating influence of legumes, found with mixed cropping as well in rotations was pronounced on sites having a low original fungus population (Duhamel and Beesetty, 2011; Thonar *et al.*, 2013).

Other practices include application of herbicides and pesticides in crop production which can have a deleterious impact on mycorrhizae. These chemicals devastate the amount of host plants and subsequently produce direct damage to fungus, impeding spore production and root colonization. Other pesticides especially fungicides often have negative effect on AM fungi (Duhamel and Beesetty, 2011).

Schulthess *et al.* (2004) observed a drop in spore numbers and a shift in species composition after disturbance in some farm sites. Similarly, Mahmood and Rizvi (2010) found out that the number of spore of AMF in a plantation of *Terminalia ivoriencis* in Cameroon greatly decreased three months after complete clearance and also notice a change in species composition.

According to Fagbola *et al.* (2009), there is need to understand that the land farmers are using for crop production has mycorrhizae propagules which has wide range of functions, such as ability to make nutrients that are highly mobile and slowly diffuse

available for plants. In addition, their filaments networks dispersed inside as well as outside the roots which allow the plant to have access to greater quantity of water and soil mineral required for its nutrition (Lendenmann *et al.,* 2011). It is apparent that many farmers are intensely aware of land degradation but their main concern are food production and income generation during the current or next cropping sequence rather than in the more distant future.

2.11 Organic and Mineral Fertilisers

Manure is plant or animal wastes (decomposed organic matter) use as fertiliser. Organic fertiliser is the by product from decomposed substances containing sufficient plant nutrients to be of value as fertiliser. These substances may be in form of green manure, compost or in processed form supplemented with mineral fertilisers (Berry *et al.,* 2009). The use of manure builds organic matter in soils and modifies soil structure and this improves soil water holding capacity, aeration, friability, and infiltration. In addition, many trace nutrients needed for optimum plant growth are available from manures. Plant nutrients are also released more slowly and over a longer period of time than from most mineral fertilisers. The main disadvantages of using manures are the handling and transportation problems which are associated with large quantities of manure required to obtain sufficient quantities of nutrients for crops; besides, the use of manures introduces weeds into fields (Williams *et al.,* 2014).

The use of green manure, which consists of forage or legumes crop species that are grown for their leafy materials needed for soil conservation. This practice is low in cost and increase crop yield in low-input agricultural systems (Kunji, 2013). When green manure is used in combination with compost, green manure can supply the necessary N to enable faster decomposition of the low quality compost and supply other nutrients such as phosphorus (Singh, 2008). An example of green manure with a potential use in semi-arid, sub-humid and humid conditions is *Gliricidia sepium* leaves, which provides high quality, forage to feed livestock and is able to fix significant amounts of atmospheric N in association with diazotrophic bacteria. In addition, *Gliricidia sepium* leaves produce total plant weight under conditions of low water availability. Pruned *Gliricidia sepium* leaves and thin twigs have a low secondary metabolite content and high N mineralization rate (Carla da Silva *et al.*, 2012).

According to Aiyelari *et al.* (2011) and Daukan (2012), in order to optimize crop production, attention is usually given to external inputs such as chemical fertilisers,

pesticides, and machines. These external inputs can lead to weakening of the soil system relatively than promoting the normal symbiosis and improvement of the soil system. The advancement of a sound approach to agriculture can result to a friendly ecosystem through the reduction of external input for crop production.

Application of inorganic fertilisers in crop production has been found to be detrimental to the environment with particular problem of underground water pollution and soil acidity. Use of manures (organic fertilisers) has the disadvantages of slow release and non-synchronization with the period of growth for most arable short term crops like maize (Abdelrahman *et al*., 2012). Organic fertilisers are modified to improve their efficiency through fortification with mineral fertilisers leading to organomineral fertiliser (Omueti *et al.,* 2000). In sustainable low input agriculture systems where nutrients availability is a serious constraint to crop production, the use of organic manure is inevitable and supplementing such manures with minerals fertiliser might be the key to attaining good yield (Soumare *et al.,* 2003; Kiani *et al*., 2005). In addition, manures improve soil structures, aggregation, infiltration, microbial activity and water holding capacity (Gilley and Risse, 2000). Hence, it is a valuable soil amendment when properly managed (Castillo *et al*., 2003). Reports showed that application of organomineral fertiliser increased crop yield and soil organic matter significantly when compared to other organic fertilisers (Jadoon *et al*., 2003; Kiani *et al.,* 2005; Williams *et al.*, 2014).

The major role played by organic matter constituent of manure in the soil is critical, especially for sustaining soil productivity. According to Singh (2008) and Abdelrahman *et al*. (2012), many physical, chemical and biological soil properties of the surface horizons depend largely on soil organic matter. Therefore, soil organic matter can be seen as the life wire of soil, and the only soil renewable resource that is essential for soil fertility and productivity maintenance (Melissa *et al*., 2015).

Therefore, for sustainable crop production in traditional farming systems, intercropping with the use of fortified organic fertiliser; (organomineral fertiliser) and biofertiliser, will go a long way in crop production program (Mahmood and Rizvi, 2010).

CHAPTER 3

MATERIALS AND METHODS

Two experiments were conducted in the study. A pot and a field experiment

3.1 Pot Experiment Study Area

The pot experiment was carried out in screenhouse at Michael Otedola College of Primary Education Teaching and Research Farm, Department of Agricultural Education, Noforija, Epe Lagos State.

3.1.1 Rainfall data for the experiment

There were rainfalls in January and December 2010 (19 mm) and this was the least rainfall recorded. However, in June, the highest rainfall of 324 mm was recorded (Appendix 1).

3.1.2 Description of the location where soil was collected for pot experiment

The coordinates of the farm from where the soil for the pot experiment was collected are as follow: N0637.168', E003.323', N0637.166', E003.325', N0637.164', E003.333' and N0637.169', E003.332. The farm was located on the northern shore of the Lagos lagoon, about 32 kilometres south of Ijebu Ode; the soil is Alfisol (Fagbami and Shogunle, 1995). The dominating weeds in the site were: *Aspilia africana, Panicum maximum, Chromolaena odorata, Imperata cylindrica, Talinum triangulare* and *Euphorbia heterophylla.* The pot experiment was carried out between January and April, 2010.

3. 1. 3 Soil samples collection

The soil used for the experiment was collected from depth of 0 – 15 cm at the experimental location. The samples were bulked, air-dried, and passed through 2 mm sieve. Pre-cropping physical and chemical analyses of the soil were carried out in laboratory.

3.2. Laboratory Analysis

The following parameters were determined: particle size distribution, pH, exchangeable bases (Na, K, Mg and Ca) organic carbon and organic matter, available phosphorus, micronutrients (Mn, Fe, Cu and Zn) and nitrogen.

3.2.1 Determination of soil particle size distribution

Method: Bouyoucous hydrometer method (Bouyoucous, 1951).

Apparatus: 1000 ml glass cylinder, Dispersion cup and Mechanical stirrer.

Procedure: Exactly 50 g of air dried 2 mm sieved soil was weighed into dispersion cup, 20 ml of 5% sodium hexametaphosphate (Calgon) solution and 200 ml of distilled water was added and the suspension was stirred for 5 minutes with mechanical stirrer. The suspension was transferred through 2 mm sieve (to collect the sand fraction) into a graduated cylinder and made to 1000 ml mark with distilled water. The top of the cylinder was covered with hand and the suspension shaken by inverting the cylinder carefully fifty times. The cylinder was set down and after 40 seconds, the first reading on the hydrometer was taken and the temperature was also recorded. The second reading was taken after two hours. The percentage sand, silt and clay were determined.

Calculation:

First hydrometer reading = concentration silt + clay particles

Second hydrometer reading = concentration of clay particles

Temperature correction at 1 minute and 2 hours = $0.3(T - 20)\ ^{0}C = XgL^{-1}$

$$\% \text{ silt} + \% \text{ clay} = \frac{(\text{temperature correction factor} + \text{hydrometer reading}) \text{ at 1minute}}{50\ g} \times \frac{100}{1}$$

$$\% \text{ clay} = \frac{(\text{temperature correction factor} + \text{hydrometer reading}) \text{ at 2 hours}}{50\ g} \times \frac{100}{1}$$

% silt = (% silt + % clay) - % clay

$$\% \text{ coarse sand} = \frac{\text{weight of oven dried sand (g)}}{50\ g} \times \frac{100}{1}$$

% coarse sand + % silt + % clay + % fine sand = 100

% fine sand = 100 - % (coarse sand + silt + clay)

The textural class of the soil was determined using USDA textural triangle.

3.2.2 Soil pH determination

Method: Glass electrode pH meter was used in 1:1 soil solution in distilled water.

Apparatus: Glass electrode pH meter, 50 ml beaker and a glass rod stirrer.

Procedure: Ten grammes of air dried soil (< 2 mm fraction) was weighed into 50 ml beaker while 10 ml distilled water was added to form 1:1 ratio. The glass rod stirrer was used to stir the mixture for 10 minutes. The electrode was inserted into the suspension and the reading was taken after the pH had been standardized.

3.2.3 Determination of exchangeable bases

Apparatus: Fifty ml beaker, Flame photometer, Atomic Absorption Spectrophotometer (AAS), mechanical shaker and filter paper (Whatman No. 42, 9 cm diameter).

Reagent: Ammonium acetate with pH 7 was prepared by addition of 58 ml of acetate acid to 600 ml of distilled water in the beaker (2 litres) after that, 70 ml of concentrated NH_4OH was added to it. The solution was then cooled and adjusted to pH 7 with pH meter by addition of acetic acid or NH_4OH. The solution was then put into a flask measuring 1 litre with addition of distilled water to making it up to one litre.

Procedure: Two grammes of air dried soil sieved with 2 mm sieve was weighed into a dispersion cup, 20 ml of ammonium acetate (NH_4OAC) was added and shaken on the mechanical shaker for 10 minutes and later filtered with filter paper. The filtrate was taken to the flame photometer to determine Na and K while Mg and the Ca were determined with the Atomic absorption spectrophotometer (AAS).

Calculations:

mg/kg in solution = R × gf

where R = reading on flame photometer or absorption spectrometer

gf = graph factor

mg/kg in soil = mg/kg in solution × Ef × Df

where Ef = Extraction factor

where Df = Dilution factor

$$= \frac{\text{Volume of final extractant}}{\text{Volume of extractant}}$$

Exchangeable base (meq/100 g of soil)

mg/kg in soil × 10

Equivalent weight of element

Exchangeable Bases = Meq of Ca + Mg + Na + K

Exchangeable cation exchange capacity (ECEC) cmol/kg =

Ca + Mg + K + Na + (exchangeable H^+ and Al^{3+})

3.2. 4 Determination of exchangeable acidity

Exactly 2.0 g of 2 mm sieved air dry soil was weighed into extraction cup and 20ml of 1N KCl solution was added. The mixture was placed on mechanical shaker for 10 minutes and filtered.

Then, 2 -3 drops phenolphthaleneindicator was added to the filtrate collected and was titrated with 0.01N NaOH until the colour change to pink. The titre value obtained was the volume of hydrogen ion (H^+) present.

To the (filtrate) content in the extraction cup 5 ml of 0.1N HCl was added to bleach to colourless, and 5 ml of 1 N NaF was added, (the presence of Al^+ changed the filtrate to pink colour after about 2- 3 minutes), then further titration was carried out with 0.01 N HCl, until it changed to colourless, and the titre value was the volume of (Al^+) present in the soil sample.

3.2.5 Determination of organic carbon and organic matter

Method: Wet oxidation method (Walkey and Black, 1934)

Apparatus: Burette, conical flask, pipette and graduated cylinder.

Procedure: Approximately 0.5 g of air dried 0.5 mm sieved soil was weighed into 500 ml conical flask, then 10 ml of 1 N $K_2Cr_2O_7$ was added to the flask from a burette and mixed by swirling. Twenty millilitre of concentrated H_2SO_4 was added and mixed vigorously for 1 minute and then allowed to stand for 30 minutes. The solution was diluted using 200 ml of distilled water, 3 drops of orthophennothroline indicator was then added. Blank solution was prepared following the same procedure but without the sample. The two solutions were titrated to a fine-red end point with 0.5N ferrous ammonium sulphate solution.

Equation of the reaction

$2Cr_2O_7 + 3C + 16H \longrightarrow HCr_3^+ + 3CO_2 + 8H_2O$

Back reaction

$6Fe^{2+} + Cr_2O_7 + 14H \longrightarrow Cr_2 + 6Fe + 7H_2O$

Calculations:

% OC was calculated using the formula below:

$$Y = \frac{\text{Volume of } K_2Cr_2O_7}{\text{Blank value}} \times \frac{0.003 \times 100 \times 1.33}{\text{weight of sample}}$$

% OC = (Blank titre - Sample titre) × Y

Organic matter of the soil was obtained from OC by multiplying with the conventional 'Van Bemmelar factor' of 1.724

3.2.6 Determination of available phosphorus

Method: Bray P – 1 method (Bray and Kurtz, 1945)

Apparatus: Analytical trays, tubes, Mechanical shaker, volumetric flask and spectrometer.

Reagent: 0.5M HCl, NH_4F, Ascorbic acid, Antimony potassium tartarate, H_2SO_4 and Ammonium molybdate. 12 g of Ammonium molybdate was dissolved in 250 ml of distilled water, 0.2908 g of Antimony Potassium tartarate in 100 ml of distilled water, the two dissolved reagents (Ammonium molybdate and antimony potassium tartarate) to 1000 ml of 2.5M H_2SO_4, it was mixed thoroughly and made up to 2 litres. This is reagent 'A'.

Procedure: Two grammes of soil was weighed into each of the cups, 20 ml of Bray P – 1 solution (extractant) was added and the suspension shaken for 10 minutes. The soil was filtered through 9 cm diameter Whatman No 42 filter paper. Five millilitre of clear supernatant was pipette into one 50millilitre volumetric flask and 30 ml Reagent 'B' (prepared by dissolving 1.05 g of ascorbic acid in 200 ml of Reagent 'A' which is the mixture of 12 g Ammonium molybdate in 250 ml distilled water and 0.29 g *antimony* potassium tartarate plus 1000 ml of 5N H_2SO_4). It was done to develop blue colouration. The available phosphorus was read with the aid of NV 201 Model spectrometer set at wavelength of 882 nm.

3.2.7 Determination of micronutrients (Mn, Fe, Cu and Zn)

Method: 0.1N HCl extraction.

Apparatus: Analytical trays and filter paper.

Reagents: 0.1N HCl

Procedure: Two grammes of air dried sieved soil sample was weighed into 150 ml beakers and carefully 20 ml of 0.1N HCl was added. It was shaken on mechanical shaker for 10 minutes and filtered. The filtrate collected was then used to determine the micronutrients using Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VGP

3.2.8 Determination of soil nitrogen

Method: Kjeldahl method as modified by Jackson (1962)

Apparatus: Kjeldahl flask, automatic pipette, fumes chamber, furnace, distillation apparatus and flask.

Reagents: Selenium (catalyst tablets), Boric acid, Sodium hydroxide (NaOH), concentrated H_2SO_4 and 0.01M $_{HCl}$.

Procedure: Approximately half a gramme of air dried soil sieved with 0.5 mm sieve was weighed into a dry macro Kjedahl flask, 1 selenium tablet was added, 10 ml of sulphuric acid (concentrated) was also added and the samples were heated on the digestion stand for 5 hours until the digestion is complete. Chemical decomposition of the sample is complete when the initial very dark-coloured medium has become very clear and colourless. The samples were removed from the digestion stand and then left to cool. The digest was made up to 50 ml and then into sample cups.

Distillation: Exactly 5 ml of boric acid was weighed into Erlenmeyer flask and placed under the end of the condenser of the distillation apparatus. Five ml of the digested solution was then distilled with 5 ml of sodium hydroxide in the distillation flask by opening the funnel stopcock. The condenser was kept cool by allowing sufficient cold water to flow through and regulate heat to minimize frothing and prevent suck-back. The ammonium salt which has been converted to ammonia gave a green coloured solution (distillate). A 50 ml was collected for each sample that was distilled.

Titration: Fifty millilitre distillate collected was titrated using 0.01 M HCl. The ammonia reacted with the acid. There was a colour change at the end point from green to pink. A bare sample was also prepared using previous procedure but without soil sample.

Calculation: $\%\ N = \frac{(T - B) \times 14.01 \times 0.01N \times 100 \times 10}{\text{Weight of soil sample} \times 1000}$

Where: T = Titre value

B = Blank

3.3 Compost preparation

The compost used for the pot experiment was prepared using almond leaves and poultry manure; 1:1 ratio (w/w). The mixtures were turned and watered fortnightly using a static pile method (Ayeilari *et al*., 2011). Temperature readings were taken from five spots in the compost pile every morning (10.00 am) at 50 cm depth, using a thermometer. The compost temperature was compared with the ambient temperature. The stability of the compost was taken as when the compost temperature was at equilibrium with ambient temperature at 30^0C starting from the 80th to 84th day (Appendix 2).

3.4 Experimental materials

The organomineral fertiliser (OF; Grade A), was purchased from Aleshinloye market, Ibadan and the NPK 15-15-15 used for these experiments was obtained from the Department of Agronomy, University of Ibadan, Ibadan. The seeds sown (*bara* and *sewere egusi* melon) were sourced from Ojoo market, Ibadan Oyo State.

3.4.1 Experimental design for pot experiment

The experiment was to study the influence of organic (manures) and inorganic (chemical) fertilisers on the performance of two cultivars of melon.

Five kilogrammes of air- dried soil was placed into polythene bags (20 cm circumference and 30 cm height) and the polythene bags were arranged in completely randomized design. The treatments were replicated three times. It was a 2 x 2 x 4 factorial experiment with two melon cultivars *(bara and sewere)*, two levels of mycorrhizal inoculation (with and without) and four fertiliser types (OF, NPK, compost of almond leaves and poultry droppings and no fertiliser) to give a total of 48

experimental units. All fertilisers were applied at recommended rates for melon (Omueti *et al*., 2000; Ayoola and Adeniyan, 2006).

3.4.2 Fertiliser application and weeding

The 5 kg polythene bags soil each were thoroughly mixed with OF and compost (as applicable based on treatments being applied) at 60 kg N/ha each two weeks before sowing while NPK was applied (60 kg N/ha) at sowing (Appendix 3).
The pots were kept weed-free throughout the period of the experiment by hand weeding.

3.4.3 Data collection and analyses for pot experiment

Melon leaves were counted and vine length were measured both at 3 and 5 Weeks After Sowing (WAS), fresh melon fruit weight, number of melon fruits per plant and fresh total biomass weight per pot were taken at 12 WAS. Test of significance on data collected was carried out using analyses of variance at $\alpha_{0.05}$ and mean separation was carried out using Duncan's Multiple Range Test (DMRT).

3.5 Field Experiment Study Area

The field experiments were conducted at the Department of Agronomy, Faculty of Agriculture and Forestry, University of Ibadan, Ibadan, a derived savannah zone in South Western Nigeria.

3.5.1 Rainfall data for the experimental periods

There was no rainfall in January and December of both growing years. However, the least rainfall was recorded in November 2011 and 2012 with 8.00 mm and 17.50 mm, respectively. The highest rainfall during the first growing year (2011) was recorded in August (314.90 mm). During the second cropping year, the highest rainfall was 279.00 mm in the month of July (Appendix 4).

3.5.2 Description of the experimental site

The coordinates of the plot used for the field experiments are as follow. N 0727.130', E 003.510', N 0727.132', E 003.496', N 0727.122', E 003.494' and N 0727.120', E 003.509'. The plot was under continuous cultivation with arable crops

such as yam, cassava, maize, fluted pumpkin and *Amaranthus caudatus*. The dominating weeds in the site included *Chromolaena odorata, Aspilia africana, Panicum maximum, Imperata cylindrica, Talinum triangulare, Euphorbia heterophylla and Tithonia diversifolia.* The soil is an Alfisol having base saturation of more than 25% with clay accumulation layer (Gbadegesin and Akinbola, 1995).

3.6 Pre -Planting Activities

The experimental site was manually slashed to ensure good land preparation. Ten core soil samples from the top 0 - 15 cm were taken from each of the demarcated blocks and bulked to give composite samples for soil analysis before first cropping. Laboratory analyses were carried out as described in section 3.2.

3.6.1 Experimental design and field layout

The experiment was a 2 x 2 x 3 factorial. Two cropping systems (sole and intercrop), two levels of mycorrhizal inoculation (with and without), and three fertiliser treatments: mineral fertiliser NPK 15 – 15 – 15 applied at 733 kg/ha, containing 110 kgN/ha, OF applied at 2.5 t/ha containing 110 kgN/ha and no fertiliser application were evaluated (Appendix 3). The treatments were 12, replicated three times, giving a total of 36 experimental units. The field layout was a Randomized Complete Block Design (RCBD) in a split-split plot arrangement with the mycorrhizal inoculation (with and without) as the main plot; fertilisers' treatment constituted the subplot while cropping systems made up the sub-sub plot. Each plot measured 16.5 m^2, with an intra-row spacing of 1.0 m and inter-row spacing of 1.0 m (Appendix 5).

Melon (*sewere*, the selected cultivar from pot experiment) and late branching cassava cultivar (*Oko-iyawo*, TME 1) were used as test crops for the field experiment, which consisted of cassava and melon as sole and intercrop.

3. 6.2 Planting, fertiliser application and crop management

Organomineral fertiliser was applied uniformly on the plots and worked into the soil manually immediately after land preparation. The plots were left for two weeks before planting while NPK (15-15-15) fertiliser was applied during planting. Cassava cutting; *Oko-iyawo*, TME 1 (a 20 cm cutting per stand, planted at 1.0 m x 1.0 m with a total population of 10,000 plants/ha) was collected from Department of Agronomy, University of Ibadan. The melon seeds were first sown and cassava was planted two weeks after. Melon seeds were sown at 1.0 m × 1.0 m, two seeds per stand and later

thinned to one plant per stand at two weeks after sowing, resulting in a total population of 10,000 plants per hectare.

3.6.3 Cultural practices

Weeding was done manually with hoe at three, six and eight weeks after sowing of melon.

3.6.4 Data collection and analyses

Data on melon plant were collected at two, four and six weeks after sowing. The data on cassava were collected at three, six, nine and twelve Months After Planting (3, 6, 9 and 12 MAP). Melon growth parameters taken were; vine length and number of leaves of each sampled plant, while that of cassava included number of leaves and stems per plant. Cassava plant height was measured with the aid of a metre rule. Four pre-tagged plants from 4 m^2 land area per treatment were sampled during the cropping cycle for the measurement of the growth parameters. Plant tissue analysis was carried out at the point of maturity to determine nutrient concentration and uptake.

At harvest, the tagged plants (melon and cassava) were used for yield determination. The melon fruits were counted and weighed for yield determination. Melon seeds were shelled and weighed for yield determination. For cassava, number of stem, length and weight of tubers as well as shoot weights were determined. The storage roots were processed for dry matter accumulation (*garri*).

Arbuscular mycorrhizal spore counts were determined before and after field experiments and cassava mycorrhizal root colonisation were determined as described in sections 3.11 and 3.12, respectively.

3.7 Residual Effect Experiment

Residual effects of fertiliser application and mycorrhizal inoculation on melon and cassava intercrops were conducted using the same field without any additional treatment.

3.7.1 Field activities

The melon was harvested three months after sowing and cassava at twelve months after planting in the year 2011. The second planting operations were initiated on the same experimental field and both crops were established in April 2012. The

second field experiment was for melon and cassava intercrops. At this second cropping year there was no fertiliser application and mycorrhizal inoculation.

The planting and sowing of cassava and melon were carried out as described in section 3.6. This was to evaluate the residual effects of OF, NPK fertiliser and arbuscular mycorrhizal fungi on the performance of melon and cassava intercrop.

The plot layout, experimental design, crops, and spacing were made use of as in the first experiment. Plots were cleared manually and sowing and planting of melon and cassava were done respectively with minimum soil disturbance. Weeding was as previously described in section 3.6.3.

3.7.2 Soil sampling and laboratory analysis

Soil samples were randomly collected from each plot at a depth of 15 cm from five sampling points and the collected soil samples bulked to give a (composite) combined sample before planting and Laboratory analysis was carried out as described previously in section 3.2

3.7.3 Data collection

Data were collected on dry matter yield and nutrient uptake by plants. Plant sampling at maturity stage, analysis, and other post planting operations were carried out as in section 3.6.4.

3.7.4 Data analyses

Analysis of variance was used to analyse the data collected and means were separated using Duncan's Multiple Range Test (DMRT) at $\alpha_{0.05}$.

Land Equivalent Ratio (LER) for melon and cassava was determined using.

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of crop A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of crop B}}$$

where crop A = melon and B = cassava (Onwueme and Sinha, 1999).

3.8 Plant Nutrient Analysis

3.8.1 Determination of nitrogen

Method: Kjeldahl method

Apparatus: Kjeldahl flask, automatic pipette, fumes chamber, furnace, distillation apparatus and flask.

Reagents: Selenium (catalyst tablet), 0.01MHCl, concentrated Boric acid, H_2SO_4, and Sodium hydroxide (NAOH).

Procedure: Micro-Kjeldahl procedure method was used where 0.2 g of dried ground plant samples were weighed into digestive tube. Selenium (tablet) –catalyst and 10 ml of conc. H_2SO_4 were added to the digestive tube and the sample was heated for about three hours at 360^0 C. The digested sample was allowed to cool. Then 10 ml of deionized water was added slowly by swirling. After this, the digested sample was made to 50 ml volumetric flask and distilled with the aid of 40% NaOH and boric acid indicator. About 50 ml distillate was collected and titrated with 0.01 N HCl.

Then N in the plant sample was calculated using this formula:

Calculation: Total N (%) = (T x 0.1 x 0.001*) x (S/A) / W x 100/1

= (T x S x 0.01) / (A x W)

Where:

*= conversion factor from mg to g

T= corrected titre (ml)

S= final digest solution volume (ml)

A= aliquot volume (ml)

W= sample weight (mg)

Where: T = Titre value

B = Blank

3.8.2 Determination of P, K, Ca and Mg

Method: Wet oxidation

Apparatus: Pyrex volumetric flask, tehot plate and wash bottle

Reagents: Conc. nitric acid (HNO_3), conc. sulphuric acid (H_2SO_4), Perchloric acid.

Procedure: P, K, Ca and Mg were determined using wet oxidation method in which 0.5 g of the samples measured into 125 millilitre conical flask. Ten millilitre of

mixture of an acid (perchloric, and nitric acid), was added to the plant sample in the conical flask. The sample was digested using hot plate under fume cupboard. The heating was persistent until a white fume appeared. The sample was allowed to cool before adding distilled water to make up to the mark. The sample in solution was filtered with a wash bottle into a 100 ml pyrex volumetric flask and it was made to mark with distilled water. Phosphorus was determined using Vanadomolybdate yellow colorimetry method (Jackson, 1962).

The K and Na were determined with the flame photometer (Cornin model 400) while Ca and Mg were determined with Atomic Absorption Spectrophotometer (AAS).

3.9 Compost and Organomineral Fertiliser Analyses

The procedures were as previously explained for laboratory analysis plant nutrients analysis in section 3.8.

3.10 Nutrient Uptake

Nutrients uptake by plant was calculated as;

Nutrient uptake = % nutrient content x dry matter yield (Tening and Omueti, 2011)

3.11 Determination of Percentage Root Colonized by AM fungi

Approximately 0.5 g fresh weight of clean cassava roots samples, (less than 1 mm diameter cut into 1 cm) which were taken from the treatments and preserved in 50% ethanol inside McCartney bottle for quantification of mycorrhizal colonisation. The ethanol was decanted, then rinsed with distilled water and 10% KOH was added. The KOH was decanted and the roots were washed in water and then acidified with 10% HCl for 3-4 minutes. The staining of the roots was done with 0.05% trypan blue (Philips and Hayman, 1970) prepared in glycerol, water and 1% HCl, and both were thoroughly shaken together and left overnight. Trypan blue was decanted and glycerol was added to remove excess stain and to preserve the stained roots. The percentage root colonisation was determined by observing the stained roots placed inside a plate containing grid line (Giovantti and Mosse 1980) and observed under a dissecting microscope. The presence or absence of arbuscles/vesicles and hyphae were scored along the grid lines. The score was either positive for presence or negative for absence. The percentage mycorrhizal colonisation was calculated by the ratio between

the numbers of intersects with colonisation and the total number of intersects multiplied by 100.

The percentage root colonisation was calculated using the formula.

$$\% \text{ Colonisation} = \frac{c}{d+c} \times \frac{100}{1}$$

where: c = Total number of mycorrhizal colonized roots (positive +)

d = Total number of non- colonized root (negative -).

or

$$\% \text{ Colonisation} = \frac{\text{Total No of intersections colonised by mycorrhiza}}{\text{Total No of intersections}} \times \frac{100}{1}$$

(Joseph and Sidney, 2008).

3.12 AMF Spore Extraction from Soil samples

The wet–sieving method of Gerdamamn and Nicholson (1963) was used for estimating AM spore populations. Soil (100 g) was suspended in water for sedimentation after which the suspension was mixed vigorously. The suspension was allowed to settle for 30 seconds and the supernatant was decanted through three sieves of 200, 56, 35 µm mesh sizes arranged in that order. This procedure was repeated 3 times for each sample. The sieved content was centrifuged (3000 rpm for 4 minutes) and pelleted. The pellet was re – suspended in 40% sucrose solution and centrifuged (3000 rpm for 2.5 minutes). The spores in the suspension were filtered and counted.

CHAPTER 4

RESULTS

4.1. Chemical and Physical Properties of Experimental Soils

4.1.1. Properties of soil used for pot experiment

The soil used for the pot experiment was slightly acidic and the organic carbon (OC) was sufficient, that is greater than critical level; (Table 4.1). Nitrogen was 1.7 g kg^{-1} while the available P was 21.4 mg kg^{-1} (Table 4.1). Exchangeable bases for the soil ranged from 0.2 – 4.3 cmol kg^{-1} as observed with K and Ca respectively. Mn and Fe were high: (80.9 and 62.6 mg kg^{-1} respectively) compared to other extractable micronutrients. The textural class was sandy loam with sand particle size distribution of 832 g kg^{-1} (Table 4.1).

4.1.2. Chemical constituents of organomineral fertiliser and compost

The organic fertilisers used for the pot experiment contained the macro and micro nutrients needed for crop production (Table 4.2). However, the compost obtained from mixture of Almond leaves and poultry dung was deficient in K (1.0 g kg^{-1}) which was below the required level for crop production compare to OF with 6.8 g kg^{-1}. Organomineral fertiliser was higher in nutrient compared to compost from Almond leaves (Table 4.2). The nitrogen content of OF was approximately 100.0 % higher than that of the compost, while phosphorus was about 59.4% higher in OF compared to compost. All the other elements like potassium, calcium, magnesium, iron and copper followed a similar trend (Table 4.2).

4.2. Vegetative Growth of Melon in Pot Experiment

4.2.1. Vine length of melon at three and five weeks after sowing

At the initial stages of growth (3 WAS), the vine lengths of the two cultivars were not significantly different under the respective treatments (Table 4.3). However, at 5 WAS, the vine length value (103.7 cm) of *sewere* was appreciably high compare to that of (75.7 cm) *bara* when respective experimental factors were compared in term of their effects on both cultivars.

Table 4.1: Particle size distribution and chemical properties of the soil used for the pot experiment

Parameter	Values
pH (H_2O) (1.1)	6.4
Organic C (g kg^{-1})	16.5
Total N (g kg^{-1})	1.7
Available P (mg kg^{-1})	21.4
Exchangeable Bases (cmol kg^{-1})	
K	0.23
Ca	4.34
Na	0.30
Mg	0.53
Extractable Micronutrients (mg kg^{-1})	
Mn	80.9
Fe	62.6
Cu	3.82
Zn	2.59
C.E.C	5.70
Particle size distribution (g kg^{-1})	
Sand	832.0
Clay	48.0
Silt	120.0
Textural class	Sandy Loam

Table 4.2: Nutrient composition of organomineral fertiliser and compost

Parameters	Organomineral fertilizer	Compost
Macronutrients (g/kg)		
Total N	44.2	22.7
Total P (mg/kg)	11.0	6.9
Exchangeable base (cmol/kg)		
Total K	7.0	1.0
Ca	7.0	2.7
Mg	0.57	0.2
Micronutrients (mg/kg)		
Mn	558.0	0.1
Fe	8153.0	392.0
Cu	275.0	188.0

Table 4.3: Melon vine length (cm) at three and five weeks after sowing as affected by mycorrhizal inoculation and fertilizers application in pot experiments

Treatments combinations			Weeks after sowing	
Cultivars	Mycorrhiza	Fertilizers	3	5
Bara	-	-	16.3d	52.0g
Bara	+	-	23.3c	49.0g
Bara	-	OF	22.0c	75.7f
Bara	+	OF	30.0b	51.3g
Bara	-	NPK	18.7cd	45.3h
Bara	+	NPK	16.7d	46.3h
Bara	-	Compost	18.7cd	76.7f
Bara	+	Compost	39.0a	50.3g
Sewere	-	-	16.3d	83.7e
Sewere	+	-	23.3c	103.7a
Sewere	-	OF	22.0c	95.0bc
Sewere	+	OF	25.0b	90.0c
Sewere	-	NPK	18.1cd	94.0c
Sewere	+	NPK	16.3d	85.7de
Sewere	-	Compost	18.9d	98.3ab
Sewere	+	Compost	39.6a	99.0a
Cultivar (C)			ns	ns
Mycorrhiza (M)			ns	*
Fertilizer (F)			*	ns
C x M			ns	*
C x F			*	*
C x M x F			ns	*

Means in the same column followed by the same letters are not significantly different (P = 0.05) according to Duncan's multiple range tests.

LEGEND

- Myco = without mycorrhizal
+ Myco = with mycorrhizal
OF = Orgnomineral Fertilizer
WAS = Weeks After Sowing
ns = not significant
* = significant

Varietal response to mycorrhizal inoculation showed that vine length of *bara* was significantly increased at 3 WAS by mycorrhizal inoculation but was not significantly affected at 5 WAS. *Sewere* vine length was, however, consistently significantly increased by mycorrhizal inoculation at 3 and 5 WAS (Table 4.3).

Responses to fertiliser application also varied. Application of OF significantly reduced the vine length of both cultivars at 3 and 5 WAS, whereas NPK only resulted in significant increase in vine length of *sewere* at 5 WAS. Application of inorganic fertilizer (NPK) resulted in considerable reduction in *bara* vine length at 5 WAS when compared to the corresponding treatment without NPK application. Compost also resulted in significant increase in vine length at 5 WAS for the two cultivars, whereas no significant difference was observed at 3 WAS for the two cultivars (Table 4.3).

4.2.2. Number of leaves of melon at 3 and 5 weeks after sowing

At 3 and 5 WAS, when no fertiliser was applied with mycorrhizal inoculation, the number of leaves of both melon cultivars were not significantly different compared to number of leaves obtained under no fertilizer application with and without mycorrhizal inoculation. However, at 5 WAS the number of leaves of *bara* cultivar was significantly reduced under the same treatments (Table 4.4).

Similarly, when OF was applied at 3 and 5 WAS, *bara's* number of leaves was not significantly different when compared to *sewere* when OF was applied with and without mycorrhizal inoculation. At 5 WAS the number of leaves of *bara* was significantly reduced (18.0) under OF application without mycorrhizal inoculation (Table 4.4).

When NPK was applied to *bara,* at 3 WAS, at both levels of mychorrhizal inoculation (with and without); there was no substantial effect on number of leaves when compared to *sewere* under OF application (Table 4.4). There was substantial increase in number of *sewere* leaves (35.0 and 37.7) at 5 WAS when NPK was applied with and without mycorrhizal inoculation (Table 4.4). Moreover, when compost was applied with mycorrhizal inoculation, *sewere* was not significantly different at 3 and 5 WAS in number of leaves when compared to NPK application except when mycorrhizal was not applied under similar treatment (Table 4.4).

Under compost application, both melon cultivars showed considerable difference in term of number of leaves which was significantly increased under mycorrhizal inoculation, except at 5 WAS where *bara* and *sewere* were not inoculated under compost application (Table 4.4).

Table 4.4: Number of leaves of melon plant at 3 and 5 weeks after sowing in pot experiments

Treatments combinations			Weeks after sowing	
Cultivars	Mycorrhiza	Fertilisers	3	5
Bara	-	-	7.0b	15.7e
Bara	+	-	6.0b	19.0cd
Bara	-	OF	7.0b	18.0d
Bara	+	OF	7.3b	28.7b
Bara	-	NPK	6.0b	21.3c
Bara	+	NPK	6.0b	20.7c
Bara	-	Compost	7.7b	25.7b
Bara	+	Compost	10.0a	30.3a
Sewere	-	-	7.0b	29.7b
Sewere	+	-	6.0b	32.0b
Sewere	-	OF	8.3ab	39.7a
Sewere	+	OF	7.7ab	30.7b
Sewere	-	NPK	7.3b	35.0a
Sewere	+	NPK	9.7a	37.7a
Sewere	-	Compost	10.0a	25.7b
Sewere	+	Compost	9.0a	39.0a
Cultivar (C)			ns	ns
Mycorrhiza (M)			ns	ns
Fertiliser (F)			*	*
C x M			ns	ns
C x F			*	*
C x M x F			ns	ns

Means in the same column followed by the same letters are not significantly different (P = 0.05) according to Duncan's multiple range tests.

LEGEND

- Myco = without mycorrhizal
+ Myco = with mycorrhizal
OF = Orgnomineral Fertilizer
WAS = Weeks After Sowing
ns = not significant
* = significant

At 3 and 5 WAS where both melon cultivars were inoculated under compost application, the number of melon leaves was significantly increased (10.0 and 30.3) when both melon cultivars were compared (9.7 and 37.7) under NPK and OF applications with mycorrhizal inoculation, except at 3 WAS where *sewere* was inoculated under OF application (Table 4.4). However, both melon cultivars irrespective of fertiliser application, mycorrhizal inoculation had no definite pattern of result on the number of leaves production. Whereas, at 3 and 5 WAS where mycorrhizal was inoculated under compost and NPK application, there was considerable increase in number of leaves of both melon cultivars when compared to number of leaves of both melon varieties under OF application with mycorrhizal inoculation (Table 4.4).

4.3. Yield of Melon as Influenced by Fertiliser Application and AM Inoculation in Pot Experiment

4.3.1. Number of melon fruits

At harvest, number of fruits obtained from *sewere* cultivar range from 2 – 4 fruits per plant. However, there was no fruit from *bara* under some treatments; where no fertiliser was applied and where NPK fertilisers was applied with mycorrhizal inoculation (Fig. 4.1). The maximum number of fruits obtained from *bara* was2 under OF without mycorrhizal inoculation, NPK plus AM inoculation and compost application without AM inoculation.

Under all the fertiliser applications (treatments), *sewere* cultivar produced fruits but no fruit for *bara* under no fertilizer application with mycorrhizal inoculation and NPK without mycorrhizal inoculation (Fig. 4.1). Fruit yield of *bara* compared to that of *sewere* was 75.0% lower under mycorrhizal inoculation and OF application and was 63.7% lower when under compost application and AM inoculation (Fig. 4.1).

4.3.2. Melon shoot and total plant weight yield

The shoot weight of both cultivars were significantly reduced (31.7 and 11.7g/pot) where no fertiliser and mycorrhizal were applied when compared to shoot yields obtained under fertiliser application (Table 4.5). Under the application of NPK without mycorrhizal inoculation, *bara* shoot weight was significantly higher (210 g/pot) compared to *sewere* shoot weight (96.7g/pot) under the similar fertiliser application without mycorrhizal inoculation (Table 4.5). Generally, both cultivars shoot weights were significantly reduced irrespective of fertiliser types and application

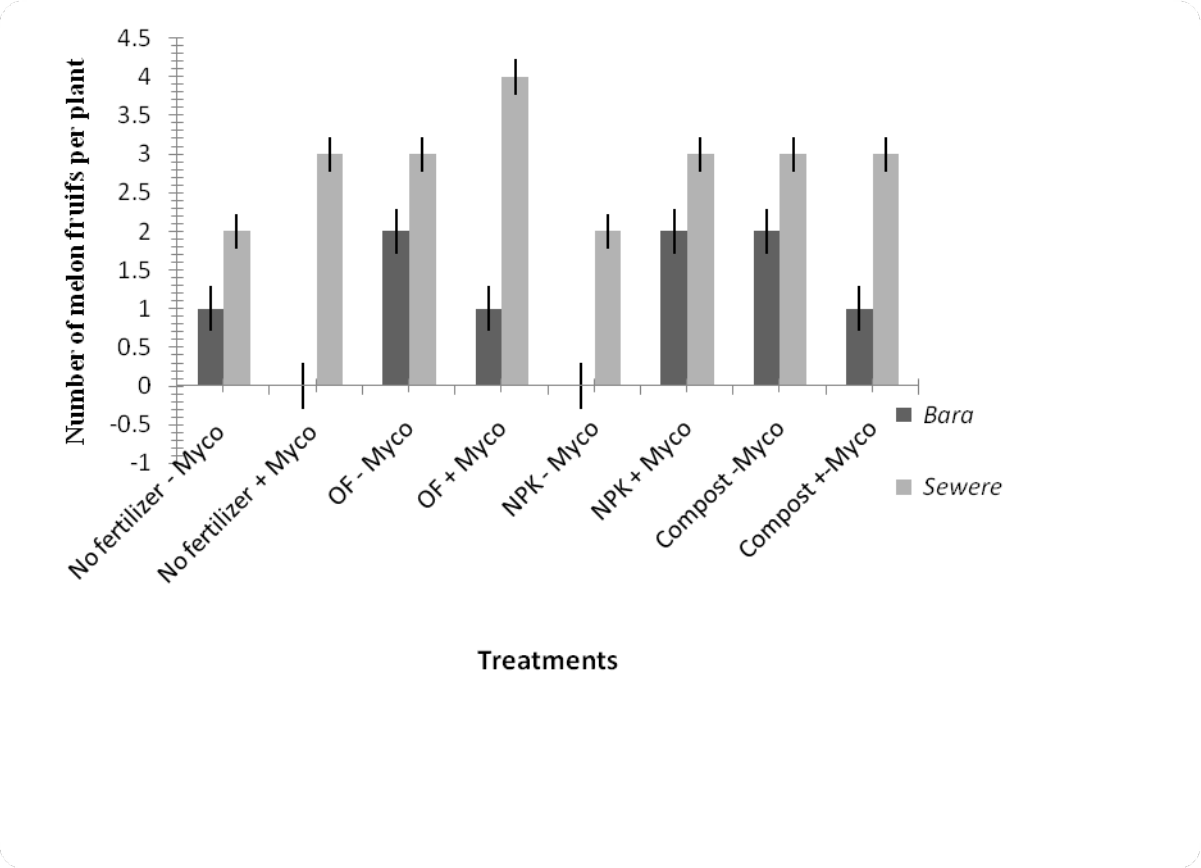


Figure 4.1: Number of melon fruits as influenced by fertiliser application and AM inoculation on two cultivars of melon in pot experiment

Bars represent standard error

LEGEND

-Myco = without mycorrhizal,

+ Myco = with mycorrhizal,

OF = Orgnomineral Fertiliser

Table 4.5: Fresh total shoot and total plant weights of two cultivars of melon as influenced by organic based fertilizers and AM inoculation in pot experiment

Treatments combinations			Fresh shoot weight (g/pot)	Total plant weight (g/pot)
Cultivars	Mycorrhiza	Fertilizers		
Bara	-	-	31.7e	66.7f
Bara	+	-	40.3d	48.8f
Bara	-	OF	25.0e	103.3e
Bara	+	OF	50.0c	93.3e
Bara	-	NPK	70.0a	96.7e
Bara	+	NPK	61.0b	168.3b
Bara	-	Compost	30.0c	91.7e
Bara	+	Compost	60.0b	131.7d
Sewere	-	-	11.7f	90.0e
Sewere	+	-	16.0f	173.3bc
Sewere	-	OF	45.0cd	206.7a
Sewere	+	OF	40.0d	211.7a
Sewere	-	NPK	58.3b	210.0a
Sewere	+	NPK	46.7cd	213.3a
Sewere	-	Compost	26.7e	155.0cd
Sewere	+	Compost	41.7d	196.7ab
Cultivar (C)			ns	ns
Mycorrhiza (M)			ns	*
Fertilizer (F)			*	ns
C x M			ns	ns
C x F			*	*
C x M x F			*	*

Means in the same column followed by the same letters are not significantly different (P = 0.05) according to Duncan's multiple range tests.

LEGEND

- Myco = without mycorrhizal
+ Myco = with mycorrhizal
OF = Orgnomineral Fertilizer
WAS = Weeks After Sowing
ns = no significant difference
* = significant difference at $p < 0.05$

where there was no mycorrhizal inoculation with exception of shoot weight of *bara* under NPK application without mycorrhizal inoculation (Table 4.5).

Where no fertiliser and mycorrhizal were applied, the total plant weight obtained (90.0 g/pot) from *sewere* was significantly different when compared to total plant yield obtained (66.7 g/pot) from *bara* cultivar under similar treatment (Table 4.5). However, with mycorrhizal inoculation, there was significant reduction of total plant yield from *bara* when compared to *sewere* total weight yield under similar treatment (Table 4.5). Both cultivars were significantly increased by mycorrhizal inoculation when compared to non-inoculated melon plant except when no fertiliser was applied (Table 4.5).

When OF was applied with and without mycorrhizal inoculation, total plant yield of *bara* was not significantly different when compared to total plant yield obtained under NPK application except where mycorrhizal was inoculated. However, there was significant difference when compared to total plant yield of *sewere* under the same treatments (Table 4.5). Under the applications of OF and NPK fertiliser with and without mycorrhizal inoculation, total plant yield of *sewere* was not significantly different when compared, but was high in value when compared to that of *bara* under the same treatment (Table 4.5).

Compost application and mycorrhizal inoculation significantly increase *sewere* total plant yield when compared to total plant yield of *bara* under similar treatment but when mycorrhiza was not inoculated with compost, (that is, compost without mycorrhizal inoculation), the total plant yield of both melon cultivars were significantly different, likewise when compost was inoculated (Table 4.5). Generally, mycorrhizal inoculation significantly increased the total plant yield of both melon cultivars irrespective of the fertiliser types when compared to total plant yield under any of the fertiliser application (that is OF, NPK or compost) without mycorrhizal inoculation (Table 4.5).

4.3.3. Fresh melon fruits weight

Fresh fruit weights for *bara*, ranged from 20.6 – 161.7 g while that of *sewere* fruits ranged from 78.3 – 171.7 g per plant (Fig. 4.2). When both melon cultivars were inoculated with mycorrhiza under OF, NPK and compost application, *sewere* gave the highest fruit weight of 171.7 g under OF application and mycorrihzal inoculation while *bara* gave 161.7g per plants under NPK and mycorrhizal inoculation (Figure 4.2). There was no major difference in *bara* fruit weight when no fertiliser

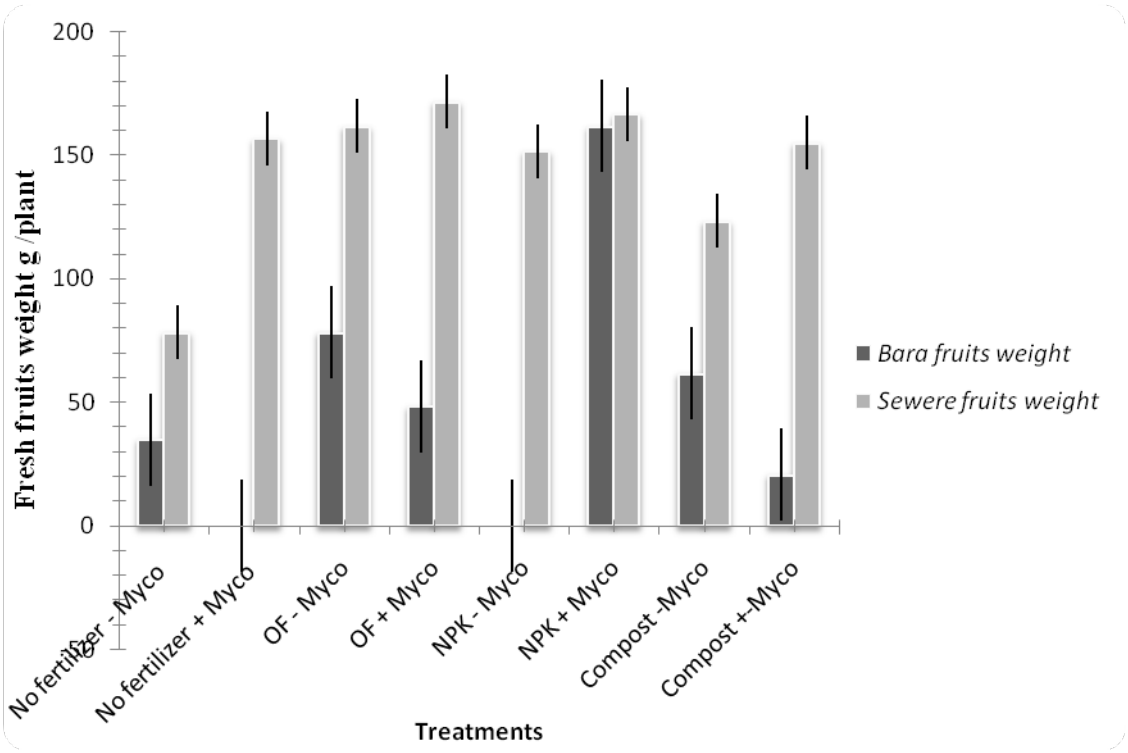


Figure 4.2: Weight of fruits of two cultivars of melon as influenced by fertiliser application and AM inoculation in pot experiment

Bars represent standard error

LEGEND

-Myco = without mycorrhiza,

+ Myco = with mycorrhiza,

OF = Orgnomineral Fertiliser

was applied with AM inoculation compared to fruit weight under NPK plus AM inoculation (Fig. 4.2).

However, under all the fertiliser applications with and without AM inoculation, *bara* fruit weight was significantly lower compared to *sewere* fruit weight, except when NPK was applied with AM inoculation. Moreover, where no fertiliser and no mycorrhizal was applied, the fruit yields of *sewere* were not significantly different with respect to all the treatments (Fig. 4.2).

4. 4 Chemical Properties and Particle Size Distribution of Field Experimental Soil

4.4.1. Properties of soil used for first field experiment, 2011 cropping year

The pre-cropping properties of the experimental soil before first cropping year (2011) were presented in (Table 4.6). The soil was slightly acidic, with 18.8 g kg^{-1} organic carbon. The nitrogen was (1.9 g kg^{-1}) moderately high and available P was (24.3 mg kg^{-1}) was high (Table 4.6). The exchangeable bases ranged from 0.2 – 2.3 cmol kg^{-1} for K and Ca respectively. Mn had the highest value 90.1 mg kg^{-1} compared to other micronutrients. The textural class was sandy loam (Table 4.6).

4.4.2. Soil characteristics before and after second field experiment, 2012 and 2013 cropping years

The soil pH was slightly acidic before the experiment and remained almost the same with approximately 4.5% reduction compared to the previous cropping year (Table 4.6). The organic carbon decreased by approximately17.8 % at the end of the experiment (Table 4.6). The available P was 22.1 mg kg^{-1} at the beginning of 2012 cropping year and decreased approximately by 28.0 % at the end of the experiment. Furthermore, the exchangeable bases such as K and Na remained almost the same at the end of the experiment.

However, Ca and Mg increased by approximately 26.8 and 18.2 % respectively (Table 4.7). Similarly, among the extractable micronutrients, Mn and Fe increased from 94.5 – 100.8 mg kg^{-1} and 58.4 – 64.5 mg kg^{-1} compared to previous cropping years (Table 4.6).

Table 4.6: Particle size distribution and chemical properties of the soil used before and after the field experiments

Parameters	Values		
	2011	2012	2013
pH (H_2O) (1.1)	6.8	6.7	6.4
Organic C (g kg^{-1})	18.8	17.4	14.3
Total N (g kg^{-1})	1.9	1.8	1.4
Available P (mg kg^{-1})	24.3	22.1	16.0
Exchangeable Bases (cmol kg^{-1})			
K	0.22	0.24	0.22
Ca	2.94	1.94	2.46
Na	0.29	0.28	0.30
Mg	0.45	0.33	0.39
Extractable Micronutrients (mg kg^{-1})			
Mn	90.1	94.5	100.8
Fe	60.0	58.4	64.8
Cu	4.14	4.22	4.61
Zn	2.62	2.07	3.87
C.E.C	4.50	3.34	3.87
Particle size distribution (g kg^{-1})			
Sand	832.0	812.0	812.0
Clay	48.0	48.0	48.0
Silt	120.0	140.0	140.0
Textural class	Sandy Loam	Sandy Loam	Sandy Loam

4.4.3. Mycorrhizal spore count before and after field experiments

The spore count showed that there was considerably low number of mycorrhizal propagules in the soil (43 per 100 g of the composite soil sample) (Fig. 4.3). However, the inoculated experimental plots without any fertiliser application were increased in spore count by 21.3% compared to OF and NPK fertilized plots (Figure 4.3). It was further observed that both fertilisers reduced the number of spore at the end of the cropping years especially plots under NPK fertiliser application. The number of spore in the soil at the end of the experiments followed an order; mycorrhizal inoculated plots > pre-planting> mycorrhiza + OF > mycorrhiza + NPK (Fig. 4.3).

4.5. Field Experiments: Vegetative Growth of Melon under OF, NPK, AM and Cassava Intercrop

4.5.1 Melon shoot spread in 2011 and 2012 cropping years

With application of OF in 2011 and 2012, there was no significant effect of mycorrhizal inoculation under intercropped and sole cropped melon on the shoot spread (Table 4.7). Nevertheless, at 2 and 6 WAS in 2011 cropping year, mycorrhizal inoculation significantly increased the shoot spread of melon (494.2 – 974.9 cm^2) under sole crop at 2 WAS and 5320.3 – 8173.3 cm^2 at 6 WAS (Table 4.7). Under the intercrop with NPK fertiliser application, there was no significant effect of mycorrhizal inoculation at 2, 4 and 6 WAS in either sole or intercropped melon except 2 WAS under sole crop, where mycorrhizal inoculation significantly increased the melon shoot spread (Table 4.7).

In 2011 cropping year, at 6 WAS under no fertiliser application and when no mycorrhiza was applied, sole cropped melon was significantly higher in shoot spread (6346.0 cm^2) compared to intercropped melon shoot spread (6005.0 cm^2). Whereas, the shoot spread of melon in intercrop was significantly reduced when compared to sole crop under mycorrhizal inoculation. All other treatments were not significant at 2, 4 and 6 WAS (Table 4.7).

In 2011, at 2, 4 and 6 WAS under NPK application with mycorrhizal inoculation, melon shoot spread under sole cropping was not significantly different when compared to the intercrop except at 6 WAS where melon intercrop was significantly lower in shoot spread compared to sole crop (Table 4.7). When melon was inoculated with mycorrhizal, sole crop was significantly higher at 4 and 6 WAS compared to melon shoot spread when melon was intercrop with mycorrhizal inoculation (Table 4.7).

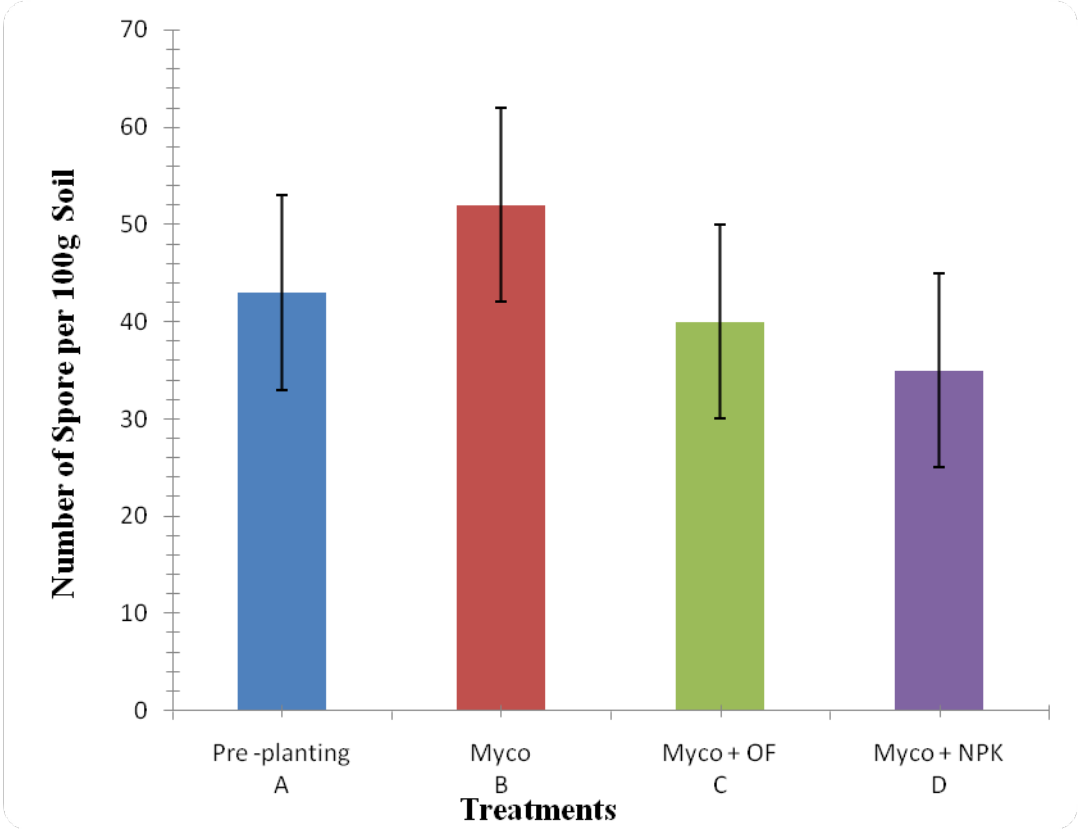


Figure 4.3: Mycorrhizal spore count before and after field experiments

Bars represent standard error

LEGEND

A = Spore count before planting

B = Mycorrhiza (where no fertiliser was applied only mycorrhizal inoculation)

C = Organomineral fertiliser and mycorrhizal inoculation plots

D = NPK (15-15-15) fertiliser and mycorrhizal inoculation plots

Table 4.7: Melon shoots spread (cm^2) in 2011 and 2012 as influenced by AM, fertilizers and cropping systems

Treatments	2011			2012		
	2 WAS	4 WAS	6 WAS	2 WAS	4 WAS	6 WAS
NO FERTILIZER						
Sole without Myco	728.0b	2966.3b	5320.3c	718.3b	2872.0b	5169.6bc
Sole with Myco	646.5bc	2759.3b	6346.0a	670.0b	2680.0b	4824.0c
Inter. without Myco	726.7b	2921.3b	6595.0a	760.0b	3040.0b	5472.0b
Inter. with Myco	494.2c	2536.3b	6005.0bc	565.8c	2263.2c	4073.8c
OF						
Sole without Myco	543.7bc	2257.3b	4975.0c	625.3c	2501.2bc	4502.2c
Sole with Myco	706.0ab	2910.3b	6429.3ab	582.7c	2330.8bc	4195.4c
Inter. without Myco	854.8ab	3569.7ab	7941.7a	818.4a	3273.6ab	5892.5b
Inter. with Myco	970.8a	4090.7a	8050.0a	937.4a	3893.4a	7008.5a
NPK						
Sole without Myco	755.2b	3324.3ab	7300.0a	740.3b	2961.2b	5330.2b
Sole with Myco	974.9a	3970.2a	8173.3a	949.8a	3799.2a	6838.6a
Inter. without Myco	750.6b	3035.7b	6691.7b	742.5b	2970.0b	5346.0b
Inter. with Myco	842.4ab	2942.0b	6508.2b	829.7a	3319.8a	5973.8b
Mycorrhiza (M)	ns	ns	ns	ns	ns	ns
Fertilizer (F)	ns	ns	ns	ns	ns	ns
Cropping system(Cs)	ns	ns	ns	ns	ns	ns
M x F	ns	ns	ns	ns	ns	ns
M x Cs	ns	ns	ns	ns	ns	ns
F x Cs	*	*	ns	*	*	ns
M x F x Cs	ns	ns	ns	ns	ns	ns

Means in the same column followed by the same letters are not significantly different (P = 0.05) using to Duncan's multiple range tests.

LEGEND

W A S = Week after sowing
Sole without Myco = Sole melon cropping without mycorrhizal inoculation
Sole with Myco = Sole melon cropping with mycorrhizal inoculation
Inter. without Myco = cassava melon intercrop without mycorrhizal inoculation
Inter. with Myco = cassava melon intercrop with mycorrhizal inoculation

***** = significant difference at $p < 0.05$. ns = not significant

In 2011 cropping year, there was no consistent trend in the shoot spread of melon with reference to fertiliser application and mycorrhizal inoculation under all the cropping systems except when OF was applied under intercropped melon with mycorrhizal inoculation, which was significantly higher at 2, 4, and 6 WAS compared to sole crop shoot spread (Table 4.7).

In 2012 cropping year, shoot spread of melon intercrop was significantly higher when compared to sole crop under OF with or without mycorrhizal inoculation except at 4 WAS when non mycorrhizal (Table 4.7). In 2012 cropping year, when NPK was applied without mycorrhizal inoculation, melon shoot spread at 2, 4 and 6 WAS were not significantly different under sole cropping. However, when OF was applied with and without mycorrhizal inoculation, there was no significant difference at 2, 4 and 6 WAS in melon shoot spread (Table 4.7).

At 2, 4 and 6 WAS, when melon was intercropped under OF and NPK fertiliser application, melon shoot spread was significantly increased, compared to when inoculated with mycorrhizal except at 6 WAS (Table 4.7). In 2012 cropping year, at 2 and 4 WAS, when no fertiliser was applied, significant reduction in melon shoot spread was only observed under intercrop with mycorrhizal inoculation compared to sole crop with mycorrhizal inoculated treatments (Table 4.7). In 2012 cropping year, mycorrhizal inoculation significantly increased the melon shoot spread at 2, 4, and 6 WAS under NPK fertiliser application with sole or intercrop except at 6 WAS under intercrop where the increase was not significant (Table 4.7). At 2 and 4 WAS in 2012, when no fertiliser was applied, there was no significant difference in the melon shoot spread when melon was sole crop. Whereas, at 2, 4 and 6 WAS under similar treatments, mycorrhizal inoculation significantly reduced the shoot spread of melon when intercropped (Table 4.7).

4.5.2 Melon vine length in 2011 and 2012 cropping years

In 2011 cropping season, when no fertiliser was applied (with and without mycorrhizal inoculation), at 2, 4 and 6 WAS, there was no significant different in melon vine length when compared to melon vine length under OF and NPK fertiliser applications under both cropping systems (Table 4.8). Similarly, there was increased in melon vine length when melon was intercropped without mycorrhizal inoculation under NPK application at 2 and 4 WAS (Table 4.8). When melon was

Table 4.8: Melon vine length (cm) at both cropping years as influenced by AM, fertilizer application and cropping systems

TREATMENTS	2011			2012		
	2 WAS	4 WAS	6 WAS	2 WAS	4 WAS	6 WAS
NO FERTILIZER						
Sole without Myco	52.9b	105.9a	354.8b	64.6ab	115.1b	315.7c
Sole with Myco	61.1ab	110.2a	423.3ab	72.7a	120.1b	385.6bc
Inter. without Myco	54.1ab	108.2a	452.0ab	63.5ab	113.8b	397.3bc
Inter. with Myco	53.0b	106.0a	400.5b	61.5b	115.0b	400.9bc
OF						
Sole without Myco	55.8ab	111.7a	331.8b	66.8ab	88.7b	349.3bc
Sole with Myco	60.6ab	121.4a	428.7ab	70.9a	132.0a	454.0ab
Inter. without Myco	56.3ab	112.6a	529.5a	65.7ab	121.2a	506.5a
Inter. with Myco	61.6ab	123.5a	536.9a	71.6a	132.3a	513.4ab
NPK						
Sole without Myco	62.3a	124.8a	486.7a	71.7a	137.0a	468.3ab
Sole with Myco	56.2ab	112.6a	545.2a	64.9ab	129.0a	504.9ab
Inter. without Myco	59.0ab	118.2a	446.3ab	66.9ab	138.3a	463.7ab
Inter. with Myco	59.8ab	119.7a	455.9ab	70.8a	126.0a	403.7bc
Mycorrhiza (M)	ns	ns	ns	ns	ns	ns
Fertilizer (F)	ns	ns	ns	ns	ns	*
Cropping system(Cs)	ns	ns	ns	ns	ns	ns
M x F	ns	ns	ns	ns	ns	ns
M x Cs	ns	ns	ns	ns	ns	ns
F x Cs	ns	ns	ns	ns	ns	*
M x F x Cs	ns	ns	ns	ns	ns	ns

Means in the same column followed by the same letters are not significantly different (P = 0.05) using to Duncan's multiple range tests.

LEGEND

Sole without Myco = Sole melon cropping without mycorrhizal inoculation
Sole with Myco = Sole melon cropping with mycorrhizal inoculation
Inter. without Myco = cassava melon intercrop without mycorrhizal inoculation
Inter. with Myco = cassava melon intercrop with mycorrhizal inoculation
***** = significant difference at $p < 0.05$ ns = not significant

sole crop without mycorrhizal inoculation, under OF and NPK fertiliser application, there was no significant effect or difference in melon vine length when compared to intercropped melon without mycorrhizal inoculation when no fertiliser was applied. Whereas, there was increase in melon vine length when melon was sole cropped without mycorrhizal inoculation compared to when no fertiliser was applied (Table 4.8). There was no significant effect of mycorrhizal inoculation when melon was intercropped under OF and NPK fertiliser application with and without mycorrhizal inoculation when compared to the same treatment when no fertiliser was applied (Table 4.8).

In 2012 cropping year, at 2, 4 and 6 WAS, when no fertiliser was applied there was no significant increase in melon vine length (Table 4.8), whereas at 4 WAS, there was significant effect of the treatment under OF and NPK fertiliser application on melon vine length when compared to when no fertiliser was applied irrespective of mycorrhizal inoculation and cropping system. At 6 WAS, there was no significant effect of all the treatments (that is, mycorrhizal inoculation and cropping systems) when no fertiliser was applied compared to when OF and NPK were applied. There was a decrease in melon vine length (315.7 cm) when melon was sole cropped without mycorrhizal inoculation under no fertiliser application (Table 4.8). When melon was intercropped without mycorrhizal inoculation at 2 and 6 WAS with each of the fertiliser, there was no significant difference in melon vine length when compared to intercropped melon under similar treatments. At 4 WAS, there was significant effect of fertiliser application and mycorrhizal inoculation on melon vine length under OF and N P K fertiliser applications when melon was sole cropped except under OF application without mycorrhizal inoculation compared to when no fertiliser was applied (Table 4.8).

In both cropping years, mycorrhizal inoculation with sole cropped melon under all the fertilisers applications were not significantly different in melon vine length when compared to melon intercropped with and without mycorrhizal inoculation (Table 4.8). However, there was significant difference at 4 WAS of 2012 cropping year, where there was increased in melon vine length under OF and NPK fertiliser applications. When compared to when no fertiliser was applied, there was a decrease in melon vine length where melon was sole cropped under OF application without mycorrhizal inoculation (Table 4.8).

4.6 Melon Productivity under Cassava-Melon Intercrop with OF, NPK and AM Inoculation

4.6.1. Number of melon fruits in 2011 and 2012 cropping years

During the first cropping year (2011), the highest number of melon fruits (454,000 fruits /ha) was obtained when melon was intercropped under NPK fertiliser and inoculated with mycorrhiza (Table 4.9). The least number of melon fruits (233,000 fruits /ha) was obtained when under sole melon cropping without any fertiliser application and without mycorrhizal inoculated (Table 4.9).

The number of fruits increased (454,000 fruits /ha) under NPK with mycorrhizal inoculation but not significantly different from number of fruits obtained under OF application with and without mycorrhizal inoculation when melon was sole and intercropped under OF (Table 4.9). Nevertheless, the increased in number of melon fruits under OF and NPK applications was significantly different when compared to sole melon crop with and without mycorrhizal inoculation when no fertiliser was applied (Table 4.9).

In 2012 cropping year, similar trends were observed; the number of melon fruits ranged from 167, 000 – 267, 000 when melon was intercropped under OF application (residual effect) with mycorrhizal inoculation (Table 4.9). However, when no fertiliser was applied, irrespective of cropping system, there was no significant difference in number of melon fruits compared to when NPK was applied except (233,000) when melon was intercrop with mycorrhizal inoculation, under NPK (Table 4.9).

4.6.2. Melon fruits weight in 2011 and 2012 cropping years

In 2011 cropping year, there was insignificant difference in melon fruits yield when OF and NPK were applied with and without mycorrhizal inoculation compared to when no fertiliser was applied irrespective of cropping systems (Table 4.11). The least melon fruit yield (7.4 t/ha) was recorded when no fertiliser was used without mycorrhizal inoculation under sole cropped melon (Table 4.11). The highest fruit yield was obtained when melon was intercrop under OF application with mycorrhizal inoculation. The value (16.3 t/ha) was significantly higher ($P < 0.05$) when compared to yield obtained when no fertiliser was applied (7.4 t/ha), but not significantly higher compared to fruit yield obtained when NPK fertiliser was applied with mycorrhizal inoculation under intercropped melon (Table 4.11).

Table 4.9: Effects of OF, NPK fertilizers and AM inoculation on number of melon fruits in 2011 and 2012 cropping years under cassava–melon intercrop

Treatments	Number of melon fruits (10,000 ha^{-1})	
	2011 cropping year	2012 cropping year
NOFERTILIZER		
Sole without Myco.	23.3c	16.7b
Sole with Myco.	26.4bc	19.2ab
Inter. without Myco.	28.1bc	17.5b
Inter. with Myco.	29.9bc	20.0ab
OF		
Sole without Myco.	29.9bc	23.3a
Sole with Myco.	43.9a	23.3a
Inter. without Myco.	44.4a	25.0a
Inter. with Myco.	45.2a	26.7a
NPK		
Sole without Myco.	29.6b	16.7b
Sole with Myco.	33.7ab	19.2ab
Inter. without Myco.	38.9ab	22.5ab
Inter. with Myco.	45.4a	23.3a
Mycorrhiza (M)	ns	ns
Fertilizer (F)	*	*
Cropping system(Cs)	ns	ns
M x F	ns	ns
M x Cs	ns	ns
F x Cs	ns	*
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at p = 0.05 using to Duncan's multiple range tests.

LEGEND

Sole without Myco = Sole melon cropping without mycorrhizal inoculation

Sole with Myco = Sole melon cropping with mycorrhizal inoculation

Inter. without Myco = cassava and melon intercropped without mycorrhizal inoculation

Inter. with Myco = cassava and melon intercropped with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

Table 4.10: Effects of OF, NPK fertilizers and AM inoculation on melon fruits weight in 2011 and 2012 cropping years under cassava-melon intercrop

Treatments	Melon fruits weight (t ha^{-1})	
	2011 cropping year	2012 cropping year
NOFERTILIZER		
Sole without Myco.	7.4b	6.7d
Sole with Myco.	8.5ab	7.7cd
Inter. without Myco.	8.8ab	6.5d
Inter. with Myco.	8.9ab	7.7cd
OF		
Sole without Myco.	13.8ab	10.5ab
Sole with Myco.	12.7ab	11.1ab
Inter. without Myco.	12.1ab	11.2ab
Inter. with Myco.	16.3a	12.8a
NPK		
Sole without Myco.	10.5ab	9.3bc
Sole with Myco.	12.9ab	9.7bc
Inter. without Myco.	11.0ab	8.4bc
Inter. with Myco.	13.5ab	11.5a
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	*
Cropping system(Cs)	ns	*
M x F	ns	ns
M x Cs	*	ns
F x Cs	ns	ns
M x F x Cs	ns	*

Under each column, values followed by similar alphabets are not significantly different at p = 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole melon cropping without mycorrhizal inoculation

Sole with Myco = Sole melon cropping with mycorrhizal inoculation

Inter. without Myco = cassava and melon intercrop without mycorrhizal inoculation

Inter. with Myco = cassava and melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = no significant * = significant at $p < 0.05$

Comparable trend was observed for the period of the second cropping year (2012 cropping year; residual effect). The least melon fruits yield (6.5 t ha^{-1}) was obtained when no fertiliser was applied without mycorrhizal inoculation when melon was intercropped (Table 4.10). Mycorrhizal inoculation irrespective of fertiliser application showed no significant difference in melon fruit weight. However, when melon was sole crop without mycorrhizal and fertiliser application, there was substantial reduction in fruit yield compared to when OF and NPK were applied under both cropping systems (Table 4.10).

4.6.3 Melon seeds yield under cassava melon intercrop in 2011 and 2012 cropping years

During 2011 cropping year, the total unshelled melon seeds ranged from 122.0 – 499.5 kg /ha (Table 4.11). When no fertiliser was applied irrespective of cropping systems, mycorrhizal inoculation had no significant effect compared to when NPK was applied when melon was sole cropped, but there was significant effect (increased) when melon was intercropped with mycorrhizal inoculation under similar treatment (Table 4.11).

When OF was applied with mycorrhizal inoculation, intercropped melon seed yield was considerably higher (499.5 kg /ha) in contrast to seed yields under other treatments (Table 4.11). However, under NPK application, with mycorrhizal inoculation; intercropped melon seeds yield was not significantly different when compared to seeds yield obtained when OF was applied in both cropping systems with and without mycorrhizal inoculation (Table 4.11). When melon was intercrop and inoculated with mycorrhizal under OF application, there was significant increase in melon seed yield (Table 4.11). Similar trend was observed with shelled melon seeds where seeds yield ranged between 79.7 and 316.8 kg /ha. Both the unshelled and shelled melon seeds yield under NPK application irrespective of other additives were not significantly ($\alpha_{0.05}$) different (Table 4.11). From residual effect, (2012 cropping year) the seed weight varied from 43 – 118 kg /ha (Table 4.11). Melon seed yield was significantly increased under OF application with and without mycorrhizal inoculation under both cropping systems when compared to other treatments (Table 4.12). However, when melon was sole cropped under NPK application, with and without mycorrhizal inoculation, there was substantial decrease in melon seed weight when compared to counterpart treatment under OF application (Table 4.12).

Table 4.11: Effects of OF, NPK fertilizers and AM inoculation on total melon seeds yield under cassava and melon intercrop in 2011 and 2012 cropping years

Treatments	Total melon seeds yield (kg ha^{-1})			
	2011 cropping year		2012 cropping year	
	unshelled seeds	shelled seeds	unshelled seeds	shelled seeds
NOFERTILIZER				
Sole without Myco.	122.0d	79.7d	62.3d	43.0d
Sole with Myco.	149.2d	92.5d	75.0d	50.8d
Inter. without Myco.	128.7d	82.8d	76.5d	47.8d
Inter. with Myco.	218.2c	142.8c	126.0c	82.2c
OF				
Sole without Myco.	348.4b	232.2ab	157.3ab	101.8a
Sole with Myco.	360.7b	234.2ab	178.8a	115.4a
Inter. without Myco.	2936bc	211.9b	175.3a	111.2a
Inter. with Myco.	499.5a	316.8a	175.0a	118.0a
NPK				
Sole without Myco.	188.7d	122.7cd	109.4c	70.0c
Sole with Myco.	179.3d	123.3cd	114.2c	72.7c
Inter. without Myco.	229.4c	145.6c	141.5bc	97.7ab
Inter. with Myco.	316.1b	198.3bc	159.0ab	104.1a
Mycorrhiza (M)	ns	ns	ns	ns
Fertilizer (F)	*	ns	ns	ns
Cropping system(Cs)	*	ns	ns	ns
M x F	ns	ns	ns	ns
M x Cs	ns	ns	*	*
F x Cs	ns	ns	ns	ns
M x F x Cs	*	ns	ns	ns

Under each column, values followed by similar alphabets are not significantly different at p = 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole melon cropping without mycorrhizal inoculation

Sole with Myco = Sole melon cropping with mycorrhizal inoculation

Inter. without Myco = cassava and melon intercrop without mycorrhizal inoculation

Inter. with Myco = cassava and melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

4.6.4. Melon 100 seeds weight for first and second (2011 and 2012) cropping years

The weight of unshelled 100 melon seeds ranged from 11.3 – 14.5 g per 100 seeds where the least seeds weight was observed when no fertiliser and mycorrhizal were applied (Table 4.12). In 2011 cropping year, when melon was intercropped under OF and NPK applications with and without mycorrhizal inoculation, 100 seeds weight was not significantly different, but when compared to the same treatment when no fertiliser was applied, there was reduction in melon seed weight (11.3 g/100 seeds) when melon was intercrop (Table 4.12). Mycorrhizal inoculation had no significant effect on melon seed weight when melon was sole crop under NPK application compared to when no fertiliser was applied with mycorrhizal inoculation (Table 4.13). However, there was significant increase in 100 seeds weight (14.5 g/100 seeds) under OF application with sole melon with mycorrhizal inoculation. Shelled melon 100 seeds weight followed similar pattern as observed in unshelled melon seeds (Table 4.12). When melon was intercrop with mycorrhizal inoculation under NPK, there was significant difference compared to the same treatment under OF and when no fertiliser was applied (Table 4.12).

Mycorrhizal inoculation significantly increased 100 seeds weight of melon under OF and NPK application when melon was sole cropped compared to when no fertiliser was applied in 2012 cropping year (Table 4. 12). Under the application of OF and NPK with and without mycorrhizal inoculation, there was no significant difference where melon was intercrop compared to when no fertiliser was applied except under OF application with mycorrhizal inoculation (Table 4.12). Similarly, the shelled melon seeds followed the same pattern under OF and NPK application when melon was intercrop with mycorrhizal inoculation (Table 4.12).

4.7. Cassava Plant Growth Parameters under Cassava-melon Intercrop, AM and Fertiliser Application

4.7.1 Cassava plant height at 2011 and 2012 cropping years

At 3, 6, 9 and 12 MAP, in 2011 cropping year, mycorrhizal inoculation had insignificant influence on cassava plant height while cassava was sole crop under OF and NPK fertiliser applications compared to when no fertiliser was applied but with mycorrhizal inoculation (Table 4.13). When cassava was intercropped and inoculated with mycorrhiza under OF application, there was no significant increase in cassava

Table 4.12: Effects of OF, NPK fertilizers and AM inoculation on 100 seeds weights (g) of melon under cassava-melon intercrop

Treatments	2011 cropping year		2012 cropping year	
	unshelled seeds	shelled seeds	unshelled seeds	shelled seeds
NOFERTILIZER				
Sole without Myco.	12.6cd	8.6ab	10.6c	8.0c
Sole with Myco.	12.1cd	8.0cd	11.6bc	7.9c
Inter. without Myco.	11.3d	7.5d	11.9bc	7.3c
Inter. with Myco.	12.5cd	8.0cd	11.5bc	7.9c
OF				
Sole without Myco.	12.8bc	8.3bc	11.8bc	8.2ab
Sole with Myco.	14.5a	9.5a	13.6a	8.9a
Inter. without Myco.	13.1abc	8.4bc	12.0b	8.1bc
Inter. with Myco.	12.5cd	8.3bc	13.6a	8.8a
NPK				
Sole without Myco.	12.5cd	8.0cd	11.8bc	8.1bc
Sole with Myco.	13.4abc	9.1ab	13.0ab	8.8a
Inter. without Myco.	13.6abc	8.8ab	11.9bc	7.3c
Inter. with Myco.	14.1ab	9.4a	11.7bc	8.2ab
Mycorrhiza (M)	ns	ns	ns	ns
Fertilizer (F)	*	ns	ns	ns
Cropping system(Cs)	*	ns	ns	ns
M x F	ns	ns	ns	ns
M x Cs	ns	ns	*	*
F x Cs	ns	ns	ns	ns
M x F x Cs	*	ns	ns	ns

Under each column, values followed by similar alphabets are not significantly different at p = 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole melon cropping without mycorrhizal inoculation

Sole with Myco = Sole melon cropping with mycorrhizal inoculation

Inter. without Myco = cassava and melon intercrop without mycorrhizal inoculation

Inter. with Myco = cassava and melon intercrop with mycorrhizal inoculation

OF = Organomineral fertiliser

ns = not significant at * = significant at $\alpha_{0.05}$

Table 4.13: Height (cm) of cassava plant as influenced by OF, NPK fertilizers and AM inoculation under cassava - melon intercrop in 2011 and 2012 cropping years

Treatments	2011 cropping year (MAP)				2012 cropping year (MAP)			
	3	6	9	12	3	6	9	12
NO FERTILIZER								
Sole without Myco.	62.1ab	108.3a	128.1a	141.7d	54.8ab	93.2a	113.1a	150.2a
Sole with Myco.	58.8b	100.3a	134.2a	158.5ab	51.3ab	85.3a	119.2a	134.8b
Inter. without Myco.	53.2bc	86.3bc	131.7a	148.0cd	45.7bc	71.3b	105.7b	130.0bc
Inter. with Myco.	54.5bc	86.7bc	127.2a	149.0cd	47.0bc	71.7b	107.7b	122.1c
OF								
Sole without Myco.	57.8b	98.7ab	129.5a	148.2cd	50.3abc	83.7ab	114.5a	138.7b
Sole with Myco.	63.3ab	106.0a	132.5a	151.8c	55.8a	91.0a	100.7bc	124.5cd
Inter. without Myco.	52.2bc	98.7ab	127.9a	152.3bc	44.7bc	83.7ab	89.3c	150.3a
Inter. with Myco.	60.3ab	101.3a	128.6a	148.4cd	52.7ab	86.3a	113.6a	129.8c
NPK								
Sole without Myco.	64.1ab	104.7a	133.9a	158.0ab	56.6ab	89.7a	85.7c	118.6cd
Sole with Myco.	66.8a	108.3a	130.3a	159.0ab	59.3a	93.3a	112.7a	116.7d
Inter. without Myco.	54.5bc	105.0a	136.3a	165.4a	47.1bc	90.0a	111.7ab	115.5d
Inter. with Myco.	50.3c	85.4c	129.8a	156.7ab	42.8c	70.4b	114.8a	159.3a
Mycorrhiza (M)	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer (F)	ns	ns	ns	ns	ns	ns	ns	ns
Cropping system(Cs)	*	*	ns	*	*	*	*	ns
M x F	ns	ns	ns	ns	ns	ns	ns	ns
M x Cs	ns	ns	ns	ns	ns	ns	ns	ns
F x Cs	ns	ns	ns	ns	ns	ns	ns	ns
M x F x Cs	ns	ns	ns	ns	ns	ns	ns	ns

Under each column, figures followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test.

LEGEND

M A P = Month after plant
Sole without Myco = Sole cassava cropping without mycorrhizal inoculation
Sole with Myco = Sole cassava cropping with mycorrhizal inoculation
Inter. without Myco = cassava and melon intercrop without mycorrhizal inoculation
Inter. with Myco = cassava and melon intercrop with mycorrhizal inoculation
OF = Organomineral fertilizer
ns = not significant * = significant at $p < 0.05$

height compared to when no fertiliser was applied, however, there was meaningful increase in plant height in contract to intercropped cassava plus mycorrhizal inoculation.

At 3 and 6 MAP, in 2012 cropping year, sole cassava plant height was not significantly different when not inoculated with mycorrhizal under all fertiliser applications (Table 4.13). Also, similar trend was obtained when sole cropped cassava was inoculated under the same treatment (Table 4.13). However, when cassava was inoculated and intercropped, at 6 MAP, there was significant increase in cassava plant height (86.3 cm) under OF application compared to NPK application (70. 4 cm) with the same treatment (Table 4.13).

At 9 MAP in 2012, cassava plant height ranged from 85.7 – 114.8 cm when cassava was sole cropped without mycorrhizal inoculation and when cassava was intercropped and inoculated under NPK application respectively (Table 4.13). Whereas, when cassava was intercropped with mycorrhizal under OF application, there was significant reduction in plant height (89.3 cm) when compared ($p \leq 0.05$) to other fertiliser application under the same treatments (Table 4.13).

Cassava plant height ranged from 122.1 - 159.3 cm at 12 MAP under OF and NPK applications when cassava was intercropped and inoculated respectively (Table 4.13). However, sole cassava plant height was not significantly different when no fertiliser and mycorrhiza was applied compared ($p \leq 0.05$) to when cassava was inoculated under NPK application (Table 4.13). Also, when cassava, was sole cropped plus mycorrhizal inoculation, there was considerable difference of plant height when no fertiliser was used compared ($p \leq 0.05$) to the same treatment under OF and NPK applications (Table 4.13).

4.7.2. Number of cassava leaves in 2011 and 2012 cropping years

In 2011 cropping year, intercropped cassava with mycorrhizal inoculation under OF and NPK applications, the number of cassava leaves were significantly reduced when compared to the same treatment when no fertiliser was applied at 3 MAP (Table 4.14). At 6 MAP, the least number of leaves (64.3) was obtained when cassava was intercropped without mycorrhizal under OF application and the highest number of leaves (86.3) when cassava was sole cropped with mycorrhizal inoculation under NPK application (Table 4.14).

At 9 MAP, sole cassava with and without mycorrhizal inoculation, under OF and NPK

Table 4.14: Number of cassava leaves as influenced by OF, NPK fertilizer and AM under cassava - melon intercrop in 2011 and 2012 cropping years

Treatments	2011 cropping year (MAP)				2012 cropping year (MAP)			
	3	6	9	12	3	6	9	12
NO FERTILIZER								
Sole without Myco.	50.7ab	68.6a	130.7ab	80.3a	45.7ab	63.3abc	120.7abc	80.3b
Sole with Myco.	44.7bc	66.6a	129.5bc	74.5b	39.7ab	63.7abc	119.7abc	75.3bc
Inter. without Myco.	31.6d	64.7a	120.5bc	78.7b	28.3c	62.0bc	110.7c	66.7c
Inter. with Myco.	45.3b	64.5a	133.7ab	78.6b	41.0ab	61.0bc	120.3abc	79.3bc
OF								
Sole without Myco.	55.7a	75.3a	129.3ab	86.0a	50.7ab	70.3abc	122.0abc	85.3ab
Sole with Myco.	55.7a	75.0a	132.3ab	91.0a	50.7ab	70.0abc	122.3ab	91.7a
Inter. without Myco.	31.7d	64.3a	127.7b	61.7c	29.3c	60.0c	117.7abc	62.3c
Inter. with Myco.	37.3cd	67.3a	127.3b	67.6bc	35.7c	67.3abc	117.3bc	69.7c
NPK								
Sole without Myco.	59.0a	84.0a	137.0a	89.3a	54.7a	84.0a	127.0a	88.3ab
Sole with Myco.	55.7a	86.3a	137.3a	82.7a	47.3ab	82.0ab	127.3a	80.0b
Inter. without Myco.	52.3ab	73.3a	138.7a	60.7c	36.3bc	69.0abc	128.7a	63.0c
Inter. with Myco.	33.0cd	67.0a	138.7a	63.7c	32.3c	66.0abc	127.3a	66.3c
Mycorrhiza (M)	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer (F)	ns	ns	*	*	ns	ns	*	ns
Cropping system(Cs)	*	ns	ns	ns	*	ns	ns	*
M x F	ns	ns	ns	ns	ns	ns	ns	ns
M x Cs	ns	ns	ns	ns	ns	ns	ns	ns
F x Cs	ns	ns	ns	*	ns	ns	ns	ns
M x F x Cs	ns	ns	ns	ns	ns	ns	ns	ns

Under each column, figures followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test.

LEGEND

M A P = Month after plant
Sole without Myco = Sole cassava cropping without mycorrhizal inoculation
Sole with Myco = Sole cassava cropping with mycorrhizal inoculation
Inter. without Myco = cassava and melon intercrop without mycorrhizal inoculation
Inter. with Myco = cassava and melon intercrop with mycorrhizal inoculation

OF= Organomineral fertilizer. ns = not significant *= significant at $p<0.05$

applications have no significant effect on the number of leaves of cassava when compared to number of leaves obtained when no fertiliser was applied. However, cassava intercropped with and without mycorrhizal inoculation under NPK application significantly increased the number of leaves when compared to the same treatment under OF application (Table 4.14).

At 12 MAP, number of leaves of cassava ranged from 60.7 - 91.0. The least number of leaves was obtained when cassava was intercropped with mycorrhizal under NPK application and the highest number of leaves from sole cropped cassava when no fertiliser and mycorrhizal was applied (Table 4.14). Similarly, intercropped cassava with and without mycorrhizal inoculation under OF and NPK applications, the number of cassava leaves were within the range of 60.7 – 67.6, but increased significantly (78.7) when no fertiliser was applied with the same treatments (Table 4.14).

At 3, 6 and 9 MAP, in 2012 cropping year, the number of leaves of sole cassava under OF and NPK applications with and without mycorrhizal inoculation was not significantly different when compared to number of leaves when cassava was inoculated under the same treatments (Table 4.14). However, at 3 MAP, in intercropped cassava with mycorrhizal inoculation under OF and NPK applications, the number of leaves was significantly reduced when compared to number of leaves obtained under the same treatment when no fertiliser was applied (Table 4.14).

At 3, 6 and 9 MAP, under intercropped cassava without mycorrhizal inoculation, the difference in number of leaves was not significant, whereas, at 9 MAP, the number of cassava leaves increased under NPK application (Table 4.14). At 12 MAP, the number of leaves ranged from 66.0 – 91.7; the least was obtained under intercropped cassava without mycorrhizal inoculation under NPK application and the optimum number of leaves was obtained under mycorrhizal inoculated sole cropped cassava with OF application (Table 4.14). Also the number of leaves of intercropped cassava without mycorrhizal inoculation showed no significant difference under OF and NPK applications when compared to number of leaves obtained when no fertiliser was applied (Table 4.14).

4.7.3. Number of cassava stems at harvest in 2011 and 2012 cropping years

Number of cassava stems in 2011 ranged from 10,000 – 30,000 cassava stems per hectare (Table 4. 15). The least was obtained under NPK fertiliser application without mycorrhizal inoculation when cassava was sole crop while the highest number

Table 4.15: Effect of OF, NPK fertilizers and AM inoculation on number of cassava stems in 2011 and 2012 cropping years

Treatments	Number of cassava stems (10,000 ha^{-1}) 2011	2012
NOFERTILIZER		
Sole without Myco.	3.0a	2.0a
Sole with Myco.	2.7a	2.0a
Inter. without Myco.	1.7b	2.0a
Inter. with Myco.	2.3a	1.3b
OF		
Sole without Myco.	2.7a	1.3b
Sole with Myco.	2.7a	2.0a
Inter. without Myco.	1.7b	1.3b
Inter. with Myco.	3.0a	1.7ab
NPK		
Sole without Myco.	1.0b	2.0a
Sole with Myco.	3.0a	1.3b
Inter. without Myco.	3.0a	1.7a
Inter. with Myco.	2.0ab	1.3b
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	ns
Cropping system(Cs)	ns	ns
M x F	ns	ns
M x Cs	ns	ns
F x Cs	*	ns
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range tests.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

of stems (30,000) was obtained with sole cropped cassava when no fertiliser was applied without mycorrhizal inoculation. The same value was obtained under OF application with mycorrhizal inoculation when cassava was intercrop, and when NPK fertiliser was applied to sole cropped cassava with and without mycorrhizal inoculation as well as when cassava was intercrop respectively (Table 4. 15).

During second cropping season (2012), the number of cassava stems ranged from 13,000 – 20,000 per hectare compared to 10,000 – 30,000 stems per hectare obtained in the previous cropping season (Table 4. 15). When no fertiliser was applied, at all levels of mycorrhizal inoculation when cassava was sole cropped, the numbers of cassava stems obtained were the same (20,000) but different from the number of stems obtained when cassava was intercropped under mycorrhizal inoculation. However, there was a reduction by approximately 35.0% compared to other levels of mycorrhizal inoculation and cropping system when OF and NPK were applied (Table 4. 15).

In the same cropping season (2012), when OF was applied, the number of cassava stems ranged from 13,000 – 20,000 under sole cassava cropping and intercropping system without mycorrhizal inoculation and was increased when cassava was intercropped with mycorrhizal inoculation approximately by 35.0% under OF and NPK application (Table 4. 15).

4.8. Yield of Cassava as Affected by Melon Intercrop, AM Inoculation and Fertiliser Application

4.8.1. Cassava storage roots length of cassava in 2011 and 2012 cropping years

Cassava storage roots length in 2011 ranged from 36.0 – 62.7 cm (Table 4. 16). The longest tuber was obtained under the application of OF when cassava was sole crop with mycorrhizal inoculation, which was considerably greater when compared to other treatments with and without mycorrhizal inoculation under NPK application. Similarly, when cassava was sole crop without mycorrhizal inoculation under OF application, tuber length was significantly different compared to sole under NPK application (Table 4.16). The least tuber length was obtained under intercropped cassava without fertiliser and mycorrhizal inoculation. This, however, was not significantly different from cassava storage roots length obtained when NPK fertiliser was applied irrespective of cropping system and mycorrhizal inoculation, except sole cropped cassava without mycorrhizal inoculation (Table 4. 16).

Table 4. 16: Effects of OF, NPK fertilizers and AM inoculation on cassava storage roots length in 2011 and 2012 cropping years

Treatments	Cassava tuber length (cm)	
	2011	2012
NOFERTILIZER		
Sole without Myco.	43.0bc	29.6bc
Sole with Myco.	41.7bc	45.0a
Inter. without Myco.	36.0c	42.0a
Inter. with Myco.	37.3c	41.3a
OF		
Sole without Myco.	49.3b	31.9bc
Sole with Myco.	62.7a	32.1bc
Inter. without Myco.	41.3c	28.3bc
Inter. with Myco.	41.7bc	32.0bc
NPK		
Sole without Myco.	36.3c	34.5bc
Sole with Myco.	48.0b	35.7bc
Inter. without Myco.	41.7bc	41.7a
Inter. with Myco.	42.3bc	47.8a
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	*
Cropping system(Cs)	ns	*
M x F	ns	ns
M x Cs	ns	ns
F x Cs	ns	ns
M x F x Cs	ns	ns

Under each column, figures followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range tests.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

At the second cropping year, the highest cassava storage roots length (47.8 cm) was obtained under the application of NPK in intercropped cassava with mycorrhizal inoculation (Table 4. 16). The least cassava storage roots length (28.3 cm) was obtained under the application of OF when intercrop without mycorrhizal inoculation. This was not significantly different from all treatments under OF application as well as when cassava was sole crop under NPK and when no fertiliser was applied without mycorrhizal inoculation (Table 4. 16). However, there was no major dissimilarity ($P \leq 0.05$) in comparism to cassava storage roots length when no fertiliser was applied under intercropped cassava with and without mycorrhizal inoculation.

4.8.2 Number of cassava storage roots in 2011 and 2012 cropping years

During the first cropping (2011) year, sole cropped cassava under OF application with mycorrhizal inoculation, the number of tubers per hectare (70,000) was significantly higher compared to when NPK was applied under the same treatment (Table 4.17). However, there was no significant difference when number of tubers obtained under intercropped cassava with NPK application was compared to when no fertiliser was applied irrespective of mycorrhizal inoculation (Table 4. 17). Moreover, there was significant reduction in number of cassava storage roots (20,000) when sole cropped cassava without mycorrhizal and fertiliser application (control) was compared to the similar treatments under OF and NPK applications (Table 4.17).

Generally, intercropped cassava without mycorrhizal inoculation under all the fertiliser applications showed no significant difference in the number of cassava storage roots (Table 4.17). Similar trend was observed when mycorrhiza was inoculated to other fertiliser treatments under intercropped cassava (Table 4. 18). However, with sole cropped cassava and mycorrhizal inoculation, under OF application, number of cassava storage roots significantly increased compared to when cassava was intercrop with mycorrhizal inoculation when no fertiliser was applied (Table 4. 18). Nevertheless, this was not significantly different when compared to intercropped cassava with and without mycorrhizal inoculation under NPK application (Table 4. 17).

Table 4. 17: Effects of OF, NPK fertilizers and AM inoculation on number of cassava storage roots in 2011 and 2012 cropping years

Treatments	Number of cassava tuber (10,000 ha^{-1})	
	2011	2012
NOFERTILIZER		
Sole without Myco.	2.0c	2.7b
Sole with Myco.	5.3b	3.0a
Inter. without Myco.	4.3b	3.0a
Inter. with Myco.	4.6b	3.3a
OF		
Sole without Myco.	4.3b	2.7b
Sole with Myco.	7.0a	3.7a
Inter. without Myco.	6.0ab	3.0a
Inter. with Myco.	4.0bc	4.3a
NPK		
Sole without Myco.	5.5ab	3.7a
Sole with Myco.	4.6b	3.0a
Inter. without Myco.	6.3ab	3.0a
Inter. with Myco.	5.0ab	3.7a
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	ns
Cropping system(Cs)	ns	ns
M x F	ns	ns
M x Cs	ns	*
F x Cs	ns	ns
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco. = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco. = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco. = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

At the second cropping year (2012), the number of cassava storage roots obtaine d under each cropping systems and fertiliser treatments were insignificantly different (Table 4. 17). The amount of cassava storage roots per hectare ranged from 27,000 to 43,000 when fertilisers were applied (Table 4.17). There was approximately 10.0 – 30.0 % increase in number of cassava storage roots in intercropped cassava under OF application with mycorrhizal inoculation but not significantly different compared to remaining treatments (Table 4. 17).

4.8.3. Fresh cassava storage root yields in 2011 and 2012 cropping years

At 2011 cropping year, the fresh cassava storage roots weight ranged from 4.6 to 22.3 t/ha (Table 4. 18). The yield was significantly increased under cassava sole cropped and OF application with mycorrhizal inoculation when compared to other treatments. Nevertheless, the increased was not significantly different (16.5 t/ha) when compared to tuber yield under OF application with mycorrhizal inoculation in intercropped cassava (Table 4. 18)

Similarly, at the second cropping year (2012), the tuber yield ranged from 5.4 – 11.9 t/ha and following a similar pattern observed in 2011 cropping year. Nevertheless, the tuber yield was significantly higher (11.9 t/ha) under sole cropped cassava with mycorrhizal inoculation and OF application. Under all the fertiliser applications, intercropped cassava with and without mycorrhizal inoculation, the fresh tuber yield was not significantly different (Table 4. 18). Likewise, under sole cropped cassava (with and without mycorrhizaal inoculation) without fertiliser application, tuber yield was not significantly different when compared to other treatments except when cassava was sole cropped with mycorrhizal inoculation under OF application (Table 4.18).

4.8.4. Cassava leaves weight (fresh and dry leaves) in 2011 and 2012 cropping years

The fresh cassava leaves weight ranged from 0.18 to 0.37 t/ha in the first cropping year (Table 4. 19). The highest cassava leaves weight was obtained under OF application with sole cropping system and mycorrhizal inoculation (Table 4. 19). The leaves weight was not significantly higher when compared to leaves weight under NPK fertiliser application with mycorrhizal inoculation under the two cropping systems (Table 4. 19). However, there was no significant difference between the cassava leaves weight obtained under sole cassava cropping when no fertiliser was

Table 4. 18: Effect of OF, NPK fertilizers and AM inoculation on fresh cassava storage roots yields for 2011 and 2012 cropping years

Treatments	Fresh cassava storage roots weight (t ha^{-1})	
	2011	2012
NOFERTILIZER		
Sole without Myco.	4.6d	5.4c
Sole with Myco.	9.6bc	6.3c
Inter. without Myco.	6.7cd	7.2bc
Inter. with Myco.	13.7b	10.5bc
OF		
Sole without Myco.	14.3b	10.8bc
Sole with Myco.	22.3a	11.9a
Inter. without Myco.	12.2bc	11.1b
Inter. with Myco.	16.5ab	10.8bc
NPK		
Sole without Myco.	12.9bc	10.5bc
Sole with Myco.	13.0bc	10.3bc
Inter. without Myco.	12.8bc	10.8bc
Inter. with Myco.	13.7b	11.1b
Mycorrhiza (M)	ns	ns
Fertilizer (F)	*	ns
Cropping system(Cs)	ns	ns
M x F	ns	ns
M x Cs	*	*
F x Cs	ns	ns
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

Table 4.19: Effect of OF, NPK fertilizers and AM inoculation on cassava fresh and dry leaves weight in 2011 and 2012 cropping years

Treatments	Leaves weights (10,000 ha^{-1})			
	2011		2012	
	Fresh	Dry	Fresh	Dry
NOFERTILIZER				
Sole without Myco.	0.24c	0.16bc	0.17bc	0.11c
Sole with Myco.	0.34a	0.22a	0.27ab	0.18ab
Inter. without Myco.	0.22c	0.15bc	0.15bc	0.11c
Inter. with Myco.	0.25c	0.17b	0.20bc	0.12bc
OF				
Sole without Myco.	0.30b	0.19b	0.22bc	0.15bc
Sole with Myco.	0.37a	0.24a	0.30a	0.20a
Inter. without Myco.	0.30b	0.18b	0.23bc	0.14bc
Inter. with Myco.	0.32b	0.24a	0.27ab	0.18ab
NPK				
Sole without Myco.	0.22c	0.15bc	0.15bc	0.10c
Sole with Myco.	0.36a	0.24a	0.29a	0.20a
Inter. without Myco.	0.18d	0.12c	0.13c	0.07c
Inter. with Myco.	0.36a	0.16bc	0.19bc	0.12bc
Mycorrhiza (M)	ns	ns	ns	ns
Fertilizer (F)	ns	ns	ns	ns
Cropping system(Cs)	ns	ns	ns	ns
M x F	ns	ns	ns	ns
M x Cs	*	*	ns	ns
F x Cs	ns	ns	ns	ns
M x F x Cs	ns	ns	ns	ns

Under each column, values followed by similar alphabets are not significantly different at $P \leq 0.05$ using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant

* = significant at $p < 0.05$

Table 4. 20: Effect of OF, NPK fertilizers and AM inoculation on cassava plant fresh above ground biomass weight in 2011 and 2012 cropping years

Treatments	Cassava plant above ground biomass weight (t ha^{-1})	
	2011	2012
NOFERTILIZER		
Sole without Myco.	12.0c	3.7c
Sole with Myco.	12.0c	4.2bc
Inter. without Myco.	16.8bc	3.6c
Inter. with Myco.	17.2bc	4.2bc
OF		
Sole without Myco.	16.8bc	10.5ab
Sole with Myco.	20.5b	7.7b
Inter. without Myco.	26.2a	8.1ab
Inter. with Myco.	27.1a	11.4a
NPK		
Sole without Myco.	20.7b	6.3b
Sole with Myco.	21.1b	5.9bc
Inter. without Myco.	26.2a	7.5b
Inter. with Myco.	28.7a	10.0ab
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	ns
Cropping system(Cs)	ns	*
M x F	ns	ns
M x Cs	ns	*
F x Cs	*	ns
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $P < 0.05$

Table 4.21: Effect of OF, NPK fertilizers and AM inoculation on dry matter accumulation in 2011 and 2012 cropping years

Treatments	Dry matter accumulation (t ha^{-1})	
	2011	2012
NOFERTILIZER		
Sole without Myco.	1.3c	1.5c
Sole with Myco.	1.9c	1.5c
Inter. without Myco.	2.8bc	1.8bc
Inter. with Myco.	3.4b	2.0bc
OF		
Sole without Myco.	3.6b	3.3ab
Sole with Myco.	4.6ab	3.6ab
Inter. without Myco.	4.0b	3.0b
Inter. with Myco.	6.3a	4.7a
NPK		
Sole without Myco.	3.6b	2.9b
Sole with Myco.	3.8b	2.9b
Inter. without Myco.	3.6b	2.2bc
Inter. with Myco.	3.6b	2.9b
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	ns
Cropping system(Cs)	ns	ns
M x F	ns	ns
M x Cs	ns	ns
F x Cs	*	ns
M x F x Cs	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter. without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter. with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

applied (0.34 t/ha) once compared to NPK and OF fertilisers application under the same cropping system (Table 4. 19).

Similarly, in 2012 (second cropping year), fresh cassava leaves weight increased when OF and mycorrhizal were applied (0.30 t/ha) in sole cropped cassava (Table 4.19). However, this increase was not significantly different when compared to
the leaves weight obtained when NPK was applied with mycorrhiza under the same cropping system.

The least cassava leaves weight (0.13 t/ha) was under NPK application, and when no mycorrhiza was applied. Nevertheless, this was not significantly reduced when compared to leaves weights obtained when no fertiliser was applied (Table 4. 20). Similar trend was observed in both cropping years in terms of the dry cassava leaves weight (Table 4. 19).

4.8.5. Fresh cassava plant above ground biomass weight in 2011 and 2012 cropping years

During the first cropping year (2011), cassava plant above ground biomass weight ranged from 12.0 – 28.7 t/ha; the highest yield under NPK with mycorrhizal inoculation in intercropped cassava (biomass) (Table 4. 20). However, the above ground biomass weight (28.7 t/ha) was not significantly higher ($P < 0.05$) when compared (27.1 t/ha) to OF application with and without mycorrhizal inoculation under the same cropping systems. Nevertheless, these values were significantly higher ($\alpha_{0.05}$) under sole cropping system when no fertiliser was applied (Table 4. 20).

In 2012 cropping year, similar trend was observed under these fertilisers and mycorrhizal inoculation as observed in the previous cropping year. The above ground biomass weight ranged from 3.7 – 11.4 t/ha (Table 4. 20). The highest cassava plant above ground biomass weight (11.4 t/ha) was obtained under OF application with mycorrhizal inoculation in intercropped cassava (Table 4. 20). The lowest above ground biomass weight (3.7 t/ha) was obtained while no fertiliser was used or mycorrhizal inoculation in sole cropped cassava; this was not appreciably different ($\alpha_{0.05}$) from cassava plant above ground biomass weight obtained (3.6 t/ha) when cassava was intercropped under no fertiliser application with mycorrhizal inoculation. Interaction among the fertiliser, mycorrhizal and cropping systems were not prominent ($\alpha_{0.05}$) in both cropping years (Table 4. 20).

4.8.6: Cassava storage root dry matter accumulation in the two years

At the first cropping year, the cassava storage root dry matter accumulation ranged from 1.3 – 6.3 t/ha. The least yield was obtained when no fertiliser was applied without

mycorrhizal inoculation under sole cropped cassava and the highest dry matter accumulation was when intercropped cassava with mycorrhizal inoculation under OF application (Table 4. 21). The dry matter accumulation weights (3.6 and 3.8 t/ha) under NPK application was not much higher compared to dry matter accumulation yield obtained when no fertiliser was applied under both cropping systems (Table 4. 21). Above all, intercropped cassava under OF application and mycorrhizal inoculation, the dry matter (*garri)* yield increased significantly when compared to other treatments (Table 4. 21).

Cassava intercropped with and without mycorrhiza under NPK application, the dry matter accumulation yield was not significantly different from the yield obtained when no fertiliser was applied except when cassava was sole crop with and without mycorrhizal inoculation (Table 4. 21). Similarly, in 2012 cropping year, dry matter accumulation yield was significantly increased under OF application with mycorrhizal inoculation when compared to other treatments (Table 4. 21). Sole cropped cassava with no fertiliser either with or without mycorrhizal inoculation, the dry matter accumulation yield was significantly reduced (43.5%) compared to other treatments except where cassava was intercropped without mycorrhizal inoculation under NPK application (Table 4. 21). At both cropping years, the increase in dry matter accumulation yield under OF application with mycorrhizal inoculation was not significantly higher when compared to yield obtained when cassava was sole crop with mycorrhizal inoculation under the same fertiliser application (Table 4. 21).

4.9. Relative Yield (RY) and Land Equivalent Ratio (LER)

4.9.1. Relative yield and land equivalent ratio for 2011 cropping year

The land equivalent ratios of both crops ranged from 1.0 – 3.9 with the highest LER value under NPK and mycorrhizal inoculation. In all the treatments, mycorrhizal inoculation increased the LER significantly especially under OF and NPK application when compared to when no fertiliser was applied (Table 4.22).

The relative yield (RY) value for melon ranged from 0.82 – 2.83 when melon was intercropped without any fertiliser application under non-mycorrhizal inoculation and the highest value (2.8) was obtained when melon was intercrop without mycorrhizal inoculation but with NPK fertiliser (Table 4.22). When no fertiliser was applied with mycorrhizal inoculation, there was increment of about 16.7% under sole crop with mycorrhizal inoculation and about 71.4% under intercrop with mycorrhizal inoculation compared to when intercrop without mycorrhizal inoculation (Table 4.22).

Table 4.22: Relative yields and land equivalent ratio of cassava and melon intercrop in 2011 cropping season

Treatments	Relative Yields		Land Equivalent Ratio
	Cassava	Melon	
No fertiliser application			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	0.5c	0.8d	1.3d
No fertiliser with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	0.8b	1.2cd	2.0c
OF without mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	0.5c	2.2b	2.7b
OF with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	1.5a	1.5c	3.0b
NPK without mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0e	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	1.1b	2.8a	3.9a
NPK with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0d
Sole melon 10,000 plants/ha	0.0	1.0d	1.0d
Cassava + melon 10,000 plants each/ha	1.0b	2.1b	3.1b
Mycorrhiza (M)	ns	ns	ns
Fertiliser (F)	ns	ns	ns
Cropping system(Cs)	*	*	*
M x F	ns	ns	ns
M x Cs	*	*	*
F x Cs	ns	ns	ns
M x F x Cs	*	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P = 0.05 using Duncan's multiple range test.

LEGEND

OF = Organomineral fertiliser

ns = not significant

* = significant at $p < 0.05$

Similarly, when OF was applied without mycorrhizal inoculation under sole crop, melon RY value increased approximately by 16.7% and further increment was observed (63.6%) under the same treatment when intercropped without mycorrhizal inoculation (Table 4.22).

When OF was applied and inoculated with mycorrhiza, the melon RY value increased by about 22.0% under melon intercrop compared to melon intercrop without mycorrhizal inoculation and no fertiliser application (Table 4.22).

Under NPK application, when melon was intercrop without mycorrhiza, the RY value increased approximately by 71.4% compared to the same treatment and cropping system when no fertiliser was applied (Table 4.22).

When NPK was applied with mycorrhiza and melon was intercrop, the RY values increased by about 63.6% compared to when no mycorrhiza and no fertiliser was applied. Similarly, cassava RY values followed similar pattern as observed with melon (Table 4. 22). The highest RY value (1.54) for cassava was obtained when OF was applied with mycorrhizal inoculation under cassava-melon intercrop while the least (0.48) was observed when no fertiliser was applied without mycorrhizal inoculation under cassava-melon intercrop (Table 4. 22). When no fertiliser was applied with mycorrhizal inoculation under intercropped cassava, there was about 37.5% increment compared to when not inoculated with mycorrhiza (Table 4.22). However, when OF was applied without mycorrhizal inoculation, cassava RY value increased by approximately 37.5% compared to when no fertiliser was applied but when OF was applied with mycorrhizal inoculation, there was 68.7% increment compared to when no fertiliser with mycorrhizal inoculation (Table 4.22). There was an increment of about 54.5% under NPK application without mycorrhizal inoculation when it was compared to other treatments when no fertiliser and mycorrhiza was applied. When cassava was intercrop, there was 33.3% decrease approximately under NPK application with mycorrhizal inoculation compared to the same treatment under OF application (Table 4. 22).

In all, for intercropped melon, the LER was great than 1.0 under all treatments with exception of where no fertiliser was applied. Similarly, the LER for intercropped cassava under OF and NPK with mycorrhizal inoculation (3.0 and 3.1) were significantly higher when compared to the LER (2.0 and 2.7) of when no fertiliser applied with and without mycorrhizal inoculation (Table 4.22).

Table 4. 23: Relative yields and land equivalent ratio of cassava and melon intercrop in 2012 cropping year

Treatments	Relative Yields		Land Equivalent Ratio
	Cassava	Melon	
No fertilizer application			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	0.6c	0.5d	1.1e
No fertilizer with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	0.8b	1.1c	1.9d
OF without mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	0.6c	1.1c	1.7d
OF with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	1.7a	2.7a	4.4a
NPK without mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	1.1b	2.0b	2.6c
NPK with mycorrhizal			
Sole cassava 10,000 plants/ha	1.0b	0.0	1.0e
Sole melon 10,000 plants/ha	0.0	1.0c	1.0e
Cassava + melon 10,000 plants each/ha	1.7b	2.0b	3.7b
Mycorrhiza (M)	ns	ns	ns
Fertilizer (F)	ns	ns	ns
Cropping system(Cs)	ns	*	ns
M x F	ns	ns	*
M x Cs	ns	ns	ns
F x Cs	ns	ns	*
M x F x Cs	ns	ns	ns

Under each column, values followed by similar alphabets are not significantly different at P = 0.05 using to Duncan's multiple range tests.

LEGEND

OF = Organomineral fertilizer

ns = not significant

* = significant at $p < 0.05$

4.9.2. Relative yield (RY) and land equivalent ratio (LER) in 2012 cropping Year

The land equivalent ratios of both crops under intercropping ranged from 1.0 – 4.4. The highest value (4.4) was obtained when OF was applied with mycorrhizal inoculation; followed by (3.7) under NPK and mycorrhizal application (Table 4. 23). In all the treatments, mycorrhizal inoculation significantly increased crop yield irrespective of fertiliser application. There was reduction in LER when OF was applied without mycorrhizal inoculation (1.7) by about 34.6% compared to when NPK fertiliser was applied without mycorrhizal inoculation, but increased by approximately 26.9% compared to when no fertiliser was applied with mycorrhizal inoculation (Table 4.23).

During the second cropping season, the R.Y of melon under intercrop ranged from 0.0 – 2.7 under no mycorrhizal inoculation and when no fertiliser was applied (0.5) with mycorrhizal inoculation (2.7) respectively. There were increments across all OF, NPK application, mycorrhizal inoculation and non-mycorrhizal inoculation under intercropping for both crops. When no fertiliser was applied and melon was intercrop with mycorrhizal inoculation, the melon RY increased by about 30.0% and by about 52.4% when OF was applied without mycorrhizal inoculation (Table 4.23). Similarly, the increment was by approximately 81.5% when OF was applied with mycorrhizal inoculation; and by about 76.2% when NPK was applied without mycorrhizal inoculation. Furthermore, the increment was by about 75.0% when NPK fertiliser was applied with mycorrhizal inoculation (Table 4.23).

The cassava RY value under cassava melon intercrop ranged from 0.6 – 1.7 under no fertiliser application and without mycorrhizal inoculation and when OF was applied with mycorrhizal inoculation respectively (Table 4.23). Nevertheless, when OF was applied without mycorrhizal inoculation, the RY value (0.6) was the same with when no fertiliser was applied with mycorrhizal inoculation. Similarly, when NPK fertiliser was applied without mycorrhizal inoculation, the cassava RY value was the same (0.6) when with fertiliser application without mycorrhizal inoculation (Table 4. 23)

Table 4. 24: Nitrogen and phosphorus uptake by cassava as influenced by AM inoculation in cassava - melon intercrop

Treatments	Nitrogen (g kg^{-1})	Phosphorus (g kg^{-1})
NOFERTILIZER		
Sole without Myco.	0.278bc	2.4d
Sole with Myco.	0.476ab	3.8cd
Inter.without Myco.	0.298bc	1.8d
Inter.with Myco.	0.443bc	3.1d
OF		
Sole without Myco.	0.306bc	5.9b
Sole with Myco.	0.706a	7.9a
Inter.without Myco.	0.468ab	3.4d
Inter.with Myco.	0.422bc	4.3c
NPK		
Sole without Myco.	0.293bc	2.5d
Sole with Myco.	0.520ab	5.2b
Inter.without Myco.	0.209c	1.1d
Inter.with Myco.	0.293bc	1.9d
Mycorrhiza (M)	ns	ns
Fertilizer (F)	ns	ns
Cropping system(Cs)	ns	ns
M x F	*	*
M x Cs	*	*
F x Cs	ns	ns
M x F x Cs	ns	ns
SE (Df = 35)	±0.038	

Under each column, values followed by similar alphabets are not significantly different at $P \leq 0.05$ using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter.without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter.with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant

* = significant at $p < 0.05$

4.10. Nutrients Uptake by Cassava Plants as Influenced by AM and Cropping Systems

4.10.1. Nitrogen and phosphorus uptake by cassava plants

The highest N uptake (0.706 g kg^{-1}) was examined under the treatments of OF with mycorrhizal inoculation in sole cassava plot (Table 4.24). It was meaningfully higher in related to all non-mycorrhizal inoculated treatments irrespective of cropping systems and fertiliser application except when intercropped cassava with OF application (Table 4.24). The least N uptake (0.209 g kg^{-1}) was obtained when NPK was applied to intercropped cassava without mycorrhizal inoculation. It was insignificantly different ($P < 0.05$) from other intercrop treatments with or without mycorrhizal inoculation (Table 4.24). Under each fertiliser application, the highest N uptake was observed under sole-cropped cassava with mycorrhizal inoculation; but was not considerably different ($P < 0.05$) from some other experimental factors under similar fertiliser application regimes (Table 4.24).

The highest phosphorus uptake was observed when OF was applied under sole cropping with mycorrhizal inoculation (7.9 g kg^{-1}) followed by sole cassava without mycorrhizal inoculation with a value of 5.9 g kg^{-1} (Table 4.24). When no fertiliser was applied, the P uptake ranged from 1.8 to 3.8 g kg^{-1} under intercropped cassava without mycorrhizal inoculation and sole cropped cassava with mycorrhizal inoculation respectively. However, there was no significant difference ($P < 0.05$) between the P uptakes when cassava in sole cropped compared to when it was intercropped cassava under mycorrhizal inoculation (Table 4.24). Phosphorus uptakes under cassava intercropping were lower, though, not significantly lower ($P < 0.05$) compared to other sole cropped cassava under mycorrhizal and non-mycorrhizal inoculation (Table 4.24).

4.10.2. K, Ca and Na uptakes by cassava plants

The highest K uptake (0.240 cmol kg^{-1}) was obtained under intercropped cassava with mycorrhizal inoculation when OF was applied (Table 4.25). This K uptake was appreciably higher than some other treatments except the treatment of sole cropped cassava with mycorrhizal inoculation (Table 4.25). The least K uptake (0.045 cmol kg^{-1}) was noticed under the use of inorganic fertilizer (NPK) without mycorrhizal inoculation intercropped cassava (Table 4.25). It was however, not significantly lower compared to treatments under NPK application and when no fertiliser was applied (Table 4. 25). The least K uptake was significantly lower when cassava was sole

planted with mycorrhizal inoculation under OF and when intercrop with mycorrhizal inoculation under NPK application. Under OF application, sole cropped cassava had significantly higher K uptake when inoculated with mycorrhiza compared to its intercrop counterpart, whereas under the application of NPK, intercropped cassava had significantly higher K uptake compared to sole cropped cassava (Table 4. 26). Calcium uptake was significantly higher (5.85 cmol kg^{-1}) contrary to all other experimental factors especially at the application of OF under sole cropped cassava without mycorrhizal inoculation (Table 4.26).

The Ca uptake obtained when cassava was intercrop without mycorrhizal inoculation under OF and when no fertiliser was applied was not considerably different ($P < 0.05$), but was considerably lower when compared to all treatments under NPK fertiliser application (Table 4.26).

Mycorrhizal inoculation significantly enhanced Na uptake by sole cropped cassava when sole cropped under OF application compared to all other treatments irrespective of cropping systems (Table 4.26). The sodium uptake ranged from 1.19 – 7.02 cmol kg^{-1}. The highest uptake value (7.02 cmol kg^{-1}) obtained was significantly higher compared to other treatments. This value (7.02 cmol kg^{-1}) was about five times the least Na uptake (Table 4.26). The least sodium (Na) uptake (1.19 cmol kg^{-1}) was obtained under intercropped cassava without mycorrhizal inoculation with NPK fertiliser application (Table 4.26). Nevertheless, this value was not significantly different from other treatments when no fertiliser was applied with exception of sole copped cassava without mycorrhizal inoculation and when NPK fertiliser applied (Table 4.26).

Table 4.25: Potassium, calcium and sodium uptake by cassava as influenced by AM inoculation in cassava melon intercrop

Treatments	Exchangeable bases (cmol kg^{-1})		
	K	Ca (10^{-3})	Na (10^{-3})
NOFERTILIZER			
Sole without Myco.	0.068d	2.86c	2.40cd
Sole with Myco.	0.113c	4.14b	4.40b
Inter.without Myco.	0.059d	2.42c	2.52cd
Inter.with Myco.	0.077d	2.76c	3.24c
OF			
Sole without Myco.	0.122c	5.85a	1.98de
Sole with Myco.	0.228a	3.80b	7.02a
Inter.without Myco.	0.111c	1.26de	1.98de
Inter.with Myco.	0.240a	4.14b	2.04de
NPK			
Sole without Myco.	0.050d	0.99de	1.80de
Sole with Myco.	0.078d	1.80d	4.20b
Inter.without Myco.	0.045d	0.70e	1.19e
Inter.with Myco.	0.159b	1.32de	2.40cd
Mycorrhiza (M)	ns	ns	ns
Fertilizer (F)	ns	ns	ns
Cropping system(Cs)	ns	ns	ns
M x F	ns	ns	ns
M x Cs	ns	ns	ns
F x Cs	ns	*	*
M x F x Cs	*	*	*

Under each column, values followed by similar alphabets are not significantly different at $P \leq 0.05$ using to Duncan's multiple

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter.without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter.with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertilizer

ns = not significant * = significant at $p < 0.05$

4.11. Extractable Micronutrient Uptake by Cassava plants

4.11.1 Mn, Fe, Cu and Zn uptake by cassava plants

Manganese (Mn) uptake by cassava plants ranged from 0.84 – 2.80 × 10^{-3} mg/ha (Table 4.26). The highest Mn uptake value was obtained when cassava was sole cropped under NPK fertiliser application with mycorrhiza. This value (2.80 × 10^{-3} mg/ha) was not significantly higher ($P < 0.05$) compared to (2.60 × 10^{-3} mg/ha) the one obtained when OF was applied with mycorrhizal inoculation when cassava was sole cropped (Table 4.26).

Iron (Fe) uptake was significantly higher when cassava was sole cropped when no fertiliser was applied without mycorrhizal inoculation but not significantly different under the same treatments. The least Fe uptake by cassava plants were observed under OF application with intercropped cassava under mycorrhizal inoculation. It was therefore not significantly different from treatments under NPK application except sole cropped cassava with mycorrhizal inoculation (Table 4.26).

Copper (Cu) uptake by cassava plants was influenced highly by cropping systems and mycorrhizal inoculation. The highest copper (Cu) uptake was observed under cassava-melon intercrop with mycorrhizal inoculation when OF fertiliser was applied (Table 4.26). Mycorrhizal inoculation significantly increased Cu uptake by cassava plants; the highest uptake was observed when cassava plant was intercropped under OF application with mycorrhizal inoculation though not significantly different under the same treatments and cropping system under NPK application. The least Cu uptake was observed when cassava was sole cropped without mycorrhizal inoculation under OF application (Table 4.26).

Zinc (Zn) uptake by cassava plant ranged from 1.30 – 9.60 × 10^{-4} mg/ha. Under sole cropping and NPK fertilizer application, Zn uptake of cassava plant increased more than what was observed under other treatments. Nevertheless, this value (9.60 × 10^{-4} mg/ha) was not significantly higher ($P \leq .05$) compared to Zn uptake (9.45 × 10^{-4} mg/ha) when OF was applied without mycorrhizal inoculation under sole cropping system (Table 4.26). The least Zn uptake by cassava plant (1.30× 10^{-4} mg/ha) observed when no fertiliser was applied with mycorrhizal inoculation under sole cropping (Table 24.26). The least Cu uptake by cassava plant (1.04 x 10^{-5} mg/ha) was observed when no fertiliser was applied with mycorrhizal inoculation under sole cropping system (Table 4.27).

In general, there were significant interactions between fertilizer applications, mycorrhizal inoculation and the cropping systems in the uptakes of Mn, Cu and Zn by cassava plant (Table 4.27).

4.12 Percentage root Colonisation of Cassava plants

The percentage root colonisation of mycorrhiza with cassava plants ranged from 35.3 – 45.0% (Figure 4. 4) The highest root colonisation by cassava was observed under the residual effect of NPK application under intercropped cassava without mycorrhizal inoculation (Figure 4 .4). The value (45.0%) was substantially higher contrast to other treatments. However, cassava root colonisation by mycorrhiza was not significantly different in intercropped cassava under NPK application with mycorrhizal inoculation compared to intercropped cassava under OF application with mycorrhizal inoculation (Figure 4.4). The least value of root colonisation by mycorrhiza obtained when no fertiliser was applied under sole cassava cropping was considerably reduced compared to the remaining treatments (Figure 4.4).

Table 4.26: Micronutrients uptake by cassava as influenced by AM inoculation in cassava–melon intercropping

Treatments	Micro nutrients (mg ha^{-1})			
	Mn (10^{-3})	Fe (10^{-3})	Cu (10^{-5})	Zn (10^{-4})
CONTROL				
Sole without Myco.	1.43c	3.63c	1.80e	4.95d
Sole with Myco.	1.98b	5.04b	1.04e	1.30f
Inter. without Myco.	1.98b	3.78b	1.40e	6.86b
Inter. with Myco.	1.68bc	3.06cd	4.00d	7.02b
OF				
Sole without Myco.	1.65bc	8.40a	5.10bc	9.45a
Sole with Myco.	2.60a	7.60a	4.30c	6.66bc
Inter. without Myco.	1.96b	2.31cd	1.40e	2.09f
Inter. with Myco.	1.98b	1.80d	8.10a	5.04d
NPK				
Sole without Myco.	0.90d	1.50d	5.80b	3.20e
Sole with Myco.	2.80a	4.20bc	3.00c	9.60a
Inter. without Myco.	0.84d	0.56d	4.30c	5.20bc
Inter. with Myco.	1.20cd	1.80d	7.30a	3.12e
Mycorrhiza (M)	ns	ns	ns	ns
Fertilizer (F)	ns	ns	ns	ns
Cropping system(Cs)	ns	ns	ns	ns
M x F	ns	ns	ns	ns
M x Cs	ns	ns	ns	ns
F x Cs	*	ns	*	ns
M x F x Cs	*	ns	*	*

Under each column, values followed by similar alphabets are not significantly different at $P \leq 0.05$ using to Duncan's multiple range test.

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation
Sole with Myco = Sole cassava cropping with mycorrhizal inoculation
Inter.without Myco = Cassava melon intercrop without mycorrhizal inoculation
Inter.with Myco = Cassava melon intercrop with mycorrhizal inoculation
OF = Organomineral fertilizer
ns = not significant * = significant at $p < 0.05$

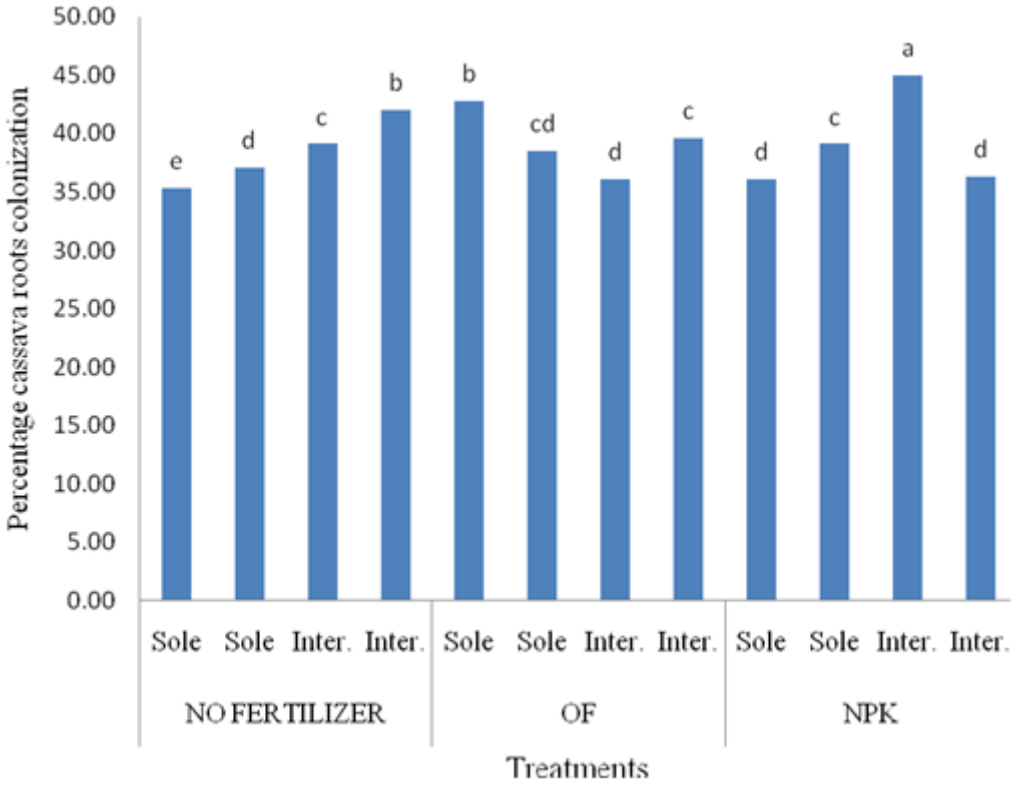


Figure 4.4: Cassava root colonisation by arbuscular mycorrhizal fungi under residual effects of fertilisers and cropping systems

Bars having similar alphabets are not significantly different at P= 0.05 using to Duncan's multiple range test

LEGEND

Sole without Myco = Sole cassava cropping without mycorrhizal inoculation

Sole with Myco = Sole cassava cropping with mycorrhizal inoculation

Inter.without Myco = Cassava melon intercrop without mycorrhizal inoculation

Inter.with Myco = Cassava melon intercrop with mycorrhizal inoculation

OF = Organomineral fertiliser

CHAPTER 5
DISCUSSION

Yield of crops under cropping systems in the tropics can be significantly improved particularly with reference to managements that can make the soil sustainable. Such include the use of organic materials or mixture of organic materials and inorganic fertilisers, hence, organomineral fertilisers can go a long way to ameliorate the infertile tropical soils to have significant yield improvement. In addition, arbuscular mycorrhizae are known to assist crops in the uptake of less mobile nutrients and can improve drought tolerance which is an added advantage with the variability in weather situation.

The organic fertilisers (especially OF) used for the preliminary trial, using two cultivars of melon (*bara* and *sewere*) positively influenced the growth and yield of melon crop especially the total plant weight and fruit yield of both cultivars. This was in conformity with the account of Omueti *et al.* (2000) as well as Lege (2012). The OF applied in this investigation was high in NPK and was available for the enhancement of the yield melon.

Response of the two melon cultivars to fertilisers under semi - controlled conditions revealed that they (*bara* and *sewere*) showed varietal differences in their responses to both organic and NPK fertilisers (OF, compost and NPK fertilisers). This agreed with the results of Joseph-Adekunle *et al*. (2003); Fagbola and Ogungbe (2007), where maize cultivars responses showed varietal difference in yield performance as influenced by organomineral fertiliser and mycorrhizal inoculation.

Spores population was negatively affected by fertiliser application in this experiment. This was similarly reported by Joseph and Sidney (2008) that fertilisers and other chemical application to farm land inhibit AMF spore. The report further showed that there was drop in spore number after the disturbance of the soil through tillage operations, fertiliser application and other activities that bring changes in the chemical, physical and biological characteristics of the edaphic environment. This was in line with the reduction in AM spore obtained from all plots used for cassava-melon intercropping under fertiliser application irrespective of fertiliser types compared to

when the soil was inoculated without any fertiliser application. This result was in agreement with reports of Fedderman *et al.* (2010), Wagg *et al.* (2011) and Munkermuller *et al.* (2012).

The highest spore was obtained when no fertiliser was applied, which showed that fertilisers application reduced AM spore abundance, while there was increment within the cropping systems especially where no fertiliser was applied as reported by Dania *et al.* (2013). The soil pH ranged from approximately 6 – 7 and the spore production and colonisation was influenced by fertilisers application and cropping systems. Nevertheless, this is not in agreement with the findings of Olfat and Jalil (2012), that pH of 7 – 8 seemed to be an optimal range for mycorrhizal association. This showed that fertiliser application, particularly inorganic fertiliser considerably reduced mycorrhizal spore under cropping system, and this is a key consideration for sustainable management of natural resources. This agreed with the report of Tanya *et al*. (2011) that increase in fertiliser rates reduced spore number and arbuscular mycorrhizal colonisation of maize (*Zea mays*).

Growing any of the two cultivars of melon with application of compost will be more profitable when mycorrhiza is applied. However, there was little response to compost by *sewere* compared to *bara* in terms of fresh shoot weight. Therefore, it might be preferred to have *sewere* cultivated with compost where mycorrhiza will not be applied. The responses of the two cultivars of melon to these fertilisers were supported by the findings of Olaniyi and Tella (2011) as the growth parameters of these melon cultivars increased irrespective of mycorrhizal inoculation. Nevertheless, the vine length and number of leaves for both melon cultivars were not significantly different under OF, NPK and compost application especially at five weeks after sowing.

The melon fruits yield varied under these fertilisers application as both fertilisers increased the fruits yield of *sewere* and *bara*. This is supported by the reports of Denton *et al.* (2000) and Olaniyi and Tella (2011) who observed that fertiliser treatment noticeably increased melon growth. The quantity of melon fruits per plant was limited in *sewere* and in some cases, no fruit in *bara* cultivar. This could be attributed to the low levels of some nutrients like K, Ca, Mg and Mn as revealed by the chemical analysis of the compost used. There was significant reduction in fruit yield of *bara* cultivar when compared to *sewere* fruit yield under OF and NPK fertilisers applications. On the other hand, since too much N result in foliage production, the

level of N in OF and compost could be attributed to high total plant weight production in *bara* compared to *sewere* cultivar. The imbalances in this nutrient constituent of organic fertilisers brought about the modification and fortification with chemical fertilisers to augment the deficient nutrient elements according to Omueti *et al*. (2000).

The positive reaction of these cultivars of melon (*bara* and *sewere*) to fertilisers' application corroborated the finding of Olaniyi (2006), that melon growth was positively influenced by mineral and organic fertilisers. Compost increased total plant weight production in *bara* cultivar and reduced fruit yield in *sewere* compared to fruit yield obtained under OF and NPK fertiliser applications. Obviously, mycorrhizal inoculation meaningfully improved the fruit yield of *sewere* under compost application which agreed with report from Carla da Silva *et al.* (2012), that the presence of mycorrhizal increased crop growth and yield performance.

The experimental soil for the field experiment was sandy-loam, with adequate nutrient status due to short term fallow period (two years) after continuous cultivation of arable crops. The selected melon cultivar (*sewere*) response showed that treatments applied had influence on growth and yield performance of these melons. The field experiments showed that the cropping systems positively affected melon plant growth. Similarly, mycorrhizal inoculation, OF and NPK fertiliser applications increased the plants vegetative growth. However, changes in the pattern of land coverage under different cropping systems could be in line with nutrient obtainability under limiting rate of nutrients release with time under different cropping systems and mycorrhizal inoculation. This was in consonance with the report of Bernard *et al.* (2007) and Montemurro *et al*. (2013) that the presence of arbuscular mycorrhiza fungi (AM) improved crop establishment and enhances crop yield.

Mycorrhizal inoculation positively affected the fresh melon fruit weights under OF and NPK fertiliser applications. However, with OF and NPK application, the fruit weights were higher especially under cassava melon intercrop compared to sole melon cropping. Besides, sole melon cropping under both levels of mycorrhizal and fertiliser application, there were no significant differences when compared to yield obtained under NPK fertiliser application. The fruit yield per plant followed similar pattern as reported by Olaniyi and Tella (2011).

Similar trend was observed with the fruit yield of melon under each cropping system irrespective of fertiliser types which were significantly influenced by arbuscular mycorrhiza fungi, this was in agreement with the report of Carla da Silva *et*

al (2012), that organic fertilisers have little or less adverse effect on arbuscular mycorrhiza fungi than equivalent quantities of mineral fertilisers, this may likely be due to temporal difference in P availability that resulted from its gradual release that was in concomitant with demands by the plant.

At both cropping years, number of melon fruits and fruit weight varied per hectare with the highest yield recorded under OF application with mycorrhizal inoculation when it was intercropped. Similar trend of fruit yield was observed during second cropping year (residual effect). The trend of melon performance may be attributed to the ability of OF (that is high in organic constituent) to release nutrients steadily. This agreed with the reports from Sesato (2013) and Osundare (2015) that organic fertilisers release available nutrients slowly. It was reported by Molta (2014) that organic fertilisers residual effect on crop yield was significantly higher compared to the yield obtained from plots with inorganic fertilisers. This finding was in agreement with various yields of melon obtained under OF and NPK application during the second cropping year in this study. The effects of mycorrhiza on melon fruit yield also supported the report that the AM are capable of increasing nutrient utilization of crop for better yield as reported by Carretero *et al.* (2009); Feddermann *et al.* (2010); Munkemuller and Meynard (2012).

However, there was insignificant influence of cropping systems on both cassava and melon crops' yield at the second cropping year compared to the first cropping year. This was in line with the findings reported by Ation (2013), that there was no significant interaction between cropping systems and fertiliser residual effect on cassava yield obtained after five years of continuous cropping on the land. Similarly, there was no major difference compared to other treatments of fertiliser applications, cropping systems and AM inoculation. The highest melon fruit yield was obtained when melon was intercropped under NPK and mycorrhizal application, but not significantly higher when compared to other treatments at the first cropping season. This result was in line with Molta (2014), that full benefits of AM hyphae connect two or more different plant species roots promoting a network system among the plants (Bernard *et al.,* 2007; Abiola and Daniel, 2014).

Number of melon fruits increased under both fertilisers application with the highest values under OF application when melon was intercropped under mycorrhizal inoculation. However, number of melon fruits per hectare was not significantly different under OF and NPK application with mycorrhizal inoculation when both were

compared. This showed that it is more profitable when melon is intercropped with cassava and proved that land under either OF or NPK fertiliser combining with mycorrhizal inoculation increased crop yield as reported by Reema and Adhaleya (2004) and Oehl *et al*. (2011).

Similar trends were observed with the dry melon seeds yield; the highest unshelled melon seeds were obtained under OF application when melon was intercropped under mycorrhizal inoculation but not significantly higher than the yield of sole cropped melon under OF application without mycorrhizal inoculation. Besides, melon seeds yield under these cropping systems with OF and mycorrhizal inoculation was similar to the yield obtained under NPK fertiliser application but the values were not significantly different from that of OF application with mycorrhizal inoculation in the two cropping years. The melon seed yields supported the report that crop yield increases with OF application (Omueti *et al.,* 2000; Yusuf *et al*., 2008; Jimin *et al*., 2013).

Plots under NPK and inoculated with mycorrhiza had significantly reduced shelled melon seeds yield when compared to other treatments. This reduction in yield under mycorrhizal inoculation with NPK fertiliser application proved that application of chemical fertilisers affects mycorrhizal associations in the soil according to Dalpe and Monreal (2004) and Jasem and Ahmad (2014). The 100 seeds weight of melon seeds was not significantly different in all the treatments in both cropping years. The melon fruit unshelled and shelled seeds weights under intercrop with mycorrhizal inoculation are in accordance with the reports of Denton and Olufolaji (2000) and Abdelrahman *et al.* (2012) that melon fruits and seeds weights followed similar pattern after shelling.

Cropping systems and types of fertiliser can affect mycorrhizal efficiency with reference to melon fruits and seeds yields. Also, the type of fertiliser can elicit differential response. From the results obtained, mycorrhizal inoculation positively influenced the melon seeds yield with particular reference to organomineral fertiliser irrespective of cropping systems as observed at both cropping years. The presence of mycorrhiza might have accounted for the melon yields in both cropping years, because when melon was intercropped with mycorrhiza and OF applications, the seeds yield was significantly higher compared to the seed yield under the same treatment with NPK application and when no fertiliser was applied in both cropping seasons (Ugwumba, 2010; Sadiq *et al*., 2013).

The cassava plant height at 3, 6, 9 and 12 months after planting in both cropping years were not significantly different. However, at the first cropping year, the presence of mycorrhiza positively influenced cassava plant height, which was similar to the work of Bernard *et al.* (2009) and Bande *et al.* (2013). The influence of NPK and OF fertiliser applications showed that NPK fertiliser without mycorrhiza increased cassava plant height at 12 MAP under cassava – melon intercrop while OF without mycorrhizal inoculation under the same cropping system influenced plant height in the first cropping season. However, reverse was the case in second cropping year. Similar response was reported by Adeola (2007), with the same cultivar of cassava under intercropping with pepper. Cassava plant height under sole cassava cropping was not significantly different from intercropped cassava irrespective of the fertiliser application when mycorrhiza was applied. This showed that the cropping system and fertiliser application and their residual effect have no significant effect on plant height. This was in agreement with the report of Muoneke and Mbah (2007) that okra and cassava heights were not significantly different in cassava - okra intercrop under organic fertiliser application.

Similar pattern was noticed as the two fertilisers enhanced the cassava plant height at the second cropping season. The least cassava plant height at the third, sixth, ninth and twelfth months after planting (MAP) were observed with intercropped cassava without mycorrhizal inoculation under OF application and when no fertiliser was applied; while the highest height was obtained with sole cropped cassava when NPK and OF were applied with mycorrhizal inoculation.

The vegetative characteristics of cassava were significantly enhanced by mycorrhizal inoculation under OF and NPK applications. Nevertheless, the cassava growth when intercrop, under each fertiliser application without mycorrhizal inoculation were not significantly different when compared to other treatments especially where no fertiliser and mycorrhiza were applied irrespective of cropping system. This corroborated the report that there was no significant difference in term of vegetative growth performance between mycorrhizal inoculated plant under intercrop and sole crop plants according to Bernard *et al.* (2007).

The contribution of mycorrhiza to nutrient uptake of crops can partly be determined by the soil nutrients status as influenced by the available elements in fertiliser applied. The higher responsiveness to mycorrhizal inoculation obtained in melon seeds and cassava storage roots yields compared to other growth and yield

variables were probably due to the interaction between fertilisers and cropping systems. The low responsiveness of the melon and cassava plant to mycorrhizal obtained was probably due to interaction between the cropping system and the residual effect of the previous fertilisers applied at the first cropping year which was more pronounced where no fertiliser and mycorrhiza were applied. Mycorrhiza and OF application significantly influenced the yield of both crops in both cropping years. This might be due to the ability of mycorrhiza to scavenge the residual nutrients at previous cropping and due to slow release of nutrients of manure (organic) fertiliser as stated by Kiani *et al*. (2005) and Straker *et al*. (2010).

The highest cassava storage roots yields obtained at both cropping years were significant under OF and mycorrhizal inoculation compared to other fertiliser treatments. The highest cassava storage roots yield was obtained when cassava was sole crop under mycorrhizal and OF applications at the first cropping year. This was also higher under the same treatment (mycorrhizal and OF application) when cassava was intercropped in the second cropping year as the residual effect. The values obtained agreed with the reports of Onwueme and Sinha (1999) and Abiola and Daniel (2014). However, these cassava storage roots yields were higher compared to a report that a yield of 10 to 15 tonnes per hectare is possible in Nigeria in farmers' field, while research farm yield up to 25 - 40 tonnes per hectare (Ezulike *et al*., 2006; FIIRO, 2006; Jimin *et al.*, 2013). This was possible because of the effect of OF as organic source of fertiliser that releases nutrients steadily and slowly. This supported the finding of Ibiremo (2010), that organic fertiliser significantly improved crop growth and yield.

The application of organic fertiliser favoured AM activity in the rhizosphere of intercropped cassava and melon when compared to where no fertiliser was applied (control treatment) accordingly. This agreed with the report from Carla da Silva *et al.* (2012) in a similar finding under intercropped maize and cowpea with organic fertiliser and mycorrhizal applications. The yield of melon seeds and that of cassava in both cropping years under OF and NPK applications when cassava and melon were intercropped under mycorrhizal inoculation resulted in positive influence as reported by Anthony and Akinrinde (2011) and Jimin *et al.* (2013) in the case of soil amendment with poultry manure in the production of water melon. As reported by Oyetunji and Osunubi (2007), that the dry leaf weight and cassava storage roots were greatly enhanced by mycorrhizal inoculation under both alley-cropping and sole cropping systems, similar things were observed under sole cropping and intercropped

melon-cassava in term of tuber yield compared to when no mycorrhiza was inoculated in either cropping system. In addition, the yields of both crops under OF and mycorrhizal inoculation was high in this experiment at both cropping years. This, however, was significantly higher for melon in the second cropping year. This was observed as their LERs were greater than one (1.0) which was in agreement with the reports of Onwueme, (1999) and Abdelrahman *et al.* (2012). This showed that intercropping in this combination was more beneficial than sole cropping.

The nutrients uptake by cassava plant was observed to be higher under OF and mycorrhizal application irrespective of cropping system followed by nutrient uptake under NPK application with similar treatments. This nutrients uptake was in consonance with the work of Bernard *et al*. (2007) that intercropping marula with millet or corn could help in the propagation of mycorrhizal spore in the soil which enhanced marula establishment and nutrients uptake especially in soil with low phosphorus and inadequate moisture.

Generally, the cropping systems without mycorrhizal inoculation reduced the macro nutrients uptake by cassava plants especially phosphorus (K) which was in agreement with reports of Joseph and Sidney (2008) and Fabio *et al*. (2014), that the mycorrhizal hyphae network produced during association with the host plant provide a greater absorptive surface than root hairs alone and thus increased significantly the absorption of nutrients such as phosphorus, copper and zinc. This was observed to be more pronounced under melon - cassava intercrop, where copper uptake by cassava was significantly higher under OF fertiliser application with mycorrhizal inoculation. This, however, was significantly higher under the same treatment compared to when NPK was applied, as corroborated by the report of Yu *et al*. (2013).

Similarly, under sole cropped cassava, mycorrhiza significantly increased copper uptake under OF and NPK fertiliser application but not significantly different ($p \leq 0.05$) when compared to when no fertiliser was applied. This observation was in line with report from Faujdar *et al*. (2014), that the micro nutrients (Zn, Cu, Fe and Mn) uptake was higher under control plot where no fertiliser was applied under inoculation of Azotobacter and arbuscular mycorrhiza only. Results on leaf nutrient content and soil nutrient level corroborated with Utobo *et al.* (2011) who in their work observed that leaf nutrients analysis can be used to adjust fertiliser recommendation when the soil nutrient level is known. The N, K and P uptakes showed similar pattern as observed in cassava plant in this study.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Intercropping is a system that ensures food security against total crop failure or with intent to maximize yield and profit making by the use of the same labour operations among other inputs. The main advantages of intercropping are that it leads to improve utilization of land, labour, capital and it results in less variability in annual returns compared to sole cropping. Furthermore, the use of organic fertilisers and arbuscular mycorrhiza fungi inoculation increased the crop yield through symbiotic association between these soil fungi and various crop roots in the soil. Besides, application of organomineral fertiliser adds organic materials, micro-nutrients and the major nutrients that made up the other inorganic fertilisers to soil. These are added advantages of organomineral fertiliser over inorganic fertilisers. However, there is limiting information indicating that local farmers in southern Nigeria inoculate their farmland with mycorrhiza for either sole cropped cassava or sole melon or cassava-melon intercrop in cultivation practices.

This study was conducted to assess the response of intercropped melon and cassava to OF and AM inoculation in an *Alfisol* in Ibadan, southern Nigeria.

Experiments were performed to.

i. Evaluate the response of two melon cultivars to OF, NPK and compost under pot trial
ii. Assess response of melon and cassava as sole or intercrop to NPK, organomineral fertiliser and arbuscular mycorrhizal inoculation in field trials
iii. Determine arbuscular mycorrhiza fungi (AMF) influence of on nutrient uptake of cassava in field
iv. Evaluate the land equivalent ratio (LER) for both cassava and melon
v. Determine the effect of OF and NPK application on arbuscular mycorrhiza fungi spore and cassava roots colonisation under the two cropping systems.

For the preliminary experiments, *sewere* and *bara* melon cultivars were subjected to pot experiment with three different fertilisers.

It was observed as follows.

In the pot experiment, OF and NPK fertilisers were effective on both melon cultivars production. Mycorrhizal inoculation, OF and NPK application on *sewere* melon was comparable with compost application on *bara* cultivar under mycorrhiza inoculation, hence, compost was dropped after the first trial. There were positive responses of melon and cassava plants to mycorrhiza under OF and NPK application under field conditions.

The study revealed that *sewere* could be used for intercropping with cassava under both fertilisers application with mycorrhizal inoculation as observed. Besides, there was positive response to fertiliser application especially organomineral fertiliser (OF). The cropping systems and fertiliser interaction was significant for AM spore population in the soil and cassava root colonisation. Therefore, soil fertility management should target favourable environment for increasing arbuscular mycorrhiza (AM) spore and colonisation.

Melon seeds and cassava storage roots yields were enhanced by OF and AM fungi in both growing seasons under both cropping systems, hence for maximum utilization of OF, it is recommended that second cropping on the same land be done after first harvesting. In addition, the cropping systems and fertiliser and AM inoculation interaction was significant for melon seed and cassava storage roots yields.

From this study, intercropping melon and cassava under NPK and mycorrhizal inoculation at the first year was productive compared to the yields of both crops at the second cropping year. However, under the application of OF with mycorrhiza, it was more effective and productive for melon-cassava intercrop for two cropping years.

Moreover, the soil fertility status has more effect on AM root colonisation of cassava as well as on the nutrients uptake as there were significant interaction between cropping system, fertiliser and AM inoculation on AM colonisation, spore abundance and melon seed yield as well as cassava storage roots yield. This showed that AM colonisation could be positively exploited through investigation of the functional diversity of indigenous AM species.

Furthermore, there was positive response by both crops (melon and cassava) to the two cropping systems. There was no significant lasting effect of inorganic fertilizer (NPK) on intercropped cassava yields compared to the sole crop in first season; but the residual (second cropping) effects of OF was significantly higher on both crops under AM inoculation compared to where no fertiliser was applied (control) and when NPK was applied in the previous cropping year.

Melon seed yield was positively influenced in intercrop under OF, NPK and mycorrhizal inoculation and showed a pattern: OF>NPK> no fertiliser application in the first cropping season but there was no definite order in the second cropping season under the same treatments.

It was also observed that irrespective of the fertiliser application and other treatments, the cassava storage roots yield was only significantly higher under OF application when sole crop with AM inoculation in the first cropping year, and was significantly higher under OF application when intercropped and with AM inoculation in second cropping year. This could be due to long term effects of organic matter components of OF in the soil that encourages slow release of nutrients.

It was also observed that AM significantly increased LER and this showed the positive effect of mycorrhiza on intercropped melon and cassava over their sole crops in both cropping seasons. This should therefore be encouraged for effective land use and management. The significant effect of mycorrhiza on intercropping the two crops could be attributed to the Arbuscular Mycorrhizal (AM) hyphae – root elongation for large surface areas available for nutrient absorption by the host crops (mycorrhiza crops).

Potassium (K) and phosphorus (P) uptakes were significantly enhanced by mycorrhizal inoculation irrespective of cropping system; Cu uptake under OF application was higher compared to other treatments with mycorrhizal inoculation irrespective of cropping system. The presence of arbuscular mycorrhizal (irrespective of fertiliser rates and types) significantly increased nutrient uptake by cassava plants.

In conclusion, arbuscular mycorrhizal fungi (AM) and OF application should be encouraged in intercropping for melon and cassava production, as the use of OF will encourage the mycorrhizal colonisation and increase soil fertility for sustainable crop production. Also, the practice of NPK fertiliser application and sole cropping of either melon or cassava could not benefit subsequent cropping without fertiliser application. Hence, all cultural practices including fertiliser application that can reduce arbuscular mycorrhizal fungi spore abundance and root colonisation should be avoided as observed with the use of NPK fertiliser in this experiment.

REFERENCES

Abdelrahman, H.M., Erriquens, F.G., Ceglie, F.G., Verrastro, V., Rivera, C.M., and Tittarelli, F., 2012. Compost Based Growing Media for Organic Melon Seedlings Production. Retrieved, July 20, 2014 from http.//www.researchgate.net/publication/235635971.

Abiola, M.O. and Daniel, I. 2014. Efficiency of melon production in Oredo and Egor Local Government Area of Edo State, Nigeria. *International Journal of Agriculture Innovations and Research.* 2.5: 732 – 738.

Adaso, F.D. 2014. Total plant weight production and nitrogen fixation potentials of four cowpea varieties and their effects on maize yield in southwestern Nigeria. *International Journal of Soil Science and Land Development.* 67: 502 – 508.

Aden, M. J. 2013. The potassium requirements of cassava (*Manihot esculenta* Crantz). *Journal of Food Technology and Applied Science*10.2: 45 – 52.

Adeola, R.G. 2007. Effects of Organic and Mineral Fertilisers on growth and yield of pepper (*Capsicum annum*) under cassava (*Manihot esculenta* Crantz) relay intercrop, in Ogbomosho, Nigeria. Ph.D. Thesis Department of Agronomy, University of Ibadan, Oyo State. 117 pp.

Adewusi, H. G, Ladipo, D. O., Sarumi, M. B., Adebisi A. A. and Vodouhe, R. 2000. Egusi Production, Utilization and Diversity in Nigeria. *Agronomy in Nigeria.* Agronomy Re-union day, Wednesday 4. October 2000. 43 – 56 pp.

Agahiu, A. E, Baiyeri, R.O., Ogbuji, U.E. and Udensi 2012. Assessment of status, Perception of Weed infestation and Methods of weed control Adopted by cassava Farmers in Kogi state, Nigeria. *Journal of Animal and Plant Sciences*, 2012. 13.3: 1823 – 1830. Retrieved, July 20, 2014 from http//www.m.elewa.org/

Agegnehu, G. VanBeek, C. and Bird, M I 2014. Influence of integrated soil fertility management in wheat productivity and soil chemical properties in the highland tropical environment. *Journal of Soil Science and Plant Nutrition* 14.3 Retrieved, April 17, 2016 from www.google scholar.

Aiyelari, E. A., Ogunsesin, A. and Adeoluwa, O. O. 2011. Effects of *Terminalia catappa* leaves with poultry manure compost, mulching and seedbed preparation on the growth and yield of okra (*Abelmoschus esculentus* l. moench). *Proceedings of International Soil Tillage Research Organization*. 21-24 February, 2011. Ogunlela, A. O. Eds. University of Ilorin, Nigeria. 356 - 370.

Alves, A. A. C. 2002. *Cassava Botany and Physiology. Cassava. Biology, Production and Utilization*. R.J Hillocks, J.M. Theresh, and A. Bellotti, Eds. CABI Publishing, UK. 67 - 89.

Ation, A. D. 2013. Fertility status of an Alfisol after five years of continuous cassava cropping. *Soil Fertility*58:1082 – 1088.

Aweto, C. O. 2014. Potassium nutrition and fertility aspects of cassava production in Southwestern Nigeria. *Plant Nutrition and Fertilizer Research.* 21: 231-23.

Ayoola, O. T. and Makinde, E. A. 2007. Complementary organic and inorganic fertilizer application. Influence on growth and yield of cassava/maize/melon intercrop with a relayed cowpea. *Australian Journal of Basic and Applied Sciences,* 1.3: 187 – 192.

Ayoola, O. T. and Adeniyan, O. N. 2006. Influence of poultry manure and NPK fertilizer on yield and yield component of crops under different cropping systems in southwest Nigeria. *African Journal of Biotechnology* 5.15: 1386 – 1392.

Bande, Y. M., Adam, N. M., Jamarei, B. O., Azmi Y and Zubairu U. B. 2013.Egusi melon (*Citrullus lanatus*) crop – Malaysian new oil/energy source. production, processing and prospects 7(13).2101-2107 *Australian Journal of Crop Science.* 5.4: 396-410. Retrieved August 27, 2015 from www.google scholar.

Beader, R. I. 2013. Study on mineral nutrition of cassava under different tropical legumes. *International Journal of Science and Technology.* 23.2: 552 – 558.

Beets, W.C., 1982. *Multiple cropping and farming systems*. Grower participants Limited, Hamshire. England. Cited by Adeola, 2007.

Belay, A.A.S. Classens, Wehner, F.C. and De Beer, J.M. 2001. Influence of residual manure on selected nutrient elements and microbial composition of soil under long-term crop rotation. *South Africa Journal of Plant and Soil.* 18: 1 – 6.

Bernard, O.M, Atsushi, M, Takaaki, I and David W.O 2007. The effects of Intercropping *Seleocaryabirrea* (A. Rich.) Hochst, millet and corn in the presence of arbuscular mycorrhizal fungi. *African Journal of biotechnology* 8.5: 807 – 812

Bennett, A. E., Bever, J. D. and Bowers, M. D. 2009. Arbuscular mycorrhizal fungal species suppress inducible plant responses and alter defensive strategies following herbivory. Oecologia, 160, 771–779.

Berry, S. D., Dana, P., Spaul, V. W., and Cadet, P. (2009). Effect of intercropping on nematodes in two small-scale sugarcane farming systems in South Africa. *Nematropica* 39: 11-33.

Bilalis D, Papastylianou P, Konstantas A, Patsiali S, Karkanis A, and Efthimiadou A 2010. Weed-suppressive effects of maize-legume intercropping in organic farming. *International Journal of Pests Management* 56: 173-181.

Bouyoucous, G. H. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. *Agronomy Journal* 43: 434 – 438.

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

Carla da Silva. S. Romulo. S.C.M, Evarardo, V. S. B. S, Fritz. O., Leonor. C. M, Marlon S. G and Francico. S. L 2012. Occurrence of arbuscular mycorrhizal fungi after organic fertilization in maize, cowpea and cotton intercropping systems. ACTA Scientiarum. *Agronomy of Moringa*, 34.2: 149- 156.

Carretero, C.L., Cantos, M., Gracia, J.L., Azcón, R., and Troncosco, A. (2009) Growth responses of micropropagated cassava clones as affected by *Glomus intraradices* colonisation. *Journal of Plant Nutrition.* 2:261–273.

Castillo, A. E., Benito, S. G., and Fernadez, J.A. 2003. Using organic manures as living materials. *Agrochemical* XLVII. 14-20.

Dalpe, Y. and Monreal, M. 2004. Arbuscular mycorrhiza to support sustainable cropping systems. Online crop management. Retrieved September12, 2012, from 10. 1094/cm-2004-0301-09 RV.

Dania S. O; Fagbola, O and Iyamu, M. I. 2013. Assessment of the effects of arbuscular mycorrhizal fungi *(Glomus clarum)* and pigeon pea hedgerow on the yield of maize and soil properties in degraded Ultisols. 3.5: 2013 *Journal of Biology, Agriculture and Healthcare*.www.iiste.org

Daukan, M. Y. 2012. Study on nitrogen fertilization of maize. *Plant Nutrition.* 43: 1222 – 1229.

Denton, O. A. and Olufolaji, A. O. 2000. Nigeria's most important Vegetable Crops. *Agronomy in Nigeria.* Agronomy Re-union day, Wednesday 4. October 2000. 43 – 56

Duhamel, M. and Beesetty, Y. 2011. Reciprocal rewards stabilize cooperation in the mycorrhizal symbiosis. *Science* 333: 880–882.

Ekwere, O. J., Muoneke, C. O., Eka, M. J. and Osodeke, V. E. 2013. Growth and yield parameters of maize and *egusi* melon in intercrop as influenced by the cropping system and different rates of NPK fertiliser. *Journal of Agricultural and Crop Research 1.5: 69-75*. Retrieved August, 2014 from http.//sciencewebpublishing.net/jacr/archive.

Ezulike, T. O., Nwosu, K. I., Udealor, A. and Eke-Okoro, O. N. 2006. Guide to cassava production in Nigeria. NRCRI, Umudike. *Extension Guide No. 16*: 20.

Fabio, T., Gabriele, C., Roberta, F., Rosario, N., Corrado, C., Elena, T., Fabrizio, L., and Stefano, C. 2014. Effect of cover crop management and compost application on soil N fertility of organic melon. Proceedings of the 4th ISOFAR Scientific Conference. *'Building Organic Bridges'*, at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey. Retrieved Sept. 3, 2015 from www.google scholar.

Fagbami, A. A and Shogunle, E. A. A. 1995. Nigeria: Reference soil of the coastal swamps near Ikorodu (Lagos State). *Soil Brief Nigeria 2*. University of Ibadan, Ibadan, and International Soil Reference and Information Centre, Wageningen. pp17.

Fagbola, O., Osinubi, O., Mulongoy, K. and Odunfa, S. A. 2001. Effects of Drought Stress and Arbuscular Mycorrhiza on the Growth of *Gliricidia septum* (Jacq). Walp. And *Leucaena leucocephala* (Lam) de wit in simulated Eroded Soil Conditions. *Mycorrhiza*. 11: 215-223.

Fagbola, O. and Ogungbe, P.W. 2007. Productivity of three maize cultivars as affected by organomineral fertiliser and arbuscular mycorrhizal fungi under greenhouse conditions. *Book of Abstracts* of International Research, on food security, Natural Resource Management and Rural Development Tropentag 2007. Organized by the University of Kassel and the University of Gottingen October 10 - 11, 2007 in Wiizenhausen WWW, tropentag 442 pp.

Fagbola, O., Oyetunji, O. J. and Olugbemi, P.W. 2009. Mycofertigation Production of Okra (*Abelmoschus esculentus*, L, Moench) under pot and field conditions. *Nigerian Journal of Horticultural Science* 4: 38 – 43.

FAO. 2012. Food and Agricultural Organization, Production Year Book. FAOSTAT Data Base. Retrieved October 2015 from http.//appsl.fao.org

FAO. 2014. Food and Agricultural Organisation, Production Year Book. FAOSTAT Data Base. Retrieved November 2015 from http.//appsl.fao.org

Faujdar, R. S., Sharma, M., Solanki, R. L. and Dangi. R.C. 2014. Effect of FYM, Biofertilisers and Zinc on Yield and Micronutrients Uptake in Maize. *Asian Journal of Soil science.* 9.1: 121 – 125.Retrieved from October 24, 2015//.www.researchjournal.co.in/online/AJSS.htm

Feddermann, N., Finlay, R., Boller, T. and Elfstrand, M. 2010. Functional diversity in arbuscular mycorrhiza—the role of gene expression, phosphorous nutrition and symbiotic efficiency. *Fungal Ecology, 3: 1–8.*

FIIRO. 2006. Cassava. Production, Processing and Utilization in Nigeria. Federal Institute of Industrial research, Oshodi. 1st ed, Oke Ado, Ibadan 247.

Gbadegesin, A and Akinbola, G.E. 1995. Nigeria: Reference soil of the Southern Guinea Savanna of South western Nigeria. Soil Brief Nigeria 7. University of Ibadan, Ibadan, and International Soil Reference and Information Centre, Wageningen. pp13

Gao, L. L., Delp, G. and Smith, S. E. 2001. Colonisation patterns in mycorrhizal-defective mutant tomato vary with different arbuscular-mycorrhizal fungi. *New Phytologist* 138: 275- 283.

Gerdamann, J. W. and Nicholson, T. H. 1963. Spores of mycorrhizal endogone species extracted from soil by wet sieving and decanting. *Transactions of the British Mycological Society* 46: 235 – 244.

Gilley, J. F. and Risse, M. 2000: Run off and Soil Loss as affected by the Application of Manure. *Transactions of the American Society of Agricultural Engineers* (ASAE) 43: 1583 - 1588.

Giovanetti, M, and Mosse, B.1980. An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. *New phytologist* 84: 489 – 500.

Hillocks, R. J. 2002. Cassava in Africa: Cassava.Biology, Production and Utilization. RJ Hillocks, JM Thresh, A Belliot, (eds.) CABI Publishing, UK. 41-54.

Hodge, A. 2000. Microbiology Ecology of the arbuscular mycorrhiza. Federation of European Microbiological Societies. *Microbiology Ecology*. 32: 91-96.

IITA. 2004. The Cassava industrial revolution in Nigeria: The Potential for a New Industrial Crop. IITA, Ibadan. 16.

IITA. 2012**.** Cassava varieties developed by IITA show promise of tackling famine in the Horn of Africa. IITA News –Archive, *14 December 2012*. Retrieved July 28, 2014, from http.//www.iita.org/interviews**.**

IITA. 2013.Nigeria releases improved cassava varieties to boost productivity. IITA News –Archive,14 January 2013, from http.//www.iita.org/interviews

IITA. 2015. Scientists and development partners' spot agronomy as a remedy for Africa's cassava production problem, IITA News –Archive, *04 May 2015*. Retrieved December 20, 2015, from http.//www.iita.org/interviews

Ijoyah, M. O., Bwala, R.I. and Iheadindueme, C.A. 2012. Response of cassava, maize and egusi melon in a three crop intercropping system at Makurdi, Nigeria, *International Journal of Development and Sustainability*, 1.2 : 135–144 Retrieved September 4, 2015 from www.isdsnet.com/ijds/www.google scholar.

Irwin, B.Y. 2010. Fertilization and mineral nutrition of cassava. *Fertilizer and Food Science Research.*16.1: 342 – 349.

Jadoon, M.A., Bhatti, A.U., Khan, F. and Sahibzada, Q. A. 2003. Effect of farm yard manure in combination with NPK on the yield of maize and soil physical properties. *Pakistan Journal of Soil Science.* 22: 47-55.

Jansa, J., Smith, F.A, and Smith, S. E. 2008. Are there benefits of simultaneous root colonisation by different arbuscular mycorrhizal fungi? *New Phytologist*, 177: 779–789.

Jasem, A.1., and Ahmad, G. 2014. Biological facilitative interactions and their roles on maximize Growth and Productivity of crops in intercropping systems. *Scientia Agriculturae* 2 6.2: 90-95. Retrieved August 16, 2015 from www.pscipub.com

Jimin, A. A., Asema, U. S., Ortserga D. D. and Onuh S. O. 2013. Effect of amending soil with different levels of poultry droppings on the performance of water melon (*Citrullus lanatus*) in southern savannah of Nigeria. *Agriculture and Biology Journal of North America.* 4.1: 19 -.22. Retrieved August 28, 2015 from http.//www.scihub.org/ABJNA

Joseph – Adekunle, T.Y. Fagbayide. J. A and Fagbola. O. 2003. Effect of fertiliser applications on the growth and yield of pepper cultivars under field conditions. *Test of Agrochemical and Cultivars* 25: 10 – 11.

Joseph, D. B. and Sidney, L. S. 2008. Arbuscular Mycorrhizal Fungi (AMF): Handbook of tropical soil biology sampling and characterization of below-ground biodiversity. Fatima, M. S., Moreira, E., Jeroen Huising and David, E. Bignell (eds) 131 -147.

Joyce, A. and Idisi, P. O. 2014. Gendered participation in cassava value chain in Nigeria. Merit *Research Journal of Agricultural Science and Soil Sciences.* 2.11: 147-153 Retrieved July 20, 2015 from http.//meritresearchjournals.org/asss/index.htm

Kiani, M. J., Abbas, K. M. and Rahim, N. 2005. Use of organic manure with mineral N fertiliser increases wheat yield at Rawalot Azad-jammu and Kashmin. *Archives of Agronomy and Soil Science.* 51: 299-309.

Kunji, A. N. 2013. Effects of inorganic fertilization on hydrocyanic acid content of cassava root. *Journal of Agriculture and Food Science*. 15.2: 330 – 336.

Lege, B. N. 2012. Soil chemical properties as affected by phosphorus and nitrogen – based manure and compost application. *Soil Science Research.* 71: 666 – 673.

Lendenmann, M., Thonar, C. and Barnard, R. 2011. Symbiont identity matters: carbon and phosphorus fluxes between Medicago truncatula and different arbuscular mycorrhizal fungi. Mycorrhiza, 21: 689–702.

Mahmood, I. and R, Rizvi, 2010. Mycorrhiza and organic farming. *Asian Journal of Plant Science* 9: 241 – 248.

Mead, R. and Willey, R.W., 1980. The Concept of a ‘Land Equivalent Ratio‘ and Advantages in Yeilds from Intercropping. *Experimental Agriculture*. 16: 217-228.

Melissa, M. J., Sarah, J. R., Peter, J. B., Michael, J. C., and Daniel, C. L. 2015. Soil fertility induces coordinated responses of multiple independent functional traits. *Journal of Ecology*. 103.2: 374–385

Michael, O. I, Richard I. B and Churchline, A. I. 2012. Response of cassava, maize and egusi melon in a three crop intercropping system at Makurdi, Nigeria International Journal of Development and Sustainability 1(2):135-144Online ISSN: 2186- 8662 www.isdsnet.com/ijds

Molta, B. J. 2014. Growth and yield responses of maize to fertilizer types in southwestern Nigeria. *Plant Nutrition and Crop Improvement*. 23: 444 – 449.

Montemurro, F., Fiore, A., Campanelli, G., Tittarelli, F., Ledda, L., and Canali, S. 2013. Organic fertilization, green manure and vetch mulch to improve organic zucchini yield and quality. *Horticulture Science* 48.8: 1027-1033.

Munkemuller, T., de Bello, F. and Meynard, C. N. 2012. From diversity indices to community assembly processes. a test with simulated data. *Ecography*, 35: 468–480.

Muoneke, O. O. and Mbah, E. U. 2007. Productivity of Cassava /Okra intercropping systems as influenced by okra planting density; *African Journal of Agricultural Research.* 2.5: 223 – 231, www.academicjournals.org/AJAR.

Nair, A. A. 2014. Effects of continuous cassava cropping on soil fertility status. *Soil Science Bulletin.* 8.2: 12 – 19.

Nottidge, D. O; S.O. Ojeniyi and C.C. Nottidge 2010. Grain legumes residual effects on soil physical conditions, growth and grain yield of maize in an Ultisol. *Nigerian Journal of Soil Science*. 20.1: 150 – 153.

Nweke, F.L., Spencer, D. S. C. and Lynam, J. K. 2002. The Cassava Transformation: Africa's Best-kept Secret. Michigan State University Press, East Lansing, USA. 147- 164.

Nyle, C. B. and Ray, R. W. 2014. The nature and properties of soils. 14th ed. Published by Dorling Kindersley (India) Pvt. Ltd licences of Pearson Education Inc. in South Asia, 1031 pp

Oehl, F., da Silva, G.A., Sánchez-Castro, I., Goto, B. T., Maia, L. C., Vieira H. E. E., Barea, J. M., Sieverding, E., and Palenzuela, J. 2011. Revision of *Glomeromycetes* with entrophosporoid and glomoid spore formation with three new genera. *Mycotaxon* 117: 297-316

Ogungbe, P. W. and Fagbola, O. 2007. Influence of mycorrhiza and organo-mineral fertilisers application on growth of maize cultivars in nutrient depleted soil. *Nigeria Journal of Mycology* 1: 111 – 118.

Ogunkunle, A. O. 1995. Nigerian soils and their capacity for crop production. Green, Publication of the Nigerian Association of Agricultural Student (NAAS) University of Ibadan. 7-12.

Okon, I. E. O., Solomon, M. G. and Osinubi, O. 2010. The effects of Arbuscular mycorrhizal fungal inoculation and mulch of contrasting chemical composition on the yield of cassava under humid tropical Conditions. *The Scientific World Journal.* 10: 505–511

Okon, I. E. 2011. Field response of two cassava genotypes inoculated with Arbuscular mycorrhizal fungus to *Gliricidia sepium* mulch in tropical alfisol. *Botany Research International* 4.1: 04 – 08

Olaniyi, J. O. and Tella, B. A. 2011. Effects of nitrogen and potassium fertilizers on the growth, seed yield and nutritional values of egusi melon (*Citrullus lanatus* (Thumb) mansf.) in Ogbomoso South West Nigeria. *International Journal of plant Science.* 2.11: 328 – 331. Retrieved October 20, 2013, from www.intersjournals.org/RJPS.

Olfat, K. and Jalil, K. 2012. Spore density and root colonization by arbuscular mycorrhizal fungi in some species in the northwest of Iran. *International Research Journal of Applied and Basic sciences.* 3.5: 977 – 982, http.//www.irjabs.com/

Olorunda, N. B. 2010.Trends of cassava responses to fertilization in southwestern Nigeria. *Journal of Biology and Physical Sciences*. 19: 412 – 418.

Olorunmaiye, P. M. 2010. Weed control potential of five legume cover crops in maize/cassava intercrop in a Southern Guinea savanna ecosystem of Nigeria. *Australian Journal of Crop Science.* 4.5: 324-329

Oluleye, A. K. and Akinrinde, E. A. 2011. Phosphorus-use efficiency of cassava/maize/egusi-melon and economics of phosphorus fertiliser application on Alfisols of Ekiti State, South-Western Nigeria. *Journal of Food, Agriculture & Environment*.8.2: 594 - 598.

Omueti, J. A. I., Shridhar, M. K. C., Adeoye, G. O., Bamiro, O. and Fadare, D. A. 2000. Organic fertiliser use in Nigeria: Our experience. *Agronomy in Nigeria,* Agronomy Re-union day, Wednesday 4. October 2000. 208-215.

Onuh, M. O., Ohazurike, N. C. and Ijezie, A. 2011. Effects of mung bean / melon/maize intercrop on the growth and yield of mung bean *(Vigna radiata* (L.) Wilczek*)* Cultivated in Owerri rainforest area. *World Journal of Agricultural Sciences* 7.2: 161-165. Retrieved August 13, 2013 from http.//www.idosi.org/wjas/wjas7 (2)/9.

Onwueme, I. C. and Sinha, T. D. 1999. Field crop production in tropical Africa. Published by CTA, Wageningen, Netherlands 159 - 175.

Onwueme, I. C. 2002. Cassava in Asia and the Pacific. Cassava Biology, Production and Utilization. RJ Hillocks, JM Thresh, and A Belliotti, Eds. CABI Publishing, UK, 55-65.

Osiname, O. A. 2000. Soil fertility in Nigeria: My experiences. *Agronomy in Nigeria.* Agronomy Re-union day, Wednesday 4. October 2000. M.O. Akoroda (ed). 183-194.

Ornella, L., Rita, L., Angelo, F., Giambattista. D and Francesco, M. 2010. Yield and soil responses of melon growth with different organic fertilisers. *Journal of Plant Nutrition* 36.3: 415 – 428.

Osundare, B. 2015. Changes in soil fertility status after five years of continuous Cropping.*International Journal of Innovation Sciences and Research.*4.2: 60 - 63

Oyetunji, O. J. and Osinubi O 2007. Assessment of influence of Alky cropping system and Arbscular Mycorrhizal (AM) fungi on cassava productivity in derived savanna zone of Nigeria. *World Journal of Agricultural Sciences* 3.4: 489 – 495.

Philips, J.M., and Hayman, D.S. 1970. Improved procedures for cleaning and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection. *Transactions of British Mycology Society* 55: 158 – 160.

Pukwu, W. J. 2013. Study on fertiliser effects on yield and nutrient content of cassava. *Journal of Root and Tuber Crops.* 23: 332 – 338.

Reema, S. and Adhaleya, A. 2004. Comparison of AMF spore population and total microbial count in farmers' field with various crop residue practices. *Mycorrhizal* News 16.2: 131 – 143.

Rillig, M. C. and Mummey, D. L. 2006. Mycorrhizas and soil structure. *New Phythologist* 171: 41 – 53.

Sadiq M. S, 2015. Profit efficiency of Egusi melon (Colocynthiscitrullus var. lanatus) Production in Bida Local Government Area of Niger state, Nigeria. Indian Journal of Economic Development, 11(2): 543-552. DOI No. 10.5958/2322-0430.2015.00062.1

Sadiq, M. S., Mohammed, A. and Yusuf, T.L. 2013. Economies of scale and cost efficiency in small scale *egusi* melon production. *Bida LocalJournal of Agriculture and Veterinary Science* Government Area of Niger State, Nigeria. 2.6: 92 – 97. Retrieved September 5, 2015,from www.iosrjournals.org /www.google scholar

Salami, O. O. 2014. Study on N, P, and K nutrition of cassava in Eastern Nigeria. *International Journal of Food Technology and Agricultural Research*. 21.2: 342 – 349.

Schuessler, A., Schwarzott, D. and Walker, C. 2001. A new fungal phylum, the glomeromycota phylogeny and evolution. *Mycological Research* 105: 1413-1421.

Schulthess, E., Chabi–Olaye, A. and Gounou, S. 2004. Multi-tropic level interactions in a cassava – maize mixed cropping systems in the humid tropics of West Africa. *Bulletin of Entomological Research* 94: 261 – 272

Sesato, I. G. 2013. Effects of fertiliser types on growth and yield attributes of maize. *Crop Protection.* 11.2: 1 – 6.

Singh, P. I. 2008. Influence of plant residues management techniques on soil fertility and maize performance. *Soil Fertility and Plant Nutrition*. 12: 6 – 12.

Soumare, M., Tack, F.M.G., and Aloo, M. G. 2003. Effects of a municipal solid waste compost and mineral fertilization on plant growth in two tropical fertilization on plant growth in two tropical agricultural soils of Mali. *Bioresource Technology* 86: 15-20.

Sri Budiastuti, Djoko, P., Trijono, D. S., Suharto, P. R., Linayanti, D. and Yosef, V. P. 2012. The enhancement of melon fruit quality by application of the fertiliser and gibberellin. *Journal of Agricultural Science and Technology*. 2: 455-460. Retrieved June 27, 2013, from www.google scholar

Straker, C. J., Hilditch, A. J., Rey, and M. E. C. 2010. Arbuscular mycorrhizal fungi associated with cassava (*Manihot esculenta* Crantz) South Africa. South *African Journal of Botany.* 76: 102 – 111.

Sturmer, S. L., and Siqueira, J. O. 2011. Species richness and spore abundance of Arbuscular fungi across distinct land uses in Western Brazilian Amazon. Mycorrhiza 21: 255-267.

Tanya, E. C., Brian, A. P., Todd, N. R., Mitchell, B. C. 2011.The influence of fertiliser level and spore density on arbuscular mycorrhizal colonisation of transgenic *Bt* 11 maize (*Zea mays*) in experimental microcosms. *Microbiology Ecology* 304 – 312. Retrieved October 23, 2014, from http.//dx.doi.org/10.1111/j.1574-6941.2010.01013.x

Tare, M. I. 2009. Influence of K fertilisers on the yield and chemical composition of cassava root. *Crop Improvement*. 12.1: 22 – 28.

Tening, A.S and Omueti, J. A. I. 2011. Suitability of extractants for predicting iron in soils of the humid zone of south- western Nigeria. *Agriculture and Biology Journal of North America. 2(8): 1244 – 1250.*

Thonar, C., Frossard, E., Smilauer, P. and Jansa, J. 2013. Competition and facilitation in synthetic communities of arbuscular mycorrhizal fungi. *Molecular Ecology.* 23: 733 – 746. Retrieved September 4, 2015, from http.//www.researchgate.net/publication/259315653.

Ugwu, B. O., and Ukpabi, U. J. 2002. Potential of soy-cassava flour processing to sustain increasing cassava production in Nigeria. *Outlook on Agriculture* 31.2: 129-133.

Ugwumba, C. O. A. 2010. A locative efficiency of 'egusi' melon (*Colocynthis citrullus lanatus)* production inputs in Owerri West Local Government Area of Imo State, Nigeria. *Journal of Agricultural Science*.1.2: 95 – 100. Retrieved August 31, 2015, from www.google scholar.

Ukpabi, U. J., and Ejiofor, M. A. N. 1997. Utilization of Leaves and Peels of Cassava as Livestock Feed Supplements. Cassava Processing for Health. Some Major Advances in Nigeria. MAN Ejiofor and UJ Ukpabi, Eds. Top-class Services, Umuahia, Nigeria. 82-85.

Utobo, E. B., Ogbodo, E. N. and Nwogbaga, A. C. 2011. Techniques of extraction and quantification of arbuscular mycorrhizal fungi. *Libyan Agriculture Research Centre Journal International* 2.2: 68 – 78, 2011

Verbruggen, E., El Mouden, C. and Jansa, J. 2012. Spatial structure and interspecific cooperation. Theory and an empirical test using the mycorrhizal mutualism. *American Naturalist*, 179: 133–E146.

Wagg, C., Jansa, J., Schmid, B., Van der Heijden, M. G. A. 2011a. Below ground biodiversity effects of plant symbionts support aboveground productivity. *Ecology Letters*, 14: 1001–1009.

Wagg, C., Jansa, J., Stadler, M., Schmid, B., Van der Heijden, M. G. A. 2011b. Mycorrhizal fungal\identity and diversity relaxes plant-plant competition. Ecology, 92: 1303–1313.

Walkley, A.; Black, I.A. 1934. An examination of Degtjareff method for determining soil organic matter, and proposed modification of the chromic acid titration method. Soil Science 37: 29-38.

Williams, F. L, Jeffery S and Kenneth G. C, 2014. Agricultural expansion and its impacts on tropical nature. Trends in Ecological Evolution 29.2:107–116 Retrieved February 16, 2015 from,doi.10.1016/j.tree.2013.12.001

Yusuf, O., Sanni, S. A., Ojuekaiye, E. O. and Ugbade, O.O. 2008. In profitability of Egusi melon (*Citrusllus lanatus* (Thumb) Masf) production under sole and mixed cropping systems in Kogi State, Nigeria. *Journal of Agricultural and Biological Sciences* 2.2: 14 - 18.

Yu, T., Elke, G. N., Angelika, K., Bernard, N., Eckhard, G. and Monika S. 2013. Interactive effects of arbuscular mycorrhizal fungi and intercropping with sesame (*Sesamum indicum*) on the glucosinolate profile in broccoli (*Brassica oleracea* var. Italica) *Mycorrhiza* 23: 543-550

APPENDICES

Appendix 1: Monthly mean rainfall (mm) and temperature (°C) for 2010

Months	Rainfall (mm)	Minimum Temp. (°C)	Maximum Temp. (°C)	Average Temp. (°C)
January	19.0	23.2	32.6	27.9
February	39.0	24.5	33.1	28.8
March	97.0	25.2	33.2	29.2
April	123.0	24.7	32.6	28.6
May	221.0	24.2	31.8	28.0
June	324.0	23.5	30.1	26.8
July	276.0	23.1	28.7	25.9
August	95.0	22.7	28.3	25.5
September	215.0	23.4	29.1	26.2
October	194.0	23.5	30.2	26.8
November	72.0	23.9	32.0	27.9
December	19.0	23.3	32.4	27.8

Sources: Climate data. Org, 2010 ***https://www.ncdc.noaa.gov/sotc/, 2010*** *and State of the climate; lagos - National Climatic Data Center https://www.en.climate-data.org/*

Between the driest and wettest months, the difference in rainfall is 305 mm. The average temperatures vary during the year by 3.7 °C.

Appendix 2: Daily temperature readings for composting almond leaves and poultry dung

Days	Abient temperature	Compost temperature	Days	Abient temperature	Compost temperature
1	30	46	43	30	49
2	27	46	44	28	51
3	32	50	45	29	50
4	30	48	46	28	49
5	31	50	47	29	49
6	30	50	48	30	51
7	30	50	49	28	52
8	32	50	50	29	49
9	29	52	51	30	50
10	29	55	52	28	50
11	30	55	53	29	42
12	30	54	54	26	42
13	30	55	55	25	42
14	30	55	56	25	42
15	30	50	57	26	42
16	30	55	58	26	42
17	30	55	59	26	42
18	29	55	60	26	42
19	29	55	61	28	40
20	30	55	62	28	40
21	28	54	63	28	40
22	30	55	64	28	38
23	29	56	65	28	38
24	27	54	66	28	37
25	28	56	67	26	38
26	28	56	68	28	39
27	30	55	69	28	38
28	30	54	70	27	39
29	30	55	71	28	38
30	30	55	72	28	34
31	30	55	73	28	34
32	30	55	74	27	33
33	30	53	75	27	34
34	30	55	76	28	33
35	30	55	77	28	34
36	28	55	78	29	30
37	28	55	79	30	30
38	29	53	80	29	30
39	28	51	81	30	30
40	29	51	82	30	30
41	27	55	83	30	30
42	29	49	84	30	30

Appendix 3: Fertiliser calculation and amount applied

A. Fertiliser application (Pot Experiment)

i. Organomineral Fertiliser (OF)

100 kg OF contained 4.42 kg N (Table 4.2)

Therefore, 1 kg N = $\frac{100}{4.42}$ = 22.6kg OF

Therefore, 60 kg N /ha = $\frac{100\text{kg} \times 60 \text{ kg N}}{4.42 \text{ kg N}}$ = 1357.5 kg

I hectare = 2×10^6 kg soil and required 1,357.5 kg OF

Therefore 5 kg soil = $\frac{1{,}357.5 \text{ kg} \times 5 \text{ kg OF}}{2 \times 10^6 \text{ kg}}$

$= 3.39 \times 10^{-3}$ kg $\times$ 1000 g

3.39 g $\approx$ 3.4 g OF

Material applied (OF) = 3.4 g/5 kg of soil.

ii. Compost application (pot experiment)

100 kg compost contained 2.27 kg N

Therefore, 60 kg N /ha = $\frac{100 \times 60}{2.27}$ = 2643.2 kg compost

1 ha = 2×10^6 kg soil and require 2,643.2 kg compost

Therefore, 5 kg soil = $\frac{2643.2 \times 5 \text{ kg}}{2 \times 10^6}$ = 0.006608 kg

= 6.61 $\approx$ 6.6 g compost

Compost applied = 6.6g/5 kg soil

iii. NPK (15 – 15 – 15) fertiliser application (pot experiment)

100 kg NPK (15 – 15 – 15) contained 15 kg N

Therefore, 60 kg N/ha = $\frac{100 \times 60 \text{ kg}}{15}$ = 400 kg NPK/ha

1 ha = 2×10^6 kg soil and require 400 kg NPK

Therefore, 5 kg soil = $\frac{5 \times 400}{2 \times 10^6}$ = 0.001 kg NPK

= 1.0 g NPK (15 – 15 – 15)

NPK applied = 1g/5kg soil

B. Fertiliser application in the field

i. Organomineral Fertiliser (OF)

100 kg OF contained 4.42 kg N (Table 4.2).

Then, 1 kg N = $\frac{22.6 \text{ kg OF}}{4.42}$

Therefore, 110 kg N/ha = $\frac{22.6 \times 110}{1 \text{ kg}}$ = 2486 kg OF

Approximately = 2.5 t/ha

If 1 ha (10,000m^2) require 2.5 tonnes OF

Therefore, 16 m^2 = $\frac{2500\text{kg} \times 16\text{m}^2}{10{,}000 \text{ m}^2}$ = 4.0 kg

16 m^2 require 4.0 kg OF

ii. NPK 15 – 15 – 15

100 kg NPK (15 – 15 – 15) contained 15 kg N

Therefore, 110 kg N/ha = $\frac{100 \times 110 \text{ kg N}}{15}$ = 733.33 ≈ 733 kg NPK

If 1 ha (10,000 m^2) required 733 kg NPK (15 – 15 – 15)

Therefore, 16 m^2 wide required, $\frac{733 \text{ kg} \times 16 \text{ m}^2}{10{,}000 \text{ m}^2}$ = 1.17 kg

≈ 1.2 kg NPK

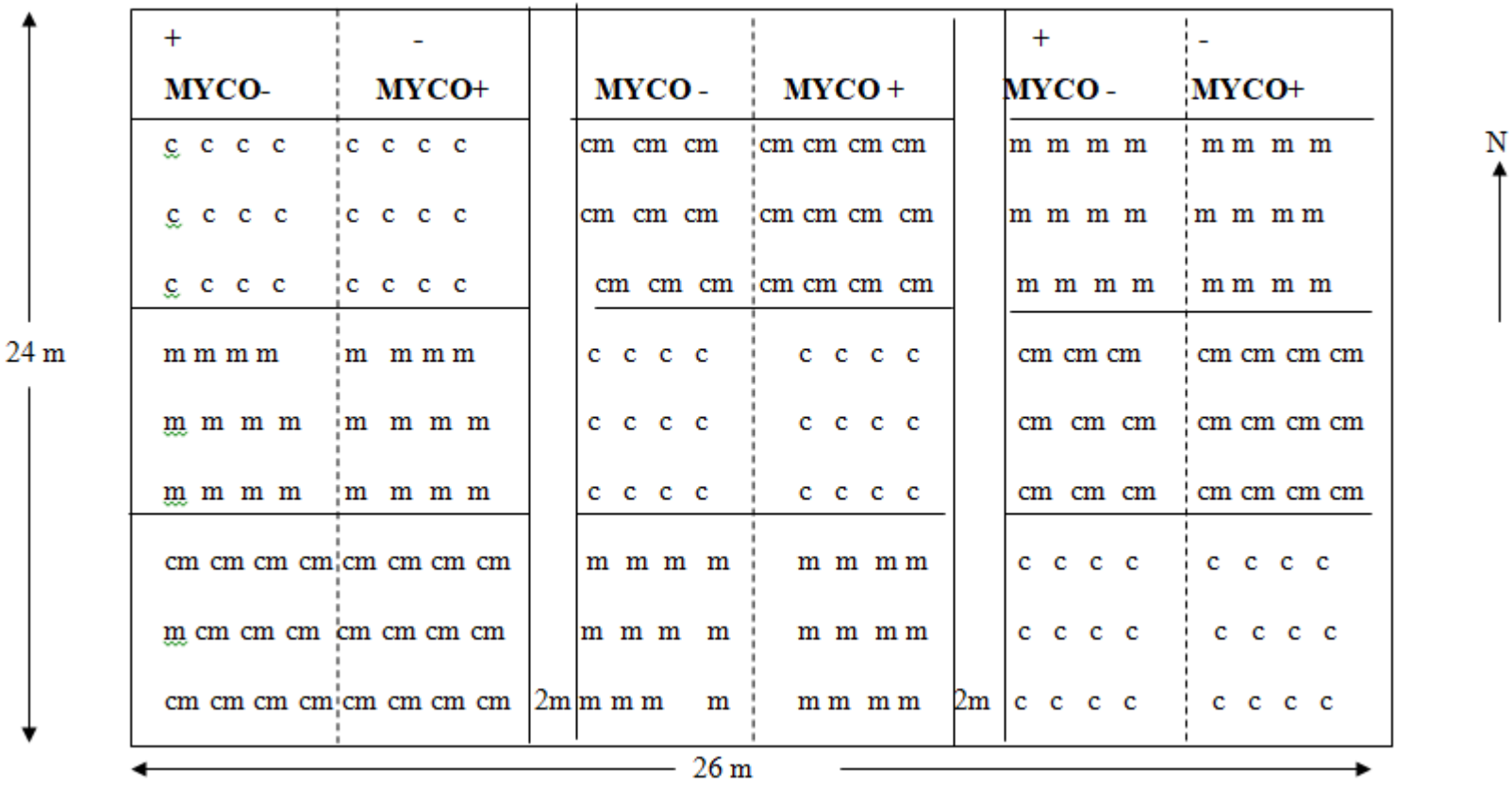
Material applied (NPK) = 1.2 kg/ 16 m^2.

Appendix 4: Monthly mean rainfall (mm) of the experimental site for 2011 and 2012

Month	2011	2012	Mean
January	0.00	0.00	0.00
February	134.60	34.65	84.63
March	72.30	105.40	84.63
April	103.00	83.45	92.23
May	146.10	181.97	164.04
June	224.40	182.65	203.53
July	156.40	279.70	218.05
August	314.90	42.85	178.88
September	280.90	204.40	242.65
November	8.00	17.50	12.75
December	0.00	0.00	0.00

Source. IITA weather station, Ibadan

Appendix 5: The plot layout for the field experiment



LEGENED.

mm = sole melon plot, **cc** = sole cassava plot,

cm = cassava and melon intercropped plots.

The total land area for the experiment was 624m^2 consisting of each block of 8m by 24m (192m^2) with 1m in between the row of each micro plot and 2m between each block for easy movement, while each micro plot measured 16 m^2.