EVALUATION OF DIFFERENT SOIL AMENDMENTS ON GROWTH AND YIELD OF THREE ACCESSIONS OF TARO (*COLOCASIA ESCULENTA*)

BY:

MRS. SOPHIA ANSAH (BSc. AGRICULTURAL TECHNOLOGY)

NOVEMBER, 2016

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI – GHANA SCHOOL OF GRADUATE STUDIES

FACULTY OF AGRICULTURE

DEPARTMENT OF CROP AND SOIL SCIENCES

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR A MASTER OF PHILOSOPHY (AGRONOMY) DEGREE

BY:

MRS. SOPHIA ANSAH (BSc. AGRICULTURAL TECHNOLOGY)

NOVEMBER, 2016

DECLARATION

I, Ansah Sophia (Mrs.) declare that this thesis presented contains no material previously published by another person for the award of a degree in any other University, except where acknowledgement has been made in the text.

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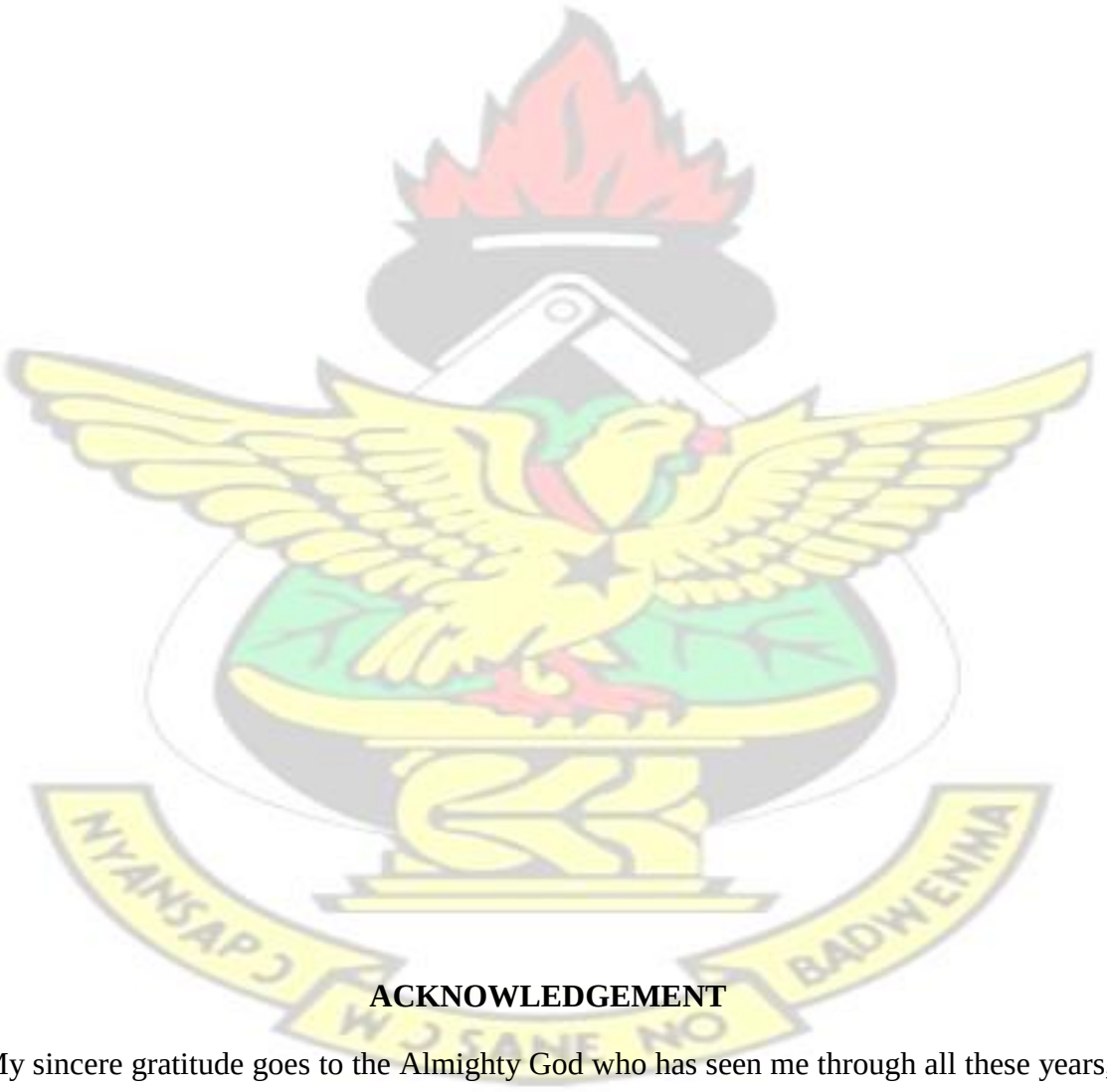
(HEAD OF DEPARTMENT)

DEDICATION

I dedicate this work to Dr. Lawrence Misa Aboagye (The Director, CSIR – Plant

Genetic Resources Research Institute) for his unmerited support to me and also to Prof. Joseph Sarkodie Addo (The Dean, Faculty of Agriculture, KNUST) for his dedication towards the completion of the work. It is also dedicated to my lovely husband, Mr. Bismark Ansah and the entire family.



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ABSTRACT

A field study was carried out at CSIR-Plant Genetic Resources Research Institute at Bunso (lat. 06° 46' N, long. 01° 01' W, 149m above sea level) in the East-Akim District of the Eastern Region to evaluate different soil amendments on growth and yield of three accessions of taro (*Colocasia esculenta*). It was a 3×4 factorial experiment and treatments were laid in a Randomized Complete Block Design (RCBD) with three replications. The

two factors studied were soil amendments and taro accessions. The fertilizer rates were 0, 60 kg NPK/ha, 4 t poultry manure/ha and combined application of 40 kg NPK/ha + 2 t poultry manure/ha. The three taro accessions studied were KA/035, BL/SM/116 and CE/MAL/032. There were variations in the vegetative and growth parameters, yield and yield components and the biochemical composition of the taro accessions. KA/035 was the least in all the vegetative growth parameters, yield and yield components except in plant height and number of suckers. Accessions CE/MAL/032 and BL/SM/116 were statistically the same in all the vegetative growth parameters, yield and yield components except in the number of leaves where BL/SM/116 was significantly higher than CE/MAL/32. Differences in the composition among the accessions were only observed in accession KA/035 in percentage moisture and calcium, while all the other elements were insignificant. Soil amendments did not significantly ($P > 0.05$) affect number of leaves, number of suckers and disease count but influenced plant height, leaf length and width, cormel weight, number and yield, corm length, diameter yield and total yield. Application of 4 t poultry manure per hectare resulted in greater plant height, cormel weight, number and yield. Generally N source did not significantly affect the composition of the accessions. The results indicated that N application is beneficial to the growth and yield of taro, without having any adverse effects on the biochemical composition of the corms. It is recommended that further studies be done with higher rates of soil amendments, as well as with different soil amendments in an attempt to enhance production and profit margin of farmers. Also, other studies can look at several organic and inorganic fertilizer combinations.

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CHAPTER ONE

1.0 INTRODUCTION

Colocasia esculenta (taro) is believed to be one of the vital world's most old food crops, with a historical past of more than 2000 years in cultivation. According to Goenaga *et al.* (1991), taro is a most important food crop in areas including Africa, Pacific and the Caribbean and belongs to the family of Araceae. FAOSTAT (2010) ranked taro the fourteenth major vegetable crops, with about 12 million tonnes produced from about 2 million hectares with a yield of 6.5 t/ha**.** The crop plays a principal role within the livelihood of farmers in the rural areas, who on the whole resort to cocoyam as their source of everyday energy throughout durations of food shortage and economic stress (Onyeka, 2014). The report of FAO (2012) indicated that nutritionally, taro is superior to cassava and yam with regards to higher protein, mineral and vitamin contents as well as easily digestible starch. According to FAO (1990), the relatively low price of cocoyam compared to yam makes cocoyam a ready alternative for yam during offseasons. In addition, it also brings foreign exchange where it is produced on large scale (Revill *et al.*, 2005).

The crop is the fourteenth most consumed vegetable worldwide (Lebot and Aradhya, 1991) serves as an export commodity. In Ghana, existing yield levels of taro production are slightly low. Ghana produced 1.8 million metric tonnes as the second highest *Colocasia* producer after Nigeria in 2005 (FAO, 2005). On a global basis, taro yields 6,000 kg/ha compared with 14,746 kg/ha for potato (*Solanum tuberosum L.*) and 13,628 kg/ha for sweet potato (*Ipomoea batatas L.)* FAO (1991). Singh *et al.* (2012) reported that cocoyam farmers in most African countries use minimal inputs. Regardless of its financial abilities as a food and cash crop and it's nutritional worth the crop is under exploited and

poorly understood. Onyeka (2014) stated that there is nonexistence of well documented and consolidated understanding on taro cultivation even though the crop is contributing extensively to the food security and earnings of many households.

Soil fertility decline is a major constraint to crop production in Ghana. Continuous land cultivation without soil amendment is a major means through which the soil losses essential plant nutrients. In the West African sub region, Ogbonna and Nweze (2012) reported that without soil amendments, growth and yield of taro is drastically reduced. Poultry manure is an effective organic fertilizer and a vital source of plant nutrients. Application of poultry manure helps improve the soil's physical conditions. Reddy and Reddi (1995) presented the average nutrient composition as 3.03 % N, 2.63 % P_2O_5 and 1.4 % K_2O. Poultry manure is an important means of creating and sustaining optimal physical condition of the soil for proper plant growth and development. Also, it is an affordable means of nitrogen for sustaining agricultural production (Rahman, 2004; Dauda *et al.,* 2008).

Generally, the Pacific and Asian countries produce higher yields of taro than those in the West African countries where it is widely grown (FAO, 1987). Research has indicated that taro yields increased in the tropical soils using inorganic nitrogen fertilizers. According to Manrique (1994), early growth development of taro requires high nitrogen fertilization. Enhanced methods of farming are essential to increase taro yields which may include the use of inorganic fertilizers (Blamey, 1996; Osorio *et al.,* 2003) as constant farming without fertilization decreases crop yield (Hartemink *et al*., 2000). The information about inorganic fertilization on taro production is inadequate compared to

other agricultural crops. Some researchers have shown that NPK fertilization enhanced growth and corm yield of taro (Udoh *et al*., 2005 and Shiyam *et al*., 2007). It is known that taro consumes substantial amounts of potassium (O'Sullivan *et al*., 1996).

The agronomic abilities and value of taro stays unidentified considering the fact that it has remained underutilized and abandoned crop in the country as a result of little awareness on the crop, which has resulted in unsafe levels of reduced economic livelihoods and loss of its genetic diversity (Akwee, 2015). In the last three decades, taro production in Africa has continuously attained an increasing percentage of global cocoyam production, which currently stands at about 10 million tonnes each year (FAO, 2012). This increase largely depends on cultivating extra land than increasing crop yields. This contradicts the predictions of FAO that the 70% growth in the world's agricultural production required to feed yet another 2.3 billion people by 2050 have got to be carried out by using increased yields and cropping intensity on existing farmlands, as a substitute than increasing the area under cultivation (FAO, 2009). It is, therefore, necessary to conduct research to come out with the appropriate agronomic practices and inputs that will help optimize yield of taro as there is very little information on soil amendment requirements and high yielding varieties.

The objectives of the study were to:

i. Determine the growth responses of the different taro accessions to soil amendments.

ii. Determine impact of different soil amendments on yield and yield components of taro.

iii. Evaluate the responses of the soil amendments on the nutritional quality of the various accessions.

iv. Determine the best soil amendment that will give optimum yield.

The above objectives were based on the following hypotheses that;

i. Application of soil amendments will increase yields of taro. ii. Soil amendments will affect the biochemical composition of taro corm.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of taro

Colocasia esculenta (L.) Schott (taro) is an aquatic and semi – aquatic, developing perennial, herbaceous plant belonging to the Araceae family, and native to Asia (Plucknett, 1976). Jianchu *et al*. (2001) reported that deliberation and research continue on the centers of its origin of taro with Northeast India and Melanesia being considered as separate centers of origin and domestication. However, ethno-botanical proof indication suggests that the crop originated from South Central Asia, probably India or the Malay Peninsula. According to Purseglove (1972), undomesticated forms are seen in

several parts of South Eastern Asia but have continually spread all over the globe and are currently a staple crop in Asia, Africa, the Caribbean and Pacific (Rao *et al*., 2010). The crop was introduced to the east coast of Africa some 2,000 years ago and was taken to West Africa and later on slave ships to the Caribbean; and is currently cultivated in over 65 countries (USDA, 2001).

Though taro is intensively produced in the Pacific Islands and forms a significant proportion of their diet, West Africa cultivates the largest area and is the leading producer of the crop (FAOSTAT, 2010). A substantial quantity of taro is also produced in the Caribbean region, as well as in most humid or sub-humid areas of Asia. The crop has been found to have naturalized in the Galapagos Islands (Tye, 2001), Canary Islands (GarcÃa-Camacho and Quintanar, 2003; Kunkel 1975) and Africa (Henderson, 2007).

2.2 Botany and morphology of taro

Lawrence (1966) reported that the family Araceae consists of 105 genera with about 1400 - 1500 species scattered principally in the tropics. *Colocasia esculenta* (L.) Schott. is one member of the family that exhibits pronounced variations in morphological characteristics. The taro plant is basically a collection of long-stemmed leaves which grows from the swollen stem/corm underground. According to Purseglove (1972), the crop grows about 1 – 2 m in height, and its species is considered to be polymorphic. Characteristic features of the plant are: a corm which lies underneath the soil surface, peltate leaves which grow from the apical bud of the corm and a fibrous root system at the lower portion. It has daughter corms, cormels, and runners which grow laterally. The corm is mainly for the storage of nutrients and has characteristically abundant periderm; food is stored in large, thin – walled parenchymatous cells with few poorly developed

vascular bundles, presence of mucilage cells, latex cells and ergastic substances like raphides and druses (Miyasaka, 1979).

According to O"Sullivan *et al.* (1996), there are eight known variants of *Colocasia esculenta* of which two are normally cultivated. These are: *Colocasia esculenta (L.) Schott* var. *esculenta,* which has a large cylindrical corm that grows up to 30 cm in length, 15 cm in diameter, and has only a few cormels; the variety is also referred to as dasheen. The corm constitutes the main edible portion of this type. *Colocasia esculenta (L.) Schott* var. *antiquorum,* also known as the eddoe type, has a small and globular central corm with a number of fairly large cormels developing from the corm (Lebot and Aradhya, 1991; Purseglove, 1972). Most *C. esculenta* varieties produce heart-shaped leaves of varying size (20-30 x 30-60 cm).

The daughter corms and cormels together form a substantial quantity of the edible harvest in eddoe taro. Daughter corms develop subsidiary shoots even when the main plant is still growing; however, cormels stay dormant and only develop new shoots after the death of the main plant if left in the soil. The daughter corm and cormels have axillary buds in the axils of the many scale leaves over its body and terminal buds at the tips.

2.3 Uses of taro

Colocasia esculenta is an essential primary staple food crop cultivated for its fleshy corms and nutritious leaves in several Pacific countries, some parts of Africa, Asia and the Caribbean (Lebot and Aradhya, 1991; Agueguia *et al*., 1992; Opara, 2001). Lee (1999)

reported that taro is one of the few staple food crops cultivated for both their leaves and corms making it a very important food crop. The corm and cormels are the main economic parts with its nutritional worth similar to sweet potato (Deo *et al.* 2009). According to both Onwueme (1999) and Ndon *et al*. (2003), the young leaves and petioles which are sometimes used for food contains about 23% protein on a dry weight basis. It is an important constituent of human diet because taro is a rich source of calcium, phosphorus, iron, vitamin C, thiamine, riboflavin and niacin.

A considerable quantity of taro is produced as a cash crop; some quantities are also produced and consumed on a subsistence basis. Excesses from the subsistence production are sold on the market eventually helping to lessen poverty. In the Pacific Island, taro is gradually becoming a major export commodity providing considerable foreign exchange (Revill *et al*., 2005).

Griffin (1982) emphasized some other economic importance of taro as: taro silage development for use as animal feed (swine); the potential of using taro starch as a raw material in cosmetic and plastic manufacture; and the possibility of using taro alcohol as fuel on remote islands. According to Lee (1999), taro flour and other products are essential components of some infant formulae in the United States and form a considerable constituent of proprietary canned baby foods.

In addition to the above, taro starch is highly digestible because it has granules of sizes below 5 μm and for this reason is highly recommended for infant foods (Nip, 1997; Aboubakar *et al*., 2008). In biodegradable plastics, toilet formulations or aerosol production, it is used as filler (Nip, 1997). Proposed to mimic oil droplet in food emulsions

such as mayonnaise, taro starch contributes to reducing the risks of cardiovascular diseases by reducing the consumption of oil (Nip, 1997).

2.4 Ecology of taro

Miyasaka *et al*. (2003) revealed that taro in its native range inhabits tropical zones ranging from sea level to an elevation of 1,800 m, warm temperatures (25-35°C) and high rainfall (1,800-2,500 mm). The crop is adapted to moist environments and can be grown under upland as well as flooded conditions. Taro can grow in areas where the water is standing; and only taro and rice can grow in such areas. Deep planting is required for optimum corm set, because shallow soils provide a restrictive environment for corm and root development. Because of high variability and unpredictability of rainfall and the cost of irrigation, the soil's ability to store water becomes an essential consideration in upland taro cultivation.

Though taro can be grown on range of soil types, best results are achieved on deep well drained, friable loamy soils with pH 5.5 - 6.5. Stony or rocky soils should be avoided because they produce deformed corms and make harvesting difficult. According to Hill *et al*. (1998), the crop has a salinity tolerance threshold (95% of maximum growth) of 4 mM NaCl.

2.5 Brief overview of plant nutrition

Chumpawade *et al.* (2005) reported that earlier studies on the chemical analysis of plants and the mineral contribution of soils initiated the modern research on plant and nutrition. A list of sixteen (16) elements was completed from the ninety (90) or more elements and

the basic concept of plant nutrition were developed in the 20th century. There are six macronutrients out of the sixteen essential elements needed by plants in large quantities which include nitrogen, phosphorus and potassium. According to Hull (2004), a dearth of an essential nutrient makes it difficult for plants to complete reproductive or vegetative stages of their life cycle. The deficiency is specific to the element in question and can be corrected or prevented only by supplying that element. Again, apart from its possible ability to correct some unfavourable microbiological or chemical condition of the soil, the element, contributes directly to the nutrition of the plant. Studies have shown that soil amendments are required after they become depleted of these essential elements in order for crops to remain productive. In order to obtain good-quality produce and high yields, optimal crop nutrition is an essential requirement. Plant nutrient requirements are obtained from both soil reserves and external sources like the atmosphere, fertilizers and organic manures (Roy *et al., (*2006).

2.6 Effect of number and size of leaf on crop growth and yield

Leaves are essential organs for photosynthesis, which is an essential process that influences crop growth rates. Photosynthesis is affected by the number and/or area of leaves. According to Karadogan and Akgun (2009), the growth and development of leaves is dependent on the plant's photosynthetic efficiency and productivity.

Work done by Mouhamed and Ouda (2006) indicated that taro yield is strongly dependent on leaves efficiency for absorption of solar radiation for photosynthesis. According to Lieth and Pasian (1990), various plant factors such as leaf position, leaf age, number of leaves, mutual shading and sink effects, and environmental factors like temperature, light, water availability and nutrition can influence leaf photosynthesis.

2.7 Effect of N, P and K on plant growth

Several studies including Boddey *et al*. (1997) and Giller and Cadisch (1995) confirmed that nitrogen is the only plant nutrient which can be added to the soil by biological fixation (BNF), however, the addition of N through BNF is inadequate to cover the loss of N with crop removal, leaching and denitrification for most cropping systems in the tropics. Improvement of crop yield in continuous cultivation needs timely application of N from inorganic and organic sources and is vital to sustain the system.

N is taken by plants as nitrates and to some extent ammonium ion. There is the conversion of nitrate to ammonium in the plant and then utilized to form protein. Nitrogen is associated with vegetative growth of plants (Adams *et al.*, 1998). It is also linked with vigorous vegetative growth, photosynthesis, and a dark green colour pigmentation (Havlin *et al.,* 2005). Availability of usable nitrogen in most agricultural conditions is a major limiting factor of plant growth and in most tropical soils yields of taro may be improved when inorganic N fertilizers are used. Studies conducted by Manrique (1994) revealed that taro requires relatively high N especially in its early stages of growth.

Phosphorus (P) is another essential macronutrient required for plant growth, but in many regions of the world it is limiting in crop production (Holford, 1997). Cordell *et al.* (2009) revealed that global P fertilizer demand continues to rise while P reserves decline. Phosphorus is used by plants for photosynthesis and nutrient/energy transport and it is

therefore, vital for cell division, growth, root lengthening, fruit and seed development, and ripening. Plant growth retards, root development and tillering are hampered and ripening delayed with P deficiency. Older leaves usually start to show P deficiency symptoms. A bluish-green to reddish colour develops, which can lead to bronze tints and red colour. A shortage of inorganic phosphate in the chloroplast reduces photosynthesis (Roy *et al.,* 2006).

The works of O'Sullivan *et al*. (1996) indicates that taro responds to potassium (K) fertilizer because the crop consumes substantial quantities of K. Potassium, one of the most essential elements in healthy soil nutrition, can significantly improve crop yields. It helps in the absorption and retention of water, sturdy stems and contributes to stronger roots, healthy crops that have longer storage life. Potassium aids the plant in using water efficiently, preventing heat damage and many diseases. Several crops depend on adequate potassium supply; they therefore, must rely on fertilizers/soil amendments to add the required quantities of potassium to soil. Potassium is important in recycling nutrients through leaves, roots and stems. K deficiency in taro is seen as a chlorosis along the leaf boundary and subsequent scorching and browning of tips of older leaves. In most plants, it shows shortened internodes, stunted growth, weak stalks, susceptibility to lodging, high incidence of pests and diseases, poor crop quality and low yield (Roy *et al.*, 2006).

According to Blamey (1996) the use of inorganic fertilizers is a vital opportunity to improve taro yields and forms a critical component of the required improved taro production systems since yields drop under continuous farming (Hartemink *et al*., 2000).

There is abundant literature on the application of inorganic fertilizers in taro production even though the information is limited when compared to other staples.

2.8 Organic manures

Mare and Modi (2009) reported that taro responds well to fertilizer application. In 2008, the State of the Future report of the Millennium Project indicated that 50% increase in food production will be needed by 2013 and double in 30 years in order to solve the present food crisis. This will have to be achieved through intensification of production on less available arable land; production intensification must, however, be environmentally safe. Many have projected between 30 and 50% increase in crop yield with nutrient inputs (Stewart, 2002).

The critical factor of soil fertility in most soils of the tropics is organic matter and this account for its use. According to Ikpe and Powel (2002) the addition of poultry manure can be able to sustain soil fertility. Maintaining soil organic matter is one of the ways to improve soil fertility and this is possible through using organic sources of fertilizer.

Many researchers elsewhere have shown that organic based fertilizers are less leached than the inorganic fertilizer (Sridhar and Adeoye, 2003). Because organic based fertilizers are cheap and less likely to pollute ground water unlike chemical fertilizers, their use has found favour in boosting crop production. It improves soil fertility status as well as increasing the income of farmers through increase in yield. Several research works, have shown that complimentary use of organic fertilizers is able to provide the desired higher sustainable crop yields than using only inorganic fertilizer (Adeoye *et al*.,

2008; Akanbi *et al*., 2010 and Ogunlade *et al*., 2011).

It is reported that there is the need to ensure soil management through organic matter application to improve crop yields (Ayenigbara, 2000). Uko *et al.* (2013) reported that the slow release of balanced nutrient resources from organic matter during decomposition and the huge residual benefit distributed across a longer time interval makes it superior to inorganic fertilizers (Obi *et al*., 2005). In addition, Muoneke and Asiegbu (1997) indicated that the gradual release of nutrient may render them unavailable to short season crops in the year of application when treatment is done shortly before cropping. Chemical fertilizers do not ensure sustainably of agricultural production since they guarantee only a rapid interim growth and yield improvements

(Funda *et al.,* 2011, Uko *et al*., 2013).

Poultry manure, is an important source of plant nutrients and for that matter an efficient organic fertilizer. Reddy and Reddi (1995) stated that poultry manure has an average N content of 3.03%, P_2O_5 of 2.63% and 1.4% of K_2O. It also improves soil physical properties because it has a rich organic matter content (Ayeni, 2011), and has often been found to increase crop yields.

2.9 Effect of suckering on yield

Suckers are produced as a lateral proliferation of the mother plant. Taro produce suckers few months after planting and these compete with the main plant for water and nutrients and reduce productivity (Oluwafemi, 2013). Suckers physiologically depend on the mother plant for resources that should have been partitioned to the storage organ. Salter and Bonnet (2000) suggested that dormant underground buds from which suckers develop

are produced several months before they actually appear. On the other hand, the actual mechanism that triggers the emergence and development of suckers is not well understood. According to Gravois *et al.* (2002), the existence of suckers in sugarcane at harvest is a probable factor for reduced sucrose content in some Louisiana varieties. Again, Gravois *et al*. (2002) suggested that sucker production may be influenced by genetic and environmental conditions because it varies with year and variety.

Studies conducted in the 20th century indicated that sucker production is critically affected by sunlight directly heating the surface of the soil. Though germination of suckers occur several months before they appear in the field, suckers generally develop in fields where crop canopy is easily penetrated by sunlight to reach the soil, causing buds underground to germinate. It must be emphasized that if suckers are not controlled, they will rob the primary leaves of needed nutrients (Oluwafemi, 2013).

2.10 Factors affecting cooking of taro corm

It is known that texture (boiled or baked), as well as volatile and non-volatile compounds affect the flavour of tubers. Flavour of food is one of the significant factors considered by consumers but remains the most difficult objective for breeders in breeding programs. Research done by Jansky (2010) showed that owing to a very complex chemistry, boiling results in changes in some compounds; also, due to unknown underlying environmental and genetics factors during growth and storage, breeding methods for improving tuber flavour is difficult and time-consuming.

Most often, consumers accept organic foods as an option for improving dietary value and assume that products are positively affected by organic farming, and that organically produced foods are more flavorsome and nutritious than conventional foods. White *et al*. (2009) in an extensive tubers mineral composition investigation concluded that concentrations of mineral is dependent on genotype and the phytoavailability of different elements to the crop. Relatively few publications are dedicated to comparisons of mineral constitution of tubers from conventional and organic cultivations. It is suggested that conventionally cultivated tubers have lower concentrations of some elements compared to tubers from organically grown crops (Wszelaki *et al*., 2005). As compared to conventional cultivation, organically grown potatoes give more tasty tubers (Rembiałkowska, 2003; Wszelaki *et al*., 2005) which had higher dry matter content (Hajšlova *et al*. 2005) but yields were lowered (Maggio *et al*. 2008). These differences in tuber flavour, dry matter and yields were, however, not reported by other authors (Warman and Havard, 1998; Maggio *et al*., 2008; Hajšlova *et al*., 2005).

2.11 Diseases of taro

Colocasia esculenta production has decreased as a result of urbanization but recent decline in growth and development has resulted from pests and diseases (Hao, 2006). *Colocasia* diseases significantly decreased the number of active leaves and have reduced yield to about 50% lower globally (Jackson, 1999). *Colocasia esculenta* is affected by a number of infectious diseases caused by bacteria, fungi, viruses and nematodes as well as noninfectious or abiotic factors. Ooka (1994) reported that fungal diseases of taro are the

most significant. According to Guarino (2010), taro leaf blight spread was reported in West Africa in 2010 and has spread to other countries including Ghana.

The disease is caused by *Phytophthora colocasiae* and was first reported in Java. It starts as a purple-brown water-soaked lesion with a yellow liquid oozing from the lesion which enlarges with time and destroys the entire lamina in 10 – 20 days. High temperature and humidity are favourable to spreading the disease. According to Jackson (1996), the disease is spread by wind and splashing rain and is capable of compelling farmers to abandon their crop fields and rely on other staple crops. The disease may occur throughout the year only if conditions (temperature and humidity) are favourable, taro leaf blight can spread the whole field within five to seven days under these favourable conditions (Ooka, 1994). Other diseases of taro include Pythium rot,

Sclerotium rot and Cladosporium leaf spot (Evans, 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The field study was carried out at CSIR-Plant Genetic Resources Research Institute at Bunso (lat. 06^{o} 46’ N, long. 01^{o} 01’ W, 149 m above sea level) in the East-Akim District of the Eastern Region of Ghana. Bunso lies in the semi-deciduous forest zone of Ghana with the soil type Nta series (FAO: Gleyic Arensol) (Adu and Asamoah, 1992). The study area is characterized by a bimodal rainfall pattern. The major season starts in March and ends in July, while the minor season is between September and midNovember.

3.2 Experimental design and treatments

The study was a 3×4 factorial experiment and treatments were laid in a randomized complete block design (RCBD) with three replications. The two factors studied were fertilizer type and taro accessions. The fertilizer rates were 0, 60 kg NPK/ha, 4 t poultry manure/ha and combined application of 40 kg NPK/ha and 2 t poultry manure/ha. The bases for choosing these fertilizer levels were based on existing information. Three accessions of taro were studied, namely KA/035, BL/SM/116 and CE/MAL/032 Ghana, Samoa and Malaysia, respectively. Each plot sized 6 m × 2.8 m with a total of twentyfour plants.

3.3 Morphological characteristics of the accessions

BL/SM/116 has a medium (50 – 100 cm) plant span, tall (50 – 100 cm) and the position of the lamina surface being erect apex down. The leaf blade margin has a purple coloration and is smooth (entire). The leaf blade colour is green with the top third colour of the petiole observed as purple. The leaf vein main colour is also purple with no variegation and there is also a purple leaf sheath edge. BL/SM/116 was collected from Samoa which is located at Polynesian region of the Pacific Ocean.

KA/035 is tall in height, medium in plant span and an erect apex down lamina surface position. The leaf blade is entire with a green leaf blade colour, the top third colour of the petiole is light green and the sheath colour is brownish. The leaf vein main colour is whitish with no variegation. KA/035 is a local variety in Ghana.

CE/MAL/32 has almost the same morphological characteristics as KA/035 except that the leaf blade margin is undulate, with dark green leaf blade colour and light green leaf sheath colour. This accession was collected from Malaysia.

3.4 Agronomic practices

3.4.1 Land preparation

The experimental field was slashed, ploughed and harrowed after which the lay-out was done.

3.4.2 Fertilization

Application of the poultry manure was done two weeks before planting and 15:15:15 NPK fertilizer was also applied two weeks after planting.

3.4.3 Planting

The planting materials which were obtained from demonstration fields within the Atiwa district were planted on 25th September, 2015. Each plot size was 6m x 2.8m and suckers were planted at 100 cm x 70 cm. Holes were dug with hoes to a depth of about 7 – 10 cm and one sucker placed gently housed in and soil was pushed around and firmed.

3.4.4 Weed control

This was done manually using the hoe as and when necessary. At least weeds were controlled every three to four weeks.

3.4.5 Irrigation

This was done mainly in the dry season, i.e. from mid-November to mid of March.

During this period the field was irrigated twice a week.

3.4.6 Disease control

Fungicide (Thiopsin 70% PM) was applied every three weeks to control taro leaf blight.

Plate 1.0: Taro at 4 WAP

3.5 Data collection

3.5.1 Soil characteristics

Soil samples were taken from five spots at 0 – 20 cm and bulked together for laboratory analyses which include % organic carbon, total N, available P and exchangeable bases (Appendix A).

3.5.2 Plant Height

Seven plants were randomly sampled from each plot, tagged and their height measured with tape measure. The height of each plant was measured from the maximum vertical distance reached by leaves, relative to ground level and the average for each plot was calculated. This was taken at four weeks interval (4, 8, 12, 16 and 20 WAP).

3.5.3 Number of leaves per plant

This parameter was taken every four weeks interval by counting the number of fully opened leaves on the mother plant of the seven (7) randomly sampled ones in each of the thirty-six plots. The average of each plot was then obtained.

3.5.4 Leaf length

Leaf length was taken by measuring the maximum length of the leaf lamina excluding petiole of the seven (7) sampled plants and an average calculated on each plot.

3.5.5 Leaf width

Leaf length was taken by measuring the maximum width of leaf lamina excluding petiole of the seven (7) sampled plants and an average calculated on each plot.

Plate 2.0: Taro plants (6 WAP) growing on the field

3.5.6 Number of suckers

Number of suckers emerging directly from the mother plant was counted from the randomly sampled plants. This was taken at every four weeks intervals after transplanting and the average for each plot was calculated.

3.5.7 Disease incidence

Disease incidence (DI) was obtained by counting the number of diseased plants over the total plant population expressed in percentage.

That is, DI = number of diseased plants / total plant population x 100

Plate 3.0: CE/MAL/032 showing taro leaf blight infestation

3.5.8 Number of cormels

This was done at harvest. The total number of cormels was obtained by counting all the cormels on the seven plants which were sampled per plot. Averages for each plot were determined.

3.5.9 Cormel yield

The electronic scale was used to measure this parameter at harvest. The total weight of cormels found on the seven plants which were sampled was obtained and averages for each plot were determined.

3.5.10 Corm length

After harvesting of the corms, corms from the seven (7) sampled plants were selected, their length taken with the aid of a tape measure and the mean calculated.

3.5.11 Corm diameter

Corms from the sampled seven (7) plants were selected, their diameter taken with the aid of a tape measure and the mean calculated.

3.5.12 Corm weight

Corms from the sampled seven (7) plants were selected and their weights taken with the aid of an electronic scale (ADAM AFP – 3100L) and mean calculated.

3.5.13 Corm yield

Electronic scale was used to measure this parameter at harvest. The total weight of corms found on the seven (7) sampled plants and averages for each plot were determined.

3.5.14 Total yield

Total yield of both corms and cormels were bulked together and their averages from each plot were determined.

$$\text{Corm yield (kg/ha)} = \frac{10000m^2 \; x \; Corm \; (kg)}{Harvest \; Area \; (m^2)}$$

3.5.15 Biochemical analysis of corm

A corm from each plot was selected and sent to the laboratory for the proximate and mineral analysis (Appendix C).

3.6 Data analysis

Data were analyzed in Analysis of Variance (ANOVA) using the Genstat statistical package (12th Edition). Treatment differences were determined with the Least Significant Difference (LSD) method at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic data and soil chemical properties of the study area.

Climatic data during the period of experimentation was collected from the meteorological substation at Bunso. Total rainfall for the study period was 3147.6 mm of rain and a mean minimum and maximum temperature of 22.9 °C and 27.8 °C respectively.

Table 4.1: Climatic data recorded for the period of study.

MONTH	RAINFALL (mm)	TEMPS (oC)		R. HUMIDITY (%)	
2015		**Min.**	**Max.**	**0900**	**1500**
September	111	22.3	31.3	83	67
October	179.8	22.6	32.3	81	70
November	48	23.3	33.22	80	62
December	-	20.4	34.4	69	37

2016					
January	-	22.0	35.5	66	37
February	1.1	23.5	37.3	74	40
March	155	24.5	35.2	79	59
April	435	24.6	34.4	80	61
May	1977.8	23.8	33	80	68
June	150	23	30.6	84	74
July	89.9	22.9	29.6	85	72

Source: Meteorological substation at Bunso (2015-2016)

4.2 Characterization of soil and poultry manure

Results of the chemical properties of soil of the study area and poultry manure used are presented in Tables 4.2 and 4.3. The organic carbon content of the soil was 1.22 % whilst total N was 0.08 %. Generally, the fertility of the soil was low. The C:N ratio of the poultry manure was 10.53 indicative of its high quality.

Table 4.2: Chemical properties of the soil and poultry manure (27th August, 2015)

Soil parameter	Value
% Organic carbon	1.22
% Organic matter	2.10
% Total N	0.08
Available P (mg/kg^{-1})	16.38
Exchangeable bases (cmolkg^{-1})	
K	0.15
Ca	5.00
Mg	1.40

pH	6.38

Table 4.3: Chemical properties of poultry manure (27th August, 2015)

Parameter	Value
Total nutrient (%)	
Organic carbon	36.02
N	3.42
P	0.64
K	1.02
Ca	1.28
Mg	1.08
C:N ratio	10.53
pH	7.98

4.3 Growth and development of taro

4.3.1 Plant Height

Table 4.4 shows the results for plant height at all sampling days. Differences in height among the accessions were significant ($P < 0.05$) at 4, 8 and 12 WAP. On these sampling days, CE/MAL/032 produced the tallest plants. At 4 WAP, plant height values of CE/MAL/032 were higher than that of BL/SM/116 and KA/035. At 8 WAP, KA/035 and BL/SM/116 accessions were of similar height and either accession was significantly shorter than CE/MAL/032. At 12 WAP, values of accession CE/MAL/32 were greater than that of BL/SM/116 only. Treatment differences at 16 and 20 WAP were not

significant (P > 0.05). Plant height was significantly affected by soil amendments on all sampling days (Table 4.4). 4 t poultry manure/ha treatment attained the greatest plant height on all sampling days, except at 20 WAP, when the combined organic and inorganic fertilizers produced the greatest effect. The 60 kg NPK treatment effect was the least at 4, 8 and 12 WAP, whilst the control treatment effect was the least at 16 and 20 WAP.

Table 4.4: Effect of various treatments on plant height of taro

TREATMENT	Plant height (cm)				
	4 WAP	8 WAP	12 WAP	16 WAP	20 WAP
ACCESSIONS					
BL/SM/116	29.9	58.7	66.0	63.6	56.0
CE/MAL/32	48.8	75.2	85.5	68.0	59.6
KA/035	37.4	64.6	77.8	67.9 **NS**	60.4
LSD (5%)	**5.56**	**8.08**	**8.07**		**NS**
SOIL AMENDMENTS				60.5	
0	36.9	60.8	72.6	64.0	50.4
60 kg NPK	34.4	59.6	70.3	71.3	58.1
4 t PM/ha	44.0	74.7	83.8	70.1	61.5
40 kg NPK + 2 tPM/ha	39.3	69.6	78.9	**6.10**	64.7
LSD (5%)	**6.52**	**9.33**	**9.32**	**2.4**	**8.77**
CV (%)	**7.7**	**0.4**	**3.7**		**6.1**

4.3.2 Number of Leaves

The results for the number of leaves under the various accessions and soil amendments are presented in Table 4.5. The accessions were significantly different in the number of leaves ($P < 0.05$) at 4, 8 and 12 WAP. CE/MAL/32 produced more leaves at 4 WAP, which was significantly higher than that of accession BL/SM/116 only. At 8 and 12 WAP, number of leaves BL/SM/116 was more than that of the other accessions. At 8 WAP, CE/MAL/32 produced more leaves than KA/035, but at 12 WAP, their numbers of leaves were similar. Differences among accessions at 16 and 20 WAP were not significant ($P > 0.05$).

On all days of sampling, soil amendment did not significantly ($P > 0.05$) affect leaf production.

Table 4.5: Effect of accessions and soil amendments on taro number of leaves

TREATMENT	Number of leaves at				
	4 WAP	8 WAP	12 WAP	16 WAP	20 WAP
ACCESSIONS					
BL/SM/116	4.03	5.61	3.45	3.37	2.42
CE/MAL/32	4.57	4.71	2.59	2.83	2.59
KA/035	4.24	3.17	2.29	2.82 **NS**	2.13
LSD (5%)	**0.36**	**0.68**	**0.36**		**NS**
SOIL AMENDMENTS				2.69	
0	4.28	4.57	2.87	3.27	2.24
60 kg NPK	4.10	4.34	2.85	2.77	2.37
4 t PM/ha	4.43	4.61	2.64	3.30	2.12
40 kg NPK + 2 t PM/ha	4.31	4.47	2.74	**NS**	2.79
LSD (5%)	**NS**	**NS**	**NS**	**11.1**	**NS**
CV (%)	**2.6**	**3.4**	**2.4**		**25.1**

4.3.3 Leaf length and width

Table 4.6 shows the results of the various treatments during the sampling period. The leaf length over the sampling period did not differ significantly ($P > 0.05$) among the accessions on the two sampling occasions. Soil amendment with 40 kg NPK + 2 t PM/ha resulted in statistically ($P < 0.05$) longer leaves compared with the control treatment only at 16 WAP. At 20 WAP, soil amendments did not significantly affect leaf length of the taro plant. Leaf width among the accessions on both sampling days was not significantly different ($P > 0.05$). The combined soil amendment effect produced longer leaves ($P < 0.05$), compared to the control treatment only at 16 WAP. Differences among the accessions at 20 WAP were not significant ($P > 0.05$).

Table 4.6: Effect of various treatments on leaf length and width of taro plants

TREATMENT	Leaf length (cm)		Leaf width (cm)	
	16WAP	20WAP	16 WAP	20 WAP

ACCESSIONS				
BL/SM/116	25.53	36.92	19.62	30.53
CE/MAL/32	23.40	33.14	19.22	28.30
KA/035	22.25	35.95	17.48	29.83
LSD (5%)	**NS**	**NS**	**NS**	**NS**
SOIL AMENDMENTS				
0	21.34	33.53	16.41	28.42
60 kg NPK	23.68	35.93	18.86	30.58
4 t PM/ha	23.87	37.29	18.94	30.20
40 kg NPK + 2 t PM/ha	26.02	34.59	20.88	29.02
LSD (5%)	**3.83**	**NS**	**3.04**	**NS**
CV (%)	**7.7**	**6.7**	**7.5**	**5.8**

4.3.4 Number of suckers

At each sampling period, the accessions were significantly different ($P < 0.05$) in number of suckers produced (Tables 4.7). Number of suckers produced by CE/MAL/32 was more than that of all other accessions on each sampling day. Number of suckers of accession KA/035 was more than that of BL/SM/116 at 8 WAP only. Soil amendments, however, did not significantly affect sucker production on all sampling days.

Table 4.7: Effect of various treatments on number of suckers of taro

TREATMENT	Number of suckers/plant			
	8 WAP	12 WAP	16 WAP	20WAP

ACCESSIONS				
BL/SM/116	1.05	1.57	1.78	1.84
CE/MAL/32	1.93	2.14	2.20	2.18
KA/035	1.48	1.70	1.78	1.80
LSD (5%)	**0.28**	**0.29**	**0.26**	**0.26**
SOIL AMENDMENTS				
0	1.39	1.66	1.80	1.84
60 kg NPK	1.45	1.73	1.81	1.82
4 t PM/ha	1.63	1.89	2.09	2.08
40 kg NPK + 2 t PM/ha	1.59	1.93	1.99	2.02
LSD (5%)	**NS**	**NS**	**NS**	**NS**
CV (%)	**8.2**	**4.6**	**6.3**	**6.7**

4.4 Yield and yield components of taro and disease incidence

Table 4.8 shows the results of cormel number, cormel weight, corm length, corm diameter and disease count. Number of cormels per plant was more in the CE/MAL/32 accession, but this was significantly higher than that of the KA/035 accession only. The poultry manure only treatment effect was the greatest among the other soil amendments, but was only significantly greater than the control treatment effect only. All other treatment effects were statistically similar.

Cormel weight showed significant differences ($P < 0.05$) in both accessions and soil amendments. Cormel weight of accession CE/MAL/32 was significantly higher than those from the other accessions, which recorded similar weights. The 4 t PM/ha treatment effect was significantly higher than the control treatment only. All other treatment effects were similar.

Corm length was similar in the CE/MAL/32 and BL/SM/116 accessions, and either effect was significantly ($P < 0.05$) greater than that of the KA/035 accession (Table 4.8). Among the soil amendments, the combined fertilizer application effect was significantly higher than that of the control treatment. All other treatment effects were similar. Corms of CE/MAL/32 accession were significantly wider in diameter ($P < 0.05$) than that of accession KA/035 only. Corm diameter of BL/SM/116 was also greater than that of accession KA/035. Corm diameter among the soil amendments showed no significant difference ($P > 0.05$) (Table 4.8).

Disease incidence (%) was highly significant ($P < 0.001$) among the accessions, with KA/035 and CE/MAL/32 recording greater disease incidence than accession BL/SM/116. Soil amendment did not significantly influence ($P > 0.05$) disease incidence.

Table 4.8: Effect of various treatments on cormel weight, cormel number, corm length, corm diameter per plant and disease count

TREATMENT	Cormel number	Cormel weight(kg)	Corm length (cm)	Corm diameter (cm)	Disease Incidence (%)

ACCESSIONS					
BL/SM/116	4.75	0.54	17.51	24.86	6.20
CE/MAL/32	5.31	0.79	17.65	25.70	95.10
KA/035	4.39	0.44	15.76	21.49	97.20
LSD (5%)	**0.77**	**0.15**	**1.61**	**1.75**	**7.49**
AMENDMENTS					
0	3.87	0.46	16.01	23.57	60.20
60 kg NPK	4.60	0.61	17.07	23.61	69.40
4 tPM/ha	5.45	0.67	16.87	24.20	67.10
40kgNPK + 2tPM/ha	5.36	0.62	17.96	24.68	68.10
LSD (5%)	**0.89**	**0.18**	**1.86**	**NS**	**NS**
CV (%)	**13.5**	**8.2**	**2.3**	**3.8**	**3.5**

4.5 Biochemical and Chemical properties

Table 4.9 shows results of the proximate (biochemical) analysis conducted on the taro. The accessions were not statistically different ($P > 0.05$) from one another in all parameters excluding moisture content. Moisture content of accession KA/035 was significantly higher than that of BL/SM/116 only.

Among the different amendments, significant differences ($P < 0.05$) occurred only in carbohydrate and moisture contents. The 60 kg NPK/ha treatment recorded the greatest carbohydrate content, which was significantly higher than that of the combined fertilizer application only. All other treatment differences were not significant.

The moisture content of the control and the combined fertilizer application treatments were similar, and either effect was significantly higher than that of the 60 kg NPK/ha treatment only.

Table 4.9: Effect of treatments on biochemical analysis of the various treatments

TREATMENT	ASH (%)	CARBOHYDRATE (%)	FAT (%)	FIBRE (%)	)ISTURE (%)	PROTEIN (%)
ACCESSIONS						
BL/SM/116	2.16	86.91	1.79	2.66	68.25	3.81
CE/MAL/32	2.62	85.68	1.84	2.80	69.99	4.24
KA/035	2.44	85.83	1.72	3.03	73.07	3.95
LSD(5%)	**NS**	**NS**	**NS**	**NS**	**4.66**	**NS**
AMENDMENTS						
0	2.64	85.81	1.56	2.97	73.60	4.04
60 kg NPK	2.18	87.36	1.75	2.46	66.45	3.79
4 t PM/ha	2.42	86.59	1.92	2.56	69.25	3.94
40kgNPK+2tPM/ha	2.39	84.79	1.91	3.33	72.45	4.22
LSD (5%)	**NS**	**2.33**	**NS**	**NS**	**5.38**	**NS**
CV (%)	**7.8**	**0.9**	**5.3**	**9.5**	**2.1**	**30.4**

Table 4.10 shows results of the mineral composition analysis of taro corms. Calcium content had significant differences ($P < 0.05$) among the accessions. KA/035 recorded significantly greater calcium content than the other accessions which had similar amounts of the element. Soil amendments also had a significant effect ($P < 0.05$) on calcium content with the control treatment recording significantly greater amount than all other treatments. All other treatment means were statistically similar. Treatment differences for all other determinations were not significant at 5% level of probability.

Table 4.10: Chemical composition of taro corms as affected by the various treatments

TREATMENT	**Fe (mg/kg)**	**Ca (%)**	**K (%)**	**Mg (%)**	**P (%)**

ACCESSIONS					
BL/SM/116	15.00	0.27	1.05	0.24	0.23
CE/MAL/32	12.00	0.22	0.73	0.23	0.29
KA/035	9.1	0.42	0.79	0.43 **NS**	0.28
LSD (5%)	**NS**	**0.06**	**NS**		**NS**
AMENDMENTS				0.45	
0	11.30	0.41	0.95	0.23	0.33
60 kg NPK	11.70	0.27	0.75	0.25	0.27
4 tPM/ha	11.00	0.25	0.86	0.28	0.25
40kgNPK+2tPM/ha	14.10	0.28	0.87	**NS**	0.21
LSD (5%)	**NS**	**0.07**	**NS**	**14.8**	**NS**
CV (%)	**21.00**	**2.4**	**3.10**		**16.20**

4.6 Corm and cormel yield

Table 4.11 shows the results of cormel yield, corm yield and total yield. Cormel yield was significantly different among the accessions. The greatest cormel yield was recorded in accession CE/MAL/32 which was significantly higher than in the others. Cormel yield of accession BL/SM/116 was also greater than that of KA/035. Among the soil amendments, the 4 t PM/ha treatment effect was the greatest but this was significantly higher than the control treatment effect only. All other treatment differences were not significant.

Corm yield was similar in the CE/MAL/32 and BL/SM/116 accessions, and both accessions produced higher corm yield than that of the KA/035 accession. The 60 kg NPK/ha treatment led to the highest corm yield, but this was significantly higher than the control treatment effect only. All other treatment means were similar (Table 4.11).

Among the accessions, total yield was greatest in CE/MAL/32, and this was

significantly higher ($P < 0.05$) than the yield of the other accessions (Table 4.11). Total yield from the BL/SM/116 accession was also significantly higher than that of the KA/035 accession. Soil amendment had significant effect on total yield. Treatment effects from all amendments were similar, but each effect was significantly higher than the control treatment effect.

Table 4.11: Cormel yield, corm yield and total yield

TREATMENT	CORMEL YIELD (kg/ha)	CORM YIELD (kg/ha)	TOTAL YIELD (kg/ha)
ACCESSIONS			
BL/SM/116	1092.0	1058.0	2149.0
CE/MAL/32	1633.0	1061.0	2694.0
KA/035	910.0	694.0	1604.0
LSD(5%)	**326.8**	**185.5**	**442.1**
AMENDMENTS			
0	948.0	787.0	1735.0
60 kg NPK	1243.0	1057.0 886.0	2299.0
4 t PM/ha	1379.0	1020.0	2265.0
40kgNPK+2t PM/ha	1277.0	**214.2**	2297.0
LSD (5%)	**377.3**	**14.1**	**510.5**
CV (%)	**8.1**		**10.3**

CHAPTER FIVE

5.0 DISCUSSION

5.1 Treatment effects on vegetative growth and development

All the accessions had plant height values greater than 50 cm at maturity and were considered as tall plants (IPGRI/IITA, 1999). Plant height at 4, 8 and 12 WAP showed significant differences among the accessions with CE/MAL/32 attaining the highest plant

height. This could be due to genetic differences between the accessions (Mangave *et al.*, 2016), which suggest that there was differential growth response of plant genotype.

The poultry manure only produced significantly taller plants than other soil amendments from 4 WAP to 16 WAP (Table 4.4). John *et al*. (2004) in their work indicated that poultry manure contains vital nutrient elements that promote high photosynthetic activities which stimulates root and vegetative growth. In addition, poultry manure is a source of nitrogen which promotes plant growth, increases the number and length of the internodes and thus results in progressive increase in plant height. Different researchers including Saigusa *et al.* (1999), Gasim (2001) and Dauda *et al.* (2008) made similar observations.

Differences in the number of leaves were significantly different in the accessions observed at 4, 8 and 12 WAP (Table 4.5). Leaf is the site where the photosynthetic process occurs, and it means that more leaves will extend the area of photosynthetic activity of the plant, and the opposite will mean less photosynthetic area. Therefore, the plant that has less number of leaf will produce less assimilates. According to LawOgbomo and Ajayi (2009), variations in leaf number affected the general performance of taro because leaves serve as photosynthetic organ of the plant.

The different soil amendments used in the experiment did not show any significant differences throughout the sampling periods with regard to leaf number. Onwu *et al.* (2008) reported no significant effect of organic manure on the vegetative growth of castor oil in the first year of cropping and explained that the seedlings had not fully established, coupled with the insufficient release of nutrients.

There was no significant difference in leaf length among the accessions which could be due to unfavourable climatic and environmental conditions as the period of the study

witnessed prolonged dry season. A similar report was made by Ogbonna and Nweze (2012) that environmental factors including moisture availability may lower availability of applied nutrients to crops.

The combined fertilizer application caused greater leaf length than the control treatment. This may be as a result of the efficiency of different sources of plant nutrients that promoted plant growth and development and this observation supports the findings of Bindra and Kharwara (1994), Elmar (2001) and Abdel Gader (2007). Additionally Ogbonna and Nweze (2012) reported that treating the soil with NPK fertilizer improved both growth and yield of taro. Similar reports were made by other researchers elsewhere (Kader and Rolle 2004; Mondal and Sen 2005; Shiyam *et al*., 2007; Mare and Modi 2009). Similarly, there was no significant difference in leaf width among the accessions used for the study. Several factors including disease buildup could have contributed to such results. Among the nitrogen treatments, effects of the combined application were greater than the control treatment. The difference could be as a result of sufficient sources of plant nutrients including nitrogen, phosphorus, potassium and many others which promote vegetative growth. Thus, the increase in leaf width under fertilizer application established the role of fertilizer in promoting vegetative growth in plants as stated by Tijani-Eniola *et al.* (2000). The control produced the least leaf width as the plants could make use of only the inherent low nutrients level in the soil.

There were significant differences in the number of suckers among the accessions throughout the sampling period, with CE/MAL/32 producing the most, followed by BL/SM/116 and the least being KA/035 (Table 4.7). Suckers are known to compete with the main plant for water and nutrients and reduce productivity (Oluwafemi, 2013). No

significant difference was observed in the number of suckers with regards to the soil amendments.

5. 2 Yield and Yield Components

The accession CE/MAL/32 produced the highest yield and yield parameters (cormel weight, yield and number, corm length, diameter and weight), and KA/035 recording the least in all the parameters mentioned above. Although CE/MAL/32 gave the highest in yield (Table 4.10), this was lower than the yield reported by FAO (1991) that taro yields 6,000 kg/ha. The period of the experiment experienced long period of drought and could be a major contributory factor for the recorded low yield. In addition, many of the corms got rotten, presumably due to increased soil temperature as a result of the drought.

Mishra and Singual (1992) observed that extremely higher temperature restricts most of the biological activities as well as increasing the potentials of roots damage (root rot). This was especially so in accession KA/035 which recorded the lowest corm yields. KA/035 was also seriously infested with taro leaf blight (Table 4.8) which reduced the number and area of functional leaves where photosynthesis will take place. Jackson (1999) reported that taro leaf blight significantly reduced the number of functional leaves and has led to yield reduction of about 50% worldwide. Genotypic differences among the accessions could also be one of the factors responsible for the differences in yield due to variations in the utilization of resources. Thus, one accession could better utilize resources applied to it than the other. Goenaga and Chardon (1995) established that there were varietal differences in nutrient uptake and dry matter accumulation in various components of taro plant.

All the amended treatments showed a significant difference in at least one of the yield components mentioned above. The poultry manure only resulted in significantly greater cormel number, weight and yield (Table 4.8). This implies that the poultry manure made available plant nutrients at a later stage of the plant growth, thus cormel size and number. Premsekhar and Rajashree (2009) stated that nutrients from organic manures are released slowly. Combined manure and fertilizer treatment was significant with corm length and corm diameter. Quansah (2010) demonstrated that the use of fertilizers (organic and/or inorganic) increased maize biomass production. The 60kg NPK/ha treatment produced the greatest corm yield and total yield. Work done by Ogbonna and Nweze (2012) showed that application of 15:15:15 NPK fertilizer increased tuber yield in cocoyam grown in south eastern Nigeria.

5.3 Biochemical Analysis

The analysis of variance for the proximate analysis indicated that there were no significant differences in the percentage ash content within the accessions which were used for the study (Table 4.9). Values ranged between 2.16% to 2.62%. These values are higher than those reported by Alinnor and Akalezi (2010), Kaur *et al.* (2011) and Owusu – Darko *et al.* (2014). There were also no significant differences in the ash content among the soil amendments; percentage ash content among the various soil amendments ranged from 2.18% to 2.64%.

Application of nitrogen fertilizer had effect on mineral content of foliage. If nitrogen is applied in the ammonium form, uptake of cations such as calcium, potassium, and magnesium is reduced (George and Thill, 1979). Other reports indicate that nitrogen fertilization on mineral composition of foliage is unpredictable. A study by Whitehead *et*

al. (1986) showed that lower concentrations of macro and micro nutrients caused mainly by dilution, whereas Reid and Jung (1974) suggested that there was little effect of nitrogen fertilization on mineral composition of foliage.

The results indicated that carbohydrate content among the accessions ranged between 85.68% and 86.91%. This was in conformity with results of Anon *et al*. (2011). Research has revealed that taro is a good source of carbohydrates for people suffering from diabetes and gastrointestinal disorders (Onwuene, 1978). Srilakshmi (2008) suggested that taro corms may have a very good digestibility. These results makes taro much more competitive with other root and tuber crops and hence its inclusion in the food system of people will enhance their health.

The fat content of the taro corm ranged between 1.84% and 1.72%, however, these were not significantly different. Boampong (2015) reported values ranging from 1.04% to 3.6%.

The differences in the accessions with regard to the fibre contents were not significant and values ranged between 2.66% to 3.03%. These values were, however, higher than those (1.87% to 2.47%) reported by Anon *et al*. (2011). The variations in the results from the other researchers might be due to differences in the genotypic make-up of the taro cultivars used for the various studies. The high crude fibre content provides roughages that enhance digestion (Eva, 1983). Dietary fibre decreases the dangers of heart diseases. It has been reported that increase in fibre intake might reduce certain diseases including diabetes, coronary heart disease, colon cancer and several digestive disorder.

There were significant differences in the moisture content of the taro corm. KA/035 had the highest moisture content of 73.07% with the least for BL/SM/116 (68.25%) and these values were quite higher than those reported by www.fao.org/docrep (54.50%). This moisture content of the accessions gives an indication that they will have a very short shelf life because moisture content greater than 12% becomes conducive for microbial growth. According to Aryee *et al.* (2006), low levels of moisture contents are favourable and give comparatively longer shelf life. Among the soil amendments, there were significant differences with respect to moisture.

The crude protein content within the accessions was between 3.81% and 4.24% with CE/MAL/32 having the highest protein content and BL/SM/116 (3.81%) the least. Although the figures were not significant, they were higher than those reported by Oladabeye *et al*. (2008) (1.41% and 1.63%) in red cocoyam and sweet potato respectively.

Minerals are vital component of diet because of their physiological and metabolic function in the body. The analysis of variance revealed that percentage calcium was different (ranging from 0.22 to 0.42%) among the accessions. These values were within range (0.29% to 0.72%) reported by Boampong (2015). Calcium is a fundamental mineral required for bone formation and neurological function of the body (Bueno and Czepielewski, 2008).

Iron content ranged between 9.10mg/kg and 15.00mg/kg with BL/SM/116 recording the highest and these figures indicate that the taro accessions used were a good source of iron. The commended dietary allowance for iron is 10 mg/day, while female adult is 15 mg/day. Iron is essential for blood formation and it is vital for normal functioning of the central

nervous system (Adeyeye and Fagbohon, 2005). It also aids in the oxidation of carbohydrate, protein and fats.

Magnesium content was not significantly different among the accessions, values range between 0.23 – 0.43%. The element plays a crucial role in calcium metabolism in bones and prevention of circulatory diseases. Both Onyiriuka *et al*. (1997) and Umar *et al*. (2005) reported similar results that magnesium aids in regulating blood pressure and insulin releases. Generally, the variations in the mineral content of these accessions were similar to the reports of Sen *et al*. (2005) and Guchhait *et al.* (2008).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The results indicated variations in growth and yield in the accessions following application of different fertilizers. Accession CE/MAL/32 produced the highest total yield. Also, corm yield and its components of the fertilized treatments increased over the unfertilized treatment, presumably because of availability of nutrients. Additionally, the results indicated that application of soil amendment did not significantly affect nutritional quality of the corms. This is good from the nutritional point of view. Finally, corm yield was highest in the poultry manure only treatment whilst total yield (corm + cormel yield) was higher in the NPK only treatment.

6.2 RECOMMENDATIONS

- From the results, accession CE/MAL/032 produced the highest yield under NPK treatment, hence farmers can adopt it to optimize yields.
- Further studies can be done with higher rates of soil amendments, as well as with different soil amendments in an attempt to enhance production and profit of farmers.
- Other studies can look at several organic and inorganic fertilizer combinations.

REFERENCES

Abdel Gader, E.O. (2007). Effect of different nitrogen sources on growth and yield of maize (Zea mays L.). Unpublished M.Sc. Thesis, Omdurman Islamic University, Faculty of Agriculture (in Arabic).

Aboubakar, Njintang Y.N., Scher J. and Mbofung C.M.F. (2008). Physicochemical, thermal properties and microstructure of six varieties of taro (*Colocasia esculenta* L. Schott) flours and starches. Journal of Food Engineering 86, 294–305.

Adam, R.M., McCarl B.A., Segerson K., Rosenzweig, C., Bryant, K.J., Dixon, B.L., Corner, R., Evenson, R.E. and Ojima, D. (1998). The economic effects of climate change on U.S. agriculture, Chap 2. In: Mendelsohn R, Neuman J (eds). The economics of climate change. Cambridge University press, Cambridge (in press)

Adeoye, G.O., Adeoluwa, O.O., Oyekunle, M., Shridhar, M.K.C., Makinde, E.A.

and Olowoake, A.A. (2008). Comparative evaluation of organo-mineral fertilizer (OMF) and mineral fertilizer (NPK) on yield and quantity of maize. Nigerian Journal of Soil Science 18:132-137.

Adeyeye, E.I. and Fagbohon, E.D. (2005). Proximate, mineral and phytake profiles of some selected spices found in Nigeria. Pak. J. Sci. Ind. Res., 48:14-22.

Adu, S.V. and Asamoah, R.D. (1992). Soils of Ayensu/Densu Basin, Nta series (FAO: Gleyic Arenosol). Soil Research Institute Memoir, 9.

Agueguia, C. A.F and Hahn, S. K. (1992). Protein analysis of ten cocoyam, *Xanthosoma sagittifolium (L) Schott and Colocasia esculenta (L)* Schott genotypes. Root crops for food security in Africa proceedings of the fifth triennial symposium, Kampala, Uganda. 348p.

Akanbi, M. O., Odaibo, A.B. and Ademowo, O. G. (2010). Effect of antimalarial druds and malaria infection on oxidative stress in pregnant women. Afri. J. Reprod. Health.14:209-212.

Akanbi, W. B., Togun, A. O., Adediran, J. A. and Ilupeju, E. A. O. (2010). "Growth, drymatter and fruit yields components of okra under organic and inorganic sources of nutrients," *American-Eurasian Journal of Sustainable Agriculture*, vol. 4, no. 1, pp. 1–13,.

Akwee, P.E., Netondo, G., Kataka, J.A. and Palapala, V.A. (2015). A critical review of the role of taro Colocasia esculenta L. (Schott) to food security: A comparative analysis of Kenya and Pacific Island taro germplasm. Scientia Agriculturae, 9(2), 101-108. Retrieved from www.pscipub.com (DOI:10.15192/PSCP.SA.2015.9.2.101108)

Alinnor, I.H.J. and Akalezi, C.O. (2010). Proximate and mineral compositions of white yam (Dioscorea drotundata) and white cocoyam (Colocoassia esulenta). Pak. J. Nutr., 9(10): 998-1001.

Anon, S.A., Rene, Y.S., Pamphile, K.B.K., Edmond, A.D. and Lucien, P.K. (2011). Biochemical characteristics of flours from Ivorian taro (colocasia esulenta cv. Yatan) corms as affected by boiling time. Advance Journal of Food Science and Technology 3(6): 424-435.

Aryee, F.N.A., Oduro, I., Ellis, W.O. and Afoakwa, J.J. (2006). The physiochemical properties of flour samples from roots of 31 varieties of cassava. Food control, 17:916-922.

Ayeni, L.S. (2008). "Integrated application of cocoa pod ash and NPK fertilizer on soil chemical properties and yield of tomato,"*American-Eurasian Journal of Sustainable Agriculture*, vol. 2, no.3, pp. 333–337.

Ayenigbara, E.A., (2000). Growth and nutrient composition of organically fertilized Indian spinach (*Basella alba L.*) in the humid tropical environment. M.Sc. Thesis, Federal University of Technology, Akure, Nigeria.

Benton Jones, J. Jr. and Vernon W. C (1990). Sampling, handling and analysing plant tissue samples. In R.L. Westerman (Ed.) Soil Testing and Plant Analysis (3rd ed.). SSSA Book Series No. 3

Bindra, A.D. and Kharwara, P.C. (1994). Growth and yield of sparing sunflower in relation to nitrogen levels and plant population. J. Agric. Res. Himachal Pradesh, India 20, 72–74.

Blamey, F.P.C. (1996). Correction of nutrient disorders of sweet potato and taro:

Fertilizers and soil amendments. In: Craswell, E.T., Asher, C.J., O'Sullivan, J.N. (Eds.), Mineral nutrient.

Boampong, R. (2015). Agro – morphological and biochemical characterization of some taro (*Colocasia esculenta* (L)Schott) germplasm. Department of Crop and Soil sciences Education, College of Agriculture Education, University of Education, Winneba. Mampong – Ashanti, Ghana.

Boddey, R.M., Sa, J.C.D., Alves, B.J.R. and Urquiaga, S. (1997). The contribution of biological nitrogen fixation for sustainable agricultural systems in the tropics. Soil Biol. Biochem. 29, 787–799.

Bray, R.H., and Kurtz, L.T. (1945): Determination of Total organic and Available forms of Phosphorus in soils. Soil Science 59: 39-45

Bueno, A.L. and Czepielewski, M.A. (2008). The importance for growth of dietary intake of calcium and vitamin D. J Pediatr (Rio J). 84(5):386-394.

Chumpawadee, S., Sommart, K., Vongpralub, T. and Pattarajinda, V. (2005). Effects of Synchronizing the rate of dietary energy and nitrogen release on ruminal fermentation, microbial protein synthesis, blood urea nitrogen and nutrient digestibility in beef cattle. Department of Agricultural Technology, Faculty of Technology, Mahasara Kham University. Mahasara Kham 44000, Thailand.

Cordell, D., Drangert J.O. and White S. (2009). The story of phosphorus: global food security and food for thought. Global Environmental Change.;19:292– 305.

Dauda, S.N., Ajayi, F.A. and Ndor, E. (2008). Growth and Yield of Watermelon (*Citrullus lanatus*) as Affected by Poultry Manure Application. Journal of Agriculture and Social Sciences, 4: 121–124.

Deo, P.C., Tyagi, A.P., Taylor, M., Becker, D.K. and Harding, R.M. (2009). Improving taro (*Colocasia esculenta var. esculenta*) production using biotechnological approaches. South Pacific Journal of Natural Science, 27.pp.6-13.

Elmar, S., (2001). The importance of ammonium sulphate nitrate (ASN) as highly efficient sulphate Sudanese crops (Fertiva CmbH, Germany). Fertilizer Workshop on May 26, 2001, Khartoum, Sudan.

Eva, R. (1983). Food, Health and you. A Book on Nutrition with Special Reference to East Africa. Macmillan publishers. London, pp: 14-25.

Evans, D. (2008). Taro: Mauka to Makai. A taro production and business guide for Hawaii Growers. Second Edition. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu.

F.A.O. (1991). Production Yearbook. Volume 45, pp. 67 – 184. 1992. Rome, Italy.

FAO (1987). Food and Agriculture Organization (FAO) production statistics.

FAO (1990). Food and Agriculture Organization (FAO) production statistics.

FAO (2009). Food and Agriculture Organization (FAO) production statistics.

FAO (2012). Food and Agriculture Organization (FAO) production statistics.

FAOSTAT 2010. FAO Statistical Database. http://faostat.fao.org.[1]

Funda, Y., Safak, C., Nilgun, M. and Bihter, C.E. (2011). Effect of organic and inorganic fertilizers on yield and mineral content of onion (*Allium cepa L.*). African Journal of Biotechnology. Vol. 10(55), pp. 11488-11492.

Garcia-Camacho, R. and Quintanar, A. (2003). Estudio preliminary de las plantas vasculares aloctonas de los Parques Nacionales espanoles. Real Sociedad Espanola de Historia Natural, Madrid, Spain, 89 pp

Gasim, S.H. (2001). Effect of nitrogen, phosphorus and seed rate on growth, yield and quality of forage maize (*Zea mays L.*). M.Sc. Thesis, Faculty of Agric., Univ. of Khartoum.

George, J.R. and Thill, J.L. (1979). Cation concentration of N- and K-fertilized smooth brome-grass during the spring grass tetany season. Agron. J. 71: 431– 436.

Giller, K.E. and Cadisch, G., (1995). Future benefits from biological nitrogen fixation: an ecological approach to agriculture. Plant Soil 174, 255–277.

Goenaga, R. and Chardon, U. (1995). Growth, yield and nutrient uptake of taro grown under upland conditions.

Goenaga, R., U. Singh, F.H Beiroth, and H. Prasad. (1991). SUBSTOR – Aroids: A model in the making. Agrotechnology Transfer 14: 1 – 4.

Gravois, K.A., B.L. Legendre, and K.P. Bischoff. (2002). Cultivar and crop effects of sugarcane bull shoots on sugarcane yield in Louisiana. J. Amer. Soc. Sugar Cane Technol. 22:42-52.

Griffin, G.J.L. (1982). *Potential applications of taro starch.* Paper presented at the Regional Meeting on Edible Ariods, Suva, Fiji.

Guarino, I. (2010). Taro leaf blight in Cameroon: Biodiversity wedlog. htt://agro.biodiver.se/2010/07/taro-leaf-blight-in-cameroon.

Guchhait, S., Bhattacharya, A., Pal, S., Mazumdar, A.D., Chattopadhyay, A. and Das, A.K. (2008). Quality evaluation of cormels of New Germplasm of taro, International Journal of Vegetable Science, 14:4, 304-321.

Hajšlova, J., Schulzová, V., Slanina, P., Janné, K., Hellenäs, K.E. and Andersson, C.H. (2005). Quality of organically and conventionally grown potatoes: fouryear study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Additives & Contaminants*, *22*(6),514-534. http://dx.doi.org/10.1080/02652030500137827

Hao, S. (2006). "Rain, pests and disease shrink taro production to record low". *Honolulu Advertiser*, February 2, 2006, p.C1.

Hartemink, A.E., Poloma, S., Maino, M., Powell, K.S., Egenae, J. and O'Sullivan, J.N. (2000). Yield decline of sweet potato in the humid lowlands of Papua New Guinea. Agric. Ecosyst. Environ. 79, 259–269.

Havlin, J.L., Tisdale, S.L., Beaton, J.D. and Nelson, W.L. (2005). Soil Fertlity and Fertilizers. Pearson Education, Inc., Upper Saddle River, NJ.

Henderson, L. (2007). Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA). *Bothalia* 37: 215-248

Hill, P.C., Pargament, K.I., Swyers, J.P., Gorsuch, R.L., McCullough, M.E., Hood, R.W., and Baumeister, R.F. (1998). Definitions of religion and spirituality. In D. DB. Larson, J. P. Swyers, M. and E. McCullough (Eds.), Scientific research on spirituality and health: A consensus report (pp. 14-30). Baltimore: National Institute for Healthcare Research.

Holford, I.C.R. (1997). Soil phosphorus: its measurement and its uptake by plants. Australian Journal of Soil Research.35:227–239.

Hull, R.J. (2004). Less familiar nutrients also deserve spotlight.

www.turfgrasstrends.com.

Hunter, R.C., Halverson, T.L. and Anderson, R.D. (1984). Quality assurance for plant tissue analysis by ICP-AES. Commun. In Soil Sci. Plant Anal., 15(11), 1285-1322.

Ikpe, F.N. and J.M. Powel, (2002). Nutrient cycling practices and changes in soilo properties in the coop-livestock farming systems of Western Nigeria. Republic of West Africa. Nut. Cyc. Agroecosyst., 62: 37-45.

IPGRI/IITA, (1999). Descriptors for taro, (*Colocasia sp.*). International Institute for Tropical Agriculture, Ibadan, Nigeria k/International Plant Genetic Resouce Istitute, Rome Italy. 56p.

Jackson, G.V.H. (1996). Strategies for taro leaf blight research in the region. Taro Leaf Blight Seminar. *Proceedings*. Alafua, Western Samoa, 22–26 November, 1993. (pp. 95–100). Noumea, New Caledonia: South Pacific Commission.

Jackson, G.V.H. (1999). Taro leaf blight. Pest Advisory Leaflet (No. 3), 2 pp. Published by the Plant Protection Service of the Secretariat of the Pacific Community.

Jansky, S.H. (2010). Potato flavour. *American Journal of Potato Research, 87*, 209-217.

Jianchu, X. Ting, Z. and Yongping, Y. (2001). Genetic diversity in Taro (*Colocasia esculenta*) in China: An ethnobotanical and genetic approach. Economic Botany 55:1.

John, L.W., Jamer, D.B. Samuel, L.T. and Warner, L.W. (2004). Soil Fertility and Fertilizers: An Introduction to Nutrient Management, Pearson Education, India pp: 106–53.

Kader, A.A. and Rolle R.S. (2004). The role of post-harvest management in assuming the quality and safety of horticultural produce. FAO Agric. Service Bulletin. P.152.

Karadogan, T. and Akgun I. (2009). Effect of leaf removal on sunflower yield and yield components and some quality characters. Helia, 32 (50): 123-134.

Kaur, M., Kaushal, P. and Sandhu, K.S. (2011). Studies on physiochemical and pastering properties of taro (*Colocasia esulenta L*.) flour in comparison with a ceral, tuler and legume flour. J. food Sci. Technol., Dio: 10. 1007/s13197-0100227-6.

Kunkel, G. (1975). Novedades y Taxones criticos en la Flora de La Gomera. *Cuadernos de Botanica Canaria* 25: 17-49

Law-Ogbomo, K. E. and Ajayi, S. O. (2009). Growth and yield performance of *Amaranthus cruentus* influenced by planting density and poultry manure application. Not. Bot. Hort. Agrobot. Cluj 37 (1) 195-199.

Lawrence, G.H.M. (1966). *Taxonomy of vascular plants* IV. Indian Edition Oxford and IBH Publication Co., New Delhi. pp. 36-40.

Lebot, V. and Aradhya, K.M. (1991). Isozyme variation in taro (*Colocasia esculenta* (L.) Schott) from Asia and Oceania. *Euphytica* 56: 55-66

Lee, W. (1999). Taro (*Colocasia esculenta)* [Electronic Version]. Ethnobotanical Leaflets.

Lieth, J.H. and Pasian, C.C. (1990). A model for photosynthesis of rose leaves as a function of photosynthtically active radiation, leaf temperature and leaf age. J. Amer. Soc. Hort. Sci., 115:486-491.

Maggio, A., Carillo, P., Bulmetti, G.S., Fuggi, A., Barbieri, G., and De Pascale, S. (2008). Potato yield and metabolic profiling under conventional and organic farming. *European Journal of Agronomy*, *28*, 343-350. http://dx.doi.org/10.1016/j.eja.2007.10.003

Mangave, B.D., Dekhane, S.S. and Patel, D.J. (2016). Effect of plant growth regulaters on growth and sex expression of bitter gourd. International Journal of Development Research, vol. 6, Issue, 04, pp. 7310-7312.

Manrique, L.A. (1994). Nitrogen requirements of taro. J. Plant Nutr. 17, 1429–1441.

Mare, R. and Modi, A.T. (2009). Influence of planting date and organic fertilization on growth and yield of Taro landraces. African Crop Sci. Conf. Proc. 9:179 – 189.

Mishra, R.K and Singhal, G.S. (1992). Function of photosynthetic apparatus of intact leaves under highlight and heat stress and its relationship. Plant physiology 98:1-6.

Miyasaka, S.C. (1979). *Calcium nutrition of taro (Colocasia esculenta (L.)Schott) and its possible relationship to guava seed disease.* MSc Thesis, University of Hawaii.

Miyasaka, S.C., Ogoshi, RM., Tsuji, GY. and Kodani, L.S. (2003). Site and Planting Date Effects on Taro Growth Comparison with Aroid Model Predictions. Agron. J., 95(3): 545-557.

Mondal, S. and Sen, H. (2005). Growth and productivity of eddoe taro (*Colocasia esculenta var antiquorum*) as influenced by fertilizer levels and spacings. J. Root Crops. 31(1):34-40

Moss, P. (1961): Limits of interference by Fe, Mn, Al and phosphate in the EDTA determination of Calcium in the presence of Mg using calcon-red as indicator. J. Sci., F. Agriculture, 12: 30-34.

Motsa, M.R. and Roy, R. N. (2008): Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. 201 pp.

Mouhamed, S.G.A. and Ouda, S.A.H., (2006). Predicting the role of some weather parameters on maize productivity under different defoliation treatments. J. Appl. Sci. Res., 2 (11): 920-925.

Muoneke, C.O. and. Asiegbu, J.E. (1997). Effect of okra planting density and spatial arrangement in intercrop with maize on the growth and yield of the component species. J. Agron. Crop Sci., 179: 201 207. |

Ndon, B.A., Ndulaka, N.H. and Ndaeyo, N.U. (2003). Stabilization of yield parameter and some nutrient components in cocoyam cultivars with time in Uyo, southern Nigeria. Global Journal of Agricultural Sciences 3: 75 – 78.

Nelson, D.W. and Sommers, L.W. (1982): Total carbon and organic matter. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.): Methods of soil analysis Part 2, 2nd ed. No.9. American Society of Agronomy. Soil Science of America. Madison, Wisconsin, USA.

Nip, W.K. (1997). Taro. In: Smith DS (ed) Processing vegetable and technology, 1st edn. Technomic Publishing, Lancaster.

O'Sullivan, J.N., Asher, C.J. and Blamey, F.P.C. (1996). Diagnostic criteria for nutrient disorders of taro. In: E.T. Craswell, C.J. Asher and J.N. O'Sullivan

(Eds.), Mineral nutrient disorders of root crops in the South Pacific. Australian Centre for International Agricultural Research, Canberra, pp. 83–90.

Obi, C.O., P.C. Nnabude and Onucha, E. (2005). Effect of kitchen wastes compost and tillage on soil chemical properties and yield of okra (*Albemoschus esculentus*). Nig. J. Soil Sci., 15: 69-76.

Ogbonna, P.E. and Nweze, N.J. (2012). Evaluation of growth and yield responses of cocoyam (*Colocasia esculenta*) cultivars to rates of 15:15:15 NPK fertilizer. African Journal of Agricultural Research, 7(49), 6553-6561.

Ogunlade, M.O., Adeyemi, E.A., Ogunleti, D.O. and Ibiyomi, P.S. (2011). "Effect of cocoa pod husk, urea fortified cocoa pod husk and NPK fertilizers on the growth and yield of *Solanum macrocarpon* cultivation," *International Journal of Organic Agriculture Research and Development*, vol. 3, pp. 1–8,.

Okalebo, J.R. Gathua, K.W. and Woomer, P.L. (1993): Laboratory methods of soil and plant analysis: A working manual. Tropical Soil Biology and Fertility. Soil Science Society of East Africa. Technical Publication No.1. Nairobi, Kenya. 88 pp.

Oladebeye, A.O., Oshodi, A.A and Oladebeye, A.A. (2008)). Proceedings of International Conference of Chemical Society of Nigeria.

Oluwafemi, A.B. (2013). Influence of number of sucker per plant on the growth, yield and yield components of Plantain (Musa sp) in Ado-Ekiti, Nigeria. Agric. Sci. Res. J. 3(2): 45-49,

Onwu, A.C., Ayuba, S.A. and Ali, A. (2008). The Effects of Organic Manure on the Growth and Yield of Castor Plant (*Ricinus cumunis*). Journal of Sustainable Development in Agriculture and Environment. 3 (2): 64-70.

Onwueme, I.C. (1979). The tropical tuber crops, yam, cassava, sweet potato and cocoyam. John Wiley and Sons, New York and Brisbone Toronto, Pp: 199227.

Onwueme, I.C. (1999). Taro cultivars in Asia and the pacific, RAP publication. Food and Agricultural organization for the United Nations Regional Office for Asia and the pacific Bankok, Thailand.

Onyeka, J. (2014). Status of Cocoyam (*Colocasia esculenta* and *Xanthosoma spp*) in West and Central Africa: Production, Household Importance and the Threat from Leaf Blight. Lima (Peru). CGIAR Research Program on Roots, Tubers and Bananas (RTB).. Available online at: www.rtb.cgiar.org

Onyiriuka, S.O., C.A. Nwadinigwe, M.N. Nwaji, L.E.S. Akpansi and U.C. Okoro, (1997). Principle of Organic Chemistry. 1st Edn., pp: 12, 206-209.

Ooka, J.J. (1994). Taro diseases: A guide for field identification. College of Tropical Agriculture and Human Resources, University of Hawaii. Honolulu, Hawaii.

Opara, L.U. (2001). Edible aroids: Post harvest operations AGST/FAO.

Osorio, N.W., Shuai, X., Miyasaka, B., Wang, R.L. and Wigmore, W.J. (2003). Nitrogen level and form affect taro growth and nutrition. HORTSCIENCE 38(1):36-40.

Owusu-Darko, P.G., Paterson, A. and Omenyo, E.L. (2014). Cocoyam (corms and cormels) – An underexploited food and feed resource. J. Agric Chem Environ 3:22-29.

Plucknett, D.L. (1976). Edible aroids: *Alocasia, Colocasia, Cyrtosperma,*

Xanthosoma. In: Simmonds NW (ed), Evolution of crop plants. Longman Press, London, pp 10-12

Premsekhar, M. and Rajashree, V. (2009). Influence of Organic Manures on Growth, Yield and Quality of Okra. American-Eurasian Journal of Sustainable Agriculture, Vol. 3 No. 1: pp. 6-8, ISSN 1995-0748

Purseglove, J.W. (1972). *Tropical crops, monocotyledons* London: Longman.

Quansah, G.W. (2010). Effect of organic and inorganic fertilizers and their combinations on the growth and yield of maize in the semi-deciduous forest zone of Ghana.

Rahman, S.A. (2004). The Place of Organic Manure in Sustaining Agricultural Development in Nigeria. Paper presented at Science Technology and Society National Workshop in Lafia, Nasarawa State.Nigeria.

Rao, V.R., Hunter, D., Eyzaguirre, P.B. and Matthews, P.J. (2010). Ethnobotany and global diversity of taro. In: Rao RV, Matthews PJ, Eyzaguirre PB, Hunter D (eds), The Global Diversity of Taro: Ethnobotany and conservation. Biodiversity International, Rome, Italy, pp 1-5

Reddy, T.Y. and Reddi, G.H. (1995). Principles of Agronomy. 2nd Edition, Kalyani Publishers. New Delhi, 110002. p. 223.

Reid, R.L. and G.A. Jung. (1974). Effects of elements other than nitrogen on the nutritive value of forage. "Forage Fertilization". Amer. Soc. Agron. pp. 420-424.

Rembiałkowska, E. (2003). Organic Farming as a System to Provide Better Vegetable Quality. In Tijskens & Vollebregt (Eds.): *Proceedings of International Conference Quality in Chains, Acta Horticulturae, 604,* 473-479.

Revill, P.A., Jackson, G.V.H., Hafner, G.J., Yang, I., Maino, M.K., Dowling, M.L., Devitt, L. C., Dale, J.L. and Harding, R.M. (2005). Incidence and distribution of viruses of taro (colocasia esculenta) in Pacific countries. Australasian Plant Pathology 34:327-331.

Roy, R.N., Finck, A. Blair, G.J. and Tandon, H.L.S. (2006). Plant nutrition for food security. A guide for integrated nutrient management. Fao fertilizer and plant nutrition bulletin 16. pp. 25 –43.

Saigusa, M., Kasagaya, Y., Watarable, A. and Shibuya, K., (1999). Ecology of apple of pru (Nieandra physalodes L.). Press and Velvet Leaf (Abudtilon avicennae Garth).

Salter, B., and G.D. Bonnett. (2000). High soil nitrate concentrations during autumn and winter increase suckering. Proc. Aust. Soc. Sugar Cane Technol. 22:322-327.

Sen, S., Bhattacharya, A., Mazumdar, D., Sen, H., Das, A.K. and Pal, S. (2005). Nutrient and antinutrient composition of cormels of *Colocasia esculenta var. antiguoum.* J. Veg. Sci. 11:17-34.

Shiyam, J.O., Obiefuna, J.C., Ofoh, M.C., Oko, B.F.D. and Uko, A.E. (2007). Growth and corm yield responses of upland cocoyam (*Xanthosoma satittifolium L*) to sawdust mulch and NKP 20:10:10 fertilizer rates in the humid forest zone in Nigeria. Continental J. Agron. 1: 5- 10.

Singh, S.V., Tiwari, A., Singh, A.V., Singh, P.K., Singh, B., Kumar, A., Gururaj, K., Gupta, S. and Kumar, N. (2012). Contamination of Natural Resources (Soil and River water) with *Mycobacterium avium* subspecies

paratuberclulosis in three districts of Uttar Pradesh: A pilot study. Haryana Vet. 51:1-5

Sridhar, M.K.C. and Adeoye, G.O. (2003). Organo mineral fertilizers from urban wastes: Developments in Nigeria, The Nigerian Field. 68:91-111.

Srilakashmi, B. (2008). Nutritional Science. (3rd ed), New Age International (p) Ltd. Publishers, New Delhi Pp: 21-39. State/Hawaii/publication/Archive/Xtar-08.

Stewart, W.M. (2002). A regional newsletter published by the Potash & Phosphate Institute of Canada (PPIC).

Tijani-Eniola, H., Nwagwu, O.W.F. and Aiyelari, O.P. (2000). Response of *Celosia argentea* L. to different nitrogen sources and frequency of harvest. Proceedings of the 18th HORTSON Conference, IAR/ABU, Zaria, May 28 – June 1, 2000. pp 151 – 160.

Tye, A. (2001). Invasive plant problems and requirements for weed risk assessment in the Galapagos Islands. In: Groves RH, Panatta FD, Virtue JG (eds), Weed Risk Assessment. CSIRO, Collingwood, Australia, pp 153-175.

Udoh, D.J., Ndon, B.A., Asuquo, P.E. and Ndaeyo, N.U. (2005). Crop production techniques for the tropics. Concept Publications Limited, Lagos, Nigeria. 446pp.

Uko, A.E., Udo, I.A. and Shiyam, J.O. (2013). Effects of poultry manure and Plant Spacing on the Growth and Yield of Waterleaf (*Talinum fruticosum* (L.) Juss). Journal of Agronomy, 12:146-152.

Umar, I. A., Ibrahim, M. A., Fari, N. A., Isah S. and Balogun, D. A. (2005). In-vitro and –vivo anti- Trypanosoma evansi activities of extracts from different parts of Khaya senegalensis. Journal of Cell and Animal Biology Vol. 4 (6), pp. 91-95.

United Stated Department of Agriculture (USDA) (2001). Crop profile for taro in American Samoa. Washington, DC: National Agricultural Statistics Service.

Warman, P.R. and Havard, K.A. (1998). Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. Agriculture, Ecosystems and the Environment. 68: 207-216.

White, M.A., De Beurs, K.M. and Didan, K. (2009). Intercomparison, interpretation and assessment of spring phenology in North America estimated from remote sensing for 1982, Ai2006. Global Change Biology, 15, 2335-2359.

Whitehead, D.C., Goulden, K.M. and Hartley, R.D. (1986). Fractions of nitrogen, sulphur, phosphorus, calcium, and magnesium in the herbage of perennial ryegrass as influenced by fertilizer nitrogen. Anim. Feed Sci. Tech. 14: 231– 242.

Wszelaki, A.L., Delwiche, J.F., Walker, S.D., Ligget, R.E., Scheerens, J.C. and Kleinhenz, M.D. (2005). Sensory quality and mineral and glycoalkanoid concentrations in organically and conventionally grown redskin potatoes (*Solanum tuberosum*). Journal of the Science of Food and Agriculture, 85(5), 720-726. www.fao.org/docrep (2016)

APPENDICES

Appendix A: Procedure for laboratory soil analysis

Soil pH

Soil pH was determined in 1:1 suspensions of soil and water using a pH meter. Twenty grams soil sample was weighed into 100 ml polythene bottles. To this, 50 ml of distilled water was added and the bottle shaken for two hours. After calibrating the pH meter with buffer solutions of pH 4.0 and 7.0, the pH was read by immersing the glass electrode into the upper part of the suspension.

Soil organic carbon

Organic C was determined by the modified Walkley-Black Wet oxidation method as outlined by Nelson and Sommers (1982). Two grams (2.00 g) of soil was weighed into 500 ml conical flask and 10 ml of 0.166 *M* (1.0 *N*) $K_2Cr_2O_7$ solution added, followed by

20 ml conc. H_2SO_4 and allowed to cool on an asbestos material for 30 minutes. A 200 ml of distilled water was added followed by 10 ml of H_3PO_4 and then 1.0 ml of diphenylamine indicator solution. This mixture was then titrated with 1.0 *N* ferrous sulphate solution until the colour changed from a blue-black coloration to a permanent greenish colour. A blank determination was carried out in a similar fashion in every batch of samples analysed without soil.

Calculation:

$$\%C = \frac{N \times (V^{bl} - V^{s})}{0.003 \times 1.33 \times 100}{g}$$

where

N =Normality of $FeSO_4$ solution
V_{bl} = ml of $FeSO_4$ used for blank titration

V_s = ml of $FeSO_4$ used for sample titration g=

mass of soil taken in gram

0.003= milli-equivalent weight of C in grams (12/4000)

1.33 = correction factor used to convert the Wet combustion C value to the true C value since the Wet combustion method is about 75 % efficient in estimating C value , (i.e. 100/75 = 1.33).

Organic matter content was determined using the formula:

% C X 1.724. (1.724 is the Conventional Van Bemellen factor)

Soil total nitrogen

Total N was determined using the Kjeldahl digestion method. Ten (10) grams soil was weighed into a 500 ml Kjeldahl digestion flask and one spatula full of copper sulphate, sodium sulphate and selenium mixture added followed by 30 ml of concentrated H_2SO4. The mixture was heated strongly to digest the soil to a permanent clear green colour. The digest was cooled and transferred to a 100 ml volumetric flask and made up to the mark with distilled water. A 10 ml aliquot of the digest was transferred into a Tecator distillation flask and 20 ml of 40 % NaOH solution added. Steam from a Foss Tecator apparatus was allowed to flow into the flask. The ammonium distilled was collected into a 250 ml flask containing 15 ml of 4 % boric acid with mixed indicator of bromocresol green and methyl red. The distillate was titrated with 0.1 N HCl solution. A blank digestion, distillation and titration were carried out without soil as a check against traces of nitrogen in the reagents and water used (Okelabo et al., 1993).

Calculation:

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

Where;

a = ml HCl used for sample titration

b = ml HCl used for blank titration

1.4 = 14 x 10^{-3} x 100 % (14 = atomic weight of N)

N= normality of HCl.

V = total volume of digest

S = mass of air dry soil sample taken for digestion in grams (10.0 g)

t = volume of aliquot taken for distillation (10.0 ml)

Available phosphorus (Bray-1 method)

Available P was determined by the Bray and Kurtz (Bray P-1) method (1945). Five grams of soil was weighed and transferred into a 50 ml centrifuge tube. Thirty (30) ml of Bray-1 extracting solution (0.025 *N* HCl + 0.03 N NH_4F) was added. Soil suspension was shaken for five minutes via a mechanical reciprocating shaker and allowed to stand for 2 minutes and then centrifuged for 10 minutes at 3000 rpm.

Working standards in Bray 1 extractant using 5 clean 250 ml volumetric flasks were prepared. 0, 2, 4, 8, 12, 16 and 20 ml of stock 250 µg P / ml of KH_2PO_4 (A.R. grade) solution were pipetted into each 250 ml volumetric flask and made up to the 250 ml mark using Bray 1 solution. The working standards contained respectively 0, 1, 2, 4, 6, 8 and 10 µg P/ml in 250 ml volumetric flasks.

One (1.0) ml of the clear supernatant solution (sample), blank and the standard solutions were pipetted into a set of clean 15 ml centrifuge tubes. Six (6) ml of distilled water was added and mixture shaken vigorously followed by the addition of 2.0 ml of molybdate-HCl reagent. Finally, 1.0 ml of 1.76 % solution of ascorbic acid (reducing reagent) was added to the mixture and was vigorously shaken. The mixture was allowed to stand undisturbed for 6 minutes for development of the blue coloration after which the percent transmittance values were recorded at 650 nm wavelength on a colorimeter or visible range spectrophotometer.

A graph of absorbance versus concentration (ppm) P was plotted. Read the unknown samples and obtain ppm P by interpolation on the graph plotted.

The P content was determined by comparing the recorded values to a standard curve plotted using standard P solutions after the percent transmittance (% T) was converted to absorbance by the formula:

Absorbance = 2- log T.

Calculation:

ppm P (µg P / kg soil) = C* 30/5

= C* 6

Where;

C = concentration derived from the standard curve

30/6= volume of extractant/ dilution factor.

Exchangeable cations by ammonium acetate solution (ph=7.0) (Moss, 1961)

Ten (10.0) grams of soil was weighed into a 150 ml extraction bottle and 100 ml of 1.0 *N* NH_4AOc solution (pH=7.0) was added. This was shaken for 1 hour on a mechanical reciprocating shaker. Potassium content was read by means of Jenway PFP 7 Flame Photometer after calibration with prepared K standards.

Appendix B: Laboratory procedure for poultry manure analysis

Total Nitrogen

A spatula full of a mixture of Sodium Sulphate, Copper and Selenium was added to 2 g of the poultry manure sample weighed into digestion flasks and 30 ml of H_2SO_4 was added to each mixture to convert organic and nitrate nitrogen to ammonium sulphate, NH_2SO_4. The mixtures were digested on a bench flame connected to an extractant for about one and

half hours, allowed some time to cool and decanted into 100 ml volumetric flasks, topped with distilled water to the 100ml mark (system 1002) and followed by distillation which was done by a Kjedahl Distillation Unit where 10 ml of 4% boric acid was poured into a conical flask and four drops of bromocresol green methyl red indicator was added. 15 ml of 40% NaOH was added to 10 ml of the digests in other conical flasks heated to vapourize ammonia, condensed, and collected over into the boric acid and indicator solution which changed from red to blue and was removed when flasks were about 100ml full. The blue solution was titrated against 0.1 N

HCl until a red end point was obtained. The titre value was read and used to obtain the amount of Nitrogen.

Total Phosphorus

Ten grams of the poultry manure sample was put in a furnace for 4 hours to be ashed. A 20 ml of Bray – P 1 solution was added to 2 g of the ashed sample in shaking bottles, shaken on a Stuart Reciprocating Shaker for one minute and filtered with filter papers. A 10 ml of the filtrate was pipetted into a 25 ml volumetric flask (the test is run along a blank which is water) and added with 1 ml of ammonium molybdate and HCl solution after which L - ascorbic acid was also added. This is the colour development stage. Transmittance was measured by a Jenway 6051 calorimeter at 600 nm wavelength after the solution was topped up with distilled water, shaken and allowed to stand for 30 minutes for colour change. The solution was compared with standard solutions to determine the amount of phosphorus.

Total Potassium

Ten grams of the organic samples were ashed for 4 hours in a furnace. A 100 ml of ammonium acetate (pH 7) was added to 1 g of the ashed samples in a shaking bottle, shaken in a Stuart Reciprocating Shaker for one and half hours, filtered and filtrate compared against standards of 2, 4, 6 and 8. A Jenway Flame Photometer was used to read the emission of the solution at 600 μm.

Organic Carbon

Ten milliliters of 1.0 N potassium dichromate and 20 ml of concentrated H_2SO_4 were added to 0.5 g of the compost sample in a flat bottom flask, shaken and allowed to stand for 30 minutes. It was run along a blank test without compost. A 200 ml of distilled water (H_2O), 10 ml of orthophosphoric acid and small amounts of diphenalamine indicator were added and titrated against 1 N ferrous sulphate. The titre value was read and used to determine the amount of carbon.

Appendix C Procedure for Proximate and Mineral Analysis

Procedure for moisture determination

The moisture can was weighed and 5.0 g of the sample was also weighed into the moisture can. This was allowed to dry overnight in an air oven at 105 ^oC for 24 hours and the sample re-weighed.

Calculations

(A + B) - A = B

(A + B) - (A + C) = B – C = D

% Moisture = D/B × 100

Where A = crucible weight, B = sample weight, C = dry sample weight, D = moisture weight.

Procedure for ash determination

Ash crucible was removed from the oven, placed in a desiccator cooled and weighed. Two grams (2.0 g) of the sample was weighed into a porcelain crucible in duplicate placed into furnace for 4 hours at 550 ^{o}C which was allowed to cool below 200^{o}C for 20 minutes. Finally, the crucible was placed in a desiccator with stopper top, cooled and weighed.

Calculation

(A + B) – A = B

(A + C) – A = C

% Ash = C/B × 100 where A = crucible weight, B = sample weight, C = ash weight.

Procedure for ether (fat) determination

A piece of filter paper was folded to hold the sample; a second filter paper was wrapped around it and left opened at the top. A piece of cotton wool was placed at the top to evenly distribute the solvent as it drops on the sample during extraction. The sample packet was placed in the butt tubes of the extraction apparatus and extraction with petroleum ether for 2 hours was done without interruption by gentle heating. This was allowed to cool and the extraction flask dismantled which was followed by evaporation of the ether on the steam

until no odour of the ether remains. It was then cooled at room temperature for overnight after which the dirt or moisture was carefully removed outside the flask and was weighed.

Calculations

(A + B) – A= B

% ether extract = B/C x 100

Where A = flask weight, B = ether extract weight, C = sample weight

Procedure for crude fibre determination

Weighed residue was transferred from the ether extract to a digestion flask and 200 ml of the boiling H_2SO_4 solution was added. The digestion flask was connected to the condenser and heat was applied. After 30 minutes, the flask was removed, filtered through linen and washed with boiling water until washings are no longer acid. NaOH solution was heated to boiling point and kept under constant temperature until the reflux condenser is used. The residue is washed back into a flask with 200 ml of boiling NaOH solution which was then connected to the flask with reflux condenser and boiled for 30 minutes. The flask was removed and filtered through the Gooch crucible. After thorough washing with boiling H_2O, it was washed with 15 ml of 95% ethanol, this was followed by drying the crucible and its content at 110 ^oC to constant weight. It was then cooled in a desiccator and weighed. Finally, the crucible was burnt in muffle furnace at 550^oC for 30 minutes until the carbonaceous matter was

consumed which was then cooled in a desiccator and weighed. Losses in weight were recorded as crude fibre.

Calculation

% crude fibre $= \frac{A-B}{C} x\ 100$

where A = wt. of dry crucible and sample

B = wt. of incinerated crucible and ash, C = sample weight

Procedure for crude protein determination

Two grams (2.0 g) of the sample was weighed and transferred to a 30 ml digestion flask. One spatula of full of Kjeldahl catalyst and 20 ml concentrated H_2SO_4 was put into the digestion flask. Boiling chips was added and digested till the solution turned colourless. After cooling the digest, it was diluted with a small quantity of distilled ammonia free water and transferred to the distillation apparatus. A 100 ml conical flask containing 5 ml of acid solution with a few drops of mixed indicator with the tip of the condenser dipping placed below the surface of the solution. Then, 10 ml sodium hydroxide – sodium thiosulphate solution was added to the test solution in the apparatus which was followed by distilling and collecting the ammonia on boric acid. The tip of the condenser was rinsed and solution titrated against the standard acid until the first appearance of violet colour, i.e. the end point. Lastly, a reagent blank with equal volume of distilled water was run and subtracted the titration volume from that of sample titration volume.

Calculation

The N content of the sample can be calculated by the formula:

$$N\ (g\ kg^{-1}) = \frac{(ml\ HCl - ml\ blank)\ x\ Normality\ x\ 14.01}{\text{Weight of sample (g)} \times 10}$$

Calculation of Nitrogen Free Extract

Principle

The calculation of nitrogen- free extract (NFE) is made after completing the analysis for ash, crude fibre, ether extract, and crude protein. The calculation is made by adding the percentage values on dry matter basis of these analysed contents and subtracting them from 100%.

Calculation

NFE (%) on DM basis = 100% - [% ash on DM basis + % crude fibre on DM basis + % ether extract on DM basis + % protein on DM basis]

% Carbohydrate = % NFE + % Crude fibre;

NFE = digestible carbohydrate

Preparation and dry ash digestion of cocoyam (taro) for elemental analysis (Hunter *et al.*, 1984) and Benton Jones, *et al.*, 1990)

One (1.0) gram of sample was weighed into a clean ceramic crucible. An empty crucible was included for a blank in each batch of 24 samples. The samples were arranged in a cool muffle furnace and temperature ramped to 500^{o}C over a period of 2 hours. This temperature was allowed to remain for an additional 2 hours. The samples were allowed to cool down in the furnace.

Samples were then removed from furnace ensuring that the environment is free from breeze. Ashed samples were transferred first into already numbered 50 ml centrifuge tubes. Crucibles were rinsed with 10 ml of distilled water into the centrifuge tubes. More rinsing of the crucible with 10 ml of aqua regia was done. The samples were shaken for 5 minutes for proper mixing on a mechanical reciprocating shaker. Samples were then centrifuged for 10 minutes at 3000 rpm and then transferred into 100 ml volumetric flask and again made up to the 100 ml mark. The clear supernatant digest were decanted into clean reagent bottles for P, Ca, Mg, K, Na, Zn, Cu, Mn, and Fe determinations.

Method of determination of iron (Fe)

The basic setup (air pressure = 50 – 60 psi, acetylene pressure = 10 -15 psi and voltage = 208 – 240V) of the AAS was ensured. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths - Fe at 248.3 nm. A calibration curve was plotted for the element to be analyzed from the stock standards

(Buck Scientific). The prepared sample solution digest were analyzed for the element. The Y in the calibration equation is absorbance of the element and X is the concentration of the element in the sample. X was calculated after substituting the absorbance reading of the sample into the calibration equation. This gave X in terms of mg/L. The total concentration of the element in the sample solution (100 ml) was calculated by multiplying the concentration in mg/L by 0.1L. This gave the total mass of the element in solution. The percentage amount of the element was found by dividing the mass of the element in solution by initial amount of sample taken followed by a multiplication by 100.

Calculation:

$$\text{Conc. (Fe) (mg/kg)} = \frac{\text{Concentration recorded from AAS X Nominal volume}}{\text{Sample weight (g)}}$$

Where,

Nominal volume =100 ml

Sample weight = 1.00g

Method of determination of Phosphorus (P) (Motsa *et al.*, 2008) and Moss (1961) A vanadomolybdate reagent was prepared by dissolving 22.5 g of ammonium molybdate in 400 ml of distilled water and 1.25 g of ammonium vanadate in 300 ml of boiling distilled water. The vanadate solution was added to the molybdate solution and cooled to room temperature. 250 ml of analytical grade HNO_3 was added to the solution mixture and diluted to 1 litre with deionized water. The standard phosphate solution was also prepared by dissolving 0.2195 g of analytical grade KH_2PO_4 in 1000 ml distilled water.

This solution contains 50 µg P/ml. A standard curve was prepared by pipetting 1, 2, 3, 4, 5 and 10 ml of standard solution (50 µg P/ml) in 50 ml volumetric flasks. 10 ml of

vanadomolybdate reagent was added to each flask and the volume made up to 50 ml. This gave a P content of the flasks as 1, 2, 3, 4, 5, and 10 µg P/ml. These concentrations were measured on the Spectronic 20 spectrophotometer to give absorbance measurements at a wavelength of 420 nm. A plot of absorbance against concentration was used to prepare the calibration curve. 10 ml of the sample solution was transferred into a 100 ml volumetric flask. 10 ml of vanadomolybdate reagent was added and volume made up to 100 ml. The sample was kept for 30 minutes for colour development. A stable yellow colour was developed. The sample was read on the Spectronic 20 spectrophotometer at 420 nm. The observed absorbance was used to determine the P content from the standard curve. The % P was calculated as:

P content (g) in 100 g sample (% P) = $\frac{C\ x\ df\ x\ 100}{1\ 000\ 000} = \frac{C\ x\ 1000\ x\ 100}{1\ 000\ 000} = \frac{C}{10}$

Where C = concentration of P (µg /ml) as read from the standard curve;

df = dilution factor, which is 100 *10 = 1000, as calculated below:

1 g of sample made to 100 ml (100 times);

5 ml of sample made to 50 ml (10 times)

1 000 000 = factor for converting µg to g

Method of determination of potassium (K) using flame photometer

A 1.908 g and 2.542 g of analytical grade KCl and NaCl respectively previously dried in an oven for 4 hours at 105^{o}C were each dissolved in 200 ml of deionised water. The two solutions were mixed together and volume made up to 1000 ml. This gave a combined standard of 1000 ppm. For K, a calibration curve (standard curve) of 200, 400, 600 and 800 ppm was prepared. All the absorbance reading was taken using the flame photometer.

The sample solution from the $HClO_4$ and HNO_3 was read on the flame photometer. From the standard curve, the concentration of K was calculated using the particular absorbance observed for the sample.

Calculation:

K content (µg) in 1.0 g of plant sample = C x df

K content (g) in 100 g plant sample, (% K) = $\frac{\text{C x df x 100}}{\text{1000 000}} = \frac{\text{C x 100 x 100}}{\text{1000 000}} = \frac{\text{C}}{\text{100}}$ Where

C = concentration of K (µg / ml) as read from the standard curve

df = dilution factor, which is 100 x1 = 100, calculated as : ➢ 1.0 g of sample made up to 100 ml (100 times)

- 1000 000 = factor for converting µg to g.

Method of determination of calcium (Ca) and magnesium (Mg)

Calcium and magnesium determination by EDTA titration involves addition of several reagents. These reagents were prepared as;

Buffer solution – 60 g of ammonium chloride was dissolved in about 200 ml of distilled water. 570 ml of concentrated ammonium hydroxide was added and diluted to 1000 ml in a volumetric flask.

Potassium cyanide: 10 % KCN (W/V) was prepared by dissolving 50 g of KCN in 500 ml of distilled water in a volumetric flask. This solution complex off all cations that react with EDTA.

Potassium hydroxide: 10 % KOH (W/V) was prepared by dissolving 100 g of KOH in a litre of distilled water. Necessary when determining Ca^{2+} since it enables it to react with EDTA.

Calcon – red (cal – red) indicator: This indicator gives red coloration when Ca^{2+} is absent but gives bluish color when Ca^{2+} is present.

Triethanolamine (TEA): 30 % (V/V) was prepared by diluting 300 ml TEA in a litre of distilled water. This is a viscous solution which is included to maintain p H.

Erichrome Black T (EBT): 0.2 g of EBT was weighed and dissolved in a mixture of 50 ml methanol (85 %) and 2 g hydroxylamine hydrochloride. Indicator for determining Ca^{2+} + Mg^{2+}. Gives red coloration in the absence of Ca^{2+} + Mg^{2+} and bluish coloration in the presence of Ca^{2+} + Mg^{2+}.

0.02N EDTA Solution (Versenate): 3.723 g of reagent grade disodium ethylenediamine tetra acetate dehydrate was dissolved in distilled water. It was diluted to 1000 ml and standardized against magnesium solution with EBT indicator (one ml of 0.02 N EDTA = 0.4 mg Ca = 0.24 mg Mg). EDTA complexes with Ca^{2+} and removes it from solution giving a blue end point in the presence of Ca^{2+}.

Calcium standard (0.02 N): 1.0 g of reagent grade calcium carbonate ($CaCO_3$) was dissolved in 1 ml of conc. HCl and diluted to 1000 ml with distilled water.

Magnesium standard (0.02 N): 2.465 g of reagent grade magnesium sulfate

heptahydrate was dissolved in 1000 ml distilled water.

Determination of calcium

A 5.0 ml of sample solution was transferred into a 100 ml Erlenmeyer flask. 10 ml of 10 % KOH solution was added followed by 1 ml of 30% TEA. Three drops of 10 % KCN and few drops of EBT indicator solution. The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02 N EDTA solution from a red to blue end point.

Calcium in mg = Titre value of EDTA x 0.4008

$$\% \text{ Calcium} = \frac{\text{mg Calcium} \times 100}{\text{Sample wt x volume}}$$

Determination of magnesium

5.0 ml sample solution from 3.4.2.2 was emptied into a 100 ml Erlenmeyer flask. 5 ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1 ml 30% TEA. Three drops of 10 % KCN and a few drops of EBT indicator solution.

The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02 N EDTA solution from a red to blue endpoint.

Magnesium in mg = Titre value of EDTA x 0.243

$$\% \text{ Mg} = \frac{mg\ Magnesium}{Sample\ wt\ x\ Volume} x\ 100$$