RESPONSES OF *WOROWO [Senecio biafrae* (Oliv. & Hiern.) S. Moore] TO COMPOSTS ENRICHED WITH ORGANIC NITROGEN SOURCES

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DEDICATION

To the Almighty God, the author and finisher of my faith, the beginning and the end, who made it possible for me to complete this study, despite all odds.

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ABSTRACT

Worowo (*Senecio biafrae)* is a semi-wild, indigenous and nutritious vegetable. Demand for *worowo* is increasing due to its nutritional values, thus necessitating its domestication for increased production. However, there is limited information on soil fertility requirements of *worowo* and the use of inorganic fertilisers for its production could be expensive and detrimental to environment. Composts are more environment-friendly and effective in improving soil fertility but their use are constrained by low nitrogen contents, thereby necessitating enrichment with various nitrogen sources. Therefore, responses of *worowo* to organically nitrogen-enriched composts were investigated.

Composts from Cattle Dung+Sawdust-CDS at 1:1 (w/w) and Poultry Droppings+Sawdust-PDS at 1:1 (w/w) were enriched to 15, 30, 45 and 60 g N/kg with meals from dried bone-BnM, blood-BM, hoof-HM, and horn-HnM, neem-Nm and Tithonia leaves-TM. Compost treatments obtained were: CDS and PDS (no enrichment added), CDSBnM, CDSBM, CDSHM, CDSHnM, CDSNM and CDSTM; PDSBnM, PDSBM, PDSHM, PDSHnM, PDSNM and PDSTM. Compost treatments (30 t/ha) in 2.0 kg soils and control (soil alone) were incubated for 16 weeks for nitrogen analysis. W*orowo* was raised in pots with CDS, PDS and 60 g N/kg enriched composts at 30 t/ha and control (soil alone), compared with 60 kg N/ha NPK 15-15-15 in a completely randomised design with three replicates. Edible Shoot Yield (ESY) of *worowo* (t/ha) was measured at 180 Days After Planting (DAP). On the field, effects of CDSNM (60 g N/kg) at 0, 10, 20, 30 and 40 t/ha were compared with NPK 15-15-15 at 60 kg N/ha on the ESY of *worowo* at 180 DAP, using randomised complete block design with four replicates, in two raining seasons. Samples of *worowo* edible shoots at harvest at the two seasons were analysed for Crude Fibre-CF (%). Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

Highest and least N (g N/kg) contents (9.2 and 0.4) from soils incubated with compost treatments were from CDSNM at 60 g N/kg (16 weeks) and control (8 weeks), respectively. In pots, ESY (t/ha) of 60 g N/kg CDSNM (54.93±1.91) was significantly higher than NPK (36.53±1.27) and others but similar to CDS (50.93±1.77) while pots treated with PDS were lowest (8.00±0.28). At first season on the field (180 DAP), CDSNM at 40 t/ha had the highest ESY (8.66±1.24) which significantly differed from other treatments except CDSNM at 30 (6.30±0.90) and 20 (5.53±0.79) t/ha while control gave lowest (3.00±0.43). The ESY (180 DAP) from CDSNM at 40 t/ha (10.55±1.95) was highest in the second season and differed significantly from other treatments but comparable to CDSNM at 30 t/ha (7.30±1.35). Lowest ESY (1.41±0.26) was from plots allotted to NPK. At first season, CF contents of 60 g N/kg CDSNM treatments, NPK 15-15-15 and control were in the order: 40 t/ha-12.00±0.59> NPK-11.20±0.59> 30 t/ha-11.00±0.59> 20 t/ha-10.62±0.59>Control-10.50±0.59> 10 t/ha-10.45±0.59, which followed the same order at the second season.

Cattle dung-sawdust compost enriched with neem to 60 g N/kg applied at 30 t/ha improved edible shoot yield and crude fibre of *worowo*, hence could be adopted for its production.

Keywords: Compost-Enrichment, Organic Nitrogen sources, Nutrient release, Growth responses, Nutritional qualities, *Senecio biafrae*

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CHAPTER ONE

1.0 INTRODUCTION

Green leaf vegetables, which are the succulent parts of plants grown in gardens, are an essential part of the African diet (Chyma and Igyor, 2007). They are usually consumed alongside with starchy staple food (Guarino, 1995) and are valuable components of many Nigerian families' diets. Leaf vegetables are notable sources of essential food nutrient like protein, minerals, vitamins and fiber, often lacked by the regular diets, especially in rural areas (Mosha *et al*., 1995). Although, reliable statistics on production and consumption are scarce, the abundance of various types of vegetables in most food markets in Nigeria is a pointer to their usefulness in human diets (Dairo and Adanlawo, 2007).

There are several neglected and under-exploited indigenous vegetables found growing spontaneously in the wild/semi-wild state and not given any cultivation attention. One of these neglected and under-exploited indigenous leaf vegetables is *Senecio biafrae* (Oliv. & Hiern, S. Moore). It is called *worowo* in Yoruba (Nigeria) and bologi in Sierra Leone. *Worowo* (*Senecio biafrae*) grows wild in West Africa's forest zone, where the fresh succulent leaves are prepared for consumption as a vegetable, after seasoning with pepper, tomato, and onions. In Sierra Leone, *worowo* leaves are steamed or boiled before being served as a vegetable with okra and fish. The increasing awareness of the potentials of *worowo* in terms of yield, nutrient compositions and roles in nutritional health which compare favourably with or exceed the routinely-cultivated leaf vegetables are stimuli to their domestication for regular cultivation. However, they are often scarce in most urban markets which is an indication of their being threatened by extermination. Therefore, for optimum production and hence, increased availability of these indigenous vegetables in markets at reasonable and attainable prices, an urgent move to develop management practices which farmers will be encouraged to adopt becomes necessary.

Generally, the tropical soils have low levels of organic matter and accessible nutrients. This had caused a rapid decline in the productivity and sustainability of the soils of the tropics, especially when cultivation is on a regular basis, without proper management (Zingore *et al*., 2003). Soil fertility is decreasing very rapidly in Africa, but the expectations for increased crop production are still built on these fragile resources. However, farmers encounter great difficulties in getting plants nutrients supplied from supplementary sources, particularly inorganic fertilisers which are becoming gradually inaccessible to the real farmers; hence, land use intensification to meet food needs, without nutrient inputs from external sources becomes eminent. The continuous use of agricultural lands accentuates soil nutrient 'mining' which has caused crop production to be stagnated or on a rapid decline. The problem of nutrient depletion must therefore be urgently addressed; so as to prevent the rapidly declining agricultural output from jeopardizing the sustainable economic growth. Reduction of soil organic matter content is gradually becoming a prominent aspect of soil degeneration, particularly in Nigeria, therefore, soil fertility restoration and management must target raising the available nutrient status and maintaining organic matter content at high levels. The relative cost and ease of availability are parts of the factors considered in the choice of fertilisers selected (Peter *et al*., 2004) even as the controversy rages over organic versus inorganic sources of nutrients. Plants would not discriminate between organic and inorganic nutrient sources but their tiny roots would only absorb nutrients that have been mineralized into inorganic, water soluble ions and radicals. However, the results of several studies comparing organic and inorganic fertilizers in terms of supplying an equivalent amount of nitrogen (N) have favoured organic fertilisers due to their competence in improving soil's physical attributes and nutritional qualities, including microbiological activities (Ahn, 1993). These positive effects are noticeable in soil fruitfulness and productivity (Anikwe, 2000). Proper investigation of organic fertilisers, particularly manures and composts, could be profitable means of soil fertility improvement for sustainable production of vegetables, such as *worowo*.

Compost is an organic fertiliser made from the regulated and monitored biological breakdown of organic materials that have been sterilized, stabilized, and cured to the point where they are useful to plant growth. Its use alleviates the nutritional, physical and biological aspects of soils by increasing soil organic matter quality and quantity, as well as the number, diversity, and activity of soil organisms

(Rodale, 2012). Compost has therefore become a valuable ingredient in organic farming. On the other hand, using mineral fertilisers alone increase crop yields only for a few years after which yields decline due to increase in soil acidity level which would definitely increase nutrient imbalance and toxicity (Ojeniyi, 2002; Adeoye *et al*., 2008).

In Nigeria, *worowo* is a common, volunteer, under-storey plant in cocoa plantations found in the lowland rainforest and dry upland forest especially in the south-west zone. The decline in cocoa production due to the concentration of national economy on petroleum resources, as well as seasonal wild fire destroying the farms, had led greatly to a serious decline in the production of *worowo*. This decline has led to the vegetable becoming scarce and often costlier than *Amaranthus* spp, *Celosia argentea* or *Corchorus olitorius* vegetables (Adebooye, 2004). Cultivation of *worowo* is practised on a small scale mainly in south-western part of Nigeria where sale of the succulent vines, in small bunches, is predominantly in urban markets. Increased and optimum production of this neglected and under-exploited indigenous vegetable will greatly increase the income of farmers and traders, particularly women, and therefore contribute to alleviating rural poverty. This desired enhancement can only be realized through the accelerated production of this vegetable and one of the cultural requirements is soil fertility management. However, there is paucity of information on nutrient requirements for optimum production of *worowo*. Research investigations therefore become necessitated, to ascertain the soil fertility requirements of *worowo* vegetable in order to develop recommendations which farmers could adopt to attain optimum production.

Justification of the study

Worowo is an important source of nutritive substances, particularly in rural areas, where these are often lacking in regular daily meals. This indigenous, under-exploited leaf vegetable is highly nutritional and medicinal and has valuable nutrient composition (Ijarotimi *et al*., 2010). It is medicinally important and had been reportedly used for treatment of diabetes, high blood pressure and infertility (Bello *et al*., 2018). Unfortunately, its soil fertility requirements have not been established due to a lack of agronomic research on the species. Moreover, w*orowo* is becoming scarce in most urban markets and this is an indication that its production may be exterminated in the nearest future. Increased cultivation of this indigenous vegetable, with a view to making it available at cheap prices in food markets then becomes a necessity. This further underscores the need for the development of management practices which will facilitate its optimal production.

One of the components of improved cultural practices for crops is nutrient management, especially the use of organic fertilisers (IAEA, 2021) whose effects have been more beneficial on soils in the tropics than the supply of nutrients from inorganic fertilisers (Ahn, 1993). Nutrient management is one of the components of enhanced crop cultural practices, particularly the use of organic fertilisers, which has been shown to be more beneficial to tropical soils than inorganic fertilisers. Organic agricultural approaches that enhance natural nutrient supply systems are therefore being advocated, in the recent times. Unfortunately, despite the importance and long history of composts in agriculture, low nitrogen contents have been the major limitation. This creates a serious challenge for organic farming when it comes to getting enough nitrogen during the growth and developmental stages of plants (Stockdale *et al.*, 1992; Wilson *et al.*, 2001). The implication is that the extent to which N in the compost would support crop performance is limited and additional N input is inevitable. This thereby necessitates efforts aimed at identifying the possible materials available, for improvement of N content of composts at low cost. Such efforts had been in the: - fortification of manures with inorganic N fertilisers and mineral ores, complementary use of manure-chemical fertilisers, development of organo-mineral soil additives (Zahir *et al*., 2007), use of microbiotic enzymes to improve decay/rotting woody substances (Manjunatha and Ravi, 2013) and bio scientifically-energetic materials (Ahmad *et al*., 2009). Few works have been done on potentials of various farm scraps, as sources of organic N, as enrichment materials, to improve nitrogen contents of various composts. The cattle enterprise is a rich nursery/home of effluents, such as bone, hoof, blood and horn which can be collected, desiccated, ground and made into meals that can be used to enrich composts with organic nitrogen. The dried leaves of plants, such as neem and Mexican sunflower, can also be prepared into useful meals for composts enrichment.

Objectives of the Study

This study therefore:

i) assessed nutrient status of some compost ingredients (cow dung, poultry droppings and sawdust) and their potentials as organic N sources;

ii) assessed the rate at which nutrients are released from the enriched composts;

iii) identified the most suitable enriched compost for improved and optimum production of *worowo* (*Senecio biafrae*);

iv) assessed the responses of *worowo* (*Senecio biafrae*) vegetable to various levels of the identified enriched compost;

v) determined the effects of various rates of the identified enriched compost on the nutritional quality of *worowo* (*Senecio biafrae*); and

vi) evaluated the residual effects/aftermath of the identified enriched compost on soil parameters, growth and yield of *worowo*.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Vegetables in Nigerian diets

The diet of most Nigerians is based on starchy cereals (maize, rice, sorghum, millet) roots and tubers (yam, cocoyam, sweet potato) which are low in proteins, minerals and vitamins. The health implication of this deficiency is protein and vitamin malnutrition such that other sources must be sought to supplement the low levels of these essential food components.

Vegetables are plants or parts of plants (stem, roots or leaves) which are edible, excluding mature seeds and fruits (John, 1993). In food and nutrition terminology, vegetables are palatable plants or parts of plants which may be cooked or eaten raw (Harri and Bianchini, 2003). Salads and savoury or salty foods are the most common ways to eat vegetables. Products which are vegetable derived refer to a great variety of processed foods that incorporate vegetable ingredients. Vegetables contain good supplements of vegetable protein, fats, minerals (calcium (Ca), iron (Fe)), vitamins such as carotene, pro-vitamins, thiamine, carbohydrates, and some dietetical nutrients and supplements (Whitaker, 2001), which are necessary for appropriate growth, eye sight development and the formation of strong teeth and bones. These herbaceous plants are particularly, strong providers of vitamins A, C, and foliate (folic acid), as well as thiamine (B1) and riboflavin (B2). They also contain some useful amounts of vitamin E (USDA, 1998). The consumption of vegetables in diets lowers susceptibility to heart disease and diabetes, protects against growth of certain cancer cells and reduces bone loss. The potassium (K) content of vegetables has been linked to the prevention of kidney stones. Furthermore, various phytochemicals are found in vegetables, which possess the ability to inhibit oxidation reaction, and growth of disease-causing organisms (bacteria, fungi, virus) and carcinogenic materials (Steinmetz and Potter, 1996; Gruda, 2005). Fibre and some other important nutrients which are required and necessary for gastro-intestinal functions and formation of healthy hair and skin are reportedly being contained by some vegetables. Presence of toxins and anti-nutrients such -solanine and -chaconine (Finotti, 2006) enzyme moderators, cyanide indicants and toxic organic acids, could cause edibility of vegetables, including its nutrient value and health advantages to be harmed. However, cooking, boiling and some other forms of preparation, on the other hand, could eliminate or diminish these anti-nutritional elements. Adequate production and consumption of vegetables, should therefore be emphasized in the nation's health programme through output expansion, efficient marketing, post-harvest handling of produce (preservation, storage, processing and utilization) which would ensure availability of vegetables in large quantities and at affordable prices, at all times and places. The many foodstuffs provided by vegetables as rich sources of carbohydrates, proteins, vitamins, minerals and oil ensure easy and cheap nutritional well-being from balanced diets, variety in taste precedence and absence of sameness in food intake (Fayemi, 1999). A trip through rural and urban food markets would reveal the diversity of vegetables available as condiments (ingredients) needed to prepare the soups, stews and sauces used to eat the starchy staple foods and so would contribute to nutritional status, health and well-being of the population in Nigeria.

Badmus and Yekinni (2011) noted that production of foreign and new vegetables is a thriving business that has been an encouraging source of income for the growers, and that; government participation in rural extension programmes and services, introduction of better, new and uncommon variety of vegetable seeds and issuing suitable incentives to growers, could stimulate profit maximization. An increase in output would significantly impinge the household food security, particularly those of urban areas. The assessment by the National Fadama Development Programme showed that irrigated vegetables could be planted alone, or as a mixed crop within some other crops. Ibrahim and Omotesho (2011) opined that boosting the long-term viability of fadama vegetable production will necessitate the design of policies that favour land consolidation in fadama communities. In Nigeria, dry-season vegetable production under irrigation, characterized by intense mixed cropping, has become such a key source of income that adequate land for the numerous growers is always scarce. However, well-jointed, formal or informal irrigation techniques, whether on a small or medium scale, that can serve a large number of growers, is the major determinant of sustainable irrigated vegetable production in Nigeria (Dittoh, 2014). Increased awareness and gender training, according to Adebooye (2014), have empowered women's access to resources, allowing them to make independent decisions about the type and size of land to cultivate, sources of credit, fertiliser purchasing, quantity, and application method, irrigation time, harvest time and how much to sell the harvested vegetables.

Adeyanju (2014) reported low consumption level of leaf vegetables in Nigeria and noted the preference for fluted pumpkin (*Telfairia occidentalis)* leaves which is believed to boost blood supply. Since marital status, religion and level of awareness were observed to determine the consumption of leaf vegetables, strategic awareness-raising campaign to impact people's behaviour was suggested. A kind of nutrition education, to increase people's knowledge of nutritional importance of leaf vegetables, so as to foster the development of personal skills and motivation to habitually consume leaf vegetables was also recommended.

2.2 Indigenous vegetables

Vegetables had been identified as (i) wild plants which grow spontaneously in their natural habitat and are not cultivated such that regeneration is by natural means; (ii) semi-wild plants frequently encountered in homestead gardens or compound farms and in farmlands and protected during land clearing and weeding; and (iii) cultivated plants harvested from regular farms where they benefit from routine cultural practices Okigbo (1983). The three sources represent phases of plant domestication and commercialization in which indigenous vegetables can be regular features. Vegetables that are native to or originated in a certain place or habitat are known as indigenous vegetables. It includes naturalized species and variants that have evolved over time from materials introduced to the region from another geographical area. The natural vegetation cover in the agro-ecological zones contains edible vegetables whose casual and daily harvests are the ingredients in a variety of traditional dishes (Okafor, 1983). This is because very few vegetables are eaten raw while those cooked are innumerable and consist of herbs, shrubs and young leaves of trees but which may be processed to the dried forms for use during the dry season. The wide knowledge gap between what is eaten or not in particular places and cultures, discovery of new uses for some plants and because abandoned species would become useful to meet dietary needs during periods of famine or ecological disasters make the compilation of the list difficult. Indigenous vegetables have short production cycles which are labour intensive, with few purchased inputs but with production of high yields and sound nutritional value (Schippers, 2000). These indigenous vegetables are simpler to grow, pest-resistant, and acceptable to local tastes (Ekesa *et al*., 2009). These reasons qualify the use of our native vegetables as befitting as cash crops in peri-urban systems, as vegetables for subsistence farming in homestead farms or gardens, as new crops, and as a tool for variation in production systems and diets' diversification. They can provide both subsistence and income to rural, peri-urban, and urban populations without requiring substantial capital inputs. However, these traditional and orthodox varieties are being phased out in favour of high-yielding commercial cultivars, which are perceived to be more profitable and hence favoured by most farmers (Agric. Business Week, 2012). Olufolaji and Denton (2000) gave a list of semi-wild under-utilized and neglected vegetables in Nigeria. The agronomic information needed for their optimum production is lacking and efforts are being made to domesticate them and study their production techniques. *Worowo* is included in the list. It has been confirmed to be an example of the vegetables indigenous to West Africa (Adebooye, 2004).

2.3 *Worowo* as an indigenous vegetable

Worowo **(**Sierra Leone 'bologi': *Crassocephalum biafrae* (Oliv. and Hiern) S. Moore); Syn. *Senecio biafrae* (Oliv. and Hiern) belongs to the family Asteraceae, which has its origin in West Africa, probably from Sierra Leone or Guinea (Adebooye, 2004). *Worowo*, a perennial climbing plant which is about 3 m long, usually consists of a cylindrical, succulent, and heavily branched stem (vine) that is usually braced by a trellis or a semi-permanent stick or rod (Adebooye, 2004). The plant grows naturally in the forest zone and is mainly collected from the wild. It also occurs as a weed in the cocoa plantations in south-western Nigeria and so protected during weeding even as the cocoa trees provide shade, support and stakes. *Worowo* can be cultivated in home gardens and occasionally in fields where adequate moisture, enough shade and wooden pole stakes are provided. The juicy, succulent leaves and stem portions are used as a leaf vegetable which is usually consumed majorly in Nigeria, in the southern zone but less consumed around the West and Central Africa's humid zones (Adebooye, 2004).

Plants with purple or green stems exist and are being divided into these two categories based on their colour. Succulent leaves with long slender stems, glaborous, a bit triangular (Plate 2.1), typically with one or two side segments of about 5-8 cm x 3-5 cm, exceptionally 15 cm x 8 cm, with new leaves that are borne vertically and matured leaflets, dangling (Schippers, 2000). The flowers are borne in stalked clusters that are endmost or short, abundant and cream in colour. About 1800 seeds per gram which are distinct from the fruits, glaborous, consciously carinated, dark brown, pointed and 3-5 cm long are produced.

The plant is suitable to growing under light shade as an under-storey climber in the humid vegetation possessing an estimated rainfall value around 1,500 mm annually. When directly exposed to sunlight, the characteristic growth of the vegetable is limited. The plant is grown in nutrient-dense soils; particularly, organic matter and are moist, well-drained, and fertile. It is frequently grown under cocoa trees where the moist conditions ensure that growth continues in the dry season (Adebooye, 2004).

Planting is done with stem pieces (20-25 cm long) collected from mature vines with the leaves cut off, but seed propagation is also possible. The cuttings are planted 1.5×1.5 m^2 in tilled plots to allow for field management when the plants start branching, usually under a tree, to provide shade and support. Where natural shade or support are not obtainable, staking is required in the form of horizontal trellis 1 m high, wooden poles 1.5 m long, or along a fence consisting of chicken wire/mesh. Mulching with plant materials and watering are advantageous during the dry season. A frequently-used management practice is the removal of flowering shoots in order to encourage leaf production (Schippers, 2000). Shoots' yield output can be gathered from 60-70 days after planting and may last for a year or longer, depending on the plant's vitality, to get about 15 kg of leaves from each vegetable plant in each year (Adebooye, 2004). The harvest remains fresh for 3 days under humid conditions. *Worowo* is locally marketed for domestic consumption, as there are no records of inter-regional trade (Adebooye, 2004).

Worowo has medicinal properties and its juice is applied to sore eyes (Adelakun *et al*., 2018). It can also be used as a replacement for spinach in soups and stews' preparation. The moisture, calories, protein, fat, carbohydrate, fibre, calcium and phosphorus contents of *worowo* leaves were recorded to be 7.9 %, 64 g, 3.2 g, 0.7 g, 14 g, 1.9 g, 260 mg and 52 mg, respectively (FAO, 1968). Leaves of green-stemmed *worowo* contain; 12.3 g, 11.8 g, 342 mg, 39 mg and 53 mg respectively, of protein, fibre, calcium, phosphorus and iron, per 100 g dry matter, whereas the leaves of the purple-stemmed species contain 11.6 g, 10.5 g, 320 mg, 46 mg, 53 mg of crude protein, crude fibre, calcium, phosphorus and iron, per 100 g dry matter (Adebooye, 1996).

Plate 2.1: ***Senecio biafrae*** **(*Worowo*) on the field, before staking**

2.4 Reasons for organic farming

Soil, as an active natural medium is mainly known to support plants' growth. Soil, environment and farm productivity benefit from proper management of soil quality. When this happens, the soil can be used at length without interruption, weakening or losing in power or quality and so able to support humans now and far into the future. An healthy living soil is expected to be balanced in nutrients, with high humus content and diversity of soil organisms (fungi, bacteria, protozoa, arthropods, algae, earthworms, small mammals etc) and contain organic matter (Preston, 2001).

Soil fertility is based on the environment's physical, biological, and chemical features but it is also greatly influenced by human management practices. Conventional practices associated with mechanized large open farms, continuous deep tillage, excessive utilization of synthetic amendments, including agrochemicals and luxury watering have been indicted for soil degradation. Soil nutrient depletion is primarily caused by the continuous extraction of nutrients from the soil through crop removal without adequate restoration (Isitekhale and Osemwota, 2010), soil formation processes, geographical location, climate, irrigation water applied, cropping history and tillage practices (including continuous cultivation). Thus, in turn, external inputs must be used in order to rectify the negative nutrient budgets and therefore preserve soil productivity. The interrelated environmental problems of desertification, erosion, accelerated greenhouse effects, global warming and climate change also have roots in this soil degradation whose reversal will require the use of natural processes and optimization of their functions to retain productivity on the farms. Zingore *et al*. (2003) concluded that there has been an increased intensity of agricultural land use for food production which had depleted soils of humus and readily available nutrient elements, resulting in diminished productivity and long-term viability. Yearly, about 5 to 10 million hectares of cultivable lands are taken out of production due to soil erosion, nutrient exhaustion, salinization and water- logging (Hole *et al*., 2005). Due to the enumerated factors, crop productivity is declining fast in many agricultural lands.

Soil deterioration is majorly characterized by a decrease in soil organic matter content. Degraded soils become unfertile and produce poor yields which compromise food security, reduce rural income and cause risks to the environment (Alain, 2004). Nutrient depletion is the main reason why crop production systems are not sustainable, therefore, soil fertility restoration and management must target raising the available nutrients status and maintaining organic matter content at high levels. To introduce additional nutrients into the negative nutrient budget of crop output system, utilization of inorganic amendments as a form of fertiliser has become imperative in Nigeria (Kekong *et al*., 2010). Fertilisers are available in several forms and types whose choice by farmers is influenced by the relative cost and ease of availability (Peter *et al*., 2004). Chemical fertilisers, as 'green revolution' inputs, have raised farm yields substantially, depending on management practices and environmental conditions. The fertilisers are often too expensive for subsistence farmers or may be uneconomical and difficult to obtain (Hartemink, 2004). The scarcity and high cost of the fertilisers in most African countries have prompted research focus on the promotion of cheap, locally available organic fertilisers (Adediran *et al*., 1999).

The controversy rages on over the usage of organic and inorganic nutrition sources despite the fact that plants do not distinguish between these sources. Plants can absorb only nutrients in the ionic inorganic forms and the sources do not matter. However, the results of various investigations comparing manure and chemical fertilisers to provide similar quantities of nitrogen had usually approved the manure as being better, basically due to its capability for the improvement of the general characteristics of soil (Ahn, 1993). Chemical fertiliser use would only boost crop yields for a few years and thereafter lead to soil acidification (Isherwood, 2000). Continuous fertiliser application to tropical soils has resulted in lower yields, reduced soil pH value (acidity) and the resultant nutrient imbalance, antagonism and toxicity (Ojeniyi, 2002; Adeoye *et al*., 2008). Several studies had reported the capability of organic wastes to positively impact soil performance (Anikwe, 2000; Omolayo *et al*., 2011). Moreover, farmers are growing more interested in using organic materials to dispose of waste generated by animal industries (which is rapidly becoming an environmental problem), to preserve soil fertility (Alasiri and Ogunkeyede, 1999; Adeleye and Ayeni, 2010). In Nigeria, due to the ease of getting compost materials, compost is gaining popularity and becoming accepted and preferred to other forms of organic fertilisers among farmers especially in Nigeria.

Traditional farming practices had evolved through centuries of trial-and-error in local resources management with knowledge of resources application constant in the form of long-established routines, techniques and practices passed from father to son (Okigbo, 1993). Crop production represents a pattern of land use and varies with geographical location and climate, farmers and the types of crops grown in relation to the production technology, available resources and the farmer's adaptability to the ever-changing conditions and times in the environment. Benneh (1972) used methods of fertility restoration in fallow to classify the farming systems in Africa south of the Sahara and identified compound farming and extensive subsistence agriculture as the most predominant under traditional and transitional systems while modern systems and their adaptations are the few, rain fed or irrigated large scale farms and tree crop plantations. The operations are on small holdings which give little consideration to economic returns but guarantee survival (food supply) and diversity of farm products. Farms differ in the size of production units, types and amounts of inputs, technology available and adoption, and quantity of output. Recent modifications relate to integration of cash crops with the food crop economy and adoption of components of improved technologies (varieties, spacing, planting pattern, fertiliser, agrochemicals etc) to produce transitional systems.

The bane of agricultural development in Nigeria is the traditional system of cropping whose output cannot match the demands of an increasing population growth, urbanization and industrialization. Commercialization of agriculture has been favoured in which operations are carried out in large-scale farms whose features are continuous and intensive cropping of the same piece of land with the same crop, thus requiring judicious soil management and conservation, mechanization of field operations and effective use of crop protection strategies. These are the components of conventional agricultural practices whose adoption has led to the 'green revolution' accomplishments in Southeast Asia and South America. Despite the jumbo yields, continuous cultivation has been indicted for soil physical, chemical and biological degradation, pollution of land, water sources and air by toxic chemical residues while persistent use of pesticides poison farm products and so make them unwholesome for consumption. The current fad is to grow food using organic cultivation practices which avoid agro-chemicals and synthetic fertilisers as well as planting genetically-modified organisms (GMOs) but rather emphasize manual labour (to the extent possible), natural nutrient supplementation (minerals, manure, symbiosis etc), disease and pest resistant/tolerant varieties and botanicals for crop protection.

2.5 Practices and goals of Organic farming

Organic farming makes use of plant rotation, compost, green manuring, natural pest control methods and mechanical tillage in maintaining soils' high productiveness and subjecting pests. Synthetic fertilisers and pesticides are outlawed or severely restricted (Douglas, 2003). Organic farming has been practised for thousands of years as the primary type of agriculture. Plant rotation, compost, green manuring, natural pest management coupled with mechanical tillage are all used in organic farming to maintain soil productiveness and also to subject pests under control. Synthetic fertilisers, pesticides and insecticides are outlawed or severely restricted (Douglas, 2003). Organic farming has been the prevalent mode of agriculture for several numbers of years. The prehistoric forest gardening, which was majorly involved in the production of organic foods was the world's oldest and largest agro community (Douglas, 2003). After the integration of some underdeveloped inorganic methods by progressive revolution which had resultant serious negative effects, Rudolf Steiner, the author of biodynamic agriculture, which was one of the initial forms of organic farming (Paull, 2006), worked the rise of an organic body in the Central Europe, in the mid-1920s (Holger *et al*., 2008; Paull, 2011c). In the 1940s, in England, Albert Howard independently established organic agriculture so as to be a counter to the rising dependent of agriculture on synthetic fertilisers (David, 1991).

During the 18th century, synthetic fertilisers which were firstly developed with the use of superphosphates were subsequently mass-produced using ammonia-based fertilisers through the Haber-Bosch process, which was established at the time of the Second World War. The incipient resultant fertilisers were inexpensive, effective and were easily transported in large quantities. In the 1940s, similar breakthroughs in chemical pesticides occurred, earning the decade the title "pesticide period" (Horne, 2008).

The merits of organic farming include making fresher food items that taste better, cheaper at farmers' market, not using chemical fertilisers or pesticides but promoting soils that are teeming with life and rich in micronutrients and so can be used to grow crops virtually all-year-round for decades (Paull, 2011a). The use of artificially produced fertilisers, herbicides, germicides, growth regulators and hormones, antibacterial, food supplements, GMOs, sewage sludge and several other materials (Paull, 2011a) are eliminated or strictly limited in organic farming. Many countries have legalized and regulated organic agriculture methods using the criteria that were implanted by the Organic Agriculture Movement, which is an international body, founded in 1972, to govern the affairs of the different organic farming groups (Paull, 2010). The following are the overarching goals of organic farming:

i) sustaining the soil's health, ecosystems and the people.

ii) ensuring the adoption and usage of various ecological processes, biodiversity and phases that are tailored to localized conditions, rather than making use of inputs that may have negative consequences.

iii) blending tradition, creativity, and science to serve the common good and ensure equitable relationships and high degree of life for the various parties involved.

The organic products market has grown in value, from nothing as recorded in 1990 to $55 billion. This demand might have been motivated by an interchangeable rise in organically controlled farms, which expanded at an annual rate of 8.9 % (Paull, 2011b). Organic farming today covers around 37 million hectares (ha) worldwide, accounting for about 0.9 percent of all cropland (Willer and Kilcher, 2011).

2.5.1 Soil management practices in organic farming

Several methods have been used for soil management to ensure that plants get adequate nutrients for optimum productivity. These methods include:

(i) **Crop rotation**: To thrive well, plants essentially demand high values of nitrogen, phosphorus and potassium, with some few levels of minor nutrients, and symbiotic interactions involving fungi and other creatures, however, availability of the required quantity of N at the right time is likely to be the greatest challenge for organic farming (Wilson *et al.*, 2001). Tarfa *et al*. (2006) reported that crop rotation supports N supply through legumes, which aid in fixing N atmospherically through some symbiotic relationships with rhizobial bacteria. They listed groundnut, soybean and cowpea as examples of grain legumes which farmers prefer to rotate, especially with cereals**.** They observed that, rotating soybean and cowpea with maize increased the soil's chemical qualities, including alkaline metals and thereafter, finally concluded that; cycling of maize fields with soybean and cowpea led to 11.67 and 18.91 percent yield increase, respectively.

(ii) **Green manuring**: The main contribution of green manure (cover crop) to soil fertility restoration is nutrients supply and the protection of soils from physical and chemical degradation. Besides, the decomposing green plant material stimulates microbial activities (Leidger, 1995). If commercial N is not easily available or available only at high prices, leguminous green manure can supply the N needs of crops. Onwu *et al*. (2006) observed that a leguminous weed (*Calopogonium* *mucunoides*) used as green manure contributed to soil fertility improvement needed for high seed production of castor plant (*Ricimus cummunis*) in Makurdi, Nigeria.

(iii) Intercropping: The sandy nature of most of the soils which are usually left bare after bush burning before the beginning of the rains ensures loss of the native soil N through leaching. Legumes capable of N fixation are usually intercropped with cereals so as to guarantee some harvest and minimize risk of total crop failure on such highly depleted soils (Agbede *et al*., 2006). Although, the magnitude of mulch obtained through litter could be significantly less than the required organic residues for soil fertility maintainance, but N input from fixation by legume scould benefit the following crop (Tarfa *et al*., 2006). The benefits of including cowpea in many crops mixtures include improved N status through N fixation (Aya, 2004; Gerh, 2007), its short life span and the effective ground covering which reduces weed invasion and soil erosion (Aya, 2004; Gerh, 2007). Addition of some legumes to crop mixtures had reportedly influenced positively, soil chemical qualities (Singh *et al*., 2006).

(iv) Animal manure: The use of animal manure has been adopted by organic farmers to improve soil productivity and thereafter ensure its sustainability. In Nigeria, huge amount of animal manure is produced and stacked on dumpsites thereby posing potential environmental hazards. Since most Nigerian soils are low in organic matter (Adeleye and Ayeni, 2010), it is expected that these wastes would be beneficial to crop production, if incorporated into the soil. Numerous investigations carried out have shown that animal wastes have good effects on soil parameters (Anikwe, 2000) by increasing the cation exchange capacity (CEC) and definitely thereafter, by improving soil's capacity for greater nutrient retention. Adeleye and Ayeni (2010) evaluated the potential of organic wastes for improving soil nutrient contents and maize production and then recommended that poultry, swine and cow wastes could be used as bio-fertilizers for high grain yield of maize and soil productivity maintenance under continuous cropping in an Alfisol in southwestern Nigeria's rain forest.

(v) Crop residues: Different plants leave varied amounts of N, which when ploughed back into the soil can aid synchronization (Watson *et al*., 2002). Crop residues can be recycled into the soil either by direct incorporation or by mulching. Mulches derived from plant residues could be good sources of plant nutrients, though their effects are influenced by their nature and composition. Soils' pH, essential elements and organic matter contents are positively impacted by mulches (Ojeniyi and Ighomrore, 2004). Nottidge *et al*. (2010) concluded that incorporating leguminous food crops residues like groundnut and cowpea is a better alternative for the improvement of soil physical conditions and productivity of maize, than planting on short or bare fallow lands at Umudike, part of the rain forest zone of southeast Nigeria.

(vi) **Mulch**: Mulch is made up of materials like straw, grasses, leaves, or withered plants and is used to cover the soil. They are spread as a cover on the soil and also, around the plants. Decomposition of mulch over time manufactured foods for the beneficial soil creatures. Mulch ensures moisture retention in soils and thereby prevents moisture evaporation. It also protects the soil surface during heavy rains, thereby reducing erosion. Mulch smothers (Kaufman, 2004) and blocks weed emergence (Szykitka, 2004).

(vii) **Organic Fertiliser**: Organic fertilisers and manures are made from organic materials that are found existing in nature. Poultry dung, manure, earth worm casts, compost, seaweed, guano and animal bones (ground to powder forms) are just a few examples. Since animal wastes, particularly poultry and cattle dung, cause environmental and disposal issues, their usage as fertiliser could be considered advantageous (Alasiri and Ogunkeyede, 1999). Bones, which are often burnt or buried in landfills, can be processed into bone meal which is rich in phosphate. Composts, meals of animal blood and bones, humic acid, amino acids, and extracts from seaweeds are all, forms of processed organic fertilisers. Naturally enzyme-digested proteins, fish and feather meals, and agricultural leftovers or residues from past seasons are useful organic fertilisers. Decomposed animal wastes (as manures) enhanced with some additives, such as rock powders, plant wastes/residues and also, some animal wastes such as blood, bone, and feather meals are used to make some commercially available organic fertilisers.

2.5.2 Advantages of organic farming

Soil organisms have been shown to be useful to organic farming in many biological studies on soil and soil organisms. Certain chemical compounds in the soil, plant debris, and generated animal residues are broken down into useful essential soil nutrients by bacteria and fungi, which benefit the soil in terms of better and stronger harvests and also, more productive and sustainable soil for crop production (Ingram, 2007). Farms with little or no application of manure produce much reduced yields due to low population and diversity of soil microbial community, which is expected to generate a healthier and more favourable soil conditions and ecosystem (Alexandra and Jose, 2005). People and the environment, both enjoy the long-term benefits offered by organic farming (Age *et al*., 2010). These benefits include:

i) increase in long-term soil fertility (Enwall *et al*., 2005).

ii) suppression of weeds instead of the much expensive eradication, which is achieved by the increased competitions within the crops and the resultant phytotoxic effects of the increased crop population on weeds (Kathleen and Robert, 2003). Weed suppression could also be through crop rotation by planting weed-suppressive cover crops (UNCTAD, 2012) even as some common weed seeds can be destroyed by some microorganisms (Robert and Jianmei, 2003).

iii) weed control using biological methods like grazing and making use of geese (Wurtz, 1995; Belsie, 2003).

iv) ensuring clean and safe water.

v) resource use based on what is already available to the farmer and so less capital required for farm inputs purchase, unlike capital gulping inorganic farming which requires more energy and manufactured inputs.

vi) giving more profit to the farmer (Rodale Institute, 2011).

vii) provision of rural jobs for the young unemployed since organic farming would require much more labour to work on the farm (Morison, 2005).

viii) production of more nutritious foods, animal feeds and high quality crops to sell at good and profitable prices.

ix) production of improved foods, which are goodlier and healthier than the conventional foods. Organically produced foods are reported to contain an average of 20% more of the beneficial nutrients than the conventional foods (Narayanan, 2005; Pattanapant and Shivokoti, 2009; Age *et al*., 2010).

x) improving soil conditions, particularly lowering bulk density and improving soil’s water retention, pH and organic matter quantity, which encouragingly increases the microbial biomass and N, thereafter creating better soil aeration as against the traditional agricultural methods (Pacini *et al*., 2003; Wood *et al*., 2005). This could indicate that increased microbial activity makes appropriate nutrient’s quantity available to the crops.

xi) possibility of surviving harsh weather stipulations more than the normal farms, thereby making organically cultivated farms to yield 70-90 percent more during droughts than the conventional farms (Pimentel *et al*., 2005; Gomiero, 2021).

xii) production of reliable and high yields which are higher than yields from inorganic farms (Nwajiuba and Akinsanmi, 2002; Stanhill, 2005), even during drought.

xiii) reduction to the minimum level or complete eradication of some problems associated with modern intensive agriculture which include:

a. the easy removal of synthetic additives, herbicides and pesticides from the soil, resulting to contamination in rivers, lakes, and waterways (Tuomisto *et al*., 2012).
b. microbial population loss resulting from excessive utilization of artificial additives (Gracia and deMagistris, 2008), whose consequential effects is eminent in marked reduction of soil organic portion, thus making soil to be susceptible to erosion by either wind or rain.
c. relying on fertilizers, hence necessitating the requirement of greater amounts of fertilizers to produce the same yields of crops year after year.
d. persistence of artificial pesticides in the soil for a long time which could aid their entrance into the food chain and thereafter building up in the bodies of animals and humans thereby causing health issues (Mie *et al*., 2017).
e. destruction of soil microbial population as a resultant effect of the continuous use of artificial chemicals. This result in poor soil structure, aeration and decrease in nutrient availability (Gracia and deMagistris, 2008).
f. difficulties in controlling pests and diseases as the causal agents of pests and diseases develop resistance to pesticides.

2.5.3 Challenges of organic farming

(i) ***Weeds***: Weeds may grow in some fresh manure due to the presence of weed seeds. The weed seeds would be eliminated as high temperatures during composting kill weed seeds (Schonbeck, 2012).

(ii) ***Diseases***: Some organic residues harbour diseases that may affect the next crop. These are controlled biologically through crop rotation (UNCTAD, 2012). Pests and diseases are controlled without harming the environment. Problems on organic farms are usually caused by organisms such as arthropods (insects and mites), nematode, fungi and bacteria which are being controlled by biological methods especially the use of predatory mites to control other mites (Rueda-Ramirez *et al*., 2008) such that less pesticide is involved (Maeder, 2002).

(iii) ***Growth inhibitors or allelochemicals***: Allelopathic chemicals are compounds that are produced when a plant grows (or as its waste decays), which have the ability of hindering the growth of other plants. Allelopathic chemicals are beneficial when they affect weeds only but they become a problem when the growing crop becomes affected. Allelopathic effects are complicated and are influenced by plant genetics, weather, and stressors. Coumarins, a class of allelochemicals restrict plant growth by blocking or slowing down cell division in the affected plant, particularly in root cells (Cheng and Cheng, 2015). Germination of seeds may also be hindered. Some allelochemicals, such as flavonoids, phenolics, and tannins, inhibit or change hormone production or activity in affected plants. Other chemical substances, such as terpenes and some certain antibiotics, change the permeability of host cell membranes, rendering them leaky or impermeable (Chou, 2006).

(iv) ***Contaminants***: Heavy metals and other contaminants usually characterize the use of municipal solid wastes and sewage. Testing of the materials before application is therefore necessary. Monitoring of soil nutrient contents when using these products should also be ensured. A more common contamination problem involving P build up in the soil which is caused by the use of P manure (manure high in P) over an extended period of time can be avoided by ensuring that manure application rates are basically determined by crop nutrient requirements as well as soil nutrient levels.

(v) ***Pests***: A continuous pest’s cycle is encouraged by high temperatures, humidity and sunshine throughout the year. However, the heavy rains being experienced in the tropical regions would provide a break in the pest’s life cycle and hence, a reduction in the pest population which increase again in the dry season. Also, weeds which are fast growing in the tropics and some other weeds harbour pests. Although, organic farming is not aimed at the total eradication of pests, but at least a degree of balance could be maintained between beneficial organisms and pests. Since bio-pesticides are limited in the market and could be at times costly and unaffordable to farmers, other measures reduce the pest population are necessitated. These include:

a) **aphids**: these are mainly controlled by organically enriching the soil and also by growing trap crops, applying dormant oil sprays, washing of the insects from the plants using yellow water pan traps with detergent, using shinning aluminium surface and providing adequate water to avoid water stress in plants.
b) **caterpillars**: are controlled by making use of *Bacillus thuringiensis,* neem – based spray, parasitoids and predators.

c) **adult moths**: can be controlled by using pheromone traps, sticky traps and mechanical barriers.

(vi) **Marketing**: Marketing of farm products could also be a challenge if roads to the farms are not properly channelled for easy transportation. For example, the most significant challenge, as cited by organic producers in California has been marketing.

2.5.4 Development of organic fertilisers

Manure contains all of the essential macro and micronutrients, making it a viable source of nutrients for crops. (Ahn, 1993; Anikwe, 2000). Application of organic fertilisers is a major human intervention into the nutrient cycle in agriculture. Incorporation of solid and liquid manure, poultry manure, and human wastes is essentially partial re-utilization of the nutrients that had previously been taken up by crops and contributed to their yield. However, the utilized nutrients from the inorganic fertilisers applied to the soil eventually find their way into the manure through animal feed and litter and then returned into the soil when manure is applied. Although the nutrients concentrations of organic materials are comparatively modest, they are still advantageous. Organic fertilisers are tagged as N slow-release fertilisers because they are rich in insoluble N. Organic fertilisers improve the physical and biological nutrient storage processes of soils due to their nature thereby preventing the risks of over-fertilisation (Plantsfood, 2012b). Organic fertilisers have substantially lower nutrient content, solubility, release rates, and availability than inorganic/chemical/mineral/ synthetic fertilisers but several studies have shown that when utilized over a longer length of time, organic fertilisers are just as effective as chemical fertilisers (CSA, 2010) and their use emphasizes the roles of humus and other soil organic components in:

i) effectively utilizing the available soil nutrients, making good plant growth achievable with lower nutrient concentrations and thereby preventing waste (Plantsfood, 2012b);
ii) guaranteeing that nutrients are released at a slower, more consistent rate, avoiding the boom-and-bust cycle (Plantsfood, 2012b). Thus making the organic fertilisers to be classified and known as 'slow-release' fertilisers which mitigates against N burn;

iii) aiding moisture retention in soils, thereby preventing the temporary stress due to moisture content reduction (Pacini *et al*., 2003; Wood *et al*., 2005);

iv) improving the soil structure (Mbah and Mbagwu, 2006);

v) preventing erosion of the topsoil which has been reported to be responsible for desertification and dust bowl;

vi) enhancing soil biodiversity (soil life) and ensuring sustainable productivity of soil (Enwall *et al*., 2005);

vii) increasing the soil microbial population as the organic material and micronutrients provided would enhance the abundance and activities of organisms such as fungal mycorrhiza (Pimentel *et al*., 2005);

viii) avoiding certain problems usually accompanying consistent and heavy use of artificial fertilisers such as:

a) necessitation of regular re-application of the artificial fertilisers (and perhaps at increasing rates) in maintaining soil fertility;

b) comprehensive wash of soluble N and P into water bodies, which could cause death of several lives, especially fishes (Eoearth, 2012);

ix) lowering the cost of nutrient application through the use of organically-made fertilisers because the materials for their production are easily available and accessible.

Nevertheless, the disadvantages of organic fertilisers are as listed:

i) organic fertiliser components appear to be more complex and changeable than inorganic fertilisers with standardized compositions;

ii) when not properly treated, organic fertilisers can harbour disease pathogens from plant or animal debris which can be dangerous to humans or plants lifes but can be removed by proper composting (Hoitink *et al*., 1991);

iii) organic fertilisers have variable nutrient contents whose release into the available forms for plant uptake and usage may not occur at the appropriate stage of plant growth (Watson *et al*., 2002);

iv) they are comparatively voluminous, thus the correct nutrient's quantities which would be serviceable and thus, profitable to plants may be too cumbersome to deploy;

v) more applications are needed to supply sufficient nutrients. These involve the use of multiple equipment which use up more fuel and require more labour even as their passages cause soil compaction;

vi) nutrient contents, dissolution, availability and mineralization of organic fertilisers are particularlly lower than in the inorganic ones;

vii) results of several studies have found that the content of nutrients in organic fertilisers is low and that they are also not readily available for utilization by plants; and

viii) concentration of composts and other sources of organic fertilisers varies from one batch to the other; hence batch testing becomes necessary so as to precisely know the exact amounts of applied nutrients.

2.5.5 Types of organic fertilisers

i) ***Poultry litter:*** Chicken dung mixed with sawdust positively affects soil conditions for improved harvests than chemical fertilizers. Cotton fields fertilized with poultry litter had 12% increase in yields compared to fields fertilized with synthetic fertilizer (USDA Agricultural Research Service, 2010a). Growth performances and the overall output of leaf amaranth reportedly improved by applying broiler wastes at 30 Mt/ha (Omolayo *et al*. 2011). Kekong *et al*. (2010) suggested poultry droppings at 15 Mt/ha for optimum production of garden egg and maintenance of suitable soil chemical characteristics. Adeleye and Ayeni (2010) listed poultry manure as one of the organic wastes that could be used as bio-fertilisers for high grain yield of maize and soil productivity maintenance under continuous cropping. Eneje and Ezeakolam (2009) concluded that application of nutrients from poultry manure lowered soil acidity and provided cations which affected the structural stability of the soil at Umudike, Southeastern Nigeria. Garden egg output in Samaru, Nigeria had also, been reportedly boosted by adding poultry wastes at 28 Mt/ha (Dauda *et al*., 2003).

ii) ***Farm yard manure*****:** From a research work conducted at Maiduguri, Nigeria, to study the growth and yield responses of roselle to treatments from farm yard manure, Sodangi *et al*. (2011) concluded that farm yard manure could be used to significantly improve the growth characters including yield of roselle.

iii) ***Algae*****:** Algae is a type of organic fertiliser that is used to prevent the washing away (by rain) of N and P from agricultural lands, thus keeping these nutrient elements from contaminating water bodies. The "algal turf scrubber" minimizes nutrient wash, thereby enhancing the water quality in streams, rivers, and lakes. Application of the dried nutrient-rich algae gave results which were comparable to synthetic fertilisers on the production and output of cucumber and corn seedlings (USDA Agricultural Research Service, 2010b). Eneje and Azu (2009) concluded that algae compost, when compared to compost solely made from poultry manure, proved to be more effective for improving the structure, N content and exchangeable bases of a sandy loam at Umudike, Nigeria.

iv) ***Night soil*****:** This mixture of human excreta and urine is suitable for application in organic agriculture because of the large amounts of P it contains. Apart from directly applying urea solely to the soil, conversion of urine to struvite could also be employed in order to improve its quality (Nagy *et al*., 2019).

v) ***Cover crops*****:** Legumes, when grown as cover crops can concurrently act as a form of green manure, which would automatically enrich our soils due to its capability for fixing N atmospherically (USDA Agricultural Research Service, 2010a) as well as increasing the P content of soils through nutrient mobilization.

vi) ***Crop residues*****:** A useful alternative for the improvement of soil physical conditions and productivity of crops is to incorporate residues from leguminous food crops like groundnut and cowpea (Nottidge *et al*., 2010). Akpegi *et al*. (2006) evaluated the impacts of rice husk on the yield of tomatoes at University of Agriculture, Makurdi, Nigeria and submitted that it is possible to reduce the over dependence on inorganic fertiliser by incorporating fresh rice husk into poor soils. Tekwa and Olawoye (2009), who investigated the effects of separately incorporating cow dung and rice husks on soil nutrient status, found that incorporation of 20-30 t/ha of rice husks had an edge over cow dung and therefore recommended its use for improving the soil aggregate stability and supplementing essential nutrients needed for profitable crop production in the largely degraded Lithosols of Mubi, North-eastern Nigeria.

vii) ***Municipal Wastes***: Domestic garbage, paper, rags, dirt, dust and ash are municipal wastes which are similar to manure in nutrient content and fertilising properties, however, its decomposition rate in the soil depends on the C: N ratio. Municipal waste with a large portion of domestic garbage and dust decomposes faster and can be used directly as fertiliser without composting. Wastes with much paper, rags and sawdust take more time to decompose and should be composted. When applied as a basal fertiliser, municipal waste is better incorporated into the soil well in advance. Municipal refuse (wastes from farm produce, animal wastes, household wastes) can be a good storehouse for plant nutrients and so will provide beneficial chemical and physical effects on soils and stimulate crop production (Ibitoye and Ipinmoroti, 2004). Uzobo and Oti (2006) investigated the effects of composts obtained from municipal solid waste on cowpea's (*Vigna unguiculata*) growth parameter in an Ultisol in Ihiagwa, southeastern Nigeria and recommended its use as a low input technology for sustained cowpea production.

viii) ***Compost***: Naturally occurring materials that have been digested and repurposed as a fertiliser and soil additive are referred to as compost. It can also be defined as a slow-release organic fertiliser which rejuvenates soil life and improves soil structure. Compost is made from materials and resources which are renewable and can be produced by farmers themselves, thus making it a key ingredient in organic farming (Muller-Samann and Kotschi, 1994). It is a mass of rotted organic materials made from wastes and plant residues which had been heaped and allowed to decompose biologically (Donahue *et al*., 1990). Compost is utilized in gardening, landscaping, horticulture and agriculture generally because it is rich in nutrients.

2.6 Composting

Composting has long been a part of our global culture and had been used to accumulate local organic fertilisers since ancient times (Muller-Samann and Kotschi, 1994). It prevents the wasting of valuable natural resources, which could cause environmental issues, while also providing a high-quality, low-cost soil amendment. More than half of rubbish consists of organic material that can be decomposed and thereafter utilized for soil restoration. Composting of organic wastes restores the food web which sustains humanity. Composting can be defined as purposefully breaking and converting plant wastes and remains; biologically and chemically, to generate humus. It takes place in heaps or pits, under regulated conditions. As a technique of recycling organic materials, after decomposition, the organic wastes become soil-like in appearance and it is practically termed as compost. Diverse groups of invertebrates (insects and earthworms) and microorganisms (bacteria and fungi) are responsible for transforming the generated wastes into compost. Composting, which is a purely natural process makes use of important organisms like bacteria, fungi, and earthworms to instill organic materials' (leaves, manure, and dead plants) decomposition and conversion into nutrients for growing plants. When compost is added to the soil, the essential nutrients and microbes that produce humus, which contains the life processes, which support and nourish plants are automatically available in the soil (Kaufman, 2004).

Compost benefits the soil as a natural pesticide as well as a soil additive and a reliably good essential humus and humic acids source. As revealed by research, organic matter’s addition to the soil could be greatly rewarding, because it greatly influences soils’ active microbial populations, which resultantly aids the control of root pathogens (Grobe and Buchanan, 1993). Compost can be used to control erosion, reclaim land and streams, build wetlands and cover landfills. Compost is a recommended soil additive as tilth improver which supplies humus and nutrients. Compost microbes create a variety of esters that aid in the development of aggregates, giving the soil a friable, crumbly feel (Diaz *et al*., 1993). It provides moisture and soluble minerals’ retention, as well as the necessary support and essential nutrients for plants to thrive. Addition of compost to the soil or any growing channel increases the humus content and thereafter, the general fertility. Compost that has matured and safe to apply as a nutrient source in soil is usually dark brown in colour and has an earthy odour (Healthy Soils, Healthy Landscapes, 2012). Morestill, unlike synthetic fertilisers, the effects of organic fertilisers are not short-termed because its continous application improves soil's sustainable productivity. For the smallholders, especially for those who have little or no access to manure, composting could be a way to ensure long-term soil fertility without using any external inputs. Steps involved in the compost’s processing include; building an accumulation-heap for collection of organic materials, which could be; leaves and reminants of green foods, watering, turning and observing the break down of heaped substances through weeks or months depending on temperature and some other factors. A more controlled process referred to as methodical modernized composting, where the supplied moisture, aeration, carbon and nitrogeneous materials are strictly measured and monitored could also be adopted. Shredding of plant debris, adequate watering, keeping optimum aeration and regular turning of the mixture for effective break down of the organic components by the microorganisms, to form compost are the necessary factors that can aid the decomposition of the organic materials (Compost Made Simple, 2010). Active composting involves a wide variety of microorganisms, but the most common are listed below:

i) Bacteria- these are the most abundant of all the microorganisms that contribute to composting.
ii) Actinomycetes- these are vital and required for the breakdown of paper products such as newspapers, barks, and other similar materials.
iii) Fungi- these include moulds and yeast that are helpful in breaking down of materials which are not attacked by bacteria, particularly, the woody lignin.
iv) Protozoa- aid in the intake and digestion of bacteria, fungi and other microbial groups.
v) Rotifers- support the control of bacterial and protozoan populations (Cornell University, 2010).

In addition to the aforementioned, the earthworms eat partially composted materials and also help to break up the materials; thereby continously aerating and draining the tunnels as they go through the compost. The chemical process is managed by aerobic bacteria, which ensures libertion of heat, ammonium and carbon dioxide from the inputed materials. This is then followed by nitrification of the produced ammonium, by bacteria. An unhealthy micro-organism ecosystem in landfills which lack oxygen, nutrients and water could retard composting processes (Cornell University, 2010). Carbon and N-based materials are needed by the organisms which do the work of composting for their personal diets. Examples of N-based materials are; fruits and vegetables, grass and garden cuttings, leaves, animal manures and kitchen reminants. They're green or colorful and high in nitrogen because they're high in protein and/or amino acids. Wood shavings, sawdust, straw and dried leaves are examples of brown or high carbon materials that contain significant levels of cellulose. A pleasant odor, the release of heat during turning, the appearance of a white thread-like material on the degenerating materials, the reduction in size with each passing day and a gradual change in color to dark brown describe an healthy compost. Seizure of heat production indicates the readiness of the compost, for use (Rodale, 2012). Four important things are needed for effective performance of composting organisms:

i) Carbon: Energy in the form of heat is produced from the microbial oxidation of carbon provided carbon is supplied at recommended levels (University of Illinois Extension, 2009).

ii) Nitrogen: Growth and reproduction of more organisms which could aid in the oxidation of carbon is ensured by adequate supply of nitrogen (University of Illinois Extension, 2009).

iii) Oxygen: Sufficient quantity of oxygen is also needed for carbon oxidation and effective breakdown of materials (Donahue *et al*., 1990).

iv) Water: Water is also necessary in the appropriate amounts to keep the compost heap active without generating anaerobic conditions.

2.6.1 Factors influencing composting process

All organic materials eventually decay into nutrients for plant uptake and utilization. The factors which dictate the speed of their decomposition are hereby listed:

i) C:N portion of the substances: In composting, carbon and nitrogen are the two most significant ingredients, and their ratio (C:N) is crucial. Carbon is digested or oxidized as energy source while N is ingested for protein synthesis by the bacteria and fungi in the compost. This automatically means that Carbon translates to be the food and N, digestive enzyme. For fast and effective decomposition, the amount of carbon in the organic materials should be greater than N. The recommended quantity, for the duo is 30 parts carbon to 1 part N, that is ratio 30:1 (w/w) (Muller-Samann and Kotschi, 1994). Excess N in the compost can trigger the production of NH_3 gas, which can cause unpleasant odour, while low N slows down the composting process (Kubota and Nakasaki, 1991). Carbon could be abundantly obtained from leaves while fresh grass, manure and blood meal are rich sources of N.

ii) The exposed surface area: When the particle surfaces in the compost pile come into contact with air, their decomposition by the microbes is effected. Cutting, shredding, mowing, or breaking up the material to be composted, could bring about an increase in the expanse of the item. The expansion may result in more substrates being digested, faster proliferation and generation of more heat by the microbes. Expansion of the surface area may not be necessary when composting, but it could speed up the process. Insects and earthworms also aid the decomposition process by breaking the organic materials into tiny pieces for easy digestion by bacteria and fungi (Hachicha *et al*., 1992).

iii) Aeration or oxygen concentration: Oxygen in the compost heap is being totally consumed, necessitating addition of oxygen to the centre of the depleted compost heap. This is because, decomposition would only occur when enough oxygen is made available and this type of decomposition is termed aerobic. Aerobic decomposition is naturally aided by wind, or rising of the heated air during composting process through the pile to draw in new breeze from the surroundings. Appropriate ventilation should be included in composting systems or structures. Addition of oxygen, to the pile and exposure of newly added material to microbes is encourage by turning of the pile. Turning of a compost pile could be achievable through a pitchfork, shovel or the purposely-designed aerator, which is developed for the particular. When a compost pile is poorly aerated, there may be the development of an indicative odour, typical of the process of anaerobic decomposition (Donahue *et al*., 1990).

iv) Moisture content: Because the microbes' organic molecules are dissolved in water, an adequate moisture content of about 40-60% should be maintained by the compost pile. When the moisture content goes below 40%, microbial activity slows or stops and when the moisture content rises above 60%, there is hindered supply of air, leaching of nutrients, reduced decomposition rate, and then, the indicative odour of anaerobic decomposition. The moisture status of the composting materials could be checked using the "squeeze test".

v) Temperature: Temperatures both in the compost pile and on the outside affect the composting rate. Heat is being generated by the microorganisms as they decompose the organic materials. Temperatures in a functioning compost pile range from 32 to 60 degrees Celsius, indicating that it is composting effectively. Temperatures above 60 degrees Celsius hinder the activity of many of the pile's most vital and active creatures. Quick composting requires high temperatures, indicating that the process of composting may likely stall over during the cold months, especially from November to March, in Nigeria.

2.6.2 Benefits of using composts

The results of several studies have produced various benefits of composting and soil application of composts.

i) General improvement in the fertility level of the soils in the farm or garden (Ahn, 1993; Anikwe, 2000; Ibitoye and Ipinmoroti, 2004; Kaufman, 2004; Omolayo *et al*., 2011).

ii) Improvement in the soil mechanical structure (Smith, 1992; Mbah and Mbagwu, 2006) in terms of its granulation, tilth and pore spaces. Clay soils which are heavy are made lighter while sandy soils are made more cohesive for better moisture retention (Compost Gardener, 2019). Moisture is preserved and does not dry out as quickly, hence making cultivation easier (Pacini *et al*., 2003; Wood *et al*., 2005).

iii) Elimination of unnecessary waiting time because the farmer can return to work on the soil (to farm) quickly after a rain; the spongy porous soil structure minimizes muck and stickiness, as well as soil breaking into clods. Gardens that were previously difficult to work on when wet due to its stickiness and subsequent baking hard as a brick, resulting in the formation of large cracks in the surface when dried out, become easy to work on, and hand cultivators can easily push through such soil (Rodale, 2004; Compost Gardener, 2019).

iv) Increasing the soil's water retention capacity by 20 to 50% (Pacini *et al*., 2003; Wood *et al*., 2005).

v) Preventing soil erosion and reducing flood threats, thus saving money that could otherwise be spent on engineering devices for soil erosion control, such as drains, contours, dams, and terraces (Plantsfood, 2012b).

vi) Preventing soil surface hardening caused by heavy/hard rains. The effect of a hard rain creates a surface crust in a hard and poorly formed soil whereas the porous spongy texture of organic soil prevents this. (Mbah and Mbagwu, 2006).

vii) Multiplication of earthworms due to increase in organic matter which naturally serves as their food. Artificial fertilisers kill or drive them away, but the earthworm is often regarded as one of the farmer's best friends, assisting in soil aeration and production of topsoil. (Enwall *et al*., 2005; Rodale, 2012).

viii) Multiplication of the soil’s microbial population. The bacterial and fungi population of organically enriched soil is tremendously increased, thus enormously aiding plant growth. Improved aeration and constant availability of moisture also greatly encourage their increase (Pimentel *et al*., 2005).

ix) Land can be ploughed deeper in a safe manner. The topsoil layer thickens and can be ploughed deeper if the land is organically rich and has the correct mechanical structure (Pacini, 2003; Wood *et al*., 2005) .

x) Formation of Hard-pans are prevented. The gradual disappearance of any hard-pan formed is aided by earthworms which gradually crumbles it up (Diaz *et al*., 1993).

xi) Reduction in soil consolidation due to the use of heavy machinery. Springiness of soils being organically treated makes it rebound after the weight of the heavy machinery has been removed but the weight of tractors, trucks, and other large machines still exacerbates the situation on hard-packed soil.

xii) Improvement of soil aeration. One important criterium for attaining optimal fertility level in soils is sufficient aeration, which is required for good root development (Compost Gardener, 2019). The proper crumb structure of the soil and burrows of earthworms are parts of the factors that aid soil aeration. The pore gaps provide a larger expanse for the soil water film to get attached to. The wind blowing through the surface keeps the ground air moving in well-aerated soils. This type of air movement aids in the control of pathogenic (harmful) germs (Grobe and Buchanan, 1993).

xiii) Absorption of heat is quicker and more effective in soils made darker by humus. This follows the principle of colour in insolation. White color repels heat, but darker colours would absorb greated amount of heat. This allows the land to warm up considerably faster during the colder seasons, thus allowing work to commence and plants to germinate and would also prompt the initiation of bacteria's work. Soil temperature is also determined by the soil's moisture content and air spaces.

xiv) Composts are advantageous in dry weather. Plowing could be difficult when the soil is too dry as well as when the soil is too wet because the soil could be blown away. This disadvantage is however not experienced in the organic system because of better moisture storage. In dry weather, the land in organic soil cools faster, and also, due to its water storage, organic soil will fare better in droughts (Rodale, 2004).

xv) The quality of manure produced by animals that are fed on organically operated land improves year after year. The manure becomes progressively richer thus making the quantity required to become less until the farm or garden gets to a point/position where it can survive for a few years without fertilizer. The value of manure produced by animals fed on a chemicalized farm is much lower.

xvi) All of the nutrient elements in manure are preserved in compost heaps. The green matter, manure earth and ground limestone are greatly interlayered, hence there is little loss in the compost heap, unlike in an old-fashioned manure heap where more than half of the nutrients are leached out. In a correctly built compost heap, there is a lot of N fixation during the ripening period. Also, there are no odors or flies like there are with manure piles (Plantsfood, 2012b).

xvii) Composts exhibits long-term influence termed residual effects. In studies with regular manure, 48% of the nutrients were depleted in the initial year and later, 24, 15 and 13%, respectively in the second, third and fourth year that followed. However, when composts were utilized, some long-term impacts could be felt up to 15 years later (Adediran *et al*., 1999; Isitekhale and Osemwota, 2010).

xviii) The grounds are cleaner with the implementation of organic system. Weeds are trimmed on a regular basis for use in composting, thereby preventing seeding and spreading of weeds. Cuttings from the lawn, clippings, and other debris are also carefully gathered (Alasiri and Ogunkeyede, 1999; Adeleye and Ayeni, 2010).

xix) Weeds may be removed from an organic soil more easily. Weeds are easier to pull out with a hoe or cultivator because organic soil is soft and crumbly. It is thus no longer necessary to postphone weeding till after a rain. Weeds appear to be embedded in cement in a soil that has been treated with chemical fertilisers on a regular basis.

xx) Compost is a safer alternative to regular stable manure. Compost is a ready-to-use product, whereas raw manure requires being broken down by soil organisms and so, the release of nutrients might be more prolonged.

xxi) Compost helps in killing weed seeds whereas, by applying raw manure to the land, a farmer or gardener may actually be introducing a weed crop to the farm land. The high heat generated at the thermophilic stage of the fermentation process destroys most weed seeds found in the compost heap (Hoitink *et al*., 1991; Muller-Samman and Kotschi, 1994).

xxii) There is less risk of crop failure when composts are used. There is an infrequent crop failure due to the problems associated with the usage of chemical fertilisers, such as plant diseases and soil acidification from abuse of chemicals. Corn stalks and cereal plants such as wheat, oats, and barley are blown down by wind storms. However, where the soil is rich in humus and the plants are strong and healthy enough to stand on their own due to the stronger root systems they create, this does not happen.

xxiii) Plant disease is reduced to the bearest minimum. The plant is not fully nourished in chemical farming and gardening, and hence its resistance is minimal, but crops cultivated with enough of compost are far more disease resistant. Plant disease is less severe in soils rich in organic matter due to improved plant vigor combined with antagonistic effects of diverse soil microorganisms that become more active in the presence of an adequate organic matter..

xxiv) Reduction of insect menace to the minimum level (Maeder, 2002). Insects, for a variety of reasons, may not attack plants that are healthy. Insects are selective eaters and those that have not been imported appear to have been genetically programmed to prefer sickly or improperly grown plants. This could possibly be the nature's way of weeding out the unsuitable. Predatory insects tend to be attracted to plants developed with chemicals that are not entirely healthy.

xxv) Chemical (poisonous) sprays are rarely, if ever, required. In organically managed farms and gardens, vegetables and plants require only a few or no toxic sprays because insect and disease problems are seldom. There is 50% lower expenditure on fertilisers, energy and 97% less pesticides (Maeder, 2002). Time and money are thus saved in large sums, thereby making organic farming more profitable than conventional farming (Rodale Institute, 2011).

xxvi) Yields are higher in organic farms than in inorganic farms (Nwajiuba and Akinsanmi, 2002). Organically grown crops yield 95-100% higher than inorganically grown crops (Stanhill, 2005); even during drought years.

xxvii) Seeds do not require any chemical treatments. Seeds produced by chemicalized farming harbor and are more prone to attacks by numerous disease pathogens, thus necessitating a poison bath to kill the disease pathogens as a compulsory practice in modern agriculture. On an organic farm or garden, this procedure is unnecessary (Maeder, 2002).

xxviii) Compost promotes and improves health. The religious use and application of humus results in vitamin and mineral-rich conventional meals (Galgano *et al*., 2016). If all of our meals could be grown organically, we could save a lot of money on doctor's expenses.

xxix) Farm animals which are fed on organically-produced feeds are healthier (Narayanan, 2005; Age *et al*., 2010). When farm animals are fed with devitalized feeds grown with artificial fertilisers, the prevalence of horrible diseases of all types increases dramatically. Sicknesses in animals may be an indicator of a sure sign of bad farming (Pattanapant and Shivokoti, 2009).

xxx) Food cultivated organically have better tastes (Carbonaro *et al*., 2002; Fillion and Arazi, 2002; Chassy *et al*., 2006). Commercially developed modern foods are losing their old-fashioned flavour. Vegetables that are tougher and more fibrous which lack a full-bodied flavour unlike those raised with composts, are raised with chemicals.

xxxi) The overall quality of the harvest and the preservation quality of organically cultivated goods are significantly greater and much higher (Rodale, 2004; Age *et al.*, 2010). For example, a few days after being sliced open, a pumpkin produced with artificial fertilisers becomes mouldy.

xxxii) The effects of toxins in the soil appear to be mitigated by humus. The toxicity of plant poisons is reduced in a humus-rich soil compared to a humus-deficient soil; high salt concentrations are less harmful and aluminum solubility and its particular damaging actions are significantly reduced.

xxxiii) Pesticides, which can harm the environment and negatively impact human health, particularly in youngsters are used sparingly on organic farms (Maeder, 2002).

xxxiv) Organic farming sometimes necessitates more labour than regular farming, thus resulting in creation of more rural jobs (Morison, 2005).

xxxv) Composts reduces methane production (Compost Gardener, 2019)

xxxvi) Composts aid in carbon sequestration. Composts function as a “carbon sink” which traps the element carbon in the dirt, it is therefore prevented from getting to the environment where it can wreak havoc on the planet (Haunt, 2019; UCLA, 2020).

With these benefits, farmers and gardeners should be advised to use composts. This is especially necessary because they can produce all of the composts they require on their own farms to ensure maximum soil fertility.

2.6.3 Composting materials

The components (feed stuffs) used to prepare a compost would determine its quality. Existing composting materials are listed below:

i) Urine

The major components of urine are water and urea. Urine also contains some water-soluble plant nutrients (N, P and K) in higher quantities than faeces (Stockholm Environment Institute, 2012). Urine can be composted or used directly as a fertiliser. When a healthy person's urine is put to compost, the temperature rises, increasing the compost's effectiveness in eliminating disease causing agents (pathogens) and undesired weed seeds. Urine, repells flies (such as house flies), which could spread diseases and disease pathogenes that are particularly hardy, such as parasitic worm eggs are not found in urine, unlike feces. Human urine has been used successfully to fertilise cabbage plants (Heinonen-Tanski, 2007).

ii) **Manure and bedding**

Manure from the farm serves as the foundation for composting. The most popular bedding materials are straw and sawdust. Newspaper and chopped cardboard are among the non-traditional bedding materials that are utilized. The cleaning schedules (Alasiri and Ogunkeyede, 1999), land availability and weather conditions, are all factors which could influence the manure quantity obtainable on a livestock farm. The physical, chemical and biological features of each variety of manure are unique. When mixed with bedding, cattle and horse manures have strong composting properties. Swine manure, on the other hand would only have strong composting properties by blending with straw or some other similar materials due to its wetness and non-bedding material content. Poultry manure must also require mixing with carbonaceous materials, particularly nitrogen-free materials like sawdust or straw (Schonbeck, 2012).

iii) Cattle dung

Cattle dung is made up of fibre material that travelled through the digestive tract of the animal, as well as other liquid material, which remains after fermentation, absorption, and filtration of food materials, before acidification and the ensued re-absorption. The principal components include C, H, O, N, P, salts, urea, mucus, cellulose, lignin and hemicelluloses, as well as cells which were cut off as the digested food particles passed through the digestive canal. As a result, the faecal matter produced is mineral-rich. Faeces of cows may dry out and remain on the pasture if not immediately recycled into the soil by earthworms and dung beetles, thereby creating an undesirable grazing environment for livestock (Rodale, 2004). When cattle dung or faeces are mixed with bedding material, wasted feed and water, it becomes cattle manure. Cattle manure contains the majority of the nutrients required for plant growth, thus making its application to farmlands a cost-effective and environmentally sustainable way to boost crop production. As a result, cattle manure may be adopted as a supplement to replace synthetic fertilisers in crop cultivation. Cattle manure is an efficient soil additive that improves soil condition (Mosebi *et al.*, 2015). The organic part of cattle manure contributes significantly to improved soil's organic matter, tilth, structure and water infiltration (Nyamangara *et al.*, 2001). It can boost crop yields by adding some nutrients and improving soil's humic portion (Reddy *et al.,* 2000). The advantages of the nutrients and organic substances may not be apparently instant. This therefore recommends the usage of the overall response and yield of crops measured over years as the ideal way to quantify the value of organic spreads. The fortifying ability of cattle spread differs greatly, as it is conditionally dependent on the type of cattle, age, feed mix, rations, environment, bedding type, manure storage and handling. Solid cattle manure can be applied fresh and as compost which differs in nutrient composition. For the following reasons, applying the manure as compost is an efficient approach for handling cattle manure and may be superior, to using fresh manure:

i) by reducing the quantity and volume of composted manure, it can be applied more consistently and efficiently.
ii) the nutrients are in a more stable state, akin to soil humus.
iii) proper composting can help to get rid of viable weed seeds and pathogens that may be contained in the finished product.
iv) smells are minimized during application because the compost would have been cured (Soilfacts, 2012).

Cattle dung has been used alone (Ano and Agwu, 2006; Mbah, 2006; Mbah and Mbagwu, 2006; Kekong *et al*., 2010) or combined with other materials as composts (Adeoye *et al*., 2004) for soil restoration, and improving production of crops.

iv) Poultry dropping/manure

Poultry dung is the most valuable of all livestock manures when it comes to plant nutrients and soil amendments (Charles and Donald, 2012). It consists of all the fundamental nutrients inevitable for crops in reasonable amounts. Poultry dung is a more concentrated nutrient elements' source, particularly N, P, K and Ca. Available organic entity and nutrients for soil restoration and nutrient supply to crops, which thereafter ensures increased output in form of yield, are contained in poultry dung (Alasiri and Ogunkeyede, 1999). Composting of poultry dung/manure may not be always required, as its application could be done, right away from the farm to the cultivated lands (Prabu, 2009). All nutrients contained in poultry manure take the form of available compounds. Nutrient makeup of poultry manure varies, depending basically on species of poultry, their feed diet, litter to droppings ratio, manure handling technology, and litter type (Soilfacts, 2012). The majority of nutrients in poultry dung are readily available except for N which occurs in several forms that can be lost under different management or environmental conditions. Nitrogen in poultry dung is in majorly in uric acid form which, in storage, first turns to urea and then to gaseous ammonia that is volatilized under unfavourable storage conditions (Soilfacts, 2012). As the manure decomposes (mineralizes), the organic N fraction becomes accessible for crop absorption. Depending on the environment, mineralization rates might range from 40 to 90% (Charles and Donald, 2012). Poultry manure is applied both before sowing and for dressing (Rodale, 2004). Poultry manure is normally stored and spread as a solid and liquid slurry. Poultry manure, like cattle manure, can be used to replace or reduce the use of commercial nutrients in crop cultivation. Poultry manure, had been used alone (Busari *et al*., 2004; Mbah, 2006; Mbah and Mbagwu, 2006; Ano and Agwu, 2006; Ewuzie *et al*., 2010 and Kekong *et al*., 2010) and also combined with some other materials as composts (Adeoye *et al*., 2004; Agunsoye *et al*., 2009; Eneje and Azu, 2009 and Eneje and Ezeakolam, 2009) to boost agricultural output and soil nutrient status.

v) Sawdust

Sawdust is a solid organic component which consists of smooth wood portions that are obtained from sawing of woods from timber logs in sawmills. It is also obtainable from splitting of planks in carpentry workshops. Sawdust is highly carbonaceous (WNC, 2009; University of Illinois Extension, 2019) and has various practical uses as mulch, fuel and in the manufacture of particle boards. Sawdust is high in carbonaceous compounds (lignin, cellulose and pectin) and low in useful plant nutrients such that for bacterial decay to occur, carbohydrate for energy and N to build new bodies as they grow and multiply are needed (Rudiger *et al*., 2018). The N deficiency limits building of bacterial tissues and can deplete available nitrogen in soils and thereby hinder plant growth. The N consumed by microorganisms becomes available and definitely utilizable to crops after the sawdust is degraded. Orchardists, small fruit farmers and nurserymen utilize sawdust as a mulch. It is used as a litter in barns, as well as a soil additive in general agriculture. Sawdust and other wood wastes are good as mulches due to their clean handling, easy application, sustainable and effective moisture retention. Plants thrive well in sawdust mulches.

The high absorptive strength of sawdust makes it important in composting as it helps to wick up water from rain and juices from the green materials; the N source (Rhoades, 2022). It should be noted that sawdust from all types of tree can be used, whether soft or hard. However, composts made of sawdusts obtained from chemically treated wood should be doused with water for some times before use. This process will leach any harmful chemicals away out of the compost pile. Composting with an appropriate amount of sawdust, is likely to provide the most favourable conditions for compost maturation (Waqas *et al*., 2018).

2.6.4 Organic Sources for N Enrichment in Composts

i) **Neem (*Azadirachta indica)***

The tree called Neem, falls into the Meliaceae family. It reportedly originated from India, Pakistan, and Bangladesh, but it can also be found in the tropical regions (Adjorlolo *et al*., 2016). It spreads and grows to be as tall as an oak, with masses of honey-scented white flowers. Neem is a rough tree and grows vigorously in difficult sites especially on dry, stony, clayey and shallow soils. Its ideal soil pH is 6.2 and higher; nevertheless, acidic soils (pH=5-6) do not inhibit its growth; rather, its leaf litter brings the surface pH of such soils to neutral (Schmutterer, 1990). It grows very well on acid soils where its fallen leaves with pH of 8.2 neutralize the soil acidity (Roederer and Beliefontaine, 1992). Neem is evergreen; bearing foliage throughout the year, but may shed most or nearly all of its leaves in severe drought. Neem tree may die in waterlogged soils (Ogbuewu *et al*., 2011).

Neem is useful for health- related purposes; the oil is used to treat dandruff and acne. Extract of neem leaf is also taken orally. In some cases, the bark, flowers and fruits are also used medicinally (Wong, 2018; Jose *et al*., 2020). Neem tree (*Azadirachta indica*) has leaves which are valuable as mulch, amendments to neutralize soil acidity. The leaves are also utilized as fertilisers, resulting in increased crop growth and output (Moyin-Jesu, 2012). Neem returns worn-out lands that are unsuitable to crops to productive use. Neem by-products (the seedcake and leaves) can be used to enhance local soils and encourage long-term productivity. Soil amendments with farm yard manure plus neem extract would generally stimulate heterotrophic microbial activity and organic matter decomposition.

Neem leaves mould applied to the soil along with sawdust was used in suppressing the populations of plant parasitic nematodes on tomato (Javed *et al*., 2007). Azadirachtin repels and distrupts the growth and reproduction of insects. Melantrior causes insects to cease feeding while Sallanin also inhibits feeding. Nimbin and Nimbidin have antiviral activities (Sanguanpong and Schimutterer, 1991). Neem extract could influence almost 200 insect species. With the use of a commercial preparation of neem seeds, young cockroaches are killed, while adults are prevented from laying eggs. Neem cake and oil have also been used to control insects and pests (Schimutterer and Freres, 1990). Neem products affect various types of Nematodes (Roederer and Belsiefontaine, 1992). Neem has also demonstrated antifungal activities (USDA, 1990). Neem is efficient at preventing plant viruses from being transmitted by insects.

ii) **Mexican sunflower [*Tithonia diversifolia* (Hemsley A. Gray)]**

Mexican sunflower, Tithonia or sunflower is juicy with soft shrubs, belonging to the Asteraceae family, which had its source in Mexico and Central America, however, as an imported plant; it has a practically pan-tropical distribution (Taxon, 2011). It is however currently found in most parts of America, Asia, and Africa (Liasu and Abdul Kabir, 2007). Options for propagating Tithonia include: direct sowing, cuttings and bare-root seedlings from farmers' nurseries or wilding. Tithonia could be annual or perennial with a growing height of 1-3 meters.

Tithonia is utilized for different purposes, including fodder, poultry feed, compost ingredient, fuel, boundary, soil erosion management, building materials and in building hiding places for poultry (Liasu and Atayese, 1999). In Kenya, traditional Tithonia hedges are used to demarcate both the external and internal boundaries of farms and compounds. Hedgerows provide protection for soil and crops and produce fodders, green manure and mulch and therefore good for composting but during the dry season, cattle and goats may browse on it. Tithonia can be used as a continuous green manure during the crop's active growing season, either along the rows of plants or incorporated into the soil. It is qualified as a valuable fertiliser by its ability to absorb nitrogen and phosphorus in reasonably large quantities in the soil. The leaves and succulent stems decompose readily when applied to the surface of the soil or integrated into it to release and make available nearly all the N in about 2 weeks (REAP Teaching Leaflet, 2012). As a result, it provides a vital source of biomass and nutrients for short term crops, supplying N, P and K in quantities comparable to or better than poultry, cattle and swine manure (Olabode *et al*., 2007).

The best fertiliser is made when the plant is dark green and about 1 m tall. Once the plant has flowered it is no longer high in N as most of it has been used in producing the flowers and seed ((Jama *et al*., 2000)). In Kenya, Malawi and Zimbabwe, tithonia has been used to generate biomass for growing yearly crops like rice and as a nutrition source for maize (Jama *et al*., 2000). The stems and leaves of tithonia prevent the effects of harmful microorganisms in soils (Adoyo *et al*., 1997; Wanjau *et al*., 1997).

The following other facts were discovered about tithonia:

i) in the aspect of N, P and K contents, tithonia outperforms Siamweed (*Chromolaena odorata)* and Guinea grass (*Panicum maximum)* in N, K and Ca.
ii) tithonia's nitrogen content was comparable to poultry and swine manure. The expected primary nutritional contents of blood meal are; nitrogen, phosphorus and potassium of 13.25, 1.0 and 0.6% respectively.
iii) tithonia had a P content that was not substantially different from swine dung but much higher than cow manure.
iv) it has a substantially higher K content than chicken, cattle or swine manure.
v) soil treated with crushed fresh and powdered dry tithonia led into greater okra growth and yield (Olabode *et al*., 2007).

iii) **Abattoir wastes**

These include bones, skin, hides, horns, hooves and blood.

(a) ***Blood meal***

Blood meal is a by product of animal processing. Slaughtered cattle give out 25 litres of blood which is rich in N and so can be used as an enrichment material for a finished compost in order to increase its N content (Sridhar *et al*., 2004). Blood meal is a high-nitrogen fertiliser created from a dry, inert powder made from blood. It is a rich, non-synthetic source of nitrogen. Blood of animals, when dried and ground into powdery form, is a natural technique to increase the soil’s nitrogen content, if applied directly. Release of N is rapid and it is suited to fast growing vegetables as blood meal increases plant yields, due to leafy green growth. It returns nitrogen to the soil in a highly efficient way. Because blood meal is water soluble, it can be used as a liquid fertiliser, thereby making its action to be quick in fixing N deficiency (Smith, 2016). However, if blood meal is added in an inappropriate quantity, it can burn plants due to release of excessive NH_3. Blood meal, if properly added to compost piles could balance the C: N values ratio.

(b) *Bone meal*

From every cattle slaughtered, about 70-90 kg bones are obtained, which could thereafter be washed, dehydrated and burned-out so as to convert to bone meal which has a huge market in livestock feed and fertiliser industries (Sridhar *et al.*, 2004). There is a huge export demand for bones from Nigeria in western countries, especially in the U.S.A where they are processed into phosphate fertilisers. Bone meal is made from steamed and crushed animal bones. Animal bones are cooked, ground, packed and then sold as a slow release fertiliser that adds a good amount of P to the soil (Smith, 2016). It also contains Ca (Smith, 2016) and a little bit of N (Scott, 2012). The reported N-P-K recipe of bone is 4-12-0, whereas steamed bone meal has an N-P-K recipe of 1-13-0 (Scott, 2012). Bone meal contains crushed, ground bones which are prepared for further usage as an organic source of phosphorus for production of plants, especially leaf vegetables, in gardens, on lawns and in containers. Bone meal is primarily used as a slow release fertiliser source for P such that there is little risk of plants being burned even if too much of this fertiliser is used (Smith, 2016). Bone meal is emphasized as a good soil amendment especially on degraded soils where the physical properties of soil are unaffected by inorganic fertilisers (AdeOluwa and Oshunsanya, 2009). Where the use of bone meal is accepted, pH testing becomes important because a pH of 7 or higher in the soil may render bone meal ineffective (Smith, 2016).

(iii) *Hoof and horn meal*

Cooked, ground and dehydrated hooves and horns obtained from cattle slaughter houses are good N sources (12%). In addition, horn and hoof meals also contain about 2% P which makes it a 12-2-0 NPK fertiliser. It is alkaline in nature and so a good choice for improving acidic soils (InterHort, 2012). The N locked inside the horn and hoof meal is released slowly so that it does not burn the plants (Maisie, 2012). The N release starts at 4-6 weeks after application and can last for 12 months (Organic Garden Info., 2012).

2.6.5 Composting Techniques

The key to successful composting is to choose a method and technology that is appropriate for our needs and way of life. The option chosen will be determined by the available space, type of composting materials, the intended use of the compost, time to be spent and how neat the compost pile would look (Muller-Samman and Kotschi, 1994; University of Illinois Extension, 2009). If only a little quantity of compost is needed, then a minimal effort is required as a small area is needed for the composting. This may even be done in a commercially-available bin. The methods that had been used in composting include:

i) ***Holding units*: The holding units are bins that are used to store yard and kitchen waste until they are composted** (NRAES, 1993). This approach requires relatively little upkeep (NRAES, 1993; Cornell Waste Management Institute, 2012). Non-woody materials might be added to a holding unit as they are being produced. Composting in a holding unit is easy, but it takes longer since the cage makes it difficult to turn the heap so as to ensure increase in oxygen supply (Aggie Horticulture, 2016). This leads to lack of aeration which may cause the composting process to take longer time, but using portable containers helps speed up the procedure (NRAES, 1992). These units can be taken from an existing heap and transported to another site. The heap is then turned back into the unit, where the materials are mixed and aerated.

ii) Aeration in holding units can be increased by adding one or more ventilation stacks or piercing holes in the bin's center before constructing a pile. ii) Stacks can be created from perforated tubing, wire mesh cylinders or simply a cluster of loosely linked twigs. Placing the holding unit on a wood pallet or a plastic aeration mat is another way to promote aeration. Because yard clippings and other organics are regularly added to holding units, the phases of decomposition will vary from the top to the bottom of the heap. The most finished compost are found at the pile’s bottom. The finished compost at the bottom can thereafter be collected and used. (University of Illinois Extension, 2009). Holding unit is easy to build, least labour intensive and the slowest way to compost (NRAES, 1993).

iii) ***Turning units*:** Turning units, unlike the holding units, (NRAES, 1993; Aggie Horticulture, 2016) are turnable systems to enhance aeration and so perform faster than holding units as the aerobic bacteria involved in the breakdown of materials get the required oxygen on time. Composts can be made in two months or less, by turning and mixing the organic materials on a regular basis (every five to ten days) (NRAES, 1992). In addition to faster composting, frequent rotating has other benefits. For instance, higher temperatures (60°-80° C) produced by turning, will kill important disease organisms, fly larvae and weed seeds, while providing a favorable habitat for the most effective decomposer organisms (Cornell Waste Management Institute, 2012). Turning systems are usually more expensive than holding units and may require more efforts to construct (NRAES, 1993). Food scraps can be collected in a pest-proof container and sawdust could be placed to the top of each day's scraps, if need be, so as to lessen the odour.

iv) ***Heaps*****:** The composting in heaps can be compared to operating the holding and turning units except that no built-up structure is require (NRAES, 1993; Aggie Horticulture, 2016). The recommended width for a heap is 2.5 m while the recommended heigth is 1.5 m. However the length may vary depending on the quantity of the available materials (Aggie Horticulture, 2016). Because of gravity, heaps may take up more space. Wider piles retain heat better but, too large heaps can overheat, destroying almost all the microorganisms (Muller-Samman and Kotschi, 1994). Materials can be added as they are produced or stockpiled until a sufficient amount is available to form a good-sized heap. Making a good-sized heap during the wet and chilly months will assist the composting process last longer into the dry and hot months. Although turning of a heap is not compulsory, the composting process will take longer if it is not done. Throwing of food scraps on an unturned pile may likely attract pests and bugs. Woody materials, not broken to pieces may also pose a problem to the pile.

v) ***Sheet composting*****:** Sheet composting entails laying down of some thin layers of organic materials like leaves, garden trash, weeds, grass clippings, and vegetative food scraps, which are chopped and tilled into the soil with a hoe, spade, or garden fork. If sheet composting is done correctly, an healthy, productive and low-maintenance ecosystem is produced (Craig and Kim, 1998; Mason, 2003).

vi) ***Pit or Trench composting*****:** The composting takes place in shallow pits dug in the ground as opposed to above-ground structures (Aggie Horticulture, 2016). This is the easiest way for decomposing kitchen wastes (University of Illinois Extension, 2009). The wastes are chopped, mixed with soil, put in 30 cm deep holes and covered with at least 20 cm of soil. Decomposition can take place from a month to a year, depending on the soil temperature, microbe availability and content of available material. The composting process takes longer in pits than in above-ground structures (Aggie Horticulture, 2016). Food waste burial can be done in an orderly method or at random in underused portions of the garden.

vii) ***Grub composting*****:** This is a method of composting, where the black soldier fly larvae (BSFL) are employed as the active agents of composting procedure; to rapidly transform generated organic wastes into feeds for chickens, fish, pigs and as required for use (Biopod, 2009; Sheppard, 1992). The grub bin is simple. The BSFL, at maturity crawls out of the grub bin into the collection container. Composted wastes had been reportedly utilized as soil additive or worm food (University of Illinois Extension, 2009).

viii) ***Plastic Bag composting*****:** This has been thought to be the easiest of all the composting techniques (Aggie Horticulture, 2016). It requires no structure; just a black plastic garbage bag. No turning is required; meaning that the composting process takes place mainly under anaerobic condition and would definitely be much slower than composting in well-ventilated structures.

ix) Bokashi composting: Bokashi is a Japanese word that translates to "fermented organic materials". It is a form/kind of anaerobic fermentation (Planet Natural, 2004) carried out inside a recently started bokashi bin. It is easy and generally odour-free (Compost Guy, 2012). The effective microorganisms which ferment and accelerate organic matter decomposition in bokashi bin are the innate carboxylic acid bacteria, leavening and eubacteria which function in kitchen scraps, as microbial community. It is a type of anaerobic fermentation (Planet Natural, 2004). Food reminants are mixed with bokashi in alternate layers in a container until the container is full. It is allowed to ferment in the container for one to two weeks before being buried at 15-20 cm in the ground or in a non-reactive container. Food leftovers, under normal situation would be broken down into rich humus after two weeks of burial under the soil.

x) Compost tea: could be described as not just a suspension of compost brewed from composted materials, but rather a liquid extract or a dissolved solution. It is obtained when compost is steeped in water for 3-7 days. Compost tea is rich in a variety of useful microbes which attack some pathogens in plant (Scheurell and Mahaffee, 2004). Although lab studies reveal that it has a very low nutrient content, with less than 100 ppm of accessible N and K, it has been employed as a fertilizer. Sodium, chlorides, and sulphates are among the other salts found in the tea solution (Zhang *et al*., 1998). Administration of the extract as a form of pesticide to some inedible portions of plants, like seedlings, as well as the application as root dip or as an aboveground spray had been adopted as a method to lower the occurrence of hazardous phytopathogenic fungi in the phyllosphere (Trankner, 1992; Kaufman, 2004).

Variability in formulations and preparation procedures can lead to inconsistencies in results, or even the harmful proliferation of deadly bacteria in compost teas (Briton, 2004).

xi) Hugelkultur: This is the act of raising and filling garden beds with rotting wood (Permaculture, 2010). It has the effect of turning into a dirt-covered nursing log. Water retention and soil warming are part of the advantages of hugelkultur garden beds (Permaculture, 2012). As buried wood decomposes, it acts like a sponge which captures and stores water for subsequent use by crops grown on hugelkultur beds. Heats are liberated from the buried rotting woods, for several years.

xii) Humanure: This is human waste (feces and urine) that is composted for use in agriculture or other applications. In 1994, the phrase was coined to promote its usage as an organic nutrient sources (Jenkins, 2005). Humanure composed of wastes that has been modified after being treated in some assigned facilities. It contains wastes from industries and other related sources, but it majorly consists of feces and urine, some paper and carbonaceous materials, like sawdust. A humanure system, requires no water or electricity and brings out no smell, if adequately maintained. Humanure decomposition process involves the erection of a compost toilet for collection of human wastes, which is thereafter mixed with sawdust and other carbonaceous materials in a hot compost heap, where pathogens are killed (Jenkins, 2015). The trash is composted in situ in a composting toilet. Because there is no authoritative definition for "humanure," it is prone to misinterpretation and can be difficult to distinguish from "sewer sludge" or "biosolids." (Courtney, 2011). The nutrients in feces and urine are returned to the soil when they are composted and consequently contribute to the prevention of soil degeneration. Human excreata, including urine possess nitrogen, phosphorus, potassium, carbon, and calcium in quantities, equivalent of most of fertilisers and manures from the garden store. By annuling the use of potable water required by a regular flush toilet, Humanure helps to conserve fresh water. It also reduces groundwater pollution by managing the breakdown of feces before it enters the system (Jenkins, 2015). Leachate does not contaminate the ground when it is properly controlled. If treated in compliance with local health rules and composted appropriately, humanure could be judged as safe for use on crops. A curing stage is frequently required to ensure crop safety by allowing the compost to pass through a second mesophilic phase, involving low temparatues, so as to minimize possible toxic substances. Humanure is unlike night soil, which when spread on crops with the aim of returning the nutrients in human feces to the soil, transmits and spreads a variety of human parasites.

xiii) ***Vermiculture (Earthworm Composting)*****:** The earthworms eat garbage so, earthworm composting can be done anywhere. However, composting of earthworms in a moist container filled with beddings; like peat moss, soil, degraded leaves, old plants and some farm yard manure, can be done effectively. Earthworms are then added, buried in vegetable food scraps, kept moist and covered with leaves. Vermiculture recycles food wastes into a rich, dark and good soil conditioner (Elcock and Martens, 1995; Planet Natural, 2015). Outdoor earthworm composting is done in any-size pit lined with old cotton cloth or burlap to keep the worms in and allow drainage of excess water. The pit is then filled with soil, manure and leaves after which the earthworms are added, buried in vegetable food scraps and watered. Fruits and vegetable scraps , which are rich in nutrients are converted, by the worms, into composts, which are equally rich in nutrients, as they eat them (Cornell Waste Management Institute, 1996). Castings from earthworms are a microbially rich plant fertilizer that is particularly beneficial to seedlings. Soil disease is prevented by earthworm manure (Kaufman, 2004).

2.7 Factors influencing organic matter source selection

The majority of people choose organic matter sources based on convenience and cost (Peter *et al.*, 2004). However, several points should be considered when assessing an organic matter source. These include:

i) The organic source's nutrient content. This will assist in the determination of how much organic material is required so as to reduce fertiliser inputs.
ii) The organic source's C:N ratio, which will ensure that crops get adequate quantity of the nitrogen required on time if the organic material is eventually used.
iii) The form or state in which the material for the organic source exists. For example, it is important to consider whether the material is in liquid form which will disintegrate rapidly or whether it is a coarse material that can assist in controlling runoff.
iv) The presence of potentially damaging components such as weed seeds, heavy metals or pesticides that could retard crop growth.

v) Whether the chemicals produced as it decomposes act as growth inhibitors that will affect the succeeding crops.

vi) The requirements for transportation and application are important too and should also be put into consideration. For example, the types of equipment needed, as well as the scheduling (in relation to other farm tasks) and whether or not soil integration is desirable. The types of equipment required, giving consideration to timing (relative to other farm activities) and whether incorporation into the soil is desirable.

Excessive addition of organic materials is not likely to be an issue, provided the organic matter sources are green manures or crop wastes from the same field where they are cultivated. However, too much manure, sludge, or other rich materials can be applied.

2.8 Aftermaths of improper organic fertiliser application

The consequences of over application of organic fertilisers include:

i) inefficient nutrient resource utilization.

ii) Excess nitrogen in the soil, which may harm the plants or leach into water sources.

iii) excessive P or other nutrients that could pose a threat to the environment when washed into nearby rivers or bodies of water being used by people in the environment.

Quantity of manure and other organic amendments applied should be determined by the nutrient needs of the succeeding crop plants, thus necessitating the assessment of the material's and soil's nutritional level.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study site

This research was undertaken from March, 2008 to October, 2011, at Ekiti State University's farms, Iworoko Ekiti road, Ado-Ekiti, Nigeria, which is strategically placed between latitude $7^{o}15^{1}$ and $8°5^{1}$N, and longitude $4°45^{1}$ and $5°13^{1}$E, in south-western Nigeria. The site is situated inside the rain forest zone. Mean annual temperatures of 28 °C and 27 °C were recorded for the assumed hottest months; February and March, respectively. The average sunshine hours per day are approximately 5 hours, per year, while the mean annual radiation is 130 k $cal/cm^2/year$. The major soil types identified are Iregun, Apomu and Ondo Series, derived from the dominating crystalline igneous and metamorphic rocks, evolving from the pre-Cambrian cellar complex of south western Nigeria (Fasina *et al*., 2005). Arable and cash crops, such as maize, yam, cassava, cocoa and kolanut, are the major agricultural crops of the area.

3.2 Experimental materials

The experimental materials are as listed:

i) Poultry dung
ii) Cattle wastes; dung, blood, bones, hooves and horns
iii) Sawdust
iv) Neem leaves
v) Tithonia plant (young stalk with leaves)

(i) **Poultry droppings**: These were collected from the waste pile at Top Feeds Farm, Ado-Ekiti, Ekiti State. The farm had 680 layers and the poultry droppings were collected in a pile to be dried and burnt.

(ii) **Cow wastes**: Collection of blood, horns, hooves, bones and dung were done at Ifelodun Abattoir on Ilawe Road, Ado-Ekiti where about 20 cattles are slaughtered daily. The blood was collected from a drain which was created for flushing away the blood while horns, hooves, bones and dung were gathered from assigned dumps which were created for burning of the dried hooves, bones, horns and dung.

(iii) **Sawdust**: This was packed from Falegan Sawmill, Ilawe Road, Ado-Ekiti where timber logs of Iroko, Obeche, Mahogany and Mansonia, are processed into sawn wood and planks daily. A space is provided for the collection of sawdust and unutilizable pieces of wood within the Sawmill where they were burnt.

(iv) **Neem and tithonia leaves**: Succulent young leaves of neem and tithonia were cut and gathered from within the Ekiti State University, Ado-Ekiti. Young neem branches were cut and the leaves were pulled off. Also, several immature and tender stalks of tithonia, were used. Matured, hard and even, flowering plants were averted.

3.3 Chemical analysis of organic wastes and composts

The organic wastes, including the enrichment materials, were prepared by separately air-drying and milling them and they were analysed chemically. The pH of the finished compost was ascertained by electrometric method using the dried compost sample in water, at ratio 1:2. (IITA, 1982). The dry ashing process was used to ascertain the organic carbon measure (Nelson and Sommers, 1996) while the micro-Kjeldahl procedure was employed for detecting total nitrogen portions of digests (Bremner, 1996). Perchloric and nitric acid were used to digest the samples and P was assessed using the yellow colour process involving vanado molybdate (Olsen and Dean, 1965). Flame photometry procedure was adopted for evaluating the K and Na quantities of the dried composts, while Atomic Absorption Spectrophotometry was employed for estimating Ca, Mg, Mn, Fe, Zn, Cu and Pb values.

3.4 Experiment 1: The after-effects of composting on composts' properties

In the course of this study, the heap method of composting was adopted. Cattle dung mixed with sawdust (CD + S), and poultry/chicken dung mixed with sawdust (PD + S) in ratio 1:1, were placed on different heaps. The heaps were 1.5 m broad and

1 m tall. At every two weeks, the heaps were watered and turned. The temperatures in the heaps were measured before each watering and turning and the trends in temperature changes during composting were analysed using descriptive statistics. Samples were taken from the heaps at 2 weeks and at 22 weeks into composting (when the temperature in the heaps had become constant) and analysed for non-synthetic carbon, nitrogen, phosphorus, calcium, magnesium, potassium, sodium, manganese, iron, zinc, copper and lead. The dry ashing method was adopted for organic carbon determination (Nelson and Sommers, 1996) while micro-Kjeldahl procedure was adopted for determining total nitrogen in the digests (Bremner, 1996). Perchloric and nitric acid were used to digest the samples and P was assessed using yellow colour process of vanado molybdate (Olsen and Dean, 1965). Flame photometer was employed for calculation of potassium and sodium in digest while estimation of calcium, magnesium, manganese, iron, zinc, copper and lead was carried out using Atomic Absorption Spectrometer (AAS).

3.4.1 Enrichment of composts using natural N-rich substances

Cow blood, bare bone, foot (hoof), appendage (horn), neem leaves (dongonyaro) and tithonia samples were air dried and milled into powder form (meals) and mixed with the corresponding composts produced after 22 weeks of composting. The combinations obtained for the compost treatments were shown in Table 3.1. The composts were enriched at 15, 30, 45 and 60 g/kg N levels to achieve 50 treatments labelled C_1 to C_{50} (Table 3.2).

3.5 Determination of some attributes of soils in the study site.

Soil from the site of experiment at Ekiti State University Teaching and Research Farm were randomly sampled at the surface layer between 0 and 15 cm, were air dried and thereafter sieved using 2 mm sieve. A representative sample was used to determine the measurement of particle size distribution of soils, pH in water, total Nitrogen, organic matter, available phosphorus, potassium, sodium, calcium, and magnesium. Sizes of particles were determined through the hydrometer method of Bouyoucos (Sheldrick and Hand Wang, 1993). Determination of pH of soils was done in distilled water at ratio 1:2 of soils in water, through the electrometric method.

Table 3.1 Treatment combinations of the organic fertilisers used in the study

Treatments	Description
A- CONTROL	Soil with no enrichment
B- NPK	Inorganic Fertiliser
C- CDS	Cattle dung plus sawdust
D- CDSBM	Cattle dung plus sawdust plus blood
E- CDSBnM	Cattle dung plus sawdust plus bone
F- CDSHnM	Cattle dung plus sawdust plus horn
G- CDSHM	Cattle dung plus sawdust plus hoof
H- CDSTM	Cattle dung plus sawdust plus tithonia
I- CDSNM	Cattle dung plus sawdust plus neem
J- PDS	Poultry dung plus sawdust
K- PDSBM	Poultry dung plus sawdust plus blood
L- PDSBnM	Poultry dung plus sawdust plus bone
M- PDSHnM	Poultry dung plus sawdust plus horn
N- PDSHM	Poultry dung plus sawdust plus hoof
O- PDSTM	Poultry dung plus sawdust plus tithonia
P- PDSNM	Poultry dung plus sawdust plus neem

Table 3.2 N-contribution rates of the composts and the enrichment materials

Treatments	Description	N Contribution Rates (g)	
		Composts	**Enrichments**
C0	Control	Soil with no enrichment	
C1	CDS	6.40	
C2	CDSBM at 15 g/kg N	6.40	109.0
C3	CDSBnM ,,	,,	4300.0
C4	CDSHnM ,,	,,	194.6
C5	CDSHM ,,	,,	148.0
C6	CDSNM ,,	,,	87.1
C7	CDSTM ,,	,,	104.9
C8	CDSBM at 30 g/kg N	6.40	299.5
C9	CDSBnM ,,	,,	11800.0
C10	CDSHnM ,,	,,	533.9
C11	CDSHM ,,	,,	406.2
C12	CDSNM ,,	,,	239.1
C13	CDSTM ,,	,,	287.8
C14	CDSBM at 45 g/kg N	6.40	489.8
C15	CDSBnM ,,	,,	19300.0
C16	CDSHnM ,,	,,	873.3
C17	CDSHM ,,	,,	664.4
C18	CDSNM ,,	,,	391.1
C19	CDSTM ,,	,,	470.7
C20	CDSBM at 60 g/kg N	6.40	680.2
C21	CDSBnM ,,	,,	26800.0
C22	CDSHnM ,,	,,	1212.7
C23	CDSHM ,,	,,	922.5
C24	CDSNM ,,	,,	543.1
C25	CDSTM ,,	,,	653.7
C26	PDS	4.22	
C27	PDSBM at 15 g/kg N	4.22	136.8
C28	PDSBnM ,,	,,	5390.0
C29	PDSHnM ,,	,,	243.9

Table 3.2 continued

Treatments	Description		N Contribution Rate (g)	
			Composts	Enrichments
C30	PDSHM	,,	,,	185.5
C31	PDSNM	,,	,,	109.2
C32	PDSTM	,,	,,	131.5
C33	PDSBM at 30 g/kg N		4.22	327.2
C34	PDSBnM	,,	,,	12890.0
C35	PDSHnM	,,	,,	583.3
C36	PDSHM	,,	,,	443.7
C37	PDSNM	,,	,,	261.2
C38	PDSTM	,,	,,	314.4
C39	PDSBM at 45 g/kg N		4.22	517.5
C40	PDSBnM	,,	,,	20390.0
C41	PDSHnM	,,	,,	922.6
C42	PDSHM	,,	,,	701.9
C43	PDSNM	,,	,,	413.2
C44	PDSTM	,,	,,	497.3
C45	PDSBM at 60 g/kg N		4.22	707.9
C46	PDSBnM	,,	,,	27890.0
C47	PDSHnM	,,	,,	1262.0
C48	PDSHM	,,	,,	960.1
C49	PDSNM	,,	,,	565.0
C50	PDSTM	,,	,,	680.2

Legend

CDS	Cattle dung plus Sawdust
CDSBM	Cattle dung plus Sawdust plus Blood
CDSBnM	Cattle dung plus Sawdust plus Bone
CDSHM	Cattle dung plus Sawdust plus Hoof
CDSHnM	Cattle dung plus Sawdust plus Horn
CDSNM	Cattle dung plus Sawdust plus Neem
CDSTM	Cattle dung plus Sawdust plus Tithonia
PDS	Poultry dung plus Sawdust
PDSBM	Poultry dung plus Sawdust plus Blood
PDSBnM	Poultry dung plus Sawdust plus Bone
PDSHM	Poultry dung plus Sawdust plus Hoof
PDSHnM	Poultry dung plus Sawdust plus Horn
PDSNM	Poultry dung plus Sawdust plus Neem
PDSTM	Poultry dung plus Sawdust plus Tithonia

method (IITA, 1982). The macro-Kjeldahl digestion method was used to estimate total nitrogen (Bremner, 1996) while the organic matter content was evaluated with the wet oxidation procedure (Nelson and Sommers, 1996). Quantity of phosphorus available in soils was evaluated using Bray's procedure (IITA, 1982). Neutral, 1 N NH_4OAc was used to extract the exchangeable metals: potassium, calcium, magnesium and sodium (Hendershot and Lalande, 1993), after which flame photometer was employed for quantifying K and Na, while estimation of calcium and magnesium contained in filtrates was with Atomic Absorption Spectrophotometer. The effective acidity, pressed out, using 1 N KCl, was thereafter measured by titrating with 0.05 N NaOH (Thomas, 1982), and phenolphthalein as an indicator. The exchangeable metals and acidity were summed to compute the effective cation exchange capacity (ECEC).

3.6 Experiment 2: Nutrient release pattern of composts through Incubation Studies

Two (2) kilogrammes (kg) samples of soil from the experimental plot were weighed into pots. Each enriched compost was used; by properly mixing with the soils at 30 t/ha. Properly mixed substances were dampened, covered and wrapped in black polythene bags before being stored in a cool environment. Thorough mixing of pots' contents was done at weeks 4, 8, 12 and 16 of incubation and thereafter, total N, accessible phosphorus and inter-exchangeable potassium contained in sampled soils from the pots were measured. The macro-Kjeldahl method was adopted for Nitrogen determination, while the Bray P-1 method was involved in available P calculation and exchangeable K quantified by flame photometry after extraction with neutral normal NH_4OAc.

3.7 Experiment 3: Growth and yield responses of *worowo* to composts enriched with organic N-rich sources

Enriched composts at 60 g/kg N enrichment level which outperformed composts at other enrichment levels in quantities of soil N obtained from incubation were used in the pot experiment, with 16 treatments: CDS, CDSBM, CDSBnM, CDSHnM, CDSHM, CDSTM, CDSNM, PDS, PDSBM, PDSBnM, PDSHnM, PDSHM, PDSTM, PDSNM, NPK and CONTROL. Each of the treatments had three replicates. The experimental design was completely randomized design (Figure 3.1).

RI	RII	RIII
CDSHnM	CDSBM	PDSHnM
CDS	NPK	PDSHM
CDSBM	CDS	PDSTM
NPK	CDSBnM	PDSNM
CDSBnM	CONTROL	CDSHM
CONTROL	CDSHnM	CDSTM
PDS	CDSHM	CDSNM
CDSTM	PDSBM	PDS
PDSBnM	CDSTM	PDSBM
CDSHM	PDSBnM	PDSBnM
CDSNM	PDS	NPK
PDSBM	CDSNM	CDS
PDSNM	PDSHM	CDSBM
PDSHnM	PDSNM	CDSBnM
PDSTM	PDSHnM	CDSHnM
PDSHM	PDSTM	

Figure 3.1: Experimental Layout used for the pot experiment in this study

Legend:

CDS	Cattle dung plus Sawdust
CDSBM	Cattle dung plus Sawdust plus Blood
CDSBnM	Cattle dung plus Sawdust plus Bone
CDSHM	Cattle dung plus Sawdust plus Hoof
CDSHnM	Cattle dung plus Sawdust plus Horn
CDSNM	Cattle dung plus Sawdust plus Neem
CDSTM	Cattle dung plus Sawdust plus Tithonia
PDS	Poultry dung plus Sawdust
PDSBM	Poultry dung plus Sawdust plus Blood
PDSBnM	Poultry dung plus Sawdust plus Bone
PDSHM	Poultry dung plus Sawdust plus Hoof
PDSHnM	Poultry dung plus Sawdust plus Horn
PDSNM	Poultry dung plus Sawdust plus Neem
PDSTM	Poultry dung plus Sawdust plus Tithonia
CONTROL	Soil alone
NPK	Inorganic fertiliser
RI, RII and RIII	= Replicate 1, Replicate 2 and Replicate 3 respectively

Each pot (of 4 m^3volume) contained 5 kg soil which was treated with composts at 60 g/kg N enrichment level, applied at 30 t/ha and NPK 15-15-15, which was thereafter utilized in the assigned pots at 400 kg/ha (60 kg N/ha). Bunches of *worowo* vegetables were obtained from Erekesin market (Oja Oba) in Ado-Ekiti. Worowo stems were defoliated and cut to 20 cm in length, and were thereafter planted at the rate of four stems per pot a week after mixing the enriched composts with the soil and the pots were kept under shade. At 2 weeks after planting, the best two stands were retained in each pot. At 2 weeks after planting, application of NPK 15-15-15 to the allotted pots was done and weeds were uprooted from the pots as necessary at 30, 90 and 150 days after planting. The metrics measured in the study include; vine length, number of leaves and branches on individual plants, vine girth, leaf area index-LAI (which is calculated by dividing the obtained leaf area values of plants with the area of the total space used up by the particular crop plant), and edible shoot yield (ESY). The measurements were taken at 60, 120 and 180 days after planting. Matured edible shoots, at 20 cm away from soil surface were harvested as marketable produce with stumps left in pots for further studies. The data generated were submitted to analysis of variance test, adopting Duncan's Multiple Range Test at $\alpha_{0.05}$, in separating the means.

3.8 Experiment 4: Growth and yield responses of *worowo* to compost enriched with neem (CDSNM)

The CDS enriched with neem (CDSNM) treatment which produced/yielded the best result from the pot experiment was used for planting, varying the rates at 0, 10, 20, 30, 40 t/ha and 400 kg/ha of NPK 15-15-15, was thereafter utilized, for compares. This experiment, conducted from April to October, 2010, comprised of six treatments in four replicates. Twenty four beds of 2 m × 4 m each were made (Figure 3.2). The five different levels of CDSNM were applied to the respective beds randomly, mixed thoroughly with the topsoil and left for 2 weeks before the stems of *worowo* were planted. Stems were cut into 20 cm long pieces, defoliated and planted at 40 cm × 60 cm on the beds such that there were 30 stands per bed. Artificial shades were made for the vegetables by erecting poles which were covered with palm fronds. Trellises were also built to provide support for the vegetables. Staking was done at 30 DAP and the vines of *worowo* were trained to climb on to the trellises and round the erected sticks (Plate 3.1). Weeding was done at 30, 90 and 150 DAP. The parameteric quantities

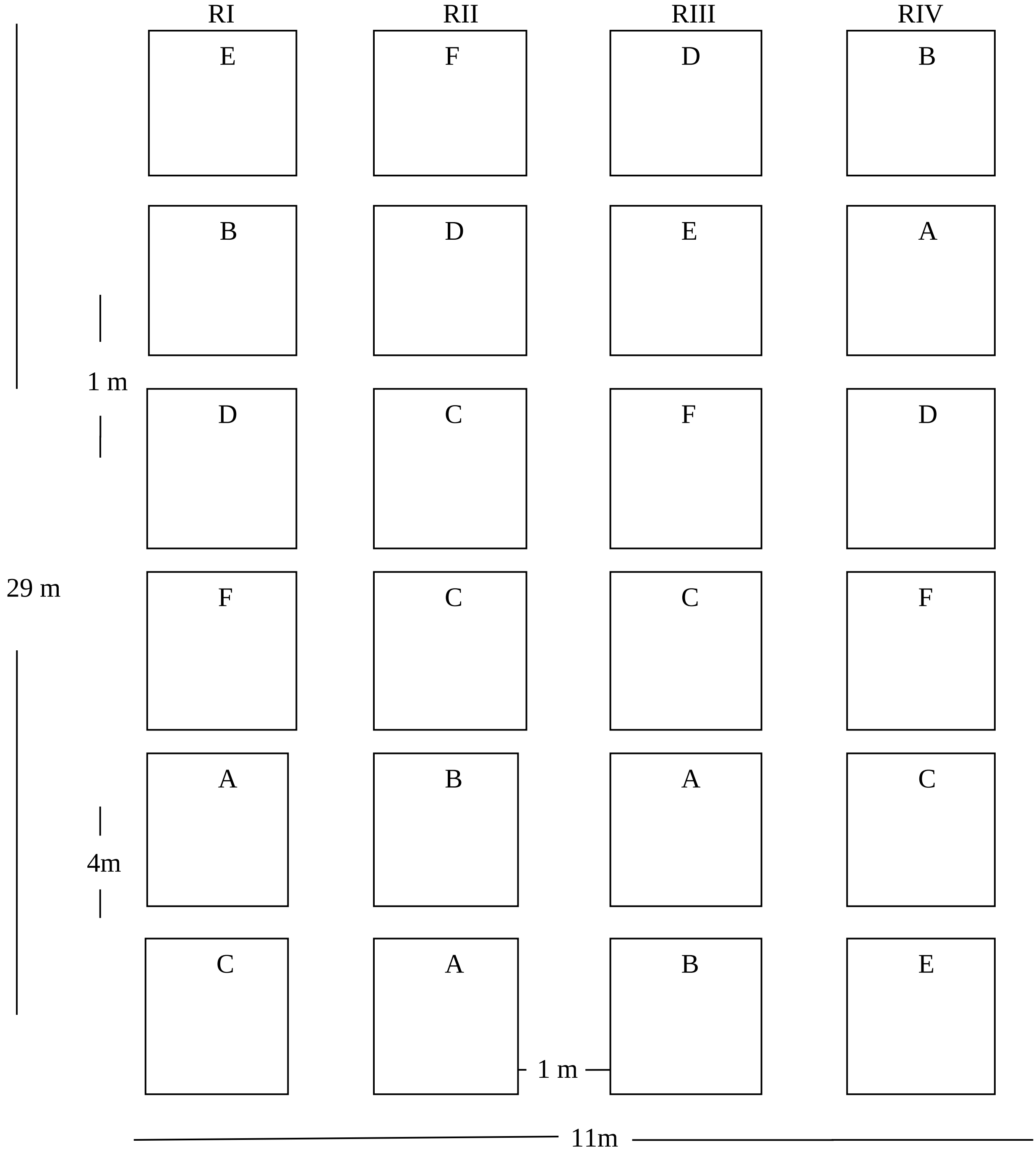

Figure 3.2: Experimental Layout for the field trial

Legend

CD = Cattle dung

A = CONTROL
B = NPK 15-15-15
C = CDSNM at 40 t/ha
D = CDSNM at 30 t/ha
E = CDSNM at 20 t/ha
F = CDSNM at 10 t/ha

SD = Sawdust
NM= Neem
RI = Replicate 1
RII= Replicate 2
RIII = Replicate 3
RIV = Replicate 4

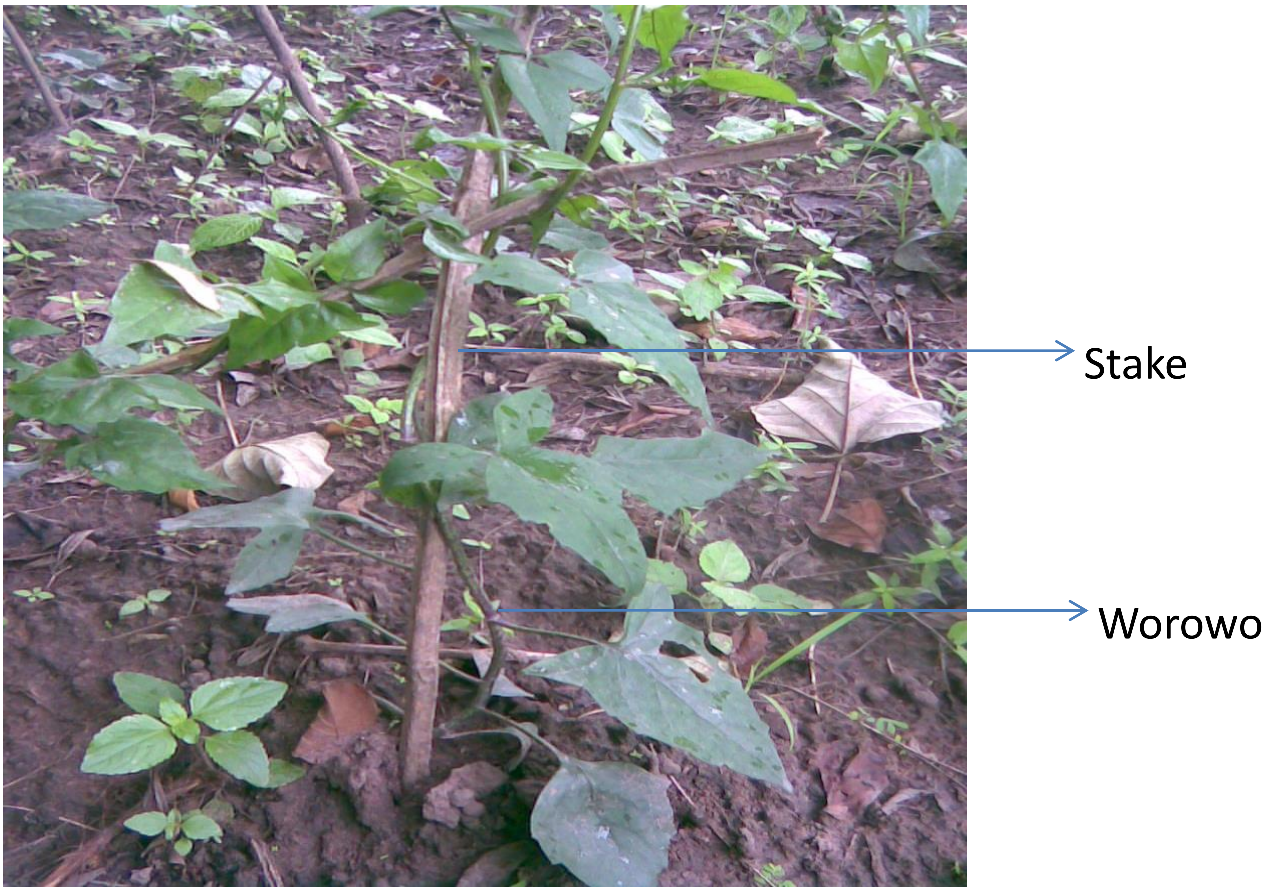

Plate 3.1: ***Worowo on the field,*** **as a climbing plant**

evaluated were: vine length, number of leaves and branches, leaf area index, vine girth and edible shoot output. The intended measurements were taken at 60, 120 and 180 DAP. Matured edible shoots, at 20 cm away from soil surface were harvested as marketable produce with stumps left on beds for further studies. Data generated were submitted to analysis of variance and the means separated using Duncan's Multiple Range Test (DMRT) at $\alpha_{0.05}$. A repeat of the experiment took place between April and October, 2011.

3.9 Experiment 5: Residual effects of compost enriched with neem (CDSNM) on selected soil attributes, growth parameters and edible shoot output of *worowo*.

The residual effects of CDSNM on selected attributes of soils of the study site, growth and production of *worowo* edible shoots were also measured.

3.10 Effects of compost enriched with neem (CDSNM) on the nutritional quality of *worowo*

Samples of *worowo* leaves, after harvesting at 180 DAP in the two seasons, were prepared for proximate examination. Evaluation of protein, moisture, ash, crude fibre, fat and carbohydrate; likewise, K, Ca, Mg, Na, Fe, Zn and Cu was done. Protein content was calculated by determination of N using the micro-Kjeldahl procedure and N was thereafter converted by multiplying with 6.25, as a constant. Moisture quantity was detected through drying method; where samples were heated in line with the drying procedure and the weight loss was thereafter used to calculate amount of moisture contained. The fat content was determined by digestion of the protein component with boiling hydrochloric acid in order to break the strong bonds of lipids and protein compounds. Product of digestion was then filtered and the resulting fat, after drying was squeezed out with petroleum ether. The residue, after evaporation and distillation of solvent, was dried and weighed. Determination of crude fibre was done using fibre bag (Gerhardt method). Evaluation of K and Na was through flame photometry and Ca, Mg, Fe, Zn, Cu were detected through Atomic Absorption Spectrophotometry (AAS) (AOAC, 2005).

CHAPTER FOUR

4.0 RESULTS

4.1 Nutrient makeup of composts and enrichment materials

Table 4.1 describes the chemical attributes of the compost manure stuffs and the enrichment substances. The compost materials (poultry dung, cattle dung and sawdust) had pH values of 8.4, 8.0 and 8.4, respectively. Out of the compost materials used, poultry dung gave the highest N (79.2 g/kg) followed by cattle dung (53.9 g/kg N). The least value was in saw dust which contained 1.5 g/kg of N. Total P in cattle dung was 26 g/kg while the other two compost materials-poultry manure and sawdust contained 8.6 and 0.2 g/kg P respectively. The Ca content of poultry manure (13.1 g/kg) was the highest of the compost materials, which was followed by saw dust with 10.4 g/kg and cattle dung was the lowest (9.5 g/kg). Poultry dung gave the highest Mg (6.7 g/kg), followed by sawdust (6.4 g/kg) which contained a slightly higher Mg than cattle dung (6.0 g/kg). Total K was 5.2, 4.8 and 4.4 g/kg for poultry dung, cattle dung and saw dust respectively while Na content was 0.8 g/kg for cattle dung and poultry dung but it was 0.5 g/kg for sawdust.

Poultry dung contained 0.3 g/kg Mn while the content in cattle dung and sawdust was the same (0.2 g/kg). The Fe content was the same for cattle dung and poultry dung (0.5 g/kg) but 0.3 g/kg in sawdust. The Zn content was higher in cattle dung (0.2 g/kg) than in poultry dung and saw dust with 0.1 g/kg. The Cu values ranged from 0.03 to 0.1 g/kg while Pb was below detectable levels in the compost materials. Bone, horn and tithonia meals were basic (pH between 8.2 and 10.5) while the blood, hoof and neem leaf meals were mildly acidic (pH 6.2-6.5). Neem meal contained more N (98.7 g/kg) followed by tithonia meal (82.0 g/kg) and blood meal (78.8 g/kg) while bone meal contained the least (2.0 g/kg). Values recorded for total P was in the order horn > bone > tithonia > neem > hoof > blood with values at 25.6, 24.1, 2.7, 1.2, 0.9 and 0.3 g/kg, respectively. The Ca contents of blood meal and hoof meal were similar (12.1 and 12.2, g/kg respectively) and lower in neem leaf meal (9.2 g/kg). The Mg content of the enrichment materials varied from 5.8 to 6.6 g/kg for bone meal and hoof meal respectively.

Table 4.1: Nutrient composition of composts and enrichment materials used in the study

Parameter	Value								
	Blood	**Bone**	**Hoof**	**Horn**	**Tithonia**	**Neem**	**Cattle dung**	**Poultry dung**	**Saw dust**
pH	6.2	10.5	6.2	8.2	8.2	6.5	8.0	8.4	8.4
Total N (g/kg)	78.8	2.0	58.1	44.2	82.0	98.7	53.9	79.2	0.9
Organic C (g/kg)	325.6	7.8	405.4	182.6	339.1	407.8	222.9	327.2	334.3
Phosphorus (g/kg)	0.3	24.1	0.9	25.6	2.7	1.2	26.8	8.6	0.2
Calcium (g/kg)	12.2	10.9	12.1	10.0	9.7	9.2	9.5	13.1	10.4
Magnesium " "	6.1	5.8	6.6	6.0	6.2	5.9	6.0	6.7	6.4
Potassium " "	4.4	4.1	5.0	4.1	5.1	4.1	4.4	5.2	4.8
Sodium " "	1.1	0.8	0.7	0.7	0.5	0.5	0.8	0.8	0.5
Manganese (g/kg)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Iron " "	0.4	0.4	0.5	0.5	0.3	0.5	0.5	0.5	0.3
Zinc " "	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1
Copper " "	0.1	0.0	0.04	0.1	0.04	0.1	0.1	0.03	0.03
Lead " "	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The K status ranged between 4.1 and 5.1 g/kg with the lowest values obtained in neem, horn and bone meals while hoof and tithonia meals had the highest values. The Na content followed a similar trend as in K as 1.1 g/kg which was the highest K value was obtained from blood meal and followed by bone meal (0.8 g/kg), hoof and horn meals (0.7 g/kg) while tithonia and neem leaf meals contained the least value (0.5 g/kg). The Mn contents were the same for the enrichment materials at 0.2 g/kg while Fe was highest for hoof, horn and neem leaf meals (0.5 g/kg) and least for tithonia meal (0.3 g/kg). Only neem leaf meal contained 0.1 g/kg Zn while other enrichment substances contained 0.2 g/kg. Bone, hoof and tithonia meals contained 0.04 g/kg of Cu while blood, horn and neem leaf meals contained 0.1 g/kg of Cu. Pb was detected only in bone meal at 0.01 g/kg.

4.2 Experiment 1: Physical and chemical characteristics of composts as affected by weeks of composting

The two main temperature ranges: for mesophilic (with optimum temperature of 20 and 45°C), together with thermophilic (optimum temperature of 50 and 70°C), often encountered in aerobic composting, were observed (Fig 4.1). At the first turning (2 weeks into composting), the temperature was 40 and 42^{o}C but increased to 53 and 56^{o}C for PDS and CDS respectively at the second turning (4 weeks into composting). At the third turning (6 weeks into composting), the temperatures of the materials increased to 62 and 66°C but decreased to 58 and 56^{o}C for PDS and CDS respectively at 8 weeks and to 50^{o}C for both heaps at 10 weeks. The temperature continued to decrease to 42 and 40^{o}C at 12 weeks, 30^{o}C at 14 weeks and to 24^{o}C for PDS and 25^{o}C for CDS at 16 weeks into composting. At 18 weeks, the temperature remained constant at 24 and 25^{o}C in the PDS and CDS heaps respectively. At 20 weeks, the temperature on both heaps was observed to remain at 24^{o}C and turning no longer reheated the piles; an indication that the piles have attained the curing stage. The temperatures for the heaps remained constant till 22 weeks, at which time the composts had become black in colour.

The chemical properties of compost samples at 2 and 22 weeks are shown in Table 4.2. At 2 weeks into composting, the pH values in the two composts were high with PDS having pH 8.0 and CDS having 8.3; an indication that the two

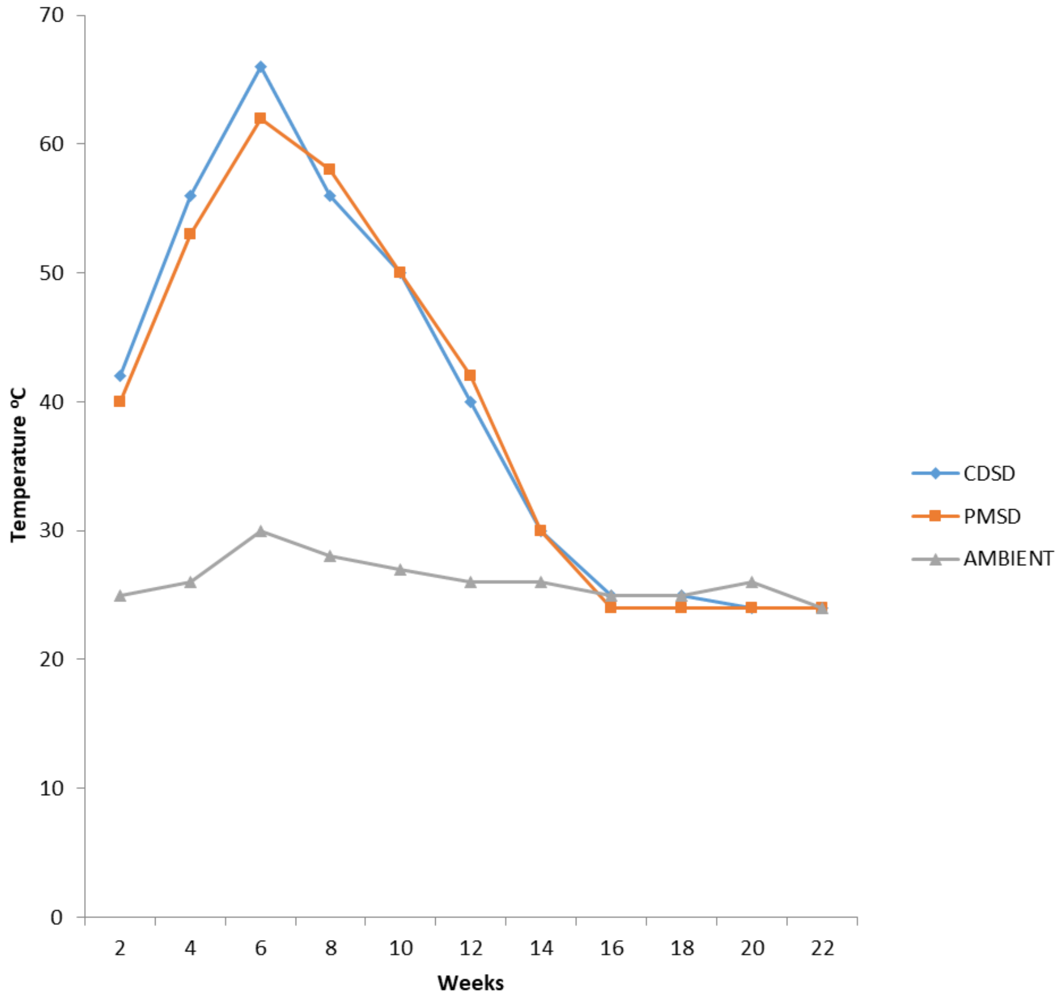

Fig. 4.1: Temperature changes during composting of cow dung+sawdust and poultry droppings + sawdust

Table 4.2: Chemical properties of the composts at 2 and 22 weeks into composting

Property		PDS Value		CDS Value	
		2 weeks	22 weeks	2 weeks	22 weeks
pH		8.0	8.2	8.3	8.4
Total N	g/kg	3.91	4.22	6.02	6.40
Organic C	,,	161.2	158.0	249.0	243.0
Total P	,,	19.7	23.0	5.5	10.0
Calcium	,,	9.0	11.5	11.2	13.0
Magnesium	,,	5.3	6.2	6.3	6.8
Potassium	,,	4.2	5.4	5.0	6.1
Sodium	,,	0.04	0.04	0.11	0.13
Manganese	,,	0.2	0.3	0.3	0.4
Iron	,,	0.3	0.2	0.5	0.4
Zinc	,,	0.2	0.3	0.2	0.5
Copper	,,	0.1	0.2	0.1	0.3
Lead	,,	0.0	0.0	0.0	0.0

Legend

PDS = Poultry dung + Sawdust

CDS = Cattle dung + Sawdust

composts were basic. The values obtained for Total N, organic carbon and all the exchangeable bases were higher in the CDS based composts at 2 weeks into composting while total P was higher in PDS. The Pb content of the two composts was not detectable.

At 22 weeks into composting, the pH of the two composts increased becoming more basic with pH values 8.2 for PDS and 8.4 for CDS. Also, an increase was recorded for total N, organic carbon, total P and exchangeable cations of both composts except in Fe, where a reduction in the initially recorded values was observed. The particles had reduced in size and became consistent and soil-like in texture. It was also observed that the C: N for both compost samples got reduced at 22 weeks into composting.

4.3 Chemical properties and particle size distribution of soils at the experimental site

Table 4.3 reveals selected attributes of soil for incubation studies. The soil was sparingly acidic with pH of 5.8 and 6.6 in KCl and water, respectively. It was loamy sand with organic matter content at 14.6 g/kg. Soil N was 0.8 g/kg; P was 13 mg/kg and the interchangeable cations; K, Ca, Mg and Na were sequentially recorded, as 0.3, 7.0, 1.8 and 0.1 cmol/kg.

4.4 Experiment 2: Nutrient release patterns of composts as observed under incubation studies

Tables 4.4 to 4.7 show the soil N contents during incubation. At 4 weeks, the soil to which CDSBM at 60 g/kg N enrichment level was applied contained the highest N followed by PDSBnM at 60 g/kg N enrichment level while the least N was obtained from CDSBnM at 15 g/kg N enrichment level. There was decrease in soil N contents across the treatments at 8 weeks of incubation. Only CDSNM at all N enrichment levels and PDSBM at 30 g/kg N enrichment level showed consistent increase in soil N contents. At 8 weeks, PDSTM at 60 g/kg N exhibited the highest nitrogen status while CDSHM at 15 g/kg N was the least in soil nitrogen. The highest soil N content at 12 weeks was from CDSNM at 60 g/kg N level and the least N content was recorded from CDSBM raised to 10 g/kg N. Except in CDSBM enriched to 15 g/kg N and PDSHM at 60 g/kg N where lower values were recorded, the N

Table 4.3: Chemical attributes and particle distribution of experimental soils

Property		Value
pH (1:1 KCl)		5.8
pH (H_2O)		6.6
Total Nitrogen (g/kg)		0.8
Organic matter (g/kg)		14.6
Available P (mg/kg)		13
Exchangeable cations		
Calcium	(cmol/kg)	2.8
Magnesium	(cmol/kg)	1.8
Potassium	(cmol/kg)	0.3
Sodium	(cmol/kg)	0.1
Exchangeable Acidity	(cmol/kg)	0.6
ECEC	(cmol/kg)	5.6
Base saturation	(g/kg)	893
Particle Distribution	(g/kg)	
Sand		799
Silt		132
Clay		69
Textural Class (USDA)		Loamy sand

Table 4.4: Total N released during incubation for treatments enriched to 15 g/kgN

Treatment	Quantity (g/kg) in weeks			
	4	8	12	16
C0	0.6	0.4	0.5	0.6
C1	4.1	3.2	4.1	4.4
C2	4.2	3.2	3.1	3.5
C3	2.7	2.8	4.0	4.9
C4	3.5	2.5	3.3	3.3
C5	3.3	3.0	3.4	3.5
C6	2.9	3.5	3.8	4.0
C7	4.2	3.9	4.4	4.4
C26	5.1	3.7	4.4	5.1
C27	4.8	4.5	5.0	5.1
C28	4.4	3.8	4.0	5.6
C29	4.1	3.5	4.8	5.4
C30	3.4	4.2	5.2	6.1
C31	5.5	4.1	5.2	5.2
C32	4.3	3.7	4.4	5.4

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C2	CDSBM at 15 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 15 g N/kg
C3	CDSBnM at 15 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 15 g N/kg
C4	CDSHM at 15 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 15 g N/kg
C5	CDSHnM at 15 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 15 g N/kg
C6	CDSNM at 15 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 15 g N/kg
C7	CDSTM at 15 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 15 g N/kg
C26	PDS	Poultry dung plus Sawdust
C27	PDSBM at 15 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 15 g N/kg
C28	PDSBnM at 15 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 15 g N/kg
C29	PDSHM at 15 g/kg N	Poultry dung Sawdust plus Hoof- N raised to 15 g N/kg
C30	PDSHnM at 15 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 15 g N/kg
C31	PDSNM at 15 g/kg N	Poultry dung Sawdust plus Neem- N raised to 15 g N/kg
C32	PDSTM at 15 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 15 g N/kg

Table 4.5: Total N released during incubation for treatments enriched to 30 g/kg N

Treatment	Quantity (g/kg) in weeks			
	4	8	12	16
C0	0.6	0.4	0.5	0.6
C1	4.1	3.2	4.1	4.4
C8	4.2	3.7	3.7	4.3
C9	4.1	3.8	4.3	5.1
C10	3.9	3.9	4.1	4.3
C11	4.0	3.4	3.6	3.6
C12	3.0	3.8	4.9	5.9
C13	4.5	3.4	5.2	5.2
C26	5.1	3.7	4.4	5.1
C33	4.9	5.3	5.2	6.5
C34	5.9	4.8	5.0	5.7
C35	4.5	3.8	5.2	5.5
C36	5.3	5.2	5.8	6.4
C37	6.0	4.2	5.5	6.0
C38	4.4	4.2	4.4	6.0

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C8	CDSBM at 30 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 30 g N/kg
C9	CDSBnM at 30 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 30 g N/kg
C10	CDSHM at 30 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C11	CDSHnM at 30 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 30 g N/kg
C12	CDSNM at 30 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 30 g N/kg
C13	CDSTM at 30 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 30 g N/kg
C26	PDS	Poultry dung plus Sawdust
C33	PDSBM at 30 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 30 g N/kg
C34	PDSBnM at 30 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 30 g N/kg
C35	PDSHM at 30 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C36	PDSHnM at 30 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 30 g N/kg
C37	PDSNM at 30 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 30 g N/kg
C38	PDSTM at 30 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 30 g N/kg

Table 4.6: Total N released during incubation for treatments enriched to 45 g/kg N

Treatment	Quantity (g/kg) in weeks			
	4	**8**	**12**	**16**
C0	0.6	0.4	0.5	0.6
C1	4.1	3.2	4.1	4.4
C14	4.9	4.4	4.5	4.6
C15	4.9	3.9	4.7	5.6
C16	4.9	4.1	4.3	5.1
C17	4.4	3.8	4.4	4.4
C18	3.2	4.4	6.7	6.6
C19	5.2	4.6	5.2	5.3
C26	5.1	3.7	4.4	5.1
C39	6.1	5.3	6.1	6.8
C40	6.4	5.3	5.4	6.0
C41	5.8	4.4	5.4	5.7
C42	5.7	5.3	5.9	6.5
C43	6.4	5.2	5.7	6.1
C44	7.9	5.5	5.5	6.4

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C14	CDSBM at 45 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 45 g N/kg
C15	CDSBnM at 45 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 45 g N/kg
C16	CDSHM at 45 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C17	CDSHnM at 45 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 45 g N/kg
C18	CDSNM at 45 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 45 g N/kg
C19	CDSTM at 45 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 45 g N/kg
C26	PDS	Poultry dung plus Sawdust
C39	PDSBM at 45 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 45 g N/kg
C40	PDSBnM at 45 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 45 g N/kg
C41	PDSHM at 45 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C42	PDSHnM at 45 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 45 g N/kg
C43	PDSNM at 45 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 45 g N/kg N
C44	PDSTM at 45 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 45 g N/kg N

Table 4.7: Total N released during incubation for treatments enriched to 60 g/kg N

Treatment	Quantity (g/kg) in weeks			
	4	8	12	16
C0	0.6	0.4	0.5	0.6
C1	4.1	3.2	4.1	4.4
C20	9.9	5.2	5.3	5.9
C21	8.6	5.1	5.2	5.6
C22	6.9	4.4	4.5	5.4
C23	5.2	4.9	5.8	6.1
C24	5.2	5.6	7.3	9.2
C25	5.4	4.9	6.6	6.6
C26	5.1	3.7	4.4	5.1
C45	6.3	6.2	6.9	7.8
C46	8.7	5.8	6.1	6.7
C47	6.7	5.6	5.5	6.1
C48	7.1	5.3	6.6	6.6
C49	6.6	6.2	6.2	6.5
C50	8.0	6.5	6.8	7.1

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C20	CDSBM at 60 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 60 g N/kg
C21	CDSBnM at 60 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 60 g N/kg
C22	CDSHM at 60 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 60 g N/kg
C23	CDSHnM at 60 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 60 g N/kg
C24	CDSNM at 60 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 60 g N/kg
C25	CDSTM at 60 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 60 g N/kg
C26	PDS	Poultry dung plus Sawdust
C45	PDSBM at 60 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 60 g N/kg
C46	PDSBnM at 60 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 60 g N/kg
C47	PDSHM at 60 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 60 g/kg
C48	PDSHnM at 60 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 60 g N/kg
C49	PDSNM at 60 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 60 g N/kg
C50	PDSTM at 60 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 60 g N/kg

contents were higher for all treatments at 12 weeks of incubation. This similar trend was observed at week 16 of incubation, as 60 g/kg N of CDSNM at still supplied the most superior soil nitrogen while CDSHM raised to 15 g/kg N possessed the least. The most superior soil N content from the incubation study was obtained from CDSBM at 60 g/kg N enrichment level. Though the highest N value released through incubation was recorded from pots treated with CDSBM at 60 g/kg N, only CDSNM showed continuous increase in N content at all N levels throughout the incubation period. Soil N contents measured for the enriched composts during incubation increased with the N enrichment levels.

Tables 4.8 to 4.11 show the trend of soil available P values during incubation. At the fourth week of incubating, CDSBM fortified, to 60 g/kg N mineralized the highest quantity of P (12.2 mg/kg) followed by PDSBnM at 45 g/kg N which mineralized 9.9 mg/kg P. The least P value (8.2 mg/kg P) was obtained from addition of CDSNM at 45 g/kg N. Available P increased across the treatments at 8 weeks but CDSHM fortified to 15 g/kg N, CDSBnM fortified to 30 g/kg N, PDS gave lower P values than they had at 4 weeks of incubation. The highest P value (18.6 mg/kg) was recorded for PDSNM at 60 g/kg N enrichment level followed by PDSTM at 60 g/kg N (17.8 mg/kg P). The least P was obtained from CDSHM at 15 g/kg N (8.2 mg/kg). The increase in recorded P values continued for all the treatments at 12 weeks of incubation. The highest P content (25.6 mg/kg) was obtained from PDSBM at 60 g/kg N followed by PDSTM at 60 g/kg N (24.2 mg/kg). The least P content was obtained from CDSHM at 15 g/kg N (10.5 mg/kg). At week 16 of incubating, the increasing trend in P mineralization continued as PDSNM at 60 g/kg N enrichment level giving the highest value (29.0 mg/kg) while CDSHnM at 15 g/kg N released the least P (16.2 mg/kg). Increase in N levels of the enriched treatments coupled with interactions of other factors could be said to have positively affected the availability of P at all weeks.

Tables 4.12 to 4.15 show the exchangeable K contents in soils to which the enriched composts were applied. At the fourth week of incubating, PDSTM enriched at 60 g/kg N mineralized the highest amount of exchangeable K (2.43 cmol/kg) while the least value (0.33 cmol/kg) was from CDSHnM at 15 g/kg N. From week 8 of incubation, it was observed that the highest K (2.44 cmol/kg) was released from PDSTM at 60 g/kg N followed by CDSNM also at 60 g/kg N (1.99 cmol/kg), while PDSBnM enriched to 15 g/kg N mineralized the least K (0.37 cmol/kg) At week 12 of incubating, exchangeable K increased across the treatments but CDSBnM and CDSNM at 30 g/kg N including CDSHM at 60 g/kg N had lower values while CDSBM both at 30 and 60 g/kg N enrichment levels had same K values as at 8 weeks of

Table 4.8: Accessible P released during incubation for treatments enriched to 15 g/kg N

Treatment	Quantity (g/kg) in weeks 4	8	12	16
C0	3.0	2.1	3.2	3.8
C1	8.4	9.2	12.4	19.0
C2	8.4	11.2	12.7	19.8
C3	8.4	9.0	12.1	19.9
C4	8.3	8.2	10.5	17.2
C5	8.4	10.9	12.6	16.2
C6	8.3	11.8	13.4	21.1
C7	8.4	10.8	14.9	19.5
C26	9.1	9.0	16.8	18.5
C27	9.1	13.6	16.7	21.3
C28	9.2	13.6	15.7	21.8
C29	9.0	11.8	16.8	22.0
C30	9.0	14.0	16.3	22.7
C31	9.1	13.3	17.2	23.0
C32	9.1	14.3	15.8	23.3

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C2	CDSBM at 15 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 15 g N/kg
C3	CDSBnM at 15 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 15 g N/kg
C4	CDSHM at 15 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 15 g N/kg
C5	CDSHnM at 15 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 15 g N/kg
C6	CDSNM at 15 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 15 g N/kg
C7	CDSTM at 15 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 15 g N/kg
C26	PDS	Poultry dung plus Sawdust
C27	PDSBM at 15 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 15 g N/kg
C28	PDSBnM at 15 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 15 g N/kg
C29	PDSHM at 15 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 15 g N/kg
C30	PDSHnM at 15 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 15 g N/kg
C31	PDSNM at 15 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 15 g N/kg
C32	PDSTM at 15 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 15 g N/kg.

Table 4.9: Accessible P released during incubation for treatments enriched to 30 g/kg N

	Quantity (g/kg) in weeks			
Treatment	**4**	**8**	**12**	**16**
C0	3.0	2.0	3.2	4.0
C1	8.4	9.2	12.4	19.0
C8	8.5	11.3	14.8	20.3
C9	9.6	9.1	12.8	20.0
C10	8.4	10.9	12.3	19.8
C11	8.6	10.9	13.8	18.5
C12	8.8	12.6	13.4	21.5
C13	9.1	11.2	15.7	20.4
C26	9.1	9.0	16.8	18.5
C33	9.3	14.8	17.7	22.5
C34	9.6	13.9	18.4	23.3
C35	9.2	13.4	17.1	22.9
C36	9.1	14.4	16.3	24
C37	9.2	15.2	18.3	23.3
C38	9.2	15.7	20.5	24.0

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C8	CDSBM at 30 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 30 g N/kg
C9	CDSBnM at 30 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 30 g N/kg
C10	CDSHM at 30 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C11	CDSHnM at 30 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 30 g N/kg
C12	CDSNM at 30 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 30 g N/kg
C13	CDSTM at 30 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 30 g N/kg
C26	PDS	Poultry dung plus Sawdust
C33	PDSBM at 30 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 30 g N/kg
C34	PDSBnM at 30 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 30 g N/kg
C35	PDSHM at 30 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C36	PDSHnM at 30 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 30 g N/kg
C37	PDSNM at 30 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 30 g N/kg
C38	PDSTM at 30 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 30 g N/kg

Table 4.10: Accessible P released during incubation for treatments enriched to 45 g/kg N

	Quantity (g/kg) in weeks			
Treatment	**4**	**8**	**12**	**16**
C0	3.0	2.0	3.2	4.0
C1	8.4	9.2	12.4	19.0
C14	9.3	14.2	18.3	20.9
C15	8.5	11.4	15.7	20.4
C16	8.7	12.7	14.8	20.2
C17	8.6	12.9	14.4	19.2
C18	8.2	13.3	15.8	22
C19	9.4	12.0	16.6	21.3
C26	9.1	9.0	16.8	18.5
C39	9.5	14.9	18.4	25.0
C40	9.9	15.3	19.8	26.0
C41	9.5	13.8	17.6	24.5
C42	9.3	15	17.4	25.0
C43	9.4	17.5	21.2	25.0
C44	9.2	16.7	21.3	26.0

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C14	CDSBM at 45 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 45 g N/kg
C15	CDSBnM at 45 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 45 g N/kg
C16	CDSHM at 45 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C17	CDSHnM at 45 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 45 g N/kg
C18	CDSNM at 45 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 45 g N/kg
C19	CDSTM at 45 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 45 g N/kg
C26	PDS	Poultry dung plus Sawdust
C39	PDSBM at 45 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 45 g N/kg
C40	PDSBnM at 45 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 45 g N/kg
C41	PDSHM at 45 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C42	PDSHnM at 45 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 45 g N/kg
C43	PDSNM at 45 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 45 g N/kg N
C44	PDSTM at 45 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 45 g N/kg N

Table 4.11: Accessible P released during incubation for treatments enriched to 60 g/kg N

Treatment	Quantity (g/kg) in weeks 4	8	12	16
C0	3.0	2.0	3.2	4.0
C1	8.4	9.2	12.4	19.0
C20	12.2	14.7	19.8	21.0
C21	8.9	16.5	18.9	23.3
C22	9.3	13.1	17.8	21.0
C23	9.5	13.1	14.8	19.2
C24	9.5	14.0	16.8	23.9
C25	9.7	14.0	17.1	22.4
C26	9.1	9.0	16.8	18.5
C45	9.6	15.3	25.6	27.0
C46	9.3	15.6	22.5	28.0
C47	9.6	14.3	20.5	28.0
C48	9.6	15.4	20.2	27.0
C49	9.7	18.6	21.7	29.0
C50	9.1	17.8	24.2	26.3

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C20	CDSBM at 60 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 60 g N/kg
C21	CDSBnM at 60 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 60 g N/kg
C22	CDSHM at 60 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 60 g N/kg
C23	CDSHnM at 60 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 60 g N/kg
C24	CDSNM at 60 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 60 g N/kg
C25	CDSTM at 60 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 60 g N/kg
C26	PDS	Poultry dung plus Sawdust
C45	PDSBM at 60 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 60 g N/kg
C46	PDSBnM at 60 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 60 g N/kg
C47	PDSHM at 60 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 60 g/kg
C48	PDSHnM at 60 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 60 g N/kg
C49	PDSNM at 60 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 60 g N/kg
C50	PDSTM at 60 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 60 g N/kg

Table 4.12: Quantity of K released during incubation for treatments enriched to 15 g/kgN

Treatment	Quantity (g/kg) in weeks 4	8	12	16
C0	0.13	0.12	0.14	0.15
C1	0.47	0.49	0.55	0.55
C2	0.47	0.51	0.53	0.58
C3	0.34	0.40	0.42	0.58
C4	0.37	0.39	0.52	0.54
C5	0.33	0.45	0.46	0.51
C6	0.37	0.41	0.46	0.51
C7	0.47	0.51	0.60	0.62
C26	0.37	0.41	0.54	0.65
C27	0.37	0.40	0.67	1.13
C28	0.31	0.37	0.45	1.09
C29	0.37	0.44	0.64	1.09
C30	0.41	0.45	0.68	1.19
C31	0.27	0.48	0.76	1.02
C32	0.47	0.52	0.80	1.06

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C2	CDSBM at 15 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 15 g N/kg
C3	CDSBnM at 15 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 15 g N/kg
C4	CDSHM at 15 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 15 g N/kg
C5	CDSHnM at 15 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 15 g N/kg
C6	CDSNM at 15 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 15 g N/kg
C7	CDSTM at 15 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 15 g N/kg
C26	PDS	Poultry dung plus Sawdust
C27	PDSBM at 15 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 15 g N/kg
C28	PDSBnM at 15 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 15 g N/kg
C29	PDSHM at 15 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 15 g N/kg
C30	PDSHnM at 15 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 15 g N/kg
C31	PDSNM at 15 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 15 g N/kg
C32	PDSTM at 15 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 15 g N/kg.

Table 4.13: Quantity of K released from incubation for treatments enriched to 30 g/kg N

	Quantity (g/kg) in weeks			
Treatment	**4**	**8**	**12**	**16**
C0	0.13	0.12	0.14	0.15
C1	0.47	0.49	0.55	0.55
C8	0.57	0.58	0.58	0.65
C9	0.42	0.55	0.54	0.66
C10	0.47	0.50	0.67	0.7
C11	0.35	0.51	0.53	0.54
C12	0.49	0.59	0.57	0.57
C13	0.44	0.64	0.76	0.89
C26	0.37	0.41	0.54	0.65
C33	0.38	0.43	0.79	1.16
C34	0.52	0.61	0.78	1.34
C35	0.41	0.66	0.94	1.2
C36	0.4	0.78	0.96	1.27
C37	0.39	0.84	0.97	1.1
C38	0.48	0.86	0.97	1.08

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C8	CDSBM at 30 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 30 g N/kg
C9	CDSBnM at 30 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 30 g N/kg
C10	CDSHM at 30 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C11	CDSHnM at 30 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 30 g N/kg
C12	CDSNM at 30 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 30 g N/kg
C13	CDSTM at 30 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 30 g N/kg
C26	PDS	Poultry dung plus Sawdust
C33	PDSBM at 30 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 30 g N/kg
C34	PDSBnM at 30 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 30 g N/kg
C35	PDSHM at 30 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 30 g N/kg
C36	PDSHnM at 30 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 30 g N/kg
C37	PDSNM at 30 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 30 g N/kg
C38	PDSTM at 30 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 30 g N/kg.

Table 4.14: Quantity of K released from incubation for treatments enriched to 45 g/kg N

	Quantity (g/kg) in weeks			
Treatment	**4**	**8**	**12**	**16**
C0	0.13	0.12	0.14	0.15
C1	0.47	0.49	0.55	0.55
C14	0.58	0.62	0.8	0.93
C15	0.46	0.6	0.66	0.83
C16	0.57	0.61	0.71	1.06
C17	0.53	0.55	0.73	0.72
C18	0.58	0.62	0.66	0.69
C19	0.62	0.7	0.93	1.21
C26	0.37	0.41	0.54	0.65
C39	0.48	0.79	0.89	1.25
C40	0.61	1.02	1.09	1.53
C41	0.54	0.87	1.03	1.29
C42	0.42	0.83	1.1	1.27
C43	0.57	0.91	1	1.43
C44	0.7	0.98	1.23	1.47

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C14	CDSBM at 45 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 45 g N/kg
C15	CDSBnM at 45 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 45 g N/kg
C16	CDSHM at 45 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C17	CDSHnM at 45 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 45 g N/kg
C18	CDSNM at 45 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 45 g N/kg
C19	CDSTM at 45 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 45 g N/kg
C26	PDS	Poultry dung plus Sawdust
C39	PDSBM at 45 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 45 g N/kg
C40	PDSBnM at 45 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 45 g N/kg
C41	PDSHM at 45 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 45 g N/kg
C42	PDSHnM at 45 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 45 g N/kg
C43	PDSNM at 45 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 45 g N/kg
C44	PDSTM at 45 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 45 g N/kg.

Table 4.15: Quantity of K released during incubation for treatments enriched to 60 g/kg N

Treatment	Quantity (g/kg) in weeks			
	4	8	12	16
C0	0.13	0.12	0.14	0.15
C1	0.47	0.49	0.55	0.55
C20	0.84	0.92	0.92	0.98
C21	0.52	1.01	1.03	1.33
C22	0.97	0.98	0.97	2.91
C23	0.89	0.96	0.99	1.13
C24	0.69	1.99	2.20	2.51
C25	0.42	1.30	2.54	3.41
C26	0.37	0.41	0.54	0.65
C45	0.78	1.25	1.50	1.74
C46	0.97	1.22	1.73	2.05
C47	0.64	0.96	1.04	1.43
C48	0.9	1.24	1.72	2.10
C49	1.48	1.49	1.85	2.07
C50	2.31	2.44	3.54	4.42

Legend

C0	Control	Soil with no enrichment
C1	CDS	Cattle dung plus Sawdust
C20	CDSBM at 60 g/kg N	Cattle dung plus Sawdust plus Blood- N raised to 60 g N/kg
C21	CDSBnM at 60 g/kg N	Cattle dung plus Sawdust plus Bone- N raised to 60 g N/kg
C22	CDSHM at 60 g/kg N	Cattle dung plus Sawdust plus Hoof- N raised to 60 g N/kg
C23	CDSHnM at 60 g/kg N	Cattle dung plus Sawdust plus Horn- N raised to 60 g N/kg
C24	CDSNM at 60 g/kg N	Cattle dung plus Sawdust plus Neem- N raised to 60 g N/kg
C25	CDSTM at 60 g/kg N	Cattle dung plus Sawdust plus Tithonia- N raised to 60 g N/kg
C26	PDS	Poultry dung plus Sawdust
C45	PDSBM at 60 g/kg N	Poultry dung plus Sawdust plus Blood- N raised to 60 g N/kg
C46	PDSBnM at 60 g/kg N	Poultry dung plus Sawdust plus Bone- N raised to 60 g N/kg
C47	PDSHM at 60 g/kg N	Poultry dung plus Sawdust plus Hoof- N raised to 60 g N/kg
C48	PDSHnM at 60 g/kg N	Poultry dung plus Sawdust plus Horn- N raised to 60 g N/kg
C49	PDSNM at 60 g/kg N	Poultry dung plus Sawdust plus Neem- N raised to 60 g N/kg
C50	PDSTM at 60 g/kg N	Poultry dung plus Sawdust plus Tithonia- N raised to 60 g N/kg

incubation. Highest K value at 12 weeks of incubation (3.54 cmol/kg) was recorded from PDSTM at 60 g/kg N. This was followed by CDSTM at 60 g/kg N (2.54 cmol/kg) while CDSBnM at 15 g/kg N had the least K (0.42 cmol/kg). At 16 weeks of incubation, the trend was similar and showed that CDSHnM at 45 g/kg N had a reduction in its K content while CDS and CDSNM at 30 g/kg N had same K content as at 12 weeks of incubation. The PDSTM at 60 g/kg N enrichment level gave the best exchangeable K (4.42 cmol/kg) followed by CDSTM at 60 g/kg N (3.41 cmol/kg) while the least was obtained from CDSHM and CDSNM at 15 g/kg N (0.51 cmol/kg). As it was observed for N and P, increase in N levels of the enriched composts coupled with some suspected interactions from other factors positively influenced the availability of K at all weeks of incubation.

4.5 Experiment 3: Growth and yield responses of *worowo* to organically-enriched composts (in Pots)

Table 4.16 shows the effect of composts fortified to 60 g/kg N, with organic N-rich substances on *worowo*'s growth and yield at 60 days after planting. The CDSNM treatment gave the longest vines of 135.00 cm, though not significantly different from PDSBM which had a vine length of 116.33 cm while the CDSNM produced vine lengths that differed significantly from CDSBM, PDSBnM, PDSHnM, CDSHnM, CONTROL and PDS. The PDS treatment had the shortest plants (36.33 cm) and was only significantly lower than CDSNM, PDSBM, CDS, PDSNM and CDSBnM. The CDSNM treatment produced the leafiest vegetables (38.00) which were significantly leafier than CDSBM, PDSBnM and PDS. Plants treated with CDS produced 37.33 leaves and PDSBnM, the least leaves (22.33). The stem girth followed a similar trend as number of leaves with CDSNM and CDS having the highest values (3.10-3.23 cm) while the thinnest vegetables (2.60 cm) were produced by CDSHnM. The leaf area index showed significant differences at $\alpha_{0.05}$. The highest values were obtained from CDSNM (3.97) followed by CDSHM (3.80) which significantly differed from the values from all other treatments except PDSBM, CDS, PDSNM, CDSBnM, PDSTM, NPK and CDSTM. The least leaf area index value was obtained from CDSBM (1.20). The worowo yield from CDSNM (19.47 t/ha) was best, and significant from yields obtained for PDSBnM, PDSHnM, CDSHnM and PDS treated pots.

Table 4.17 displays the consequent effects of the enriched composts on the growth and yield of *worowo* at 120 DAP. The CONTROL treatment produced the longest vines (73.33 cm), though not significantly different from NPK and CDSNM. The shortest vines were

Table 4.16: Effects of Organic-N-enriched composts on *worowo*'s growth and yield at 60 DAP in pot experiment

Treatment	Vine length (cm)	Number of leaves	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
CDSNM	135.00a	38.00a	3.23a	3.97a	19.47a
PDSBM	116.33ab	35.67ab	2.93abc	3.07abc	15.07abc
CDS	114.33ab	37.33a	3.10ab	3.50ab	18.00ab
PDSNM	102.33ab	36.00abc	2.87abc	2.40c	14.27abc
CDSBnM	101.33ab	36.33ab	2.80bc	2.30cd	13.20abcd
PDSTM	93.33abc	28.67abc	2.83abc	2.10cd	13.33abcd
CDSHM	88.67abc	32.33abd	2.90abc	3.80ab	12.40abcd
NPK	79.67abc	34.00abd	2.77bc	2.30cd	14.13abc
PDSHM	77.67abc	34.33abc	2.63c	1.90d	12.80abcd
CDSTM	74.00abc	27.00abd	2.93abc	2.40c	10.13abcd
CDSBM	70.33bc	25.00bd	2.67c	1.20cd	9.73abcd
PDSBnM	68.00bc	22.33d	2.83abc	1.50cd	8.40bcd
CONTROL	65.00bc	33.00abd	2.67c	1.70cd	13.87abc
PDSHnM	64.00bc	26.33abd	2.80bc	1.90cd	6.27cd
CDSHnM	55.00bc	26.33abd	2.60c	1.40cd	7.73cd
PDS	36.33c	24.33c	2.67c	1.30cd	3.73d

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP =	Days After Planting
CDSNM =	Cattle dung plus sawdust plus neem
PDSBM =	Poultry dung plus sawdust plus blood
CDS =	Cattle dung plus sawdust
PDSNM =	Poultry dung plus sawdust plus neem
CDSBnM =	Cattle dung plus sawdust plus bone
PDSTM =	Poultry dung plus sawdust plus tithonia
CDSHM =	Cattle dung plus sawdust plus hoof
PDSHM =	Poultry dung plus sawdust plus hoof
CDSTM =	Cattle dung plus sawdust plus tithonia
CDSBM =	Cattle dung plus sawdust plus blood
PDSBnM =	Poultry dung plus sawdust plus bone
PDSHnM =	Poultry dung plus sawdust plus horn
CDSHnM =	Cattle dung plus sawdust plus horn
PDS =	Poultry dung plus sawdust

Table 4.17: Effects of Organic-N-enriched composts on *worowo*'s growth and yield at 120 DAP in pot experiment

Treatment	Vine length (cm)	Number of leaves	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
CDSNM	65.00ad	45.67a	3.47a	4.51abc	18.80a
PDSBM	30.67bc	42.67abcd	3.20ab	4.47abc	13.33ab
CDS	48.00abc	45.00ab	3.33a	4.94a	17.20ac
PDSNM	52.33abc	41.33abcde	3.07abc	4.77ab	12.67ab
CDSBnM	38.33bcd	43.67abcd	3.30ab	3.53abc	12.00ab
PDSTM	55.67abc	41.67abcde	3.13abc	3.89abc	12.40ab
CDSHM	61.00ab	44.33abc	3.27abc	4.90a	11.33ab
NPK	70.00ad	41.33abcde	3.03abc	4.19abc	12.27ab
PDSHM	52.33abc	43.00abcd	2.83c	3.67abc	11.33ab
CDSTM	37.67bcd	35.00abcde	3.17abc	3.98abc	9.33ab
CDSBM	28.67bc	32.67de	2.90bc	2.49abc	8.13ab
PDSBnM	40.00abc	30.33e	3.07abc	2.82abc	12.00ab
CONTROL	73.33a	41.33abcde	2.93bc	3.76abc	12.27ab
PDSHnM	27.00c	39.33abcde	3.00bc	2.79abc	5.20ab
CDSHnM	48.00abc	33.33cde	2.83c	1.85bc	3.33bc
PDS	56.67abc	32.33de	2.93bc	1.80c	2.67b

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting
CDSNM = Cattle dung plus sawdust plus neem
PDSBM = Poultry dung plus sawdust plus blood
CDS = Cattle dung plus sawdust
PDSNM = Poultry dung plus sawdust plus neem
CDSBnM = Cattle dung plus sawdust plus bone
PDSTM = Poultry dung plus sawdust plus tithonia
CDSHM = Cattle dung plus sawdust plus hoof
PDSHM = Poultry dung plus sawdust plus hoof
CDSTM = Cattle dung plus sawdust plus tithonia
CDSBM = Cattle dung plus sawdust plus blood
PDSBnM = Poultry dung plus sawdust plus bone
PDSHnM = Poultry dung plus sawdust plus horn
CDSHnM = Cattle dung plus sawdust plus horn
PDS = Poultry dung plus sawdust

27.00 cm and obtained from PDSHnM. The CDSNM treatment produced more leaves (45.67) than all other treatments and was significantly higher than CDSBM, PDSBnM, CDSHnM and PDS. Pots treated with CDSNM produced the thickest vegetables at 3.47 cm and was significant to PDSHM, CDSBM, CONTROL, PDSHnM, CDSHnM and PDS. The least stem girths were from the PDSHM and CDSHnM. Pots treated with CDS gave the highest leaf area index (4.94) and was followed by CDSHM and differed significantly from CDSHnM and PDS. Leaf area index values obtained for all other treatments did not differ significantly. The CDSNM and CDS treated pots gave highest yield values (18.80 and 17.20 t/ha respectively) and both differed significantly from CDSHnM and PDS. The leastt yield (2.67 t/ha) came from the PDS pots.

Table 4.18 shows that *worowo* from CDSNM had the longest vines (33.33 cm) at 180 DAP which were not significantly different from CDSBnM, PDSTM, CDSHM, CDSTM and PDSBnM. The PDSNM gave the shortest vines of 21.33 cm. The highest number of leaves at 180 DAP was observed from CDSNM with 21.00 leaves followed by CDSHM and were not significantly different from CDSBnM, PDSTM, CDSHM, NPK and CDSTM. The lowest number of leaves was from PDSBnM which produced 12.00 leaves. Pots treated with CDSNM produced the thickest vines (4.03 cm) while PDSHM gave the least stem girth (3.13 cm). Leaf area index was highest in CDSNM with leaf area index value of 2.44 but was not significantly different from PDSTM, CDSHM and CDSTM. The least leaf area index (0.74) was obtained in the PDS treatment. Quantity of *worowo* (16.67 t/ha) harvested from CDSNM treated pots was highest, and more than the vegetables harvested from the CDS treated pots with 15.73 t/ha, but the two were not significantly different. The least yield values were recorded from PDS.

Table 4.19 shows the sum of these parameters obtained at 60, 120 and 180 DAP. The CDSNM treatment gave the highest values for all the parameters except in leaf area index where CDSNM and CDSHM had same values. The CDS-based treatments gave the best three values for each parameter such that CDS enriched with neem leaf meal gave the best vegetative growth and yield performance of *worowo*.

4.6 Experiment 4: Growth and yield responses of *worowo* to the enriched compost (CDSNM) under field conditions

Table 4.20 shows the weather information for the two planting seasons on the field. The consequent effects of CDS enriched with neem leaves (CDSNM) at 60 g/kg N level, on

Table 4.18: Effects of Organic-N-enriched composts on *worowo*'s growth and yield at 180 DAP in pot experiment

Treatment	Vine length (cm)	Number of leaves	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
CDSNM	33.33a	21.00a	4.03a	2.44a	16.67a
PDSBM	20.67d	13.00cd	3.50abcde	1.60bcd	10.67abc
CDS	23.00cd	14.33bcd	3.87abc	1.58bcd	15.73a
PDSNM	21.33cd	12.33cd	3.37cde	1.42bcde	10.27abc
CDSBnM	28.00abc	17.33abcd	3.60abcde	1.13bde	10.00abc
PDSTM	28.33abc	18.33abc	3.77abc	1.95ac	10.27abc
CDSHM	30.67ab	19.67ab	3.77abc	2.17ac	12.93ab
NPK	26.00bcd	15.00abcd	3.37cde	1.55bcd	10.13abc
PDSHM	21.67cd	13.33cd	3.13e	1.17bde	8.80abc
CDSTM	26.67abcd	15.00abcd	3.67abcd	1.70abc	8.00abc
CDSBM	23.67bcd	13.67bcd	3.20de	1.06bde	5.60bc
PDSBnM	26.33abcd	12.00d	3.37cde	1.13bde	5.07bc
CONTROL	23.67bcd	13.33cd	3.23de	1.27bde	10.80abc
PDSHnM	21.67cd	13.67bcd	3.27de	0.90de	3.87bc
CDSHnM	24.67bcd	14.00bcd	3.33cde	1.18bde	2.40c
PDS	25.00bcd	13.33cd	3.23de	0.74e	1.60c

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP =	Days After Planting
CDSNM =	Cattle dung plus sawdust plus neem
PDSBM =	Poultry dung plus sawdust plus blood
CDS =	Cattle dung plus sawdust
PDSNM =	Poultry dung plus sawdust plus neem
CDSBnM =	Cattle dung plus sawdust plus bone
PDSTM =	Poultry dung plus sawdust plus tithonia
CDSHM =	Cattle dung plus sawdust plus hoof
PDSHM =	Poultry dung plus sawdust plus hoof
CDSTM =	Cattle dung plus sawdust plus tithonia
CDSBM =	Cattle dung plus sawdust plus blood
PDSBnM =	Poultry dung plus sawdust plus bone
PDSHnM =	Poultry dung plus sawdust plus horn
CDSHnM =	Cattle dung plus sawdust plus horn
PDS =	Poultry dung plus sawdust

Table 4.19: Cumulative effects of composts enriched with organic N-rich sources on *worowo*'s growth and yield at 60, 120 and 180 DAP in the pot experiment

Treatment	Vine length (cm)	Number of leaves	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
CDSNM	233.33a	104.67a	10.73a	11.00a	54.93a
PDSBM	167.67ab	91.33ab	9.63ab	9.10abc	39.07ab
CDS	185.33ab	96.67ac	10.30abc	10.00ab	50.93ab
PDSNM	176.00ab	89.67ab	9.30bc	8.60bc	37.20ab
CDSBnM	167.67ab	97.33ab	9.70ab	6.90ce	35.20abc
PDSTM	177.33ab	88.67abcd	9.73ab	8.00c	36.00abc
CDSHM	180.33ab	87.67abcd	9.93ab	11.00a	36.67abc
NPK	175.67ab	90.33ab	9.17b	8.00c	36.53abc
PDSHM	151.67b	90.67ab	8.60b	6.70cd	32.93abc
CDSTM	138.33b	77.00bc	9.77ab	8.10bc	27.47abc
CDSBM	122.67b	71.33bd	8.70b	4.80df	23.47bc
PDSBnM	134.33b	64.67d	9.27bc	5.50def	25.47bc
CONTROL	162.00ab	87.67abcd	8.83b	6.70cd	36.93ab
PDSHnM	112.67b	79.33bc	9.06bc	5.60def	15.33bc
CDSHnM	127.67b	73.67bc	8.77b	4.40f	13.47bc
PDS	118.00b	70.00bd	8.83b	3.84f	8.00c

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting
CDSNM = Cattle dung plus sawdust plus neem
PDSBM = Poultry dung plus sawdust plus blood
CDS = Cattle dung plus sawdust
PDSNM = Poultry dung plus sawdust plus neem
CDSBnM = Cattle dung plus sawdust plus bone
PDSTM = Poultry dung plus sawdust plus tithonia
CDSHM = Cattle dung plus sawdust plus hoof
PDSHM = Poultry dung plus sawdust plus hoof
CDSTM = Cattle dung plus sawdust plus tithonia
CDSBM = Cattle dung plus sawdust plus blood
PDSBnM = Poultry dung plus sawdust plus bone
PDSHnM = Poultry dung plus sawdust plus horn
CDSHnM = Cattle dung plus sawdust plus horn
PDS = Poultry dung plus sawdust

Table 4.20: Minimum and maximum temperature, relative humidity and rainfall for the 2010 and 2011 growing seasons.

Month	Tmin (°C)	Tmax (°C)	RH (%)	Rainfall (mm)	Tmin (°C)	Tmax (°C)	RH (%)	Rainfall (mm)
	2010				2011			
Jan	17.2	33.5	73.6	9.2	13.0	32.2	67.6	2.0
Feb	17.5	33.7	78.9	19.4	18.6	31.5	83.2	54.4
Mar	20.7	34.1	78.8	33.3	21.1	33.6	83.6	24.3
Apr	20.8	33.9	85.2	101.6	21.2	33.2	85.6	67.2
May	22.1	30.9	89.3	168.9	21.9	30.1	89.9	181.6
Jun	21.2	29.8	90.2	211.1	20.2	30.7	90.1	205.9
Jul	19.9	29.4	90.6	196.0	20.1	28.7	90.3	219.1
Aug	19.8	29.1	90.1	271.5	19.8	28.4	90.2	225.7
Sep	20.0	29.2	90.2	381.3	20.1	29.0	89.8	238.4
Oct	20.2	29.1	90.2	198.7	19.8	29.5	89.0	209.8
Nov	20.5	30.4	85.4	76.9	15.5	30.3	80.9	50.1
Dec	15.4	31.2	72.1	47.1	13.7	30.8	67.9	1.2
Annual	15.4	34.1	84.6	1715.1	13.0	33.6	84.0	1479.8

Source: https://power.larc.nasa.gov/data-access-viewer/

Legend
Tmin = minimum temperature
Tmax = maximum temperature
RH = relative humidity

growth and output of *worowo* at first planting at 60 DAP are as displayed (table 4.21).
Marked differences were observed in *worowo* vegetables' vine length, with NPK producing the longest vines of 65.08 cm which was followed by CDSDNM applied at 30 t/ha (56.82 cm). The shortest plants with 29.00 cm vine length were produced from the control plots. Treatment D (CDSNM at 30 t/ha application rate) recorded the highest production of leaves which differed significantly from other applied treatments, except the CDSNM utilized at 10 t/ha. NPK-treated plots and the plots treated with CDSNM at 40 t/ha were similar in branches production, as recorded, though they did not differ significantly from each vegetable stand. Thickest vegetable vines were 2.20 cm and were sorted from CDSNM-treated plots at 40 t/ha although it did not significantly differ from other existing treatments. Plots assigned to CDSNM at 10 t/ha recorded the smallest stem girth of 1.86 cm The highest leaf area index value of 1.53 emerged from CDSNM-treated plots at 30 t/ha application rate, followed thereafter, by CDSNM at 10 t/ha with 1.16; though the two did not significantly differ from other tried treatments. The highest yield value of 12.90 t/ha recorded for worowo vegetables came from plots treated with 50 t/ha CDSNM but was not significant to 30 t/ha of CDSNM which produced 8.28 t/ha of *worowo*. The yield value of 2.08 t/ha, from plots designated as control was the lowest.

Table 4.22 shows the growth and yield responses of *worowo* to CDS amended with neem leaves at 60 g/kg N level (CDSNM) at 120 DAP. CDSNM at 40 t/ha produced the longest *worowo* vines (121.50 cm) which did not significantly differ from CDSNM at 20 t/ha. Vegetable vines from the control plots were 77.50 cm long and were the shortest. More leaves were found on vegetables from CDSNM-treated plots at 30 t/ha which produced 63.50 leaves while the CDSNM-treated plots at 20 t/ha had the fewest leaves (42.75). Higher number of branches was recorded for all treatments except for CDSNM at 40 t/ha which gave 1.50 branches as in the first harvest. Plots assigned to CDSNM at 30 t/ha showcased most branched vegetables (3.00) which only significantly differed from CDSNM-treated plots at 40 t/ha while CDSNM at 20 t/ha and NPK had same number of branches of 2.00. Leaf area index was lowest (1.80) in CDSNM-treated plots at 20 t/ha and differed notably from the values observed in plots treated with: CDSNM at 40, 30 and 10 t/ha, which had 3.53, 4.74 and 3.17 respectively. Plots assigned to 30 t/ha of CDSNM produced the biggest leaf area index of 4.74. Plots treated with CDSNM applied at 40 t/ha yielded significantly more vegetables (10.50 t/ha) than the control and CDSNM treated pots at 10 t/ha which yielded 1.63 and 3.80 t/ha of *worowo* vegetables, respectively.

Table 4.21: Growth and yield responses of *worowo* to CDSNM at 60 DAP in the first planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	29.00b	26.10b	0.00	1.87	0.57b	2.08d
B	65.08a	29.00b	2.00	2.13	0.63b	7.30bcd
C	56.07ab	28.43b	2.00	2.20	0.63b	12.90a
D	56.82a	42.67a	1.00	2.19	1.53a	8.28ab
E	36.51b	27.90b	0.00	1.87	0.70b	3.79bcd
F	31.29b	32.10ab	0.00	1.86	1.16a	2.44cd

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

Table 4.22: Growth and yield responses of *worowo* to CDSNM at 120 DAP in the first planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	77.50bc	49.25ab	2.75a	4.50a	2.42cd	1.63c
B	78.50b	45.75b	2.00ab	3.00b	2.58bcd	7.50ab
C	121.50a	49.00ab	1.50b	4.00a	3.53b	10.50a
D	80.25bc	63.50a	3.00a	4.00a	4.74a	7.38ab
E	86.50ab	42.75b	2.00ab	3.75ab	1.80d	7.19ab
F	83.25b	54.50ab	2.00ab	4.00a	3.17ac	3.80bc

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

The effects of cow dung and neem-enriched sawdust (CDSNM) on the growth and yield of *worowo* at 180 DAP was shown in Table 4.23. Plots treated with CDSNM CDSNM at 30 t/ha produced the longest vegetable vines (226.00 cm) which did not significantly differ from the vines produced from 20 and 40 t/ha CDSNM-treated plots which were 193.75 and 215.75 cm, respectively. The CDSDNM-treated plots at 30 t/ha produced the leafiest vegetables, with 168.75 leaves, which though did not differ significantly from vegetables harvested from CDSDNM-treated plots at 40 t/ha, with 137.50 leaves. More branched *worowo* vegetables, with 6.00 branches, were harvested from CDSNM-treated plots at 30 t/ha but it did not differ significantly from plots assigned to CDSNM application at 40 t/ha (5.75) while NPK gave the lowest number of branches (2.25). Plots treated with CDSNM at 40 t/ha produced the thickest vegetable vines (5.00 cm) followed by the control plots and CDSNM at 30 t/ha while NPK plots gave the thinnest vegetable vines (3.75 cm). The highest leaf area index of 18.0 was obtained from CDSNM at 40 t/ha application rate and it differed significantly from other examined treatments. Plots treated with NPK had the lowest leaf area index value of 3.4. The best edible shoot yield was discovered from CDSNM-treated plots at 40 t/ha (8.66 t/ha); followed thereafter, by CDSNM applied at 30 and 20 t/ha but the three differed not, significantly. The lowest edible shoot yield (3.00 t/ha) emerged from the plots assigned to control.

Table 4.24 shows growth and output parameters of *worowo* at 60 DAP in the second planting season of year 2011. There were no notable differences in the vine length from various treated plots, except between NPK, which gave the least vine length (69.25 cm), and CDSNM applied at 40 t/ha with the longest vines (124 cm). The CDSNM-treated plots at 30 t/ha yielded the leafiest vegetables (77.5), though not significantly differed from other treated plots. Values for leave production observed from other examined plots differed not significantly from one another but least leafy vegetables (31.75 leaves) were brought forth by CDSNM-treated plots at 10 t/ha. Notably significant differences were not recorded in output of branches of *worowo* produced at 60 DAP in the second season, but the most branched vegetables were brought forth by plots treated with CDSNM at 30 t/ha which had 2.25 branches, followed strictly by CDSNM-treated plots at 20 t/ha which produced 2.00 branches. The thickest vines produced by CDSNM at 40 t/ha (3.50 cm) and CDSNM at 30 t/ha (3.25 cm) were similar but differed significantly from the stem girth values obtained from NPK which had the thinnest vines (2.00 cm). The significantly best leaf area index (6.17) was from CDSNM applied at 30 t/ha, while the lowest leaf area index value of 1.70 was observed in the

Table 4.23: Growth and yield responses of *worowo* to CDSNM at 180 DAP in the first planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	135.00bc	82.25bc	3.00b	4.75ab	5.8a	3.00b
B	98.75c	36.00c	2.25b	3.75c	3.4a	3.41b
C	215.75ad	137.50ab	5.75a	5.00a	18.0b	8.66a
D	226.00a	168.75a	6.00a	4.75ab	16.8b	6.30ab
E	193.75ab	92.25bc	3.75ab	4.00bc	7.5a	5.53ab
F	158.25bcd	73.00c	3.50b	4.00bc	6.6a	4.04b

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

Table 4.24: Growth and output of *worowo* as influenced by CDSNM at 60 DAP in the second planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	85.25ab	42.75b	1.50	2.75ab	3.32a	2.28b
B	69.25b	47.25b	1.50	2.00b	3.14a	7.55ab
C	124.00a	35.50b	1.50	3.50a	2.88a	8.98a
D	120.75ab	77.50a	2.25	3.25a	6.17b	8.77a
E	100.00ab	35.50b	2.00	2.75ab	2.57a	5.95ab
F	105.50ab	31.75b	1.50	3.00a	1.70a	4.86ab

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

plots treated with CDSNM applied at 10 t/ha. The largest quantities of marketable vegetables were yielded by CDSNM-treated plots at 40 t/ha (8.98 t/ha) and plots treated with CDSNM applied at 30 t/ha (8.77 t/ha). The duo did not differ significantly from each other, but rather from the CONTROL plot which had the least output (2.28 t/ha).

The impacts of the enriched additive on worowo output at 120 DAP are showcased in table 4.25. The CDSNM- treated plots at 40 t/ha gave the longest vegetable vines (121.75 cm), with CDSNM-treated plots at 30 t/ha following, with vines which were 92.50 cm long. These two treatments were observed not to have differed significantly from each other. Shortest vegetable vines were obtained from the NPK plots (56.75 cm). Vegetables from the plots treated with CDSNM applied at 30 t/ha had 57.25 leaves which were more leaves than other treatments though not significantly different from NPK and CDSNM applied at 10 t/ha while CDSNM applied at 20 t/ha brought forth the least leafy vegetables (35.50). Plots treated with NPK and CDSNM at 10 t/ha produced 2.75 branches followed by CDSNM at 40 t/ha which produced 2.50 branches and differed significantly from the CONTROL which produced least number of branches (1.25). Plots treated with CDSNM applied at 40 t/ha produced the thickest vegetable vines (4.75 cm) and was significantly different from the CONTROL, NPK and CDSNM-treated plots at 20 and 10 t/ha. Plots assigned to NPK fertilizer gave the thinnest vegetable vines of 2.13 cm. The highest leaf area index of 3.05 was obtained from the NPK plots followed by CDSNM at applied at 40 t/ha (2.98). The CONTROL which gave the lowest index differed significantly from all compared treatments while NPK that gave the highest values differed significantly from the CONTROL and CDSNM-treated plots at 30 and 20 t/ha. Plots assigned to CDSNM at 40 t/ha application rate yielded more vegetables (12.88 t/ha) than the other plots, though not significantly different from CDSNM-treated plots at 30 t/ha which produced a vegetable weight of 9.75 t/ha The CONTROL plots yielded the least edible shoot of *worowo* (1.83 t/ha).

At 180 DAP, the CDSNM applied at 40 t/ha gave the best vine length (114.75 cm) which was followed by CDSNM applied at 30 t/ha (87.00 cm) while vines measured from the plots assigned to CONTROL were the shortest (44.00 cm) (Table 4.26). The CDSNM employed at 40 t/ha differed significantly from CONTROL, NPK and CDSNM applied at 10 t/ha. The CDSNM applied at 30 t/ha produced more leaves

Table 4.25: Growth and output of *worowo* as influenced by CDSNM at 120 DAP in the second planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	67.00b	40.25b	1.25b	3.00bc	1.84a	1.83c
B	56.75b	54.50a	2.75a	2.13c	3.05b	1.95c
C	121.75a	38.00b	2.50a	4.75a	2.98bc	12.88a
D	92.50ab	57.25a	2.00ab	3.75ab	2.46c	9.75ab
E	89.75ab	35.50b	2.00ab	3.25b	2.55c	5.05bc
F	83.75b	46.00ab	2.75a	3.50b	2.60bc	3.88c

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

Table 4.26: Growth and output of *worowo* as influenced by CDSNM at 180 DAP in the second planting season

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	44.00d	36.50ab	1.25b	3.00cd	1.72a	1.53c
B	45.75d	47.75a	1.50bc	2.50c	2.27bd	1.41c
C	114.75a	38.00ab	2.75a	4.75a	2.94c	10.55a
D	87.00ac	48.25a	2.25ac	4.25ab	2.62bc	7.30ab
E	82.75ac	34.75b	2.00ab	3.75bd	2.39bd	3.48bc
F	79.50bc	41.50ab	1.75bc	3.50bc	1.91ad	3.32bc

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

(48.25) than the other treatments while CDSNM-treated plots at 10 t/ha yielded *worowo* with least leaves (34.75) which differed significantly from CDSNM at 30 t/ha and NPK. Plots treated with CDSNM applied at 40 t/ha gave 2.75 branches which was the highest and differed significantly from the CONTROL, NPK and CDSNM at 10 t/ha plots. The CONTROL plots yielded least branches of 1.25. The plots treated with CDSNM applied at 40 t/ha had stem girth of 4.75 cm followed by CDSNM applied at 30 t/ha with 4.25 cm while NPK produced the thinnest vegetables with stem girth of 2.50 cm. The highest leaf area index value of 2.94 was from CDSNM applied at 40 t/ha and differed not significantly from CONTROL, NPK, CDSNM at 20 and 10 t/ha with leaf area index values of 1.72, 2.27, 2.39 and 1.91 respectively. The CONTROL gave the lowest leaf area index value. The yields obtained were in the order CDSNM at 40 >CDSNM at 30>CDSNM at 20>CDSNM at 10>CONTROL >NPK. The highest marketable yield of 10.55 t/ha emerged from the CDSNM at 40 t/ha which differed significantly from other treated plots, except CDSNM at 30 t/ha that yielded 7.30 t/ha. Plots treated with NPK gave the least marketable yield (1.41 t/ha).

4.7 Experiment 5: Residual effects of the enriched compost (CDSNM) on some soil attributes and on growth and output of *worowo*

Attributes of soils of the study sites for the study seasons were highlighted in table 4.27. Great residual effects of the enriched composts on the soils of the study site could be observed, as the soil was higher in pH value, organic matter content, available N, P, K and exchangeable bases, hence base saturation.

Table 4.28 evaluates the residual impacts of CDSNM on growth and output of *worowo* at 60 DAPS. Although, there were no notable differences in the vine length of *worowo* but vines from CDSNM-treated plots were longer than CONTROL and the NPK-treated plots. The CDSNM at 40 t/ha produced the longest vines (125.75 cm) and was followed by CDSNM at 30 t/ha whose vegetable vines were 125.00cm long. The shortest vines of 85.25 cm were produced from NPK plots. The CDSNM at 40 t/ha differed significantly from other treated plots, except CDSNM at 30 t/ha in leaves production. Vegetables from the CDSNM-treated plots at 40 t/ha yielded the best leafy vegetables (74.25) while vegetables from the CDSNM-treated plots at 10 t/ha were the least leafy (26.50). The CDSNM applied at 40 t/ha yielded the most branched vegetables (2.50) which differed significantly from CDSNM utilized at 10 t/ha with the least value (1.25). The thickest vegetable vines were from CDSNM applied at 40 t/ha

Table 4.27: Chemical properties and particle size distribution of soils of the study sites for the two planting seasons

Property		Value		
		1st Season	2nd season	
			Site 1 (Residual)	Site 2
pH (KCl)	1:1	5.8	7.0	6.7
pH (H_2O)	1:1	6.6	7.6	7.2
Organic matter (g/kg)		14.6	19.5	15.1
Total Nitrogen (g/kg)		0.8	2.7	1.4
Available P (mg/kg)		13	24	15
Exchangeable cations	(cmol/kg)			
Calcium	,,	2.8	7.0	2.9
Magnesium	,,	1.8	2.2	1.8
Potassium	,,	0.3	1.3	0.4
Sodium	,,	0.1	0.2	0.1
Exchangeable Acidity	,,	0.6	0.1	0.2
ECEC	,,	5.6	10.8	5.4
Base saturation	(g/kg)	893	991	962
Particle Distribution	(g/kg)			
Sand		799	797	795
Silt		132	134	133
Clay		69	69	72
Textural Class (USDA)		Loamy sand	Loamy sand	Loamy sand

Table 4.28: Residual impacts of Neem-enriched compost (CDSNM) on growth and output of *worowo* at 60 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	87.25	39.00b	1.50ab	3.00ab	2.55bc	8.33b
B	85.25	34.00b	1.50ab	2.50b	2.00c	7.50b
C	125.75	74.25a	2.50a	4.00a	8.06a	15.42a
D	125.00	47.25ab	1.50ab	3.63a	4.75b	13.58a
E	107.38	29.50b	1.50ab	3.38ab	2.33bc	12.00ab
F	97.75	26.50b	1.25b	3.38ab	2.00c	9.00b

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem leaf meal.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

(4.00 cm) which differed significantly from the NPK with the thinnest vines (2.50 cm). The CDSNM treatments gave thicker vines than the control and NPK plots. The highest leaf area index was observed from CDSNM at 40 t/ha (8.06) followed by the CDSNM at 30 t/ha which had 4.75. Both NPK and CDSNM applied at 10 t/ha gave the lowest leaf area index values of 2.00. The CDSNM-treated plots at 40 t/ha outputted the highest edible shoot yield (15.42 t/ha) which significantly differed from the CONTROL, NPK and CDSNM at 10 t/ha treated plots.

At 120 DAP, the CDSNM-treatments produced longer vines than the CONTROL and NPK though they differed not significantly in values (Table 4.29). The CDSNM at 40 t/ha produced the longest vegetable vines of 156.27 cm followed by CDSNM at 30 t/ha (132.13 cm) while NPK produced the shortest vegetable vines (95.73 cm). The outputted branches differed significantly, with CDSNM treatments giving the highest number of branches. Plots treated with CDSNM at 40 t/ha produced the thickest vegetable vines with stem girth value of 4.02 cm which significantly differed only from NPK with the thinnest vines of 2.50 cm. The leaf area index of *worowo* vegetables differed significantly in the observed values. The highest leaf area index values of 11.00 were obtained from CDSNM at 40 t/ha which did not differ significantly from CDSNM at 30 t/ha. The NPK plots gave the least leaf area index values of 4.40. *Worowo* output from the various treated plots differed significantly, with CDSNM applied at 40 t/ha giving the largest marketable yield (18.80 t/ha) closely marked by CDSNM applied at 30 t/ha which produced 14.50 t/ha. This duo did not differ significantly from each other. The NPK plots outputted the least *worowo* vegetables (5.50 t/ha).

At 180 DAP, the CDSNM at 40 t/ha treatment produced the longest vines followed by plots treated with 30 t/ha CDSNM (Table 4.30). The vine length recorded for the two plots were 123.93 and 122.93 cm respectively while NPK gave the shortest length (83.33 cm). The 40 t/ha CDSNM produced the leafiest vegetables (129.10) which differed significantly from the CONTROL, NPK and 10 t/ha CDSNM. The least leafy vegetables (51.73) were from the NPK plots. The plots treated with 10 t/ha CDSNM produced 2.75 branches followed by 40 t/ha CDSNM which produced 2.50 branches and were significantly different from the NPK treatment which produced 1.25 branches. Vegetables from the plots treated with 40 t/ha CDSNM had stem girth

Table 4.29: Residual impacts of Neem-enriched compost (CDSNM) on growth and output of *worowo* at 120 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	102.00bc	132.10	3.00a	3.00ab	6.00cd	7.70b
B	95.73c	106.60	1.00a	2.50b	4.40d	5.50b
C	156.27a	173.40	12.00b	4.02a	11.00a	18.80a
D	132.13ab	169.60	10.00b	3.65a	10.00ab	14.50ab
E	124.60abc	134.20	10.00b	3.39a	7.60bc	10.00b
F	112.53bc	133.70	4.00a	3.38ab	7.10c	8.50b

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem leaf meal.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

Table 4.30: Residual impacts of Neem-enriched compost (CDSNM) on growth and output of *worowo* at 180 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	88.00	57.80b	1.25b	2.50ab	2.81a	4.02b
B	83.33	51.73b	2.75a	2.00b	2.51a	3.25b
C	123.93	129.10a	2.50a	4.02a	8.01b	10.25a
D	122.93	107.50a	2.00ab	3.65a	8.53b	8.75ab
E	117.47	91.97ab	2.00ab	3.39a	4.60a	6.46ab
F	90.20	60.30b	2.75a	3.38ab	3.77a	6.04ab

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$

Legend

DAP = Days After Planting

CDSNM = Cattle dung + saw dust enriched with neem leaf meal.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

of 4.02 cm and were followed by the vegetables from the plots treated with 30 t/ha CDSNM with 3.65 cm thickness while the NPK plots produced the thinnest vegetables with stem girth of 2.00 cm. *Worowo* with biggest leaf area index of 8.53 was outputted by 30 t/ha CDSNM and it differed significantly from other treated plots, except 40 t/ha CDSNM. The smallest leaf area index was from plots treated with NPK with a value of 2.51. The Edible shoot yield was in the order 40 t/ha CDSNM >30 t/ha CDSNM >20 t/ha CDSNM >10 t/ha CDSNM >CONTROL >NPK.

4.8 Nutritional quality of *worowo* (*Senecio biafrae*) as affected by application of the enriched compost (CDSNM)

Table 4.31 highlights the effect of the enriched composts on *worowo's* nutritional quality in the year 2010. All the parameters measured increased with the rates of the enriched compost. The CDSNM applied at 40 t/ha was higher in protein (6.54%) than CDSNM applied at 30 t/ha (6.20%). CONTROL plot was least in protein (5.3%). Plots treated with CDSNM both at 40 and 30 t/ha gave the same value of 66.0% which was the highest value observed for moisture content. The same moisture content value of 65.0% was observed for vegetables from the CDSNM-treated plots at 10 t/ha and the NPK plots, but the CONTROL plots were the least moistured. Similar trend continues in ash content as the highest ash value of 8.70% was observed in CDSNM-treated plots at 40 t/ha and CDSNM-treated plots at 30 t/ha followed closely, with 8.61% ash, while the lowest value of 8.10% was recorded from the CONTROL plots. The crude fibre content was highest in CDSNM-treated plots at 40 t/ha which gave 12.00% fibre and was followed by the NPK plots which gave 11.20% fibre. The lowest crude fibre of 10.45% was given by the plots treated with CDSNM at 10 t/ha. The fat content of the NPK-treated plots was the highest (3.20%), CDSNM-treated plots at 40 t/ha follows (3.10%). The lowest fat content of 2.53% was recorded from vegetables harvested from the plots assigned to CONTROL. Carbohydrates values were lowered as the enriched composts' utilization rates increased. The CONTROL plot gave the highest carbohydrate value of 10.05% followed by CDSNM applied at 10 t/ha (8.54%) while CDSNM at 40 t/ha contained the least carbohydrate (3.66%). The NPK plots contained highest N (8.00 g/kg), followed by CDSNM applied at 40 t/ha (5.00 g/kg) and the plots allotted to CONTROL, contained the least N (2.00 g/kg). The bases; K, Ca, Mg, Na, Fe, Zn and

Table 4.31: The nutritional quality of *worowo* (*Senecio biafrae*) as affected by CDSNM in the first planting season

Parameter		Treatments						Mean	SD
		A	B	C	D	E	F		
Protein (%)		5.32	6.00	6.54	6.20	5.41	5.30	5.80	0.53
Moisture content (%)		63.5	65.0	66.0	66.0	65.2	65.0	65.10	0.92
Ash	,,	8.10	8.45	8.70	8.61	8.25	8.16	8.38	0.25
Crude fibre	,,	10.50	11.2	12.00	11.00	10.62	10.45	10.96	0.59
Fat	,,	2.53	3.20	3.10	2.85	2.62	2.55	2.81	0.29
Carbohydrate	,,	10.05	6.15	3.66	5.34	7.90	8.54	6.94	2.33
Nitrogen	(g/kg)	2.00	8.00	5.00	3.50	3.00	2.40	3.98	2.23
Potassium	(mg/100g)	500.00	501.20	510.20	505.54	502.46	501.10	503.42	3.83
Calcium	,,	230.50	232.06	236.00	233.64	233.50	232.91	233.62	1.83
Magnesium	,,	322.52	323.50	330.50	327.22	324.60	323.65	325.48	3.00
Sodium	,,	12.57	12.70	14.40	14.25	13.50	12.95	13.40	0.79
Iron	,,	3.58	3.70	4.00	3.82	3.74	3.70	3.76	0.14
Zinc	,,	2.65	2.64	3.25	3.00	2.86	2.52	2.82	0.27
Copper	,,	0.51	0.50	0.52	0.51	0.50	0.50	0.51	0.01

Legend

CDSNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

Cu, gotten from the various treatments, were highest in plots treated with CDSNM applied at 40 t/ha. The values recorded for the metals were respectively; 510.20, 236.00, 330.50, 14.40, 4.00, 3.25 and 0.52 mg/100g. The CONTROL-assigned plots contained least quantities of the measured metals. Plots with (CDSNM) at 40 t/ha had best values in most measured parameters, except in fat and N values where NPK was best by having 3.20% fat and 8.00 g/kg N. It was followed closely by CDSNM applied at 40 t/ha. The CONTROL plot gave the lowest values in all the parameters measured except in carbohydrate where it gave the highest value (10.05%) and in crude fibre where the plots treated with the enriched compost (CDSNM) at 10 t/ha presented the lowest crude fibre of 10.45%.

Residual effect of the enriched compost (CDSNM) was also noticed on the nutritive attributes of *worowo* vegetables at second planting (Table 4.32). The values for all the parameters measured increased across the treatments with CDSNM applied at 40 t/ha giving the highest values in all the parameters measured except in carbohydrate where it gave the lowest value (2.47%). The carbohydrate content of *worowo* decreased with increasing rates of the CDSNM with plots assigned to CDSNM at 40 t/ha having the least carbohydrate (2.47%) while the CDSNM-treated plots at 10 t/ha contained the highest (7.53%). The CONTROL-treated plots contained least quantities of most parameters measured but for crude fibre, where CDSNM applied at 10 t/ha was least, as it was in the first planting season (2010) and in carbohydrate where the CONTROL plot gave the highest value (9.61%).

Table 4.32: The nutritional quality of *worowo* (*Senecio biafrae*) as affected by CDSNM in the second planting season

Parameter		Treatments					Mean	SD
	A	B	C	D	E	F		
Protein (%)	5.34	6.02	6.60	6.30	5.60	5.50	5.89	0.50
Moisture content (%)	63.60	65.40	66.00	64.00	65.50	65.40	64.98	0.95
Ash ,,	8.15	8.48	8.80	8.72	8.58	8.30	8.51	0.25
Crude fibre ,,	10.75	11.65	12.60	12.20	11.00	10.65	11.48	0.81
Fat ,,	2.55	3.52	3.53	3.02	2.68	2.62	2.99	0.45
Carbohydrate ,,	9.61	4.93	2.47	5.76	6.64	7.53	6.16	2.42
Nitrogen (g/kg)	2.50	3.00	7.50	4.50	3.45	3.10	4.01	1.84
Potassium (mg/100g)	500.60	501.75	512.00	507.25	504.30	502.40	504.72	4.26
Calcium ,,	231.00	233.22	240.00	236.52	234.80	233.02	234.76	3.17
Magnesium ,,	323.20	323.51	333.00	330.60	326.40	324.50	326.87	4.05
Sodium ,,	12.80	12.82	14.52	14.30	13.65	13.00	13.52	0.76
Iron ,,	3.62	3.75	4.18	4.00	3.85	3.83	3.87	0.20
Zinc ,,	2.68	2.72	4.01	3.65	3.01	2.92	3.17	0.54
Copper ,,	0.51	0.50	0.53	0.52	0.51	0.50	0.51	0.01

Legend

CDSDNM = Cattle dung + saw dust enriched with neem.

A = CONTROL

B = NPK 15-15-15

C = CDSNM at 40 t/ha

D = CDSNM at 30 t/ha

E = CDSNM at 20 t/ha

F = CDSNM at 10 t/ha

CHAPTER FIVE

5.0 DISCUSSION

Soil productivity diminution remains a major confinement to sustainable crop output. The soils used for this study were deficient in organic matter, N, K and other exchangeable bases. The low nutrient state of the soils of study site which might have been caused by ceaseless nutrient mining by crop removal without adequate replenishment (Isitekhale and Osemwota, 2010), soil formation processes, geographical location, climate, irrigation water applied, cropping history and tillage practices (including continuous cropping) made them to be suitable for the experiments (Omolayo *et al*., 2011).

In this research work, composts made from poultry dung integrated with sawdust and cattle dung integrated with sawdust attained the thermophilic stage at the third turning (6 weeks into composting) with temperature at 62 and 66 ^{o}C for PDS and CDS respectively. This rise in temperature indicated that intense microbial activity was taking place (Robert *et al*., 2000). The peak heating stage is important for compost's quality improvement, as pathogens and weed seeds are killed (Hoitink *et al*., 1991; Muller- Samann and Kotschi, 1994). Most pathogens, especially those originating from animals, cannot survive at these high temperatures. The lower and constant temperature (24-25 ^{o}C) obtained from 18 to 22 weeks into composting when turning no longer reheated the piles, is an indication that the piles had reached the curing stage. Curing conspicuously results into reduction in microbial activities, which would resultantly, stabilize the products of active composting (Hoitink *et al*., 1991). Curing also makes the pile habitable to certain fungi and would also improve disease-suppressant abilities of composts (Muller- Samann and Kotschi, 1994). Proper management of the pile during the curing period would prevent recontamination with weed seeds (Robert *et al,* 2000).

Slightly higher temperature and faster reactions recorded in the CDS heap during composting might mean more effective activities of the microbes on the cattle dung which contained a slightly higher C: N proportion. Eminent C: N proportion makes organic material decomposition and nutrients' mineralization in the organic material to be slower. The dark brown/black colour of the composts at 22 weeks indicated that they were mature and ready for use in planting (Healthy Soils, Healthy Landscapes, 2012). The analysis of the composted materials at 22 weeks showed that the C: N proportion decreased, which could be an indication of more decomposition, mineralization and stadardization through microbial activities had occurred (Robert *et al*., 2000). The pH increased in relation to higher levels of exchangeable bases. Muller-Samann and Kotschi (1994) observed an increase in exchange capacity and hence the alkalinity of the composts occurred 22 weeks after composting. This might be due to the several microbial activities which could have led to organic matter breakdown, and hence mineralization of the exchangeable cations. The increase in the nutrient status of the composts may be ascribed to breaking down of waste matters to produce generative/rich soil essential elements, by diverse microbes, bacteria and also fungi (Ingram, 2007). The differences in the nutrient status of the two composts might be due to the more intense microbial activities on the CDS heaps caused by the slightly higher C: N of cattle dung.

The incubation study showed that there was initial immobilization of N in the various compost products at 8 weeks of incubation. This could be due to the fixation of N and other nutrients (Harrison and Henry, 1994) by the large population of microorganisms which multiplied to decompose the composts applied to the soils (Murwira and Kirchman, 1993). This trend in N release pattern might also be due to the quality of the materials that made up the different composts (Haynes, 1986). Goos (1995) submitted that N contained in plant and animal residues describes the clear relationship between rates of nutrient release and immobilization. The Researcher concluded that if the N contained in an organic material is less than 24 g N/kg, fixation of nutrient will surpass mineralization and the decaying organic manure will fix up N instead of releasing it. N-concentration of various enriched composts in this study was below 24 g N/kg; this may therefore explain the reduction in N values observed at 8 weeks. Eghball *et al*. (2002) and Jae-Hoon *et al*. (2006) submitted that nutrient mineralization differs depending on the organic manure types and the variation in the component fractions and attribute of organic N should explain the different nutrient peaks observed for the different enriched composts. Ribeiro *et al*. (2010) also observed that N release depends on the carbon attribute of the materials employed or used. Quantities of nitrogen recorded for CDSNM at all enrichment levels however increased steadily. The continuous increase of N for CDSNM at all enrichment levels might mean a reduction in N immobilization. This performance of CDSNM might be ascribed to superior N quality of neem and to the C: N proportion of the CDS based composts which is lower than in PDS based composts. This is an indication that N from CDS-based compost might be released earlier and faster than from PDS based compost (Olayinka and Adebayo, 1984). Fangueiro *et al*. (2008) and Chadwick *et al*. (2000) reported that mineralization of N is mainly determined by C to N proportions of the organic substances imputed to the soil.

The available soil P values increased through the treatments over the period of incubation (Ayeni *et al*., 2008) and this is an evidence of the mineralization of the organic forms of P in the composts. Different peaks were observed for the different composts examined; an indication that, the nutrients and their availability distinctly vary among composts and may convincingly depend on compost makeup and full development (Harrison and Henry, 1994). However, the continous improvement of quantity of P measured in majority of the evaluated organic-N-enriched substances, the CDS-enriched composts, in particular, could be ascribed to N-addition fron N-rich substances utilized in CDS enrichment (Adegbite and Olayinka, 2010).

Exchangeable K also increased throughout the incubation period but with different peaks for the different enriched composts (Ayeni *et al*., 2008). This also indicates that nutrients quality and accessibility vary markedly among composts and rely majorly on composts’ makeup and full development (Harrison and Henry, 1994).

The pot experiment indicated that CDSNM increased plant height, number of leaves, stem girth, leaf area index and output of *worowo*. This superior performance of CDSNM might not be unconnected with the best N quantity it mineralized in the incubation study and which incessantly increased throughout the time of investigation. More excellent performance of the composts over NPK could be ascribed to the enrichment of the composts with the various N-rich organic sources which apart from increasing the N content has some other benefits on the soils used for the experiment. Adediran *et al*. (1999) concluded that the performance of composts was enhanced when the N level was supplemented with urea as N source. This better performance of the composts is an indication that composts can be used to replace NPK in soil fertility remediation and sustainable cultivation of *worowo*.

In the first planting season on the field, the CONTROL plots produced the least yield. Increase in branches and stem girth recorded from different treatments at each measurement might have indicated that the longer the *worowo* vegetables stayed on the field, the higher the possibility of producing more branches and the thicker they become. The least yield recorded from the control plot in the first planting season could be ascribed to the organic matter and nutritive qualities of experimental soil which resultantly negatively affected the productivity and sustainability of the vegetables (Zingore *et al*., 2003).

In the second study season, an improvement in the chemical and the particle distribution of soil taken from study site 2 prior to planting, was observed, when compared to values obtained for site 1 at the commencement the study. This could be attributed to the effect of fallow and might be due to leaving of soils at site 2 to fallow throughout the first planting season as fallowing aids soil fertility and nutrient status (Hartemink, 2004; Amiolemen *et al.,* 2012; Nyamadwazo *et al*., 2012). The more luxurious performance of vegetables in site 2 in second study season over those in site 1 in the first season could also be traced to the fallow effects, as site 2 was left under cover while site 1 was being cultivated during the first planting season. Fallowing aids crop outputs, as a resultant effect of soil fertility improvement and nutrient statuses elevation (Nyamadwazo *et al.*, 2012).

The soil analysis before planting in the second season showed that the application of CDSNM had improved the physical and chemical properties of the soil. It gave high residual effects on soil properties and hence, fertility. This is in line with the findings of Ahn (1993) that in many experiments conducted to compare organic manure with chemical fertilisers to supply an equivalent amount of N, the result had often favoured manure application because of the ability of manure to modify the soil physical, biological and chemical properties. The tallest, thickest, leafiest and the highest yielding vegetables were from the plots fertilised with enriched compost at 40 and 30 t/ha. The shortest, thinnest, least leafy and least yielding vegetables were from the control and NPK plots. This confirmed the non-residual effect of the inorganic fertilisers compared to organic fertilisers. Some of the microorganisms which could help to improve the soil physical and chemical structures and hence aid plant growth might have been adversely affected by the addition of NPK fertiliser which at times tends to be hot and toxic to the micro-organisms. Isitekhale and Osemwota (2010) compared the residual effects of poultry manure and NPK fertilisers on nutrient contents and uptake by tomato in the forest and derived savannah soils of Edo State and reported that all manure levels had superior residual effects than all the NPK fertiliser levels. Adediran *et al*. (1999) compared the effectiveness of organic-based fertiliser with mineral fertiliser on crop yield and concluded that the application of organic-based fertiliser improved the nutrient status of the soil and the maize grain yield and also gave high residual effects on soil fertility. The superiority of organic-based fertilisers over the mineral fertilisers could be attributed to the fact that different bacteria and fungi break down chemicals, plant matter and animal waste into productive soil nutrients which would make soils treated with any form of organic fertiliser higher in nutrients (Ingram, 2007). According to Pacini (2003) and Wood *et al.* (2005), soils under organic farming conditions have lower bulk density, higher water holding capacity, higher microbial biomass and N and higher soil respiration activities compared to the conventional farms. This indicates that sufficiently higher amounts of nutrients were made available to the crops due to enhanced microbial activity under organic farming. Unlike other fertilisers, compost does not have only a short-term effect; if applied regularly over many years it can improve the long-term productive capacity of the soil and hence aid plant growth.

The enriched organic fertilisers gave better residual effects on the soil than NPK fertiliser alone and even supplied soil organic matter, Ca and Mg that are not supplied by NPK fertiliser (Ojeniyi and Adeniyan, 1999). The organic fertiliser would also ameliorate the physical and chemical properties of soils such as the plastic limit, water retention, aggregate stability, total N, soil OM, pH and CEC. The improvement of these parameters definitely leads to higher yield of the crops planted (Mbah and Mbagwu, 2006). Kekong *et al*. (2010) demonstrated and validated the effectiveness of cattle dung and poultry dung in improving the fertility status of savannah and rainforest soils for sustainable vegetable production. The best performance overall recorded from site 1 in the second planting season (Residual planting) can be linked to the improvements recorded in the physical and chemical parameters of soils of site 1 as influenced by the addition of the enriched composts in the first planting season which led to improved fertility (Mbah and Mbagwu, 2006). Omolayo *et al*. (2011) had observed that degraded soils could be restored and rehabilitated to an optimum level of productivity by proper and regular additions of various organic wastes, including plants and animal manure, especially poultry droppings.

The yield values in this study were in the order of 40 t/ha > 30 t/ha > 20 t/ha > 10 t/ha, but there were no significant differences between the 30 and 40 t/ha treatments. The 30 t/ha CDSNM could therefore be recommended for optimum production of *worowo.*

The nutritional values of *worowo* were positively affected by the addition of the enriched composts, an indication of the general improvement in the quality of crops to which composts are applied (Age *et al*., 2010; Rodale, 2004). The nutritional values of *worowo* increased with the different rates of the enriched compost. The highest values for protein and crude fibre, which are very important properties when nutritional composition is being considered, were recorded from 40 and 30 t/ha of the enriched compost. The values observed for all the treatments were higher than the nutritional value of *worowo* given by Adebooye (1996). Masarirambi *et al*., (2012) had observed that poultry manure levels significantly ($P < 0.05$) affected growth, yield and nutritional quality of lettuce with the best values attained at 60 t/ha which was recommended for a more productive enterprise. Ojetayo *et al*. (2011) submitted that organo-mineral fertilisers (Pacesetter > Sunshine > Alesinloye) were comparable to NPK (15:15:15) in terms of leaf yield and enhanced optimum nutritional compositions of cabbage varieties before and after storage. Mofunanya *et al*. (2014) also found that organic fertiliser produced higher nutritional values in *Amaranthus spinosus* whole plant (leaf, stem, inflorescence and root) when compared with inorganic fertiliser.

The lower value of soil N observed for soils treated with the enriched compost in the first planting season in year 2010 might be due to the fact that the rate of decomposition was insufficient to release N rapidly enough to meet the needs and uptake of a fast growing leaf vegetable (Onyango *et al*., 2011). The higher soil N values recorded for the enriched compost in the second planting season in 2011 showed that composts enriched with organic N sources had more residual effects than the NPK fertiliser. This was eminent in the better nutritional quality of vegetables recorded in the second planting season. Makinde *et al*. (2010) studied the effects of organic, organo-mineral and NPK fertilisers on the nutritional quality of leaf amaranth in Lagos, Nigeria and submitted that NPK gave the least values of the measured parameters on residual basis compared to organic materials.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Very scanty information is available on the soil fertility requirement of *worowo* (*Senecio biafrae*), however, the crop is being produced throughout the seasons. Due to continuous cultivation, the soils in the tropical areas are poor in organic matter and available nutrients and hence productivity and sustainability decline over time. For more permanent cropping systems, fertilisers are essential to add nutrients needed to sustain high crop yields. Due to the scarcity and high cost of chemical fertilizers, research should be focused on promotion of cheap, locally-available organic sources of plant nutrients, especially composts. The extent to which the N content in composts could support crop performance is limited and additional input of N source is inevitable. Therefore, more work is needed to identify the organic materials which would improve the N content of composts at low cost and also improve soil fertility for optimum production of *worowo*.

Experiments were conducted in four phases to meet the objectives of this study which were to:

i) determine the nutrient compositions of the compost materials and organic N sources;
ii) measure the nutrient release pattern of the enriched composts through incubation studies;
iii) identify the most suitable enriched compost for optimum production of *worowo* (*Senecio biafrae)*;
iv) evaluate the growth and yield responses of *Senecio biafrae* to various levels of the most suitably enriched composts in the field;
v) evaluate the residual effects of the identified best enriched compost on some soil properties and on the growth and yield of *worowo* (*Senecio biafrae*); and
vi) evaluate the main and residual effects of the identified best enriched compost on the nutritional quality of *worowo* (*Senecio biafrae*).

Cattle dung and sawdust (CD+S), poultry dung and sawdust (PD+S) were mixed in the ratio of 1:1 and left in separate heaps; watered and turned fortnightly until matured and attained curing stage. Samples were taken from the compost piles at 2 and 22 weeks and analyzed for organic carbon, total N, available P, Ca, Mg, K, Na, Mn, Fe, Zn, Cu and Pb. The N contents of the composts were raised using organic sources (cattle slaughter wastes and plant materials- neem and tithonia leaves) as N enrichment after 22 weeks. There were fifty treatments. The nutrient contents of the enriched composts were measured at 4-week intervals for 16 weeks of incubation. In a pot experiment, the composts enriched with N at 60 g/kg N: CDSBM, CDSBnM, CDSHnM, CDSHM, CDSTM, CDSNM, PDSBM, PDSBnM, PDSHnM, PDSHM, PDSTM and PDSNM; CDS and PDS, each applied at 30 t/ha were compared with 400 kg/ha of NPK 15-15-15 to identify the best enriched compost for the production of *worowo (Senecio biafrae)*. The effects of CDSNM (the best enriched compost from the pot experiment) applied at 0, 10, 20, 30 and 40 t/ha on the growth, yield and nutritional quality of *Senecio biafrae* were also studied for two seasons in field experiments laid out in a randomized complete block design and treatments were replicated four times. The residual effects of CDSNM on the soils, growth, yield performances and nutritional quality of *worowo* were also studied.

The studies depicted and affirmed that:

i) Composting reduced the sizes of the component materials and converted them into a substance soil-like in texture with decreased carbon-nitrogen ratio (C: N), higher pH and cation exchange capacity and lower heavy metal contents.
ii) There was reduction in the quantity of N in all the composts between 4 and 8 weeks of incubation followed by a slight stability in the nutrient contents as from the 12thweek.
iii) Only CDSNM showed increase in soil N at all levels of enrichment throughout the incubation study. The highest values of soil N (10.5 g/kg), available P (25.0 mg/kg) and exchangeable K (4.57 cmol/kg) were obtained from 60 g/kg N enrichment level of all composts and was therefore selected as the best treatment.
iv) Enrichment of Cattle Dung+Sawdust with neem leaves at 60 g N/kg contributed to good nutrient release in the soil.
v) There were significant differences (P =0.05) in plant height, number of leaves, leaf area, stem girth and marketable yield among all the enriched composts

applied at 30 t/ha in a pot experiment. The CDSNM gave the best values in plant height, number of leaves, number of branches, stem girth, leaf area and yield of *worowo*.

vi) Edible shoot yield of *worowo* with Cattle dung+Sawdust compost enriched with neem leaves at 60 g N/kg was better than that of mineral fertiliser NPK in the screen house.

vii) Application of CDSNM caused improvement in the soil properties, especially the increase in N, P, K, exchangeable bases and organic matter contents.

viii) The edible shoot yield of *worowo* with Cattle Dung+Sawdust compost enriched with neem leaves at 60 g N/kg, applied at 40 t/ha was better on the field than other compost rates and the inorganic fertiliser used in this investigation.

ix) The longer the *worowo* vines, the smaller and fewer the leaves are likely to become. Also, the longer the *worowo* stays on the field, the thicker the vines.

x) The control and NPK treatments gave the least values of the growth parameters measured during the second planting season confirming the lack of residual effects of inorganic fertilisers in the soils.

xi) The CDS and PMS enriched with organic wastes compared well with NPK in all the parameters measured despite the quick nutrient-releasing ability of NPK.

xii) The 40 t/ha of CDS fortified with neem leaf in powdery form (CDSNM) at 60 g N/kg which gave the highest values in most of the growth and yield parameters measured (both in the first and second planting seasons), was not significantly different from the 30 t/ha level. Therefore, CDSNM at 30 t/ha could be recommended for optimum and sustainable production of *worowo*.

xiii) The enriched compost (CDSNM) also improved the nutritional quality of *worowo* as all the parameters measured increased with the rates of the enriched compost.

xiv) Cattle Dung+Sawdust compost enriched with neem leaves at 60 g N/kg and applied at 40 t/ha increased crude fibre and protein contents of *worowo* better than other compost rates and treatments investigated.

xv) The following areas are suggested for future work as part of the process of domestication and taking *worowo* from the wild:

a) N, P and K requirements of *worowo*.

b) Evaluation of the cutting length of the vine as planting materials.

c) Evaluation of the harvesting interval for *worowo* as some vines were no longer succulent at the 60-day harvesting interval used in this study.

In conclusion, the CDSNM applied at 40 t/ha which gave the highest values in most of the growth, yield and nutritional quality parameters measured (both in the first and second planting seasons on the field), was not significantly different from the CDSNM applied 30 t/ha. Therefore, CDSNM at 30 t/ha may be used for optimum production of *worowo*.

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