RATTLE TREE (*ALBIZIA LEBBECK*) EFFECTS ON SOIL PROPERTIES AND PRODUCTIVITY OF IRISH POTATO (*SOLANUM TUBEROSUM*) ON THE JOS PLATEAU, NIGERIA

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DECLARATION

I hereby declare that this work is the product of my own research efforts, undertaken under the supervision of Professor A. A. Adepetu and Dr. E. A. Olowolafe and has not been presented elsewhere for the award of a degree or certificate. All sources have been duly distinguished and appropriately acknowledged.

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ABSTRACT

This study was carried out with the aim of assessing the rattle tree *(Albizia lebbeck)* effects on soil properties and Irish potato (*Solanum tuberosum)* productivity on the Jos Plateau, Nigeria. In carrying out the research, a randomized complete block design (RCBD) was employed consisting of five treatments and three replicates. The five treatments applied were as follows: Treatment 1 (T_1): Irish potato planted in the alley (space) between *A. lebbeck* tree rows without green manure; T_2: Potato planted without *A. lebbeck* tree rows but with its green manure application, two weeks before planting of potato at 5 ton/ha; T_3: Potato planted in the alley of *A. lebbeck* tree rows with its green manure (as mulch) at 5 ton/ha; T_4: Potato planted in the alley of *A. lebbeck* tree rows at 10 ton/ha and T_0: Potato planted without *A. lebbeck* green manure and tree rows as control. Plot size was 3 m x 2 m (6 m^2) in form flat bed. Apart from T_3 with the green manure as mulch on the plot, the green manure applied to other treatments was ploughed with the soil. Green manure application was done two weeks before planting of potato and *A. lebbeck* seedlings were planted one week prior to planting of potato. The field experiment lasted for three years (2004 – 2006) and both rainy and dry cropping seasons were carried out. The observations made include significant effect ($P \leq 0.01$) of the treatments, blocks, seasons and treatment x season (interaction) on the growth parameters (seedlings' emergence percentage, plant height, leaf count and collar girth) and yield indices [tuber count ($P \leq 0.05$) and tuber weight ($P \leq 0.01$)]. T_4 which had the highest level of green manure application (10 t/ha) with *A. lebbeck* tree rows emerged as the most effective treatment in terms of growth performance and optimal mean yield (10.24 t/ha). From the five cropping seasons, the mean yield from dry season harvests (7.89 t/ha) was higher than those of rainy season (7.73 t/ha). The independent variables (collar girth, leaf count and plant height) showed positive correlation with the dependent variable (Irish potato yield) while stem count had a negative correlation with yield. Very importantly leaf count and collar girth were the two determinants of yields (of this bertita variety of Irish potato) from this study. They accounted for 61.6 – 91.3% of the variation in yield (R^2 = 0.616 – 0.913). Similarly, improvement on soil nutrient status and significant effect of treatments and blocks on some soil properties such as available phosphorus (P) (at 0 -10 cm depth) and potassium (K) (0 – 10 cm and 10 – 25 cm depths) at $P \leq 0.05$ were observed. However, only block effect was recorded on pH and Mg and there was a general decrease in the organic matter, total nitrogen (TN), calcium (Ca), sodium (Na), exchangeable acidity and effective cation exchange capacity (ECEC) after planting. This could probably due to leaching, absorption by the crops and crop removal. Thus, it could be inferred that the green manure (at 10 ton / ha) and tree rows of *A. lebbeck* can improve soil nutrient status and productivity of this crop. Also, sustainable production of Irish potato without the use of nitrogenous / inorganic fertilizer under this agroforestry system is feasible on the Jos Plateau.

Key Words: Rattle tree, effects, soil properties, Irish potato, productivity, Jos-Plateau,Nigeria.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY PROBLEM

Trees play some vital roles in improving the nutrient status of soils in the forest and savanna ecosystems. The non-nitrogen fixing trees augment soil fertility through erosion control, addition of organic matter (by means of litter deposition, especially the deciduous and semi-deciduous ones), water conservation, protection of water catchment areas and creation of balanced micro-climatic conditions within an ecosystem. The nitrogen fixing trees (NFT) have an edge over the non-nitrogen fixing ones in the sphere of nitrogen fixation due to the presence of *Rhizobium* bacteria in their root nodules or ability of some NFT to nodulate with the ubiquitous *Bradyrhizobium* bacterial strain in th1e soil thereby increasing the nitrogen status of the soil.

Trees and certain agronomic crops are parts of the components of agroforestry system and the former (trees) through some of their activities enhance the productivity of the latter (crops). Forest tree species, right from time immemorial are often left on agricultural farmlands in scattered manner. They are later utilized by farmers for various purposes (such as timber, fuel wood, fodder/forage, gum, tannins, fencing poles, stakes and medicinal uses among others) in addition to their (trees') roles in soil conservation in modern agroforestry systems.

Further steps have been taken in utilizing some multipurpose tree species (MPTS) to improve soil nutrient status on farmlands. One of such steps is the use of green manure obtained from the trimming or pruning of hedgerows or trees in or around the farm. The green manure is incorporated into the soil during land preparation or used as mulch after land preparation (ploughing/harrowing, ridging, heaping) and planting. More importantly, when appropriate quantity of foliage is applied to soils (as green manure) it could bring about optimum production per unit area and even substitute for nitrogenous fertilizer requirements. This phenomenon was observed by Kang *et al.* (1981) and Kwapata *et al.* (1992) on the use of *Leucaena* for maize production.

Agroforestry serves is a sustainable land use option. It has been described as a sustainable land management system that increases the overall productivity of the land (King and Chandler, 1978; Kareem and Famuyide, 2006). It combines the production of forest plants with crops including tree crops and/or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local people.

Almost invariably, most trees incorporated into agroforestry systems are nitrogen fixing ones due to high amount of nitrogen transferred from tree or hedge rows and pruning to the food crops in the alleys after decomposition and subsequent mineralization (Sanginga and Mulongoy, 1995). Notable examples of the MPTS employed in agroforestry systems include *Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrsus, Senna siamena, Acacia albida, Acacia auriculiformis* and *Sesbania grandiflora.* Others include *Parkia biglobossa and Albizia lebbeck* on which very little research has been conducted.

In areas where agroforestry systems are practised, farmers plant these tree species on their farms and obtain green foliage from the trees (pruning) and incorporate them during land preparation as green manure (Fomba, 1998). The prunings (from matured trees) or trimmings (from young hedgerows) of tree species in agroforestry farms comprise leaves and succulent stems (of the nitrogen fixing tree species).

The essence of practising this system, apart from the beneficial roles of trees, is to obtain certain benefits which include drastic reduction in the use of chemical fertilizers (especially nitrogenous ones) thereby reducing the cost of production and also achieve multiple harvests of products from such farms, high income to farmers and better quality of products. Most of our tropical soils are highly weathered and leached, the organic matter content is very low due to continuous cultivation and high temperatures which lead to rapid decomposition and disappearance of organic matter and persistent application of chemical fertilizer does not produce required results (Adepetu *et al.*, 1979).

Okali (1993) observed that continuous application of chemical fertilizers to crops on impoverished soils of low organic matter content often leads to loss of substantial parts of fertilizer through erosion especially during periods of heavy rainfall in the rainy season though subject to the nature of the slope and soil texture. He also asserted that crops produced from natural or organic manure are valued more than those produced from inorganic fertilizers most especially in the advanced countries of the world. When chemical fertilizers are washed to the streams or stagnant water bodies, they could have toxic effects on the aquatic organisms such as fishes and when these organisms are eaten by man the toxic effect could be magnified. In addition to this, if the quantity of the nitrogenous fertilizer is high, it could lead to eutrophication when the fertilizer dissolves and forms nitrate ions thereby reducing the volume of oxygen in water bodies considerably (Nyle and Ray, 1996).

It has been reported that organic fertilizers though do work less quickly but improve the soil and plants better than inorganic fertilizers. Also, there is virtually no cases of leaf burn and toxicity/damage to the soil, beneficial soil micro-organisms are more stimulated to release nutrients and plants are less prone to diseases. Conversely, inorganic fertilizers have destructive action on useful soil micro-organisms, can burn plants' roots and ruin soil structure (The Organic Gardener, 2006).

Krause (1997) also reported that strict regulations were placed on the marketing of organic products by the European Union (EU) and more costumers were prepared to pay higher price for organic products. He stressed further that buyers of coffee preferred high-quality varieties and organic coffee (coffee produced from organic fertilizer) owing to its comparatively higher quality. The Organic Gardener (2006) further highlighted the advantages of organic fertilizers over inorganic ones which include serving as reservoir of water and nutrient, soil conditioner for the improvement of the physical texture and cohesion of soil particles, buffer material during extreme condition and means of support for a healthy population of soil micro-organisms.

1.2 THE STUDY PROBLEM

For many years, emphasis has been laid on the need to improve the nutrient status of impoverished soils in the tropics in a bid to increasing and sustaining agricultural production. Nitrogen as an element is abundantly available in the atmosphere (about 79%) but very deficient in most soils. Several tons of chemical (nitrogenous) fertilizers are purchased yearly to remedy soil nitrogen deficiencies. Besides its being exorbitant, its (chemical fertilizer) application could adversely affect the ozone layer thereby causing increase in skin cancer and rates of mutation in organisms due to harmful radiation (Alexander, 1982).

Integration of non-nitrogen and nitrogen fixing trees into agroforestry systems has been identified as one of the ways of increasing the organic matter and nitrogen content in most savanna soils. These are the soils which Alasiri (1997) described as being low in nutrients and of poor structure due to continuous cultivation. In soil fertility improvement and land reclamation, nitrogen fixing trees can play significant roles particularly under alley cropping system which has been known to enhance both nutrient and structural characteristics of soils (Osunde, 1995).

Most tropical soils are highly weathered and leached, some of which are typical Ultisols that are usually characterized by low levels of organic matter and nitrogen content of about 0.3 – 0.6% and 0.03 – 0.05% respectively (D’Hoore, 1964). In the past, organic matter build-up was achieved under bush fallow system or shifting cultivation or land rotation as a means of fertility maintenance (Greenland and Nye, 1959). But owing to rapidly increasing population, these systems are no more practicable due to pressure on land by other sectors of the economy (Yayock *et al.*,1988). The vital role played by organic matter in the soil cannot be over-emphasized as Nye (1961) had earlier described it as a vital component of soil exchange complex. This can be increased through ample supply of organic residues such as litter and compost. These inputs can be achieved under alley cropping with trees that are characterized by profuse litter deposition and nitrogen fixing capacity.

Also, Adepetu *et al.* (1979) reported a 58% drop in the organic matter content of the low soil series in a virgin forest site at Ile-Ife, South Western Nigeria during a seven-year continuous cropping. Among the major constraints to sustainable soil management and cropping on the Jos Plateau are high cost and inadequate supply of inorganic fertilizer at the right time while some of the available ones are even adulterated. It is pertinent to mention here that farmyard manure was initially used to remedy the ugly situation of low nutrient status. This is limited to small area of land since the demand by large scale farmers or the numerous small scale farmers cannot be met owing to major constraints such as unavailability/scarcity or insufficient quantities of animal wastes, transportation and labour costs (Yayock *et al.*, 1988).

Arising from this situation, is the need for an alternative and inexpensive technique of soil/input management. Under agroforestry system, trees can help in the improvement of soil fertility through physical remediation which can sustain higher water holding capacity coupled with good permeability. Greater erosion resistance, litter deposition, better microclimate, improved rate of mineralization are also feasible.Effective timing of nutrient release through decisions on when to prune the hedge or tree rows in agroforestry farm for mulching or as green manure is easily determined (Young, 1985; Adebagbo, 1997).

Thus, a suitable nitrogen-fixing tree such as *Albizia lebbeck* could be used by incorporating it into agroforestry system. Its pruning in form of green manure add nitrogen to the soil since large quantities of nitrogen are normally harvested along with the prunings. Saginga and Mulongoy (1995) reported that more than 3000 kg N ha^{-1} y^{r-1} was realized when *Gliricidia* or *Leucaena* hedge rows were pruned and their nitrogen in the range of 40 – 70 $kgNha^{-1}$ per season released to crops. Also, the soil nutrient status would be augmented through organic matter decomposition, mineralization and subsequent transfer of nutrients from tree rows of this species (*Albizia lebbeck)* to the companion crops in the alleys.

Crops can thrive and produce well in alleys of *Albizia lebbeck* if efficiently employed, more so when Dommergues (1987) described it as being capable of fixing high amount of nitrogen because most soils in the tropics habour the *Bradyrhizobium* strains of nitrogen fixing bacteria needed for nodulation which is present in this species (*Albizia lebbeck).* Hitherto, no research work has been carried out on the roles of this species under agroforestry in soil management and on Irish potato yield in the area. Thus, this study is set up to answer the following questions:

a. What are the effects of *Albizia lebbeck* green manure and tree rows on soil properties in the study area?

b. What are the effects of *Albizia lebbeck* green manure and tree rows on the growth of Irish potato in the area?

c. What are the effects of *Albizia lebbeck* green manure and tree rows on Irish potato yield in the area?

d. What is the optimum level of *Albizia lebbeck* foliage application for Irish potato production?

1.3 OBJECTIVES OF THE STUDY

The aim of this study is to quantify the effects of rattle tree (*Albizia lebbeck)* on soil properties and Irish potato productivity on the Jos Plateau, Nigeria. However, in order to achieve this aim, the specific objectives are as follows:

a. to determine the effects of *Albizia lebbeck* green manure and tree rows on soil properties in the study area.

b. to investigate the growth response of Irish potato to the green manure application and tree rows of *Albizia lebbeck*

c. to determine the quantity of *Albizia lebbeck* green manure (ton/ha) that would bring about optimal yield of Irish potato for both rainy and dry season croppings.

1.4 THE STUDY SCOPE

The study entails conducting a field experiment for a period of three years (2004, 2005 and 2006) comprising five cropping seasons (three rainy season and two dry season croppings). Prior to the commencement of the field experiment, rattle tree (*Albizia lebbeck*) seedlings were raised in the nursery and they were six months old in May, 2004 when the first cropping season began. The Federal College of Forestry, Jos was chosen as the only study area due to the fact that the Jos Plateau is mainly biotite granite with little basalt and the climate is also the same. Thus, carrying out the experiment in three or more locations on the Plateau was not imperative.

The growth parameters assessed include plant height, leaf count, stem count and collar girth while the yield indices considered are tuber count and tuber weight (tuber yield). Also, the soil properties were assessed before and after the field experiment so as to quantify the possible change in nutrient status. The physical properties assessed include the particle size distribution and textural classes while the chemical properties are the soil pH, organic matter, total nitrogen, available phosphorus, the exchangeable cations (Ca, Mg, K, Na), exchangeable acidity and effective cation exchange capacity (ECEC).

1.5 JUSTIFICATION OF THE STUDY

Albizia lebbeck is a deciduous tree, whose profuse litter deposition during the dry season and prunings from its tree rows in the rainy season contribute in no small measure to the nitrogen and organic carbon content of soil. Mulongoy and Gasser (1993) reported that most plant nitrogen is obtained from the mineralization of nitrogen derived from organic materials especially in natural ecosystems and that, in alley cropping, selection of woody species based on their capacity to supply prunings is an essential factor. It has been observed that soils formed from biotite-granites on the Jos Plateau, are low in terms of total nitrogen status, available phosphorus and calcium due to erosion, leaching, crop removal, acid and lateritic nature of the soils (Olowolafe and Dung, 2000).

It is therefore expected that alley cropping on these soils especially with this species would tremendously or significantly improve the nutrient status over time. Also, the areas of land which have been degraded as a result of tin mining activities on the Jos Plateau and the areas under cultivation which has been expanded owing to the rapidly increasing population (Adepetu, 1986) could be made more productive under alley cropping system with this species.

Irish potato (*Solanum tuberosum L.)* responds well to organic and inorganic fertilizers on the Jos Plateau (Ifenkwe *et al*.,1986). The low levels of soil nitrogen is attributable to annual bush burning and overgrazing (Okonkwo et *al.*, 1995), which are prevalent on the Jos Plateau. Thus, in order to remedy this ugly situation, *Albizia lebbeck* can be introduced to supply the much needed nitrogen and to some extent other nutrients after decomposition and subsequent mineralization of its litter and pruning as green manure in the alleys.

Similarly, Fomba (1998) has reported about the positive response of Okra (*Abelmoschus esculentus L. Moench)* to application of leaf mulch (as green manure) of Gliricidia *sepium* and Oloyede (1994) also indicated that Okra responded significantly in term of leaf number to *Leucaena leucocephala* leaf mulch. No research has been conducted with *Albizia lebbeck,* particularly with regard to the effects of its tree rows and green manure on soil properties and crop such as Irish potato as a means of soil management on the Jos Plateau.

Thus, it will be worthwhile if the potentials of this species is investigated more so that Kareem *et al.* (2001) reported about ease of germination of the seeds when pretreated only with hot water at 50 ^{0}C and attaining a mean height of 10.10 cm and leaf count of 19 at the 8th week which are indicative of fast growth. Prisen (1986) also pointed out that stands in hedge rows at a row spacing of 3 m produced pruning of 2500 kg/ha/yr and can thrive well in lower rainfall tropics and sub-tropics. Irish potato, the test crop of this investigation was chosen due to the fact that it is one of the most important and commonly cultivated annual/economic crops on the Jos Plateau.

1.6 RELEVANCE OF THE STUDY TO ENVIRONMENTAL AND RESOURCE PLANNING

The role of trees in improving environmental quality cannot be over emphasized. When trees are introduced or incorporated into farmlands in a properly planned manner such as in alley cropping, alternate row planting, border tree planting and shelterbelts, numerous benefits or advantages are often derived on a sustainable basis. For instance, presence of trees provides a good micro climatic condition. When trees attain maturity, wind and water erosion are checked, the foliage from the trees could be used as green manure in addition to the litter from the trees which releases nutrients to the soil after decomposition and mineralization, thereby improving the nutrient status of the soil and reducing the amount of money expended on chemical fertilizers considerably.

Furthermore, deforestation and overgrazing which lead to soil acidity (Tulu, 2002) could be drastically reduced since some of the foliage from trees in agroforestry farm could be utilized as forage or fodder. Some trees in the farm could be selectively felled (coppiced) after harvesting annual crops, for different purposes such as fuel wood, fencing poles, stakes and timber from those that have been planted as border trees for relatively long time (Young, 1985). Trees serve as carbon dioxide sink and release oxygen to the atmosphere through their photosynthetic activities, thereby purifying the atmosphere.Thus,an environmentally sustainable ecosystem is put in place.

1.7 PRACTICAL IMPLICATIONS OF THE STUDY

It is hoped that the findings from this study would be of immense contribution to knowledge in terms of knowing the:

(i) Most appropriate quantity of foliage of *Albizia lebbeck* as green manure to be incorporated into soil in order to achieve optimum yield of the potato crop.

(ii) Effects of the green manure and tree rows of *A. lebbeck* on the growth and yield of Irish potato on the Jos Plateau.

(iii) Improvement on the soil nutrient status as a result of the green manure and tree rows of *Albizia lebbeck* (which is characterized with nitrogen fixing ability).

CHAPTER TWO

LITERATURE REVIEW

2.1 THEORETICAL BACKGROUND

2.1.1. Agroforestry System

Agroforestry is a form of multiple land use system, which involves the production of both perennial forest tree crops, annual (agronomic) crops and animals (in some cases) on the same land management unit either simultaneously or sequentially. It is an age-old system, which had been in practice right from time immemorial. Trees (either nitrogen fixing or non-nitrogen fixing) are often left in farms by peasant farmers, they are later used as timber, poles, fuel wood or to supply forage/fodder, fruits or stakes for crops in their farms.

Peasant farmers know little about the beneficial roles of trees in soil fertility maintenance probably except in the area of organic matter production as a result of litter deposition by the trees which they believe does add nutrients to the soil (though after decomposition and mineralization). Some of the trees that are often left in farms or on abandoned farmlands in the Jos Plateau and savanna ecosystem include Parkia *biglobossa, Vitellaria paradoxa*, *Elaeis guineensis, Vitex doniana, Anogeiossus leocarpus, Lophira lanceolata, Moringa oleifera, Khaya senegalensis*, *Acacia albida (Fadherbia albida) and Ficus sychomorus* among others.

Obviously, no general consensus has been reached with regard to the definition of agroforestry. Many experts/researchers have put forward various definitions from various perspectives and many of them believe that it is a superior and more successful approach to land development or soil conservation. Few of the definitions look at agroforestry as the production of trees and annual crops on the same piece of land while many others base their definitions on alley cropping. Alley cropping is a modern form of agroforestry system that entails special arrangement such as establishing hedgerows of tree crops which are often multipurpose tree species (MPTS) and planting of annual crops in the space between the hedge rows (alleys). Some definitions are given below which are considered to have contained appropriate words that convey the meaning of the term. To start with, Lungren (1982) defined agroforestry as:

> Land use systems in which trees are grown on the same land as agricultural crops and/or animals, either in a spatial arrangement or a time sequence and in which there are both ecological and economic interactions between the tree and non-tree components.

The above definition is to a reasonable extent comprehensive owing to the fact that all major forms of the system are adequately accommodated with regard to the components of and interactions within the systems.

A definition similar to the one quoted above was given by Young (1983), he defined agroforestry as:

> A land use system where woody perennials (trees or shrubs) are deliberately used on the same land management unit as annual agricultural crops and/or animals either sequentially or simultaneously, with the aim of obtaining greater outputs on a sustained basis.

This definition stresses two additional points (main ideas), which are the ‘greater outputs’ and ‘sustained basis’ which are the advantages of multiple land use and the positive roles of trees in soil conservation which pave way for higher agricultural productivity perpetually on such land management unit under astute management.

The International Council for Research in Agroforestry (ICRAF) seems to have been using a particular definition though the body is yet to adopt a permanent one. Lundgren and Nair (1985) pointed out that ‘certainly no general consensus has been reached and that many definitions have been proposed.’ Therefore, a more objective definition that is often given in ICRAF publications (ICRAF, 1983) is that:

> Agroforestry is a collective name for landuse systems and practices where woody perennials (trees, shrubs, palms, bamboos, etc) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In Agroforestry systems, there are both ecological and economic interactions between the different components.

It could be observed that this definition encompasses a good number of popular land use systems in the tropics such as shifting cultivation, the bush fallow and taungya systems which could be regarded as primitive agroforestry owing to the fact that they lack deliberate choice and planting of woody species. In areas where soil nutrient status is low and organic matter is dependent upon, erosion and surface soil desiccation is high, agroforestry has very ecological potential in increasing land productivity substantially (Lundgren and Nair, 1985).

The main components of agroforestry systems feature prominently in the definition. These components are the tree (woody perennial which is often multipurpose), herb (agronomic/annual/pasture plants) and animal (livestock which may not be present always or at once). Land use systems such as shifting cultivation and bush fallowing are primitive forms of agroforestry owing to the fact that no deliberate choice and planting/spatial arrangement of wood species occur and are operating at low levels of efficiency.

In other development, Beets (1990) defined agroforestry as:

> A land-use or farming system in which trees are grown on the land as crops and/or animals either in a spatial arrangement or in a time sequence, and in which there are both ecological and economic interactions between the tree and non-tree components.

The above definition encompasses many other forms of land-use systems that had been in practice in the tropics a long time ago. Notable among them are bush fallow, taungya, home gardens, alley-cropping and silvipasture. Beets (1990) opined that agroforestry is only a new nomenclature for a system that had been in practice a long time ago. He stressed further that it is a system that embraces forestry, agriculture, animal husbandry, aquaculture and fisheries and land resources management. Agroforestry also brings into focus the awareness about the various interactions between man and the environment and between demand and available resources in a particular area.

Therefore,from the author’s point of view and forthe purpose of this research, agroforestry could be defined as a form of multiple land use system that entails the cultivation of woody shrubs/forest tree species and agricultural (annual) crops and sometimes tentative integration of livestock on the same piece of land either simultaneously or sequentially in a specially designed spatial arrangement or at random so as to pave way for even growth, positive interactions and development of the components, ensure optimum / sustained yield of diversified products/services and enable the land to remain productive continually or perpetually.

It is pertinent to mention at this juncture that one of the goals of agroforestry entails optimization of positive interactions among the components and between these components and physical environment in order to achieve a more diversified (multiple) products. A more sustainable production from available resources that is impossible with other forms of landuse under the prevailing ecological and socio-economic conditions is another goal of agroforestry systems and practices.

2.1.2 Origin

Agroforestry is not a new name or terminology more so when agricultural and forest tree crops have been co-existing in farmlands right from the period of early man. It is an age-old landuse system, which entails the combination of forestry, agriculture and or pastorialism (PTPU, 1988; Beets, 1990). The old systems of land cultivation (for example, bush fallow system, shifting cultivation and land rotation among others) are forms of agroforestry. This is based on the fact that different species of trees are randomly left in the farm without any specific arrangement and later utilized for various purposes which include fuelwood, timber, poles, forage, gum, tannins, stakes (for agronomic crops), vegetables, medicine and fruits.

However, it is essential to mention here that few other forms of agroforestry systems were developed or formulated by researchers, which could be said to have specific origin. For instance, taungya system which is a form of agroforestry was first introduced in Burma about 1861 (Nwoboshi,1982) by Diatrick Brandis (chief conservator of forests in Burma: then part of British colony) when shifting cultivation was wide spread and there were several court cases against the villagers for encroaching on forest reserves. Brandis realized the detrimental effects of shifting cultivation on the management of timber resources and encouraged the practice of regeneration with *Tectona granids* (teak) by taungya system. Thus, two decades later the system proved so efficient that teak plantation could be established at a very low cost in the taungya way.

Farm forestry is another form of agroforestry system which originated in Nigeria about one and a half decades ago sequel to the report of the Raw Material Research and Development Council (RMRDC) in 1992 which initiated the plantation establishment project based on RMRDC survey on the wood and wood products sector (Ogazi *et al.,* 1997). Also, the modern agroforestry system which applies newly acquired technologies to improve traditional landuse practices was introduced or came into being about three decades ago. The organization under which this system is being developed is International Council for Research in Agroforestry (ICRAF) which is established in 1978 with the headquarters in Nairobi, Kenya. Presently, it has spread to almost every part of the world with emphasis on alley cropping with multipurpose tree species.

2.1.3 Objectives/Benefits of Agroforestry

Since more than two decades ago, there has been a continuous clamour for the adoption of modern agroforestry practices especially in the parts of the world where the practice is at its lowest ebb or non-existent. Many agroforestry researchers have made their opinion known with regard to what should be the actual objectives of agroforestry. For instance, Raintree *et al.* (1984) opined that they (objectives) should be the conservation of degraded areas or areas under threats of desertification, drought, erosion and flooding. Agroforestry practice could also contribute in no small measure towards regenerating degraded lands, improving crops yields as well as ensuring adequate protection of environmental biodiversity (Leakey, 1994).

Agroforestry practice could also be geared towards achieving better/positive interactions among the components in the agroforestry system (which include agronomic crops, woody perennials, microbes/ livestock, water and the soil). These interactions could lead to higher agricultural productivity, efficient utilization of resources and proper environmental management (Gordon *et al.,* 1997). It is pertinent to mention that agroforestry practice is not limited to the tropical countries of the world but evidences abound that it is practised in the temperate regions of the globe such as Europe, North America and South East Asia (Newman and Gordon, 1997).

By and large, the objectives/benefits of agroforestry could be summarized as follows:

i. Soil Conservation / Improvement

The woody perennial component of the agroforestry system helps in sustaining nutrient recycling and soil fertility through litter deposition and mineralization. Nitrogen fixing trees (such as *Parkia biglobosa* and *Albizia lebbeck)* add nitrogen to the soil thereby increasing the percentage of nitrogen.

Also, when multipurpose tree species are introduced into agroforestry farms and degraded farmlands, they bring about profound improvement on soil nutrient status and the farm lands thus remain productive perpetually (PTPU, 1988; Leakey, 1994; Riechelt, 1999).

ii. Improvement on Agricultural Yield

Owing to the positive effects of trees on soil in the spheres of soil improvement, conservation,water control and creation of microclimatic condition, crop yield could be improved reasonably. The interactions among the components (agronomic and forest tree crops, livestock, water and soil) also bring about higher agricultural productivity (Raintree *et al.*, 1984; Backes, 1999). Eventually a profound increase in food supply is achieved as a result of the combination of the components of the system in a rather complex and ecologically sound manner (Spore, 1988). Also, risk of crop failures is reduced to the barest minimum.

iii. Availability of Wood and Other Products

Apart from increase in food supply, agroforestry practice paves way for enhanced wood production in form of timber, poles, fuel wood and other products such as fodder/forage, gum, leaf, vegetables (for example, leaves of *Moringa oleifera, Adansonia digitata, Vitex doniana)* and ropes. These products are very effective in meeting household needs or as cash crops. Besides, they are able to withstand price fluctuation without loss in value and their quality and quantity are even improved with time under sound management (PTPU, 1988; Falconer, 1990).

iv. Efficient Utilization of Resources

Being a form of multiple land use system, agroforestry accommodates agriculture, forestry, pastoralism, apiculture, aquaculture among others on the same land management unit. Therefore, efficient utilization of available resources is ensured. It thus serves as an antidote to the conflicting demand for food, wood and livestock production. Also, sustainable resource use is achieved, for instance, it does not encourage destruction of environmental biodiversity. Trees could be left in a scattered manner in the farm and animals could feed on farm remnants after harvest and they (livestock) in turn enrich the farmland with their wastes (Ehuri, 1992).

v. Employment Opportunities

Owing to the fact that many people are involved in agroforestry practices, it thus serves as employment opportunities and source of income. In most cases farmers do sell many products from their agroforestry farms which include annual/biennial crops and wood products. This practice paves way for reasonable level of participation of the local populace, which in turn brings about high level of success of the practice (Ijere and Giro, 1988). Also, local technologies that are compatible with people's culture are embraced (Scheir and Muller, 1991).

2.1.4 Classification of Agroforestry Systems

It is imperative to highlight the factors that are considered in the classification of agroforestry systems. These factors include:

a. Component combination

b. The role of the component in the system.

c. The type of reaction among the components whether spatial or temporal

d. The way and manner by which woody components are distributed in the agroforestry farm.

Besides the above factors, any sound agroforestry system should have the following features:

a. Presence of at least two living plant species, one of which should be woody perennial (the other could be an annual / biennial crop or livestock).

b. There should be interaction (biological/economic) among the components (agronomic / annual crop, forest tree/woody perennial, livestock, soil and water).

c. At least, the system should yield two products

d. The system must have a cycle of more than one year

e. Application of the system to small or medium sized projects involving indigenous initiatives should be easy.

Thus, agroforestry systems according to Nair (1989) could be classified into the following categories:

a. **Agri-Silviculture** (combination of agronoimic and forest tree crops/woody perennial for example, tanngya system, alley cropping, alternate row planting, random mix or scattered tree farm or parkland system, live fencing and border planting.

b. **Silvo-Pastoralism** (involves trees and livestock).

c. **Agro-Silvi-Pastoralism** (management of annual crops, woody perennial and livestock).

d. **Api-Silviculture** (beekeeping/honey production and tree / wood production).

e. **Aqua-Silviculture** (fish and wood production).

f. **Multipurpose Wood Lot** [establishment of family and village wood lots (that is Community forestry)].

In another development, PTPU (1988) grouped agroforestry systems into three categories, viz:

a. **Community Forestry** (Village woodlots, planting of trees along road sides or canals, planting of trees in yards or gardens of village houses).

b. **Silvipasture** (integrated wood production and livestock grazing).

c. **Agrisilviculture** (Crop rotation systems, shifting or swidden cultivation and Taungya system), intercropping systems (Border tree planting along the border of the farm, alternate row or alternate strip planting, alley cropping and random mix systems).

2.1.5 Types of Agroforestry Systems

In the course of discussion on the definition and origin of agroforestry, many forms of this system have been enumerated. However, due to limited space/time and to prevent digression from the subject matter, detailed elucidation will be given on agri-silvicultural systems (agrosilviculture) only.

a. Shifting Cultivation

The first one that readily comes to mind is the shifting cultivation**,** which is also called slash and burn agriculture or swidden cultivation and is regarded as the oldest known practice. Under this system, the forest is cut and cleared, few desired trees are left and agricultural crops are planted for 2 – 5 years after which the land is left to forest fallow for 8 – 10 years in order to recover its lost nutrients. This practice, according to Watters (1960) entails five stages, namely site selection, clearing, burning, cropping and fallowing. The clearing and subsequent burning of the debris release nutrients (Nye and Greenland, 1960, Sanchezs and Salinas, 1981), which help in crop production.

However, owing to pressure on land as a result of the rapidly increasing population, governmental restriction on forest reserves, water and catchment areas, changes in land tenure laws (in some cases leading to increased private land ownership), large scale migration and resettlement of people due to wars/calamities and introduction of cash crops, there has been drastic reduction in the length of the fallow period, which cannot bring about adequate vegetative cover (Lagemann, 1976; Nair and Fernades, 1984). Presently, the length of the fallow period has further been reduced to the extent that no productive farming is achieved owing to low nutrient status of the soil while in other places it is no longer practised due to pressure on land.

b. Taungya System

Secondly, the taungya system is another form of multiple landuse system, which Nwoboshi (1982) defined as “a plantation establishment technique in which forest crops are raised in combination with temporary cultivation of arable crops". Beets (1990) described 'taungya' system as one of the earliest recognized forms of agroforestry which entails the modification of 'farming practices of shifting cultivators to include the planting of tree seedlings with annual food crops'. The cultivation of arable crops (which are annuals) in between forest trees is discontinued as soon as trees close canopy.

However, the success of this practice depends on certain socio-economic conditions. These include land hunger (scarcity of arable land), poor or low standard of living of peasant farmers, nearby community of farmers must be industrious and under employed.Also, there must be fertile soil for agriculture in the forest reserve and no other alternative, availability of rapidly growing tree species, good administrative staff, timely execution of planting operations and supervision. As earlier mentioned, this system originated in Burma, therefore taungya is a Burmese word, 'taung' means hill and 'ya' connotes cultivation; meaning hill cultivation though it was initially meant for hilly areas in Burma to check the menace of shifting cultivation but it has been adopted in many parts of the world as a cheaper method of plantation establishment.

Enabor (1981) observed that more than 80% of the total area of plantations in Southern Nigeria were established by the taungya system. This system is no longer widely practised due to some factors, the major one being lack of incentives to the peasant farmers operating the systems (Kareem, 1988). This was the main reason why the system failed at Onigambari Forest Reserve, Ibadan. In taking care of the young trees, farmers need to be given some incentives or prizes in addition to the food crops realized. Other factors include alternative land for farming, other sources of employment and problem of transportation for farmers.

c. Farm Forestry

Farm forestry is also a form of agroforestry, which Adebagbo (1997) defined as:

> Planting of trees on farmlands in scattered form at no specific spacing for purposes of crop protection, soil improvement, water catchment protection, fuelwood, poles and fodder production.

Closely related to this is the tree – farm system, which was advocated by Adeyoju's committee in 1973 when the Federal Government was looking for solution to the perennial drought in the extreme northern parts of the country (Kano, Borno, Katsina, and Sokoto States). The system involves the supply of healthy/vigorous tree seedlings to farmers to plant around their homes and on their farms.

d. Alley Cropping

Alley cropping is perhaps the most widely practised form of modern agroforestry system. It could be defined as a system whereby agronomic crops are planted in the intervening spaces or areas or alleys between successive rows of trees. It is also called hedge rows inter-cropping (Lulandala and Hall, 1991). It was first called 'alley cropping' at the International Institute for Tropical Agriculture in the 1970s (Kang *et al.,* 1981). The trees are multipurpose ones, which are given various forms of management practices such as trimming, pruning or pollarding to produce green manure, fodder or fuelwood depending on the level; age and time of pruning.

Similarly, CTA (2003) defined alley cropping as “a system in which strips (or alleys) of annual crops are grown between rows of trees or shrubs”. Lining up the woody plants in hedges should ensure that there is little interference with cultivation of the field. Crops derive a lot of benefits from the woody perennials in such environment. Such beneficial effects include reduction of erosion by wind or water and easy maintenance of soil fertility through regular supply of mulch and green manure arising from pruning or pollarding of the woody perennials (trees/shrubs). Also, large amount of fodder is realized from the woody perennials and the manure (from livestock) is returned to the field (CTA, 2003). The species employed in alley cropping system include *Leucaena leucocephala, Cajanus cajan, Sesbania spp. Gliricidia sepium, Alibizia spp., Calliandra calothrysus, Acacia auriculiformis, Senna siamea* and *Acacia albidia (Fadherbia albida).*

CTA (2003) also stressed that tree species chosen for alley cropping should be characterized with fast growth, light open crown which can allow sunlight to pass through. They should have root system which extends downwards rather than sideward, nitrogen fixing species (legumes or non-legumes), a good response to pruning/pollarding, quick decomposing litter to release nutrients or litter that decomposes slowly to provide persistent mulch and good adaptation to site (whether saline, acid soil, flooding, wind and pest tolerant).

The spatial arrangement of the trees is always predicated on management objectives. For instance, if the object is to increase the volume of wood produced, trees and agricultural crops are combined in a row and alley arrangement in such a way that the trees are planted in widely spaced rows and the agronomic crops in between the rows of the trees, that is, in the alleys (Wilson and Kang, 1981; CTA, 2003).

This is an alternative to shifting cultivation or bush fallow system. It focuses attention on the growing of annuals (mainly food crops) in the alleys or rows formed by hedgerows of trees or shrubs (that is, the space between hedge rows of the woody perennials). The trees/shrubs which could be leguminous or non-leguminous are planted to ensure faster restoration of soil fertility so as to enhance productivity of the food crops. The hedgerows or trees are pruned or pollarded during the cropping season (except species like *Acacia albida* which has a reversed phenology: it sheds all its leaves in the rainy season and retains its foliage during the dry season) to prevent shading, reduce competition with food crops and to serve as green manure or mulch for food crops. The procedure involves:

- Selection of a suitable land
- Survey/demarcation of the land
- Clearing and land preparation. (mechanical method of land clearing should be avoided, ploughing/harrowing/ridging could be mechanically done after manual clearing or burning of debris)
- Layout of plots.
- Planting of tree crops (woody perennials) should be 2-3 m within rows and 0.5 – 2 m if the woody perennials are to be maintained at shrubby level as hedge rows and 4-10 m between rows (in order to allow easy movement of tractors and to ensure that there is enough space for annual crops per alley).

Planting should be done when rain stabilizes, soil should be firmed round the plant (seedling) and a trough (a concave lower depression) should be ensured round the plant so as to pave way for proper percolation of water (Kareem *et al.,* 2001; Kareem and Obiaga, 2003).

- Regular weeding should be ensured
- Annual crops should be carefully harvested to avoid damaging the tree crops at their early stages (1- 3 yrs.)
- Pruning or pollarding could be done to prevent excessive shading of crops that are closer to the rows of trees when the trees reach maturity period (for the desired object of management), they should be meticulously harvested for such by- product. If the trees are to provide fuel wood, they should be coppiced during the dry season when annual crops must have been harvested.
- Planting of annual crops commences again when rain stabilizes in the alleys after land preparation. Beating - up operation (replacement of dead, dying and stunted tree seedlings) should be done when tree crops are between 1 and 3 years of age (Kareem *et al.,* 2002). When they are well established for example, 5 years and above depending on the species, animals could be allowed to graze in the agroforestry farm after harvesting the annual crops (Kareem *et al.,* 2002) at this stage (age) the trees cannot be trampled upon by livestock.

e. Border Tree Planting

Border Tree Planting is another form of agri-silvicultural practice and it entails planting of trees at the borders of the farm as live fences, windbreaks, fodder and fuel wood producers. In case of small farms, rows or lines of trees may be concentrated on the border from the direction of the wind. Adaptable/suitable fast growing and drought resistant trees should be selected. The species that are characterized with large canopy and surface lateral roots must be avoided to prevent undue interference with agronomic crops.

f. Alternate – Row Planting

Alternate – Row Planting is also known as alternate strip or alternate hedge row planting. This involves planting of the trees in more than one row or strip between the strips/rows of the annual crops. Fruit and leguminous (nitrogen fixing) trees are suitable for these systems so as to ensure reasonable improvement of the soil nutrient status. Also, fodder producers could be planted. Spacing of 2 x 2 m or 3 x 3 m within and between rows/strips of trees could be used. Trees could be planted along the contour where slope is more than 10-15 % inclination to prevent surface run-off (erosion) during the rainy season. On soil levels below 10-15% inclination tree rows should be perpendicular to wind direction. The establishment procedure is the same as alley cropping (PTPU, 1988).

g. Random Mix or Scattered Tree Farm System

Random Mix (or Scattered Tree Farm System) is the system of planting the tree crops randomly in the farm without any special or specific design. The woody perennials are scattered in the farm. Tree species employed include fruit trees, nitrogen fixing trees and fodder-producing trees (PTPU, 1988). Tree species that are allelopathic or harmful to annual crops e.g. *Eucalyptus camaldulensis* should not be planted. Trees should be about 10-15 m from one another in the farm to prevent unnecessary shading of annual crops. They (trees) could be pollarded or pruned if they have large canopies. Also, trees characterized with large surface lateral roots should be avoided (Kareem *et al.,* 2005a). This system is also called Dispersed Trees in Annual Crp Field (Beets,1990). This involves the use of widely spaced trees like Acacia *albida, Prosopis cinerania, Markhamia platycalyx* and *Gravillia robusta* (Von Carlowitz, 1984).

h. Home Gardens

Home Gardens as opined by Beets (1990) are examples of traditional agrofroestry systems which entail the cultivation of forest tree species and agronomic crops simultaneously. Under this system, the home gardens comprise different combination of trees, shrubs, food crops, medicinal plants and livestock. Home gardens are established around homestead and managed for the production of food, wood and other forms of subsistence goods.Countries such as Indonesia and Srilanka have typical examples of home gardens.

i. Shade Tree Based System

Shade Tree Based System is another form of agroforestry practised especially in Central America and Southeast Asia (Beets, 1990). Tree species such as *Erythrina poeppigiana, Cordia alliodora* and *Leucacna leucocephala* are planted in association with coffee and cocoa. The nitrogen fixing trees add nutrients to the soil through the fixation of atmospheric nitrogen. Organic matter is added to the soil (from the trees) and the trees provide shade for higher yields of the cash crops on sustainable basis.

j. The Fodder Tree Based System

The Fodder Tree Based System which is a different form of agroforestry practice that entails the management of trees and shrubs together with improved pastures or natural range lands. This system paves way for a more sustainable and productive livestock production (Beets, 1990). It was reported by Sigh *et al*.(1984) that more than 80% of the fodder requirements of farm livestock in Nepal were sourced from surrounding trees under this system.

2.1.6 Multipurpose Tree Species (MPTS)

Von Carlowitz (1984) described multipurpose trees species (MPTS) as those, which are grown, or kept and managed, for more than one major purpose (product or service) economically and/or ecologically motivated in an agroforestry or other multipurpose landuse system.

Also, Huxley (1984) defined MPTS as “those, which provide more than one significant contribution to the production and/or service functions of the landuse systems they occupy”. Von Carlowitz (1984) gave main functions performed by MPTS (Table 1).

Table 1: Functions of multipurpose tree species (mpts)

Part of the Tree	**Uses**
Wood	Fuelwood (including charcoal), timber (sawn wood), poles (domestic timber), other (e.g. carvings)
Fodder	Browse
	Cut – and – carry (including leaves, seeds, shoots)
Food	Fruits, nuts, oil, beverages other edible products
Other products	Oils, gums, waxes, dyes, tannin, fibres, thatching latex
	Medicinal uses
Services	shade (from sun)
	shelter (from wind)
	soil conservation (including reclamation)
	soil improvement
	fencing (barrier function)
	moisture conservation

Source: Von Carlowitz (1984)

Generally, MPTS must possess at least two of the characteristics listed below:

- availability of seed (germ plasm) of the species in sufficient quantity
- easy propagation (must be easy to establish)
- rapidity in growth (must be vigorous)
- deep (tap) root system for proper anchorage
- heavy foliage
- rapid regeneration after pruning or pollarding
- good coppicing ability after felling
- easy eradication whenever the need arises.
- must have useful by-products
- must be appropriate to local soils
- must not be allelopathic
- profuse litter deposition
- nitrogen fixing ability
- good juvenile phase exhibitions (early growth characteristics).

It is pertinent to stress here that no single MPTS possesses all these features, once a tree has two of the above properties, it can be integrated into agroforestry system.

2.1.7 Effects of Trees on Soil Properties and Crop Yield

Young (1985) opined that in order to understand the effects of trees on soils, it is imperative to know the *modus operandi* of the soil biological processes and their influence on soil fertility. Secondly, proper identification of practical management methods by which the soil biological processes could be manipulated to improve soil nutrient status should be understood.It is pertinent to mention some scientific reasons why trees are expected to improve soil in both tropical and temperate regions of the world. Firstly, there are several scientific evidences that soils that develop under natural woodland or forest have a store of fertility in the nutrients bound up in organic molecules. This is as a result of plant succession coupled with some biochemcial processes and the fact that the soil is resistant to soil erosion.

Also, soils regain part of their lost nutrients under shifting cultivation during the fallow periods. The substantial nitrogen fixing power of certain leguminous trees and even non-leguminous species (for example, *Casuarina equisetifolia)* is a scientifically established fact. In the same vein, the detrimental effects of forest clearance on soils with regard to decrease in nutrient status and subsequent erosion problems are also evidences of vital roles played by trees in soil conservation (Young, 1985; Nye, 1961; Alasiri, 1997).

The next step is to examine the land management practice in which trees are employed in a bid to improve the productivity of soils. The practical systems of land use and management as given by Young (1985) include:

- **Protective forestry**: which involves planting of trees to protect partially, degraded and other environmentally sensitive lands. This mainly deals with restocking or enriching the natural forest cover with appropriate tree species.
- Reclamation forestry:entails planting of trees on large scale to reclaim areas that are seriously degraded.

- **Production forestry** : a system of planting trees for the main purpose of producing timber, fuel wood and poles, though soil fertility improvement may be secondary.
- **Agroforestry** : a form of multiple land use system whereby trees, agronomic crops or pastures are grown together on the same land management unit in which there are economic and ecological interactions between the tree and non-tree components.
- **Watershed management** :entails planting of the right species of trees to protect water catchment areas from drying.

However, it is imperative to mention some possible adverse effects of trees on soils so as not to view it from one perspective alone. These effects include nutrient loss due to whole tree harvesting, moisture stress/loss, which is more or less peculiar to some *Eucalyptus* species for example, *Eucalyptus camaldulensis* owing to their desiccating effect on the soil, acidification (for example, pine litter) and allelopathic effects of certain forest tree species.

The beneficial effects of trees on soil can be discussed under some biological processes involving the trees, atmosphere and soil. Young (1985) grouped the processes into four categories, viz:-

(a) The processes which augment additions to the soil: these include photosynthesis which involves fixation of atmospheric carbon and its subsequent transfer to soil, nitrogen fixation (both symbiotic and non-symbiotic), nutrient retrieval which entails absorption of nutrients released from rock weathering in the deeper layers of soil and their subsequent release by litter decay and decomposition.

(b) Processes that lead to reduction of losses from the soil which comprise protection of soil from both water/wind erosion, trapping and recycling nutrients which could have been lost by leaching (these processes ensure a closed plant–soil system).

(c) Processes that lead to soil fertility improvement through soil conditions such as higher water holding capacity coupled with good permeability/drainage and greater resistance to erosion.

(d) Processes that affect plant residues, quality and timing of their release to the soil which entail supply of litter from different tree/plant species in the forest and provision of a steadily decaying nutrient store in form of soil organic matter. Timing of nutrient release is also possible under agroforestry system by deciding when to trim or prune hedgerows for supply of green manure in alley cropping system. Also, trees bring about a sort of microclimate in the forest ecosystem especially when they are in reasonable density thereby paving way for faster rate of mineralizaiton due to adequate soil moisture and presence of certain soil microorganisms (Wilkinson and Aina, 1976; Nair and Rao, 1977; Nair and Khanna, 1978; Lal and Greenland, 1979; Wenner, 1980; Khanna and Ulrich, 1983).

2.1.8 Tree – Crop Interface

This refers to the interactions between the tree crop and the agronomic crop in an agroforestry system. Huxley (1984) observed a complex set of interactions relating to radiation exchange, the water balance, nutrient budgets and cycling and shelter/microclimatic modification. He also pointed out that in any agroforestry system, there are above and below ground interfaces and some investigations have to be made before establishing an alley cropping farm. Such investigations should reveal the following facts: the right species of tree to a particular annual crop in a particular region, how close an agronomic crop should be to the hedge row of NFTS, the optimum design (spacing) of MPTS browsed or lopped at the end of the winter if certain annual crops are to be grown as well, when should a MPTS be harvested if grown for fuelwood when certain annual crop is grown in the alleys or when a MPTS is planted on different soils in various rainfall regimes and what are the distances over which it will compete with interplanted agricultural crops?

It is pertinent to mention here that a sound knowledge on tree/crop interface is of immense importance since it will pave way for preliminary information acquisition about the following factors:

- Plant characteristics: in terms of their morphology, development, stress/shelter effects and others (yield/biomass, plant condition, pest/diseases and management records).
- Environmental changes: in terms of short term changes with regard to wind, humidity, rainfall, top soil water, soil temperature, light distributing total intercepted light. Also the long-term changes include soil fertility changes, soil loss/compaction and soil fauna.

The above information if acquired, contributes in no small measure to choosing the right MPTS and annuals to be incorporated into agroforestry system. Even if negative tree/crop interface is observed (for example, competitiveness), it could be rectified once the problems resulting to such interface are identified. Such unwanted situations could be restored to normalcy by modifying the time of the planting of agricultural crops, choosing the right cultivars with more appropriate physiological responses, limiting the density of woody component, harvesting the woody component at more appropriate time or pruning of the hedgerows (Willey and Rao, 1980; Huxley, 1983; Huxley, 1984).

2.2 SPECIFIC CASE STUDIES

2.2.1 Nodulation/ N_2 Fixation in Nitrogen Fixing Trees (Nft) with Emphasis on *Albizia lebbeck*

Generally, tree legumes may nodulate in two ways depending on the nature or type of *Rhizobium* strain present in such a tree in the tropics (Saginga and Mulongoy, 1995). The two strains of *Rhizobia* are the fast growing ones belonging to genus *Rhizobium* and the slow growing ones named *Bradyrhizobium* (Elkan, 1984). The NFTS are broadly categorized into three:

(i) Those that nodulate with *Rhizobium* strains which are considered specific and do form nodules with a narrower range of root nodule – bacteria than the remaining two groups. Tree species in this group require inoculation with the compatible fast growing strains of *Rhizobium* which are generally less ubiquitous than the *Bradyrhizobium.* Examples include *Leucaena leucocephala, Acacia nilotica* and *Acacia senegal,*

(ii) Those that nodulate with Rhizobium and *Brandyrhizobium* include *Acacia farnesiana , Acacia seyal, Calliandra calothyrsus* and *Gliricidia sepium,*

(iii)Those which nodulate with *Bradyrhizobium* are *Faidherbia albida, Acacia holocericea; Acacia mearnsil, Tephrosia vogelii* and *Albizia lebbeck* (Dreyfus and Dommergues, 1981; Dommergues, 1987; Sanginga *et al.,* 1989).

Very importantly, it is pertinent to mention here that available research findings indicated that *Albizia lebbeck* has an edge over *Leucaena leucocephala* since the latter can only fix substantial amount of nitrogen when it can is incoculated with compatible *Rhizobium* strain as opposed to the former, which effectively nodulate without inoculation. This is not unconnected with the fact that *Albizia lebbeck* undergoes nodulation with *Bradyrhizobium,* which is present everywhere (soils). Dommergues (1987) indicated that most tropical soils harbour the ubiquitous *Bradyrhizobium* strains required for nodulation in certain N_2 fixing trees such as *Faidherbia albiza, Albizia lebbeck, Acacia mearnsil, Acacia holocerica* and *Tephrosia vogelii.* With regard to N_2 fixation and nodulation of *A. lebbeck*, Porkhriya*l et al.* (1996) observed that *A. lebbeck* recorded maximum N_2 fixation during the rainy season in terms of maximum nodule number per plant while lowest N_2 fixing activity was in the winter (coldest season).

In another development, *A. lebbeck* was observed to be superior to *Leucaena* and *Gliricidia* in terms of dependence on N_2 sources, time course of biological N_2 fixation and N absorption. It was discovered that *A lebbeck* had profound increase in the number and dry weight of nodules with age. The highest incremental rate was between sowing and 8 months. The percentage of N_2 fixed was 43.6 – 83.6 which was equivalent to 533 – 6419 mg N for 4 – 16 months (Kadiata *et al.,* 1996). The values of *Leucaena* and *Gliricidia* in respect of percentage range of N_2 fixed were 17.9 – 74 and 27.7 – 71.9 respectively while their mg eq values were 191 – 3385 and 321 - 2863 respectively for 4 – 16 months. Thus, it is obvious from the experiment that *A. lebbeck* was actually superior to the remaining (and commonly) used legumes. Kadiata and his colleagues also ascertained that these three N_2 fixing woody legumes (*A lebbeck, Leucaena* and *Gliricidia*) could be relied upon as sustainable N – supply sources to soil crop systems.

Pertaining to the response of *A. lebbeck* to two contrasting soils in terms of growth, nodulation and N_2 – fixation potential, Kadiata *et al.* (1996) observed that *A lebbeck* had the most outstanding performance. Ten (10) tree species tried were in the experiment (on an acid Ultisol and a non-acid Alfisol from sites in Nigeria) for 6 months in terms of plant height and girth, nodule number, nitrogen yield and N_2 fixing potential. It is necessary to point out here that *Leucaena* and *Gliricidia* were among the 10 species tried, which were the most common hedgerow species.

In a related development, Dommergues and Ahmad (1995) investigated the level of N_2 fixation by N_2 fixing trees (NFTs) in relation to soil nitrogen. They discovered that the nitrogen fixing potential (NFP), which is the amount of fixed N_2 in a constraint free – environment, varied with genotype among the three NFTS tried (*A. lebbeck, Gliricidia* and *Leucaena)*. It was also stressed that N_2 fixing leguminous trees such as *A lebbeck* or actinorhizal trees such as *Casuarina* *equisetifolia* are characterized with higher NFP ranging from 30 – 50 g N_2 per tree through the actual amount of nitrogen fixed (ANF).

ANF is the amount of N_2 fixed in the field and is often lower than NFP due to various constraints.Prominent among the constraints are drought, salinity, nutrient deficiencies, temperature, excess of available N, pathogenic nematodes, pruning/trimming regimes (Dommergues and Ahmad, 1995; Mafuka, 1984; Sanginga and Mulongoy, 1995). Findings by these researchers indicated that N_2 fixation is diversely affected by low phosphorus (P) and high acidity and that pruning or trimming brings about nodule senescence and decay within three weeks (from time of pruning), though N_2 fixation continues only after the formation of new nodules.

It was also pointed out that as more litter is mineralized the amount of nitrogen in the soil increases with time which leads to cessation of N_2 fixation in aging plantations. It is when mineralization process is slowed down or inhibited that N_2 fixation can continue. With regard to the amount of N_2 fixed in leguminous trees, Dommergues (1987) indicated that *A. lebbeck* belonged to high N_2 fixing tree species with 100 – 300 kg N $ha^{-1}yr^{-1}$ or more.

2.2.2 Effects of Green Manure on Soil Properties and Crop Yield

Green manure in this medium refers to the fresh leaves of MPTS (for example, *A. lebbeck)* that are incorporated into the soil. It also comprises the tender or succulent stems, flowers and twigs while on the other hand, mulch, is a layer of material on the surface of the soil used to keep the soil moist or to serve a wide variety of other purposes. These include retardation of weed growth, protection of plants' roots and stems' collar region from extreme temperature. Mulch helps in reducing surface run-off, preventing soil pudding by breaking the impact of raindrops, keeping flowers, fruits and vegetables from being scattered by rain storms and improving soil texture and fertility as they decay and are incorporated into the soil especially during farm operations such as land preparation (Encyclopedia Americana, 1997).

Organic matter plays significant roles in improving soil nutrient status. This fact has been recognized even by peasant farmers right from time immemorial. This is the reason for leaving farmlands to undergo certain period of fallow before returning to such lands. This practice helps in bringing about a sustained productivity of agricultural lands (FAO, 1980; Lal and Kang, 1982) due to the fact that plant nutrients are released from organic matter (after its decomposition). Subsequently the level of effective cation exchange capacity (ECEC) is increased coupled with improved soil structure (Kang, 1993). Green manure could bring about profound efficiency of P (Hue, 1992) and also increases plants' P and K concentrations thereby improving corn yield (Hunter *et al.*,1995). Besides improving the physical, chemical and biological properties of the soil, Young (1985) observed that organic matter ensures the regulation of the flow of soil nutrients, which decreases nutrient loss due to leaching.

Before green manure can be of benefit to crops, it must be decomposed so as to pave way for nutrient release. Sanginga and Mulongoy (1995) observed that there are some environmental factors that determine the decomposition of prunings or trimmings.These include temperature, moisture, soil texture and mineralogy and such management practices like time of pruning, pruning quality and mode of application of the pruning as green manure. These researchers also noted that decomposition rate is of direct proportionality to C:N and lignin :N ratios, that is, the lower these ratios are in leaves the faster the rate of decomposition. Leaves of Gliricidia *sepium* and *Leucaena leucocephala* with low ratio of C:N and lignin : N have faster decomposition rate.

Also, the age of pruning influences the rate of decomposition, first pruning decomposes very slowly with half-life of 37 days as opposed to second pruning with half-life of 10 days (the second pruning being a younger and more tender material). The rate of decomposition of pruning or leaves of non-nitrogen fixing trees such as *Senna siamea* is slower with half-life of 75 days (Vander Meersch *et al.,* 1992), which is due to the fact that leaves of *Leucaena* are N – richer than that of *Senna siamea*. Similarly, the rate of N – Mineralization in an Alfisol treated with 16.7 g or 33.3 g of *Leucaena* leaves (C:N = 12) is faster than those of non-nitrogen fixing trees such as *Dectyladenia barteri* and *Senna siamea.* However, there is no available information with regard to the decomposition rate of *A. lebbeck* leaves/half-life of the foliage when used as green manures.

2.3 RATTLE TREE (*ALBIZIA LEBBECK* L. BENTH)

2.3.1 Origin and Botany of Rattle Tree

The rattle tree (*Albizia lebbeck* Benth*)* originated from India. It is also native to Bangladesh, Burma, Pakistan and the Andaman Islands (Prisen, 1986) and has naturalized in many tropical and sub-tropical regions of the world such as North Africa, the West Indies, South America and South East Aisa, (Streets, 1962). Large plantations of this species have been established in Nepal, central and south India (Plate 1).

This species is synonymous with *Mimosa lebbeck L.* and *Mimosa sirissa Robx.* The generic name is sometimes spelled *Albizzia* and the species' name is also spelled *labbeck* or *lebbek*. It belongs to the family *leguminosae* and sub-family *mimosoideae/mimosaceae* and has many common names such as *Lebbeck, Karana,* East Inidan Walnutt; Siris tree, Kokko, fry wood, woman's tongue, *Acacia amarilla* and Rattle tree. The common names such as 'woman's tongue' and 'rattle tree' are derived from the noise made by the dry pods of the tree when they are being shaken in the wind. The foliage is pale green when young and grey-green at maturity and consists of 2 – 4 pairs of pinnae, which are 50 –100 mm long with 3 – 11 pairs of leaflets up to 50 mm long.

Flowers are creamed coloured and hemispheric pompon (like decorative ball of tufted wool or silk). The flowers have whitish heads with striking green stamens. Its long young straw coloured pods nestle in the breeze. The seeds are produced from papery pods which are about 20 cm long and 3 cm wide. The bole (trunk) may reach about 30 m in height and 1 m in diameter in the rainforests.

Plate 1: Rattle tree *(Albizia lebbeck)* with its flower and pods (both fresh and dry pods)

It maintains straight bole in dense forests but has a spreading and low branching pattern in the open. It is highly deciduous hence it becomes leafless for part of the year (NFTA, 1988).

2.3.2 Environmental Requirements of the Rattle Tree

Prisen (1986) observed that *A. lebbeck* is adapted to a wide range of soil types (acid, alkaline and saline conditions), though it thrives well in well-drained loam and near seashore; it tolerates light frost and drought after the first year of establishment. It grows well in tropical and sub-tropical grasslands with annual rainfall of 500 – 2,000 mm at altitude of 1,600 m above sea level in Indian.

2.3.3 Plant Establishment

This species is very prolific in terms of seed production It is readily propagated by seeds even by direct sowing and seeds remain viable for four or five years at ambient (atmospheric) temperature. It could also be propagated by stem or root cutting with vigorous growth rate (NFTA, 1988, Kareem *et al.*, 2005b) and seeds germinate without scarification but germination could be improved when seeds are immersed in boiling water for 3 seconds and allowed to cool and dry (NFTA, 1988). Also when its seeds are stirred in hot water at 50^0C for 15 minutes, allowed to cool (after removal from the hot water) and planted in a growth medium of soil/potting mixture of river sand, top soil and fine cowdung manure in ratio 2:1:1, 100 percent germination is achieved . Seedlings attain a plant height of 10 cm at eight weeks is achieved (Kareem *et al.,* 2001). Seeds could be raised in nursery beds for one year or more and then transplanted as stumps with 25 cm root length and 10 cm shoot length (Anon, 1970). Also seeds could be immersed in boiling water and allowed to cool and then soaked in cold water for 24 hrs, this ensures 50 – 90 % germination (NFTA, 1988).

2.3.4 Foliage Yield of the Rattle Tree

This species is moderately fast growing. It could be single or multistemmed depending on the environment/growth medium. It coppices easily like *Leucaena leucocephala.* It yields about 1700 kg/ha/hr when matured trees are pruned once every three years while the hedgerows at 3 m spacing (within hedge rows) produces 25 kg/ha/yr in shallow soil of sub-tropical 750 mm rainfall area in Australia when compared with *Leucaena* in the same region with production estimate of 1500 kg/ha/ (NFTA, 1988). Parrotta (1988) also observed in Puerto Rico that within the first 24 months of plantings at the rate of 2,500, 10,000 and 40,000 trees/ha, above ground biomass increased per unit area yielding 12.6, 14.5 and 17.4 ton/ha respectively. There was also an increase in above ground biomass in foliage with increased density from 13% to 23% in the 25,000 and 40,000 tree / ha stands respectively at 36 months.

2.3.5 Uses of the Rattle Tree

(a) In alley cropping (agroforestry) – rattle tree performs well in agroforestry system and competes reasonably with *Leucaena* and *Gliricidia* especially in areas of nodulation and nitrogen fixation and supply of green manure (Kadiata *et al.,* 1996; NFTA, 1988, Parrotta, (1988).

(b) Fuelwood – the wood from this species is very dense with specific gravity of 0.55 – 0.6 thereby serving as good fuelwood. It has a calorific value (moisture free heartwood) of 5,200 kcal/kg (NFTA, 1988). It has also been reported that its wood provides calorific value of 22 kilojoules/kg (Anon, 1970).

(c) Timber and pulpwood – timber from this species has been found suitable for construction, furniture and veneer. Although it produces short fibre which is good for paper manufacture when mixed with long fibred pulp (Anon, 1970).

(d) As ornamental tree – it is widely used as avenue tree in India, often planted for shade in gardens and along roadsides and in general beautification of premises.

(e) In apiculture – beekeepers value this tree very well because of the light-coloured honey, which its nectar provides. It produces whitish flower with striking green stamens which are attractive to bees.

(f) Fodder – NFTA (1988) reported that most livestock browse on the foliage of this species especially its twigs and that the leaves contain about 20% crude protein, 13% and 10% for litter and twigs respectively and is devoid of toxic compounds, unlike *Leucaena* which is known for *mimosine* that is toxic to livestock. The *in viro* digestibility is 45% for mature leaf and 70% for young leaf and about 40% for twigs.

Table 2: Proximate analysis of *Albizia lebbeck* leaves and flowers

Parameter	Leaves (%)	Flowers (%)
Crude protein	19.37	22.75
Crude fat	3.82	2.86
Nitrogen free extract	5.70	8.30
Crude fibre	23.71	6.73
Ash	3.51	3.68
Moisture	10.35	13.50

Source: Kareem *et al. (*2001)

The proximate analysis for leaves and flowers as reported by Kareem *et al.* (2001) is shown in Table 2 above.

The mineral contents in meq/l for the leaves and flowers are K (053, 0.500, Ca (0.04, 0.20), Cu (1.58, 1.89), Zn (0.005, 0.004), inorganic P (0.52, 0.58), Mg (0.0004, 0.0009) and Na (0.08, 0.07) respectively (Kareem *et al.*, 2001).

(g) For soap and tanning – the bark of rattle tree contains saponins and tannins and according to Sommen (1981) these could be used for soap making and in tanning respectively.

(h) For poles – the young trees (saplings) of this species are used as poles for live fencing owing to the fact that stems from saplings readily establish as parent trees.

2.3.6 Pests and Diseases

However, *A. lebbeck* seedlings could be attacked by psyllid probably of genus heteropsylla, which Hedge and Relwani (1988) had earlier observed in India. The infestation was however controlled with Nuvacron (0.05%) with two sprayings at one week interval. Also, termites could attack the seedlings and certain fungal diseases could damage the leaves while borers may kill off few of its branches.

2.4 IRISH POTATO *(SOLANUM TUBEROSUM)*

2.4.1 Origin, Distribution and Varieties

Irish potato (*Solanum tuberosum*) is said to have originated from the Altiplano around the Lake Titicaca at an altitude of about 3000 metres in the Bolivian Andes. Its main center of species diversity is in the Andes between 10^0N and 20^0S which is above 200 m in attitude) and this place (Andes) is an important source of germplasm for breeding new cultivars till now (Burton, 1966; Kay,1987). Also, Mills (2001) reported that Irish potato originated in the Andian regions of Peru and Bolivia and the Incas had utilized it for about 2000 years prior to the advent of Spanish explorers.

Evidences from carbon 14 dating of its (potato) starch grains discovered in archaeological excavations indicated that potatoes had been in use at least 8000 years ago. The name “potato” was said or believed to have been derived from the Inca name “papa” while the association with Ireland was responsible for the name “Irish potato”. This crop was reported to have been introduced into Spain from South America about 1570, then from Spain it was taken into the neighboring European countries and before 100 years the cultivation was fairly extensive in many regions of Europe.

The distribution of the crop (Irish potato) beyond Europe as observed by Mills (2001) took place with its introduction into India (1610), China (1700) and Japan (1766). It was the Scotch Irish immigrants that introduced the crop into North America in the early 1700s. Irish potato is the second most important staple food crop in Kenya, maize being the most important (Maina and Chui, 1999) and is mainly grown in Kenyan highlands.

In another development, Irish potato is said to have originated from South America (Ifenkwe, 1981) and in the later part of 19^{th} century and early 20^{th} century it was introduced into Nigeria by the Europeans notably tin miners in Jos Plateau and the Germans in Cameroon (Stanton, 1960; Ifenkwe, 1981). It did not originate from Ireland (Britain) but it is so called because its planting stock was procured from Ireland by Scotch Irish immigrants and this crop is also very popular in Ireland, hence the name Irish Potato (Yayock *et al.*, 1988).

The total land area under Irish Potato (henceforth to be referred to as potato) cultivation in Nigeria was 20,000 ha in 1986, which was a considerable increase from its 1973 value of 10,000 ha. An increase of 5 to 10 tones per hectare average tuber yield on farmers' field was recorded and production expanded from Jos Plateau to Mambilla and Biu Plateau. Potato production also occurs in Kano, Sokoto, Taraba, Adamawa and Borno States of Nigeria in dry season only. Promising varieties include bertita, nicola, diamatat, kondor, Rc 767 – 2, desiree, delcora, arka and Rc 776 – 3 (Okonkow *et al.*, 1995).

2.4.2 Botany

Potato is botanically called *Solanum tuberosum* L and it belongs to the family Solanaceae (Huaman, 1986; Kay, 1987). Its common names are potato, Irish potato and white potato. However, it has other names such as Aardappel (Netherlands), Alu (India), Batata (Portugal) Jaga-imo (Japan), Kartoffel (Germany), papas (Latin America), Poatatos (spain), Romme de terre (France), Viazi (East Africa), Watalu (Pakistan), Yangshu (China) and Yeomilan (Cyprus). Potato is a herb that is characterized with free branching pattern, dicotyledonous and perennial in nature. Its height is often between 30 and 100 cm (Kay, 1987).

The leaves are alternate, pinnately compound and spirally arranged on the stem with mid-rib and many leaflets. With the aid of petiole the compound leaf is attached to the stem or the leaflets do have direct attachment on the rachis or short stalks (petioles). Small leaflets (named interjected leaflets) are found between the pairs of leaflets and there is presence of auxiliary bud between the petiole and the stem.

The stem is composed of stolon and tubers, multiple stems usually arise from tubers while single stem arises from true potato seeds (TPS). Potato stems are green in colour with angular or circular shape in cross section. Also purple or red-brown colour could be seen, buds could form lateral stem stolons, inflorescence and aerial tubers in the axil when covered with soil. The tubers are storage organs and modified stems, which develop from stolon or leaf axil, possess buds ('eyes') from where sprouts emerge; buds are spirally arranged and concentrated towards the apical ends. There are variations in tuber shape and skin colour. At harvest, the skin is thin and delicate particularly in tubers that are immature and peels off when roughly handled.

The roots which are adventitious, arise from the base of sprouts. Delicate roots need loose soil to grow properly up to 15 – 35 cm depth while roots from TPS may penetrate deeper. There is the possibility of the stolon becoming roots and even developing into full plant when uncovered by soil. The stolons are lateral stems that grow longer underground, under long day length and low temperatures than under short day length and high temperatures. In the tropics and when exposed to light, stolons could also develop into plants. Potato is propagated by true potato seed, potato tuber, tuber cuttings, tissue culture, sprout cuttings, stem cutting and leaf bud cuttings (Huaman, 1986; Okonkwo *et al.*, 1995).

2.4.3 Soil Requirements and Cultivation Conditions

Potato requires well-drained sandy loam or clay loam with a very high level of plant nutrients, tolerates a relatively soft soil to pave way for easy stolon development. An adequate supply of water is very essential during dry season production. It responds positively to organic and inorganic fertilizers in the Jos Plateau and adequate N and P supply is necessary for good crop yield. Low level of soil organic matter due to annual bush burning and over-grazing bring about low level of soil nitrogen which eventually results to lower productivity. Therefore N.P.K. with ratio 5:5:2 is good for sole potato in the Jos Plateau, (Okonkwo *et al.,* 1995).

The pH ranges between 4.8 and 6 (while the optimum value is 5-5.6). There is the possibility of potatoes being affected by scab if the pH is above 6.0. Kay (1987) observed that in areas where operations are mechanized, a level land is ideal. Plateaux are often cultivated in tropical highlands while valleys are more suitable (than extensive plains) in the tropical lowlands. An evenly distributed rainfall of 50 – 75 cm throughout the growing period is generally considered essential. This amounts to approximate value of 2.5 – 3.0 cm per week though as much as 15 cm per month could be tolerated in the tropics.

Differences in temperatures do affect the growth and yield of potatoes. Mills (2001) observed that they (potatoes) need frost free days of 90 – 120 days and formation of tubers (tuberization) takes place at lower temperatures. He also observed that the optimal temperature for tuberization is 12.8^0C. At temperature above 21.1^{0}C tuberization process decreases and can stop at 29.4^{0}C in certain cultivars. Knobbiness (formation of round shaped swellings) and secondary growth in potato tubers have also been reported by Mills (2001) and that the temperature at which maximum yield could be achieved is 15.6^0 – 18.3^{0}C. He observed that at low or cooler temperatures (for example,. 15.6^0 – 18.3^0 F) respiration rate is lower than the rate of photosynthesis, which results in more accumulation of carbohydrates.

2.4.4 Planting Procedure

The choice of cultivars to plant is a critical factor, Kay (1987) observed that a good number of cultivars are suitable for planting in temperate climates as opposed to the tropics where early maturing cultivars are unsuitable owing to the fact that they (early maturing varieties) need long day – length.

In planting, the seed tuber which could be whole or cut is generally planted. The seed tubers should be very healthy, virus – free and preferably be those produced from aphid – vector free areas. Prior to planting of the tubers should be kept under ambient condition, which is 20 – 30^{0}C in the tropics for 30 – 45 days to break their dormancy which is usually at least 8 weeks (Kay, 1987). He (Kay) further reported that dormancy could be broken by treating the tubers with chemicals such as chlorohydrin, potassium or sodium thiocyanate or gibberellic acid. Pre-sprouted tubers often pave way for uniform germination and generally potato tubers begin sprouting at temperature above 50^0 C. The rate of sprouting increases with increasing temperatures; thus in order to accelerate the sprouting rate, temperature could be increased to approximately 60^0 C. It is also imperative to treat tubers with suitable fungicide prior to planting in order to prevent disease. The cut tubers for planting should not be stored for more than 30 days after they might have been cured at temperatures of 15 – 21^0 C and 85% relative humidity for 7 – 10 days (Kay, 1987).

Apart from tubers, true potato seed (TPS) and the F – 1 hybrid which has greater resistance to diseases and characterized with high yield could be planted. TPS are planted directly into the field or in trays or its seedlings could be raised in the nursery prior to planting into the field. Planting of TPS solves the problem of sourcing for virus-free tubers.

With regard to method of planting, potatoes could bemanually or mechanically planted. This is usually after ploughing of the field to 25 – 30 cm depth and subsequently harrowed to pave way for fine deep tilth. They could be planted in ridges (Kay, 1987) or on flat beds (Mohammed, 1984; Fasehun, 1989) for better performance. Potato could also be propagated by tissue culture to perpetuate disease-free seed stock. This could be stored *in viro* till when needed (Mills, 2001).

The required field spacing is 20 – 30 cm in rows and could be 75 – 120 cm apart especially in temperate regions. Wider spacing paves way for better yield in terms of number and size while close spacing results to decrease in proportion of tubers of marketable size. The seed rate per hectare depends on the nature of the potato planted, whether whole tuber, cut tuber or TPS, but usually the rate is 1.2 – 2.3 tons of whole tubers per hectare (Kay, 1987). Hoeing should be regularly done so as to control weeds; the exposed tubers should also be covered with soil to avoid greening of the tuber. According to Okonkwo *et al.* (1995) the maturity period varies from 3 – 3.5 months (for early maturing cultivars) and 4 – 6 months (for late maturing varieties).

2.4.5 Irrigation Practices

During dry season, farming of potato is often practised under irrigation. Mills (2001) stated that owing to the fact that potatoes are characterized with high water requirement, roughly 2.54 cm per week. For effective tuber development, the moisture content should be consistent and held at 60 – 70% field capacity. Abnormalities in the formation of tubers have been reported from fields where there is fluctuation in soil moisture owing to irregular irrigation during dry season farming (Mills, 2001). In order to minimize evaporation and enable the soil to be cool, mulching is recommended and should be applied immediately after planting.

2.4.6 Harvesting, Handling and Yield

Harvesting is done when potatoes are fully matured especially when the skins are set so as to avoid damage during lifting. Kay (1987) reported that harvesting is done 2 – 3 weeks after the foliage has died down naturally or been killed mechanically or chemically in the temperate climates. Harvesting could be done manually by means of hoes, diggers or spinners and could also be achieved by the use of machines (harvesters). Mills (2001) observed that harvesting could be done 90 – 160 days after planting though it varies with cultivar, production area and marketing condition.

With regard to handling, the proportion of potatoes set aside for storage should be cured by keeping them at temperature of 15 – 20^0C at high relative humidity for 10 or more days so as to pave way for periderm formation and ensure healing of harvest wounds. This is because there is the formation of cork – like laryer of cells under damaged tissues which takes place rapidly at 20^0C thereby leading to wound healing. When wounds are healed the rate of disease infection is drastically reduced. After curing, there is need to lower the temperature, this again depends on the expected duration of storage and intended use (Mills, 2001).

Yields could be up to 40 ton/ha in temperate regions as opposed to 4 – 6 ton/ha in the tropics, though 40 t/ha has been reported from experiments conducted in the tropics (Kay, 1987). In Bolivia which is in Andean highlands (the original home of potato) yields have been reported to range from 6 – 7 ton/ha from local or unimproved cultivars.

2.4.7 Uses

Okonkwo *et al.* (1995) reported that over 80% of the potato produced are consumed by boiling or frying in the country. However, there are other products, which could be made from potato, they include the following:

- Potato crisps – which are in form of thin sliced and fried potatoes, often used as snacks)
- Potato chips (French fries) – potato tubers that are cut into thin slices and fried with oil but not to dry
- Potato starch – grated and sieved fresh potato tubers produce starch, which are used in pharmaceutical industries
- Other uses include potato flour and animal feed (Okonkwo *et al.*, 1995).

With regard to the nutritive value of potato, Okonkwo *et al.* (1995) indicated that it supplies all the essential food requirement of the body. Between 8 % and 3 % of the daily human requirements of protein and caloride respectively could be met with 100 g of potato. Fried potato gives the highest caloride (energy) while the one boiled or roasted with skin supplies the highest level of mineral, protein and vitamins to the body (Beukema and Zaag, 1979).

2.4.8 Pests and Diseases of Irish Potato

a. Pests

i. Aphids (*Mysus persicae)*: from the studies carried out in 1991 and 1992 in the Jos Plateau, it was observed that aphids (winged and wingless) were present in most potato fields (Okonkwo, 1992) and they caused economic damage to potato plants by sucking the sap from leaves or stem. The winged aphids transmit viruses more than the wingless aphids (Okonkwo *et al.,* 1955). Symptoms include wrinkling of tender leaves, wilting of old leaves or yellowing or dying prematurely. It could be controlled by applying insecticides.

ii. Termites: Infestation by termites could ensue when grasses are used as mulch or where water supply is inadequate. Holes are made on the potato stems and tubers and can be controlled by Furdan at the rate of 280 g per hectare.

iii. Mealybugs (*Planecocus spp*): they are more of storage pests than field pests. On the field they suck the sap and damage the terminal and axillary buds, whitish waxy secretion is often left where they attack the plant. They could be controlled by applying insecticides.

iv. Rats: They eat the potatoes thereby damaging them. They could be controlled by poisoning them and protecting the store with wire mesh.

b. Diseases

i. **Late blight** – caused by *Phytophthora infestans,* the peak period is between July and August. It appears as white bloom on the lower leaf surface, later turns pale yellow and damages the stems. It could be controlled by spraying with copper based fungicides, Dithane m – 45. The early blight is caused by *Alternaria solani* and could be controlled with suitable fungicides. Bordeaux mixture could be sprayed as a preventive measure (Greensil, 1954).

ii. **Bacterial Wilt** – caused by *Pseudomonas solanacearum* which causes wilting of the leaves, could result in death of the plant.

iii. **Bacterial Soft Rot** (*Erwinia carotovora)* is a field storage disease of potato, common in waterlogged fields, bacterium enters the tubers through the enlarged lenticels. It is also common in poorly ventilated stores. Burying of diseased plants, avoidance of water-logged fields and crop rotation system could help in controlling the diseases.

iv. **Dry Rot** – caused by *Fusarium spp* – enters the tubers through the wounds, broken sprouts or weak potato plants, favoured by high relative humidity and high temperatures of 20^0 C – 35^0 C in the store. Tubers should not be stored under high temperatures and high relative humidity; organic mercury could be used to disinfect the seed tubers prior to planting. Also, broken tubers should be sorted out and utilized/consumed immediately.

2.5 DEDUCTIONS FROM THE LITERATURE REVIEW

The foregoing review of relevant literatures on the definition of agroforestry has revealed that few of the definitions lack both comprehensiveness and vigour in some of the definitions of the subject. For instance, the two main goals of the system which are to achieve ‘greater outputs’ on ‘sustained basis’ were left out in some definitions. In describing the concept of alley cropping emphasis has been placed on hedgerows only whereas cropping in the alley (spaces) between tree rows is also alley cropping system.

Also, none of the authors stressed the merits of tree rows over hedgerows. Moderately spaced tree rows (3 - 4 m within rows and 5-10 m between rows) pave way for ploughing/harrowing in the alleys. It ensures harvest of green foliage as green manure and utilization of the trees (by employing selective felling when trees attain maturity and after harvest of annual crops) for fuel wood, poles and stakes which are advantages over hedgerows which are maintained at shrubby level continually. Available information on other parts of the literature review could be considered adequate sequel to the fact that all necessary aspects were reasonably elucidated or elaborated by the various authors.

CHAPTER THREE

MATERIALS AND METHOD

3.1 THE STUDY AREA

3.1.1 Location

The study was carried out in the Teaching and Research Farm of the Department of Agricultural Extension and Management, Federal College of Forestry, Bauchi Road, Jos, Plateau State, Nigeria in the north – eastern part of the Jos city (Fig.1). The Jos Plateau is located in the Northern Guinea Savanna but owing to its distinctive features, it has been mapped out separately from the rest of the Northern Guinea Savanna Zone (Keay, 1959). The Jos Plateau lies between latitude 8^0 50^1N and 10^0 10^1N and longitude 8^0 22^1E and 9^0 30^1E (Udo, 1978). The average elevation is about 1250 metres above sea level while its height above the surrounding plains is about 600 m and the highest point is about 1777 metres above mean sea level which is about 20 km eastwards from Shere Hill.

Also, a number of relatively low plains are found at the boundaries of the Jos Plateau, at the north-east, it is surrounded by the Bauchi plains, Jama'a - Kaduna plains to the north-west and the Benue lowlands to the South (Figs. 2). The Jos Plateau is about 8,600 km^2, its north to south length is about 105 km and 81 km from east to west and almost occupies the centre of the Nigeria's physical space (Keay, 1951; Keay, 1959; Hill, 1978; Davis, 1973; Morgan, 1979; Eziashi, 1995).

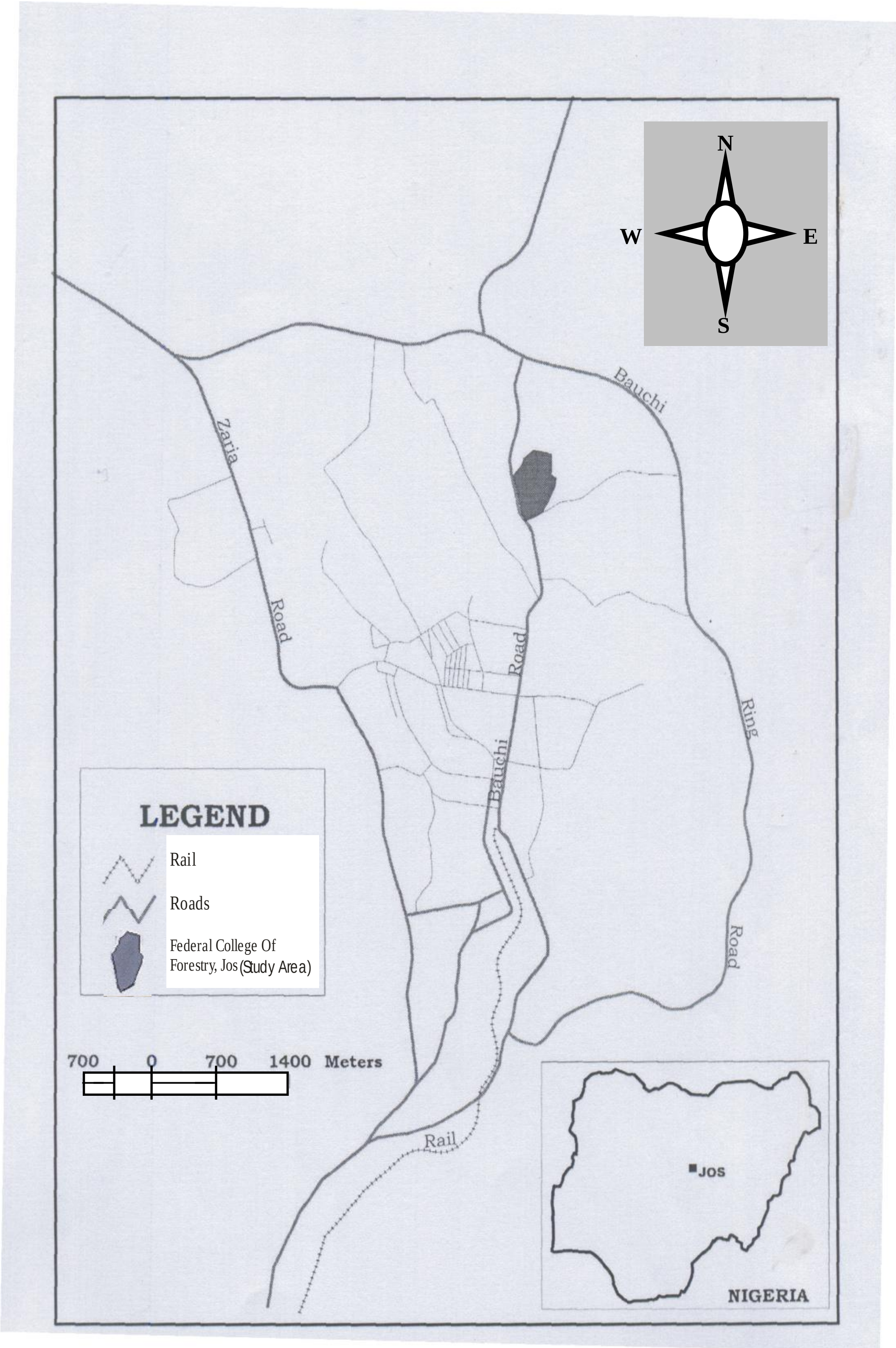

Fig 1: Jos City Showing the Study Area (Olowolafe, 2007)

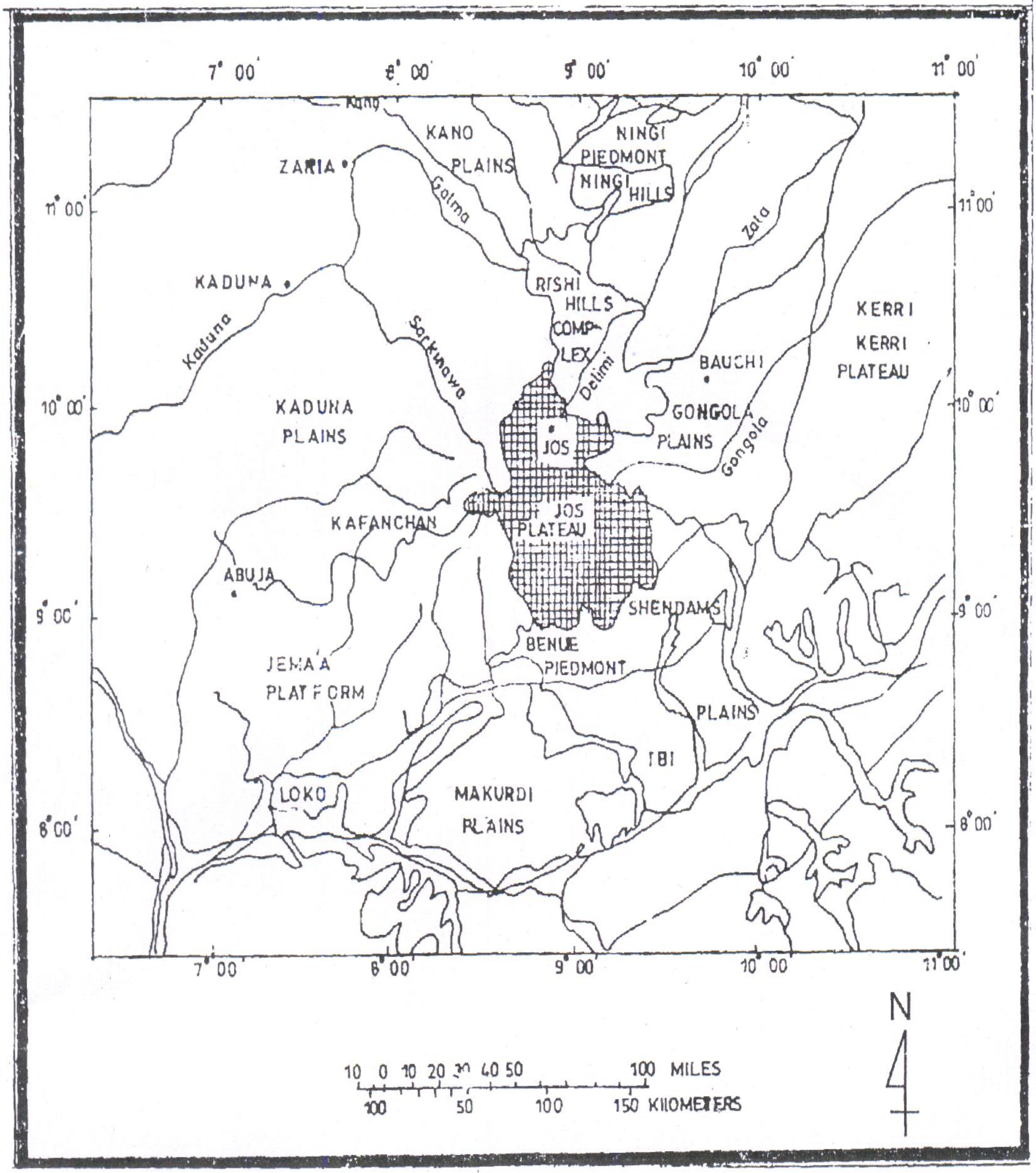

Fig. 2: The Jos Plateau Showing the Regional Setting (Eziashi, 1995)

3.1.2 Climate

The climate of the Jos Plateau is influenced by its altitude and position across the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ). Two seasons generally characterize the climate of Nigeria and they are the wet and dry seasons. The former is moisty owing to wind currents from the South West across the Atlantic Ocean and the latter dry due to the persistent sunshine with dry weather.

This is as a result of wind currents from the North Eastern direction (Keay, 1952, Eziashi, 1995). With regard to the climatic features of the Plateau detailed information was sourced and updated most especially on the temperature, rainfall, evaporation, radiation, relative humidity and wind speed by employing data obtained from the University of Jos Meteorological Station (2000 – 2006).

a. Temperature

Basically, temperatures are lowered by altitude, which in turn induces cloud formation and orographic rainfall. The highest mean maximum temperature is in April (33.3^{O}C) on the Plateau and by May it falls. Generally, there is increase in temperature towards the end of February to April (Table 3, Appendix 76). The lowest minimum temperatures occur in December and January (14.74 and 14.24^{o}C) while the lowest maximum temperatures are in the months of July, August and September (26.5, 26.8 and 27.9^{0}C respectively). In December, the low temperature is often coupled with dry harmatan and cold. This is due to the fact that wind blows from the Sahara desert. Also, the cloud cover affects the maximum daytime temperature and night radiation by reducing them and subsequently the diurnal range decreases in the rainy season. During the period under review, the mean minimum temperature is 18.10^0C (Table 3, Appendix 76).

b. Rainfall

The rainy season is between April and September while the dry season is from October to March, though rain is sometimes experienced in mid-March but not stable until April/May and also it does extend to October sometimes before dry season sets in toward middle or end of the month (October). The heart of the rainy season (based on 2000 – 2006: Table 3, Appendix 77) falls between June and August and diminishes from September.

However, Jos has been identified as one of the stations on the Plateau that is characterized with three seasons, namely: a hot season (March–April), a rainy season (May to September) and a cool/cold season (October – February). It has also been observed by Alford and Turley (1974) that rainfall pattern on the Plateau is not unconnected with the relief and an associated hill ranges in relation to the prevailing winds. Also, the upper elevations are characterized with profound increase in rainfall. On the Plateau, the mean annual rainfall is 1.371 mm, which is generally higher than that of the surrounding plains except few other stations like Wamba and Kefi (Alford and Turley, 1974; Hill and Rackham, 1974; Alford et al., 1979 and Eziashi, 1995).

c. Relative Humidity

At the beginning of the rains the relative humidity increases and temperature decreases. It increases sharply from May to September and gradually decreases from October to April. It is of inverse relation to temperature, which is

Table 3: Climatic data (mean values) of the study area (2000 – 2006)

Variables	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Rainfall (mm)	0.00	0.10	7.03	78.94	126.00	234.30	275.93	357.57	193.18	27.80	0.11	0.00	108.41
Temperature (^{0}C)													
Max	28.96	31.2	32.3	33.3	29.5	28.6	26.5	26.8	27.9	29.8	30.0	29.6	29.50
Min	14.24	16.9	20.1	21.1	20.7	19.5	19.0	18.6	18.9	18.1	15.7	14.7	18.10
Relative Humidity (%)	24.57	25.43	22.14	45.14	60.86	70.71	77.71	77.86	94.71	63.43	37.71	32.43	52.73
Evaporation (mm)	3.80	4.20	5.10	3.70	2.30	2.03	1.90	1.44	1.67	2.46	3.59	3.64	3.00
Radiation/Sunshine(Hrs)	7.7	7.4	6.5	5.6	5.7	5.7	4.5	4.2	5.7	6.9	8.2	7.8	6.32

Source: University of Jos Meteorological Station, Jos.*(The Data for 2000 – 2006 on annual basis are at the appendix) indicative of the degree of dryness of the environment or the amount of moisture or water vapour in the atmosphere in the Jos Plateau (Table 3, Appendix 78).

d. Sunshine Hours

The sunshine hours are much lower at the peak of the rainy season and higher during the dry season. For instance, from 2000 – 2006 between June and August, the radiation was much lower than that of the period between October and March. The average sunshine hours (2000 – 2006) in July were 4.5 hrs while those of December and January are 7.80 and 7.70 hrs respectively. (Table 3, Appendix 79).

e. Evaporation

It could be observed from above that there is much lower evaporation during the rainy season as opposed to the period of dry season. For instance, the rate increases from October to March and decreases from April to September. For instance, the average value in July is 1.90 mm while 4.20 mm and 5.60 mm are the mean values for February and March respectively (Table 3, Appendix 80).

3.1.3 Geology

A good number of rocks which are of igneous and metamorphic origin had intruded into the geology of the Jos Plateau. It (the geology) comprises migmatites, gneiss and older granites (which constitute the Precambrian complex rocks), the Jurassic granites, which are mainly biotite-granites and Tertiary/ Quaternary volcanic rocks (Macleod et al., 1971). It is pertinent to mention that part of the Jurassic younger granites has been exposed by erosional activities and basaltic hard rocks, pumice, lava flows and ash deposits form the Tertiary and

Quatenary volcanic rocks. In Places like Rayfield and Bokkos some biotite-granites were covered by the Quaternary deposits (Hills and Rackham, 1974; Hill, 1976; Olowolafe and Dung, 2000). Also, Wright (1971) observed that rocks such as the migmatites, granite-gneisses and older granites, which are the remaining parts of the basement complex, belong to a single orogenic cycle (Figs. 3 and 4).

3.1.4 Soils

The soil in the study area is formed from the biotite-granites on the Jos Plateau which is low in terms of total nitrogen status, available phosphorus and calcium. This is traceable to erosion, leaching, acid and lateritic nature of the soils (Olowolafe and Dung, 2000). The main soil types in the biotite granite sites are the Entisols, Inceptisols, Alfisols and Ultisols. The Entisols are found on the interfluvial crests and drainage channels characterized with faster rates of surface run-off than pedogenic processes and with shallow profiles (mainly A-C horizons). They are devoid of definite structure which range from fragile or frail granules to small fragments or crumbs (Figs. 3 and 4).

Present at the upper and middle footsteps, interfluvial sites and flood plains are the Inceptisols which are composed of weatherable minerals, definite structure, cambic B-horizons and have passed through mild weathering process.

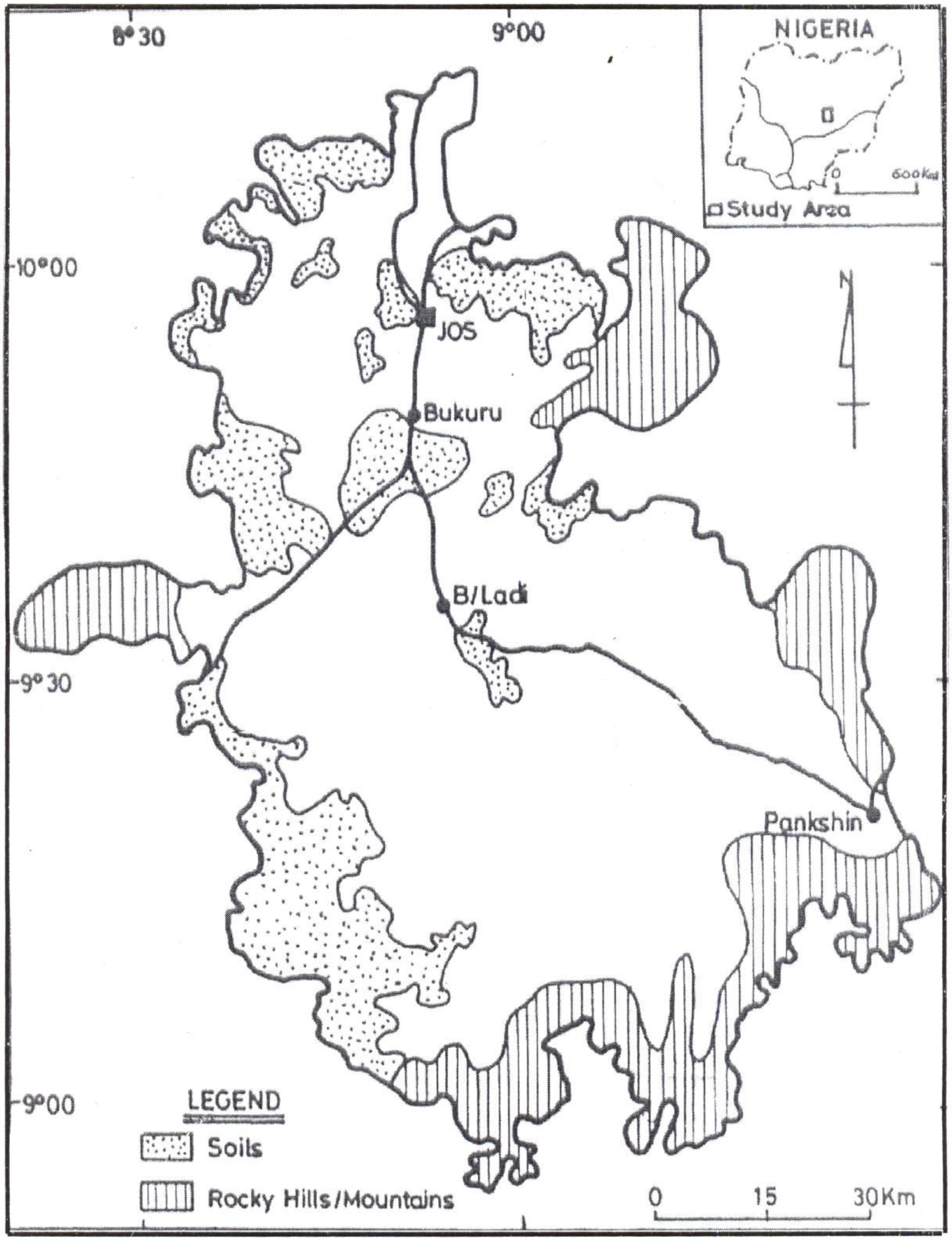

Fig 3: The Jos Plateau Showing the Area Underlined by Biotite-Granite [as Modified by Olowolafe and Dung (2000) from Macleod *et al*. (1971) and Hill (1976).

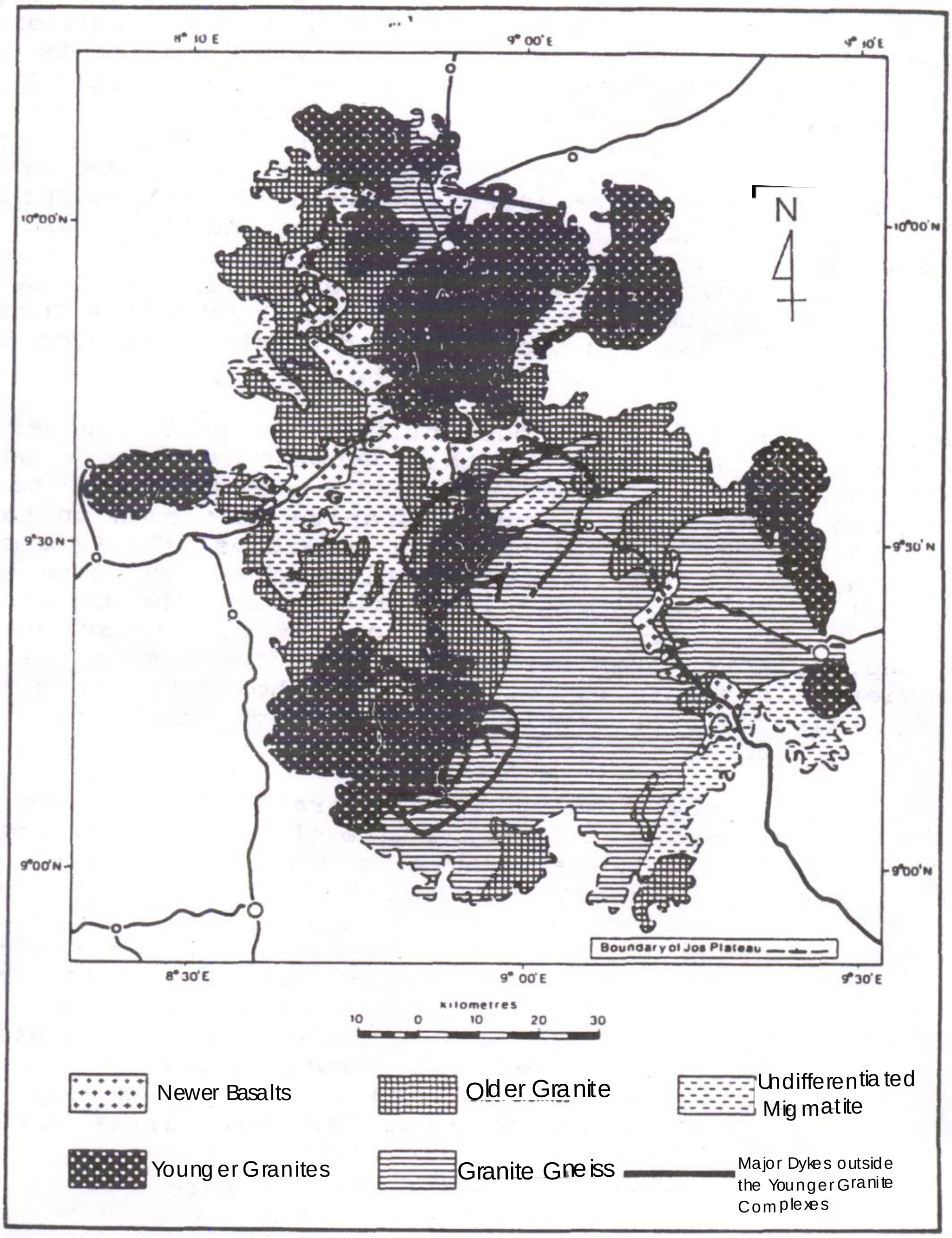

Fig.4 Geology of the Jos Plateau (Morgan *et al.*, 1979)

The soil types found on lower foot slopes and level pains with argillic horizons are the Alfisols and Ultisols, which are characterized with lateritic concretions and similar morphology. The only contrast between them is the base saturation. Also, on the Jos Plateau, there are other minor soil types like the Vertisols present in the depressions and alluvial areas characterized with heavy clays (Olowolafe and Dung, 2000).

Apart from soils derived from the biotite granites, which constitute the study area, there are other soil types derived from the hornblendepyroxene fayalite-granites and riebeckite-granites, which are the other two major types of younger granites as recognized by Macleod and Turner (1971).

3.1.5 Relief and Geomorphology of the Jos Plateau

The Jos Plateau comprises two planation surfaces and four types of hills. The planation surfaces are made up of the Lateritic Depositional Surface and the Recent Erosional Surface (Fig.5). The lateritic depositional surface which is made up of gritty or sandy clays was formed during the Tertiary. This is in form of alluvial/deluvial deposition of locally weathered material. It is situated in a flat swampy environment at an elevation of four metres above sea level. It is referred to as the oldest planation surface on the Jos Plateau (Schoeneich, 1992). Though Schoeneich (1992) observed that mining pits showed that it is not erosional but De Swardt (1956) had earlier called it the “Older Erosional Surface”.

Based on its height and elevation, King (1962) assigned it a cretaceous age and named it “Post Gondwana Surface”. It is 1250 to 1320 metres above sea level. He (King) linked it with the East African planation surfaces in term of elevation but Schoeneich (1992) observed that King had completely ignored the vertical

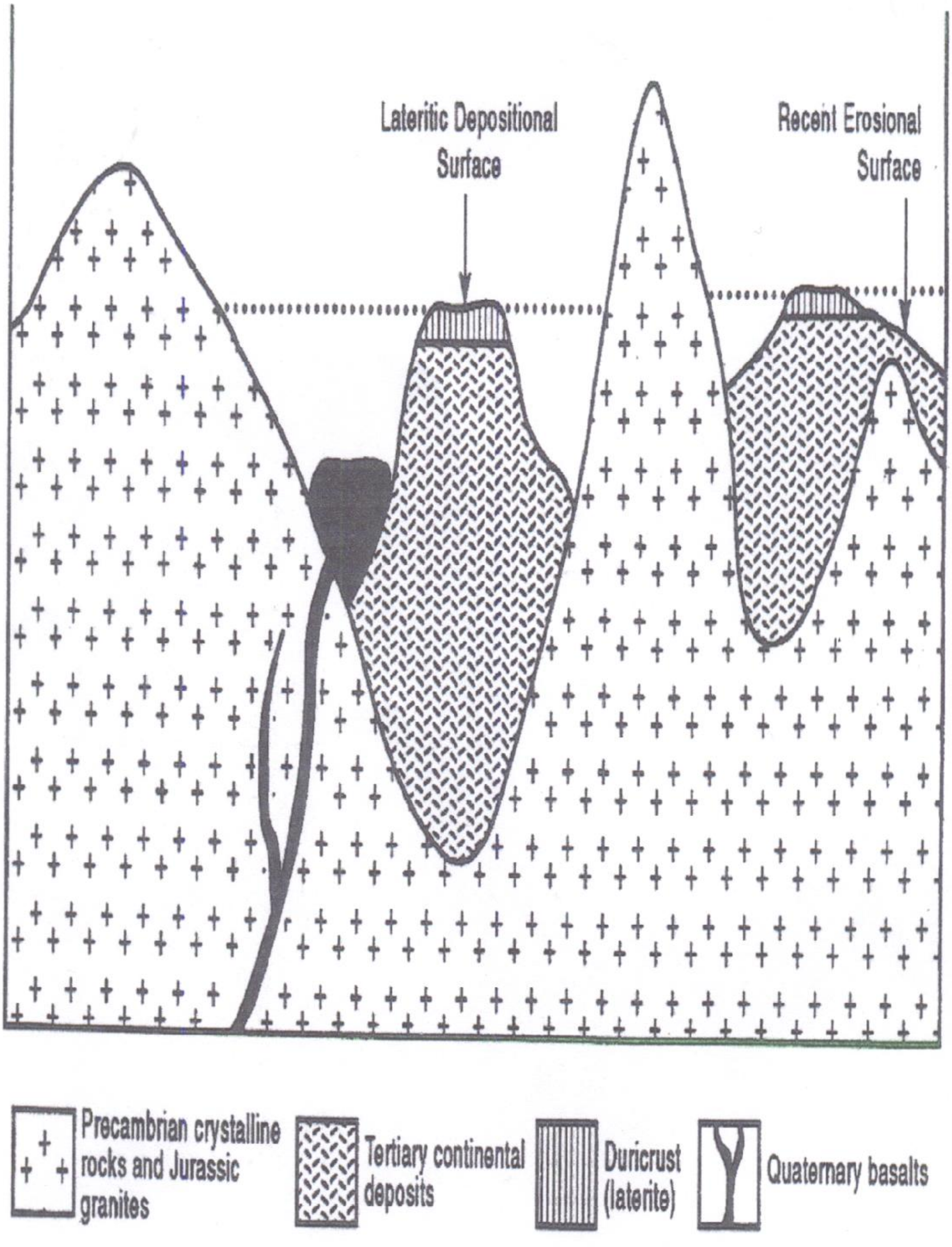

Fig 5 : Present day cross - section through the Jos Plateau. Note Cretaceous erosional valleys and ridges, Tertiary depositional plain capped by duricrust (laterite) and recent erosional plain tectonic movements that had warped (bent or twisted the natural shape) the whole African Crystalline Platform since the cretaceousage. This is evident when one considers the post cretaceous surface in Chad and Sokoto Basins which is now several metres below sea level and even deeper in the Niger Delta.

This lateritic Depositional surface has a characteristic feature of being capped by a primary rather than a secondary duricrust. As observed by Schoeneich (1992), this surface had been profoundly dissected by recent erosion and preserved mainly on watersheds or beyond watersheds on mesa hills. Also its original shape which was horizontal or sub-horizontal has become tectonically warped.

The second planation surface is the Recent Erosional Surface. This is formed after the Jos Plateau has been elevated to its present level. The process leading to its formation involved the exhumation of the old and late cretaceous valleys (that had been filled in by Tertiary sediments) by erosion. Thus, a new wave-like (with rises and falls in gentle slopes) or undulating land termed “Recent Erosion Surface” emerged (Schoeneich, 1992). This undulating surface slopes gently towards the saucer shaped valleys in the centre of the Jos Plateau or the V-shaped valleys near the edges of the Plateau.

As earlier stated, there are four hills apart from the two planation surfaces on the Jos Plateau. The first group of hills are the younger Granite Erosional Hills which are found on the Younger Granite massifs. The Rukuba and part of the Jos-Bukuru Younger Granite massits are exceptions. They are several metres in elevation above the Lateritic Depositional Surface (Schoeneich, 1992). Also, King (1962) described the hills as witnesses of his “Gondwana Planation Surface” of Jurassic age.

The second group of hills are the Inselbergs which are restricted to outcrops of either older or Younger Granites. They are considered as erosional hills formed as a result of the combined effects of deep chemical weathering of crystalline rocks and erosion (Thomas, 1979). Further research by Schoeneich and Amusa (1990) showed that the inselbergs are also believed to represent ‘bubbles’ of lighter granitic material protruding through heavier granite at the ground surface (Schoeneich, 1990).

Mesas are the third group of hills on the Jos Plateau which are all the reminants of the lateritic Depositional Surface. It is pertinent to mention here that the lateritic Depositional surface had been dissected by Quaterinary erosion (Schoeneich, 1992). The fourth group of hills are the volcanoes or the volcanic cones. They are referred to as being of Late Pliocene to duaternary age (Burke and Durotoye, 1970) otherwise considered to be of ‘Newer Basalt’ age. Schoeneich (1992) asserted that there had been no proof regarding the occurrence of any other volcanic episode during the cainozoic (Tertiary and Quaternary)

3.1.6 Vegetation

The Jos Plateau is situated in the Northern Guinea Savanna Zone but owing to its distinctive features as observed by Keay (1959) it has been mapped out separately in the map of vegetation zones. It is characterized with vegetation features different from the rest of the Northern Guinea Savanna owing to the fact that it has some peculiar floristic composition, which include *Terminalia brownii*, *Morea zambesiac* and *Disperis Johnstoni* (beautiful orchid).

Over the years, profound alterations have been done to the original vegetation of the Plateau, mainly as a result of human activities (Keay, 1953 & 1959, Eziashi, 1995). As pointed out by Hall (1957 and 1971) the original vegetation of the Plateau was a savanna woodland but presently, it has changed to a grassy savanna interspersed with few trees and shrubs. This is due to human disturbances through slash and burn agriculture, mining, persistent bush burning (annually), deforestation and overgrazing.

Sequel to the interactions/relationships among some parameters such as climate, relief and vegetation; five vegetation complexes had been identified by Alford and Turley (1974). They are Plateau complex (with mean annual rainfall of 1000-1400 mm which is open grassland); South-West complex with a mean annual rainfall of 1,400-2,000 mm (upland forest and woodland); West Escarpment (with rainfall lesser than that of South-West complex and characterized with less dense woodland), East Escarpment complex (drier Northern Guinea Savanna composed of trees and shrubs) and Toro complex (on the drier part of the Plateau, declines eastward toward the Toro plains). It is pertinent to mention here that the open grassy areas of the Plateau complex have been replaced (to a reasonable extent) by Combretum savanna and *Parkia/Daniella* parkland (Eziashi, 1995).

Furthermore, the fringing forest (which is also called riparian forest) found along river/larger stream courses or in the valleys was also identified as “Alluvial Complex” by Alford and Tuley, (1974), thus, making a total number of six classes. Evidently, very substantial alterations have been done to the original vegetation of the Plateau most especially as a result of mining activities. This was observed by Jumbo (1986) and recent researches indicated that profound changes have been made on the vegetation and landscape of the Jos Plateau (Eziashi, 1998; Kareem *et al*., 2000). Though Buckley (1986) opined that commercial tin mining had very vestigial effects on the vegetation which he said was already degraded.

Mining activities (other than tin) have further caused a lot of destruction to the remaining vegetation particularly in the Sanga forest reserve.

In view of the tremendous changes that have been done to the vegetation, Jumbo (1986) grouped it into three categories, viz: (i) Vegetation on Hills/Hill Ranges and on the steep and less Accessible Plateau Margins (made up of wood on the steep and less accessible Plateau margins and the highest hills' tops), (ii) Vegetation on the "Plains" (with open grassy plains, considerably cultivated and grazed, interspersed with trees on rocky out-crops and coppiced shrubs) and (iii) Vegetation on Mine Dumps and Mine Ditches: made up of two forms of vegetation: (a) areas colonized by grasses found on mounds, mine dumps and in-filled pits and (b) artificially established vegetation (of woody species) on mine dumps which are mainly Eucalyptus species. Other non-woody species are found here for example, *Imperata cylindrica* (spear grass).

3.1.7 Agricultural Land Use on the Plateau and the Study Site

Prior to the active tin mining activities and the increased population in the Jos Plateau, arable farming was the prevalent practice, especially in the nineteenth century. The status quo indicates that large expanse of land is under cultivation at subsistence level. This farming practice has brought about a decrease in organic matter content, loss of plants' nutrients and general soil degradation owing to the nature of traditional farming system employed which includes slash and burn agriculture, swidden cultivation (on the plains) and terrace farming (which is intensively practised in the hilly areas). Notable among the commonly cultivated crops are Irish potato (*Solanum tuberosum*), Sorghum (*Sorghum vulgale*), Maize (*Zea mais*), soya bean (*Glycine max*), hungary rice (*Digitaria exilis*), Millet (*Pennisetum americanum* Sweet potatoes (*Ipomoea batatas*) and Cocoyam

(*Colocacia escutentus*) at subsistence levels (Grove, 1952; Adepetu, 1986; Olowolafe and Dung, 2000).

It is pertinent to point out that the people in the study area have not been practising agroforestry system. The soil on which they are farming is derived from the biotite granite (acid rock) which is characterized with very low level of total nitrogen and calcium . Other macronutrients such as phosphorus, potassium and magnesium and certain micronutrients are deficient, though potassium, magnesium and the trace elements' deficiencies are not general on the area (Olowolafe and Dung, 2000). Therefore, it is expedient and imperative to employ alley cropping (which is a form of modern agroforestry system) in the area since the soil organic matter content and nutrient status of the area are low. (Grove, 1952; Howard, 1975; Jones, 1975; Olowolafe, 2003).With regard to the experiemental site, it is part of the areas set aside for arable crop production (most especially maize) by the College (that is, Federal College of Forestry, Jos). It is a fairly level, moderately well drained Alfisol (USDA, 1999). The slope of the site is 1 – 2% toards north east (Olowalafe, 2007).

The introduction of agroforestry system in the area will definitely pave way for rapid soil improvement on sustained basis. This is not unconnected with the fact that the soil will not be left uncovered (with the tree rows for example, *Albizia lebbeck* in place) coupled with their profuse litter deposition (1 – 2 months during the dry season within which new foliage/leaves emerge) and its nitrogen fixing ability. Besides these, part of the foliage when harvested could serve as green manure which could be incorporated into the soil during land preparation to augment the organic matter content of the soil. Thus, dependence on chemical or inorganic fertilizers will be drastically reduced.

Furthermore, the present situation of low agricultural productivity will gradually give way to a higher level of production. Within the farm, a sort of microclimate will be created which will contribute in no small measure to the productivity of soil and crops (for example, Irish potatoes) in the area more so when the run-off water and nutrient loss will be adequately controlled as a result of improved soil infiltration.

3.1.8 Population and Economic Activities of the People in the Study Area.

The Jos Plateau comprises four of the fourteen Local Government Areas (L.G.A's) of Plateau State. The four L.G.A's consisting of Jos, Bassa, Barkin Ladi and Mangu have a total population of 652,871 based on 1963 Census (Ajaegbu et al, 1992). The estimated population by 1985 for the four LGA's was 1, 329, 252 with a density of 147 persons per square kilometer Towns which are the main centres of the Plateau include Jos (capital of Plateau State), Bukuru, Barkin Ladi and Mangu.

The occupation of the people is agriculture which is the mainstay of the economy. It is still the major or dominant economic activity of the people of Jos Plateau regardless of the commercial tin mining in the first decade of the 20th century. Depending on the terrain and culture, crops produced include hungry rice (Digitaria exilis), maize, Irish potato, sorghum (*Sorghum valgae*), soya bean, millet (*Pennisetum americanum*), cassava, cocoyam, vegetables and sugar cane.

Out of these crops, potatoes, cassava, maize, vegetables and sugar cane have become cash crops. Livestock production is also practised (Ajaegbu *et al*., 1992; Olowalaye and Dung, 2000).Mining of minerals such as tin, cassiterite and culumbite was formerly a major activity on the Jos Plateau. Presently mining has declined drastically and mining poads, huge mine spoil dumps, pits, ditches, abanodoned equipment and declining or abandoned mining settlements are what could be observed in the mining region of the Plateau.

The state capital (Jos) is the location of most of the industries, particularly in Ango-Jos Industrial Estate. Notable among these industries are those that brew beer and produce confestionary, detergents, biscuits, metal and modern furniture. Also, the Jos Plateau is noted for pastoralism. Ajaegbu *et al*. (1992) reported that about 400,000 cattled graze the Jos Plateau (though this population fluctuates profoundly). Other economic activities include poultry farming, fruit growing and tourism. As at 1989, tin mining which has been a major economic activity on the Plateau had declined, about 1000 tons was the overall tin production in Nigeria. The number of modern mines that were active was only three and they were located in Barkin Ladi, sabo Gida Kanam and Guruum (Ajaegbu *et al*.,1992). Presently, the Plateau is witnessing post-tin mining agriculture which is the dominant economic activity of the people.

3.2 METHOD

3.2.1 Experimental Design

The experimental design used was randomized complete block design (RCBD) with five treatments and three replicates. A table of random numbers was employed in assigning treatments to each block. This (RCBD) is a two-way classification method comprising the block and treatments in columns and rows respectively. A sort of homogeneity was assumed among the mini-plots within each block while those mini-plots outside each block were assumed heterogeneous due to likely difference in soil nutrient/fertility status. The treatments used are as follows:

T_0: Irish potato planted on flat bed without tree rows and green manure of

Albizia lebbeck (as control).

T_1: Irish potato planted in alleys of *Albizia lebbeck* tree rows without green manure.

T_2: Irish potato without the tree rows of *Albizia lebbeck* on the flat bed but with incorporation of *Albizia lebbeck* green manure at 5 ton ha-1 (at land preparation, 2 weeks before planting (single application).

T_3: Irish potato planted in the alleys of *Albizia lebbeck* tree rows with its foliage as leaf mulch at 5 ton ha-1 single application on soil surface (not incorporated into the soil) 2 weeks before planting

T_4: Irish potato planted in the alleys of tree rows of *Albizia lebbeck* with its green manure incorporated into the soil at land preparation at the rate of 10 ton ha^{-1} two weeks before planting: (single application).

The three blocks were tagged BI, BII and BIII and plot size was 3 m x 2 m (6 m^2) which was inform of flat bed, alley connotes the space between tree rows of the *Albizia lebbeck* at both sides (3 m length) of the plot (Fig. 6).

3.2.2 Statistical Models

Statitistical models are the linear relations of the effects of different levels of factors that are involved in the experiment.The statistical models are employed in the analysis of variance (ANOVA) and used along with one or more term(s) that represent the error effect. In classifying the observations, the criteria used are the sources of variation.

The statistical model for RCBD is:

(a) Yij = U + Bi + Tj + Eij

Where: Yij = Individual observation, that is, observation for the jth Treatment in the ith block

U	=	General mean (that is, the population mean of all the possible similar experiments).
Bi	=	Effect of the ith block
Tj	=	Effect of the jth treatment
eij	=	Experimental error

3.2.3 Assumptions

Assumptions refer to the general assumptions made for ANOVA. The yield of the potato could be affected by the treatments and environment from one block to the other. The block effects are assumed to be additive. Secondly, the experimental errors are assumed to be randomly, independently and normally distributed about zero mean and with a common variance (б)

i. **Eijk ~ NIID (O, $б^2$):** The experimental error associated with the treatments and blocks is normally, identically, independently distributed with mean zero (0) and variance ($б^2$), (Steel and Torrie, 1960; Fasina, 2000).

ii. $$\sum_{i=0}^{4} Ti = 0 \quad \text{(ii)}$$

iii $$\sum_{j=0}^{3} Bj = 0 \quad \text{(iii)}$$

(b) $$Y = a + bx_1 + cx_2 \ldots + zx_n \ldots \quad \text{(iv)}$$

Where Y	= dependent variable (yield parameters of Irish potato)
X_1, X_2-------Xn	= predictor (independent variables) i.e. growth parameters of Irish potato.
a, b, c, -----z	= regression constants or intercepts.

3.2.4 Hypotheses

Statistical hypotheses are statements about the assumed characteristics of a population. It is a tentative theory, supposition, assumption or guess provisionally made about the probability distribution of the population (Akindele, 1996). Statistical hypotheses are of two types, namely the null and the alternative hypotheses. The null hypothesis is the “hypothesis of no difference” and is normally subjected to statistical test. If the evidence from the observation is not favourable, it is nullified or rejected.

The alternative hypothesis is the one under investigation which does not agree with the null hypothesis. For instance, this researcher intends to find out whether the green manure and tree rows of A. lebbeck have effect on soil properties and Irish potato productivity. The null hypothesis will be: there is no significant effect of green manure and tree rows of A. lebbeck on soil properties and Irish potato productivity. Then, the alternative hypothesis will be: green manure and tree rows of A. lebbeck have significant effect on soil properties and Irish potato productivity.

The general/overall hypothesis of this research is**:**

Rattle tree has no significant effect on soil properties and Irish potato productivity on the the Jos Plateau. However, beside the general research hypothesis, the researcher intends to test the following hypotheses based on the specific objectives of the study.

a. Improvement on Soil Nutrient Status

Green manure of *Albizia lebbeck* and its tree rows have no significant effect on soil properties in the study area.

b. Growth Performance of Irish Potato

Growth performance of Irish potato is not significantly affected by *A. lebbeck* green manure and tree rows.

c. Yield of Irish Potato

There is no significant difference in Irish potato yield due to the effect of *A. lebbeck green* manure and its tree rows.

d. Optimal Level of Green Manure Applciation.

There is no significant difference in the effect of different levels of A. lebbeck green manure application on Irish potato yield.

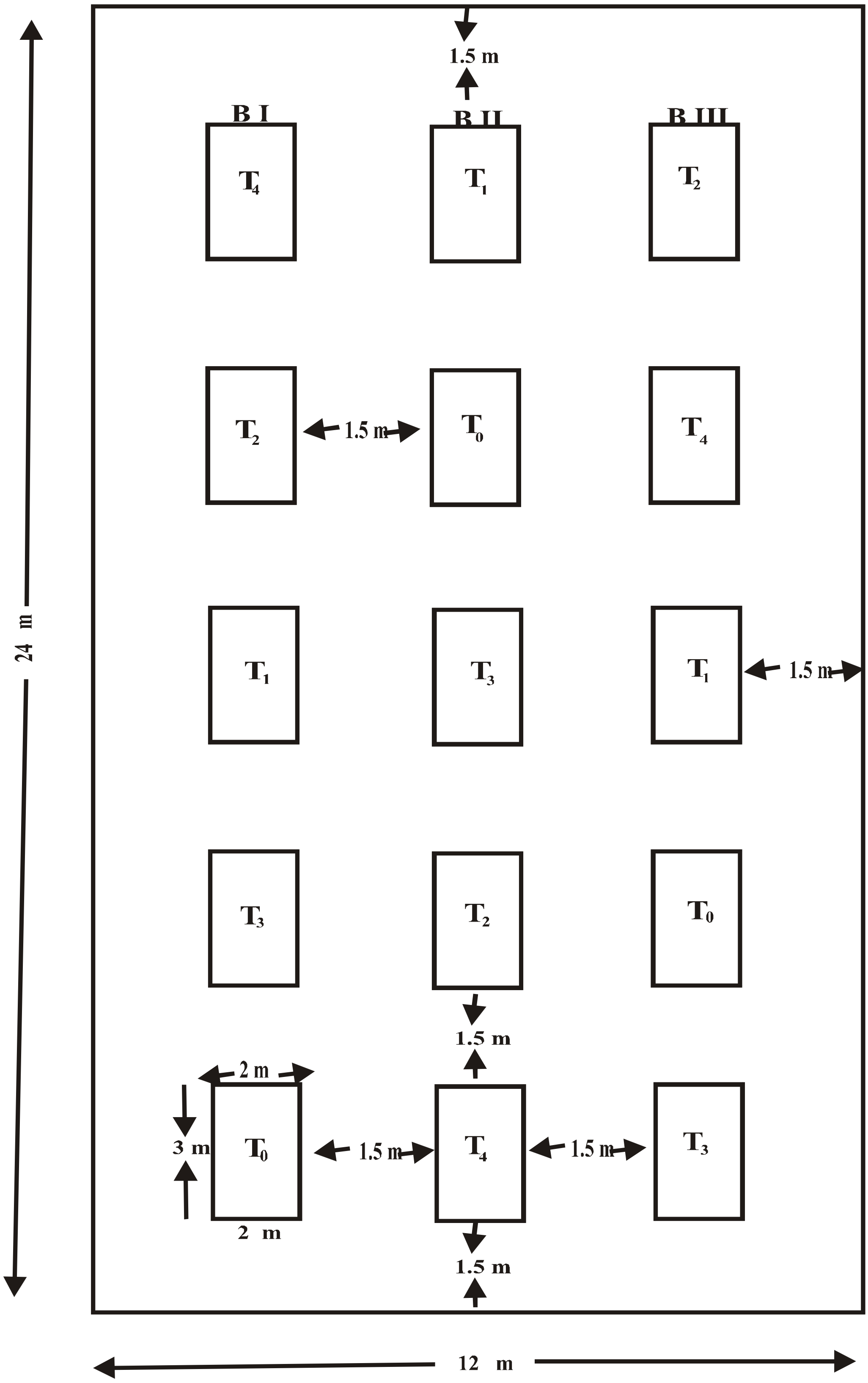

Fig. 6: Plot Lay-Out of the Experiment

T_o = Plot without green manure and trees rows of *Albizia lebbeck* (Control)
T_1 = Plot without green manure and but with tree rows of *Albizia lebbeck*
T_2 = Plot with green manure at 5 ton/ha without tree rows of *Albizia lebbeck*
T_3 = Plot with green manure at 5 ton/ha and tree rows of *Albizia labbeck*
T_4 = Plot with green manufe at 10 ton/ha with tree rows of *Albizia lebbeck*

3.2.5 Raising of *Albizia lebbeck* Seedlings

Seedlings of this species were raised prior to commencement of the rainy season. The viable seeds and cuttings of *Albizia lebbeck* were used in raising the seedlings in November, 2003. All necessary tending operations such as watering and weeding were carried out to ensure the production of healthy and vigorous seedlings. A total number of 120 seedlings were raised and 90 (10 seedlings for each of the plots with tree rows) utilized while the remaining ones were used for 'beating-up' (replacement of few seedlings that did not survive).

Owing to some records of dormancy with regard to the seeds, they (seeds) were given a sort of pre-germination treatment by stirring them in hot water at 500C for 15 minutes, which ensured 100% germination as earlier reported by Kareem *et al*.(2001). The growth medium was potting mixture comprising river-sand, top soil and organic manure (already pulverized) in ratio 2:1:1. Standard polythene bags with dimension 23.1 cm high by 12.0 cm basal diameter were used. The components were thoroughly mixed and sieved prior to filling into the polythene bags. Thirty seedlings were also produced from stem cuttings of the species which formed part of the seedlings planted. Cuttings/stakes of *Albizia lebbeck* are known for fast sprouting and subsequent growth rate (NFTA, 1988).

3.2.6 Digging of Soil Profile Pit

A soil profile pit (1 m x 1 m x 1.3 m) was dug at the experimental site. This was done to examine the nature of the horizons and the properties of the different layers (horizons).

3.2.7 Site Clearing, Land Preparation and Plot Layout

Clearing of the experimental site was done manually by means of cutlass and the debris was raked and packed out of the site. When rain stabilized in May, 2004, the area was ploughed, harrowed and marking out was done. The area was 24 m by 12 m (288 m^2) which is the Federal; College of forestry Jos, (in the north-eastern) part of the Jos city) 2m away from the experiemental plot that is, beside the agroforestry farm consisting 15 mini-plots denoting the five treatments and three replicates (blocks). Between two adjacent mini-plots, a ridge or levee in form of embankment (3 x 1x 0.5) m^3 was constructed to prevent run-off from one plot to another within blocks, which might have partially involved transfer of nutrients in addition to 1.5 m distance (apart) between blocks.

Wooden pegs were used in marking-out the area of the mini-plots, which were 3 m x 2 m (6 m^2) in size each. Accurate measurement was done by means of a 30 m tape while proper alignment was ensured by making use of twine (garden lines), ranging poles and prismatic compass. Planting of both the forest tree crop (rattle tree) and the agronomic crop (potato) was carried out and weeding was manually done by hoe at regular intervals. Ridges were not constructed in the alleys to pave way for easy transfer of nutrients from tree rows, fast decomposition of leaf mulch (Mohammed, 1984) and to enable the crop (Irish potato) have access to nutrients in the alleys. Thus, flat beds of dimension (3 x 2 x 0.1) m^3 were constructed in the alleys where the potato crops were planted (Fig 6).

3.2.8 Pre-Experimental Soil Analysis.

In order to assess the initial nutrient status of the experimental site and use the result of the laboratory analysis as basis for the block design, soil nutrient analysis was carried out. Prior to blocking of the experimental site into three parts to represent the three blocks, three portions or locations were randomly selected (as major locations/portions). This was followed by random selection of four sub-locations from each major location. Subsequently from each sub-location, soil samples were collected at three depths: 0-10, 10-25, and 25-40 (cm). Composite samples from each major location were used for analysis (that is, the three major locations were assigned Arabic numerals 1,2, and 3, their corresponding sub-locations were 1a, 1b, 1c, 1d; 2a, 2b, 2c, 2d; 3a, 3b, 3c, 3d). Each sub-location was at 3 soil depths represented in Roman numerals i, ii, and iii. To make composite samples, combinations of ai, + bi + ci, di; aii + bii + cii, dii and aiii + biii + ciii, diii were produced). Thus, a total number of 9 samples (3 from each of the major locations) were analyzed and taken as pre-experimental site nutrient status.

Furthermore, each sample was meticulously put in polythene bags separately, labelled and taken to the laboratory, removed from the polythene bags, air dried, ground, sieved with 2 mm sieve, smooth and coarse samples weighed separately, the percentage of coarse portion determined and smooth portion subjected to laboratory analysis. Also, a soil profile was dug at a suitable place in the experiment site. This enabled the researcher to have the knowledge of the different horizons in the soil profile, paved way for proper identification and classification of the different soil types (for example, Entisols, Inceptisols, Alfisols and Ultisols).

It is pertinent to mention here that the same soil sample analytical procedures were employed before (pre) and after (post) the experiment. Determination of the particle size distribution of the soil samples was done by using the hydrometer method (Day, 1965) and separated into sand, silt and clay and expressed in percentages, while the pH (1:2:5) in water and KCl was determined electronically by using a functional pH metre. Flame photometer was employed in the determination of the exchangeable cations (bases) such as Na and

K while estimation of the Ca, Mg was done by means of atomic absorption spectrometer (AAS).

Determination of effective cation exchange capacity (ECEC) was by summation method following the extraction of exchangeable acidity with the aid of IN KCL. Coleman (in Kamprath, 1984) suggested that the determination of CEC through the summation of exchangeable bases plus KCL exchangeable acidity serves as a more realistic method of evaluating the actual amount of bases experimeenced by plants. The percentage organic carbon content was determined with the aid of potassium dichromate method of Walkey and Black (1974), available phosphorus by Bray and Kurtz (1945) method and total nitrogen by Kjdeldal method (Jackson, 1962). The results obtained are presented in Tables 19, 20 and 21.

3.2.9 Establishment of *Albizia lebbeck* Trees Rows

The seedlings of the rattle tree were planted as soon as rain stabilized in May 2004 and they were six months old. The spacing within tree rows was 0.60m and the plot length was 3 m, thus a total number of 10 *Albizia lebbeck* seedlings were planted per plot, while the inter- tree rows spacing was 2 m. Prior to planting, accurate measurement and digging to required depth of 15cm were ensured. The tree rows were at both sides of each plot (5 seedlings at each side of the plot as tree rows and the crop planted in the alleys (space between the tree rows). Thus, a total of nine plots had the tree rows of *Albizia lebbeck*. Planting stock from the rattle (comprising young plants raised from seeds and cuttings) were randomly planted in the nine plots for treatments 1, 3 and 4 (Fig. 6 and Plate 3).

3.2.10 Green Manure Application

Application of green manure of *Albizia lebbeck* was carried out at land preparation in respect of three treatments (T_2, T_3 and T_4) two weeks before planting of the horticultural crop (Irish potato). In T_2 and T_4 green manure was incorporated into the soil at the rate of 5 and 10 ton ha-^{1} respectively . In T_3 green manure was applied as mulch and spread evenly on the alley two weeks before planting at the rate of 5 ton ha-^{1} [Forest trees' foliage had been successfully used as green manure in the past to improve crop yield (Oloyede, 1994; Patil, 1989; Budelman, 1989; Liyannage, 1987; Fomba, 1998; NFTA, 1988 and Okonkwo *et al*., 1995). There were no green manure and tree rows in T0 while T_1 had tree rows of *Albizia lebbeck* but without green manure or leaf mulch. The quantity of green manure applied per 3 m x 2 m (6 m^2) plot in respect of T_2, T_3 and T_4 is given below:

(i) For 5 ton ha-^{1}

1 ha = 10,000m^2

1000kg = 1 ton

Plot size (mini plot) = 3 m x 2 m = 6 m^2

Qty of green manure required $= \frac{5.0 \times 1000}{10,000\ m^2} \times \frac{6\ m^2}{1} = 3.0$ kg/ 6 m^2 / miniplot

(ii) For 10 ton ha-^{1}

Plot size = 6 m^2

1000 kg = 1 ton

Qty of green manure required $= \frac{10 \times 1000}{10,000\ m^2} \times 6m^2 = 6.0$kg / 6 m^2 / mini plot

3.2.11 Planting of the Irish Potato Tubers

This was done consecutively for five times (between 2004 and 2006) comprising three rainy seasons (May – July) and two dry seasons (November – February). In each case pre-sprouted seed tubers of Irish potato (Bertita variety) of diameter 25mm – 50mm were planted (Plates 2 and 4) at a depth of 8 – 10cm, 20-30cm within rows and 75cm -100cm between rows on flat ridges. The use of pre-sprouted seed tubers was to ensure early and uniform emergence and high crop yield (Beukema and Zaag, 1979) while the 8 – 10cm planting depth was to prevent exposure of the tubers to sun's heat, rodent and bird damages (Okonkwo *et al*., 1995).

The pre-sprouted setts were planted when rain stabilized at the end of the first week of May to avoid the peak blight period in July – August (Ifenkwe and Okonkwo,1983) and also pave way for proper decomposition and mineralization of the green manure between last week of April and end of first week of May (2 weeks). The planting was manually done by means of local hoe (Plate 2).

Plate 2: Pre-sprouted tubers of *Solanum tuberosum* (Irish Potato)

Plate 3: Irish potato crops in the alley of *Albizia lebbeck* tree rows at 1st cropping season

Improved (early maturing and high yielding) varety of Irish potato (Bertita) was sourced from National Root Crop Research Institute, Vom, near Jos and planted to ensure high yield. Planting of *Albizia lebbeck* seedlings was done at the two sides of the flat bed (and not ridges) to ensure adequate moisture conservation while the Irish potato crops were in the alley between *Albizia lebbeck* tree rows (Plate 3). Mohammed (1984) and Fasheun (1989) observed faster/higher moisture loss from ridges than flat beds. Adequate moisture on the beds was to accelerate the rate of further decomposition of the green manure. Three rows of Irish potato were planted per plot (20-30 cm within rows and 0.75–1.0 m between rows). Thus, there were 9 –10 stands per row and 27-30 stands per mini-plot of 3 m x 2 m (6 m2). Those tubers that were up to 45 – 50 mm in diameter were cut into two before planting (it was ensured that the cut tubers had sproutings on them) planting of whole or cut tubers had been reported by Kay (1987). The cut tubers were randomly distributed/ planted in the plots.

3.2.12 Tending Operations (Management/Cultural Practices)

The following operations were carefully carried out during the experiment. They are as follows: watering, weeding, pest control (rodents) and fire-tracing during dry seasons, erosion control (during rainy season) and shade reduction of *Albizia lebbeck* tree rows (in the 3rd, 4th and 5th farming seasons) by manually detaching leaves on the basal and upper parts of the stems. Pruning was avoided which could cause root nodule senescence and decay within three weeks of pruning (Dommergues and Ahmad, 1995; Mafuka, 1884; Sanginga and Mulongoy, 1995) thereby inhibiting nitrogen fixation activities of the bradyrhizobium bacteria before formation of new nodules. The detached leaves formed part of the green manure applied to the nine plots for the three treatments:

2, 3 and 4 subsequent foliage from shade control operation was not applied to avoid changing quantity of green manure per hectare.

3.2.13 Water Requirement of the Crop (Potato) During the Dry Season Cropping

The term crop water use (CWU) is often referred to as evapotranspiration (ET). ET consist of two entities, they are transpiration and evaporation. Transpiration refers to water transferred/translocated from the soil through plant roots and stems to the leaves while evaporation is the water evaporated (that disappeared inform of vapour) from water surface, bare soil, rocks as well as dead plant and animals (NMAF, 1985).

ET crop = KC x ETo was employed, where:

ETcrop = Crop water requirement of Evapotranspiration

KC = Crop coefficient (depends on type of crop and growing stage)

ETo = reference crop Evapotranspiration (related to climatic data of the area).

ETo based on evapotranspiraiton was used.

ETo mm/day = Kp x E pan

Where E pan = Pan evaporation (class A PAN/ Colorado pan).

Kp = Pan coefficient

The data on evaporation were sourced from the meteorological station of University of Jos, Plateau State. The frequency of irrigation was every two days.It is pertinent to stress here that soil moisture was maintained at field capacity during tuber initiation / tuberization and bulking but reduced to 50% at maturation. Application of water continued till 7 days to harvest. About 500 – 600 mm of water was applied (Okonkwo *et al*., 1995; Mills, 2001; King et al., 2003).

3.3 PARAMETERS INVESTIGATED

The following parameters were investigated during the five cropping seasons. These parameters include:

3.3.1 Growth Parameters of the Potato

The growth parameters investigated during the study are as follows:

- Percentage seedlings' emergence at 7 and 14 days after planting (7 and 14 DAP) per treatement in all the five cropping seasons by using the formula:

$$\% \text{ Seedlings' Emergence} = \frac{\text{Number of emerged seedings}}{\text{Total nunmber of potato tubers planted}} \times \frac{100}{1}$$

- Plant height (in cm) – was determined by the use of a metre rule from the base (collar region) to the tip of the potato plant (mean of ten randomly selected stands per replicate was obtained)
- Leaf count – by physical counting weekly (the mean was obtained per replicate from ten randomly selected stands).
- Stem count - average number of stems per stand was determined by physical counting (from mean of ten randomly selected stands per replicate).
- Collar girth – was estimated by wrapping a thread round the basal/collar region of the plants stem and stretching the thread on a ruler to know the girth (cm). Ten stands were randomly sampled per mini plot and the mean of the replicates per treatment was obtained.

3.3.2 Yield Parameters of the Potato

- **Tuber Count:** This was obtained by counting the number of tubers per replicate. Mean value from three replicates was recorded for each of the five treatments (per harvest from each of the planting/cropping seasons).

- **Tuber Yield:** Total tuber weight per replicate was obtained by using spring (sensitive) balance mean value from three replicates was recorded for each of the five treatments in kg/6m2, the values in kg/6m2 was then converted to ton per hectare (tha-1).

3.3.3 Physical and Chemical Soil Properties

With regard to the soil profile dug at the site, some of the physical soil properties investigated include depth, condition, nature of the parent material, gradient and boundary between horizons (whether clear, smooth or wavy).Others include colour, presence or absence of mottles, nature of fragments (fine, coarse and their shapes), structure, porosity, consistency and presence or absence of plant roots in each of the horizons, percentage sand, silt, clay and textural class.

The physical properties examined in subsequent samples (pre and post experimental soil samples) are the particle size distribution (sand, silt and clay) and textural class. The chemical properties assessed in the soil samples from the different horizons of the soil profile and soil samples from the experimental site before and after the experiment include the soil pH, % organic carbon, % Nitrogen, available phosphorus (ppm), exchangeable cations (Ca, Mg, K, Na), exchangeable acidity and effective cation exchange capacity (ECEC). The chemical analytical procedures have been described in section 3.2.9

3.4 POST – EXPERIMENTAL SOIL SAMPLE ANALYSIS

Immediately after final harvest at the 5th planting season, soil samples were collected for laboratory analysis by employing the same method of analysis described in pre-experiment soil sample analysis. Samples from the five treatments (T_0, T_1, T_2, T_3 and T_4) were analyzed, that is, three replications per treatment.

A comparison between the results from composite samples of pre and post – (final) experiment soil nutrient analysis was made using the analysis of variance technique (ANOVA). Thus, improvement on the nutrient status of the soil due to the nitrogen fixing activities of *Albizia lebbeck* tree rows and incorporated green manure (of this tree species) was evaluated. This was done after harvest in the 5th farming season so as to know the level of improvement on the soil fertility status at the fifth season. In order to ensure uniform results, all the soil samples were analyzed by the same analyst and with the same sets of chemicals (reagents) at the Soil Science Department of Faculty of Agriculture, Ahamdu Bello University, Zaria and Institute of Agricultural Research, ABU, Zaria.

3.5 DATA COLLECTION

By employing the methods described in sub-sections 3.3.1 and 3.3.2 data were collected on the percentage germination (at 7 and 14 DAP), platn height, leaf count, stem count, collar girth, tuber count, tuber yield (tuber weight) and incidence of bacterial wilt/root rot (at 63 DAP) on the irish potato crops in each of the five cropping seasons.

Regarding the physical and chemical properties of the soil samples collected (as enumerated in sub section 3.3.3), data were collected on the soil profile characteristics, particle size distribution, textural classes, pH, % organic carbon/organic matter (om), total nitrogen, available phosphorus, exchangeable cations (Ca, Mg, K, Na), exchangeable acidity and effective cation exchange capacity (ECEC) before and after planting.

3.6 METHODS OF DATA ANALYSIS

3.6.1 Analysis of Variance Technique

Data collected on the above-mentioned parameters (section 3.5) were subjected to statistical analysis of variance (ANOVA) technique by using F-test. Since the yield (dependent variable) is assumed to be normally distributed, having the same variance in each population, the significance of the varietyes among the population mean can be verified by employing the analysis of variance. Also, tables, graphs, and photographs were used for illustrations.

The analysis of variance (ANOVA) technique was employed in analyzing the data collected in order to find out if there were significant differences among treatments and blocks with regard to the growth and yeild parameters mentioned above. Duncan's Multiple Range Test (DMRT) was used where significant differences were recorded in separating the mean values of the variables so as to help in giving appropriate recommendations. The analyses were carried out by employing statistical analysis software (SAS) package.

3.6.2 Simple Bivariate Correlation and Regression Analyses

The data collected on the growth parameters (plant height, leaf count, stem count and collar girth) and yield parameter (tuber yield/tuber weight/crop yield) were analyzed by employing simple bivariate correlation and regression analyses. These statistical tests were used to assess the nature and strength of the relationships between the pairs of variables considered. Examples of pairs of variables assessed include: Plant height versus yield, leaf count versus yield, stem count versus yield and collar girth versus yield of the crop (Irish potato). The growth parameters were the independent variables while crop yield was the dependent variable. These analyses were done in respect of the rainfed, irrigated and combined seasons. The mean values of the growth parameters were used as the predictor variables while the mean yield of the five cropping seasons was employed as the dependent variable.

Owing to the limitations in these analyses, such as non-consideration of the effects of other variables on the yield (which is the dependent or response variable) while determining the effect of one independent variable on the dependent variable and being poor indicators of the role which the predictor might play in the regression equation (Lindeman et al., 1980). Also, the degree of confidence to be placed on the overall hypothesis cannot be determined and if a large matrix of variables is involved. Thus, the use of the simple bivariate correlation and regression analyses for examining the relationships between pairs of variables will be cumbersome. Then, the need for multiple correlation and regression analyses becomes imperative.

3.6.3 Multiple Correlation and Regression Analyses

The growth and growth parameters of the test crop (Irish potato) are interdependent. Therefore, it requires multi factor types of analysis. Thus, multiple correlation analysis is employed to examine the interrelationship among sets of variables, identify spurious correlations among variables and make known the intervening or suppressing variables (Blalock, 1971; Oche, 1992). Multiple correlation analysis enables one to handle more than two independent variables at a time.

The basic purpose of using multiple regression analysis is to explain the relationship between the dependent variable (yield) and the set of independent variables (plant height, leaf count, stem count and collar girth). The step wise regression analysis (forward selection type) was employed in this study so as to re-examine the variable performances at each step.

In assessing the influence of the growth parameters on the yield of the crop (potato) with regard to the combined seasons, the mean values of the growth parameters were used as the predictor variables while the mean yield of the five cropping seasons was employed as the dependent variable. In carrying out the above analyses, the statistical package for social sciences (SPSS 11.0) was used.

CHAPTER FOUR

RESULTS

4.1 SEEDLINGS' EMERGENCE

Seedlings' emergence of the pre-sprouted potato tubers in all the cropping seasons (CS) which was between May and July, 2004 - 2006 for the rainfed and November – February 2004 – 2005 for the irrigated commenced on the 7th day after planting (DAP) in all the treatments of the five cropping seasons (CS 1-5) at different levels. The highest percentage seedlings' emergence (PSE) was observed in T0 (i.e control) at 1st cropping season (CSI) with a mean value of 70%. The least value was recorded in T2 in the CS2 with a mean of 24.0% at 7 DAP (Table 4, Fig.8, Appendix 1).

Analysis of variance (ANOVA) indicated significant differences at 1% probability level (P=0.01) in CS1. However, there was no block effect. Similarly, significant effects of different treatments on PSE was observed in 2nd, 3rd, and 4th cropping seasons (without block effect) at P=0.01. The significant effects of the treatments on PSE was probably due to different rates of seedlings' emergence and this phenomenon agrees with Nuroboshi (1982) and Kareem, *et al*. (2002) that germination or seedlings emergence occurs in trickekles and not at once. The PSE was however low in the 2nd and 4th cropping seasons (CS2 and CS4) which were dry seasons (irrigated) as compared to CS1, CS3 and CS5 (rainfed). Treatment x season effect (interaction) was not significant. Duncan's Multiple Range Test (DMRT) showed significant differences between the mean values of the treatments (Table 8).

At 14 DAP, the PSE was significantly influenced by the treatments during the CS2 and CS4 (P = 0.01) only while no treatment effect was observed at the

CS1, CS3 and CS5 (Appendix 2). Also, no block effect was recorded in all the cropping seasons. Lack of signficiatn difference among thye treatments at CSI, CSE and CS5 could be as result of little differences in the PSE values of the treatments since farily uniform seedlings' emergence was recorded in the three cropping seasons. T_4 had the highest PSE (96.40%) followed by T_2, T_0, T_1 and T_3 which were 94.20, 94.07, 94.00 and 91.87 (in %) respectively based on combined or overall treatment effect (Fig.8). On seasonal basis, CS5 and CS1 gave the highest mean PSE at 7 DAP (59.5) and 14 DAP (97.73) respectively (Fig.9). Mean values of T_0 and T_3 were not significantly different while those of T_1, T_2 and T_4 showed significant differences (Fig.8).

Similarly, the mean values of CS1, CS3 and CS5 indicated no significant difference while those of CS2 and CS4 did when compared to either CS1, CS3 or CS5 at 7 DAP but at 14 DAP mean PSE values of CS1, CS3 gave no significant difference so also were those of CS4 and CS5. The treatment x season effect was only significant at 5%. However, CS1, CS2 and CS4 or CS1, CS2 and CS5 were significantly different (Fig.9) in terms of their mean values by DMRT (Figs.8 and 9).

4.2 PLANT HEIGHT

There was a significant effect of different treatments on plant height at 63 DAP throughout the five cropping seasons (CSs) Probably due to the different rates of green application and presence or absence of trees of A labbeck. At CS1, CS3 and CS5 (rainfed) T4 had the highest mean value of 66.3, 75.3 and 82.3 cm respectively while CS2 and CS4 (irrigated) recorded 68.3 cm and 80.7cm respectively in all the seasons. Results of the overall (pooled) mean treatment values from the five season indicated that T_4 had 74.60 cm which was followed by T_2, T_3, T_1 and T_0 with mean values of 66.73, 65.47, 62.60 and 56.60cm respectively (Tables 5,8 and 9, Appendix 3). On seasonal basis, CS4 (irrigated) gave the highest mean value out of the 5 CSs (73.27 cm) followed by CS5, CS3, CS2 and CS1 with mean values of 73.07, 66.73, 58.60 and 53.33 cm respectively (Fig.9).

ANOVA showed significant differences among the treatments in all the five CSs at P=0.01 (Appendix 3). On the plant height, DMRT indicated that mean values of T_0, T_1, T_2 and T_4 or T_0, T_1, T_3 and T_4 were significantly different (Fig.9). With regard to the influence of the season and treatment x season on plant height, ANOVA indicated significant effect at 1% and 5% levels of probability respectively. DMRT indicated that CS4 and CS5 were not significantly different while CS1, CS2, CS3 and either CS4 or CS5 (and not both) showed significant differences (Fig.9). However, no block effect was observed among the cropping seasons (CSs).

Table 4: Percentage seedlings' emergence of the pre-sprouted potato tubers at 7 and 14 days after planting (7 and 14 DAP) from five cropping seasons

Treatments	Cropping Seasons(CS)									
	1		2*		3		4*		5	
	7 DAP	14 DAP	7 DAP	14 DAP	7 DAP	14 DAP	7 DAP	14 DAP	7 DAP	14 DAP
T_0	75	97.0	30	93	56	94	33	91	60	89
	70	98.0	28	91	59	93	37	96	53	94
	65	96.0	31	94	60	97	39	92	68	96
$\bar{x}$	70.0	97.0	29.7	92.7	58.3	94.7	36.3	93.0	61.0	93.0
S.D	4.09	0.82	1.25	1.25	1.70	1.70	2.49	2.16	6.16	2.94
T_1	51	99.0	26	90	59	97	29	92	53	90
	56	95.0	23	89	51	98	30	94	48	96
	49	100.0	29	91	54	100	34	90	65	89
$\bar{x}$	52	98.0	26.0	90.0	54.7	98.3	31.0	92.0	55.3	91.7
S.D	2.94	2.66	2.45	0.82	3.30	1.25	2.16	1.63	7.13	3.09
T_2	40	98.3	22	89	44	100	30	93	67	94
	39	94.0	26	87	42	98	28	97	60	91
	44	99.0	24	85	45	96	29	95	50	97
$\bar{x}$	41	97.0	24.0	87.0	43.7	98.0	29.0	95.7	59.0	94.0
S.D	2.16	2.16	1.63	1.63	1.25	1.63	0.82	1.78	6.98	2.45
T_3	57	99.0	33	87	76	96	30	80	58	89
	61	95.0	30	90	70	98	34	84	64	93
	68	99.0	38	86	69	99	35	88	56	95
$\bar{x}$	62.0	97.7	33.7	87.7	71.7	97.7	33.0	84.0	59.3	92.3
S.D	4.55	1.89	3.30	1.70	3.09	1.25	2.00	3.27	3.41	2.49
T_4	60	99.0	25	95	56	96	44	96	63	95
	48	99.0	22	93	55	98	39	98	60	91
	64	99.0	27	97	59	97	40	97	66	96
$\bar{x}$	57.3	99.0	24.7	95.0	56.7	97.0	41.0	97.0	63.0	94.0
S.D	6.81	0.00	2.06	1.63	1.70	0.82	2.16	0.82	2.45	2.16

$\bar{x}$ = Mean (average), SD = Standard Deviation (σ), * Dry Season Croppings. For What T_o - T_4 Denote, See Fig. 6

4.3 LEAF COUNT

The treatments applied brought about some significant effects on the leaf count. The maximum leaf count was observed in T_4 in CS1, CS2, CS3, CS4 and CS5 with mean vallues of 56.7, 68.3, 70.3, 77.7 and 78.7 respectively. Next to T_4 was T_2 in CS1, CS2 and CS5 only but in CS3 and CS4 T_3 was next to T_4 (Tables 5

Table 5: Plant height (cm) and leaf count of Irish potato from five cropping seasons (63 DAP)

Treatments	Cropping Seasons (CS) 2004-2006									
	1		2*		3		4*		5	
	Plant ht	Leaf count	Plant ht	Leaf count	Plant ht	Leaf count	Plant ht	Leaf count	Plant ht	Leaf count
T_0	46	25	46	28	62	36	62	47	64	46
	45	24	48	31	63	39	69	44	60	43
	43	25	50	31	61	35	63	41	67	49
$\bar{x}$	44.7	24.7	48.0	30.0	62.0	36.7	64.7	44.0	63.7	46.0
S.D	1.25	0.47	1.63	1.41	0.82	1.70	3.09	2.45	2.87	2.45
T_1	50	27	54	34	63	50	69	60	71	70
	52	26	55	36	65	54	72	59	68	72
	52	28	58	35	67	53	70	61	73	75
$\bar{x}$	51.3	27.0	55.7	35.0	65.0	52.3	70.3	60.0	70.7	72.3
S.D	0.94	0.82	1.70	0.80	1.63	1.70	1.25	0.82	2.06	2.06
T_2	54	41	60	49	66	63	76	65	79	70
	54	43	59	56	68	60	78	66	76	69
	53	40	57	54	69	62	75	67	77	74
$\bar{x}$	53.7	41.3	58.7	53.0	67.7	61.7	76.3	66.0	77.3	71.0
S.D	0.47	1.25	1.25	2.90	1.25	1.25	1.25	0.82	1.25	2.16
T_3	56	37	61	55	61	64	76	71	71	73
	54	34	62	53	66	65	75	74	73	68
	57	36	64	50	64	63	72	72	70	70
$\bar{x}$	55.7	35.7	62.3	52.7	63.7	64.0	74.3	72.3	71.3	70.3
S.D	1.25	1.25	1.25	2.06	2.06	0.82	1.70	1.25	1.25	1.81
T_4	66	58	66	67	77	70	80	76	86	79
	68	57	69	66	75	72	82	78	79	80
	65	55	70	69	74	69	80	79	82	77
$\bar{x}$	66.3	56.7	68.3	67.3	75.3	70.3	80.7	77.7	82.3	78.7
S.D	1.25	1.25	1.70	1.25	1.25	1.25	0.94	1.25	2.87	1.41

SD = Standard Deviation (σ), ht = height, * Dry Season Croppings. For What T_o - T_4 Denote, See Fig. 6

and 8, Appendix 4). On pooled effect of the five treatments on this variable (from the 5 seasons), the highest value was recorded in T_4 (70.33) followed by T_3, T_2, T_1 and T_0 which respectively had mean values of 60.93, 59.73, 53.47 and 39.86. ANOVA showed significant effect among the treatments at 1% probability level in all the five seasons (Table 8, Appendix 4). Also, the influence of season and treatment x season was significant at P= 0.01. Pertaining to the combined seasonal effect on the leaf count, CS5 had the maximum mean leaf count of 67.67 followed by CS4 (64.00), CS3 (57.00), CS2 (58.60) and CS1 (37.09).

The significant effect observed was probably due to different levels of A.labbeck green manure application and incorporation or absence of its tree rows which must have influenced the nutrient status among the treatments. DMRT indicated that mean values of T0, T1, T2 and T4 were significantly different but T2 and T3 were not. Furthermore, T0, T1, T3 and T4 were significantly different (Fig.8). Similarly, mean separation by DMRT indicated that T0, T1, T3 and T4 were all significantly different from one another (Fig.9).

4.4 STEM COUNT

The stem count was not significantly affected by the different treatments applied. The highest mean main stem count in CS1 was recorded in T0 (3.0) while those of CS2, was observed in T2 and T4 (3.0). In C3, T0, T1 and T2 had the highest mean stem count (3.0 each). The highest value (of mean stem count) was observed in T0 and T1 in the CS4 (3.0 each) while T0, T1 and T3 had the value of 2.7 (each) at CS5. (Table 6,Fig.8, Appendix 5). The pooled means of each of the treatments from the five cropping seasons (CS1 – 5) showed that T0 and T1 were not significantly different, the same trend was applicable to T2, T3 and T4. However, T0 and T2, T1 and T4 differed significantly (Fig.8). Seasonally, CS1, CS2, CS3 were significantly different where as CS2, CS4 and CS5 were not ().

Also, ANOVA indicated no significant effect of blocks and treatment x season on stem count of the Irish potato plants (crops) throughout the cropping seasons. Okonkwo et al. (1995) reported that number of main stems developing on a tuber has correlation with skin surface area of the tuber and yield. Similarly, Beukema and Zaag (1979) reported that potato tubers with single sprout (only one main stem) yield less than tubers with two or more sprouts which later develop to main stems. These support the fact that stem count influences tuber count and tuber yield in potato production.

4.5 COLLAR GIRTH

During the five cropping seasons, collar girth of the potato crops was significantly affected by the treatments (P=0.01). Also, ANOVA showed significant effect of season and treatment x season on the variable (P = 0.01). However, no block effect was observed in the CS1. T4 had the maximum collar girth of 4.5 cm. The same trend was recorded in CS2, CS3, CS4 and CS5 where T4 had 4.70, 4.90, 5.30 and 5.33 respectively (Table 6, Fig. 8, Appendix 6). Regarding the pooled effect of the treatments from the 5 CSs on this variable, T0, T1, T2, T3 and T4 respectively had 2.39, 3.22, 3.76, 3.73 and 4.93 cm with T4 emerging as the treatment with highest mean value. DMRT indicated that T0, T1, T2, and T3 differed significantly while T3 and T4 did not (Fig. 9).

Table 6: Stem count and collar girth (cm) of Irish potato from five cropping seasons (63 DAP)

Treatments	Cropping Seasons (CS)									
	1		2*		3		4*		5	
	Stem count	Collar Girth	Stem count	Collar Girth	Stem count	Collar Girth	Stem count	Collar Girth	Stem count	Collar Girth
T_0	3	2.22	2	2.39	3	2.45	3	2.48	3	2.49
	2	2.25	2	2.40	3	2.40	3	2.40	2	2.44
	3	2.23	3	2.37	3	2.47	3	2.49	3	2.46
$\bar{x}$	2.66	2.230	2.3	2.390	3.0	2.440	3.0	2.950	2.66	2.460
S.D	0.48	0.01	0.47	0.01	0.00	0.03	0.00	0.50	0.48	0.02
T_1	3	2.87	3	2.98	3	3.25	3	3.50	3	3.52
	3	2.80	3	3.00	3	3.31	3	3.49	3	3.50
	3	2.70	2	2.97	3	3.27	3	3.51	2	3.54
$\bar{x}$	3.0	2.790	2.7	2.980	3.0	3.280	3.0	3.500	2.66	3.52
S.D	0.00	0.07	0.47	0.01	0.00	0.03	0.00	0.01	0.48	0.12
T_2	3	3.10	3	3.36	3	3.60	2	4.30	2	4.44
	2	3.12	3	3.38	3	3.59	2	4.35	3	4.38
	2	3.00	3	3.40	3	3.61	2	4.37	2	4.39
$\bar{x}$	2.33	3.070	3.00	3.380	3.0	3.600	2.0	4.330	2.33	4.40
S.D	0.48	0.05	0.00	0.02	0.00	0.01	0.00	0.03	0.47	0.03
T_3	2	3.35	2	3.46	3	3.50	2	4.00	2	4.10
	3	3.39	2	3.48	3	3.52	3	4.10	3	4.13
	2	3.40	3	3.50	2	3.54	2	4.21	3	4.22
$\bar{x}$	2.33	3.380	2.3	3.480	2.66	3.520	2.3	4.100	2.66	4.150
S.D	0.48	0.02	0.47	0.02	0.57	0.02	0.47	0.09	0.48	0.05
T_4	2	4.44	3	4.70	3	4.87	2	5.25	2	5.29
	2	4.47	3	4.81	2	4.79	3	5.30	3	5.30
	2	4.49	3	4.69	3	4.88	2	5.33	2	5.40
$\bar{x}$	2.00	4.470	3.0	4.730	2.66	4.850	2.3	5.290	2.33	5.330
S.D	0.00	0.02	0.00	0.05	0.57	0.04	0.47	0.03	0.47	0.08

SD = Standard Deviation (σ), * Dry Season Croppings. For What T_o - T_4 Denote, See Fig. 6

Table 7: Tuber count (TC) and tuber yield (TY) in ton ha^{-1} of Irish potato from five cropping seasons

Treatments	Cropping Seasons (75 DAP)									
	1		2*		3		4*		5	
	TC	TY	TC	TY	TC	TY	TC	TY	TC	TY
T0	116	5.00	113	5.13	98	5.20	90	5.20	101	5.30
	112	4.90	117	5.24	90	5.30	96	5.10	92	5.26
	109	5.20	99	5.21	89	5.33	101	5.28	98	5.28
$\bar{x}$	111.33	5.03	109.67	5.19	89.67	5.28	95.67	5.22	97.00	5.28
S.D	3.05	0.13	7.72	0.04	28.1	4.49	4.51	0.08	3.74	0.02
T1	115	5.13	114	5.47	91	5.30	93	5.70	99	5.83
	110	5.01	103	5.44	101	5.40	90	5.74	88	5.80
	102	5.10	116	5.39	92	5.42	98	5.78	86	5.91
$\bar{x}$	109.00	5.08	111.0	5.43	94.67	5.37	93.67	5.74	91.00	5.85
S.D	5.35	0.05	5.72	0.60	0.05	3.30	5.72	0.03	5.72	1.72
T_2	135	8.33	150	9.75	155	9.16	146	9.78	160	9.67
	149	8.40	152	9.72	145	9.10	140	9.72	163	9.65
	133	8.36	159	9.69	154	9.14	142	9.70	159	9.58
$\bar{x}$	139.00	8.36	153.67	9.72	151.33	9.13	142.67	9.73	160.67	9.63
S.D	7.12	0.03	3.86	0.02	0.03	1.85	2.49	0.03	33.3	0.04
T_3	119	8.13	130	9.00	124	8.67	110	8.95	146	9.08
	108	8.00	125	8.70	110	8.56	98	8.86	140	9.01
	112	7.81	128	8.80	120	8.61	102	8.90	142	8.96
$\bar{x}$	113.00	7.98	127.67	8.83	118.0	8.61	103.33	8.90	142.67	9.02
S.D	4.55	0.13	2.05	0.13	5.85	0.05	4.99	0.04	2.51	2.96
T_4	165	9.37	164	10.42	93	9.80	86	9.93	165	12.00
	161	9.40	160	10.44	90	9.77	84	9.01	161	11,88
	156	9.32	158	10.38	95	9.82	91	9.88	159	12.01
$\bar{x}$	160.07	9.36	160.67	10.41	92.67	9.80	87.0	9.61	161.67	11.96
S.D	3.73	0.03	2.50	0.03	2.05	0.08	2.94	0.42	2.51	0.06

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$\bar{X}$ = Mean (average), SD = Standard Deviation (σ), * Dry Season Croppings. For What T_o - T_4 Denote, See Fig. 6

Similarly, combined seasonal effects from the five seasons showed that CS1, CS3 and CS5 (rainfed) respectively had mean values of 3.19, 3.54 and 3.97 cm (their mean value was 3.57 cm) while those of CS2 and CS4 (irrigated) got mean values of 3.39 and 3.94 cm respectively (their mean value is 3.67 cm). DMRT indicated that the means of T0, T1, T2, and T3, and T4, were significantly different (Fig.9). The significant difference observed could be as a result of the different nutrient status of the treatments which brought about different growth rates and development.

4.6 TUBER COUNT

Tuber count was significantly influenced by the treatments during the 3-year study, in CS1, CS3 (at P=0.01) and CS5 (at P=0.05). There was no significant effect of the treatments on the variable in CS2 and CS4 (which were dry seasons) due to the fact that the values in CS2 and CS4 almost the same (160.7 and 161.7 respectively). The maximum tuber count recorded in T4 at CS1 was (160.7),CS2 (160.7) and CS5 (161.7) while T2 had the maximum mean value in CS3 and CS4 (144 and 142 respectively) during the study (Table 7, Figs.7 and 8, Appendix 7).

Pertaining to the pooled treatment effect on the variable, T2, T4, T3, T0 and T1 had mean values of 149.47, 132.42, 120.93, 100.67 and 99.87 respectively. Mean values of T0 and T1 did not differ significantly while those of T2, T3 and T4 (and either T0 or T1 considered at different times) showed that they significantly differed (Fig.9). Similarly, considering the seasonal effect on the tuber count, T0, T1,T2, T3 and T4 had 6.47,132.54,109.13,104.47 and 130.50

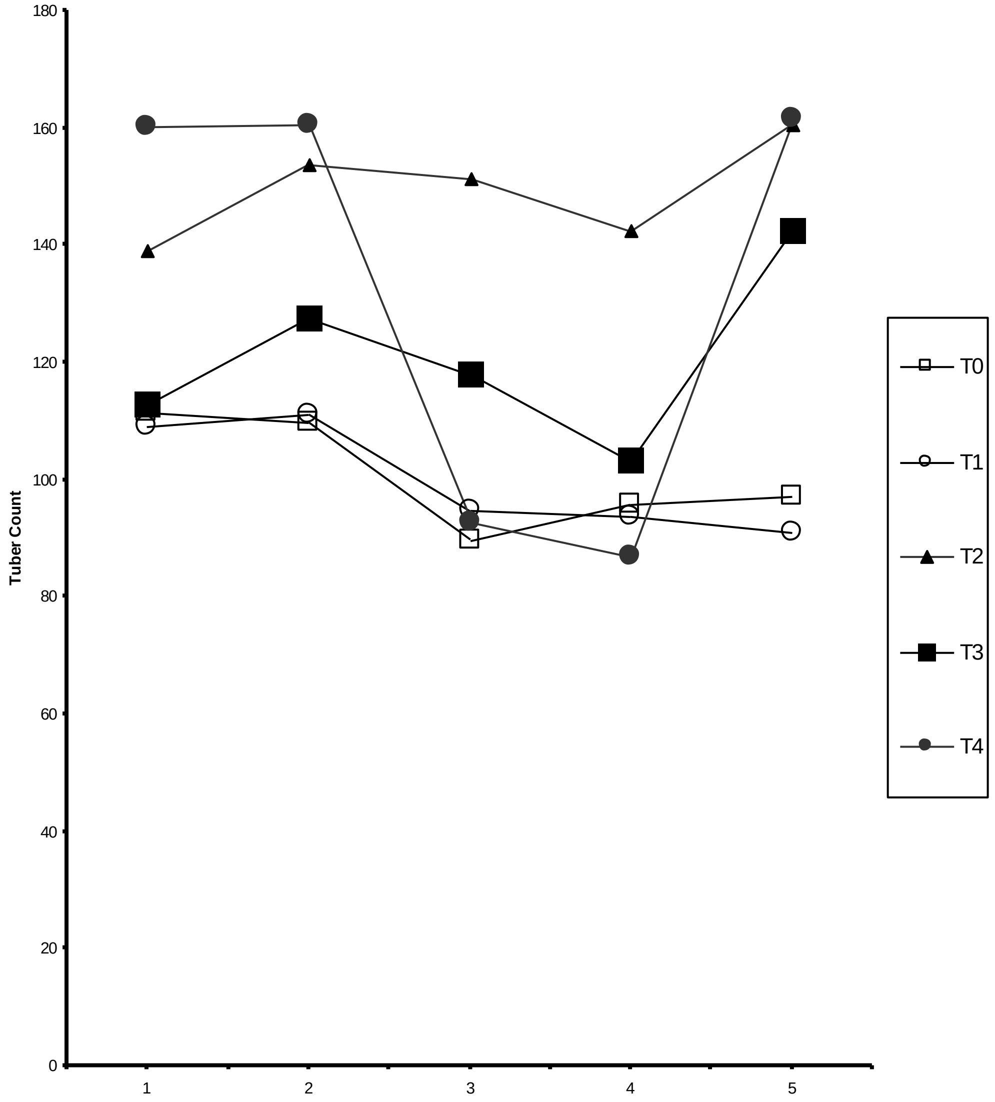

Fig. 7: Tuber Count of Irish Potato from Five Cropping Seasons (75 DAP)

respectively. Thus, the maximum tuber count was recorded in the 2nd cropping season (CS2) while the least was 4th cropping season (CS4). ANOVA indicated significant effect of season and treatment x season (P=0.05) on the variable. However, no block effect was recorded. The mean value of CS1, CS3 and CS5 (rainfed) was 122.03 while those of CS2 and CS4 (irrigated) was 118.51. DMRT indicated that the mean values of CS1 and CS3 differed significantly while those of CS1, CS2 and CS5 did not. Also, the mean values of CS3 and CS4 did not show significant differences (Fig.9). It is pertinent to stress here that the tuber sizes in T0 and T1 were smaller than those produced in T4, T2 and T3. However T4 had the largest % quantity of tubers with large sizes which were > 50mm in diameter followed by T2, T3, T1, and T0. Generally the potato tubers varied from < 30 mm to > 50 mm in diameter (Plate 4).

4.7 TUBER YIELD

In all the five cropping seasons, treatments and seasons had significant effects on tuber yield at 1%. In the CS1, T4 had the maximum tuber yield of 9.36 ton/ha-^{1}. The trend was not different in the CS2, CS3, CS4 and CS5 where T4 emerged as the treatment with highest tuber yield with mean values of 10.41, 9.80, 9.73 and 11.96 ton/ha-1 respectively. This could be due to the fact that T4 had the highest level of green manure application in addition to the tree rows of A. labbeck which must have brought about highest nutrient status for better growth, development and yield. Next to T4, was T2 then T3, T1 and T0 (Tables 7 and 8, Fig.10,Appendix 8)..

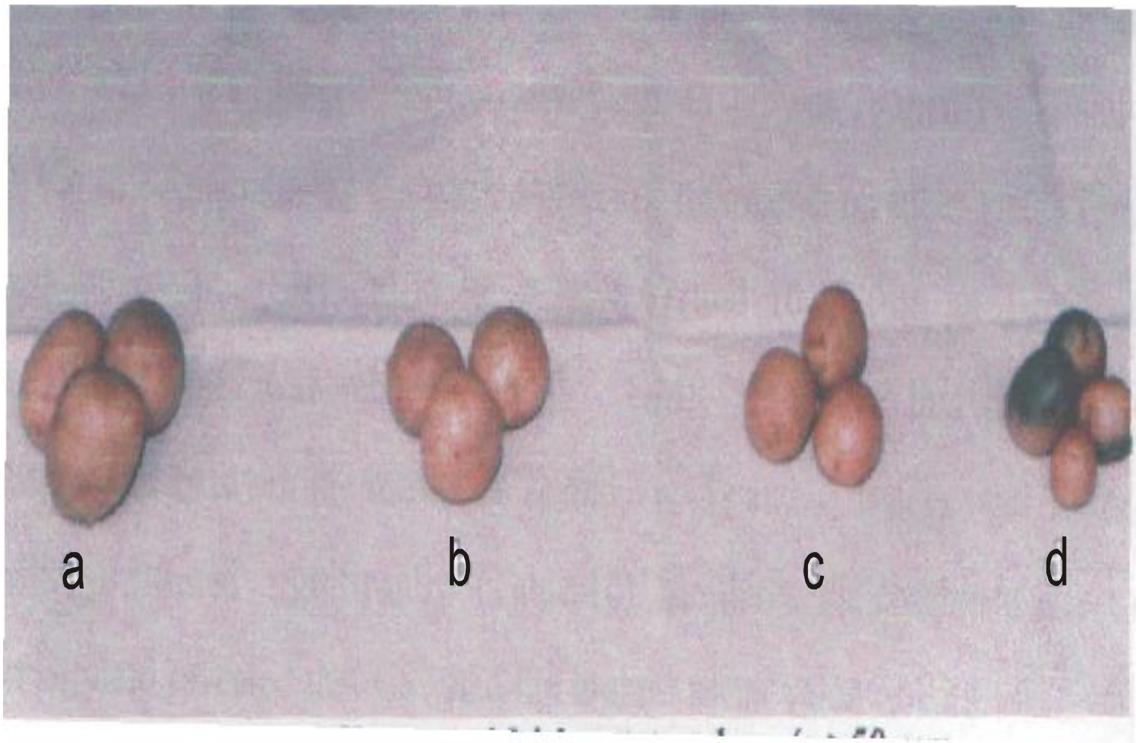

Plate 4: Different Sizes of Harvested Irish Potato Tubers (a:>50 mm, b:40-50 mm, c: 30-40 mm, d: <30 mm in Diameter).

Table 8:Growth and yield parameters of Irish potato in the 1st, 2nd, 3rd4th and 5th cropping season.

Treatments			Growth Parameters				Yield Parameters	
(5)	%S.E. (7 DAP)	%S.E (14 DAP)	Plant Ht (cm)	Leaf Count	Stem Count	Collar Girth(cm)	Tuber Count	Tuber Yield (t/ha)
1st Season								
T_0	70.0a	97.0a	44.7d	24.7d	3.0a	2.2e	112.3c	5.03d
T_1	52.06b	98.0a	51.3c	27.0d	2.7ab	2.8d	109.0c	5.08d
T_2	41.0c	97.0a	53.7c	41.3b	2.3ab	3.07c	139.0b	8.36b
T_3	62.0ab	97.7a	55.7b	35.7c	2.3ab	3.4b	113.0c	7.98c
T_4	57.3b	99.0a	66.3a	56.7a	2.0b	4.5a	160.7a	9.36a
2nd Season								
T_0	29.7b	92.7ab	48.0e	30.0c	2.3b	2.3e	79.7d	5.19e
T_1	24.3c	90.0ab	55.7d	35.0c	2.7a	3.0d	111.0c	5.43d
T_2	24.0c	87.0b	58.7c	53.0b	3.0a	3.4c	153.7a	9.72b
T_3	33.7a	87.7b	62.3b	52.0b	2.3b	3.5b	127.7b	8.90c
T_4	24.7c	95.0a	68.3a	67.3a	3.0a	4.7a	160.7a	10.41a
3rd Season								
T_0	58.3b	94.7b	62.0c	36.7d	3.0a	2.4e	92.3c	5.30e
T_1	54.7b	98.3a	65.0bc	52.3c	3.0a	3.3d	94.7c	5.40d
T_2	43.7c	98.0a	67.7b	61.7b	3.0a	3.6c	151.7a	9.13b
T_3	71.7a	97.7ab	63.7c	64.0b	2.7a	3.5b	118.0b	8.61c
T_4	56.7b	97.0ab	75.3a	70.3a	2.7a	4.9a	93.7c	9.80a
4th Season								
T_0	36.3b	93.0ab	64.7d	44.0e	3.0a	2.5e	95.7bc	5.22d
T_1	31.0c	92.0b	70.3c	60.0d	3.0a	3.5d	93.7c	5.74c
T_2	29.0c	95.0ab	76.3b	66.0c	2.0b	4.3b	142.7a	9.61a
T_3	33.0bc	84.0c	74.3b	72.3b	2.3b	4.1c	103.3b	8.90b
T_4	41.0a	97.0a	80.7a	77.7a	2.3b	5.3a	87.0d	9.73a
5th Season								
T_0	61.0a	93.0a	63.7d	46.0c	2.7a	3.1e	97.0c	5.28e
T_1	55.3a	91.7a	70.7c	72.3b	2.7a	3.5d	91.0c	5.85d
T_2	59.0a	92.3a	77.3b	71.0b	2.3a	4.4b	160.7a	9.63b
T_3	59.3a	94.0a	71.3c	70.3b	2.7a	4.2c	142.7b	9.02c
T_4	63.0a	94.0a	82.3a	78.7a	2.3b	5.3a	161.7a	11.96a

S.E. = Seedlings'EmergenceMean values with the same letters are not significantly different at 5% level fby Duncan's Multiple Range Test (DMRT).See Fig.6 for what To-T_4 denote.

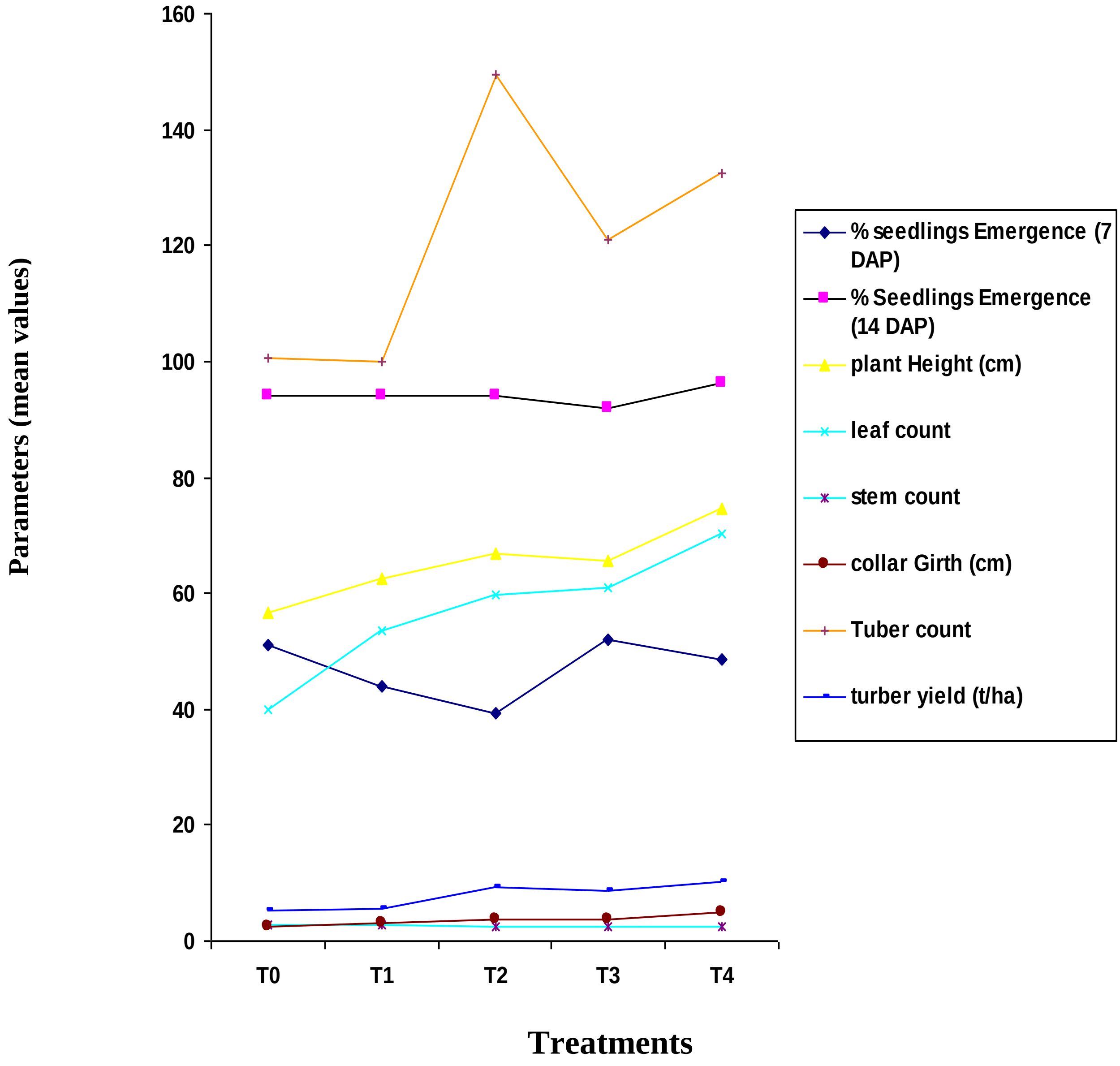

Fig. 8: Treatment Effects on Growth and Yield Parameters of Irish Potato Crop

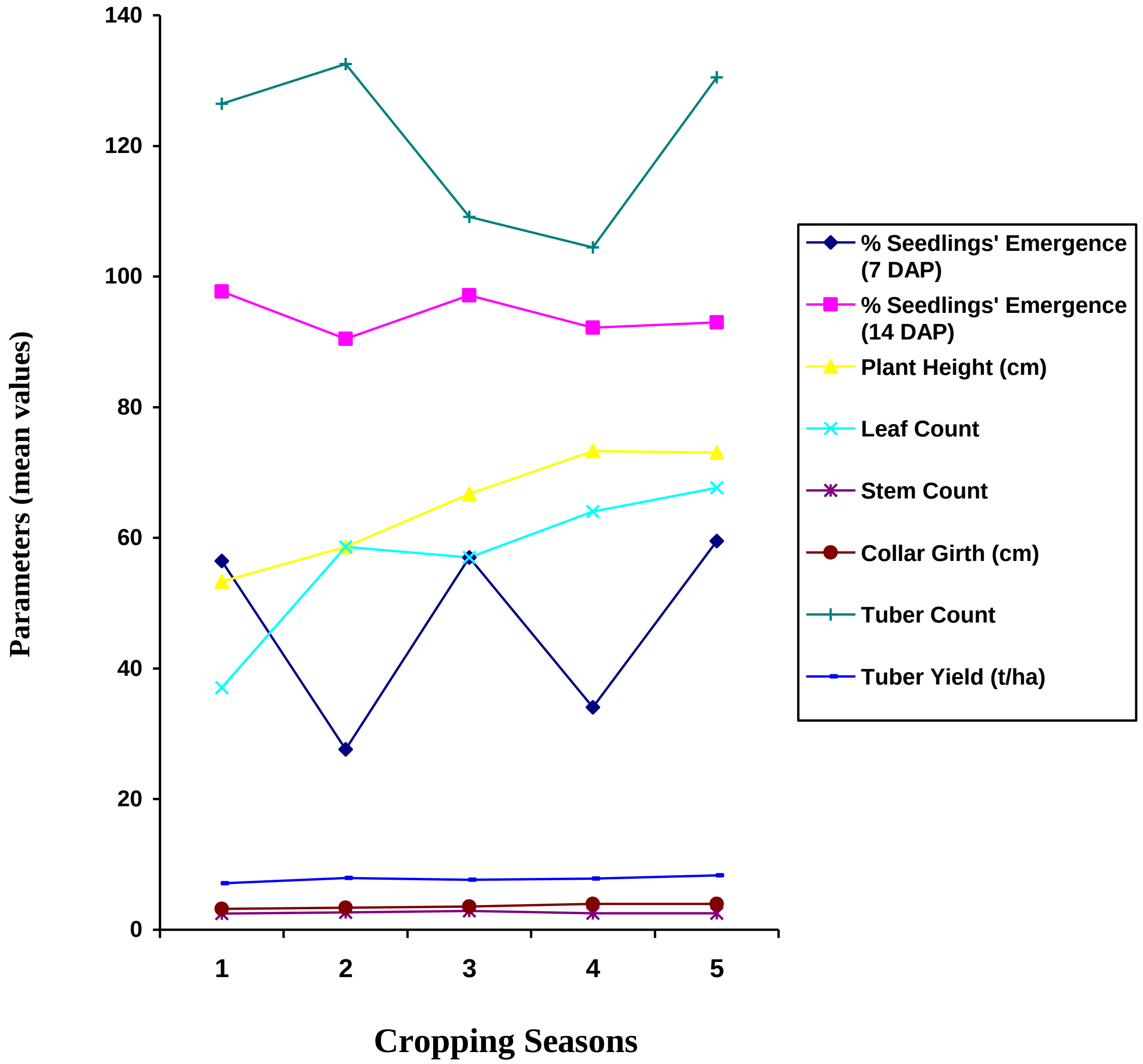

Fig. 9: Seasonal Effects on Growth and Yield Parameters of Irish Potato

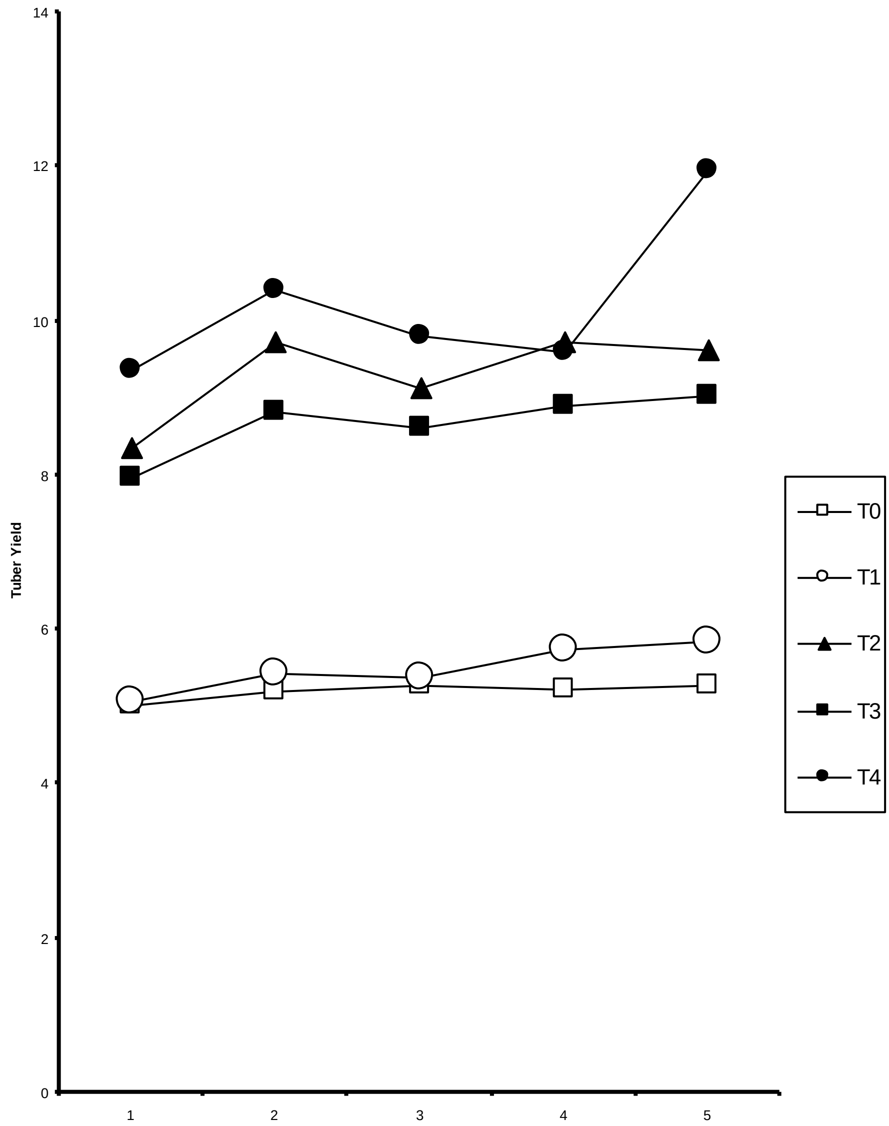

Fig. 10: Tuber Yield of Irish Potato from Five Cropping Seasons (75 DAP)

On pooled effect of treatments on tuber yield, T0, T1, T2, T3 and T4 had mean values of 5.20, 5.49, 9.31, 8.67 and 10.23 (ton ha^{-1}) respectively. Thus, the maximum yield was recorded in T4. DMRT indicated that there were no significant differences between the means of T0 and T1, T2 and T3 but T4 and T0 or T4 and T1 or T4 and T2 differed significantly (Fig.8). Similarly, the combined effect of season on the tuber yield revealed that CS5 had the highest mean value of 8.34 t ha^{-1} while the values for the remaining four (4) cropping seasons CS1, CS2, CS3 and CS4 were 7.16, 7.92, 7.63 and 7.84 ha^{-1} respectively. Mean values of all the five treatments were significantly different (by DMRT).

It is pertinent to highlight here that the mean value of the CS1, CS3 and CS5 (rainfed) was 7.11 ton ha^{-1} while CS2 and CS4 (irrigated) had a mean value of 7.88 ton ha-1 (Table 9). It was also observed that this potato variety (bertita) attained maturity within two months (60 days) unlike other varieties that take longer periods 3-4 months (90 – 120 days). The colour of the few tubers that were exposed to light before they were discovered and covered with soil changed from brown to green (Plate 4d).

4.8 RELATIONSHIPS BETWEEN THE GROWTH PARAMETERS AND CROP YIELD

As earlier stated (section 3.6.2) the interplay of the growth parameters and their relationships with the crop yield were examined by employing the multiple correlation analysis (of growth and yield parameters). Results from the correlation matrices for the rainfed, irrigated and combined cropping seasons (Tables 9, 10 and 11) indicated high correlation between the growth parameters and yield.

For instance, a very high correlation ($r = 0.954$) was observed between collar girth and yield and proved significant at 1% level in respect of the rainfed cropping seasons. Leaf count and plant height had positive correlation coefficients (r) values of 0.905 and 0.881 respectively and proved significant at 5% level while that of stem count and yield showed a negative correlation (r = -0.891). The relationships between collargirth and other growth parameters (plant height, leaf count and stem count) also indicated high positives correlation while that of stem count and the remaining independent variables showed negative correlation but were significant at 5% (Table 9).

However, leaf count had the highest level of correlation with the crop yield (r = 0.956) and was significant at 1% level in the irrigated (dry) cropping seasons. Correlation was significant at 5% level in respect of plant height, collar girth and stem count versus yield, though that of stem count was negative. Also, collar girth and plant height were positively correlated at 1% level (Table 10). Correlation matrix of the growth and yield parameters for the combined seasons (Table 11) indicated that only leaf count had a high positive correlation with yield (r = 0.938) at 1% level. Interrelationships among the independent variables showed that leaf count and plant height (5%), collar girth and plant height (1%) and collar girth and leaf count were positively correlated (Table 11). Furthermore, simple bivariate and multiple correlation statistics were employed in a bid to examining the infleucne of each of the independent variable

Table 9: Correlation matrix for the growth and yield parameters of Irish potato (rainfed)

	Y	X_1	X_2	X_3	X_4
Y	1.000				
X_1	0.881*	1.000			
X_2	0.905*	0.955*	1.00		
X_3	-0.891*	-0.898*	-0.803*	1.000	
X_4	0.954*	0.970**	0.956**	-0.941**	1.000

** Significant at 1%, * Significant at 5%

Variable Description:

Y = Crop Yield (t/ha) Y = Tuber Yield (dependent variable), X_1 – X_4 = Independent variables.

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar Girth

Table 10: Correlation matrix for the growth and yield parameters Irish potato (irrigated)

	Y	X_1	X_2	X_3	X_4
Y	1.000				
X_1	0.911*	1.000			
X_2	0.956**	0.981**	1.000		
X_3	-0.573•	-0.300•	-0.471•	1.000	
X_4	0.897*	0.984**	0.965**	-0.246•	1.000

* Significant at 5 % , ** Significant at 1 % •Not Significant

Y = Dependent variable, X_1 – X_4 = independent variables

Variables' Description

Y = Crop Yield (t ha^{-1})

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar girth

Table 11: Correlation matrix of the growth and yield parameters of Irish potato(combined cropping seasons)

	Y	X_1	X_2	X_3	X_4
Y	1.000				
X_1	0.720•	1.000			
X_2	0.938**	0.866*	1.000		
X_3	0.052•	0.053•	0.193•	1.000	
X_4	0.785•	0.977**	0.873*	-0.126•	1.000

* Significant at 5 %, ** Significant at 1 %, •Not Significant

Y = Dependent variable, X_1 – X_4 = independent variables

Variables' Description

Y = Crop Yield (t ha^{-1})

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar girth

(growth parameters) on yield. Preliminarily, bivariate correlation technique was used to investigate the relationship of individual growth parameters with yield in the rainfed, irrigated and combined cropping seasons. Then, multiple correlation analysis was employed in order to get more information on the interrelationship among variables (Tables 9 – 11).

The results obtained indicated that plant height positively correlated with yield in both rainfed and irrigated cropping seasons likewise leaf count and yield, collar girth and yield while stem count and yield were negatively correlated (Tables 12 and 13). The trend was however different in the combined seasons where only the leaf count had very high positive correlation with irish potato yield at 1% level. Though other independent variables showed positive correlation with yield but not at significant level (Table 14).

Table 12: Bivariate correlation/regression: growth parameters versus Irish potato yield (rainfed)

Variables	Correlation Coefficient 'r'	Intercept 'a'	R_2	p Value
Y vs X_1	0.881*	0.310	0.777	0.048
X_2	0.905*	0.173	0.820	0.034
X_3	-0.891*	-5.982	0.794	0.043
X_4	0.954**	2.308	0.910	0.012

** Significant at 1%, *Significant at 5%

Variables' Description

Y = Crop Yield (t/ha^{-1})

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar girth

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

Table 13: Bivariate correlation / regression: growth parameters versus Irish potato yield (irrigated)

Variables		Correlation Coefficient 'r'	Intercept 'a'	R^2	p value
Y vs	X_1	0.911*	0.304	0.830	0.031
	X_2	0.958**	0.150	0.913	0.011
	X_3	-0.573•	-6.314	0.328	0.313
	X_4	0.897*	2.313	0.804	0.039

** Significant at 1% , * Significant at 5%, • Not Significant

Variable Description

Y = Crop Yield (ton/ha)

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar girth

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

Table 14: Bivariate correlation/regression: combined effects of growth parameters of Irish potato versus yield (combined cropping seasons)

Variables		Correlation Coefficient 'r'	Intercept 'a'	R^2	p value
Y vs	X_1	0.720•	0.036	0.519	0.170
	X_2	0.938**	0.036	0.881	0.018
	X_3	0.052•	0.148	0.003	0.933
	X_4	0.785•	1.040	0.616	0.116

** Significant at 1%, •Not Significant

Variable Description

Y = Crop Yield (t/ha^{-1})

X_1 = Plant Height

X_2 = Leaf Count

X_3 = Stem Count

X_4 = Collar girth

Y = Tuber yield (dependent variable)

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

Based on the results from the multiple regression analysis on growth parameters versus yield (of Irish potato) in the rainfed cropping seasons, collar girth had high significant effect (influence) on the yield. The intercept ‘a’ and coefficient of determination (R^2) were 2.308 and 0.910 respectively. It accounted for 91.0% of the variable in tuber yield at 1% level (Table 15). The leaf count had highest R^2 (0.913) at 1% level of significance in the irrigated cropping seasons (Table 16). Similarly, the leaf count accounted for 88.1% of the variation in the crop yield (R^2 = 0.881) at 5% level of significance for the combined cropping seasons. The remaining growth parameters (plant height, stem count and collar girth) had no significant effect on the crop yield (Table 17) for the combined cropping seasons.

Table 15: Multiple regression and correlation analyses: growth parameters versus yield of Irish potato (rainfed)

Variables	‘a’	Std Error	Multiple R	R Square	F-Value	P Value
X_1	0.310	0.096	0.881	0.777	10.450	0.048*
X_2	0.173	0.047	0.905	0.820	13.653	0.034*
X_3	-5.982	1.761	-0.891	0.794	11.540	0.0426*
X_4	2.308	0.419	0.954	0.910	30.424	0.012**

* Significant at 5%, ** Significant at 1%

Variable Description

X_1 denotes Plant Height

X_2 denotes Leaf Count

X_3 denotes Stem Count

X_4 denotes Collar girth

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

Table 16: Multiple regression and correlation analyses: growth parameters versus yield of Irish potato (irrigated)

Variables	'a'	Std Error	Multiple R	R Square	F-value	P.value
X_1	0.304	0.080	0.911	0.830	14.645	0.031*
X_2	0.150	0.027	0.956	0.913	31.631	0.011**
X_3	-6.314	5.214	0.573	0.328	1.467	0.313•
X_4	2.313	0.659	0.897	0.804	12.335	0.039*

* Significant at 5%, ** Significant at 1%, •Not significant

Variable Description

X_1 denotes Plant Height

X_2 denotes Leaf Count

X_3 denotes Stem Count

X_4 denotes Collar girth

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

Table 17: Multiple regression and correlation analyses: combined seasonal effects versus yield of Irish potato (combined cropping seasons)

Variables	'a'	Std Error	Multiple R	R Square	F-value	P.value
X_1	0.036	0.020	0.720	0.519	3.231	0.170•
X_2	0.036	0.008	0.720	0.881	22.120	0.02*
X_3	0.148	1.623	0.052	0.003	0.008	0.933•
X_4	1.039	0.474	0.765	0.616	4,809	0.116•

* Significant at 5%, • Not significant

Variable Description

X_1 denotes Plant Height

X_2 denotes Leaf Count

X_3 denotes Stem Count

X_4 denotes Collar girth

a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variable (plant height,leaf count,collar girth and stemcount]

R^2 = Coefficient of determination = proportion of variation in the dependent variable which is explained by the independent variable.

4.9 INCIDENCE OF BACTERIAL WILT / BACTERIAL SOFT ROT

Bacterial wilt (caused by *Pseudomonas solanaceaurum*) and bacterial soft rot (caused by *Erwinia carotovara*) were observed during the five cropping seasons. Significant effect of the two diseases on tuber yield was observed among the cropping seasons. Thus, its overall effects on the treatements, season and treatment x season were indicated by ANOVA at 1% probability level. T3 was most affected in CS1, (3.0) while T0 was 2.0 and T1, T2 and T4 (1.0 each) were the least affected. CS1, CS3 and CS5 (rainfed) were more affected than the irrigated CS2 and CS4 (Table 18, Fig. 11 and Appendix 9). The effect of diseases could have been more severe if the cropping season extended beyond the 2nd week of July, since the peak period of rainfall was between the 3rd of July and August (Table 3).

Table 18: Incidence of bacterial wilt/brown rot on Irish potato in the five cropping seasons.

Treatments	Cropping seasons				
(s)	1	2*	3	4*	5
T_0	1	0	3	0	3
	2	0	3	0	2
	3	0	3	0	3
$\bar{x}$	2.0	0.0	3.0	0.0	2.7
S.D	0.82	0.00	0.00	0.00	0.66
T_1	1	0	1	0	1
	1	0	1	0	0
	1	0	1	0	0
$\bar{x}$	1.0	0.0	1.0	0.0	0.3
S.D	0.00	0.0	0.00	0.00	0.66
T_2	1	1	2	2	3
	1	2	2	2	3
	1	0	2	2	1
$\bar{x}$	1.0	1.0	2.0	2.0	2.3
S.D	0.00	0.58	0.00	0.00	0.18
T_3	3	2	1	2	2
	3	3	2	1	0
	3	1	3	0	1
$\bar{x}$	3.0	2.0	2.0	1.0	1.0
S.D	0.00	0.82	0.82	0.58	0.58
T_4	1	0	2	0	3
	2	0	3	1	3
	0	0	1	2	3
$\bar{x}$	1.0	0.0	2.0	1.0	3.0
S.D	0.58	0.00	0.82	0.58	0.00

$\bar{x}$ = Mean, SD = Standard Deviation, * Dry Season Croppings.

To = Plot without green manure and trees rows of *Albizia lebbeck* (Control)
T1 = Plot without green manure and but with tree rows of *A. lebbeck*
T2 = Plot with green manure at 5 ton/ha without tree rows of *A. lebbeck*
T3 = Plot with green manure at 5 ton/ha and tree rows of *A. lebbeck*
T4 = Plot with green manufe at 10 ton/ha without tree rows of *A. lebbeck*

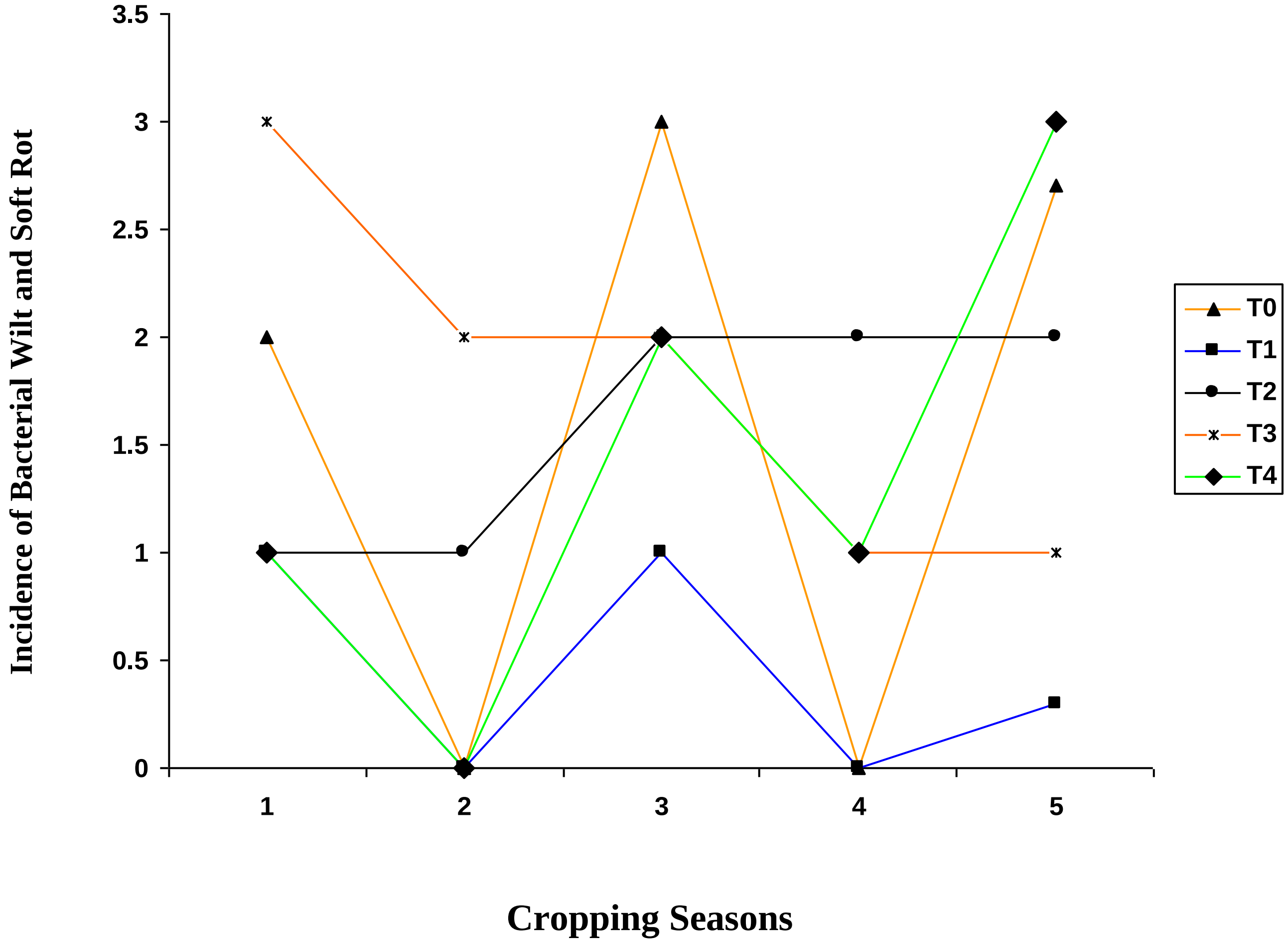

Fig. 11: Incidence of Bacterial Wilt and Soft Rot on Irish Potato Production from Five Treatments and Five Cropping Seasons (Mean Values)

Plate 5: Plots of *Albizia lebbeck* tree rows, some weeks after harvest of Irish potato crops from the alleys.

4. 10 *ALBIZIA LEBBECK* TREE ROWS AFTER FINAL HARVEST OF THE IRISH POTATO CROPS

The flourishing nature of the *Albizia lebbeck* tree rows was observed after the harvest of the potato (from the last cropping season).Trees in agroforestry farms are regularly pollarded or pruned during cropping season to prevent shading and to serve as source of organic manure to the soils. Selective felling of the trees for fuelwood, poles or forage is also a common practice in alley cropping farms where trees are maintained to maturity and not as hedges or shrubs (Plate 5).

4.11 SOIL PROPERTIES

4.11.1Morphological and Physical Properties

The soil profile pit dug at the experimental site in May, 2004 prior to land preparation for planting revealed that the soil was characterized by A-B-C profiles. The soil profile was relatively deep and moist. The B-C horizons extend to a depth of over 130 cm and the parent material is granite.There is evidence of slight sheet erosion and the gradient is about 2%.There were also evidences of human activities in form of cultivation.

The 0-15 cm depth (A_P1 horizon) has a clear and smooth boundary with the A2 horizon. It is an ochric epipedon with very dark brown colour (10 YR 2/3) and there are no mottles and coarse fragments. The structure is of weak grade, medium sized and sub- angular blocky in form. With regard to porosity, there are few pores which are fine and interstitial. It is of firm consistency and contains many fine roots (1 – 2 mm).

The 15 – 30 cm depth (A2 horizon) also has a clear and smooth boundary with the Bw1 horizon and it is a cambic horizon. There are no coarse fragments, the structure is moderate, medium sized and angular blocky type. It has common pores that are fine and medium sized. It is of firm consistency and there are common fine roots.

The next horizon is the 30 – 41 cm depth (Bw3 horizon). It has a clear and wavy boundary with the underlinying horizon and it is an argillic horizon (accumulated silicate clays), no mottling, the horizon is gravelly, of moderate structure, medium size and angular in form. It has few and fine pores, of friable consistency. It has patchy and continuous cutans and thus there is presence of very few and very fine roots.

The 65 – 130 cm depth (BCt1 horizon) of the profile is characterized by a clear and wavy boundary with the underlinying horizon and it is an argillic horizon. It has coarse, distinct and prominent mottles. It is slightly gravelly, weak in grade, medium sized structure with angular blocky type. Few fine pores are present with interstitial tubular types. It is of slightly firm consistency with continuous/broken and moderately thick cutans without the presence of roots.

The depth above 130 cm (BCt2 horizon) is slightly gravelly, with few medium sized pores and of firm consistency. It has continuous and moderately thick cutans and there is no presence of roots.

The results of particle size analysis show that the soils developed in granites are mainly sandy clay loam and it is the dominant textural class. Apart from 0 -15 cm (AP1 Horizon) and 65 - 130 cm (BCt horizon) most horizons comprise 30-45 % clay content (Table 19). It is noted that the clay content of the soil increases down the soil profile. This is a characteristic that is very unique of Alfisols and Ultisol. Since the base saturation % of the soils are higher than 50%, they are Alfisoils. Olowolafe (2007) has earlier classified the soil as an Alfisoil.

Table 19: Some physical and chemical properties of the soil profile dug at the experimental site (before planting)

Profile No.	Horizon/ depth(cm)	Sand (%)	Silt (%)	Clay (%)	Textural class USDA*	pH - H_20	pH - KCl	0C (%)	TN (%)	Avail P (ppm)	Ca	Mg	K	Na	E.A.	ECEC
											← cmol (+)Kg^{-1} →					
1	Ap1 (0-15)	59	22	19	SL	5.5	3.7	0.958	0.105	27.16	2.60	0.56	0.15	0.23	0.60	4.14
2	A2 (15-30)	57	20	23	SCL	4.7	3.4	0.638	0.088	1.75	3.40	0.99	0.21	0.36	1.80	6.76
3	Bw 1 (30-41)	52	18	30	SCL	4.1	3.5	0.479	0.053	1.05	3.20	0.72	0.21	0.15	2.60	8.88
4	Bw 2 (41-65)	49	18	33	SCL	4.0	3.6	0.219	0.070	2.40	3.40	0.35	0.14	0.21	0.80	4.90
5	BCt 1 (65-130)	40	22	38	SL	4.3	3.8	0.120	00.088	2.17	4.20	0.45	0.17	0.17	0.40	5.39
6	BCt 2 (>130)	23	32	45	CL	3.6	3.5	0.120	0.070	0.63	4.60	0.48	0.19	0.17	2.80	8.24

SL = Sandy Loam, SCL = Sandy Clay Loam, CL = Clay Loam, E.A.=Exchangeable Acidity

4.11.2 Chemical Properties

Generally, the pH is low (both:pH (H20) and pH (KCl). The soil pH (H_20) ranges between 3.6 and 5.5 with Bt (41 – 65 cm depth) having the lowest value of 4.0. The pH (H_20) seems to decrease down the profile. The percentage organic carbon ranges from 0.120 to 0.958%. The organic matter contents of the soils are low.Olowolafe and Dung (2000) earlier noted that organic matter of soils derived from biotite – granite soils in the area is low (Table 19). Similary, the nitrogen is low (0.053 – 0.105%). Available phosphorus is also generally low because the value below 15 ppm is considered as low (Olowolafe, 2002) with the exception of AP1 (0 – 15 cm) horizon which had 27.16 ppm. The remaining horizons (15 – 130 cm and above) had values that ranged between 0.63 and 2.40 ppm.

Ca and Mg were the dominant exchangeable cations at the exchange site. The Ca value range was between 2.60 and 4.60 while Mg values ranged from 0.35 – 0.99 as opposed to K whose values varied from 0.15 to 0.36 9 in cmol (+) Kg^{-1}) in all the horizons. Sodium (Na) content ranged from 0.15 to 0.36 cmol (+) Kg^{-1}. The exchangeable acidity values fell between 0.4 and 2.80 while that of ECEC varied from 4.14 to 8.88 cmol (+) Kg^{-1} (Table 19).

4.12 PRE AND POST EXPERIMENTAL SOIL SAMPLE ANALYSES

4.12.1 Physical Properties

Particle size analysis of the three randomly selected locations at the experimental site (prior to planting which served as three replicates) indicates that the soils in the granite area are predominantly sandy clay loam (Table 20).

The 0 –10 cm depth indicated that the soil had a very high percentage of sand (61%). The silt and clay contents were 26% and 13% respectively. This agrees with Olowolafe (2007) who observed that the soil in the study area is an Alfisol which is characterized by increase in clay content with increase in soil depth. For the 10 – 25 cm and 25 – 40 soil depths, the soil texture is sandy clay loam due to the fact that the sand had the highest percentage and this was followed by clay.

It was observed that the sand and silt proportions decreased with increasing depth (from 0 – 10, 10 – 25, 25 – 40 cm depth) while the clay content increased with depth. For instance, the 0 – 10 cm depth had 13% clay which increased to 23 and 33 percent respectively and at 10 – 25 cm and at 25 – 40 cm depths. This supports the classification as Alfisol owing to increase in clay content with depth which is an important property of Alfisol. However analysis of variance indicated no significant difference in the % clay at the three soil depths (Table 20, Fig.12 and Appendix 81).

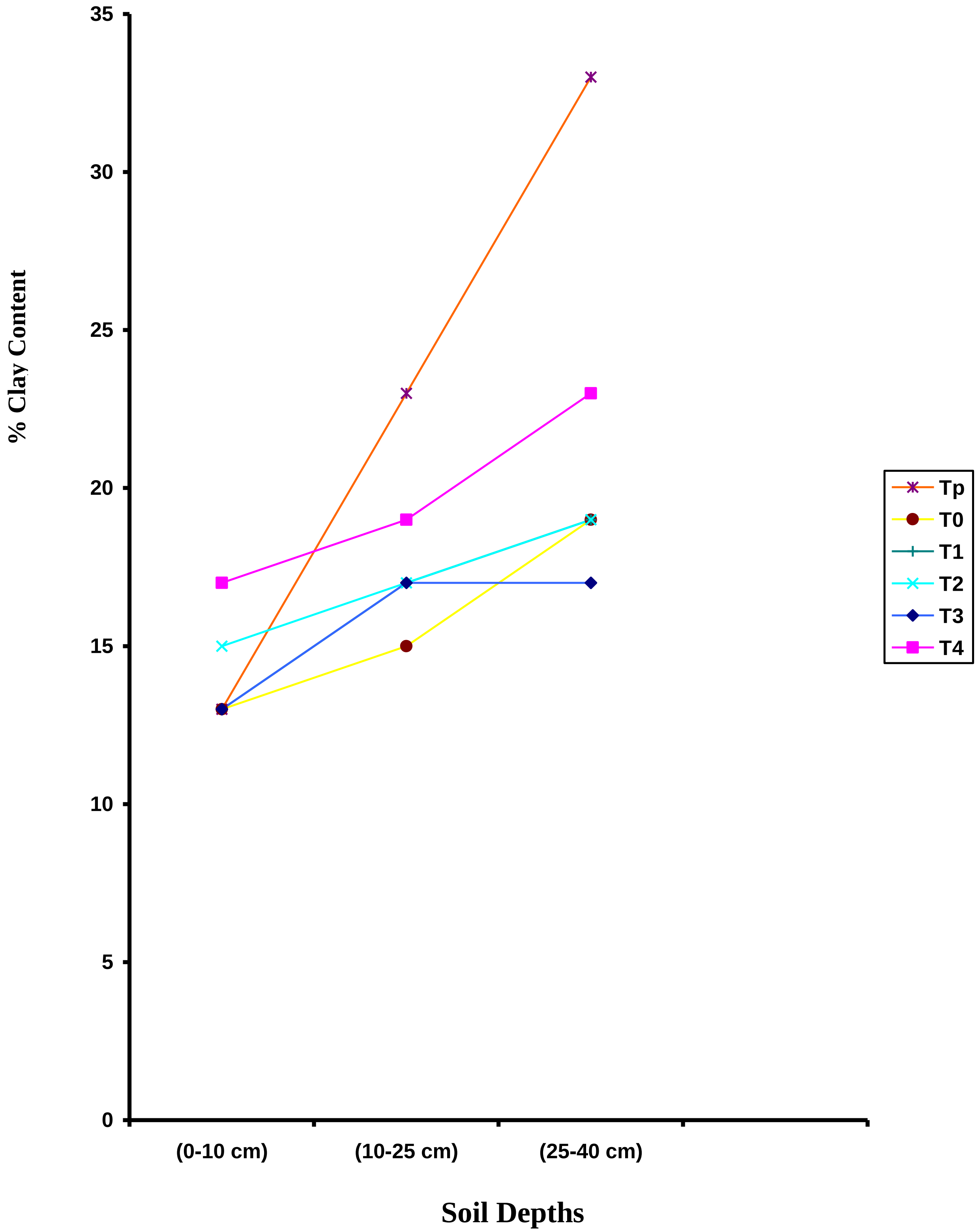

Fig. 12: Percentage Clay Content at Three Soil Depths Before (Tp) and after (T_o-T_4) Planting.

Table 20: **Particle size distribution(%) and textural classes* (TC) of the pre and post experimental soil samples**

Soil Depth (cm)		Replicate 1				Replicate 2				Replicate 3			
		Sand	Silt	Clay	TC	Sand	Silt	Clay	TC	Sand	Silt	Clay	TC
Before planting													
	0-10	61	26	13	SL	47	18	35	SCL	61	22	17	SL
	10-25	59	18	23	SCL	61	14	25	SCL	61	14	25	SCL
	25-40	51	16	33	SCL	53	16	31	SCL	49	16	35	SCL
After Planting													
T_0	0-10	75	12	13	SL	65	18	17	SL	67	18	15	SL
	10-25	71	14	15	SL	61	18	21	SCL	63	18	19	SL
	25-40	65	16	19	SL	61	16	23	SL	61	16	23	SCL
T_1	0-10	75	12	13	SL	67	20	13	SL	63	22	15	SCL
	10-25	71	12	17	SL	65	18	17	SL	49	24	27	SCL
	25-40	69	12	19	SL	61	16	23	SCL	63	22	15	SL
T_2	0-10	69	16	15	SL	63	16	21	SCL	61	18	21	SCL
	10-25	69	14	17	SL	67	18	15	SL	59	16	25	SCL
	25-40	63	18	19	SL	71	18	11	SL	63	22	15	SL
T_3	0-10	75	12	13	SL	77	20	03	SL	67	20	13	SL
	10-25	71	12	17	SL	67	20	13	SL	65	16	19	SL
	25-40	59	24	17	SL	61	16	23	SCL	61	16	23	SCL
T_4	0-10	61	22	17	SL	61	16	23	SCL	61	22	17	SL
	10-25	65	16	19	SL	65	16	19	SL	59	20	21	SL
	25-40	63	14	23	SCL	63	20	17	SL	67	22	11	SL

N.B. TC = Textural Class, SL = Sandy Loam, SCL=Sand Clay Loam, See Table 18 for what To- T4 denote.

The particle size analysis of the post experimental soil samples from the five treatments revealed that the T0 soils (from its three replicates/soil depths) were dominated by sandy loam. All the 0 – 10 cm depth samples were sandy loam, only one replicate was sandy clay loam at 10 – 25 cm depth and one replicate from 25 – 40 cm depth was also sandy clay loam. The situation was however slightly different in T1 where three samples were sandy clay loam while the remaining samples were sandy loam in texture. The condition in T2 was not quite different from what obtained in T1 except that two of the samples from 0 – 10 cm depth were sandy clay loam and one from 25 – 40 cm depth was also sandy clay loam.

The T_3 textural classes were mainly sandy loam except two samples from 25-40 cm depth which were sandy clay loam (each). In T4, all the soil samples from all depths were sandy loam with the exception of one sample from 0 – 10 cm depth and one also from 25-40 cm depth. It is pertinent to stress here that all the samples from 0 – 10 cm depth of T3 that were sandy loam soil consisting of 67-77 % sand, 12-20 % silt and 3-13 % clay (Table 20). This observation is in line with the one earlier made by Olowolafe (2003) who reported that soils developed in granite area of the Jos Plateau have sandy clay loam, caly laom and sandy loam as the dominat textural classes.

4.12.2 Chemical Properties

Results from analysis of variance (ANOVA) on the data from the experimental soil samples before and after planting indicated no significant differences among the treatments and blocks with regard to pH (H_20) at 0 – 10 cm soil depth. The mean pH value prior to planting (Tp) was 4.5 but rose to 5.2 in T0 and T2 after planting. At 10 – 25 cm soil depth, significant effect of the different blocks on pH ($P<0.01$) was observed. The pH before planting (Tp) was 4.3 which increased to 5.4 in T3 after planting. The control experiment (T0) had a pH value of 4.9 which was slightly above that of T1 (4.8). No significant effect of treatments on pH was observed at this depth.

The effect of blocking was significant at 25 – 40 cm depth ($P = 0.05$) and no significant effect of treatments on soil pH was observed. Duncan's multiple range test (DMRT) indicated significant differences among the mean values of this variable (Table 21, Fig. 13, Appendices 10 – 12, 43 – 45). Both the treatments and blocks had no significant effects on the soil pH (KCl) at 0 – 10 cm soil depth. Significant effect of blocks (at $P = 0.05$) was however observed at 10 – 25 cm depth and that of treatment at 25 – 40 cm at $p<0.01$ (Table 21, Appendices 13 – 15, 46 – 48).

The organic matter (OM) content in Tp (before planting) was higher than those of the treatments (T0 – T4) after planting. There were no significant differences among the blocks and treatments in all the soil depths. Also DMRT indicated no significant differences among the mean values of Tp and T0 – T4 (Table 21, Appendices 16 – 18, 49 – 51). The Tp was 1.94 % while those of T0 – T4 ranged from 0.79 to 1.69 % (OM = OC x 1.72, Table 21, Fig. 14). The OM decreases downwards (from surface soil to the subsoil) in respect of the Tp values (1.94 – 1.03 %). T0 – T4 exhibited the same trend but T0 had the lowest

Table 21: Some chemical properties of the pre-experimental soil samples as influenced by the treatments after planting at three soil depths

Treatments	pH H_20	pH KCl	OM (%)	TN (%)	Avail. P (ppm)	Ca	Mg	K	Na	E.A	ECEC
						← cmol (+) Kg^{-1} →					
Before Planting (Tp)											
0 – 10 cm Depth	4.5b	4.2ab	1.94a	0.10ab	23.45a	4.07a	0.78b	0.22a	0.18ab	0.87a	6.12a
After Planting (0 – 10 cm)											
T_0	5.2a	4.5a	1.22b	0.06b	15.52b	2.06c	0.61c	0.17ab	0.15b	0.73a	3.72b
T_1	4.5b	4.3ab	1.29b	0.06b	16.40b	2.07c	0.63c	0.11ab	0.19ab	0.54a	3.54c
T_2	5.2a	4.5a	1.38b	0.06b	24.62a	3.00ab	0.72b	0.14ab	0.23a	0.80a	4.89ab
T_3	5.1a	4.0b	1.45b	0.08b	6.45c	2.67b	0.69c	0.20a	0.19ab	0.73a	4.48ab
T_4	4.7ab	4.1b	1.69a	0.33a	18.90b	3.07ab	0.93a	0.17ab	0.20a	0.60a	4.97ab
Before Planting											
(10 – 25 cm)	4.3b	3.9	1.15b	0.07a	3.79c	3.93a	0.80b	0.15a	0.20a	1.20a	6.28a
After Planting (10 – 25 cm)											
T_0	4.9b	4.5a	1.03c	0.05a	10.92b	2.40b	0.46c	0.14a	0.17ab	1.13a	4.30b
T_1	4.8b	4.2ab	1.24b	0.07a	18.22a	3.07ab	1.16a	0.11a	0.20a	0.73b	5.27ab
T_2	5.1ab	4.4a	1.26b	0.08a	13.79ab	1.81c	0.34c	0.17a	0.26a	1.07a	3.65b
T_3	5.4a	4.4a	1.57a	0.08a	7.29c	2.87b	0.81b	0.19a	0.20a	1.47a	5.54ab
T_4	5.1ab	4.5a	1.38a	0.08a	10.38b	3.27a	0.99b	0.17a	0.18a	1.07a	5.68ab
Before Planting											
(25 – 40 cm)	4.3b	3.7a	0.79c	0.07a	3.04b	3.60a	0.52c	0.18b	0.27a	1.87a	6.44a
After Planting (25 – 40 cm)											
T_0	5.1a	4.6a	0.95c	0.06a	4.46b	2.87b	1.19a	0.16b	0.18ab	1.40ab	5.80ab
T_1	5.3a	4.4a	1.05b	0.07a	3.90b	2.73b	0.66b	0.14b	0.21ab	1.13b	4.87b
T_2	4.8b	4.4a	1.14a	0.31b	4.43b	2.20c	0.76b	0.47a	0.16ab	1.33b	4.92b
T_3	5.4a	4.4a	1.15a	0.07a	5.02a	2.53b	1.07a	0.16b	0.16ab	1.53a	5.45b
T_4	4.9b	4.5a	1.03b	0.27b	6.88a	1.93c	0.29c	0.13b	0.15ab	1.13b	3.63ab

OM = Organic Matter, TN = Total Nitrogen, E.A = Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity. Each value represents mean value from three replicates from a treatment. Mean values with the same letters are not significantly different at 5% Probability level by DMRT.See Table 18 for what To-T4 denote.

value (0.95) at 25 – 40 cm soil depth (Fig. 14).

The total nitrogen in the soil at the study site was generally low (below 0.35 %). The % N before planting was 0.10 at 0 – 10 cm depth which decreased to 0.06 – 08 in T0 – T3 but rose to 0.33 in T4. The mean value before planting at 10 – 25 cm depth was 0.07 and that of 10 – 25 cm was 0.07 also. T4 had the highest percentage nitrogen at 0 – 10 cm (0.33%), T1, T3 and T4 at 10 – 25 cm (0.08 each) and the highest mean value was observed in T2 (0.31). (Table 21, Fig.15, Appendices 19 – 21, 52 – 54).

At the 0 – 10cm depth, significant effect of blocks and treatments were observed (P = 0.05) in respect of available phosphorus. However, there was no significant effect of both blocks and treatments on available P at 10 – 25 cm and 25 – 40 cm soil depths. The Tp value before planting was 23.45 pp at 0 – 10cm depth which increased to 24.62 in T2 but decreased to range of 3.7 – 18.90 pp in T0, T1, T3 and T4. The Tp mean values at 10 – 25 cm and 25 – 40 cm depths were 3.07 and 3.04 respectively. DMRT indicated significant differences among the mean values of Tp and T0 and T4 (Table 21, Fig. 16, Appendices 22 – 24, 55 – 57).

Furthermore, the blocks and treatments had no significant effect on the calcium (Ca) content at the three soil depths in the experimental site. The Tp value was 4.07 at 0 – 10 cm depth which decreased to 2.07 in T0. At 10 – 25 cm, the Tp was 3.93 cmol (+) kg-1 soil which reduced to 1.81 in T2 while 2.87 was the Tp value at 25 – 40 cm depth but decreased to 1.93 in T4 after planting. DMRT indicated significant differences among the mean values at all

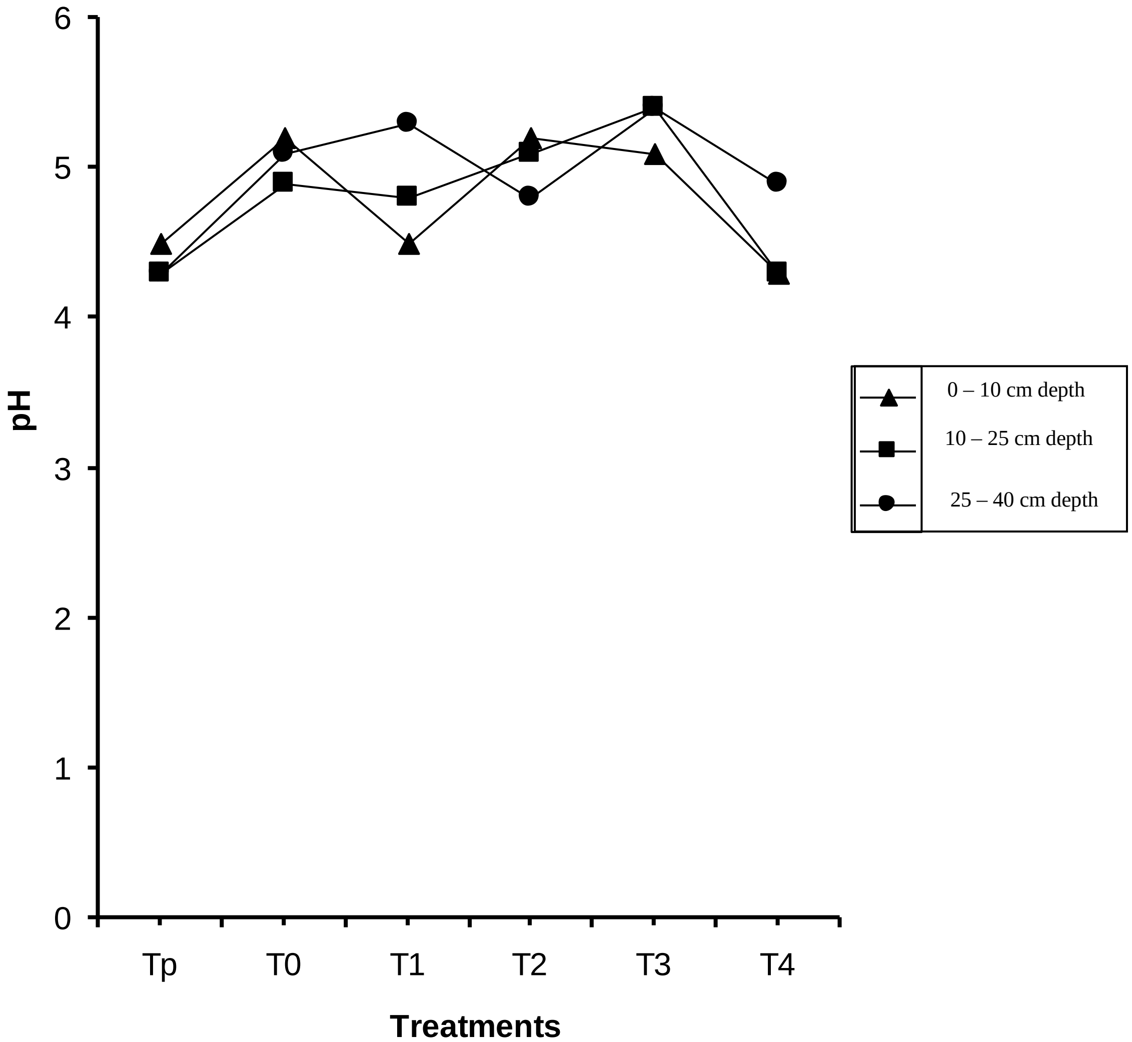

Fig. 13: Effects of Treatments on Soil pH at Three Soil Depths (Tp = Pre-Experimental Value)

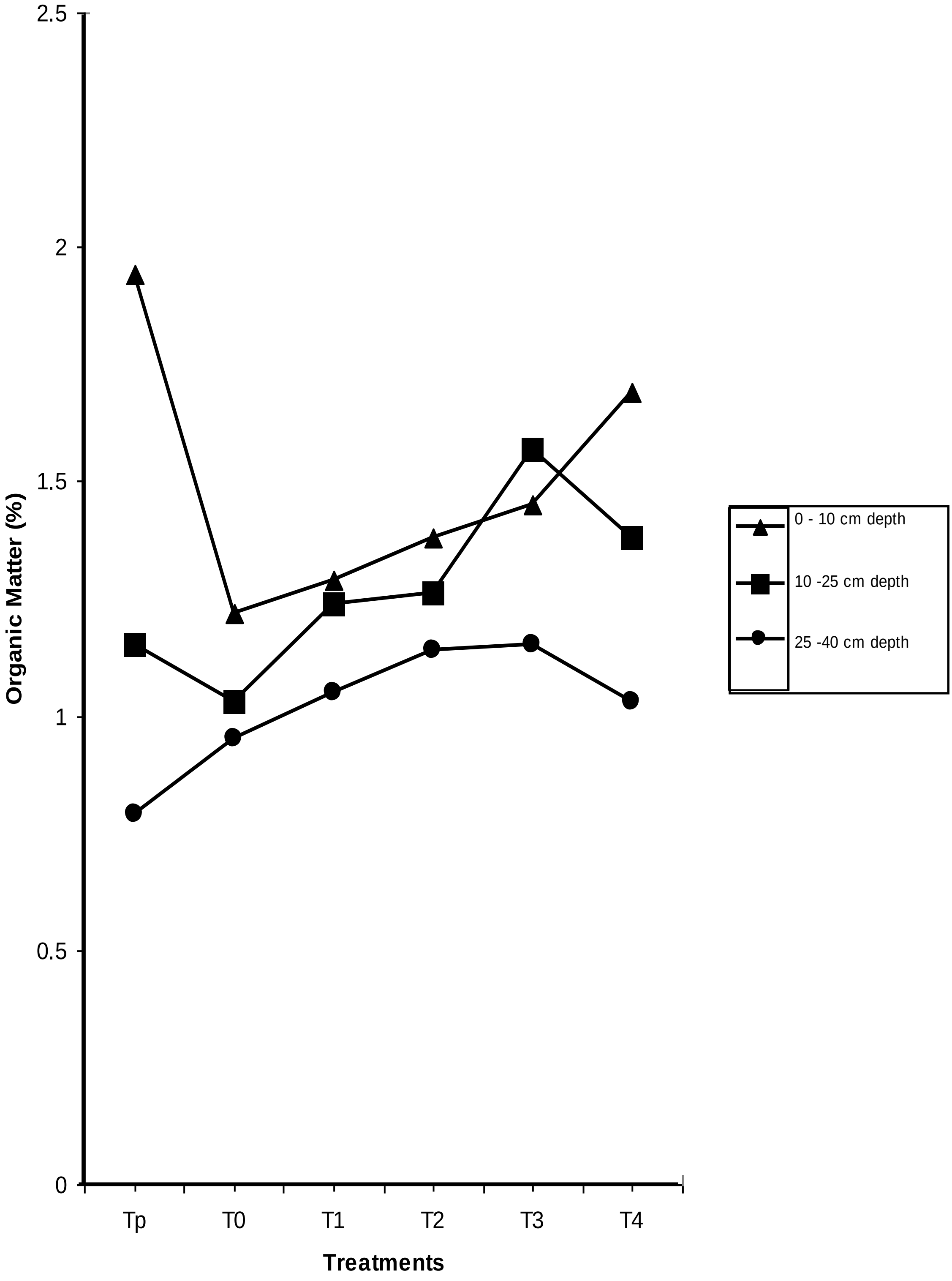

Fig. 14: Effects of Treatments on Organic Matter at Three Soil Depths (Tp = Pre-Experimental Value)

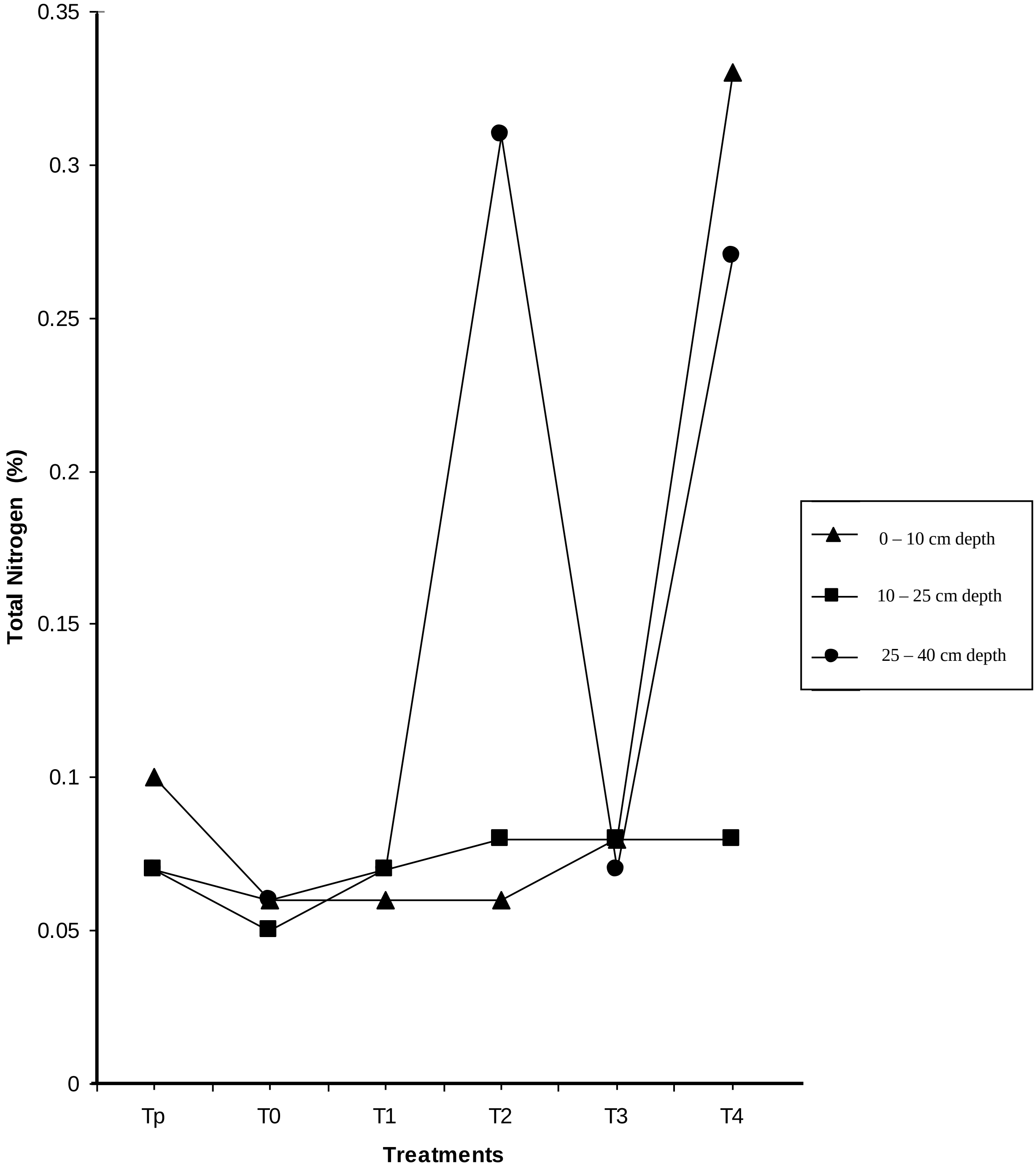

Fig. 15: Effects of Treatments on Total Nitrogen at Three Soil Depths (Tp = Pre-Experimental Value)

the soil depths (Table 21, Appendices 21 – 27, 58 – 60).

With regard to the magnesium content, only the blocks had significant effect on Mg at 0 – 10 cm depth. However, no treatment or block effect was observed at 10 – 25 cm and 25 – 40 cm depths. The Tp value was 0.78 cmol (+) kg-1 soil for the surface soil which slightly increased to 0.93 in T4 but decreased in T0 – T3 after planting. The Tp value for the sub-soils ranged between 0.52 and 0.80 but changed to value range of 0.34 to 1.19 cmol(+) kg-1 soil after planting (Table 21, Appendices 28 – 30, 61 – 63). Ca and Mg were the two dominant cations at the exchange site of the study.

Significant differences were observed among the treatments applied pertaining to their effects on the potassium (K) content of the soil at 0 – 10 cm and 10 – 25 cm soil depths. However, no block or treatment effect was observed at 25 – 40 cm depth. The mean values were generally low except at 0 – 10 cm depth before planting which was 0.22 cmol(+) Kg^{-1} soil, 0.20 in T3 at 10 – 25 cm depth and 0.47 cmol (+) kg^{-1} soil in T2 at 25 – 40 cm soil depth. (Table 21, Fig. 17, Appendices 31 – 33, 64 – 66). Effect of the treatments was not significant on the sodium (Na) content of the soil at the three soil depths. The mean values ranged from 0.18 – 0.27 before planting and 0.15 – 0.26 after planting. T2 and T4 had 0.23 and 0.20 respectively at 0 – 10 cm depth while T1, T2 and T3 had 0.20, 0.26 and 0.20 cmol (+) kg^{-1} soil at the 10 – 25 cm depth respectively. The mean values were generally low in the last soil stratum (25 – 40 cm depth) except in T1 (0.20) while other treatments had a range of 0.15 – 0.18 cmol(+) Kg^{-1} soil (Table 21, Appendices 34 – 36, 67 – 69).

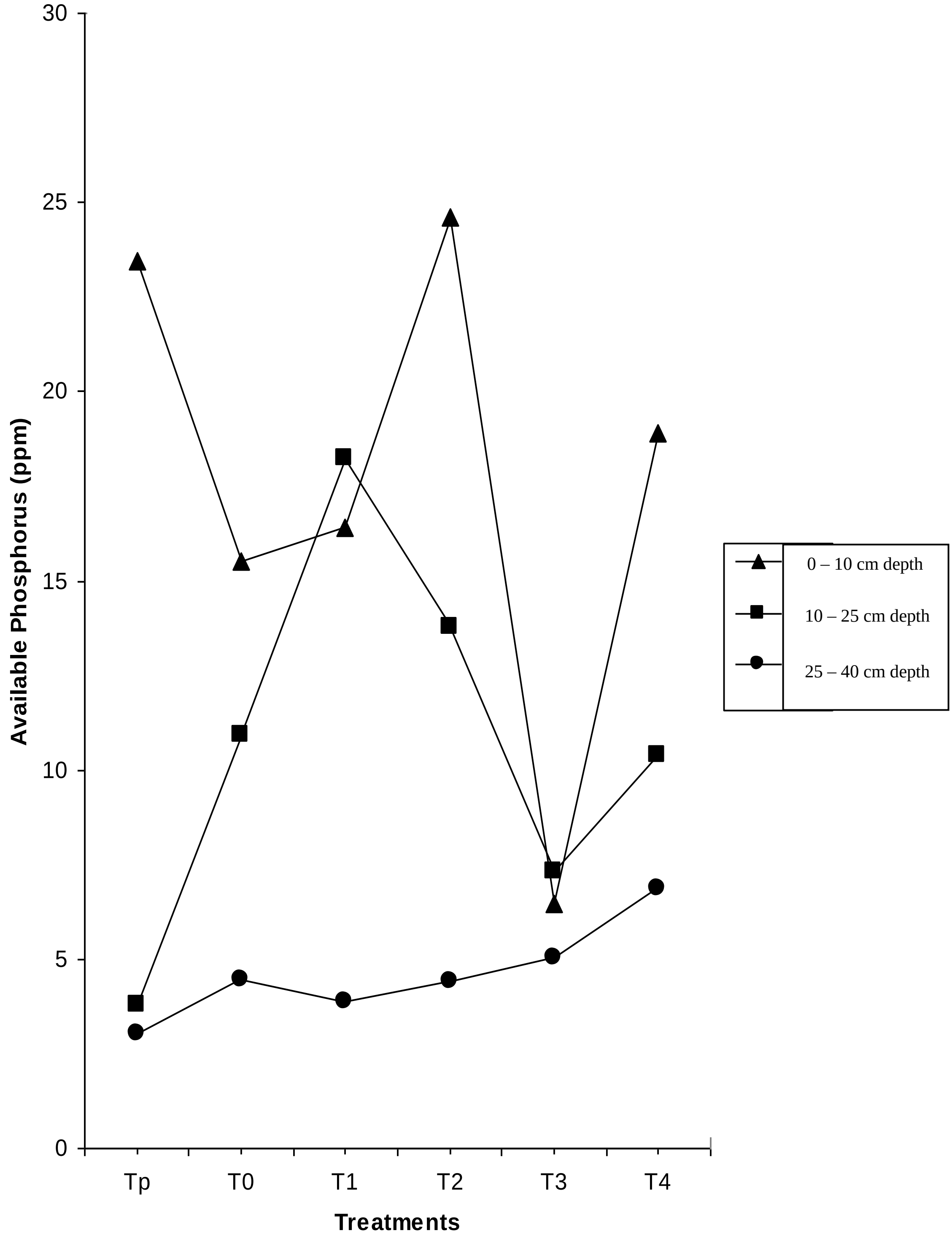

Fig. 16: Effects of Treatments on Available Phosphorus at Three Soil Depths (Tp = Pre-Experimental Value)

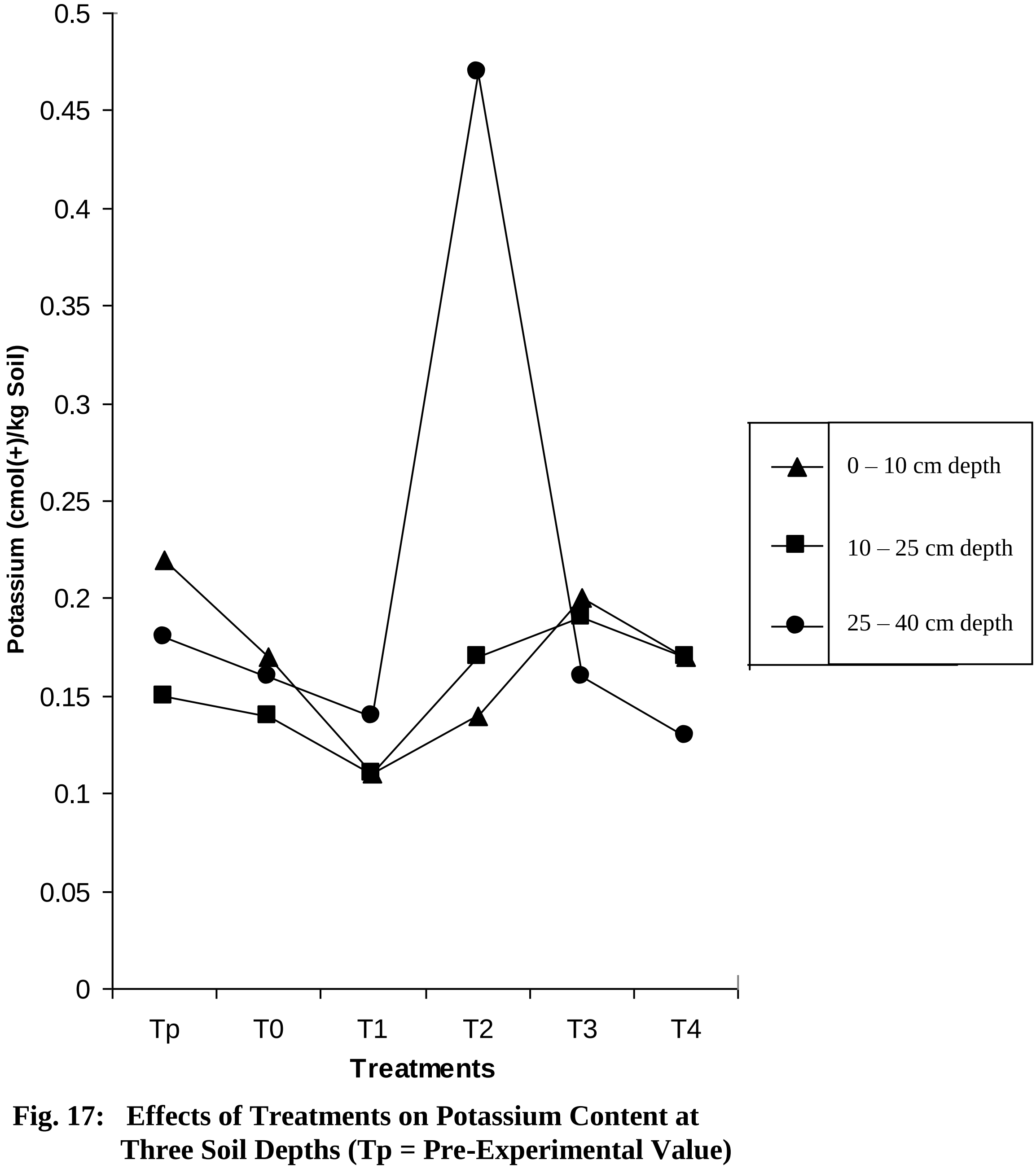

Fig. 17: Effects of Treatments on Potassium Content at Three Soil Depths (Tp = Pre-Experimental Value)

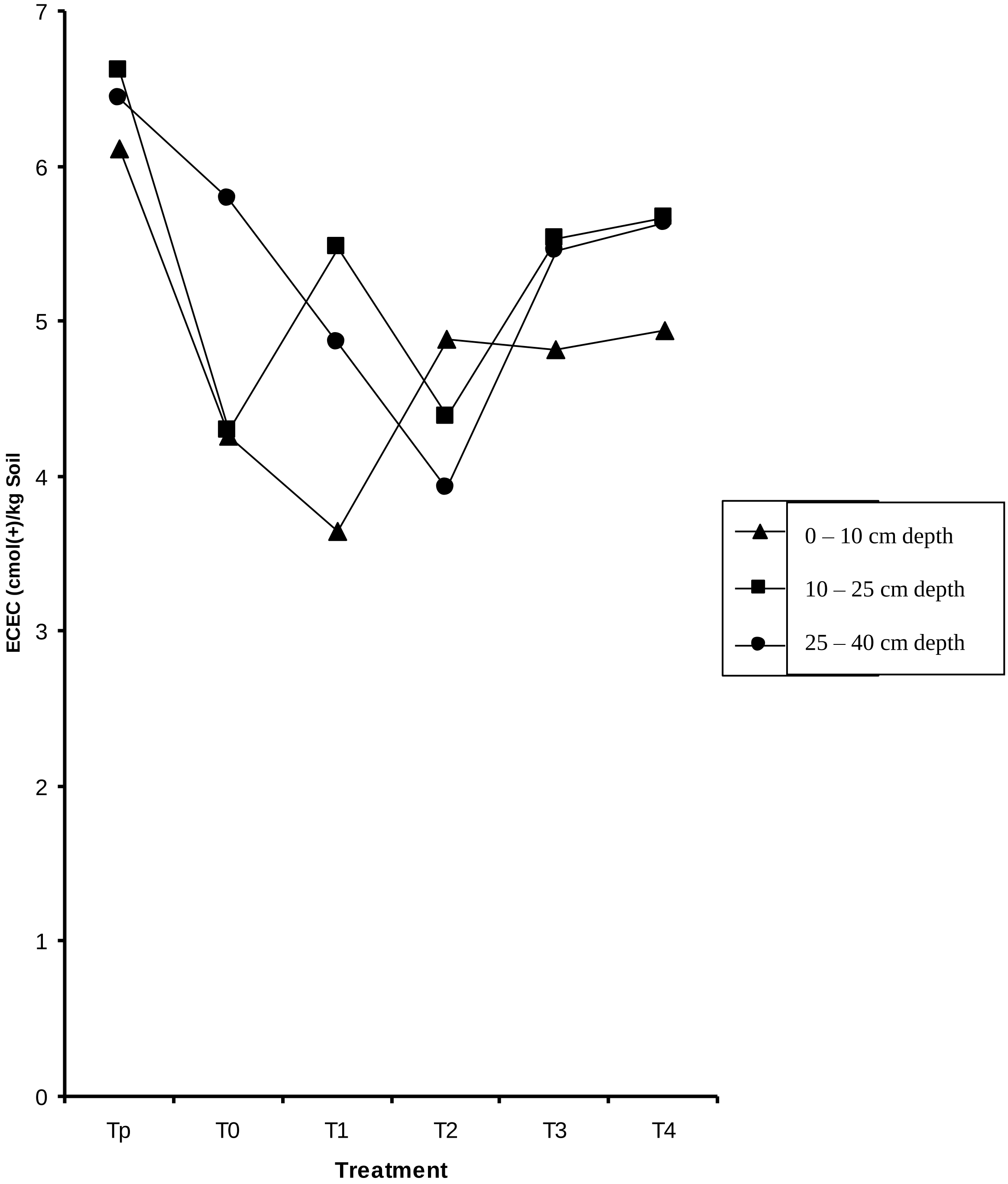

Fig. 18: Effects of Treatments on ECEC at Three Soil Depths (Tp = Pre-Experimental Value)

Pertaining to the exchangeable acidity, no significant effect of blocks and treatments was observed in all the three soil depths. The mean value from the surface soil (0 – 10 cm depth) increased down the soil strata (i.e to subsoil) before planting (0.87 – 1.87 cmol (+) kg-^{1} soil). Similarly, there was a general increase in exchangeable acidity from the surface soil to the subsoil (0 – 40 cm depth) among the treatments and blocks (0.54 – 1.53 cmol (+) Kg-^{1} soil). However, DMRT indicated significant differences among the mean values at 10 – 25 cm depth only (Table 21, Appendices 37 – 39, 70 – 72).

Furthermore, the blocks and treatments had no significant effect on the effective cation exchange capacity (ECEC) at all the three soil depths. The mean values at 0 – 10 cm, 10 – 25 cm and 25 – 40 cm depths were 6.12, 6.28 and 6.44 cmol (+) Kg-1 soil respectively before planting. The ECEC mean values of T0 – T4 ranged from 3.63 – 5.80 cmol (+) kg-^{1} soil after planting which clearly indicated a decrease when compared to the values prior to planting. DMRT showed significant differences among the mean values at all the three soil depths (Table 21, Fig. 18, Appendices 40 – 42, 73 – 75).

4.13 MINERAL CONTENT (N.P.K.) ANALYSIS OF THE POTATO (LEAVES AND TUBER) AND *ALBIZIA LEBBECK* LEAVES.

The highest percentage nitrogen (4.19%) was observed in T2 potato leaf. This was followed by T4 leaf, *Albizia lebbeck* leaf, and T3 potato leaf with 3.94, 3.94 and 3.56 (%) respectively (Table 22). The lowest value (2.94%) was recorded in T1. In term of the N content in the potato tuber from the treatments, T2 and T3 had the highest value of 1.40% each while the lowest value (0.84%)

Table 22: Mineral contents (n.p.k) analysis of the potato leaf, potato tuber and *Albizia lebbeck* leaf

Treatment	% N		% P		% K	
(5)	Leaf	Tuber	Leaf	Tuber	Leaf	Tuber
T0	3.36	0.98	0.86	0.84	1.48	1.75
T1	2.94	1.26	0.98	1.07	3.69	1.54
T2	4.19	1.40	1.05	0.82	3.83	1.54
T3	3.56	1.40	0.78	0.92	2.25	1.40
T4	3.94	0.84	0.88	0.96	2.75	1.54
Albizia lebbeck leaf	3.94	-	0.59	-	2.40	-

See Table 18 for what To-T4 denote.

was observed in T4.

With regard to the phosphorus (P) content, T2 had the highest value of 1.05% in the leaf. T1 ranked next to T2 with a value of 0.98% and *Albizia lebbeck* leaf had the least value of 0.59%. In case of the tuber, the highest value (1.07%) was observed in T1, T4 had 0.96% while T2 had the least value (0.82%).

The potassium (K) content of the leaves indicated that T2 had the highest value (3.83%), this was followed in that order by T1 (3.69%) and T0 (1.48%). Pertaining to the tubers from the five treatments, the highest value (1.75%) was observed in T0 while T1,T2 and T4 had the same value of 1.54% and the lowest value (1.40%) was recorded in T3.

CHAPTER FIVE

DISCUSSION

5.1 SEEDLINGS' EMERGENCE

The commencement of seedlings' emergence at 7 DAP in all the treatments and five cropping seasons could probably be as a result of the fact that the potato tubers were pre sprouted before planting. Okonkwo *et al.* (1995) had earlier made a similar observation. Also, it could be due to the fact that the right tuber set sizes 40 – 50 mm were meticulously selected for presprouting prior to planting. Okonkwo *et al.* (1995) reported that potato tubers less than 25 mm or those more than 50 mm in size are not generally recommended for planting owing to the fact that they have low yield (less than 40 – 50 mm seed size). Since potato tubers are generally dormant at the period of harvest, the dormancy might have been broken owing to the pre-sprouting before planting. If the tubers were not pre-sprouted prior to planting it could have resulted in delayed and erratic seedlings' emergence (Beukema and Zaag, 1979; Okonkwo *et al.*, 1995).

Furthermore, the right planting depth (8-10 cm) chosen must have brought about early seedlings' emergence (S.E.) at higher percentage and planting less than 8 cm (< 8 cm) depth could have possibly exposed some of the potato tubers to sun's heat, rodents' and birds' damages. On the other hand, planting below 10 cm depth especially during wet season could have subjected the tubers to water-logged condition which could have led to wet rot, caused delayed plant emergence or total failure to germinate. Okonkwo *et al.* (1995) had earlier reported that 8-10 cm planting depth prevents exposure of tubers to sun's heat, rodents and birds damages.

The significant differences observed in percentage seedlings' emergence (PSE) at 7 and 14 DAP in the 1st, 2nd, 3rd and 4th cropping seasons (CS1-4) could be attributed to the different rates of seedlings' emergence among the tubers of the various treatments, despite the fact that they (turbers) were all pre-sprouted prior to planting on the field. Also, this is in accordance with the observation made by Nwoboshi (1982) and Kareem *et at.*(2005a) that seed germination / seedings' emergence and sprouting of cuttings take place in trickles and not at once.

The low PSE recorded in the 2nd and 4th seasons (which were dry seasons) might be due to the higher rate of evaporation of moisture from the soil during this season and high bulk density. Olowolafe (2003) had earlier observed that the bulk density of soils derived from granite could be as high as 2.0 gcm^{-3}. Such high bulk density results in high degree of compaction which can delay or hinder seedlings' emergence. This agrees with De Geus (1973) and Vapraskas (1988), who had also observed that loams and clays with bulk densities that are above 1.46 to 1.63 g cm^{-3} result in hindrance to root penetration and inadequate aeration owing to compaction.

5.2 GROWTH PARAMETERS

The statistically significant differences observed among the treatments with regard to some growth parameters could be attributed to different rates and modes of *Albizia lebbeck* green manure application. The presence or absence of *Albizia lebbeck* tree rows could have also brought about the variations observed in the growth parameters (plant height, leaf count and collar girth of the potato plants) due to their effects on soil. At 63 DAP, T_4 (Potato planted in the alley of *Albizia lebbeck* tree rows with *A. lebbeck* green manure at 10 ton ha^{-1}) had the highest mean values from the three growth parameters (plant height, leaf count and collar girth). This could be due to its (T_4) higher nutrient status as a result of the its higher level of green manure application and nitrates (NO_3^-) from the nitrogen fixation activities of the *Albizia lebbeck* tree rows.

This agrees with the result obtained by Mureithi *et al.* (2004) in respect of the effect of purple vetch (*Vicia benghalensis*) which is a nitrogen fixing legume on Irish potato yield in Matanya, Central Rift, Kenya. In the same vein, T_2 (with incorporation of *A. lebbeck* green manure at 5 ton ha^{-1} without *A. lebbeck* tree rows) ranked second to T_4 probably due to the fact that the nutrients from the green manure was solely utilized by the potato crops. T_2 could have got an edge over T_3 (potato plants in the alley of *A. lebbeck* tree rows with green manure of the tree in form of mulch) whose nutrients (from mulching and nitrogen fixation of trees (*A. lebbeck)* could have been utilized by both plants (Irish potato and *A. lebbeck),* thereby co-sharing the nutrients.

Similarly, $T_{1,}$ (Potato planted in the alley of *A. lebbeck* tree rows without green manure*)* had higher mean values of the growth parameters over T_0 probably as a result of the addition of nutrients in form of nitrates from the *A. lebbeck* tree rows as opposed to T_0 (without green manure and tree rows of *A. lebbeck).* This agrees with the report by Chuman and Lal (1990), who observed that substantial amount of plant nutrients can be added to the soil through the application of plant biomass (foliage) and that many benefits are derived from growing of perennial trees in association with crops. This brings about soil fertility improvement through soil moisture conservation and increase the nitrogen and organic matter status (Hudgens, 2000). The absence of block effect in all the five cropping seasons is probably attributable to lack of reasonable fertility gradient in the experimental site which could have brought about significant differences as a result of blocking. However, the non -significant effects of treatments, blocks (replicated plots) , treatment x season on stem count could be due to the fact that almost all the potato plants from blocks/treatments and in all the seasons had an average of 2-3 stems /shoots per stand. Also, this could have arisen from the pre-sprouted tubers employed for planting which had fairly uniform number of sprouts per tuber prior to planting.

5.3 YIELD PARAMETERS OF THE POTATO CROPS

The tuber count and tuber yield that were significantly influenced by the treatments and season was probably due to the effect of the different levels of green manure application and the *Albizia lebbeck* tree rows. In the same vein, the soil nutrient status per treatment sequel to application or non-incorporation of green manure, level of green manure application and presence or absence of *Albizia lebbeck* tree rows could have possibly brought about the variation in sizes of the potato. For instance, T_4 with the tree rows of *A. lebbeck* and highest level of green manure application could have achieved higher level of soil nutrient status which resulted in having highest tuber count and largest quantity of big tuber size. This agrees with the observation by Iwuafor and Kumar (1992) on the effect of *Leucaeua leucocephala* foliage under alley cropping with maize. Budeman (2002) had also made similar observation on the effect of *Gliricidia* leaf mulch on early development and yield of wateryam (*Dioscorea alata*) and Tilander (1993) in respect of *A. lebbeck* green manure on surghum yield.

The mean tuber yield of T_2 ranked next to that of T_4 probably because of the fact that the nutrient released from 5 ton ha^{-1} green manure of *A. lebbeck* applied was mainly/solely utilized by the potato plants in T_2 plots. There were no tree rows of *A. lebbeck* which could have co-shared the nutrients with the potato crops. In case of the T_3, green manure of *A. lebbeck* was applied on the soil surface at 5 ton ha^{-1} as leaf mulch and *A. lebbeck* tree rows at both sides of the plots. The nutrient released after decomposition and subsequent mineralization must have been absorbed/utilized by both potato and *A. lebbeck* plants. Though the nitrogen fixing tree must have carried out its nitrogen fixation activities but the residual nutrients after absorption by *A. lebbeck* tree rows in T_1 might be less than what was available to T_2 potato crops. Thus, T_2 tuber yield was higher than that of T_3.

The tuber yield recorded in T_1 was slightly higher than that of T_0 probably due to the presence of *A. lebbeck* tree rows which were not present in $T_{0.}$ The nitrogen fixation activities must have brought about a sort of improvement in nutrient status of T_1 over that of T_0 which was the control. This agrees with the findings of Johannes *et al.* (1999) in respect of the higher yield of *Sorghum bicolor L.* when intercropped with *Acacia saligna* in Kakuma (a dry tropical savanna in Northern Kenya) over the sole crop (of *Surghum bicolor).* It is pertinent to mention that in the 3rd and 4th cropping seasons T_2 had the highest mean tuber count but when the tuber weight/yield was computed the value was lower than that of T_4. This is probably not unconnected with the fact that the sizes of T_4 tubers were more than those of T_2, therefore T_4 tubers recorded higher yield (i.e. more weight). This is supported by Amadi (2005) who reported that tuber number and average tuber weight are the most important determinants of tuber yield when compared with other attributes of potato (e.g. growth parameters). Also, Birhman and Kang (1993) had earlier asserted that potato tuber yield is a function of the number of tubers and average weight.

5.4 INTER-RELATIONSHIPS OF GROWTH PARAMETERS AND CROP YIELD

The influence of the growth parameters on the yield of Irish potato investigated in this study demonstrates the degree of interdependence or interrelationships among the growth parameters and between crop yield.

The results from the simple bivariate and the multiple correlation analyses which were employed in the statistical verification of the interrelationships indicate that there are variations among the growth parameters. This assertion is quite evident in the correlation between plant height and leaf count being positive and strong ($r = 0.955$) in the rainfed cropping season. This agrees with a similar observation earlier made by Fomba (1998) on okro. This connotes that the leaf count increases with increasing plant height. The same reason could also be advanced in respect of the high positive correlation between collar girth and plant height, collar girth and leaf count in both rainfed and irrigated cropping seasons.

However, the negative correlation observed between collar girth and stem count proves that the more the number of stems per stand the less the average collar girth and vice versa.

The high level of bivariate correlation between potato collar girth and yield (r = 0.954) at 1% level of significance connotes that the potato plants with high values of collar girth higher yield. This was exactly what was discovered during harvest in all the five cropping seasons. Those stands with 3-5 stems had lower tuber weight/yield due to smaller sizes of the tubers per stem as opposed to stands with 1-2 stems which had big sizes of potato tubers which resulted in higher tuber weight/yield. Amadi *et al.* (2005) made a similar observation regarding the negative and significant correlation between number of tubers per plant and average tuber weight and positive relationship between stem count (number of stems/plant) and tuber count. This means that each of the stems per plant produces tubers, (Irish potatoe being a stem tuber) thus making the tuber count higher but due to the fact that the sizes of those tubers are small, tuber weigh/yield is correspondingly low especially where soil nutrient status is low.

Similarly, plant height and leaf count are positively significantly correlated in the rainfed and irrigated cropping seasons. This means that potato plants with higher values of plant height had more leaves which brought about increased surface area for photosynthesis which leads to increased accumulation of photosynthates. These enhance tuber formation as a result of assimilation and eventually culminates in high tuber though an optimal number of leaves or leaf area index is needed to optimize tuber yield (Fomba, 1998; Lopez *et al.*,1987; Amadi et *al.*, 2005).

The significant effects recorded on multiple correlation and regression analyses in respect of the growth parameters versus yield in both rainy and dry season croppings indicate a high influence of the independent variables on the dependent variable (crop yield). Apart from stem count which had a negative correlation and regression coefficient with yield, all the remaining growth parameters positively correlated with yield. These phenomena demonstrates that the more the stem count per plant or stand the lesser the tuber weight though subject to soil fertility status. Since potato is a stem tuber crop, more stems bring about more tuber count which have negative correlation with tuber weight due to small sizes of the tubers.

Amadi *et al.* (2005) observed a negative correlation between tuber count and tuber yield and even if the soil fertility status is high the tuber yield can only increase to a maximum value (limit) with increasing stem density (Allen and Wurr, 1992). Most of the stands of this betertia variety under study in T_0 and T_1 which had lower nutrient status owing non incorporation of *Albizia lebbeck* green manure had lower tuber weight yield irrespective of their tuber count due to the small nature of their tubers. In the rainfed cropping. Collar girth had the highest correlation and the intercept ‘a’ probably due to the fact that it had the highest R_2 value (0.910) at 1%. Besides this, collar girth of potato stems in T_4, T_2 and T_3 with green manure of the rattle tree which brought about high nutrient status had higher values of collar girth and tuber weight/yield, as opposed to smaller stem sizes in T_0 and T_1 with corresponding smaller tuber sizes and low tuber weight/yield. This means that collar girth accounts for 91.0% of variation on tuber yield in the rainfed planting season.

Unlike the rainfed cropping season, leaf count recorded the highest value of R^2, correlation coefficient (r) and level of significance in the irrigated cropping which are 0.913, 0.956 and 0.011 respectively. This is probably due to effect of leaf count on tuberization (tuber formation and subsequent tuber weight/yield. Large leaf area index is a function of leaf count which paves way for increased photosynthetic activities and subsequent build-up anabolism / assimilation / accumulation of photosynthates for tuber formation. It accounted for 91.3% of the variation in potato yield at 1% level.

Similarly, leaf count also recorded the highest value of coefficient of determination (R^2) and level of significance in the combined cropping seasons (which are 0.881 and 0.018 respectively). This trend as earlier opined could be due to the vital roles of leaves in crop growth, development and yield (Fomba, 1998; Amadi *et al.,* 2005) with regard to photosynthesis, assimilation of photosynthates and subsequent tuber formation and yield.

5.5 INFLUENCE OF PESTS AND DISEASES

Very importantly, the mean value of potato yields in rainfed croppings (CS1, CS3 and CS5) was less than that of CS2 and CS4 (irrigated). This could be as a result of the incidence of bacterial wilt and brown rot. More number of stands of potato were affected by bacterial wilt/brown rot in the rainy seasons. The incidence of these diseases was mild (less) in the dry season cropping. Hence, higher mean tuber yield was recorded from CS2 and CS4. Kay (1987) and Okonkwo *et al* (1995) reported that higher yield of potato is realized from irrigated/dry season farming. This is not unconnected with the fact that some diseases such as early and late blight, bacteria wilt and brown rot are reduced to the bearest minimum in dry season farming.

5.6 SOIL PROFILE

5.6.1 Physical Properties

The soil is characterized by A-B-C profile and its deepness can be attributed to the flat and stable condition of the area together with the high porosity and infiltration rate which resulted in reduced erosion of the soil. This agrees with the earlier observation made by Olowolafe and Dung (2000) in respect of the biotite-granite area on the Jos Plateau. The presence of many roots in A_P1 and common fine roots in A2 and B_W3 horizons was a result of those horizons being the active growth regions of plants as opposed to the Bt horizon with few fine roots which is deeper than A_P1, A2 and B_W3 horizons.

The BCt2 horizon which is argillic could contain Alfisols and Ultisols. Olowolafe and Dung (2000) asserted that both Alfisols and Ultisols are soils found with argillic horizon of the soils derived from biotite granites on the Jos Plateau, Nigeria. The percentage clay increased with increasing depth though less than 35% due to the coarse texture and slow rate of weathering of some mineral components of granite in the study area. This phenomenon had earlier been observed by Olowolafe and Dung (2000) in the area.

5.6.2 Chemical Properties

The A_P1, A2, B_W3, Bt, BCt, and BCt2 horizons are generally low in pH. Troug (1948) opined that soils with pH levels below 4.5 are considered extremely acid while a range of 4.5 to 5.0 and between 5.0 and 5.5 are regarded as very strongly acid and strongly acid respectively. The acidic nature of these soils may not be unconnected with the nature of the parent rock (granite) which is acidic (Olowolafe, 2003), since its pH (H_20) values of the different soil samples from the horizons range between 3.6 and 5.5. It has also been observed by Tulu (2002) that crop removal of calcium (Ca) could lead to soil acidity.

However, the acidic nature of the soil does mean that no crop can be productively cultivated since different crops require different pH levels. Though there is tendency for phosphates to react with iron (Fe) and aluminum (Al) at pH <5.5 which could bring about non-availability of these minerals (Fe and Al) to crops, decrease in bacterial nitrification and possible rise in Al toxicity which culminate in low agricultural productivity (Olowolafe, 2003).

The organic carbon (OC), total nitrogen (TN) and available phosphorus (extracted by the Bray and Kurtz, 1945 method in the horizons with the exception of A_P1 horizon) are generally low. Low level of OC could be due to the effect of soil erosion on the site and high temperatures associated with tropical environment which result in disappearance of organic matter resulting from high decomposition and minerlaization rates (Metson, 1961; Landon, 1991; Olowolafe and Dung, 2000).

The fact that the study area had been under continuous cultivation could be another reason for the low OC. This agrees with Sanchez *et al.* (1982) and

Olowolafe (2007) who observed that organic matter content of soils under continuous cultivation is often very low. The low TN could be attributed to influence of high temperature, which leads to loss of nitrogen through volatilization. Soil erosion and leaching may have also contributed. Concerning the low levels of total nitrogen, a very important factor is that since the organic matter content of the soils is low, there is little or no organic matter to decompose to give rise to total nitrogen (Olowolafe, 2007).

The acidic nature of the soils gives it the high P-fixation and Al/Fe toxicity, this explains why the soils are deficient in phosphorus and the only horizon 0-15 cm (A_P1) with the highest pH value had a relatively high value of available phosphorus (27.16 ppm) due to its higher organic matter content. On the phosphorus content of the surface soils, the pre-planting values are generally higher than the critical values of 15 ppm (Landon, 1991). Since the area was formerly used for grazing, the cow dung received may have marginally enriched the surface soils' phosphorus contents.

The experimental site has been under continuous cultivation for maize production and the inorganic fertilizer applied is NPK (15:15:15 and 20:10:10). Phosophorus (P) could have a residual effect on the soil when the fertilizer is applied and P is relatively immobile (Olowolafe, 2007). Nevertheless, the sub-soils are phosphate deficient. This supports the earlier finding that one of the major constraints to sustainable crop production in the granite areas on the Jos Plateau is low available phosphorus (Olowolafe, 2002).

Also, the low values of potassium (K) recorded in all the horizons could be as a result of the low content of K in the soil parent material and leaching (Olowolafe and Dung, 2000). Probably as a result of the high rainfall pattern (1,371 mm) which brings about leaching of basic cations and low pH levels thereby leading to kaolinite formation. Subsequently, it culminates in low activity clay minerals being dominant which eventually result in low or very low cation exchange capacity (CEC).

5.7 PARTICLE SIZE DISTRIBUTION OF THE EXPERIMENTAL SOIL SAMPLES (BEFORE AND AFTER PLANTING)

The 0 – 10 cm soil depth of the pre-experimental soil samples (i.e. before planting) was loamy textured with sandy loam predominating. The same condition is applicable to all the 0 – 10 cm depth of T_0 – T_4 post experimental soil samples. However, the coarse texture and slow rate of breakdown (weathering) of some mineral components of granite could have brought about the 10 – 25 cm and 25 – 40 cm depths being completely sandy clay loam. This phenomenon was observed by Olowolafe, (2003).

The nine (9) samples from the three soil depths of T_4 were predominantly sandy loam (except two samples) probably because T_4 received the highest rate of green manure application (10 ton ha^{-1}). This must have increased the ratio of smooth to coarse fragment in favour of smooth. T_1, T_2 and T_3 had three (3) of their replicates (samples) being sandy clay loam as opposed to T_4 with only two (2). Though T_0 also had only two of its nine samples being sandy clay loam which could be attributed to the initial textural class of T_0 and probably little fertility gradient as no green manure was applied to the treatment (i.e. T_0).

There is very little or non-significant difference between the pre and post planting soil texture. This very little difference can be traced to soil mixing due to bed preparation. This is probably the reason why analysis of variance on the clay content indicated no significant difference in the soil texture before and after planting. This agrees with Olowolafe (2003) who had ealier observed that soils developed in granites are mainly loamy textured with sandy clay loam, clay loam and sandy loam constituting the dominant textural classes.

5.8 CHEMICAL PROPERTIES OF THE SOIL SAMPLES (BEFORE AND AFTER PLANTING)

The significant difference observed in block effect with regard to pH at 10 – 25 cm and 25 – 40 cm soil depths ($P \leq 0.01$ and $P \leq 0.05$ respectively) could be attributed to addition of organic matter in form of green manure from *Albizia lebbeck.* Since the pH (H_20) was initially low (4.5) before planting which made the soil very strongly acid (Troug, 1948; Olowolafe, 2003) but rose to a range of 5.1 to 5.4 in T_2-T_4 which indicates the influence of the green manure addition. Kunishi (1982) had earlier observed that organic matter raises the soil pH, helps in ameliorating phytotoxicity in acid soils, decreases soluble manganese and exchangeable aluminum (Al) and increases calcium and available phosphorus. Olowolafe (2003) had also reported that the addition of more organic matter could lead to the release of more basic cations which resulted in the improvement of base saturation and soil pH.

The soil structure could have been improved probably owing to the application of the organic manure in T_2, T_3 and T_4 which could have probably improved infiltration and porosity of the soil. Thus, the green manure applied and the tree rows of *A. lebbeck* might have contributed in reducing the acidity of the soil, which brought about better yield of potato in T_1-T_4 over that of T_0. This agrees with Kunishi (1982) who observed that the pH range of 5.5-8.5 is within the pH range of tolerance for crop production and that soil acidity does result to low agricultural productivity.

The organic matter (OM) in T_0 – T_4 (after planting) was lower than the value before planting (Tp) due to crop removal and leaching and those of T_2 – T_4 are higher than T_0 and T_1 probably because of the addition of green manure. The OM of the T_P and T_0 – T_4 are generally low below 2% (0.79 – 1.94 %) which could be attributed to the fact that the soils are of granite origin (Olowolafe, 2003) and is characteristic of tropical soils (Landon, 1991). This low level of OM is as a result of the high temperature experienced in larger period of the year which brings about high decomposition, minerlaization rates and subsequent disappearance of organic matter which is detrimental to the practice of sustainable agriculture in the tropics (Mulongoy and Merckx, 1993; Olowolafe, 2003).

Lack of significant effect of blocks and treatments at all depths on the total nitrogen (TN) could be due to the generally low level of TN in the site. This is a characteristic feature of tropical soils/environment with high temperature that results to fast loss of nitrogen owing volatilization, crop removal, soil erosion and leaching (Landon, 1991; Olowolafe, 2003). Only the effect of block and treatment at 0 – 10 cm depth on available phosphorus (avail. P) was significant probably because of reasonable differences in the values before planting and those of the treatments. For instance, the values in T_P, T_1, T_2 and T_4 are relatively higher (16.40 – 23.45 ppm) as opposed to T_0 and T_3 (which are 6.45 and 15.52 ppm respectively), thus, a significant difference among the blocks and treatments was observed.

As earlier stated by Olowolafe (2003), soils that are derived from granites contain relatively high available phosphorus and there is high P-fixation in acid tropical soils (Courley, 1987). This could be the reason why available P values are high in Tp and some of the treatments while those treatments with fairly low values could be as a result of lower fixation rate and higher rate of absorption by plants in the treatments.

Pertaining to the exchangeable cations, there was no significant effect of treatments on Ca levels. This could be attributed to the nature of the parent material, fairly uniform levels of Ca in Tp and the respective treatments (T_0 – T_4), different rates of Ca intake by plants and the dominant nature of Ca at the exchange site. The low levels of Ca in some of the treatments could also be due to leaching as a result of the high rainfall pattern which is about 1371 mm per annum (Alford *et al.*, 1979; Eziashi, 1995) on the Plateau and the generally low pH values of the soils from the site (granite) which favours the formation of kaolinite. Kaolinite is the main slicate clay mineral in the major soil types on the Plateau (Inceptisols, Alfisols and Ultisols) which is a contributory factor to the low Ca and Mg (Olowolafe, 2003).

Magnesium (Mg) is one of the exchangeable cations that dominates the exchange site of the soils. The significant effect of blocks on Mg content at 0 – 10 cm depth could be attributed to the influence of fertility gradient (in respect of block) at the experimental site. Generally, soils derived from granites are low or very low in exchangeable Ca and Mg (Olowolafe, 2003). Similarly, the significant effect of the treatments on K levels at 0 – 10 cm and 10 – 25 cm could be as a result of the application of green manure which might have influenced the K content in the soil samples from the treatments.

The generally low K levels which could be as result of leaching and the low K content of the soil parent material as earlier reported by Olowolafe and Dung (2000). The non significant effect of the treatments on Na observed at all soil depths could be attributed to the low level of variations among the mean values of the treatment which ranged from 0.15 – 0.26 cmol (+) kg^{-1} which is not enough to bring about significant differences.

However, the low level of sodium (Na) at the exchange site might not be unconnected with the nature of the parent material, leaching, intake by plants and treatments applied. The generally low exchangeable acidity is as a result of the low pH and organic matter of the soil. This phenomenon had earlier been observed by Nyle and Ray (1996) in respect of soils with low pH and organic matter. The generally low lvels of the exchangeable cations in the study site (which has been under continuous cultivation is traceable to nutrient removal by crops and grazing (by the cattle in the College). This further indicates that the amount of nutrients (cations) removed from the soil exceeds what is added to the soil through manuring or nitrogen fixation activities of the Albizia lebback trees.

Thus, the increasing value of exchangeable bases and accompanying decline in soil pH in the experimental site (Olowolafe, 2007). The differences among the mean values of exchangeable acidity could be attributed to possible effect of clay content in the soils. The values of subsoil are higher than that of the surface soil which could be due to leaching or higher infiltration rates of the exchangeable cations at the exchange site. For instance, the values of the exchangeable acidity before planting (0.87 to 1.87) decreased profoundly (0.54 – 0.80) in the surface soil (0 – 10cm depth) but to a little extent in the deeper strata (10 – 40 cm) with mean values of 0.73 to 1.53 cmol (+) kg^{-1} soil. This is due to leaching of nutrients or their uptake by the crop (potato) as more H^{+} and Al^{+} replaced the exchange site and thereby making the soil more acidic.

This phenomenon had earlier been reported by Fomba (1998) on the effects of *Gliricidia sepium* leaf mulching on okra growth and yield. Also, low organic matter contents normally adversely affect exchangeable acidity since soil organic matter plays a vital role in the supply of plant nutrients and enhancement of exchangeable acidity. The low organic carbon in the site is traceable to the influence of high temperature which is a prominent feature of tropical environment which leads to fast rates of decomposition, minerlization and subsequent disappearance of soil organic matter (Nye and Ray, 1996; Olowolafe and Dung, 2000).

Similarly, the observed decrease in the effective cation exchange capacity (ECEC) from a range of 6.12 to 6.62 downwards the soil strata (0 – 40 cm depth) before planting to a range of 3.65 to 5.79 (Table 16) down the strata (0 – 40 cm depth) after planting could be due to obsorption by plants, crop removal and leaching. Also, the values of the ECEC reduced because of the reduction in the values of exchangeable cations and exchangeable acidity since ECEC is the summation (addition) of the exchangeable cations and exchangeable acidity. Therefore, the increase in exchangeable acidity and ECEC from the surface soil to the deeper strata of the soil (subsoil) in the study site could be as a result of leaching or infiltration of the exchangeable cations or their absorption by the potato crops for growth and yield. This agrees with the earlier observation made by Olowolafe and Dung (2000) in respect of soils derived from the biotite-granite on the Jos Plateau (Nigeria) with regard to their nutrient status and management for sustainable agriculture.

Apart from factors such as leaching infiltration obsorption by crops and grazing, erosion could also be a contributory factor for the decline in exchangeable acidity and ECEC in the surface soil. This agrees with the reports by Lal (1981) and Olowolafe (2007) who observed that considerable or substantral proportion of topsoil nutrients is lost as a result of erosion. It is pertient to mention here that since organic matter helps retaining cations and EEC in soils and is very low in surface / top sopil due to crop removal, leaching, erosion among others, this must have brought about difference in ECEC values of the surface and sub-soil.

5.9 MINERAL CONTENT ANALYSIS OF THE POTATO (LEAVES AND TUBERS) AND *ALBIZIA LEBBECK* LEAVES

Based on the constituents of the *A. lebbeck* leaves, it has been established that it contained a rich source of nutrients most especially nitrogen (3.94%). The treatments that received green manure application must have got part of their nitrogen requirements from the green manure after decomposition and mineralization. Thus, the nitrogen might have influenced the yield of the potato as this is evident from the control (T_0) and even in T_1 (without green manure but with *A. lebbeck* tree rows). The yields from the T_0 and T_1 were very low compared to T_4, T_2 and T_3.

However, the efficacy of green manure in boosting the growth and yield of the potato is not limited to nitrogen alone but due to availability of other essential nutrients such as P, Ca, Mg, K, Na and Zn. This agrees with Fatokun and Chheda (1981) who observed an increase in fruit yield of okro with the application of nitrogen fertilizer and Fomba (1998) about improved yield of okro due to the application of *Gliricidia sepium* leaf mulch.

The highest percentage nitrogen (4.19%) observed in potato leaves from T_2 could probably be attributed to timely release of mineralized nitrogen for absorption by the potato crops. Moreover, the application of green manure was done two weeks before planting and solely utilized by the potato plants. Proper decomposition, mineralization and subsequent mobilization of nutrients must have conributed. The percentage nitrogen contained in the leaves of the potato crop (2.94 – 3.94) in respect of T_0, T_1, T_3 and T_4 might have contributed to good vegetative growth and influenced the yield of the crop. Fomba (1998) had earlier observed that good vegetative growth could be as a result of increased rate for photosynthetic activity thereby leading to increased surface area of the leaves under solar energy which culminates in improved yield.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

The study was conducted to quantify the effects of *Albizia lebbeck* (rattle tree) on soil properties and Irish potato productivity on the Jos Plateau .However,the specific objectives are to determine the effects of green manure and tree rows of *A. lebbeck* on soil properties; growth and yield of the potato and to determine the quantity of *A. lebbeck* green manure that could bring about optimal yield of the potato in both rainy and dry cropping seasons without the use of chemical fertilizer.

In carrying out the research, a randomized complete block design (RCBD) with five treatments and three replicates was employed. The five treatments applied were as follows: Treatment 1 (T_1): Irish potato planted in the space between *A. lebbeck* trees (alley) without green manure; T_2: Potato planted without *A. lebbeck* tree rows but with its green manure application, two weeks before planting of potato at 5 ton/ha; T_3: Potato planted in the alley of *A. lebbeck* with its green manure (as mulch) at 5 ton/ha; T_4: Potato planted in the alley of *A. lebbeck* tree rows at 10 ton/ha and T_0: Potato planted without *A. lebbeck* green manure and tree rows as control. Plot size was 3 m x 2 m (6 m^2) in form flat bed

. Apart from T_3 with the green manure as mulch on the plot, the green manure applied to other treatments was ploughed with the soil. Green manure application was done two weeks before planting of potato and *A. lebbeck* seedlings were planted one week prior to planting of potato. The field experiment lasted for three years (2004 – 2006) and both rainy and dry cropping seasons were carried out. The *A. lebbeck* seedlings were seven months old before planting them.

A soil profile pit (1 m x 1 m x 1.3 m) was dug at the experimental site to examine the physical and chemical properties of the different layers (horizons). As soon as the rain stabilized in May, 2004 site clearing, land preparation and plot lay-out were done. Pre-experimental soil samples were taken immediately after clearing the site (prior to land preparation) at three soil depths (0-10, 10-25 and 25-40 cm) so as to assess the initial soil properties/nutrient status of the study site. Thereafter, *A. lebbeck* tree rows at both sides of the 3 m x 2 m plots (for T_1, T_3 and T_4) were established and T_2, T_3 and T_4 plots were manured with the rattle tree green foliage at 5 ton/ha, 5 ton/ha and 10 ton/ha equivalent to 3 kg, 3 kg and 6 kg/6 m^2 respectively.

Planting of the pre-sprouted Irish potato tubers commenced two weeks after green manure application to ensure proper decomposition. An early maturing potato variety (bertita) was planted (20 – 30 cm with rows 75 – 100 cm between rows and 8-10 cm depth). This variety was procured from the National Root Crop Research Institute, Vom near Jos, Plateau State. Tending operations such as weeding, shade reduction (at the 4^{th} and 5^{th} cropping seasons when the rattle tree rows attained 2-3 m height) were carried out. Fire-tracing was done during the dry season cropping which involved clearing of the perimeter of the experimental site to prevent wild fire and rodents. Frequency of irrigation was at two days interval and the soil moisture was maintained at field capacity during tuber initiation, tuberization and bulking. However, soil moisture was reduced to 50% at maturation and irrigation continued till one week to harvest.

Data collection on seedling emergence at 7 and 14 DAP, growth parameters (plant height, leaf count, stem count and collar girth of the potato crops at 63 DAP) and yield parameter (tuber count and tuber yield at 75 DAP) was carried out. Post experimental soil samples were collected at the end of the 5th cropping season at three soil depths 0 - 10 cm, 10 - 25 cm and 25 - 40 cm to assess the soil properties and per treatment and compare the result with the initial nutrient status of the study site. The experimental soil samples collected before and after planting were analysed at the Department of Soil Science, Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

The data collected were anlysed statistically by using analysis of variance (ANOVA) technique. Duncan's multiple range test (DMRT) was employed in separating the mean values of treatments especially those whose F-tests were significant at either 5% or 1% probability levels. Also tables, graphs, and photographs were used for illustrations.

Apart from using the analysis of variance technique, simple bivariate correlation and regression analyses were employed to explain the nature and strength of the correlation (relationships) between some pairs of variables such as yield and plant height, yield and leaf count or yield and collar girth.

Owing to the limitations of the simple bivariate correlation and regression analyses, such as inability to consider the effects of other variables on the respondent/dependent variable, the multiple correlation and regression analyses were used. By employing these methods of analysis, it was easy to assess or examine the inter-relationships between or among the sets of variables under consideration. Thus, it was possible to adequately know and explain the relationships between a dependent variable (such as yield) and a set of independent variables (such as plant height, leaf count, stem count and collar girth). The regression analysis on the other hand was employed to serve as a highly powerful tool for comprehending the interaction among factors in the experiment and to re-assess the variable performance of each step since the forward selection type of the stepwise regression analysis was employed.

Based on the results obtained, the findings/observations are hereby summarized as follows:

(a) The percentage seedlings' emergence of Irish potato is greatly enhanced when the right size of tubers are selected and presprouted prior to planting.

(b) Apparent growth parameters (plant height, leaf count and collar girth) except stem count are highly influenced by different levels of *Albizia lebbeck* green manure application.

(c) The introduction of *Albizia lebbeck* tree rows had influenced the growth and yield of Irish potato through out the cropping seasons.

(d) In this study optimal yields of Irish potato was obtained at the application level of 10 ton/ha of *A. lebbeck* green manure with its tree rows.

(e) Simple bivariate correlation and regression analyses in the rainfed cropping seasons indicated that collar girth (as an independent variable) and yield (a dependent variable) were highly positively correlated and significant at 1% .

(f) It was observed that leaf count and yield were highly positively and significantly correlated ($P \leq 0.01$) in the irrigated cropping seasons. The level of correlation between yield and plant height and yield and collar girth was at 5% level while yield versus stem count indicated a negative correlation at 5%. With regard to the results from the simple regression analysis, leaf count, plant height and collar girth had positive effect in crop yield while stem count recorded a negative effect.

(g) Only leaf count indicated a high, positive and significant correlation with yield in the combined cropping seasons while the remaining independent variables (collar girth, plant height and stem count) were not.

(h) The multiple correlation and regression analyses of the growth parameters (independent variables) versus yield (the independent variable) revealed that collar girth had the highest positive and significant correlation ($P \leq 0.01$) with yield and highest coefficient of determination (R^2=0.910) in the rainfed cropping seasons. Leaf count had the highest positive and significant correlation (at 1 %) and highest value of R^2 (0.913) in the irrigated cropping seasons. Leaf count also had a highly and positively significant effect on the yield of the crop (R^2 = 0.881) at 5 % in respect of the combined cropping seasons. This was followed by collar girth (R^2 = 0.616) and plant height (R^2 = 519) while the least was stem count (R^2 = 0.003) and not at significant level.

(i) Based on the results from the correlation and regression analyses, the independent variables (collar girth, leaf count and plant height) and the dependent variable (Irish potato yield) were positively correlated while stem had a negative correlation with yield. Very importantly leaf count and collar girth were the two determinants of yield (of this bertita variety of Irish potato) from this study. They accounted for 61.6 – 91.3% of the variation in yield (R^2 = 0.616 – 0.913).

(j) The *Albizia lebbeck* plants shared the available nutrients with the crop (Irish potato) though it adds nutrients to the soil through its nitrogen fixation activities.

(k) The soils in the study area which were derived or developed from granite of the Jos Plateau are very low in organic matter and nitrogen.

(l) The treatments applied (*Albizia lebbeck* green manure and its tree rows: alley cropping) significantly influenced the available P at 0 – 10 cm depth and K content at 0 – 10 cm and 10 – 25 cm soil depths. However, block effects were observed at significant level on the pH at 10 – 25 cm and 25 – 40 cm depth and on Mg at 0 – 10 cm depth.

(m) The organic carbon and total nitrogen levels of the soils at the study site were generally low probably due to crop removal, leaching and high temperature which brought about high rates of decomposition, mineralization and disappearance of organic matter.

(n) The available P decreased generally from the surface soil (down wards) to the subsoil in the study site owing to absorption by the plants and crop removal.

(o) The values of exchangeable acidity and ECEC increased generally from surface soil to the sub-soil probably due to leaching or infiltration of the exchangeable cations.

(p) The incidence of bacterial wilt and brown rot is higher in the rainy season than in the dry season.

The overall nutrient status and productivity of Irish potato could be improved under alley cropping with *Albizia lebbeck* in the long run.

6.2 CONCLUSION

Irish potato can be productively and sustainably produced by employing the fresh foliage of the rattle tree (*Albizia lebbeck Benth)* as green manure under alley cropping with this tree species. The optimum yield of this crop (potato) could be achieved by applying the green manure of the *A. lebbeck* at the rate of 10 ton per hectare in the alleys (spaces) between the tree rows of this tree species. Healthy or disease-free pre-sprouted tubers within the range of 25 mm – 50 mm in diameter should be planted in May when rain stabilizes to avoid the peak blight period, bacterial wilt and brown rot in August.

Besides the enhancement of the yield of this crop under alley cropping with the rattle tree, an added advantage is the improvement on the soil nutrient status. The green manure improves the soil structure, texture and general chemical properties of the soil. This tree species being a nitrogen fixing tree, improve the nitrogen status of the soil which will concomitantly lead to better fertility status of the soil in the long run. Thus, the overall cost of production will be drastically reduced more so when the use of chemical or nitrogenous fertilizer is excluded.

Timely release of nutrients is better achieved when the green manure is applied to the alleys of the *Albizia lebbeck* tree rows 2-3 weeks prior to planting. In order to ensure rapid decomposition and minerlaization the green manure should be incorporated into the soil (that is, ploughed/harrowed) at the time of application. With proper/shrewd management and required cultural practices, sustainable production of potato could be achieved under alley cropping with *A. lebbeck* without chemical fertilizer application.

6.3 RECOMMENDATIONS

Based on the findings from this study, the following recommendations could be of immense importance.

a. The right size of potato tubers should be selected for planting especially those whose diameters ranged from 25 mm – 50 mm.

b. In order to break the dormancy period in potato tubers, the healthy/disease free tubers should be presprouted before planting.

c. The rate of green manure application should be 10 ton ha^{-1} for optimum production and should be ploughed/ harrowed with the soil at land preparation.

d. The alleys or spaces between *Albizia lebbeck* tree rows should be 5- 10 meters so as to allow tractors to operate and to prevent undue shading by the rattle (for large scale farming).

e. The trees should be pruned or pollarded at the commencement of the planting season and subsequently at intervals while the crops are in the alleys. These ‘prunings’ serve as additional manure and prevent shading of the crops that are closer to the tree rows.

f. Regular/timely cultural practices should be upheld to avoid competition for nutrients by weeds, early planting should be done to avoid the late blight disease of potato and other diseases such as bacterial wilt and brown rot.

g. The early maturing variety of potato such as bertita (which matures within two months) employed in this study could be planted, though other varieties (that mature in 3 to 4 months) could be used.

h. Dry season farming has an edge over wet season farming in the spare of disease attack (for example, bacterial wilt and brown rot) but if the irrigation water is unavailable in the right quantity and at minimal cost, dry season farming should not be ventured owing to unfavourable cost-benefit analysis.

i. Rattle trees should be at least 3 meters within rows and 5 – 10 meters between rows (to make possible for mechanized farming in the alleys). Selective felling for poles or fuelwood (after attaining full maturity) during dry seasons when crops have been harvested could be done as part of the numerous benefits derivable from this agroforestry system. The coppice shoots should be reduced to one or two vigorous one(s) per stump and given adequate silvicultural management.

6.4 CONTRIBUTION TO KNOWLEDGE

It has been established from the findings that soil nutrient status and productivity of *Solanum tuberosum* (Irish potato) can be improved through application of the green manure of *Albizia lebbeck* (rattle tree) under alley cropping with its tree rows. Higher yield of Irish potato (in the granite area of Jos Plateau) is feasible when the potato crops are planted in the alley of *Albizia lebbeck* tree rows and the alleys manured with green foliage of *Albizia lebbeck* at rate of 10 ton ha^{-1}. Proper decomposition, mineralization and subsequent mobilization of nutrients are also achievable within is 2-3 weeks prior to planting.

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APPENDICES

Appendix 1: Analysis of Variance (ANOVA) Showing the Effect of Block, Treatment, Season and Treatment x Season on % Seedlings Emergence of Irish Potato at 7 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	107.39	53.69	3.06	0.0600 NS
Treatment	4	1683.33	420.83	23.97	< 0.0001***
Season	4	133354.67	3338.67	190.19	< 0.0001***
Treatment x Season	16	1498.67	93.67	5.34	< 0.0500*
Error	48	842.61	17.55	-	-
Total	74	17486.67	-	-	-

*** = Highly Significanta at 1%, * = Significant at 5 %, NS = Not Significant.

Appendix 2: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season % Seedlings Emergence of Irish Potato at 14 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal.Value	Probability Level
Block (Replicate)	2	20.91	10.45	2.02	0.1438 NS
Treatment	4	154.48	38.62	7.46	< 0.0001***
Season	4	606.35	151.59	29.29	< 0.0001***
Treatment x Season	16	324.99	20.31	3.92	< 0.0500*
Error	48	248.43	5.18	-	-
Total	74	1355.15	-	-	-

*** = Highly Significant (1%), * = Significant at 5 %, NS = Not Significant.

Appendix 3: ANOVA Showing the Effect of Block, Treatment Season and Treatment x Season on Plant Height at 63 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block	2	3.92	1.96	0.47	0.6287 NS
Treatment	4	2572.53	643.13	153.78	< 0.0001***
Season	4	4364.27	1091.07	260.88	< 0.0001***
Treatment x Season	16	238.53	14.91	3.56	< 0.0500*
Error	48	200.75	4.18	-	-
Total	74	7380.00	-	-	-

*** = Highly Significant at 1%, * = Significant at 5%, NS = Not Significant.

Appendix 4: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season on Leaf Count of Irish Potato at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	4.67	2.33	0.66	0.5194 NS
Treatment	4	7600.00	1900.00	540.71	< 0.0001***
Season	4	8438.80	2109.70	600.39	< 0.0001***
Treatment x Season	16	1038.53	64.91	18.47	< 0.0100**
Error	48	168.67	3.51	-	-
Total	74	17250.67	-	-	-

*** = Highly Significant at 1%, ** = Significant at 1%, NS = Not Significant

Appendix 5: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season on Stem Count Potato at 63 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	0.19	0.093	0.46	0.6362 NS
Treatment	4	1.92	0.480	2.35	0.0676 NS
Season	4	1.52	0.380	1.86	0.1331 NS
Treatment x Season	16	4.35	0.272	1.33	0.2194 NS
Error	48	9.81	0.204	-	-
Total	74	17.79	-	-	-

NS = Not Significant

Appendix 6: ANOVA Showing the Effect of Block Treatment, Season and Treatment x Season on Collar Girth of Irish Potato at 63 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.006	0.003	1.50	0.2340 NS
Treatment	4	51.282	12.821	6494.52	< 0.0001***
Season	4	7.064	1.766	894.62	< 0.0001***
Treatment x Season	16	1.77	0.111	56.12	< 0.0001***
Error	48	0.095	0.002	-	-
Total	74	60.219	-	-	-

*** = Highly Significant at 1%, NS = Not Significant

Appendix 7: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season on Tuber Count of Irish Potato

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	978.11	489.053	1.67	0.5199 NS
Treatment	4	18898.59	4924.65	16.09	< 0.0001***
Season	4	7460.72	1990.18	6.78	< 0.01**
Treatment x Season	16	19420.21	1213.76	4.13	< 0.05*
Error	48	14098.56	293.72	-	-
Total	74	61356.19	-	-	-

*** = Highly Significant at 1%,** = Significant at 1%, NS = Not Significant

Appendix 8: ANOVA Showing the Effect of Block Treatment, Season and Treatment x Season on Tuber Yield of Irish Potato at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.067	0.033	2.28	0.1137 NS
Treatment	4	315.716	78.929	5390.46	< 0.0001***
Season	4	11.235	2.809	191.82	< 0.0001***
Treatment x Season	16	9.36	0.585	39.96	< 0.0001***
Error	48	0.703	0.015	-	-
Total	74	337..081	-	-	-

*** = Significant at 1 %.

Appendix 9: ANOVA Showing the Effect of the Incidence of Bacterial Wilt/Brown Rot on Irish Potato Productivity at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.747	0.373	0.84	0.4366 NS
Treatment	4	16.747	4.187	9.46	< 0.0001***
Season	4	24.213	6.053	13.67	< 0.0001***
Treatment x Season	16	32.587	2.037	4.60	0.0500*
Error	48	21.253	0.443	-	-
Total	74	95.547	-	-	-

*** Highly Significant at 1 %, Significant at 5 %, NS = Not Significant.

Appendix 10: pH (H_20) of the Pre/Post Experimental Soil Samples 0 – 10 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	4.8	4.4	4.3
T_0	4.8	5.2	5.7
T_1	4.5	4.0	5.0
T_2	4.3	5.8	5.4
T_3	4.6	5.1	5.6
T_4	4.0	5.0	5.1

Appendix 11: pH (H_20) of the Pre/Post experimental soil 10 -25 cm Depth.

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	4.5	4.2	4.1
T_0	4.3	4.7	5.7
T_1	4.0	4.6	5.8
T_2	4.2	5.6	5.6
T_3	4.6	5.8	5.8
T_4	4.2	5.6	5.5

Appendix 12: pH (H20) of the PrePost Experimental Soil Samples 25 – 40 cm Depth.

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	4.8	4.0	4.1
T_0	4.0	5.7	5.7
T_1	4.7	5.8	5.5
T_2	4.0	5.6	4.8
T_3	4.5	5.8	5.8
T_4	4.3	5.3	4.8

Appendix 13: pH (KCl) of the Pre/Post Experimental Soil Samples 0 – 10 cm Depth.

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	4.3	4.1	4.2
T_0	4.4	4.5	4.7
T_1	4.3	3.7	4.8
T_2	4.0	4.7	4.7
T_3	3.9	4.2	4.0
T_4	3.9	4.0	4.5

Appendix 14: pH (KCl) of the Pre/Post Experimental Soil Samples 10 – 25cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	4.0	3.8	4.0
T_0	4.0	4.7	4.7
T_1	3.9	4.0	4.6
T_2	3.8	4.6	4.7
T_3	4.2	4.8	4.1
T_4	4.0	4.6	4.8

T_p = Data from pre-experimental soil samples

Appendix 15: pH (KCl) of the Pre/Post Experimental Soil Samples 25 – 40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	3.6	3.8	3.7
T_0	4.0	4.9	4.8
T_1	3.9	4.8	4.6
T_2	3.8	4.7	4.8
T_3	4.0	4.7	4.6
T_4	3.8	4.9	4.8

Appendix 16: Organic Matter Content of Pre/Post Experimental Soil Samples 0 – 10cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	1.79	1.65	2.41
T_0	1.10	1.32	1.24
T_1	0.93	1.38	1.57
T_2	1.20	1.48	1.45
T_3	1.31	1.89	1.15
T_4	1.82	1.24	1.98

Appendix 17: Organic Matter Content of Pre/Post Experimental Soil Samples 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	1.45	0.59	1.45
T_0	0.93	1.03	1.15
T_1	1.03	1.15	1.57
T_2	1.03	1.48	1.24
T_3	1.10	1.89	1.69
T_4	1.38	1.26	1.48

Appendix 18: Organic Matter Content of the Pre/Post Experimental Soil Samples 25-40 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	0.83	0.96	0.59
T_0	1.14	0.86	0.86
T_1	1.03	0.91	1.20
T_2	1.03	1.33	1.07
T_3	1.31	1.24	0.91
T_4	0.96	0.95	1.19

Appendix 19: Total Nitrogen Content of the Pre/Post Experimental Soil Sample Samples 0 – 10 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	0.12	0.09	0.09
T_0	0.05	0.07	0.05
T_1	0.04	0.07	0.07
T_2	0.05	0.07	0.07
T_3	0.07	0.09	0.07
T_4	0.09	0.05	0.84

Appendix 20: Total Nitrogen Content of 10 – 25 cm Depth.

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	0.11	0.05	0.05
T_0	0.05	0.05	0.05
T_1	0.04	0.09	0.07
T_2	0.05	0.09	0.09
T_3	0.05	0.09	0.09
T_4	0.09	0.05	0.09

Appendix 21: Total Nitrogen Content of 25 – 40 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	0.12	0.05	0.05
T_0	0.07	0.05	0.05
T_1	0.04	0.07	0.09
T_2	0.76	0.09	0.07
T_3	0.05	0.07	0.09
T_4	0.05	0.07	0.69

Appendix 22: Available phosphorus (P) Content of Pre/post Experimental Soil samples 0 – 10 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	26.53	14.07	29.75
T_0	15.68	9.87	21.00
T_1	12.53	20.23	16.45
T_2	21.70	14.35	37.80
T_3	12.67	2.73	3.95
T_4	16.80	12.95	26.95

Appendix 23: Available P Content of 10 – 25 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	6.37	0.77	4.22
T_0	7.00	5.75	20.00
T_1	38.50	8.47	7.70
T_2	8.96	12.95	19.46
T_3	5.25	2.63	14.00
T_4	5.11	5.88	20.16

Appendix 24: Available P content of 25 – 40 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	3.40	2.52	3.20
T_0	2.59	6.60	4.20
T_1	1.54	6.80	3.36
T_2	4.20	3.36	5.74
T_3	7.20	5.11	2.75
T_4	2.45	3.15	15.05

Appendix 25: Calcium (Ca) Content of Pre/Post Experiment Soil Samples 0 – 10 cm Depth

Treatments	**Blocks/Replicates**		
(6)	I	II	II
T_p	3.80	3.00	5.40
T_0	2.40	3.20	2.20
T_1	2.40	2.00	1.80
T_2	2.60	3.00	3.40
T_3	2.40	2.80	2.80
T_4	2.40	2.80	4.00

Appendix 26: Calcium (Ca) Contnet of 10 – 25 cm Depth.

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	3.60	2.80	5.40
T_0	2.40	2.00	2.80
T_1	3.60	3.20	2.40
T_2	2.00	1.82	1.60
T_3	2.40	3.40	2.80
T_4	3.80	3.00	3.00

Appendix 27: Ca Content of 25 – 40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	2.80	5.20	2.80
T_0	4.00	2.60	2.00
T_1	2.20	2.80	3.20
T_2	1.20	2.40	3.00
T_3	1.60	3.40	2.60
T_4	1.80	2.20	1.80

Appendix 28: **Magnesium (Mg) Content of pre/post Experimental Soil Samples 0 – 10 cm Depth**

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.62	0.25	1.48
T_0	0.62	0.58	0.62
T_1	0.57	0.36	0.95
T_2	0.68	0.42	1.06
T_3	0.73	1.13	1.22
T_4	0.48	0.72	1.58

Appendix 29: Mg content of the 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	II
T_p	0.26	0.58	1.58
T_0	0.32	0.26	0.80
T_1	1.85	1.36	0.27
T_2	0.58	0.22	0.23
T_3	0.40	1.32	0.72
T_4	1.55	0.58	0.83

Appendix 30: Mg Content of the 25 – 40 cm Depth.

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.62	0.26	0.68
T_0	1.83	0.42	1.33
T_1	0.78	0.76	0.43
T_2	0.47	0.73	1.08
T_3	0.46	1.90	0.85
T_4	0.28	0.37	0.22

Appendix 31:Potassium (K) content of the pre/post Experiments Soil samples 0 – 10 cm Depth.

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.27	0.21	0.19
T_0	0.13	0.20	0.17
T_1	0.12	0.10	0.10
T_2	0.18	0.12	0.12
T_3	0.22	0.26	0.13
T_4	0.18	0.14	0.19

Appendix 32: K Content of the 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.17	0.16	0.12
T_0	0.12	0.15	0.14
T_1	0.11	0.11	0.12
T_2	0.20	0.19	0.12
T_3	0.17	0.23	0.18
T_4	0.16	0.20	0.16

Appendix 33: K Content of the 25-40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.22	0.22	0.10
T_0	0.14	0.17	0.17
T_1	0.12	0.16	0.13
T_2	0.17	0.14	1.10
T_3	0.18	0.18	0.13
T_4	0.11	0.13	0.16

Appendix 34: Sodium (Na) Content of the Pre/Post Experimentsal Soil Samples 0 – 10 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.17	0.17	0.19
T_0	0.17	0.17	0.12
T_1	0.23	0.17	0.16
T_2	0.37	0.18	0.15
T_3	0.23	0.20	0.15
T_4	0.18	0.29	0.14

Appendix 35: Na Content of the 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.17	0.23	0.20
T_0	0.17	0.18	0.15
T_1	0.26	0.18	0.17
T_2	0.45	0.19	0.14
T_3	0.27	0.18	0.14
T_4	0.23	0.18	0.13

Appendix 36: Na Content of the 25 – 40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	0.19	0.39	0.23
T_0	0.23	0.14	0.17
T_1	0.30	0.20	0.13
T_2	0.23	0.14	0.12
T_3	0.15	0.17	0.16
T_4	0.19	0.12	0.13

Appendix 37:Exchangeable Acidity of the Pre/Post Experimental Soil Samples 0 – 10 cm Depth.

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	1.00	1.00	0.60
T_0	0.40	1.00	0.80
T_1	0.23	0.80	0.60
T_2	0.80	0.80	0.80
T_3	0.60	0.80	0.80
T_4	0.60	0.80	0.40

Appendix 38 Exchangeable Acidity of the 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	1.40	1.80	0.40
T_0	0.80	1.40	1.20
T_1	0.60	0.80	0.80
T_2	1.40	0.60	1.20
T_3	0.80	1.60	2.00
T_4	1.60	0.80	0.80

Appendix 39: Exchangeable Acidity of the 25 – 40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	1.60	1.40	2.60
T_0	1.40	1.60	1.20
T_1	0.60	1.60	1.20
T_2	1.60	1.60	0.80
T_3	1.80	1.20	1.60
T_4	1.40	1.20	0.80

Appendix 40: ECEC of the Pre/Post Experimental Soil Samples 0 – 10 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	5.86	4.63	7.86
T_0	3.72	5.15	3.91
T_1	3.92	3.43	3.61
T_2	4.63	4.52	5.53
T_3	4.18	5.20	5.10
T_4	3.80	4.75	6.31

Appendix 41: ECEC of the 10 – 25 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	5.60	5.57	8.70
T_0	3.81	4.00	5.09
T_1	7.02	5.65	3.76
T_2	4.63	3.00	5.53
T_3	4.04	6.73	5.84
T_4	7.34	4.76	4.92

Appendix 42: ECEC of the 25-40 cm Depth

Treatments (6)	**Blocks/Replicates** I	II	III
T_p	5.43	7.47	6.41
T_0	7.60	4.93	4.85
T_1	4.00	5.52	5.09
T_2	3.67	5.01	3.11
T_3	4.19	6.85	5.34
T_4	7.78	4.05	5.10

Appendix 43: ANOVA Showing the Effect of Block and Treatment on Soil pH (H_20) at 0 – 10 cm Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	1.42	0.71	3.43	0.073 NS
Treatment	5	1.73	0.35	1.67	0.230 NS
Error	10	2.07	0.21	-	-
Total	17	5.22	-	-	-

NB: NS = Not Significant

Appendix 44: ANOVA Showing the Effect of Block and Treatment on Soil pH (H_20) AT 10 – 25 cm Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	3.94	1.97	8.39	0.007 **
Treatment	5	2.25	0.45	1.19	0.180 NS
7Error	10	2.35	0.24	-	-
Total	17	8.54	-	-	-

** = Significant at 1% , NS = Not Significant

Appendix 45: ANOVA Indicating the Effect of Block and Treatment on Soil pH (H_20) at 25 – 40 cm Depth.

Sourceof Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	3.30	1.65	5.93	0.020 *
Treatment	5	2.41	0.48	1.94	0.214 NS
Error	10	2.78	0.28	-	
Total	17	8.50	-	-	

Significant at 5%, NS = Not Significant

Appendix 46: ANOVA Indicating the Effect of Block and Treatment on Soil pH (KCl) at 0 – 10 cm Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.41	0.21	2.47	0.134 NS
Treatment	5	0.56	0.11	1.34	0.232 NS
Error	10	0.84	0.08	-	
Total	17	1.82	-	-	

NS = Not Significant

Appendix 47: ANOVA Indicating the Effect of Block and Treatment on Soil pH (KCl) at 10 – 25 cm Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.88	4.42	5.05	0.031*
Treatment	5	0.65	0.13	1.48	0.278 NS
Error	10	0.88	0.09	-	-
Total	17	2.41	-	-	-

* = Significant at 5%, NS = Not Significant

Appendix 48: ANOVA Showing the Effect of Block and Treatment on Soil pH (KCl) at 25-40 cm Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	2.22	1.11	30.38	0.00006***
Treatment	5	1.54	0.31	8.41	0.00240**
Error	10	0.37	0.07	-	-
Total	17	4.12	-	-	-

*** = Highly Significant at 1%, ** = Significant at 1%,

Appendix 49: ANOVA Showing the Effect of Block and Treatment on Organic Matter at 0 – 10 cm Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.14	0.07	1.40	0.462 NS
Treatment	5	0.65	0.14	2.80	0.924 NS
Error	10	0.58	0.05	-	
Total	17	1.36	-	-	

NS = Not Significant

Appendix 50: ANOVA Indicating the Effect of Block and Treatment on Soil Organic Matter at 10 – 25 cm Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.140	0.07	1.410	0.465 NS
Treatment	5	2.810	0.06	1.200	0.396 NS
Error	10	0.570	0.05	-	-
Total	17	0.943	-	-	-

NS = Not Significant

Appendix 51: ANOVA Showing the Effect of Block and Treatment on Organic Matter at 25 – 40 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.014	0.007	0.350	0.116 NS
Treatment	5	0.160	0.030	1.548	0.511NS
Error	10	0.190	0.020	-	-
Total	17	0.360	-	-	-

NS = Not Significant

Appendix 52: ANOVA Showing the Effect of Block and Treatment on Total Nitrogen (%) of the 0 – 10 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.064	0.032	0.961	0.415 NS
Treatment	5	0.167	0.033	0.999	0.466 NS
Error	10	0.334	0.0344	-	-
Total	17	0.565	-	-	-

NS = Not Significant

Appendix 53: ANOVA Indicating the Block and Treatment Effect on Total Nitrogen (%) of the 10 – 25cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.0021	0.0001	0.159	0.856 NS
Treatment	5	0.0020	0.0003	0.490	0.778 NS
Error	10	0.0067	0.00067	-	-
Total	17	0.009	-	-	-

NS = Not Significant

Appendix 54: ANOVA Showing the Block and Treatment Effect on Total Nitrogen (%) of the 25 – 40 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.0500	0.0250	0.466	0.641 NS
Treatment	5	1.990	0.0398	0.752	0.604 NS
Error	10	0.530	0.0530	-	-
Total	17	0.778	-	-	-

NS = Not Significant

Appendix 55: ANOVA Indicating the Block and Treatment Effect on Available Phosphorus of the 0 – 10 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	317.32	158.66	4.38	0.043*
Treatment	5	645.69	129.140	3.582	0.0414 NS
Error	10	362.57	36.26	-	-
Total	17	1325.579	-	-	-

* = Significant at 5%, NS = Not Significant

Appendix 56: ANOVA Showing the Block and Treatment Effect on Available Phosphorus of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	212.413	106.21	1.302	0.315 NS
Treatment	5	376.79	75.358	0.924	0.505 NS
Error	10	815.96	81.596	-	-
Total	17	1405.164	-	-	-

NS = Not Significant

Appendix 57: ANOVA Indicating the Block and Treatment Effect on Available Phosphorus of the 25 – 40 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	13.921	6.961	0.5704	0.583 NS
Treatment	5	25.070	5.0141	1.411	0.831 NS
Error	10	122.034	12.203	-	-
Total	17	161.025	-	-	-

NS = Not Significant

Appendix 58: ANOVA Showing the Block and Treatment Effect on Calcium(Ca) Content of the 0 – 10 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	1.191	0.5956	1.367	0.299 NS
Treatment	5	6.711	1.342	3.082	0.61181 NS
Error	10	4.356	0.4356	-	-
Total	17	12.258	-	-	-

NS = Not Significant

Appendix 59: ANOVA Indicating the Block and Treatment Effect on Ca of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.317	0.1585	0.298	0.74837 NS
Treatment	5	8.028	1.606	3.0236	0.064NS
Error	10	5.31	0.531	-	-
Total	17	13.655	-	-	-

NS = Not Significant

Appendix 60: ANOVA Showing the Block and Treatment Effect on Ca of the25 – 40 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	2.138	1.069	1.383	0.295 NS
Treatment	5	5.058	1.012	1.309	0.335 NS
Error	10	7.728	0.7728	-	-
Total	17	14.924	-	-	-

NS = Not Significant

Appendix 61: ANOVA Showing the Block and Treatment Effect on Magnesium (Mg) Content of the 0 – 10 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	1.758	0.879	12.726	0.002***
Treatment	5	0.206	0.041	0.597	0.704 NS
Error	10	0.691	0.0853	-	-
Total	17	2.656	-	-	-

*** = Highly Significant at 1%, NS = Not Significant.

Appendix 62: ANOVA Indicating the Block and Treatment Effect on Mg Content of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.039	0.020	0.0571	0.945 NS
Treatment	5	1.440	0.288	0.842	0.550 NS
Error	10	3.420	0.3420	-	-
Total	17	4.899	-	-	-

NS = Not Significant

Appendix 63: ANOVA Showing the Block and Treatment Effect on Mg Content ofthe 25 – 40 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.003	0.0013	0.005	0.995 NS
Treatment	5	1.717	0.034	1.369	0.314 NS
Error	10	2.508	0.2508	-	-
Total	17	4.228	-	-	-

NS = Not Significant

Appendix 64: ANOVA Indicating the Block and Treatment Effect on Potassium (K) Content of the 0 – 10 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.003	0.002	1.112	0.366 NS
Treatment	5	0.027	0.005	3.445	0.045 *
Error	10	0.015	0.002	-	-
Total	17	0.045	-	-	-

Significant at 5%, NS = Not Significant

Appendix 65: ANOVA Showing the Block and Treatment Effect on K content of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.003	0.002	3.028	0.094 NS
Treatment	5	0.012	0.003	4.477	0.021 *
Error	10	0.006	0.0006	-	-
Total	17	0.021	-	-	-

NS = Not Significant, * Significant at 5%.

Appendix 66: ANOVA Indicating Block and Treatment Effect on K content of the 25 – 40 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	20.018	10.009	0.926	0.428 NS
Treatment	5	52.305	10.461	0.968	0.481 NS
Error	10	108.104	0.0496	-	-
Total	17	180.427	-	-	-

NS = Not Significant

Appendix 67: ANOVA Indicating Block and Treatment Effect on Sodium (Na) Conten of the 0 – 10 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.016	0.008	2.549	0.127 NS
Treatment	5	0.011	0.002	0.670	0.656 NS
Error	10	0.032	0.0032	-	-
Total	17	0.0594	-	-	-

NS = Not Significant

Appendix 68: ANOVA Showing Block and Treatment Effect on the Na Content of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.033	0.017	3.831	0.060 NS
Treatment	5	0.015	0.003	0.711	0.629 NS
Error	10	0.043	-	-	-
Total	17	0.092	-	-	-

NS = Not Significant.

Appendix 69: ANOVA Indicating Block and Treatment Effect on Na Content of the 25 – 40 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.010	0.005	1.282	0.319 NS
Treatment	5	0.031	0.006	1.529	0.265 NS
Error	10	0.041	0.004	-	-
Total	17	0.082	-	-	-

NS = Not Significant.

Appendix 70: ANOVA Showing the Block and Treatment Effect on Exchangeable Acidity of the 0 – 10 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.221	0.112	3.276	0.081 NS
Treatment	5	0.225	0.0441	1.288	0.342 NS
Error	10	0.343	0.0343	-	-
Total	17	0.7880	-	-	-

NS = Not Significant

Appendix 71: ANOVA Indicating the Block and Treatment Effect on Exchangeable Acidity of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.031	0.016	0.057	0.945 NS
Treatment	5	0.844	0.169	0.616	0.691 NS
Error	10	2.742	0.274	-	-
Total	17	3.618	-	-	-

NS = Not Significant

Appendix 72: ANOVA Showing the Block and Treatment Effect on Exchangeable Acidity of the 25 – 40 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	0.013	0.007	0.030	0.970 NS
Treatment	5	1.147	0.229	1.042	0.445 NS
Error	10	2.200	0.220	-	-
Total	17	3.360	-	-	-

NS = Not Significant

Appendix73; ANOVA Indicating the Block and Treatment Effect on ECEC of the 0 – 10 cm Soil Depth.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	3.475	1.738	2.278	0.153 NS
Treatment	5	10.114	2.023	2.652	0.089 NS
Error	10	7.627	0.763	-	-
Total	17	21.217	-	-	-

NS = Not Significant

Appendix 74: ANOVA Showing the Block and Treatment Effect on ECEC of the 10 – 25 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	1.471	0.735	0.326	0.729 NS
Treatment	5	11.417	2.283	1.013	0.459 NS
Error	10	22.537	2.254	-	-
Total	17	35.424	-	-	-

NS = Not Significant

Appendix 75: ANOVA Indicating the Block and Treatment Effect on ECEC of the 25 – 40 cm Soil Depth

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	1.359	0.680	0.345	0.717 NS
Treatment	5	11.166	2.233	1.133	0.404 NS
Error	10	19.715	1.972	-	-
Total	17	32.240	-	-	-

NS = Not Significant

Appendix 76: Temperature (^{0}C) Data (2000 – 2006) in the Study Area

MONTHS	2000		2001		2002		2003		2004		2005		2006		Mean	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Jan.	30.5	15.5	27.4	13.7	24.0	12.0	30.5	15.3	29.0	13.1	28.3	13.1	33.0	17.0	28.96	14.24
Feb.	27.66	15.1	30.0	15.9	30.0	15.0	32.3	18.0	31.0	16.0	33.6	19.3	34.0	19.0	31.2	16.90
Mar.	30.8	18.8	33.2	19.7	33.0	22.0	30.0	20.0	32.0	19.0	34.0	22.0	33.0	19.0	32.3	20.07
Apr.	32.6	21.6	32.5	20.0	32.0	21.0	32.0	21.0	36.0	22.0	34.1	21.2	34.0	21.0	33.31	21.11
May.	32.1	21.1	20.1	20.5	32.0	21.0	32.0	21.0	30.0	20.0	30.0	21.0	30.0	20.0	29.5	20.07
Jun.	28.6	19.0	28.3	19.2	29.0	20.0	26.6	19.0	29.0	20.0	29.0	20.0	29.5	19.4	28.6	20.70
Jul.	25.9	18.8	29.4	18.9	28.0	19.0	32.5	18.9	28.0	19.0	26.0	19.0	28.0	19.3	26.5	19.50
Aug.	27.2	18.0	25.8	18.7	26.0	19.0	27.3	18.7	26.8	18.6	26.0	19.0	26.3	18.4	26.8	18.98
Sept.	26.9	18.7	27.0	18.0	28.0	18.0	27.0	18.9	32.3	18.8	27.0	19.0	27.1	21.2	27.9	18.60
Oct.	28.7	17.6	29.3.	17.4	28.0	18.0	30.2	18.5	33.1	19.0	30.0	17.0	29.4	18.9	29.8	18.90
Nov.	29.8	15.5	29.9	15.0	29.0	16.0	30.0	16.5	31.6	16.0	31.0	16.3	29.0	14.7	30.0	15.70
Dec.	25.7	14.7	29.1	15.9	30.0	15.0	31.0	14.0	32.0	15.0	31.0	15.5	28.6	13.1	29.6	14.74
Mean	28.9	17.9	17.7	17.7	29.1	17.7	30.1	18.3	30.9	18.0	30.0	18.5	29.59	18.5		

Source: Meteorological Station University of Jos, Jos, Nigeria

Appendix 77: Rainfall Data (2000 – 2006) In The Study Area

MONTHS	2000	2001	2002	2003	2004	2005	2006	Mean
January	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
February	0.0	0.0	0.0	0.0	0.0	6.9	-	0.10
March	9.6	0.0	16.7	0.0	22.9	0.0	-	7.03
April	48.2	137.1	119.1	42.3	87.8	67.0	44.10	78.94
May	112.8	178.5	80.9	43.1	181.6	76.8	208.30	126.00
June	196.4	310.2	271.5	95.1	216.1	253.4	197.60	234.30
July	411.0	273.0	132.5	306.9	368.8	192.2	247.10	275.93
August	410.0	432.0	309.2	481.0	235.8	2.29.3	405.70	357.57
September	214.1	30.4	230.8	243.0	191.0	150.7	292.30	193.18
October	17.3	0.0	65.6	13.4	4.4	56.2	37.70	27.80
November	0.0	0.0	0.0	0.8	0.0	0.0	0.00	0.114
December	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Total	1419.4	1361.2	1826.3	1325.6	1308.4	1032.5	1432.80	-
Mean	118.28	113.43	152.19	110.47	109.03	86.04	119.4	-

Source: Meteorological Station University of Jos, Jos Nigeria

Appendix 78: Relative Humidity (%) 2000 – 2006 in the Study Area

MONTHS	2000	2001	2002	2003	2004	2005	2006	Mean
January	34	21	25	23	22	24	23	24.57
February	32	21	20	24	21	32	28	25.43
March	33	17	24	22	24	19	16	22.14
April	45	52	56	50	53	33	27	45.14
May	55	70	60	47	75	56	63	60.86
June	69	74	63	72	87	68	62	70.71
July	78	81	76	78	81	77	73	77.86
August	80	84	87	84	83	49	78	77.86
September	75	80	84	74	70	68	72	74.71
October	72	59	84	76	45	49	59	63.43
November	38	33	51	62	27	24	29	37.71
December	34	24	47	53	22	22	25	32.43
Total	53.75	51.8	56.4	55.4	50.8	43.4	46.3	-

Source: Meteorological Station University of Jos, Jos Nigeria

Appendix 79: Sunshine (Hrs) 2000 – 2006 in the Study Area

MONTHS	2000	2001	2002	2003	2004	2005	2006	Mean
January	7.7	8.1	7.3	7.9	7.4	7.1	8.1	7.7
February	7.0	5.3	8.0	8.5	8.2	7.8	7.2	7.4
March	7.3	7.2	6.1	5.4	7.0	6.5	6.3	6.5
April	5.8	5.2	4.8	5.2	5.8	6.0	6.3	5.6
May	7.5	5.6	5.5	6.0	6.0	4.5	5.1	5.7
June	5.4	5.3	6.0	6.4	5.4	5.1	6.1	5.7
July	3.8	5.0	4.6	5.3	5.2	3.5	4.3	4.5
August	4.2	4.1	5.8	4.7	4.1	3.3	2.9	4.2
September	8.3	5.1	5.1	6.5	4.8	5.5	4.8	5.7
October	6.5	5.7	6.0	5.4	7.5	7.1	6.6	6.4
November	8.6	8.5	8.0	8.2	7.6	8.2	8.0	8.2
December	7.4	6.7	8.2	7.4	8.1	8.2	8.4	7.8
Mean	6.6	6.20	6.3	6.4	6.4	6.1	6.2	-

Source: Meteorological Station University of Jos, Jos Nigeria

Appendix 80: Evaporation Data (mm) in the Study Area (2000 – 2006*)*

MONTHS	2000	2001	2002	2003	2004	2005	2006	Mean
January	4.0	5.0	3.5	3.9	3.7	3.5	3.6	3.90
February	4.5	4.6	4.3	3.4	4.5	4.3	4.1	4.20
March	5.0	5.2	6.8	4.9	4.4	4.8	4.7	5.10
April	3.4	3.2	2.8	4.5	3.2	4.1	4.4	3.70
May	3.0	2.7	2.7	2.9	2.0	2.0	2.2	2.50
June	2.1	2.4	2.2	1.6	2.0	2.0	1.9	2.03
July	1.8	1.7	1.5	1.8	3.5	1.3	1.9	1.93
August	1.5	1.4	1.4	1.5	1.5	1.2	1.6	1.44
September	2.1	1.9	1.0	1.6	1.5	1.8	1.8	1.67
October	2.8	3.2	1.9	2.4	2.2	2.4	2.33	2.46
November	4.0	3.7	3.2	3.4	3.2	3.7	3.9	3.59
December	3.5	3.7	3.6	3.6	3.5	3.8	3.8	3.64
Mean	3.23	3.14	2.58	2.99	2.92	2.91	3.02	-

Source: Meteorological Station University of Jos, Jos Nigeria

Appendix 81:ANOVA Showing the Effect of the Clay Content in the Soil Samples Before and After Planting.

SV	Df	SS	MS	Fcal	F Tab.	(P=0.05)
Block	2	7.67	3.84	0.64	4.10	NS
Treatment	5	14.56	2.91	0.48	3.33	NS
Error	10	60.42	6.04	-	-	-
Total	17	82.65	-	-	-	-

NS = Not Significant