EFFECT OF FORAGE LEGUMES ON SOIL IMPROVEMENT AND THE PERFORMANCE OF MAIZE *(Zea mays* L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

BY

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JANUARY, 1999.

TITLE PAGE

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BY

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A THESIS

Submitted to the Postgraduate School, Ahmadu Bello University in partial fulfilment of the requirements for the Degree of Master of Science.

Department of Soil Science,
Faculty of Agriculture,
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January, 19 99.

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

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The above declaration is confirmed.

Dr. E.N.O. Iwuafor
(Major Supervisor)

CERTIFICATION

This thesis titled "EFFECT OF FORAGE LEGUMES ON SOIL IMPROVEMENT AND THE PERFORMANCE OF MAIZE (*Zea mays* L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA"

by

TANIMU, JOSEPH

meets the regulation governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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Date: 28/02/00

DEDICATION

To my wife (Rifkatu) and children (Josiah and Jabez) for their understanding, encouragement and support.

ACKNOWLEDGEMENT

I wish to express my profound gratitude and appreciation to my major Supervisor Dr. E.N.O. Iwuafor for supervising all aspects of this work. His patience in guidance, encouragement, correction and support at all stages of this thesis is appreciated. I also wish to thank, immensely Dr. E.O. Uyovbisere and Dr. B.A. Raji, members of my Supervisory Committee for their assistance at various stages of this work. My thanks goes to Prof. V.O. Chude, Head of Department for his moral support.

I wish to also extend my appreciation to Dr. A.C. Odunze for his supervision, encouragement and help in the preparation of this thesis; Mr. B.D. Tarfa and Dr. I.Y. Amapu for their contributions, encouragement and support. The contributions of my dear friends, Dan T. Yaro, H.W. Nakka, Duniya Lallai, A.A. Shedi, E.D. Pam, J.T. Goladi, S. Ayuba and J.M. Jibrin to the success of this work is greatly acknowledged. This work would not have been completed without the support of the technical and field staff of the Soil Science Department. My gratitude to Messrs, Ilu Ibrahim, Victor Odigie, Mathew Dogo, Simon Dashe and B.H. Agaga.

I wish to thank profoundly the following families for their moral, material and financial support, Mr. and Mrs. M.D. Tanimu, Dr. and Mrs. I.M. Tanimu, Inspector and Mrs. Wakili

Makama, Mr. and Mrs. Emmanuel Ikanne and
Mr. and Mrs. Danladi Waziri.

I am sincerely indebted to the Kaduna State Polytechnic, Zaria, for granting me permission to undertake this study. I am also extending my appreciation to the moist savanna programme, RCMD, IITA Ibadan, Nigeria for part funding of the project. My appreciation also goes to Mr. Mathias Kasa for carefully typing this thesis.

Father, thank you for doing it again. My deep desire and hope is that I shall never fail in my duty but that at all times, and especially just now, I shall be full of courage, so that with my whole being I shall bring honour to CHRIST, whether I live or die.

ABSTRACT

Greenhouse and field studies were conducted over a two-year period (1995 - 1996) at Samaru (11°11"N, 7°38"E) in the Northern Guinea savanna zone of Nigeria to evaluate the effect of legume incorporation on some soil properties and the performance of maize (Zea mays L.). In the greenhouse the treatments consisted of six forage legume species and maize stover applied at two rates (2.5 and 5.0t ha-^{1}) and a control of no amendment. The design was randomised complete block (RCBD) replicated three times. In the field, two experiments were conducted. In the first one, five legume species and a fallow control as treatments were incorporated after two years of growth, while in the second experiment, six legume species and control were incorporated only after one year of growth. The Design in the two experiments were split plot with legume species and fallow plots as main treatments and fertilizer rates (0, 40, 80 and 120kg N ha"^{1}) as sub-treatments.

The incorporation of legumes in the greenhouse generally increased shoot dry matter yield (DMY), plant height, maize shoot nutrient concentration, soil organic carbon and pH. At 2 . 5t ha-^{1} *Centrosema. pascuorum* (CP) and at 5 . Ot ha-^{1} *Chaemacrista rotundifolia* (CR) generally gave better results than the other treatments. Where legume was incorporated after one year of growth, CR gave maize grain yield, 1000-grain weight, plant and ear heights that were significantly (P<0.05) higher than

the other treatments. Increase in grain yield as a result of legume incorporation after one year of growth ranged from 0.18 to 0.61t ha-^{1} (38.3 to 129.8%) more than the control. Where incorporation was done after two years of growth, legume incorporation gave yield increases over the control which ranged from 0.13 to 1.03t ha'^{1} (15.5 to 122.6%) and 0.16 to 1.30t ha^{-1} (11.7 to 51.1%) for the first and second seasons respectively. The pooled data for the two seasons was compared with the control, legumes gave 0.14 to 0.83t ha-^{1} (12.6 to 74.8%) increased in grain yield than the control. Interaction between legume and N fertilizer showed that at 40kg N ha"^{1}, incorporating CP in the first experiment and CR in the second experiment gave maize grain yield that were comparable to the recommended dose of 120kg N ha-^{1}. This implies that with legume incorporation N requirement could be reduce by at least 80kg N ha"^{1}.

Grain yield and yield related parameters significantly responded to N fertilizer in the two experiments. In the first experiment, strong residual effect was observed. Yield increases in the second year of cropping ranged from 0.14 to 0.65t ha"^{1} higher than in the first year. Legume incorporation generally improves soil pH, SOM, exchangeable cations and CEC.

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CHAPTER ONE

1.0 INTRODUCTION

The rapid growth of population in developing countries and the resulting intensive cultivation of agricultural land is causing widespread soil degradation.

The Nigerian savanna soils are predominantly Alfisols, low in inherent fertility. They are characteristically acid in reaction, low in organic matter, cation exchange capacity (C.E.C) and plant nutrients (Jones and Wild, 1975). Clay fraction is dominated by kaolinite, generally poorly buffered and structured, hence have major chemical, physical and biological limitations (Acquaye, 1973; Jones and Wild, 1975; Kowal and Kassam, 1978).

The low and declining productivity of many tropical soils are the major constraints limiting the realization of the improved genetic potential that is now available in most important staple food crops. The need to take appropriate measures to check this decline in soil productivity is urgent as the rate of deterioration is on the increase and if not checked, will have serious implications for future food production in the developing countries.

The shortage and high cost of inorganic fertilizers have rendered them unaffordable to most resource-poor farmers,

resulting in low fertilizer consumption generally and also choice of crops grown by these farmers. There is therefore increased dependence on the use of organic wastes such as Farm Yard Manure (FYM), compost and crop residues. These are highly valued because of their contributions to soil productivity. This relationship between SOM and soil productivity is ascribed to the role of SOM in supplying plant nutrients, enhancing CEC, improving soil aggregation and hence water holding capacity, improving soil pH, supporting soil biological activity (Jones and Wild, 1975; Kowal and Kassam, 1978; Bin, 1983; Iwuafor, 1986; Dudal and Deckers, 1993) consequently giving higher crop yield compared to treatments from which crop residue had been removed (Kang, 1993).

In the Northern Guinea savanna zone of Nigeria, the acquisition of enough crop residue for use in the field does not appear very feasible. This is largely because crop residue have other attractive alternative uses such as livestock feed, fuel wood and fencing materials.

Watson and Goldsworthy (1964), Lal and Okigbo (1990) suggested that properly managed planted fallows and cover crops of mainly leguminuous species are more efficient and require less time in restoring soil fertility/productivity than natural fallows. According to Francis *et al.* (1986); Prinz (1986); Hullugale (1988); planted fallow of leguminous

crops, if properly managed will add substantial amounts of N and other nutrients and OM to the soil, recycle nutrients from the subsoil, provide effective cover against erosion, suppress weeds and pests and improve soil physical conditions.

It is the objectives of this study to:

- Study the effect of incorporation of some legume species and N fertilizer on some soil properties and maize performance.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 SOILS OF THE NIGERIAN SAVANNA

2.1.1 Chemical Properties

One of the main functions of soils is to provide adequate reservoir of nutrients for crop growth. The availability of these nutrients depends among other factors, upon the amount and nature of inorganic and organic colloids present in the soil (Kowal and Kassam, 1978).

In most savanna soils, inorganic colloids consist of kaolinitic minerals and armorphous iron and alluminium hydroxides derived from the parent material during weathering (Jones and Wild, 1975; Kowal and Kassam, 1978). These minerals have low CEC. The organic colloids are complex intermediate products formed during decomposition of organic matter by soil micro-organisms. Kowal and Kassam (1978); Lombin and Chude, (1991) explained that the organic colloids have a high capacity to retain plant nutrients and their amount in the soil affects the fertility of the savanna soils.

2.1.1.1 Soil pH

The reaction of soil in the savanna area are reported to range from 5.10 to 6.30 (Lombin and Chude, 1991). Lombin *et al.* (1985) reported that soil pH in salt solution ranged from

4.45 to 6.40 in the surface fallow soils with a mean of 5.38. Kowal and Kassam (1978) also reported that under the natural savanna vegetation and traditional farming systems, the pH values measured in 1:1 soil water ratio, ranged between 6.0 and 6.8. This range is favourable for crop production. Favourable pH is maintained through the return of crop residues to the soil, burning and proper choice of N fertilizers.

Low soil reaction reduces the availability of phosphates in soils because of the presence of high amounts of Fe, Mn, and Al ions. Decline in the availability of Mo with decreasing soil pH was observed in savanna soils by Heathcote (1972) and Heathcote and Fowler (1977).

2.1.1.2 Organic matter

The organic matter contents of most savanna soils are low. Values range from 0.098 to 1.518% (0.98 to 15.18g kg^{-1}) for surface fallow soils, with an average of 0.441% (4.41g kg^{-1}) (Lombin *et al.*, 1985). Contribution from organic matter to soil fertility is therefore low in most savanna soils.

The amount of organic matter in a soil is a product of a number of diverse factors acting over a period of time. A few of the factors include; rainfall, temperature and altitude, soil parent materials, drainage, burning, clearing,

cultivation and grazing by animals. According to Mulongoy *et al.* (1993), levels of organic matter in soils depend largely on the quality and quantity of plant materials and litter returned to the soil. Nye and Greenland (1960), Ahn (1974), reported that the organic matter content of surface soils in the savanna is generally low compared with that in the forest soils of West Africa and in soils of the temperate regions. Mean values reported by Jones and Wild (1975) for 0-15cm soil depth are about 0.5% (5.0g kg^{-1}) organic carbon in the Brown and Reddish soils, 1.2% (12g kg^{-1}) in ferrugenous soils and 2.0% (20g kg^{-1}) in the vertisols, Eutrophic Brown and Hydromorphic soils.

Kowal and Kassam (1978) attributed differences in organic matter content between a soil under closed forest and that under open savanna to the greater weight of vegetation in the forest and annual burning of the above ground parts of savanna grasses. Much of the above ground parts of savanna grasses may also be eaten by grazing animals. The organic matter in savanna soil is, therefore, mainly derived from the roots.

De Ridder and Vankeulen (1990) have indicated that increasing SOM content in cultivated soils in the semi-arid tropical zone of West Africa is tedious, since huge quantity of organic matter are required. Pichot (1971) reported that after 18 years annual application with 60kg N, 45kg P and 25kg

K ha^{-1}, organic C content increased from 2.5 to about 6.6g kg^{-1} (or from 4.5 to 12.0g organic matter kg^{-1}). Similar conclusions followed from the results of an experiment with a rotation of millet and groundnut started in 1972 in the north of Senegal with annual application of either chemical fertilizer alone (100 kg NPK at 14-7-7 ratio and 100kg N as urea) or incombination with 10 t ha^{-1} of animal manure. In 1983, the soils in this experiment were analysed, and results showed that organic C content in the soils that had received manure was 0.3g kg^{-1} higher in the upper 10cm and 0.15g kg^{-1} in the 10-20cm layer compared to the soil that had received chemical fertilizer alone.

Singh and Lal (1976) reported that the amount of plant material that can be grown on any soil in a season, then incorporated is not sufficient to maintain the percentage of SOM, since micro-organisms in cultivated soils decompose all this material and more of it before the next application is made. Thus, incorporating leguminous crops fails to arrest this down grading process. Vine (1953) found that yields were generally higher after leguminous green manure (*Mucuna deeringiana*) was incorporated if the soil had been cropped continously for several years, but that there was no detectable effect on the build-up of organic matter in the soil. Singh and Lal (1976) concluded that SOM accumulates only if cultivation ceases and the land is put down to leys or

forests, particularly those containing legumes that fix N. However, many workers had reported the maintenance of SOM in the savanna by the use of FYM, compost, crop residues and other organic materials with slightly high C:N ratio (Bache and Heathcote, 1969; Jones, 1971, 1976; Jones and Wild, 1975; Lombin and Abdullahi, 1977; Dunham, 1978; Karikari and Yayock, 1987).

2.1.1.3 Nitrogen

Available data indicate very low N levels in the entire savanna soils. According to Lombin and Chude (1991) values from 0.24 to 0.92g kg^{-1}, with a mean of 0.49g kg^{-1} have been observed.

Kowal and Kassam (1978) reported that about 99% of the N naturally present in the soil is bound in organic materials. The N status of a soil is therefore closely associated with the SOM and is a function of relative rates of gain and loss which, under stable conditions tends towards an equilibrium value.

Amount of soil N was found to decrease in cultivated soils (Lombin and Chude, 1991). This goes to signify the importance of organic matter in the N content of the soil. Two factors that account for the variability in soil N are clay content and rainfall (Jones and Wild, 1978).

One important cultural measure that can improve the present low levels of N in the soil is crop rotation involving legumes as one of the rotational crops.

2.1.1.4 Cation exchange capacity (CEC)

In most of the savanna soils, CEC is low (Kowal and Kassam, 1978). The exceptions are the vertisols, ferrisols and eutrophic brown soils which occupy only a small proportion of the savanna areas (Kowal and Kassam, 1978).

The low CEC suggests a low ability of the soils to retain and release plant nutrient elements for normal growth. Kowal and Kassam (1978) reported that the CEC values of savanna soils are closely related mainly to the SOM. The clay contents, because they are mainly kaolinitic, contribute to the CEC only by about 1-2C mol kg^{-1} soil. Lombin and Chude (1991) reported that the CEC values of the savanna surface soils range between 1.6 to 11.6 Cmol kg^{-1}, with an average of 4.3 C mol kg^{-1} soil. Jones (1971) stated that increasing soil organic C content from 0.1 to 1.0% (1.0 to 10g kg^{-1}) led to an increase in CEC from 0.08 to 4.28 C mol kg^{-1} soil, giving a contribution of 38 - 68%.

2.1.2 Causes of low fertility and productivity

The productivity of a soil is a measure of the combined effects of its fertility and physical properties assuming

favourable climatic conditions (Acquaye, 1973). The full realization of the climatic potential of the West African savanna for crop production depends on the control of fertility, water and erosion (Kowal and Kassam, 1978).

According to Acquaye (1973), generally the soils of West Africa are of low inherent fertility. Small amount of fertility that may be present is delicately dependent on the organic matter, which is usually low in these soils, and the small reserves of nutrients in the decomposing minerals is in the sub-soil. Kowal and Kassam (1978) further explained that, the soils are chemically and physically very fragile. The cultivated layer is light, and easily erodible due to high energy load of rainstorms.

The CEC, organic matter content and buffering capacity are low (Acquaye, 1973; Kowal and Kassam, 1978; Lombin, 1987). The store of soil nutrients of native savanna soils can not match the high climatic potential for crop growth, and must be supplemented by an application of widespectrum fertilizers (including major and minor elements) in amounts sufficient to meet crop requirements for higher yields, taking into account losses in crop removal and leaching (Kowal and Kassam, 1978).

2.1.3 Soil fertility maintenance in the savanna

Despite the variations in soil types, productivity and

potentialities, the problems of soil fertility maintenance are similar in many parts of Nigeria (Agboola, 1979). He further explained that the critical factors are the organic matter and mineral nutrient contents which decline during cropping but increase under fallow. An appreciation of this rhythmic development lies at the root of the bush and grass fallow systems operated in traditional farming as a means of maintaining soil fertility (Mulongoy *et al.*, 1993). Dudal and Deckers (1993) stated that the adoption by local populations of various forms of shifting and slash-and-burn agriculture clearly demonstrates that in large areas of the tropics the low level of plant nutrients is a major constraint to crop production. With increasing pressure on the land, these farming systems will no longer be able to meet the growing demand for food.

In the tropics, soil fertility undergoes a rapid decline when land is cleared and cultivated to such a critical point that crop yields are static or decline, and weed invasion becomes serious (Lal and Kang, 1982). Depending on the quality of soil resources, the system breaks down as soon as certain critical population densities are exceeded. Experience has shown that it can be sustained only under conditions of low to moderate population pressure on land (Agboola, 1979). It has been suggested that this point is reached in Sokoto, the sudan savanna zone where population

densities are 77 - 96 persons per km^2 (Prothero, 1962).

Jones and Wild (1975) pointed out that the question, whether the fertility of the savanna soil can be permanently maintained with fertilizers alone, is an unrealistic one, if it ignores other management aspects. Looking at the expensive and unaffordable cost of fertilizers by the local farmers in Nigeria today, the issue of maintaining soil fertility by the use of inorganic fertilizers should be completely ruled out.

The use of bush or grass fallow systems in maintaining soil fertility has failed in many parts of Nigeria owing to rapid population growth in recent decades and the increased demand for export crop production (Herrmann, 1968). This failure has raised questions about the future of using fallows for soil fertility maintenance, and the alternative strategies which can be adopted on a long term basis (Agboola, 1979).

Improved and new technologies designed as alternatives to the shifting cultivation and bush fallow system include mechanisms that can replenish the SOM. Some farmers selectively retain a few woody species during land clearing, while others establish trees and shrubs which have the potential to maintain soil fertility (Mulongoy *et al.*, 1993). Investigations carried out in the middle belt area have shown

that a legume (*Cajanus cajan*) and a grass (*Andropogon gayanus*) as planted covers are more efficient at restoring soil fertility than natural regeneration (Watson and Goldsworthy, 1964). Agboola (1979) reported that such an arrangement makes possible the continuance of the system under moderate to high population densities. He further explained that most of the length of fallow yet still maintain soil fertility at reasonable levels. Maximum uses should be made of local resources, such as crop residues, green manures and leguminous cover crop (FAO, 1974; Flaig *et al.*, 1977), but it should be realised that residual organic matter does replace some of the nutrients removed by harvest and that N supply needs to be supplemented by the provision of other essential plant nutrients (Dudal and Deckers, 1993).

Kang (1993) stated that for sustained crop production, alternative systems need to be developed to better incorporate biological nutrient sources, to reduce fertilizer use and to minimize the decline in soil chemical components. Legume green manuring is practiced where land is plentiful and animal manures are scarce. It is employed as a means of bringing the poorest soils into profitable cultivation, it can often find a place in sequence of many cropping systems (Garner, 1952). It is necessary to explore the potential of large number of legume species for use in managed fallows to regenerate soil fertility and improve productivity faster. Legume

incorporation when properly used, can slightly increase the SOM content and also the supply of available N and other nutrients in the soil, but rarely can it do both at the same time. The available N supply is increased only when readily decomposible materials, high in N are decomposed (Singh and Lal, 1976). According to Balasubramanian and Nnadi (1980) crop residues of leguminous plants are richer in all nutrients than the residues of cereal crops. Also, the leaves contain slightly more nutrients than the stems which contain slightly more nutrients than roots. About 40% of N, 40% of P, 86% of K 92% of Ca, 72% of Mg and 59% of S removed from the soil by crops are contained in crop residues.

Many workers have reported the maintenance of soil fertility/productivity in the savanna zone by the application of FYM, compost and crop residues, either in isolation or in combination with inorganic fertilizers (Bache and Heathcote, 1969; Jones, 1971, 1976; Jones and Wild, 1975; Lombin and Abdullahi, 1978; Dunham, 1978; Karikari and Yayock, 1987).

2.2.0 Types of herbaceous forage legumes used in the Tropics

Some of the commonly used forage legumes in the tropics. Include: *Centrosema pubescens*, *Peuraria phaseoloides*, *Stylosanthes gracilis*, *Stylosanthes humilis* and *Centrosema plumari* (Okigbo, 1977). Others that have been found

adaptable in the moist savanna of Northern Nigeria are: *Centrosema pascuorum, Lablab purpureus, Mucuna pruriens, Chaemacrista rotundifolia*. Some of these are good as green manure or ground cover in tree crops.

According to Cobbina (1992) the forage legumes are suitable in managed fallow systems. Some of these include, *Centrosema species* (12182) *Centrosema macrocarpum, C. pubescens, Calopogonium mucunoides, L. purpureus, P. phaseoloides* and *Stylosanthes guidnensis C.V. Graham.*

Okigbo (1977) gave some examples of cover crops used in rubber and oil palm plantations as *P. phaseoloides, C. pubescens, Glycine wightii, S. gracilis* and *Indigofera spicata*. Other leguminous crops such as: *S. gracilis, P. phaseoloides, C. pubescens,* may be used to protect the soil after forest clearing and before the land is ready for cropping. Sunhemp was rated the best species for early ground cover, followed by Desmodium, Mucuna, Pigeon pea, *Sesbania sesban* and *Tephrosia vogelii* Hook (f.). Cover at 50 days after planting of the various species ranged between 14 and 100% (Balasubramanian and Sekayange, 1992).

2.2.1 Legume establishment

Success or failure in legume establishment is dependent on chemical, physical and biotic influences which act upon

three different biological entities; the rhizobia, the host plant and the symbiotic system itself (Parker and Chatel, 1982). They further explained that, it is more difficult to grow a symbiotic legume than say, maize or sorghum or wheat. This was further supported by Smith (1982) who indicated that the mineral nutrition of legumes is some what more complex than that of other plant species because of the special symbiotic relationship existing between the legume host and the associated rhizobial bacteria. Smith (1982) explained that, particular nutritional requirements are necessary for this extra physiological process to operate efficiently. These affect survival and growth of the rhizobia in the soil, infection and nodulation of the host root, and functioning of N fixation reactions within the nodule. It is important to recognise that both the types and the concentrations of mineral elements required for these additional functions may not be the same as those required for normal growth of the host plant itself.

Garner (1952) gave the following criteria for the selection of a green manure crop for good establishment and utilization.

(i) the crop must germinate without an elaborate preparation of the seedbed.

(ii) The crop choosen must be a quick grower.

(iii) a good bulk of the green plant material must be ready at the proper time

(iv) the green manure has to make the best use they can at the begining or end of the growing season, only in exceptional circumstance do they enjoy the full growing season.

(v) it shall fit well with the main cropping sequence.

Garner (1952) also added that, a well distributed rainfall is a favourable factor for there is little risk of water shortage either for the germination of the catch crop it self or for the proper growth of the succeeding main crop.

2.2.2 Legume Dry Matter Production

The length of growing period determines the quality and quantity of the biomass produced (Balasubramanian and Sekayange, 1992). Legume species intended for use in conventional crop rotations and green manuring systems must have among other characteristics, the ability to produce a large biomass with high N concentration (Heichel and Barnes, 1984).

For certain species such as mucuna, leaving the plant on the ground for more than 18 weeks resulted in the shedding of leaves, production of grain and diminished addition of fixed N to the soil, especially when the grains were harvested. However, at 16 weeks mucuna produced the largest amount of

biomass (5.27t ha^{-1}) and N (153.3 kg ha^{-1}). For species such as sunhemp (*Crotolaria ochroleuca*) and pigeon pea (*Cajanus cajan*), the amount of biomass produced and N fixed in top growth increased substantially between the 16th and 24th WAP in Kagasa, Rwanda (Balasubramanian and Sekayange, 1992).

According to Cobbina (1992), over the long-term growth periods (8 months and 13 months) wide variations in herbage dry-matter yield were observed among the species. For the 13 month growth period in the establishment year, the yield ranged from 1.1 to 1.60 t ha^{-1}, while for the 8 month growth period between 16 and 24 months after planting, it ranged from 0.47 to 12.5t ha^{-1}. A comparison of the dry matter produced over the 13-month and 8-month growth periods indicates that, for a bout 35% of the species screened, there was a yield increase of 20 - 170% in the second year.

2.2.3 Ground cover

Rainstorms and heavy rains in the humid tropics cause serious erosion losses on newly cleared land, especially after preplanting cultivation on steep slopes (Okigbo, 1977). The rapid development of ground cover is therefore necessary to protect the soil against erosion (Derpsch et al. 1986).

Sunhemp was rated the best species for early ground cover, followed by Desmodium, Mucuna, Pigeon pea, *S. Sesban*

and *T. vogelli* cover at 50 days after planting in various species ranged between 14 and 100 % (Balasubramanian and Sekayange, 1992).

Maintaining ground cover during the dry season and at the beginning of rains is essential to reduce soil erosion in the semi-arid areas (IITA, 1989). Pigeon pea was found to be the most suitable species for this purpose because it was more draught resistant than other species at Kagasa, a semi-arid region in Rwanda (Balasubramanian and Sekayange, 1992).

2.2.4 Weed Supression

It is a common practice to use leguminous cover crops to control erosion and weeds in tree crop plantations. Although the legume adds N to the soil it sometimes competes with the plantation crop for water (Okigbo, 1977).

One year growth of *S. sesban* could effectively shade out the problematic chromolaena weeds at the minkomeyos site and the imperata weeds at the Yoke site, all in Cameroon (Ngiumbo and Balasubramanian, 1992). Similar results on weed suppression have been obtained elsewhere using *M. pruriens* (L.) Dc. and *P. phaseoloides* (NAS, 1979; IITA, 1985, Anon, 1989)..

2.2.5. The Decomposition of Legume Residues

The rate of decomposition of organic waste or crop residue depends primarily on its chemical composition and on those factors which affect the soil environment (Parr and Papendick, 1978). The decomposition of legume residues depends to a large extent on the proportions of different plant parts and their maturity (Henzell and Vallis, 1977). They explained that the proportion of N released during decomposition of the residues is governed by the chemical composition of these residues especially the N content, the manner in which the residues are returned to the soil, and the environmental conditions.

A predictable consequence of the variable N concentration in different legume residues is that they will contribute varying amounts of N to the soil and likewise to the crops following. Most of the differences between residues can be attributed to their N percentages.

According to Giller and Wilson (1991) legume residues are particularly useful as organic manures due to their large content of N, and because this N is more likely to become readily available for uptake by other plants than N in many other crop residues. Release of N from decomposing organic material, or mineralization, result from the activity of micro organisms breaking down the material. If the material

contains a small proportion of N relative to dry weight (i.e if it has a large C:N ratio) then the amount of N available for growth of the micro organisms themselves will be limited and any mineralized N will tend to be immediately used by the micro organisms, i.e. immobilized, for growth. Giller and Wilson (1991) further explained that the release of N into the soil (net mineralization) for use by plants is thus a balance of the processes of mineralization and immobilization. The C:N ratio is a useful guide to whether net release of N from organic material is likely to occur during the early stages of decomposition. The C:N ratio also provides an indication of how rapidly a material is likely to be decomposed. Plant residues with high C:N ratio (>30:1) are likely to decompose slowly with initial net immobilization of N, whereas residues with a smaller C:N ratio are likely to decompose more rapidly with a net mineralization of N occuring right from the beginning. Legume residues commonly have C:N ratios less than 30:1 and therefore tend to release N and decompose rapidly.

Henzell and vallis (1977) reported that a notable feature of mineralization of N in plant residues is that after a few weeks the rate is quite slow, regardless of the initial composition of the residues. Apparently, it is not the plant proteins that are resistant to the decay but the microbially produced organic N, which becomes stabilized by reactions with

aromatic polyphenols of microbial or plant origin (Bartholomey, 1965) or with montmorillonite (Sorenson, 1972, 1975). This has an important implication in practice. Nitrogen in crop residues that is not mineralized during the first season becomes available only very slowly to the crops, usually at less than 5% per year. Although a single addition of crop residues will have a negligible effect on the N supply after the years may be measurable in two or three successive crops (Bartholomey, 1965).

The residue moisture content and the mode or method of application to soil, that is, whether mixed with the soil, layered or banded in the soil, or remains at the soil surface are important factors to residue decomposition (Parr and Papendick, 1978; Giller and Wilson, 1991). Placement of residues on the soil surface rather than burying or mixing them in the soil results generally in slower decomposition and slower mineralization of N (Parker *et al.*, 1957; Moore, 1974). Drying can affect the mineralization of N in plant residues. Fresh plant material releases N far more readily than dried material (Vanschreven, 1968).

Environmental conditions have little effect on the final degree of mineralization or immobilization of N during aerobic decomposition of residues; it is only the rates of these processes that are substantially affected (Bartholomey, 1965).

Some of the environmental factors affecting mineralization are; moisture, temperature, drying, wetting and freezing (Cambell, 1978; Parr and Papendick, 1978). According to parr and Papendick (1978) many of these factors are not independent; a change in one may affect a change in the others. For example, high soil moisture may result in low soil temperature and surface residues may affect soil moisture and temperature simulteneously. Because of these strong interactions, it is often difficult to isolate effects of specific environmental factors on residue decomposition.

2.2.6 The Effect of Legume Incorporation on Crop Yield.

The usefulness of legume green manures in maintaining or building-up soil fertility has long been recognised. Legumes have been traditionally used for this purpose in some regions. Vine (1953) found that yields were generally higher after green manure (*Mucuna deeringiana*) if the soil had been cropped continously for several years.

There are many reports of increases in the growth and yield of crops sown after incorporation of green manures. For example, maize yields were more than doubled by incorporation of a three-month-old green manure of mucuna or crotolaria grown in alluvial soil on the Island of Java, Indonesia (Hariah and van Noordwijk, 1989). The N uptake of the maize

grown after the incorporation of leguminous green manures was, infact, increased by more than the total amount of N incorporated. This serves to reinforce the point made earlier that the advantages of using green manures are not solely due to the provision of N, but are often due to other beneficial effects of organic matter additions and root penetration on the soil structure and water holding capacity. Studies in the western highlands of Cameroon reported that burying legume residues gave higher maize yields in all the years than burning it on the surface of the ridges (IRA, 1988). At Yoke in Cameroon, the highest maize grain yield was recorded in the *S. sesban* intercrop treatment where the foliage was incorporated into the soil, followed by the *S. sesban* intercrop treatment with leaves surface mulched and the maize/groundnut rotation treatment (Ngiumbo and Balasubramanian, 1992).

In the Nigerian savanna a major factor in maize yield is N availability from the SOM or added to the soil as fertilizer (Urea or NPK) or manure. Carsky (1996) reported that, legume crops can fix N which can substitute for N fertilizer. The quantity of N contributed will depend on the legume, its management, and the management of its residues. Carsky (1996) gave results of three legume N contribution in Kaduna state as follows: Results from ten farmers fields 5 in northern Kaduna and 5 in southern Kaduna shows that a soybean crop in

the previous year reduced N fertilizer require by maize. The reduction was approximately 40kg N ha^{-1} (90kg urea/ha) after a well managed, late soybean variety (TGX 1660-19F) and 20kg N ha^{-1} after a well managed early variety (TGX 1456-2E). This contribution occurred inspite of the exportation of the soybean residues except roots and litter. In Kasuwan Magani (central Kaduna) an early season cowpea (Achishuru) contributed 10 -20kg N ha^{-1} to late season maize. This value may be an under estimate because the control was natural regrowth (fallow vegetation). The yield of maize following mucuna was three to four times higher than yield of maize following maize and the effect appears mostly related to N availability, reflected by N content of six week old maize plants. There was twice as much N in six week old maize plants following mucuna.

Haque (1992) reported that maize was planted inside and adjacent to five stylosanthes fodder banks and the results showed that, the grain yield of maize grown in the stylosanthes area was significantly higher than that of maize grown on adjacent natural fallow at all levels of N application in Ethopia. Maize growth without fertilizer inside the fodder banks produced an average grain yield of 1.5t ha^{-1}, compared with a yield of 750kg ha^{-1} for maize grown on adjacent fallowed land. There were no significant differences in grain yield between maize grown without

fertilizer inside the fodder bank and maize grown on fallow land when 60kg Nha^{-1} was applied. Therefore, a 2-year stylosanthes pasture resulted in increases in maize yield equivalent to applying 60kg Nha^{-1} (ILCA, 1987).

2.2.7 Adoptability of legume incorporation technology: Problems and prospects.

Legume green manuring by ploughing under of succulent leguminous crop plants has not gained acceptance in Africa (Keya, 1978). This may simply be because of the following reasons;

1. The loss of a cropping season is often mentioned as a main bottle neck for the general acceptance of the practice of green manuring, thus a small scale farmer will not grow a green manure crop if it interferes with the regular crop which fetches him money (ICAR, 1964; wade and Sanchez, 1983; Bin, 1983). Karikari and Yayock (1987) observed that, this system was not accepted because peasant farmers considered it unprofitable to grow a crop for a season only to incorporate it into the soil without any immediate returns either in terms of cash or food. Infact, the peasant farmer's type of tools may not cope with such operations.
2. The other reason is the extra investment of labour often required (Wade and Sanchez, 1983; Agboola,

1979). According to Ngiumbo and Balasubramanian (1992), fallow species planted at the end of the cropping cycle or the beginning of the fallow period are usually smothered by aggressive weeds and natural regrowth. Some kind of land preparation before planting fallow species and at least one early weeding are required to ensure good establishment of fallow legumes in the humid tropics. Just like other crops, the green manure crop grows up under the conditions of a specific kind of soil, a sufficient length of time, and adequate sunshine and temperature (Bin, 1983) and abundant moisture (Berger, 1962).

3. Berger (1962) reported that, the practice of green manuring in many maize regions of the warmer countries, particularly in the tropics, is governed almost entirely by the incidence of rainfall. Where there is rainfall in both winter and summer, green manure plants can be grown in both seasons. He further explained that, in East Africa a green manure crop is often sown in the lesser rainy season, followed by maize in the rainy season proper.

It is challenging to design appropriate planted fallow methods that will be easily assimilated into the local

cropping systems without using much labour and/or inputs and that are attractive to farmers. ICAR (1964) observed that a scientific pratice to be recommended to the farmers must be based on sound economics. Thus, it is necessary to take into account the effect of green manuring both on the crop immediately following as well as all crops in the rotation.

Vander Heider and Hariah (1989) reported that, it is unusual for green manures to be adopted solely for their beneficial effects on soil fertility but where other benefits are also found, for instance, suppression of weeds, reduction of incidence of pest or control of soil erosion, then farmers may be persuaded to use them.

A major problem for adoption is that the green manure legume most often occupy land at a time when other crops could be grown. A system known as "cut and carry" has been proposed in which the green manure is grown on the land that cannot be readily used for agriculture and is subsequently brought to the fields (Wade and Sanchez, 1983). However, this practice add still further to the other main problem restricting adoption of green manures, the extra investment of labour often required. Giller and Wilson (1991) suggested that a possible compromise is the use of grain legumes which can provide young pods as vegetables and still give sufficient leafy material to be useful as green manure.

The cropping patterns should be so planned as to include such leguminous crops which could be raised without disturbing main crops in the rotations. Some short duration legumes like cowpea, may easily be fitted into the pattern (ICAR, 1964). Nnadi and Haque (1988) reported that, like rotation fallow, the beneficial effects of relay fallow depend on the N-fixing capacity, plant-N content and biomass yield of the intercropping legume. Species selected for the fallow legume/food crop intercropping system should be less competitive with food crops (Balasubramanian and Sekayange, 1992).

A small scale farmer finds it difficult to produce green manure crops at the loss of a main crop which supports his finances. It is possible to grow green manure crops in the inter-spaces of the principal row of the crop raised by the farmers (ICAR, 1964). Or fallow legumes and food crops have to be intercropped, either simulteneously or in a relay pattern to improve the productivity of land without loosing a season for food crop cultivation (Balasubramanian and Sekayange, 1992).

ICAR (1964) observed that, it is not correct to base the evaluation of the practice on the return obtained from the following crop. The yields obtained from all the crops in the rotation should be taken into account rather than the yield of

the crop immediately following. Research data support the view that green manures has marked effect on the yields of all subsequent crops in rotation due to residual carry over. That the residual effect of green manure remained in the plot long enough to benefit the third crop in succession.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Introduction

The study involved both greenhouse and field experiments. The two experiments were carried out at the Institute for Agricultural Research (I.A.R.) Ahamadu Bello University (A.B.U.), Samaru (Latitude 11°11' N and Longitude 7°38''E) Zaria, in the Northern Guinea Savanna ecological zone of Nigeria. The soils at Samaru are developed from drift sand, overlaying basement complex (Klinkiberg and Higgins, 1968), and classified as Alfisols (Awujoola, 1979). The area has a mean annual rainfall of about 1050mm strectching from May to September and a mean daily temperature of 24°C (Kowal and Knabe, 1972). The global radiation is evenly distributed throughout the year, ranging from 440 cal cm^{-2} day^{-1} in August to 550cal cm^{-2} day^{-1} in April and May (Kowal, 1972).

3.1 GREENHOUSE EXPERIMENT

3.1.1 Description and History of Sample Sites.

The soil sample used for the greenhouse experiment was collected from I.A.R., A.B.U. Research Farm, Samaru, Zaria. Prior to the collection of the soil sample, cotton had been cropped on the field for two years.

3.1.2 Soil Sample Collection and Preparation

Soil samples were collected at 0-15cm depth. The samples were bulked, mixed thoroughly and air dry under a shade before they were sieved through a 2 mm stainless sieve. Sub-sample was taken for characterization of the soil.

3.1.3 Residue Collection and Preparation

The shoots of six selected legumes; *Centrosema pascuorum* (CP), *Chaemocrista rotundifolia* (CR), *Cajanus cajan* (CC), *Centrosema brasilianum* (CB), *Stylosanthes hamata* (SH), *Leucaena leucocephala* (LE) and maize (Mz) stover (Collected from a production field) were obtained from the field after One year of growth. They were washed with tap water, oven-dried, hand crushed and chop with cutlass weighed and stored in polythene bags for use in the greenhouse study. Sub-samples for analysis were ground using a stainless steel Thomas Willey mill before storage.

3.1.4 Pot Preparation and Sowing

Each pot was filled with 3kg of the air dried 2mm sieved soil. The legume and maize residues were weighed into the pots (as calculated below) and thoroughly mixed with the soil, watered and incubated at field capacity with tap water for two weeks before maize (var. Obasuper II) was sown. Three seeds were sown/pot and later thinned to two plants/pot at two weeks after planting (WAP).

Furrow slice = 2.0×10^6kg soil

2.5t ha^{-1} ----> 2.0×10^6kg

? ---------> 3.0kkg

$2.5 \times 3.0 = 3.75$g

2.0×10^6

for 5.0t ha^{-1} = $3.75 \times 2 = 7.5$g

3.1.5 Treatment and Design

The treatments consisted of the shoot of the six legume species (CP, CR, CC, CB, SH and LE), MZ stover and a control (without residue). Each of the residues were applied at two rates of 2.5t ha^{-1} and 5.0 t ha^{-1}. This showed that there were 15 treatment combinations.

The experiment was laidout in a Randomized complete block design (RCBD) and replicated three times.

3.1.6 Observations Taken During Experiment

Observations were made on weekly basis, starting from 2WAP.

(a) Plant height:- Plant height was measured from the soil surface to the whorl using a meter rule.

3.1.7 Harvesting:

The plants were harvested after 4 weeks of growth in the greenhouse. Each pot was harvested by cutting the plants at the soil level. The plant shoots harvested were washed

thoroughly with distilled water and dried for 48 hours in an oven set at 65°C and weighed for dry matter yield (DMY). The dry shoots were ground using a stainless steel Thomas Willey mill for chemical analysis.

3.1.8 Analysis:

The soil samples were analysed for particle size distribution by the standard hydrometer method (Day, 1965). The soil pH was determined in water and 0.01 M $CaCl_2$ with a pH glass electrode using a Soil:Solution ratio of 1:2.5 (MClean, 1965). Organic carbon was determined by the wet oxidation method of Walkley-Black method as described by Juo (1979).

3.1.9 Plant Analysis.

Plant samples were digested in triple acid mixture of perchloric acid (80mls), Nitric acid (360 mls) and Sulphuric acid (20 mls) plus a catalyst. Potassium in diluted digest was determined by flame photometer, while Ca, Mg and Zn were determined using pye unicam model sp 192 Atomic Absorption Spectophotometer. Phosphorus was determined by the vanadomolybdate yellow colour method (Juo, 1979); while N was determined by the micro-kjedahl wet-digestion method outlined by Bremner (1965).

3.1.10 Statistical Analysis

All data collected were subjected to analysis of variance

(ANOVA) using SAS Package of statistical analysis. The treatment differences were evaluated by the Duncan's New Multiple Range Test (DNMRT).

3.2 FIELD EXPERIMENTS

The first experiment was carried out in a field where 10 legume species replicated 3 times in a randomize complete block design were screened for two years in a collaborative project between IITA and IAR. Five promising legume species selected from the study were incorporated manually by hoeing. This field was cropped for two years to maize.

The second experiment was carried out in a field where 17 legume species replicated 4 times in a randomized complete block design were screened for one year. Six of the legumes that were promising were selected after one year of growth and incorporated as in the first experiment. The field was cropped for one year to maize. The difference between the first and second experiments therefore is the length of growth of the legumes before incorporation. In these two experiments, the aim was to study the effect of incorporation of some legume species and N fertilizer on some soil properties and maize yield.

3.2.1 Incorporation of Legume Residue in the Field

3.2.1.1 Treatment and Design:

In the first experiment, five selected legume species (*Chaemacrista rotundifolia (CR), Centrosema pascuorum (CP) Cajanus cajan (CC), Centrosema brasilianum (CB)* and *Pueraria phaseoloides (PPH)*) and fallow control replicated three times were incorporated by hoeing into ridges 75cm apart. Within each main plot (legume plot and the fallow control) ($60m^2$), four N levels (0, 40, 80 and 120kg Nha^{-1}) ($15m^2$) as sub-plots were randomly allocated giving a split-plot design. The two centre rows of each sub-plot made up the net plot, while the two outer rows were considered as discards. The same experimental design was maintained in the second cropping season.

In the second experiment, six legume species (PPH, CR, CC, CP, CB, *Aeschynomene histrix* (AH) and a fallow control, replicated three times were incorporated. The method of incorporation, plot sizes, N level and the experimental design are as described for the first experiment above. However, the analysis on soil chemical properties and maize nutrient content was not carried out in this experiment.

3.2.1.2 Cultural practices:

(i) Planting:- Maize (var. DMR-LSR-W) was sown on plots where the legumes were grown and incorporated at two seeds/hole, at a spacing of 25cm within the row.

The seedlings were later thinned down to one plant/hill at two WAP.

(ii) Fertilizer application:- Nitrogen fertilizer as urea was applied in two split doses at three and seven WAP. At planting there was a blanket application of P and K in the forms of single super phosphate at the rate of 60kg P_2O_5 ha^{-1} and muriate of potash at the rate of 60kg K_2O ha^{-1} respectively which is the recommended rate of application in the savanna for maize.

(iii) Weeding:- This operation was carried out when necessary during the period of the experiment.

(iv) Harvesting:- The net plot was harvested when the crop was fully matured and dried. Ears for each net plot were dehusked and fresh weight of the cobs were taken immediately. After sun drying, the cobs were shelled using the manual sheller.

3.2.2 Observations and Measurements

3.2.2.1 Germination score/percentage:

The germination score was carried out at two WAP and percentage germination caculated thus: The number of seedlings that germinated divided by the number of seeds planted, multiplied by 100.

3.2.2.2 Plant and ear height

The height of four maize plants per plot was measured with a meter rule from the soil level to the whorl at harvest. Ear height was similarly measured.

3.2.2.3 Maize grain and stover yield

The dry weight of the grains and stover from the net plot were used to calculate the grain and stover yields per hectare.

3.2.2.4 1000-grain weight, cob length and kernel depth

One thousand grains were counted from each plot and weighed to get the 1000-grain weight.

Five cobs were randomly sampled and their lengths were measured using a string, and a mean of the values taken to give the cob length. To determine the kernel depth, the circumference of the five cobs sampled was measured before and after shelling and a mean in each case was taken. These measurements were done using a string and a meter rule. Kernel depth was thus calculated as, the difference between the cob circumference before and after shelling.

3.2.2.5 Soil sampling and preparation

Composite soil samples were augured from each plot at two depths 0-15cm and 15-30cm before land preparation and at harvest, air dried and sieved through a 2mm stainless steel

sieve. The sieved samples were stored in polythene bags for routine analysis.

3.2.2.6 Soil analysis

The samples were analysed for particle size distribution, pH and organic carbon as described for green house experiment.

Exchangeable bases were determined by extraction with neutral 1N NH_4OAC saturation method. Sodium and K were determined by the flame emission; while Ca, Mg and Zn were determined by using the Pye unicam model Sp 192 Atomic Absorption Spectrophotometer. Exchange acidity was determined by shaking with 1N KCl and titrating with 0.5N NaOH. Effective cation exchange capacity was determined by summation. Details of the analytical procedures are as described by Juo (1979).

3.2.2.7 Plant sampling and analysis

The legume residues were collected, just before incorporation. Details of collection and preparation are as described for the greenhouse experiment.

Ear leaves at 50% silking and maize stover at harvest were collected. Details of preparation are as described for green house experiment.

These were analysed for N, P, K, Ca, Mg and Zn as described for the greenhouse experiment.

3.2.2.8 Statistical analysis

The statistical analysis was the same as for the green house experiment.

CHAPTER FOUR

4.0 RESULTS

4.1 GREENHOUSE EXPERIMENT.

4.1.1 Effect of legume incorporation on dry matter yield and plant height.

The effect of legume incorporation on maize DMY and plant height at various stages of growth are shown in Table 3. The incorporation of CR_2 gave a significantly higher DMY than the control (NL_o) and LE_1, while in comparison with the other treatments there were no significant differences. This showed that NLo gave the lowest DMY, though it was not significantly different from most other treatments.

The incorporation of legumes tended to increase maize plant height taken from 2 to 4 WAP. At 2 WAP the incorporation of CR_2 gave significantly taller plants than all other treatments. This was followed by MZ_2 which was not significantly different from most other treatments, but was significantly higher than NL_o, CC_1, LE_1, SH_1, and CC_2. However, NL_o gave the lowest plant height value, which was not significantly different from CC_1, LE_1, SH_1, LE_2, CC_2, CR_1 and SH_2.

At 3 WAP, MZ_2 incorporation gave the highest plant height value which was not significantly different from CR_2, but was significantly higher than all other treatments. Control

Table 1: Some physico-chemical properties of soil used in the greenhouse

Properties	Soil depth (cm)	
	0-15	15 - 30
pH (water)	5.19	5.32
0.01M ($CaCl_2$)	4.81	5.10
Soil organic carbon (gkg^{-1})	5.65	6.10
Exchangeable bases		
Ca (Cmol (+) kg^{-1})	2.13	1.83
Mg (Cmol (+) kg^{-1})	0.66	0.70
Na (Cmol (+) kg^{-1})	0.18	0.19
K (Cmol (+) kg^{-1})	0.14	0.13
CEC(Cmol (+) kg^{-1})	3.29	3.61
Particle size Analysis		
Sand (gkg^{-1})	650	
Silt (gkg^{-1})	200	
Clay (gkg^{-1})	150	
Textural class	Sandy loam	

Table 2: Nutrient content of residue incorporated.

Residues	Nutrient contents					
	N	P	K	Ca	Mg	Zn($mgkg^{-1}$)
	<----------g kg^{-1}--------->					
PPH	19.88	0.50	5.40	3.60	1.70	15.0
CR	24.64	2.00	5.40	2.10	1.70	25.0
CB	15.40	1.50	4.59	2.60	1.70	20.0
CC	21.00	0.50	5.13	2.60	1.18	15.0
CP	26.88	1.50	7.56	5.70	1.98	25.0
SH	16.58	0.70	6.27	3.26	1.45	15.0
LE	20.12	1.50	3.97	4.10	1.50	18.0
MZ	12.45	1.25	9.45	0.92	1.25	31.0

PPH = Pueroria phaseoloides CR = Cheamacrista rotundifolia
CB = Centrosema brasilianum CC = Cajanus cajan
CP = Centrosema pascuorum SH = Stylosanthes hamata
LE = Leucaena leucocephala MZ = Zea mays

Table 3: Effect of legume incorporation on maize DMY and plant height in the Greenhouse

Treatment	DMY (g)	Plant height (cm)		
Legume SPP.	4WAP	2WAP	3WAP	4WAP
NL_0	0.76c	3.13f	6.60d	7.93d
CR_1*	0.98abc	4.33b-f	7.83bcd	10.40abc
CB_1	0.96abc	4.97bc	7.53bcd	9.53a-d
SH_1	1.03abc	4.00b-f	6.97cd	8.60bcd
CC_1	1.04abc	3.53d-f	7.67bcd	9,97a-d
CP_1	1.13abc	3.87c-f	7.23cd	9.77a-d
LE_1	0.80bc	3.33ef	6.90cd	8.43cd
MZ_1	1.10abc	4.57b-e	8.03bcd	10.27abc
CR_2	1.37a	7.10a	8.77ab	11.27a
CB_2	0.99abc	4.70bcd	8.03bcd	9.90a-d
SH_2	0.93abc	4.30b-f	7.53bcd	9.73a-d
CC_2	1.27ab	3.40ef	8.17bc	10.07a-d
CP_2	0.99abc	5.03bc	7.93bcd	9.77a-d
LE_2	0.97abc	3.97b-f	7.50bcd	9.87a-d
MZ_2	1.27abc	5.20b	9.87a	10.87ab
SE±	0.14	0.38	0.45	0.68

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Note NL = No legume
*1 = 2.5tha^{-1}, 2 = 5.0tha^{-1} and 0 = no residue.

treatment still gave the lowest plant height value which was significantly lower than MZ_2, CR_2 and CC_2, but was not significantly different from the other treatments.

At 4 WAP, pots that received CR_2 had plants that were significantly taller than in NL_0, LE_1, SH_1 and CR_1 but were not significantly different from the other treatments.

For the same legume at different rates of application, the 5.0t ha^{-1} tended to give higher values than 2.5t ha^{-1} both for the DMY and plant height at all stages of measurements, though most of the differences were not significant.

4.1.2 Effect of legume incorporation on maize shoot nutrient concentrations.

The effect of legume incorporation on maize shoot nutrient concentrations are shown in Table 4. Shoot N concentration was highest as a result of incorporation of CP_2. The value was however not significantly different from CR_2, CC_1, CB_2 and CP_1, but was significantly higher than all the other treatments. Treatment NL_0 gave the lowest value which was however not different from other treatments except CP_2, CP_1 and CB_2 which were significantly higher.

Maize shoot P concentration was significantly higher when CP_2 and CR_2 were incorporated into the soil than when SH_1,

Table 4: Effect of legume incorporation on nutrient content of maize shoot in the Green house.

Treatments	N	P	K	Mg	Ca	Zn
	<----------gkg^{-1}---------->					(mgkg^{-1})
NLo	2.48d	2.08d	9.61e	1.18bc	1.83b	36.67c
CR_1	3.09bcd	2.63bcd	14.49a-d	1.55ab	2.60ab	55.67ab
CB_1	2.72cd	2.42cd	13.25b-e	1.33abc	2.73ab	55.33ab
SH_1	2.77bcd	2.00d	14.45a-d	1.35abc	2.37ab	41.33bc
CC_1	3.36a-d	2.17d	12.59cde	1.33abc	1.83b	41.33bc
CP_1	3.65ab	3.00abc	13.35b-e	1.57ab	2.73ab	46.00bc
LE_1	2.80bcd	2.04d	9.13e	1.08c	1.93ab	46.33bc
MZ_1	2.57cd	2.67bcd	15.72abc	1.40abc	2.17ab	42.67bc
CR_2	3.22a-d	3.63a	17.14ab	1.69a	3.27ab	58.33ab
CB_2	3.41abc	3.04abc	16.80abc	1.65a	3.13ab	57.00ab
SH_2	3.08bcd	2.54bcd	17.00abc	1.61ab	3.20ab	55.67ab
CC_2	2.88bcd	3.13abc	17.16ab	1.55ab	3.07ab	51.00abc
CP_2	4.05a	3.71a	18.05a	1.74a	3.40a	37.33c
LE_2	3.12bcd	2.79bcd	10.32de	1.30abc	2.73ab	55.33ab
MZ_1	3.15bcd	3.29ab	17.39ab	1.59ab	3.10ab	66.33a
$SE_{\pm}$	0.27	0.25	1.34	0.13	0.44	5.36

Mean followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

LE_1, LB_1, NL_o, CC_1, LE_2, MZ_1, CB_1, CR_1 and SH_2 were incorporated. However, the P concentration values obtained in CP_2 and CR_2 incorporations were not significantly different from LE_1, NLo, CC_1, LE_2, MZ_1, CB_1, CR_1 and SH_2 incorporations. The incorporation of SH_1 gave the lowest P concentration value which was not significantly different from LE_1, NL_o, CC_1, LE_2, MZ_1, CB_1 and SH_2 incorporations.

Potassium concentration was highest when CP_2 was incorporated. It was signifcantly higher than treatments NL_o, LE_1, CC_1, LE_2, CP_1 and CB_1 which were not significantly different from each other.

The concentration of Mg was higher in the shoot where CP_2 was incorporated. Values obtained with NL_o and LE_1 were significantly lower than CP_2. However, treatments NL_o and LE_1 were not significantly different from CC_1, SH_1, LE_2, MZ_1 and CB_1. For Ca concentration similar results as for Mg were obtained.

When MZ_2 was incorporated it gave a high Zn concentration value which was not different from CR_2, CB_2, LE_2, SH_2, CR_1 and CC_2, but was significantly higher than CP_1, MZ_1, SH_1, LE_1, CC_1, CP_2 and NL_o. Treatment NL_o gave the lowest value which was not significantly different from CP_2, CC_1, LE_1, SH_1, CC_2, CP_1 and MZ_1.

Generally, 5.0t ha^{-1} tended to give higher nutrient concentration values than 2.5t ha^{-1}, though the differences between most of them were not significant.

4.1.3 Effect of legume incorporation on organic carbon and pH.

The effect of legume incorporation on soil OC and pH are shown in Table 5. The incorporation of Cp_2 gave a significantly higher soil OC than other treatments, though it was not different from CR_2, MZ_2, CB_2, LE_2, CC_2 and SH_2. Treatments NL_0 gave the lowest value which was not significantly different from CR_1, MZ_1, CB_1, LE_1, CC_1 and SH_1. Values were generally higher than the initial soil OC before cropping indicating an increase by these amendments.

The results showed that incorporation at 5.0t ha^{-1} tended to give higher OC values than at the lower rate. However, the differences between most of them were not significant.

On soil pH measured in water, the incorporation of NL_0 and LE_1 gave a higher value which was not different from CR_2, MZ_2, CC_1, SH_1 and MZ_1; but was significantly higher than CP_2, CB_2, LE_2, CP_1, CC_2, SH_2, CR_1 and CB_2. The incorporation of CB_1 gave the lowest pH which was not different from SH_2, CR_1, CC_2, CP_1, LE_2, CB_2 and CP_2, but was significantly lower than all other treatments.

Table 5: Effect of legume incorporation on soil organic carbon and pH in the Greenhouse.

Treatment	OC ($g\ kg^{-1}$)	pH (H_2O)
Initial value	5.65	5.19
NL_0	6.28f	4.87a
CR_1	7.03b-f	4.53c-f
CB_1	6.89c-f	4.33f
SH_1	6.42ef	4.80ab
CC_1	6.65def	4.70a-d
CP_1	7.13b-e	4.53c-f
LE_1	6.33f	4.87a
MZ_1	6.71def	4.67a-e
CR_2	7.69ab	4.77abc
CB_2	7.57abc	4.57b-f
SH_2	7.39a-d	4.43ef
CC_2	7.61abc	4.53c-f
CP_2	7.93a	4.47def
LE_2	7.62abc	4.57b-f
MZ_2	7.78ab	4.83a
$SE\pm$	0.23	0.07

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2 FIELD STUDY

4.2.1 Effect of legume incorporation after two years of growth and N fertilizer on maize grain yield and some yield components.

4.2.1.1 Grain yield.

Legume incorporation and N fertilizer significantly affected maize grain yield in all seasons (Table 6). In 1995, incorporation of CP significantly out yielded all other treatments. The control (natural regrowth) gave significantly lower value than the other treatments. In 1996, incorporation of CR, CB and CP gave the highest grain yield which were not significantly different among each other, however, they gave significantly higher values than PPH and the control treatments. The grain yield where CC was incorporated was not significantly different from PPH, CR, CB and CP treatments. On the basis of the pooled data analysis, the incorporation of CB and CP were not significantly different from each other, but they gave significantly higher grain yield than other treatments. Grain yield was significantly increased with increasing rates of N in all seasons (Table 6).

A significant interaction between the effects of legume incorporation and N fertilizer on grain yield was observed in 1995 and the pooled data (Table 7). In 1995, with CB and CP incorporations, grain yield was significantly higher at 120kg N ha^{-1} than other treatments; while the pooled data analysis

Table 6. Effect of Legume incorporation after two years of growth and N Fertilizer on maize grain and stover yields.

Treatment	Grain yield (t ha^{-1})			Stover yield (t ha^{-1})		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	0.97e	1.53bc	1.25c	3.59a	3.98a	3.78a
CR	1.28d	1.93a	1.60b	4.03a	4.26a	4.15a
CB	1.66b	2.07a	1.86a	4.12a	4.18a	4.15a
CC	1.56c	1.75ab	1.65b	3.55a	4.07a	3.81a
CP	1.37a	2.01a	1.94a	4.02a	4.02a	4.02a
Control	0.84f	1.37d	1.11c	3.60a	2.37b	2.98b
SE±	0.02	0.12	0.06	0.22	0.13	0.13
N rates						
0	0.56d	0.80c	0.68d	2.33b	2.48d	2.41d
40	1.37c	1.65b	1.51c	4.06a	3.79c	3.93c
80	1.68b	2.22a	1.95b	4.35a	4.20b	4.27b
120	1.83a	2.44a	2.14a	4.55a	4.78a	4.66a
SE±	0.02	0.10	0.05	0.18	0.12	0.11
Interactions						
LXN	**	NS	**	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Note
L = legume
** = Significant at 1%
NS = Not significant
N = N fertilizer rate

Table 7. Interaction between Legume incorporation after two years of growth and N Fertilizer on maize grain yield (t ha^{-1}).

1995 season

Treatment	N rates			
Legume spp	0	40	80	120
PPH	0.35p	1.14kl	1.16jkl	1.24ijk
CR	0.31p	1.29ij	1.51h	2.00de
CB	0.89m	1.33i	1.88ef	2.53a
CC	0.58n	1.78fg	2.09cd	1.78fg
CP	1.20ijk	2.22c	1.64gh	2.41ab
Control	0.04q	0.46np	1.85f	1.021m
SE±	0.04			
PPH	0.49ij	1.21g	1.57ef	1.74c-f
CR	0.69hi	1.69def	1.75c-f	2.27b
CB	0.85ghi	1.75c-f	2.21b	2.64a
CC	0.69hi	1.62ef	2.15b	2.14b
CP	1.08gh	2.04bcd	2.04bcd	2.11bc
Control	0.27j	0.74hi	1.93b-3	1.49f
SE+	0.12			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

(Table 7) showed that, CB at 120kg N ha^{-1} gave significantly higher grain yield than in other treatments. The application of N at lower rates generally gave lower grain yields than at higher rates in all legume treatments. However, CP at 40kg N ha^{-1} in 1995 season did not show much difference with the 120kg N ha^{-1}. Infact with the pooled data, there was no significant difference between CP incorporation at 40, 80 and 120kg Nha^{-1}.

4.2.1.2 Stover yield.

Stover yield was not significantly affected by treatments in 1995 season (Table 6). In 1996 and the pooled data analysis, incorporation treatments significantly gave stover yields that were significantly higher than the control treatment (Table 6).

The application of N at 40, 80 and 120kg N ha^{-1} treaments gave stover yields which were not significantly different from each other, but were significantly higher than the 0kg N ha^{-1} in 1995 season. In 1996 and the pooled data analysis, increasing N rates significantly increased stover yield (Table 6).

4.2.1.3 Plant height

During all seasons, incorporation and N fertilizer significantly affected maize plant height (Figure 1 nd 2). In 1995, with CB incorporation, taller plants were recorded which

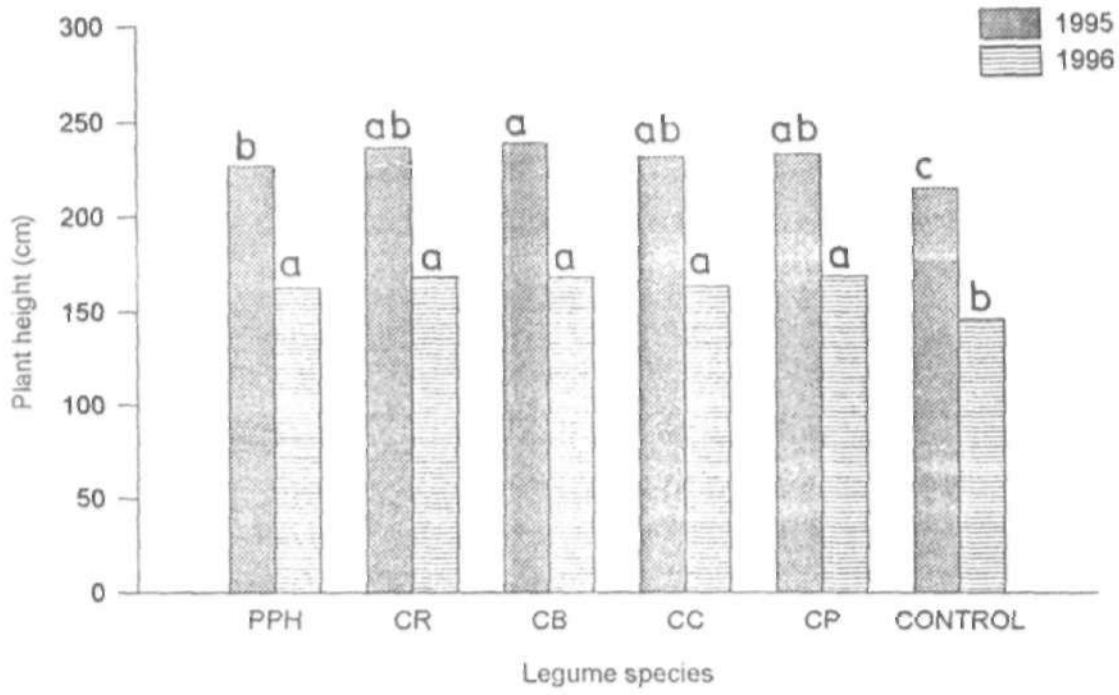


Fig.1: Effect of legumes incorporation after two years of growth on maize plant height

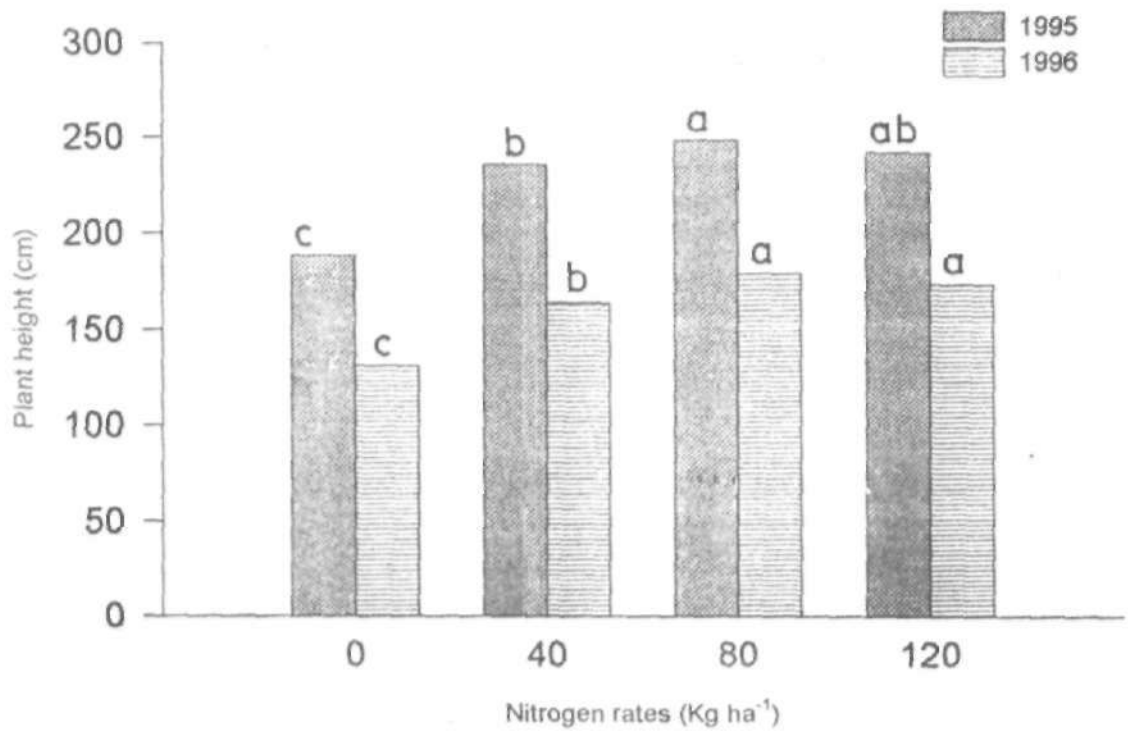


Fig.2: Effect of legumes incorporation after two years of growth and N fertilization on maize plant height

were not significantly different from CR, CC and CP treatments. In 1996, among the legume incorporation treatments, plant height did not differ significantly. They all gave plants that were significantly taller than the control. The pooled data analysis showed that CB and CR treatments gave significantly taller plants than PPH and CC treatments, but they were not significantly different from CP treatment. The control gave significantly shorter plants than all incorporation treatments. In all seasons maize plants tended to be taller with increasing rates of N.

Interactions between incorporation and N rates on plant height in 1995 and pooled data were significant (Table 8). With the interaction effects, incorporation of CR at 120kg N ha^{-1} gave taller plants.

4.2.1.4 Ear height

In all seasons, ear height was significantly affected by both incorporation and N rates (Figures 3 and 4). The incorporation of CR and CB, gave significantly greater ear height values than the other treatments in 1995 season. Ear height values were significantly shorter in control treatment than where legumes were incorporated. In 1996 season, similar results were obtained but among the legume treatments there were no significant differences. With respect to pooled data analysis, ear height was higher with CR treatment, which was

Table 8. Interaction between Legume incorporation after two years of growth and N Fertilizer on maize plant height (cm).

1995 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	172.37hi	240.37b-g	252.43a-d	239.53b-g
CR	188.97h	244.70a-f	247.87a-e	260.03a
CB	222.87g	229.43efg	252.50a-d	245.83a-f
CC	191.20h	229.77efg	258.00ab	240.20b-g
CP	191.77h	241.83b-g	254.27abc	235.43c-g
Control	163.10i	229.90efg	225.80fg	233.13d-g
SE±	6.23			
	Pooled data			
PPH	143.20j	204.37c-g	218.93ab	210.57a-e
CR	168.00i	205.06c-f	213.45a-d	220.50a
CB	178.48hi	202.32d-g	216.05a-d	213.18a-d
CC	165.48i	194.35f-g	219.55a	205.43b-f
CP	167.02i	205.38b-f	217.93a-c	206.28b-f
Control	136.32k	189.33gh	197.37e-g	193.32f-h
SE±	4.56			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

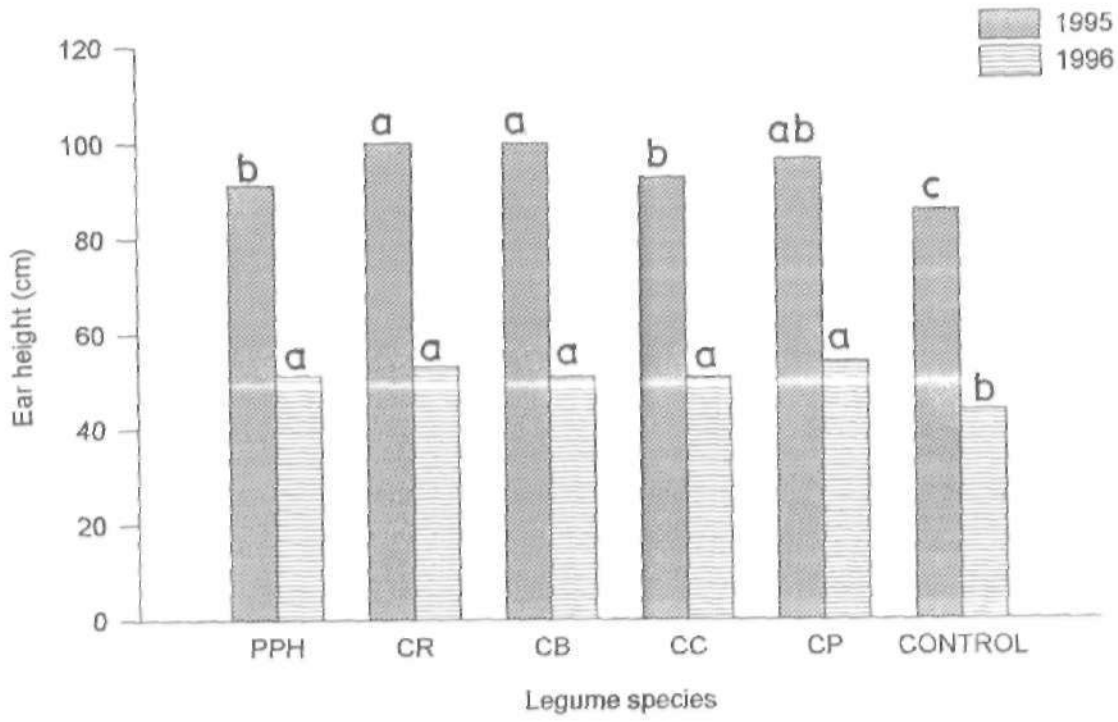


Fig.3: Effect of legumes incorporation after two years of growth on maize ear height

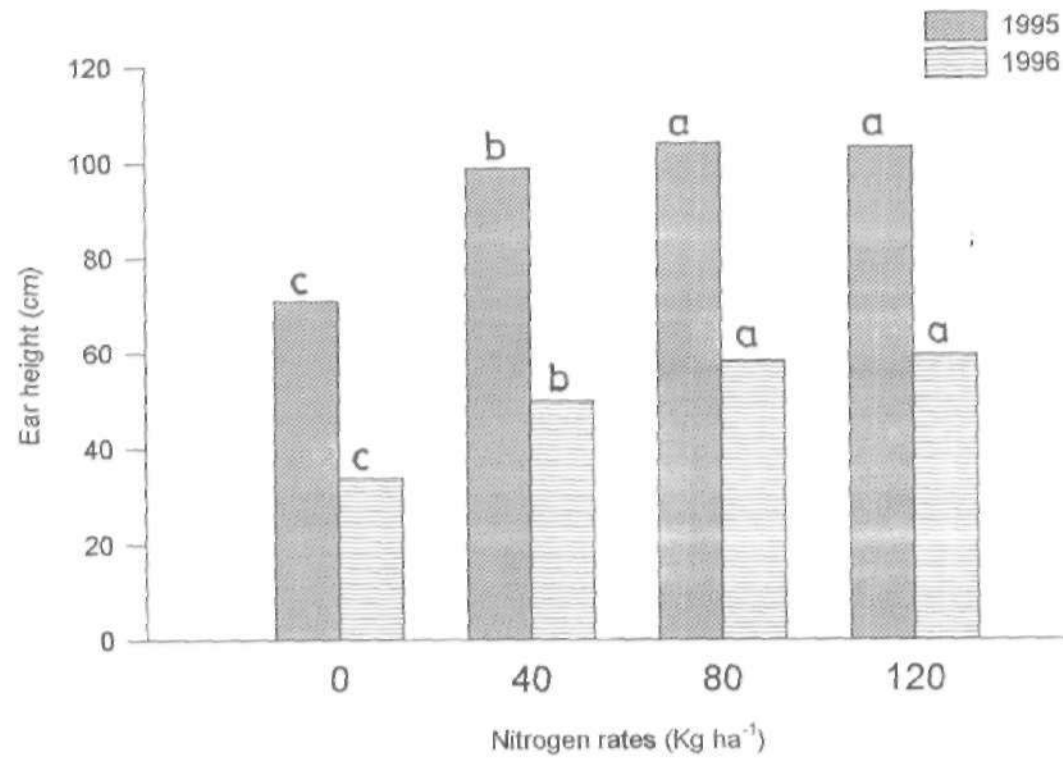


Fig.4: Effect of legumes incorporation after two years of growth and N fertilization on maize ear height

not significantly different from CB and CP treatments. The control gave a significantly lower ear height than all other treatments.

Ear height at 80 and 120 kg N ha^{-1} treatments in all seasons were significantly not different from each other but gave significantly higher ear height values than 0 and 40kg N ha^{-1} treatments. The control (0kg N ha^{-1}) gave significant lower ear height than all other treatments in all seasons.

4.2.1.5 1000-grain weight

The result of 1000-grain weight measured only in 1996 season, showed that values were significantly higher with all legume treatments than the control, except for CR treatment (Table 9). Increasing rates of N generally increased the 1000-grain weight.

4.2.1.6 Cob length

The incorporation treatments gave significantly longer cobs than the control in the 1996 season (Table 9). The incorporation of CR, CB and CP gave significantly longer cobs than all other treatments. Where PPH and CC were incorporated, the cobs were longer than that of the control. Cob length increased with increasing rates of N. The differences were significant.

4.2.1.7 Kernel depth

This parameter was also taken at the 1996 season only. Deeper kernels were observed in CR and CC treatments, though they were not significantly different from CB and CP treatments (Table 9), but were significantly greater than PPH and control treatments. Kernel depth increased with increasing N rates.

4.2.1.8 Germination Percentage

Maize germination was not significantly affected by legume incorporation at both seasons (Table 10). However, CP gave higher germination percentage than other treatments in 1995 season. In 1996 seasons, CR had a higher value than other treatments. When the two years were pooled together CP again gave higher germination percentage than other treatments.

Table 10: Effect of legume incorporation after two years of growth on maize germination percentage.

Treatment	Germination percentage (%) 1995	1996	Mean
Legume spp			
PPH	97.00a	98.00a	97.50a
CR	96.00a	99.00a	97.50a
CB	95.00a	98.00a	96.50a
CC	95.00a	98.00a	96.50a
CP	99.00a	98.00a	98.50a
Control	97.00a	97.00a	97.00a
SE±	3.10	2.30	2.45

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Table 12. Interaction between Legume incorporation after one year of growth and N Fertilizer on maize grain yield (t ha^{-1}).

Treatment	N rates			
Legume spp	0	40	80	120
PPH	0.16j	0.58gh	0.88c-f	1.04bc
CR	0.50hi	1.06bc	1.42a	1.33a
CB	0.16j	0.69f-h	0.75d-h	0.99cde
CC	0.29ij	0.54hi	0.97cde	1.00cd
CP	0.28ij	0.73e-h	0.89c-f	0.76d-h
AH	0.16j	0.58gh	0.88c-f	1.04bc
Control	0.12j	0.29ij	0.54hi	0.92c-f
$SE_{\pm}$	0.08			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.2 Effect of legume incorporation after one year of growth and N fertilizer on maize grain yield and some yield components.

4.2.2.1 Grain yield

The effect of legume incorporation after one year of growth and N fertilizer on maize grain yield is shown in Table 11. Grain yield was significantly higher in CR than other treatments. In general, all legume treatments gave significantly higher grain yield than the control. Between PPH, CB, CC and CP differences were not significant. Increasing rates of N application significantly increased the grain yield.

The interaction between legume incorporation after one year of growth and N fertilizer and grain yield is shown in Table 12. The results showed that, CR incorporation at N application of 80 and 120kg Nha^{-1} gave significantly higher grain yield than all other treatments. With all legume treatments and the control, increasing N rates gave higher grain yields.

4.2.2.2 1000-grain weight

The 1000-grain weight was significantly higher with CR and AH incorporation than all other treatments (Table 11). Values observed from PPH, CC and CP treatments were significantly higher than that of the control. The values observed from CB incorporation were not significantly

different from the PPH, CC, CP and the control treatments. The 1000-grain weight was significantly increased with increasing rates of N.

4.2.2.3 Cob length

The incorporation of CR and AH gave longer cobs, which however were significantly longer than those observed from CC and CB incorporation treatments (Table 11). Significantly shorter cobs than all other treatments were observed with the control treatment. Higher N rates, gave significantly longer cobs.

4.2.2.4 Kernel depth

The depth of maize kernels was higher with CR incorporation though not significantly different from PPH, CB and CP treatments (Table 11). The depth of the kernels generally increased with increasing N rates.

4.2.2.5 Germination percentage

The germination percentage of maize was not significantly affected by legumes incorporation. The values of CR and CP were however slightly higher than that of other treatments (Table 11).

4.2.2.6 Plant Height

The control treatment gave shorter plants than all other treatments (Figure 5). The incorporation of CR and AH which were not significantly different from each other, gave

significantly taller plants than other treatments. The application of N at 120kg N ha^{-1} did not give significantly taller plants than the 80kg N ha^{-1} treatment, however both gave significantly taller plants than 0 and 40kg N ha^{-1} treatments (Figure 6). The zero N level gave signficantly shorter plants than the 40kg N ha^{-1}.

4.2.2.7 Ear Height

Ear height was significantly higher with CR and AH incorporation than other treatments (Figure 7). Higher application of N gave higher ear height values (Figure 8).

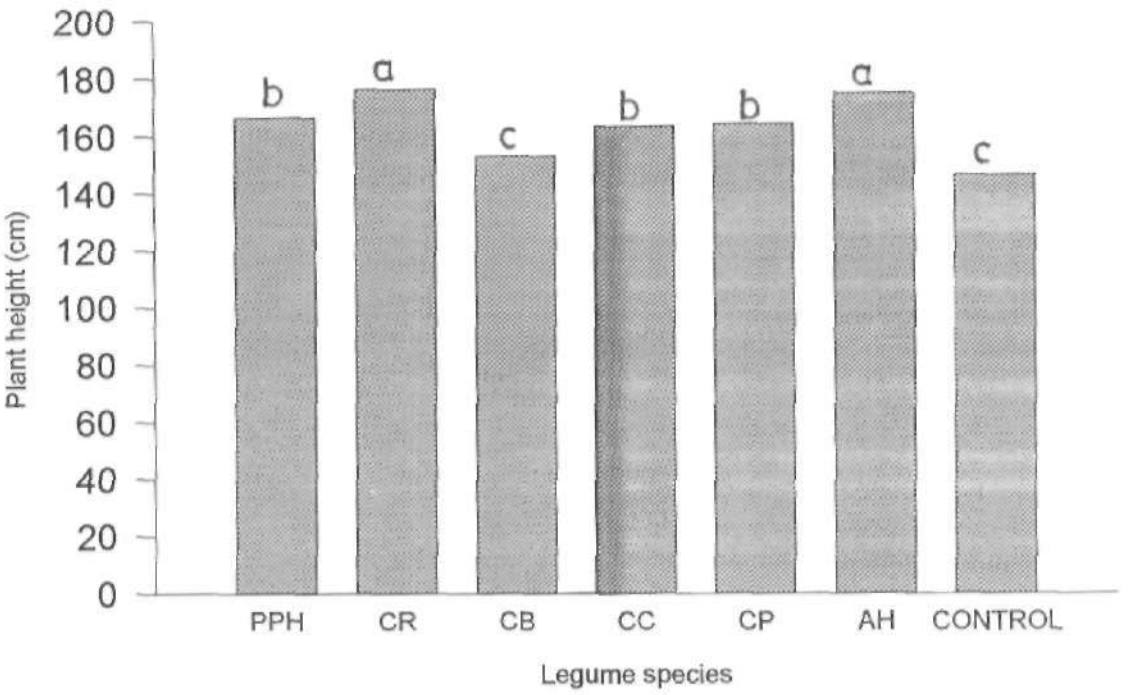


Fig.5: Effect of legumes incorporation after one year of growth on maize plant height

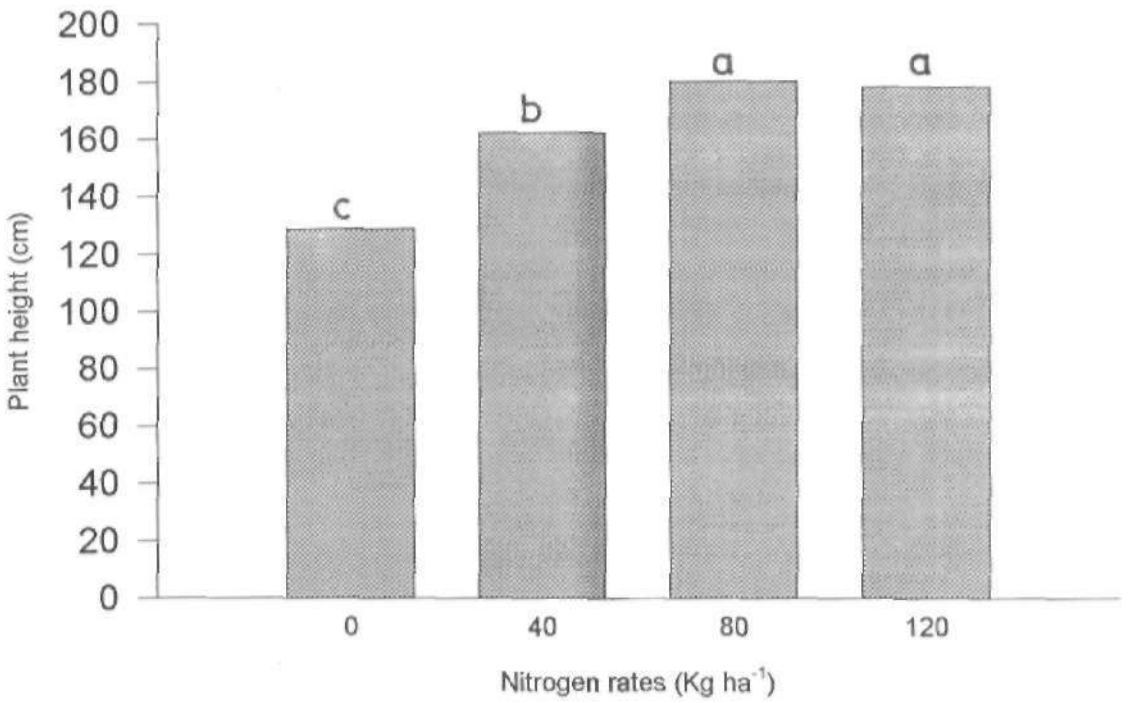


Fig.6: Effect of legumes incorporation after one year of growth and N fertilization on maize plant height

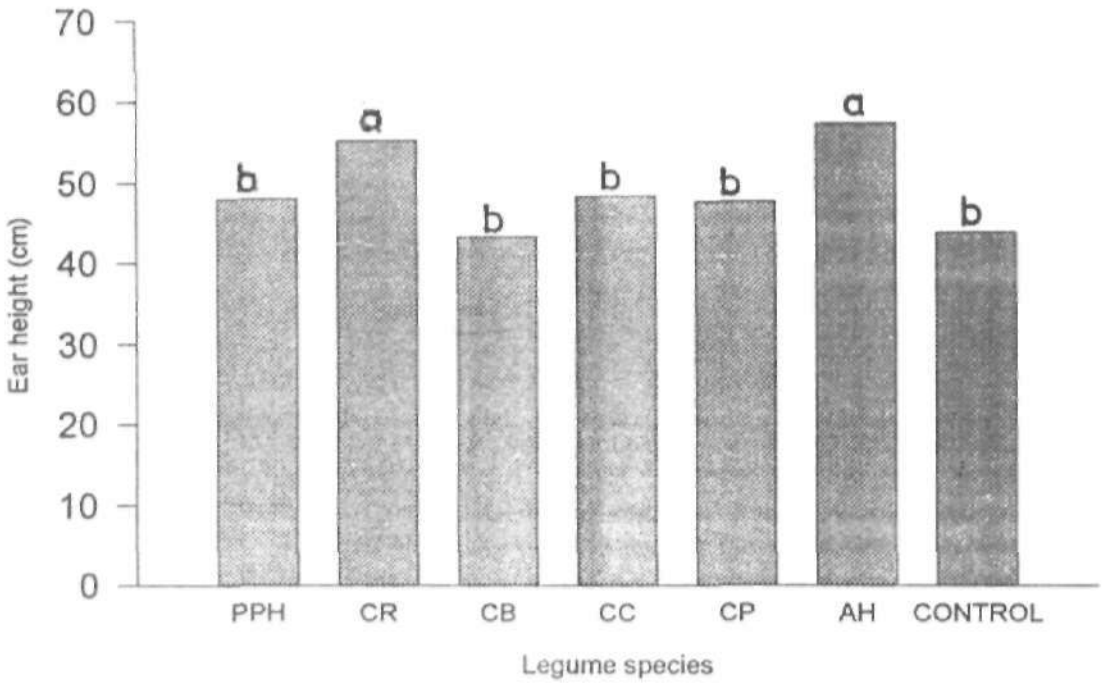


Fig.7: Effect of legumes incorporation after one year of growth on maize ear height

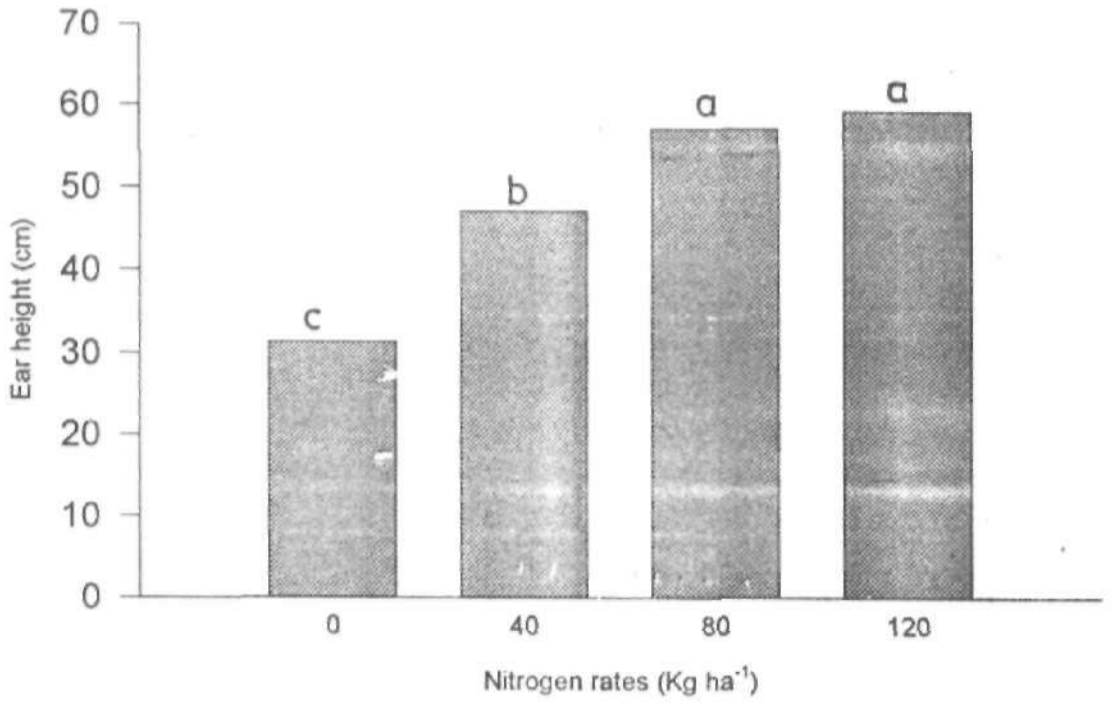


Fig.8: Effect of legumes incorporation after one year of growth and N fertilization on maize ear height

4.2.3 Effect of Legume Incorporation After Two Years of Growth and N Fertilizer on Nutrient Content of Maize Stover

4.2.3.1 Nitrogen

The effect of legume incorporation and N fertilizer on N concentration of stover is shown in Table 13. Nitrogen concentration was significantly affected by legume incorporation in 1995 and the pooled data, while in 1996 N content did not differ significantly among treatments. In 1995, N concentration was significantly higher in CC than in CR, CB and control treatments. The control gave the lowest value which was not significantly different from CR and CB incorporation treatments. With the pooled data analysis, N concentration in CC and the control treatments were highest, though they were not significantly different from PPH, CB and CP incorporation treatments. The incorporation of CR treatment gave the lowest stover N content, which was not significantly different from PPH, CB and CP incorporation treatments.

Generally, increasing N rates increased the N concentration of stover in all the seasons.

4.2.3.2 Phosphorus

Phosphorus concentration of stover was significantly affected by legume incorporation. The incorporation of PPH and CR gave significantly higher P concentrations,than other treatments in 1995 not significantly higher than CP

Table 13. Effect of Legume incorporation after two years of growth and N Fertilizer on N and P contents of Maize Stover.

Treatment	Nutrient Content (g kg^{-1})					
	N			P		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	5.12ab	5.38a	5.25ab	1.88a	0.83bc	1.36a
CR	4.72bc	4.69a	4.70b	1.19a	0.65cd	0.92abc
CB	4.81bc	5.07a	4.94ab	0.86c	1.13a	1.00ab
CC	5.80a	4.81a	5.30a	0.88c	0.76bcd	0.82bc
CP	5.37ab	5.20a	4.76ab	1.09ab	0.48d	0.94abc
Control	4.49c	5.03a	5.29a	0.91bc	0.97ab	0.79c
SE±	0.24	0.28	0.18	0.07	0.10	0.06
N rates						
0	4.23b	4.01c	4.12d	1.13a	1.19a	1.16a
40	4.38b	4.75b	4.57c	1.00ab	0.65bc	0.82b
80	5.73a	5.24b	5.49bb	1.09a	0.55c	0.82b
120	5.86a	6.12a	5.99a	0.86b	0.82b	0.84b
SE±	0.20	0.23	0.15	0.06	0.08	0.05
Interactions						
LXN	NS	NS	NS	*	**	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

incorporation treatment in 1995 (Table 13). The CB and CC incorporation treatments gave significantly lower P concentration, though they were not significantly different from the control. In 1996, the incorporation of CB gave the highest P concentration which was not significantly different from the control but was significantly different from all other treatments. Incorporation of CP gave the lowest value which was not significantly different from CC and CR incorporation treatments. The pooled data results showed that PPH incorporation gave the highest P concentration though it was not significantly different from CR, CB and CP incorporation treatments, but was significantly higher than CC and control treatments. The control treatment gave the lowest value which was not significantly different from CP, CC and CR incorporation treatments. Increasing N fertilizer rates tended to decrease stover P content in both seasons.

A significant interaction between legume incorporation and N fertilizer on P concentration of stover was observed in 1995 and 1996 seasons (Table 14). In 1995 season the incorporation of PPH treatment at 40 and 80kg N ha^{-1} and CR incorporation at 0kg N ha^{-1} gave highest stover P concentration. In 1996 seasons, CB at 120kg N ha^{-1} gave the highest stover P.

Table 14. Interaction between Legume incorporation after two years of growth and N Fertilizer on P content (g kg^{-1}) of maize stover.

1995 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	1.08a-f	1.42a	1.42a	0.83d-g
CR	1.42a	1.17a-e	0.92c-g	1.25a-d
CB	1.17a-e	0.75e-g	0.87c-g	0.67fg
CC	1.00b-g	0.67f-g	0.92c-g	0.92c-g
CP	1.25a-d	0.83d-g	1.33abc	0.96c-g
Control	0.83d-g	1.17a-e	1.08a-f	0.54g
SE±	0.14			
		1996 season		
PPH	0.33g	0.33g	0.83de	0.83de
CR	0.92cd	0.58eft	0.50fg	0.92cd
CB	0.44fg	1.17bc	1.25b	1.67a
CC	0.40fg	0.72def	0.67def	1.25b
CP	0.58efg	0.50fg	0.92cd	1.17bc
Control	0.40fg	0.50fg	0.55efg	0.92cd
SE±	0.27			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.3.3 Potassium

Potasium content of maize stover was affected by legume treatments in both seasons. In 1995, incorporation of CR gave the highest K concentration, though it was not signficantly different from the control, but it was significantly higher than PPH, CB, CC and CP incorporation treatments (Table 15). The incorporation of PPH, CB, CC, CP and the control treatment were not significantly different from each other. In 1996, K concentration was significantly higher in CR than in all other treatments except CC. Potassium concentration was lowest where PPH was incorporated. The result of the pooled data showed that K in plants that received CR was still significantly higher than in other treatments. The lowest K concentration was observed in PPH incorporation treatment, which was not significantly different from CB and control treatments. Potassium concentration generally increased with increasing rates of N in both seasons and the pooled data.

There was significant interaction between legume incorporation and N rates on K concentration in the two seasons and the pooled data analysis. In 1995, the interaction results showed that, the control treatment at 80kgNha^{-1} gave significantly higher K concentration than all other treatments (Table 16). Differences among legume treatments at 40, 80 and 120kgNha^{-1} were not significant. Generally, with all legume treatments increasing N fertilizer rates tended to increase stover K content (Table 16).

Table 15. Effect of Legume incorporation after two years of growth and N Fertilizer on K and Ca contents of Maize Stover.

Treatment	Nutrient Content					
	K			Ca		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	6.37b	4.89c	5.63c	0.68b	0.56a	0.62a
CR	7.47a	7.15a	7.31a	0.67b	0.56a	0.62a
CB	6.36b	5.67bc	6.02bc	0.88ab	0.53a	0.71a
CC	6.25b	6.86a	6.56b	0.91a	0.48a	0.70a
CP	6.25b	5.93b	6.42b	0.78ab	0.62a	0.65a
Control	7.04ab	5.79b	6.09bc	0.78ab	0.52a	0.70a
SE±	0.27	0.29	0.19	0.07	0.04	0.05
N rates						
0	6.09b	5.68b	5.89	0.53c	0.52a	0.53c
40	6.45ab	5.73b	6.09bc	0.70b	0.57a	0.64b
80	7.06a	5.88b	6.47ab	0.94a	0.54a	0.74a
120	6.89a	6.91a	6.90a	0.95a	0.55a	0.75a
SE±	0.22	0.23	0.16	0.06	0.03	0.04
Interactions						
LXN	*	**	**	NS	**	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Table 16. Interaction between Legume incorporation after two years of growth and N Fertilizer on K content (gkg^{-1}) of maize Stover.

1995 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	6.77b-e	6.04cde	6.18b-e	6.49b-e
CR	7.02bcd	7.55bc	7.80b	7.53bc
CB	5.18e	6.28b-e	6.85b-e	7.14bcd
CC	5.58de	6.22b-e	6.09cde	**7.12bcd**
CP	6.03cde	**4.49b-e**	6.03cde	6.47b-e
Control	6.01cde	6.15cde	9.36a	6.61b-e
SE±	0.53			
		1996 season		
PPH	4.56ghi	4.18hi	5.11e-i	5.70d-i
CR	6.91b-e	8.26ab	6.49c-g	6.94b-e
CB	4.63ghi	3.93i	6.58b-f	7.54abc
CC	6.04c-h	5.97c-h	6.77b-e	8.68a
CP	5.50d-i	6.24c-g	4.81f-i	7.19a-d
Control	6.43c-g	5.82c-i	5.50d-i	5.42d-i
SE±	0.57			
		pooled data.		
PPH	5.67h-k	5.11jk	5.65h-k	6.09e-k
CR	6.97a-g	7.90ab	7.14a-f	7.24a-e
CB	4.91k	5.10jk	6.71b-h	7.34a-d
CC	5.81g-h	6.09e-k	6.43c-i	7.90a
CP	6.22d-i	5.99f-k	7.44a-c	6.01f-k
Control	5.77g-h	6.36a-i	5.42i-k	6.83b-h
SE±	0.38			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.3.4 Calcium

The Ca concentration of stover was significantly affected only in the 1995 season by legume treatments, while in 1996 and the pooled data analysis showed no significant effect (Table 15). In 1995, the incorporation of CC treatment gave the highest Ca concentration which was not significantly different from CB, CP and control treatments. *Peuroria phaseoloides* and CR incorporation treatments which were significantly not different from each other gave the lowest Ca concentration and they were significantly not different from CB, CP and the control treatments. Increasing N rates gave increasing Ca concentrations.

A significant interaction between incorporation and N rates on Ca concentration was observed in the 1996 season. The result in Table 17 showed that, with the incorporatio of CB with 120kg N ha^{-1} significantly higher Ca concentration was obtained. Higher N rates at all legume treatments tended to increase Ca concentration.

4.2.3.5 Magnesium

The incorporation of legume and N rates had a significant effect on Mg concentration in stover in all seasons (Table 18). In 1995, CB, CR, CP and the control treatments gave the highest values which were not significantly different from each other, while PPH and CC incorporation treatments gave the

lowest values which were not significantly different from CP incorporation treatment. In 1996, the incorporation of Cp gave significantly higher Mg value though it was not significantly different from PPH and the control treatments. The incorporation of CB, CR and CC gave lower Mg concentration which was not significantly different from each other. On the pooled data analysis, the control treatment gave the highest value though it was not significantly different from CP, CB and CR incorporation treatments, but it was significantly higher than PPH and CC incorporation treatments. The incorporation of CC treatment gave the lowest Mg concentration, but it was not significantly different from CB, CR and PPH incorporation treatments. The N fertilizer tended to give higher Mg concentration at higher than at lower rates in all seasons.

Table 17. Interaction between Legume incorporation after two years of growth and N Fertilizer on Ca content (gkg^{-1}) of maize Stover in 1996 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	0.40ij	0.47hij	1.03bcd	0.80d-g
CR	0.37j	0.53g-j	0.87c-f	0.90b-f
CB	0.67e-i	0.67e-i	0.80d-g	1.40a
CC	0.50hij	1.13b	0.93b-e	1.07bc
CP	0.63f-j	0.73e-h	0.93b-e	0.80d-g
Control	0.63f-j	0.67e-i	1.07bc	0.73e-h
$SE_{\pm}$	0.08			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.3.6 Zinc

Zinc concentration of stover was not significantly affected in 1995 but was significantly affected in 1996 and the pooled data analysis (Table 18). In 1996, the incorporation of CR gave the highest Zn concentration which was not significantly different from CC, CP and the control treatments. *Peuroria phaseoloides* and CB incorporation

Table 18. Effect of Legume incorporation after two years of growth and N Fertilizer on Mg and Zn contents of Maize Stover.

Treatment	Nutrient Content					
	Mg			Zn		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	1.07b	1.23ab	1.15bc	18.75a	20.00b	19.38b
CR	1.21a	1.13b	1.17abc	22.33a	26.42a	24.38a
CB	1.25a	1.14b	1.19abc	18.75a	20.42b	19.58b
CC	1.06b	1.10b	1.08c	20.83a	24.58ab	22.71ab
CP	1.14ab	1.42a	1.22ab	17.50a	23.42ab	20.75b
Control	1.25a	1.21ab	1.23a	18.00a	23.50ab	20.46b
SE±	0.04	0.07	0.04	1.57	1.81	1.17
N rates						
0	1.06b	1.32a	1.19ab	21.78a	25.06a	23.42a
40	1.11b	1.12b	1.11b	17.28b	25.56a	21.42a
80	1.26a	1.11b	1.18ab	19.50ab	22.00ab	20.75b
120	1.22a	1.26ab	1.24a	18.89ab	19.61b	19.25b
SE±	0.03	0.06	0.03	1.28	1.48	0.95
Interactions						
LXN	*	N.S.	*	NS	**	*

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

treatments gave the lowest values which were not signficantly different from each other and CP, CC and the control treatments. The pooled data result showed that, CR incorporation treatment gave the highest Zn concentration, though it was not significantly different from CC incorporation treatment, but was significantly higher than all other treatments. Increasing N fertilizer rates tended to decrease the Zn concentration in all seasons (Table 18).

There was a significant interaction between incorporation and N rates in 1996 and the pooled data analysis. The result showed that, with CC incorporation at 40kg N ha^{-1}, Zn concentration of stover was highest in 1996 and the pooled data analysis (Table 19). Generally decreasing N rates tended to increase Zn concentration in stover in all legume treatments in the two interactions.

Table 19. Interaction between Legume incorporation after two years of growth and N Fertilizer on Zn content ($mgkg^{-1}$) of maize Stover.

1996 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	26.67a-e	25.00a-f	15.00efg	13.33fg
CR	26.67a-e	31.67abc	23.67b-g	23.67b-g
CB	11.67g	26.67a-e	28.33a-d	15.00efg
CC	26.67a-e	35.00a	20.00d-g	16.67efg
CP	33.33bc	13.33fg	21.67c-g	25.33a-f
Control	25.33a-f	21.67c-g	23.33b-g	23.67b-g
SE±	3.62			
		Pooled data		
PPH	22.50b-f	18.33d-f	18.33d-f	18.33d-f
CR	26.83a-b	26.00a-c	23.67a-d	21.00b-f
CB	15.83ef	20.83b-f	23.33a-d	18.33d-f
CC	23.33a-d	29.17a	20.00c-f	18.33d-f
CP	25.33a-c	19.17c-f	19.17c-f	19.33c-f
Control	26.67ab	15.00f	20.00c-f	20.17b-f
SE±	2.33			

Means followed by the same letter(s) within a treatment group are significantly different at 5% level of significance using DNMRT.

4.2.4 Effect of legume incorporation after two years of growth and N fertilizer on nutrient content of maize ear leaf.

4.2.4.1 Nitrogen

The ear leaf N concentration was significantly affected by both incorporation and N rates (Table 20). The incorporation of CC and CR gave the highest ear leaf N, which was significantly higher than all other treatments. Where PPH and CP were incorporated, N values were the lowest. Increasing N rates significantly increased ear leaf N.

4.2.4.2 Phosphorus

The incorporation of CR and the control treatments gave the highest ear leaf P concentration which was not significantly different from CB and CC treatments, but was significantly higher than PPH and CP treatment (Table 20). The PPH and CP treatments which were not significantly different from each other, gave significantly lower P concentration. Increasing N rates significantly increased ear leaf P.

4.2.4.3 Potassium

Ear leaf K concentration was significantly higher in PPH than in other treatments except CR and the control treatments, but was significantly higher than all other treatments (Table

20). The incorporation of CB, CC and CP gave the lowest K values, which were not significantly different from each other. The application of N at higher rates, increased ear leaf K.

The interaction between legume incorporation and N rates on K concentration of ear leaf was significant (Table 21). The incorporation of PPH at 40kg N ha^{-1} and CP at 120kg N ha^{-1} gave the highest K concentration of ear leaf. There were no significant differences between CB, CC, CP and control treatments at 0, 40 and 80kg N ha^{-1}. With all legume and control, treatments increasing N fertilizer rates tended to increase ear leaf K content.

Table 20. Effect of Legume incorporation after two years of growth and N Fertilizer on Nutrient Content of Maize Ear Leaf in 1996 season.

Treatment	Nutrient Content <----------gkg^{-1}---------->		
Legume spp	N	P	K
PPH	19.51c	1.95c	10.56a
CR	23.48a	2.27a	9.87ab
CB	21.25b	2.09ab	9.22b
CC	23.61a	2.17ab	9.37b
CP	19.19c	1.66c	9.38b
Control	20.44bc	2.23a	9.72ab
SE±	0.50	0.08	0.33
N rates			
0	13.79d	1.66d	8.70c
40	18.88c	1.94c	9.43bc
80	24.39b	2.21b	9.93ab
120	27.93a	2.43a	10.69a
SE±	0.41	0.06	0.27
Interactions			
LXN	NS	NS	**

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Table 21. Interaction between Legume incorporation after two years of growth and N Fertilizer on K content (gkg^{-1}) of maize Ear leaf in 1996 season.

Treatment	N rates			
Legume spp	0	40	80	120
PPH	10.52a-d	12.35a	8.66c-f	10.70a-d
CR	9.40b-f	8.99c-f	11.44ab	9.64b-f
CB	8.12ef	8.62d-f	9.65b-f	10.50a-e
CC	7.38f	9.12c-f	10.27b-f	10.73a-c
CP	8.72c-f	8.14ef	9.73b-f	12.31a
Control	8.06ef	9.37c-f	9.81b-f	10.28b-f
SE±	0.66			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.5 Effect of legume incorporation after two years of growth on some soil chemical properties

4.2.5.1 Soil pH

Surface soil pH measured in water in 1995 and the pooled data analysis was significantly affected by treatments, while in 1996 there were no significant differences due to the treatments (Table 22). In 1995, the incorporation of CB gave higher pH value which was not significantly different from CR and CC treatments, but was significantly higher than all other treatments. The other treatments, PPH, CP and the control were not significantly different from each other. When data were pooled, CB treatment still gave higher pH value which was not significantly different from CR, CC and CP treatments but was significantly higher than PPH and the control treatments. The control treatment gave the lowest pH value which was not significantly different from CP, CR and PPH treatments. Soil pH of the sub-surface soils (15-30cm) was not affected by treatments in all seasons (Table 22).

4.2.5.2 Soil Organic Carbon

In all seasons, on the surface soil (0- 15cm) legume incorporation significantly affected soil organic carbon (Table 23). In 1995, the incorporation of CB gave higher soil organic C which was not significantly different from CC and Cp treatments, but was significantly higher than PPH, CR and

Table 22. Effect of legume incorporation after two years of growth on Soil pH in water.

Treatment	Soil pH (H_2O) (1:2.5)					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	5.56b	5.38a	5.47bc	5.42a	5.48a	5.45a
CR	5.71ab	5.39a	5.55abc	5.35a	5.34a	5.35a
CB	5.95a	5.61a	5.78a	5.39a	5.54a	5.46a
CC	5.79ab	5.62a	5.71ab	5.35a	5.57a	5.46a
CP	5.55b	5.56a	5.55abc	5.26a	5.45a	5.36a
Control	5.62b	5.16a	5.39c	5.69a	5.35a	5.52a
SE±	0.08	0.14	0.09	0.18	0.10	0.10

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Table 23. Effect of legume incorporation after two years of growth on Soil Organic Carbon.

Treatment	Soil Organic Carbon					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	7.05bc	8.25a	7.65a	6.25a	7.38a	6.82a
CR	7.18bc	7.45ab	7.31a	4.92a	7.18a	6.05a
CB	9.11a	7.58ab	8.35a	5.66a	6.92a	6.29a
CC	8.11ab	6.65ab	7.38a	6.12a	6.05a	6.09a
CP	7.51ab	8.18a	7.85a	6.52a	6.78a	6.65a
Control	5.52c	5.79b	5.65b	6.25a	6.98a	6.12a
SE±	0.55	0.54	0.39	0.72	0.68	0.50

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

control treatments. The control treatments gave the lowest OC content, though it was not significantly different from PPH and CR treatments. In 1996, the organic C was higher with PPH and CP incorporation treatments. These were not significantly different from CR, CB and CC treatments but were significantly higher than the control treatment which gave the lowest value. With respect to the pooled data, all incorporation treatments which were not significantly different from each other, gave significantly higher soil organic C than the control treatment.

Organic carbon in the lower depth (15-30cm) was not affected by all treatments.

4.2.5.3 Exchangeable Calcium

The effect of legume incorporation on exchangeable Ca in the soil is shown in Table 24. In 1995, surface soil Ca was significantly affected by legume treatments. The incoporation of PPH gave the highest value which was not significantly different from CB and CC treatments, but was significantly higher than all other treatments. The control, CP and CR treatments which were not significantly different from each other gave the lowest exchangeable Ca, though their values were not significantly different from CC and CB treatments. Exchangeable Ca values were not significantly affected by treatments in 1996 season and the pooled data. Sub surface Ca

Table 24. Effect of Legume incorporation after two years of growth on Exchangeable Ca.

Treatment	Exchangeable Ca.					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	2.57a	2.90a	2.73a	2.47a	2.50a	2.48a
CR	1.83b	2.40a	2.12a	2.10a	2.43a	2.27a
CB	2.07ab	2.60a	2.33a	2.00a	2.23a	2.11a
CC	2.07ab	2.30a	2.18a	1.97a	2.23a	2.10a
CP	1.87b	2.30a	2.08a	2.13a	2.37a	2.25a
Control	1.73b	2.53a	2.13a	1.80a	1.87a	1.83a
SE±	0.18	0.37	0.21	0.28	0.30	0.21

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

was not affected in all seasons.

4.2.5.4 Exchangeable Magnesium

In 1995 and the pooled data, legume treatments had significant effect on soil Mg but not in 1996 (Table 25). In 1995, PPH gave values that were significantly higher than CR and the control. On the basis of pooled data, PPH treatment still gave the highest soil Mg content, which was not significantly higher than CP, CC and the control treatments. The control treatment gave the lowest soil Mg content.

In the sub-surface soil (15-30cm), in 1995, the incorporation of PPH gave higher soil Mg content which was significantly higher than CR treatment, but was not significantly different from all other treatments (Table 25). The control which gave the lowest Mg content was not significantly different from all other treatments except the PPH treatment. In 1996, PPH treatment gave significantly high Mg content than all other treatments which were not significantly different from each other. The pooled data showed that, the incorporation of PPH gave significantly higher soil Mg content than all other treatments. It was followed by CR, CB, CC and CP treatments which were not significantly different from each other, but were significantly higher than the control treatment which gave the lowest Mg content.

Table 25. Effect of Legume incorporation after two years of growth on Soil Exchangeable Mg.

Treatment	Exchangeable Mg.					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	0.91a	0.87a	0.89a	0.89a	0.97a	0.93a
CR	0.67b	0.75a	0.71bc	0.67b	0.79b	0.73b
CB	0.79ab	0.87a	0.83ab	0.69ab	0.80b	0.75b
CC	0.75ab	0.72a	0.74bc	0.75ab	0.79b	0.77b
CP	0.72ab	0.88a	0.80ab	0.76ab	0.79b	0.78b
Control	0.62b	0.69a	0.66c	0.72ab	0.69b	0.70c
SE±	0.06	0.06	0.04	0.06	0.06	0.04

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

4.2.5.5 Exchangeable Potassium

Exchangeable K was significantly affected by legume treatments in 1995 but not in 1996. Treatment effects were also noticed in the combine analysis (Table 26). In 1995, higher K values were observed in PPH and CP. The incorporation of CR treatments gave the lowest soil exchangeable K, which was not significantly different from PPH, CB, CC and the control treatments.

In all seasons, on the sub-surface soil incorporation did not significantly affect the soil K content (Table 26).

4.2.5.6 Effective Cation Exchange Capacity (ECEC)

On the surface soil (0-15cm) in both seasons, incorporation significantly affected CEC (Table 27). In 1995, with PPH incorporation, ECEC was significantly higher than in all other treatments. In 1996, the incorporation of PPH and CP gave the highest ECEC values which were not significantly different from CR and CB treatments, but were significantly higher than CC and the control treatments. The pooled data results showed that, the incorporation of PPH gave higher ECEC which was not significantly different from CP treatment, but was significantly higher than all other treatments. The control treatment gave the lowest ECEC value.

In the sub-surface soil (15-30cm), incorporation had

significant effect on ECEC in 1995 and the pooled data, while in 1996, incorporation did not significantly affect the ECEC (Table 27). In 1995 with PPH incorporation, ECEC was highest, though it was not significantly different from CC and CP treatments, but was significantly higher than CR, CB and the control treatments. On the basis of pooled data, PPH gave higher ECEC which was not significantly different from CC and CP treatments, but was significantly higher than all other treatments. The control treatment gave a significantly lower value than all other treatments.

Table 26. Effect of Legume incorporation after two years of growth on Exchangeable K.

Treatment	Exchangeable K.					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	0.14a	0.15a	0.15ab	0.09a	0.16a	0.12a
CR	0.09b	0.13a	0.11b	0.10a	0.13a	0.12a
CB	0.13ab	0.16a	0.15ab	0.12a	0.16a	0.14a
CC	0.12ab	0.17a	0.15ab	0.14a	0.17a	0.15a
CP	0.15a	0.19a	0.17a	0.10a	0.12a	0.11a
Control	0.12ab	0.15a	0.14ab	0.13a	0.12a	0.13a
SE±	0.01	0.02	0.01	0.02	0.02	0.01

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

Table 27. Effect of legume incorporation after two years of growth on Effective Cation Exchange Capacity (ECEC)

Treatment	E. C. E. C.					
	0 - 15cm			15 - 30cm		
Legume spp.	1995	1996	Mean	1995	1996	Mean
PPH	4.01a	4.32a	4.17a	3.47a	3.68a	3.58a
CR	2.94c	3.88ab	3.41c	2.59c	3.65a	3.12c
CB	3.47b	3.85ab	3.66bc	2.98bc	3.48a	3.23bc
CC	3.39b	3.69b	3.54bc	3.32ab	3.41a	3.37ab
CP	3.39b	4.33a	3.86ab	3.09ab	3.73a	3.41ab
Control	2.70c	3.44b	2.47d	2.55c	3.04a	2.79d
SE±	0.12	0.18	0.11	0.13	0.10	0.08

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT.

CHAPTER FIVE

5.0 DISCUSSION

5.1 GREENHOUSE EXPERIMENT

5.1.1 Effect of legume incorporation on maize shoot dry matter yield

In general, shoot DMY was increased by residue incorporation more than the control. This effect is expected, as the residues upon decomposition will release nutrients for crop use. In addition organic matter will be increased thereby enhancing CEC, improving soil aggregation and hence water retension and supporting biological activity. Haque (1992) and William (1992) reported DMY increase when legumes were incorporated into the soil and attributed this effect mainly to increase in SOM. There were yield differences among the different types of legumes. At 2.5t ha^{-1} CP gave the highest yield, while at 5.0t ha^{-1} CR gave the highest yield. This again confirms that, the higher the quantity of residue incorporated into the soil, the higher the beneficial effects discussed above. However, the slight differences among residues is likely related to the quality of the materials incorporated. According to Henzell and Vallis (1977) a predictable consequence of the variable N concentration in different legume residue is that they will contribute varying amounts of N to the soil and likewise to the following crop.

Most of the differences between residues can be attributed to their N percentages.

The C:N ratio is a useful guide to the net release of N from organic material at early stages of decomposition. The C:N ratio also provides an indication of how rapidly a material is likely to be decomposed. Plant residues with high C:N ratio (>30:1) are likely to decompose slowly with initial immobilization of N, where as residues with smaller C:N ratio are likely to decompose more rapidly with a net mineralization of N occuring right from the beginning. Therefore the excellent performance of some legumes like CR and CP could be attributed to their higher N contents and therefore lower C:N ratios (Table 2)

5.1.2 Effect of legume incorporation on plant height

Generally plant height increased with time. The control treatment consistently gave lower values than the other treatments. This may be attributed to some of the reasons already stated above. Residues when incorporated, upon decomposition will release nutrients for crop use. In addition organic matter will increase thereby improving soil physical and chemical properties which lead to higher plant heights. Among the legume treatments differences in plant height were observed. The CR treatment gave taller plants than most other treatments. This effect is probably due to

the high N content in CR compared to the other legumes. But generally, all the 5.0tha^{-1} treatments gave taller plants than the 2.5tha^{-1} treatments.

5.1.3 Effect of legume incorporation on nutrient content of maize shoot

The incorporation of residue generally affected N, P, K, Ca, Mg and Zn contents in maize shoot. The values of these nutrients were consistently higher in plants that received the residues than the control. This may probably be due to the nutrients added to the soil upon the decomposition of the residues. Between the legumes, there were slight differences in the contents of these nutrients. This could be due to the differences in the nutrient contents of the residues applied. Elemental contents of the tissue at 5.0tha^{-1} were generally higher than at 2.5tha^{-1}. Lal and Kang (1982) and Bin (1983) reported that, incorporation of organic material can enhance the nutrient balance by serving as a nutrient reservior in the soil, supplying N, P and other nutrients. Therefore the higher the material incorporated the more nutrients will be supplied for crop uptake and utilization. Dahiya and Singh (1980) and Singh and Dahiya (1980), however had observed decreases in Ca, Mg, Mn and Fe concentrations in oats shoot with increasing levels of manure and attributed it to dilution effect.

5.1.4 Effect of legumes incorporation on soil organic carbon and pH

The incorporation of residues into the soil significantly increased soil organic carbon content than the control. Mulongoy et al. (1993) made similar observations. They observed that the levels of organic matter in soils depend largely on the quantity and quality of plant materials and litter returned to the soil. Cobbina (1992) also reported significant increases in SOM after incorporation of tropical forage legumes at Fashola, near Ibadan, Nigeria. Among the legume treatments differences in SOM were observed. The C:N ratio provides an indication of how rapidly a material is likely to be decomposed. Residues with high C:N ratio are likely to decompose slowly, whereas those with smaller C:N ratio are likely to decompose more rapidly. Maize residue (high C:N ratio) at 5.0tha^{-1} gave higher soil organic carbon content compared to the legume treatments except CP. Between the application rates, the 5.0tha^{-1} gave significantly higher values than the 2.5tha^{-1}, except with CR and CB. According to Jekinson and Ayanaba (1977) 25-30% of residues from cereals and 40-50% of that from legumes can decompose in a month, the amount of material returned to the soil needs to be quite high in order to maintain adequate levels of soil organic matter in agroecosystems. This shows that 4 weeks after incorporation only about 40-50% of residues had been decomposed thereby not giving the expected clear difference between the 2.5 and

5.0tha^{-1} rates.

The incorporation of residues decreased the pH of the soil in all the treatments including the control. However, NL_o and LE_l still gave higher pH than other treatments. These results are similar to those reported by Olaniyan (1986), who stated that the incorporation of cover crops in the field decreased soil pH including the control plot.

5.2 FIELD STUDY: EFFECT OF LEGUME INCORPORATION ON MAIZE PERFORMANCE AND SOIL IMPROVEMENT

5.2.1. Effect of legume incorporation and N fertilizer on grain yield and some yield related parameters.

Grain yield was significantly higher with the incorporation of legumes than the control after one and two years of growth. After one year growth, legume incorporation gave yield increase of between 0.18 - 0.61t ha^{-1} (38.3 - 129.8%) over the control. Yield increases over the control upon incorporation after two years of growth were 0.13 - 1.03t ha^{-1} (15.5 - 122.6%), for 1995 season and 0.16 - 1.30t ha^{-1} (11.7 - 51.1%) for the 1996 season. The yield increase observed in the 1996 season clearly demonstrated residual effect of these legumes. With the pooled data, legume incorporation gave 0.11 - 0.83t ha^{-1} (12.6 - 74.8%) yield increase over the control.

Increase in grain yield with the incorporation of forage legumes have been reported (Balasubramanian and Sekayange, 1992; Simpson *et al.*, 1992; Chiyenda and Materechera, 1987; Hariah and Van Noordwijk, 1987; Nnadi *et al.*, 1981 and vine, 1953). Hariah and Van Noordwijk (1987) reported that maize yield was more than doubled by incoporation of three month old mucuna and crotolaria grown in alluvial soil on the Island of Java, Indonesia. Soil data after cropping showed that there was increase in SOM. These results clearly demonstrated that, organic matter has tremendous benefitial effect on soil. In addition to the supply of nutrients for crop uptake, it improves soil physical properties, CEC, soil microbial activity among many others.

The interaction effects of the pooled data between legume incorporation and N fertilizer showed that, incorporating CP after two years of growth with the addition of 40kg N ha^{-1} as urea gave 2.04t ha^{-1} maize that were close to the recommended dose of 120kg N ha^{-1} which gave 2.11t ha^{-1}. A similar result was observed with one year growth of CR which gave maize grain yield of 1.06 t ha^{-1} at 40kg N ha^{-1}, compared to the recommended dose of 120kg N ha^{-1} which gave 1.33t ha^{-1}. This implies that legume incorporation at one or two years growth before incorporation gave yield increases that were almost equivalent to 80 kg N ha^{-1}. Haque (1992) and ILCA (1987) reported maize yield equivalent to applying 60kg N ha^{-1} where forage legumes

were incorporated.

Among the legume treatments, CR after one year of growth gave significantly higher grain yield than the other treatments, while incorporation of CP and CB after two years of growth gave higher values than the control in all the seasons. The differences recorded among legumes either after one or two years of growth before incorporation could be attributed to their quality and quantity of biomass produced (Henzell and Vallis, 1977 and Nnadi *et al.*, 1981).

Legume incorporation after two years of growth gave higher grain yield than where incorporation was after one year of growth. It is possible that OM increased with residue return after two years of growth due to the larger biomass incorporated. The beneficial effect of OM has already been stated.

Grain yield and yield related parameters significantly responded to N fertilizer in the two experiments. This result is expected. As earlier indicated, cereal crops in the study area demand high amounts of N for improved yield since the soils are inherently low in soil N. Higher doses of N fertilizers have been reported to increase grain yield and yield related components (Stockinger, 1966; Goldsworthy, 1967; Balasubramanian, 1978; and Ologunde and Obilana, 1982).

The 1000 grain weight increased with legume incorporation. This is expected as grain yield was also increased by legume incorporation. As earlier explained for grain yield, this result may also be due to the same reasons. The 1000 grain weight significantly responded to N fertilizer in the two experiments. This is expected, because 1000 grain weight is a yield related parameter which had a similar result.

5.2.2. Effect of legume incorporation after two years of growth and N fertilizer on nutrient concentration of maize stover and Earleaf.

Maize stover and Earleaf concentrations of N, P, K, Ca and Mg were not affected by the treatments in both years. No particular trend was evident. Mchtosh and Varney (1972) reported similar inconsistencies in nutrient concentrations in their study.

Increasing N fertilizer tended to increase the concentrations of N, K, Ca and Mg in maize Stover. On the other hand, ear-leaf N, P, K, Ca and Mg increased significantly with increasing rates of N fertilizer. These increases are expected as N, P, K fertilizers were applied. This will have enhanced good growth especially roots, leading to adequate absorption of these nutrients from the soil. Lal (1979) reported increases in earleaf N and K concentration with N fertilizer application.

5.2.3. Effect of Legume Incorporation after two years of growth and some soil chemical properties

There were slight increases in Soil pH due to legume incorporation. It has been observed that legume incorporation generally increase SOM than the natural fallow. This increase in SOM is known to play a major role in supplying plant nutrients upon decomposition. Among the nutrients added to the soil are the exchangeable cations, which when added to the soil, could increase the pH (Jones and Wild, 1975; Kowal and Kassam, 1978 and Dudal and Deckers, 1993). According to Balasubramanian and Nnadi (1980) crop residues of leguminous plants are richer in all nutrients than cereal crop residues. This implies that even though the control plot had some weeds that could contribute to SOM, they were of low quality compared to the legumes. Differences among the treatments were not significant when pH was measured at 15-30cm depth in both seasons. This shows that the legumes only made an impact on the soil pH on the top soil.

The top soil organic carbon increased significantly with the incorporation of legumes in comparison with the control treatment. According to Watson and Goldsworthy (1964), Lal and Okigbo (1990), properly managed planted fallows composed mainly of leguminous species are more efficient and requires less time in restoring soil fertility/productivity than natural fallows. One of the major things that these planted

fallows add to the soil is the SOM which inturn affects many other soil properties. Many workers have reported increases in soil organic matter by the incorporation of forage legumes (IITA 1985; Francis *et al.*, 1986; Prinz, 1986; Hullugale, 1988 and Bin, 1983). There were significant differences among the legume treatments in both seasons. This may be due to the C:N ratio of the materials incorporated. The C:N ratio provides an indication of how rapidly a material is likely to be decomposed. Plant residues with high C:N ratio (>30:1) are likely to decompose slowly, whereas residues with lower C:N ratio are likely to decompose more rapidly, hence low SOM content. There were no signficant differences among the treatments at 15-30 cm depth. This still confirms that the impact of the legumes were felt at the top soil 0-15cm.

There were increases in the soil contents of exchangeable cations and CEC after the years of cropping. In most cases the control treatment gave lower values. Inputs of organic material have been reported to enhance nutrient balance as well as serving as a nutrient reservoir by raising the CEC, recycling of nutrients from subsoils, thereby supplying N, P and other elements (Bache and Heathcote, 1969; Lal and Kang, 1982). Also the higher CEC by legume incorporation is expected as increase in organic material has been reported to raised soil CEC. (Nye and Greenland, 1960; Nye, 1963; Hawkins and Brunt, 1965; and Juo and Lal, 1977). The CEC values of

second season of cultivation were higher than that of the first season. ICAR (1964) reported a similar result, that the impact created by OM in the soil could be enjoyed by the third crop in the rotation.

CHAPTER SIX

6.0. SUMMARY AND CONCLUSION

The emphasis of this study was to ascertain an integrated management approach which requires a combination of low chemical inputs and organic matter that may offer a good opportunity for the poor resource farmer to maintain yields at reasonable and sustainable levels. To accomplish this, Greenhouse and Field studies were conducted to evaluate the effect of legume incorporation in improving soil properties and the performance of maize in the Northern Guinea Savanna zone of Nigeria.

In the Greenhouse, foliage residues of six legumes (CP, CR, CC, CB, SH and LE) and MZ stover were incorporated into pots at two levels of 2.5 and 5.0 tha^{-1}. A control of no amendment was maintained. The design was a randomized complete block design, replicated three times. The materials were incubated for two weeks and maize variety, Oba Super II was planted. In the field, two experiments were conducted. In the first experiment five promising legume species selected from a previous study where ten legume species were screened for two years in a randomized complete block design replicated three times were incorporated manually using the hoe. This experiment was conducted for two years. In the second experiment, six promising legume species selected in a one

year screening trial in which 17 legumes species were also incorporated manually by hoeing after the one year of growth. This field was cropped for one year. The major difference between the first and second experiments therefore is the length of growth of the legumes before incorporation. Maize variety, DMR-LSR-W was planted in both fields.

Results from the Greenhouse studies showed that legume incorporation generally increased shoot DMY. For the pots that received 2.5 tha^{-1} CP gave the highest yield, while at 5.0 tha^{-1}, CR gave the highest yield. The slight differences observed among treatments is attributed to the differences on the quality of the legume species. Similar result where the maize height was positively influenced by legume incorporation was observed. Residue incorporation generally affected nutrient contents of maize shoot. The values of these nutrients were consistently higher in plants that received the legume residues than the control. The elemental contents of maize tissue at 5.0 tha^{-1} were generally higher than at 2.5 tha^{-1}. The incorporation of residues increased soil organic carbon than the control treatment. Among the legume treatments differences in soil organic carbon was observed and it was attributed to the quality of the materials incorporated. The application rate of 5.0 tha^{-1} gave higher soil organic carbon content than the 2.5 tha^{-1} rates. Soil pH was highest in pots that received LE_1 and LE_2. Generally residue incorpo-

ration increased the pH of soil in all treatments.

Maize grain yield and yield related parameters were significantly higher with the incorporation of legumes than the control after one and two year of growth. Incorporation after one year of growth yielded higher than the control by upto 0.18-0.61 tha^{-1} (38.3 - 129.8%) depending on the legume. Where incorporation was after two years of growth, yields were higher than the control by 0.13-1.03 tha^{-1} (15.5 to 122.6%) and 0.16-1.30tha^{-1} (11.7-51.1%) for 1995 and 1996 seasons respectively. With pooled data legumes incorporation gave 0.14 - 0.83 tha^{-1} (12.6 - 74.8%) yield increase over the control. Interaction effects with the pooled data showed that incorporation of CP after two years of growth with an additional input of chemical fertilizer at 40$kgNha^{-1}$ as urea gave grain yields comparable to when 80 and 120kg Nha^{-1} were applied. A similar result was observed with one year growth of CR, at 40 $kgNha^{-1}$ gave maize grain yield which were close to the recommended dose of 120 $kgNha^{-1}$.

Among the legume treatments CP and CB after two years of growth gave higher grain yield in both seasons than the other treatments, while the incorporation of CR after one year of growth gave significantly higher grain yield than the other treatments. Legume incorporation after two years of growth gave higher grain yield than where incorporation was after one

year of growth. The pooled data grain yield for the first experiment was compared with the second experiment, the result showed that there were more than 100% grain yield increase of the first experiment over the second experiment. Yield increases in the second year of cropping in the first experiment ranged from 0.14-0.65tha^{-1} higher than in the first year indicating strong residual effect.

Grain yield and yield related parameters significantly responded to N fertilizer in the two experiments. Nutrient contents of both stover and earleaf were not affected by treatments. However, increased application of N fertilizer tended to increase the stover and ear leaf concentrations of N, K, Ca and Mg.

Soil pH was observed to decrease with increase in soil depth and at the second season of cultivation. Incorporation of legume increased top SOM significantly. Exchangeable cations and CEC were increased by the legume treatments. Values were generally higher than the control.

CONCLUSIONS

1. Incorporating some legume species into the soil after one or two years of growth can considerably reduce the amount of N fertilizer required by a cereal crop. *Centrosema*

pascuorum and CR for example, on incorporation with the addition of 40kgNha^{-1} could give grain yields as much as when 120kgNha^{-1} which is the recommended rate of N for maize.

2. Legume incorporation generally improves soil pH, SOM, exchangeable Cations and CEC.
3. Legume species when incorporated into the soil could have strong residual effect depending on the stage of growth before incorporation.
4. It may be more beneficial to incorporate some legume species after two years of growth.
5. Even though these conclusions can be drawn from this study, the problem might be that of adoption by farmers as these legumes do not give immediate food grain benefit like the grain legumes for example cowpea, soyabean and lablab.

The fallow legumes and food crops have to be intercropped, either simultaneously or in a relay pattern to improve the productivity of land without loosing a season for food crop cultivation.

FURTHER RESEARCH

Further research can focus on these grain legumes in addition to the forage legumes especially in livestock/crop farming system.

REFERENCES

Acquaye, D.K. (1973). Some Problems in the Use of West African Soils. In Factors of Agricultural Growth in West Africa (ed) Ofori, I.M. Inst. of Statistical, Social and Economic Research, University of Ghana, Legon

Agboola, S.A. (1979). An Agricultural Atlas of Nigeria. Oxford University Press London.

Ahn, P.M. (1974). West African Soils. Oxford University Press, London.

Anon, (1989). Promoting Environmentally Sustainable Development. World Farmers Times 7 (87): 10 - 12.

Awujoola, A.T. (1979). Soil Mapping and Soil Characterized Studies in the Zaria Area. M.Sc. Thesis Ahmadu Bello University, Zaria, Nigeria. 150 pp.

Bache, B.W. and Heathcote, R.G. (1969). Long-term Effects of Fertilizers and Manure on Soil and Leaves of Cotton in Nigeria: Experimental Agriculture 5: 241 - 247.

Balasubramanian, V. and L.A. Nnadi (1980). Crop Residue Management and Soil Conservation in Savanna Areas. In FAO Soil Bulletin No 43, Rome - 15.

Balasubramanian, V. and L. Sekayange (1992). Five Years of Research on Improved Fallow in the Semi arid High lands of Rwanda. In Biological N Fixation and Sustainability of Tropical Agriculture (Eds) Mulongoy, K.M. Gueye and D.S.C. Spencer.

Bartholomew, W. (1965). Mineralization and immobilization of N in the Decomposition of Plant and Animal Residues. In, Soil Nitrogen, (eds) W.V. Bartholomew and F.E. Clark. Am. Soc. of Agron. Madison, Wisconsin pp 285 - 306.

Berger, J. (1962). Maize Production and the Manuring of Maize. Centre Detude De L'azote, Geneva.

Bin, J. (1983). Utilization of Green Manure for Raising Soil Fertility in China. Soil Sci. Vol. 135 No. 135 - 137.

Bremner, J.M. (1965). Total Nitrogen. In, C.A. Black (ed) Methods of Soil Analysis Part II. Chemical and Microbiological Properties. A M Soc. of Agron Madison Wisconsin. 1149 1178.

Cambell, C.A (1978). Soil Organic Carbon, Nitrogen and Fertility. In, Soil Organic Matter, (ed) Schnitzer,M. and Khan, S.U. Elsevier Scientific Publishing Company, The Netherlands pp 173 - 265.

Carsky, R.J. (1996). Agronomic Research in the Guinea savanna of Northern Nigeria, 1995 result of moist savanna programme of IITA.

Chiyenda, S.S. and Materechera, S.A. (1987). Effect of incorporating prunning of Leuceana leucocephala, cassia siamea and Cajanus cajan on yield of maize in alley cropping system. In: Nutrient management for food crop production in Tropical Farming Systems. IB (Institute for Soil, fertility) Haren, the Netherlands.

Cobbina, J. (1992). Herbage Yield and Soil Fertility Restoration Potential of Some Tropical Forage Legumes. In, Biological N Fixation and Sustainability of Tropical Agriculture, (Eds) Mulongoy, K., M. Gueye and D.S.C. Spencer. A Wiley-Sayce Co-publication.

Dahiya, S.S. and Singh, R. (1980). Effect of Farm Yard Manure and $CaCO_3$ on the Dry Matter Yield and Nutrient Uptake by Oats (Avena Sativa) Plant and Soil 56:391 - 402.

Day, P.R. (1965). Hydrometer Method of Particle Size Analysis Part II. In, C.A. Black (ed) Methods of Soil Analysis, Chemical and Microbiological Properties. AM. Soc. of Agron. Madison, Wisconsin.

Dennison, E.B. (1961). The Value of Farm Yard Manure in Maintaining Fertility in Northern Nigeria. Emp. J. Expl. Agric. 29: 330 -336.

DeRidder, N. and Van Keulen, H. (1990). Some Aspects of the Role of Organic Matter in Sustainable Intensified Arable Farming Systems in the West African Semi-arid Tropics (SAT) Fertilizer Research 26: 299 - 310.

Derpsch, R; Sidiras, N. and Roth, C.H. (1986). Results of Studies Made from 1977 to 84 to Control Erosion by Cover Crops and No-tillage Techniques in Parana, Brazil. Soil and Tillage Res. 8:253 - 263.

Dudal, R. and Deckers, J. (1993). Soil Organic Matter in Relation to Soil Productivity. In, Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture, Edited by Mulongoy, K and Merck, R. pp. 377 - 380.

Dunham, R.J. (1976). The Significance of Crop Residues to the Maintenance of Fertility Under Continous Cultivation at Samaru, Nigeria. J. Agric. Sc. Camb. 86: 117 - 125.

FAO (1974). Organic Materials as Fertilizer. Soil Bulletin No. 27. Rome, Italy. FAO.

Fauck, R. (1963). The Sub-group of leached Ferruginous Tropical Soils with Concretions. Afr. Soils, 8, 408 - 429.

Flaig, W. Nagar, B. Schtig, H; and Tietjen, C. (1977). Organic Materials and Soil Productivity. Soil Bulletin No. 35 Rome, Italy. FAO.

Francis, C.A. Harwood, R.R. and Parr, J.E. (1986). The Potential of Regenerative Agriculture in the Developing World. Amer. J. Alter. Agric. 1: 65 - 73.

Garner, H.V. (1952). Manures and Fertilizers. Bulletin No. 36 Her Majesty's Stationery Office. London.

Giller, K.E. and Wilson, K.J. (1991). Nitrogen Fixation in Tropical Cropping Systems. CAB International, Wallingford U.K.

Goldsworthy, P.R. (1967b). Responses of Cereals to Fertilizer in Northern Nigeria. Maize II Experimental Agric. 3: 263 - 273.

Hariah, K and Van Noordwijk, M. (1989). Root distribution of leguminous cover crops in the humid tropics and effects on a subsequent maize crop. In: Vander Heide, J (ed.) Nutrient management for food crop production in tropical farming systems. Institute for Soil Fertility, Haren, The Netherlands. pp. 157-170.

Haque, I. (1992). Use of legume biological N fixation in Crop/livestock production systems. In: Biological N fixation and sustainability of Tropical Agriculture (eds.) Mulongoy, K., M. Gueye and D.S.C. Spencer. A Wiley-Sayce Co-publication. pp. 423-437.

Hawkins, P and Brunt, M. (1965). The soil and ecology of West Cameroon Vol. 1 . F.A.O.

Heathcote, R.G. (1972). The effect of Potassium and trace elements on yield in northern Nigeria. Afr. Soils, 17: 85-89.

Heathcote, R.G. and Fowler, A.M. (1977). Molybdenum deficiency in g/nuts in Northern Nigeria. Samaru Misc. paper, I.A.R., Samaru.

Heichel, G.H. and Barnes, D.K. (1984). Opportunities for meeting crop N needs for symbiotic nitrogen fixation. IN: Bezdicek, D.E.; Power, J.F. Keeney, D.R. and Wright, M.J (eds). Organic farming: Current Technology and its role in a sustainable Agric. special publication No. 46 Madison, Wisconsin, U.S.A. ASA.

Henzell, E.F. and Vallis, I. (1977). Transfer of Nitrogen between legumes and other crops,. In: Biol. N Fixation in farming systems of the tropics, edited by Ayanaba, A. and Dart, P.J. pp. 73-88.

Herrmann, O.W. (1968). Soil fertility in the tropics. A research proposal (consortium for the study of Nigerian Rural Devt. No. 12, East Lansing).

Hullugale, N.R. (1988). Effect of cover crop on soil physical and chemical properties of an Alfisol in the Sudan savanna of Burkina Faso. Arid Soil Res. and Rehabilitation 2: 251-67.

ICAR (1964). Handbook of manures and fertilizers. Indian Council of Agricultural Research. New Delhi.

IITA (1985). Control of Imperata cylindrica. In: IITA Annual Report for 1984. Ibadan Nigeria: IITA.

IITA (1989). Sustainable crop and livestock production for Rwanda. Final report of the first phase (1983-1988) of the Farming Systems Research Project of the Institut des Sciences Agronomiques du Rwanda (ISAR) Rubona, Rwanda. Ibadan, Nigeria : IITA.

ILCA (1987). Annual Report. Addis Ababa, Ethiopia. ILCA.

IRA (1988). National Cereal Research and Extension project Annual Report 1988. Yaounde, Cameroon: IRA.

Iwuafor, E.N.O. (1986). The effect of tillage and crop residue management practices on soil properties and crop performance in the Southern Guinea zone of Nigeria, Unpublished Ph.D thesis. ABU, Zaria.

Jenkinson, D.S. and A. Ayanaba (1977). Deccomposition of C-14 Labelled plant material under tropical conditions. SSSAJ 41: 912-915.

Jones, M.J. (1971). The Maintenance of soil organic matter under continous cultivation at Samaru, Nigeria. J. Agric. Sci., Cambridge, 77, 473-82.

Jones, M.J. (1976). The significance of crop residues to the maintenance of fertility under continuous cultivation at Samaru, Nigeria. J. Agric. Sci. Camb. 86:117-125

Jones, M.J. and Wild, A. (1975). Soils of the West African Savanna Tech. Comm. No. 55. CAB, Harpenden.

Juo, A.S.R. (1979). Selected methods for soil and plant analysis. IITA manual series. No. 1, Ibadan, Nigeria.

Juo, A.S.R. and R. Lal (1977). The effect of fallow and continous cultivation on physical and chemical properties of an Alfisol in Western Nigeria Plant and Soil 47: 507-584.

Kang, B.T. (1993). Changes in soil chemical properties and crop performance with continous cropping on the Entisol in the humid tropics. In: soil organic matter dynamics and sustainability of tropical Agriculture Edited by Mulongoy, K. and Merck, R. pp. 297-306.

Karikari, S.K. and J.Y. Yayock (1987). Organic fertilizer sources in Nigeria. In: Towards efficiency of fertilizer use and development in Nigeria. Proc. of the National Fertilizer seminar, held in P/Harcourt, Oct. 28 - 30, 1987. pp. 65-85.

Keya, S.O. (1978). Soil management with respect to liming, manuring and other soil amendments. Improved use of plant nutrients. FAO soils Bulletin No. 37 Rome, Italy. FAO.

Klinkiberg, K. and Higgins, G.M. (1968). An outline of northern Nigeria soils. Nigerian Journal of Science 2: 91-115.

Kowal, J.M. (1972). Radiation and potential crop production in Samaru, Nigeria. Savanna Vol. 1, pp. 89-101.

Kowal, J.M. and Kassam, A.H. (1978). Agricultural Ecology of savanna. A study of West Africa. Oxford University Press. London.

Kowal, J. and Knabe, D.T. (1972). An agroclimatological Atlas of Northern Nigeria with explanatory notes ABU, Press. 114-115.

Lal, R. (1979). No tillage effects on soil properties under different crops in Nigeria. Soil Science Soc. of Amer. Journal 40: 762-768.

Lal, R. and Kang, B.T. (1982). Management of organic matter in soils of the tropics and sub-tropics. In: Transanction of 12th International Congress of soil sci. New Delhi, India Feb. 1982: Symposia paper 1: Non-symbiotic N fixation and organic matter in the tropics , New Delhi india: In Soc Sci. Indian Agric. Res. Inst.

Lal, R. and B. Okigbo (1990). Assessment of soil degradation in the Southern states of Nigeria. The World bank sector policy and Research staff environment working paper. No. 39.

Lombin, G. (1987). Fertilizer requirement of the major cereal crops in the Nigerian savanna. In: Towards efficiency of fertilizer use and devt. in Nigeria. Proc. of the national Fert. Sem. Held at P/Harcourt, Oct. 28-30 1987. pp. 106-126.

Lombin, G. and Abdullahi, A. (1977) Longterm fertility studies at Samaru, Nigeria . II Effect of farm Yard Manure on the monocropped cotton, sorghum and g/nut under continous cultivation. Samaru Misc.Paper Series No. 72.

Lombin, G; Singh, L. and J.Y. Yayock (1985). A decade of fertilizer research and g/nuts (Arachis hypogea L.) in the savanna zone of Nigeria. Fertilizer Research Vol. 6: 157-170.

Lombin, G. and V.O. Chude (1991). A review of soil fertility /fertilizer research in North West Zone (Kaduna, Kano, Katsina and Sokoto States) of Nigeria commission by FPDD, Lagos.

Mchtosh, J.L. andd Varney, K.E. (1972). Accumulative effects of manure and N on continuos corn and clay soil I. Growth, yield and Nutrient uptake of corn. Agron. Journal 64: 374-379.

McLean, J. (1965). Soil pH measurement. In Black, C.A. (ed) (1965) Methods of soil analysis. Agronomy No. 9 Part 2. Amer. Soc. Agron, Madison, Wisconsin.

Moore, A.W. (1974). Availability of Rhodes grass Chloris gayana of Nitrogen in taps and roots added to soil. Soil Biol. Biochem. 6: 249 - 255.

Mulongoy, L. Kunda, K.N. and Chiang, C.N.K. (1993). Effect of alley cropping and fallowing on some soil fertility parameters in Southern Nigeria. In: Soil Organic matter dynamics and sustainability of tropical agriculture, edited by Mulongoy, K. and Merck, R. IITA/KU pp.

NAS (1979). Tropical Legumes. Resources for the future. washington DC, USA. National Academy Press.

Ngiumbo, K.A.B. and V. Balasubramanian (1992). Effect of fallow and residue management practices on biomass production, weed suppression and soil productivity. In: Biol. N fixation and sustainability of tropical agriculture (eds). Mulongoy, K.; M. Gueye and D.S.C. Spencer. A Wiley-sayce Co-publication.

Nnadi, L.A. and Haque, I. (1988). Forage legumes in African crop-livestock production systems. ILCA Bulletin 30:10-19.

Nnadi, L.A.; L. Singh and V. Balasubramanian (1981). Effect of grain legumes and sorghum on soil nitrogen status and the yield of subsequent maize crop. Samaru J. of Agric. Res. Vol. 1 No. 2: 183-190.

Nye, P.H. (1963). Soil analysis and the assessment of fertility in tropical soils. J.Sci. Food Agric. 14: 277-280.

Nye, P.H. and Greenland, D.J. (1960). The soil undershifting cultivation. Tech. Comm. No. 51 commonwealth Bureau of soils, Harpenden.

Okigbo, B. (1977). Legumes establishment in the tropics. In: FAO Soils bulletin No. 43. pp. 245-246.

Ologunde, O.O. and Obilana, O. (1982), Maize production in the savanna zone of Northern Nigeria. Factors which affect grain yield. A lecture delivered at the Rice and maize production training course at Dan Hazzan, Kano State, Nov. 1982.

Parker, C.A. and D.T.Chatel (1982). factors determining success or failure in legume establishment. In: Vincent, J.M. (ed) Nitrogen fixation in legumes. Based on Proc. of an International Seminar by the Australian Dev. Assistance Bureau and the University of Sydney. Academy

press. Australia.

Parker, D.T.; Larson, W.E. and Bartholomey, W.V. (1957). Studies on N tie-up as influenced by location of plant residues in soils. Proc. Soil Sci. Soc. Am. 21: 608-612.

Parr, J.F. and Papendick, R.I. (1978). Factors affecting the decomposition of crop residues by microorganisms. In: Crop residue management systems, edited by Oschwald, W.R. Am. Soc. of Agron., Crop Sci. Soc. of Am., Soil Sci. Soc. of Am., Madison, Wisconsin.

Pichot, J. (1971) Stude de l'evolution du sol en presence de faure organique on minerals cinaqannees d'experimentation a la station de Boukoko. RCA Agronomic Tropicale 26: 736-754.

Prinz, D. (1986). Increasing the productivity of small holder farming systems by introduction of planted fallows. Plant and Res. Devt. 24: 31-56.

Prothero, R.M. (1962). Some observations and dessication in North-western Nigeria. Erdkunde, 16:111-119.

Simpson, J.R.;.Karanja, D.R.; Ikombo, B.M.; Keating, B.A. (1992). Effects of legumes in a cropping rotation on an infertile soil in Machakos District, Kenya. In: ACIAR Canberra, Australia. A search for strategies for sustainable dryland cropping in semi-arid eastern kenya. ACIAR Proceedings No. 41:44-49.

Singh, A. and B. Lal (1976). Organic matter in soils and its maintenance. In: Soil fertility theory and practice (ed) Kanwar, J.S. ICAR. New Delhi pp. 128-155.

Singh, R. and Dahiya, S.S. (1980). Effect of farm yard and iron on dry matter yield and nutrients uptake by oats (Avene sativa) Plant and soil 56: 403-412.

Smith, F.W. (1982). Mineral nutrition of legumes. In: Vincent, J.M. (ed). Nitrogen fixation in legumes. Based on procs. of an International seminar by the Australian Dev. Assistance Bureau and the Univ. Sydney. Academic press. Australia.

Sorensen, L.H. (1972). Stabilization of newly formed amino acid metabolites in soil by clay minerals. Soil Sci. 114: 5-11.

Sorensen, L.H. (1975). The influence of clay on the rate of decay of Amino acid metabolite synthesized in soils during decomposition of cellulose. Soil Biol. Biochem 7: 171-177.

Stockinger, K.R. (1966). Fertility studies on maize. In: third annual report of the AID-ARS Project on major cereals of Africa OAU/STRC. J.P. 26

Vander Heider, J. and Hariah, J. (1989). The role of green manure in rainfed farming systems in the humid tropics. ILEA, 5: 11-13.

Vanschreven, D.A. (1968). Mineralization of the carbon and nitrogen of plant material added to soil and of the soil humus during incubation following periodic drying and rewetting of the soil. Plant and Soil, 28: 226-245.

Vine, H. (1953). Experiments on the maintenance of soil fertility at Ibadan, Nigeria. Emp. J. of Agric. 21: 65-85.

Wade, M.K. and Sanchez, P.A. (1983). Mulching and green manure applications for continous crop production in the Amazon basin. Agron. J. 75: 39-45.

Watson, K.A. and Goldsworthy, P.R. (1964). Soil fertility investigations in the middle Belt of Nigeria. Emp. J. Expl. Agric. 32: 290-302.

William, E.J. (1992). Nitrogen fertilizer and dairy manure effects on corn yield and soil nitrate. J. of soil Sci. Soc. of Am. 56(1) 148-154.