EFFECT OF INCREASED INTIMACY BETWEEN MAIZE AND BEANS IN AN INTERCROP SYSTEM ON GROWTH AND YIELD OF MAIZE UNDER VARYING NITROGEN LEVELS.

by

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

Date 29/1/93

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This thesis has been submitted for examination with my approval as the University supervisor

Date 30/1/93

Dr. J.O. Nyabundi

DEDICATION

To my beloved father, the late Mzee Francis Ndiema Chemorion, who took a keen interest in my academic work.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE

TABLE

TABLE

TABLE

LIST OF APPENDICES

APPENDIX

APPENDIX

APPENDIX

APPENDIX

LIST OF FIGURES

FIGURE

Abstract

Field experiments were conducted at the University of Nairobi's Faculty of Agriculture farm to investigate the merits of increasing the proximity between maize and bean plants in an intercrop system and how N-fertilizer levels influence this interspecific interaction. Four planting patterns and four nitrogen levels were tested in a factorial experiment and laid out in a completely randomised block design with three replicates. The planting patterns consisted of sole maize, maize and beans intercropped in alternate rows, maize and beans intercropped as alternating plants in the same row and maize and beans intercropped in the same hill. The N levels were 0, 50, 100 and 150 Kg N/ha. Maize variety Embu 512 and bean variety GLP-2 were used. Plants were sampled bi-weekly during the growing season to determine dry matter weight and leaf area. At the end of the vegetative cycle, yield and yield components were also measured.

Results showed that at 15 and 19 WAE in the first season and at 19 WAE in the second season, maize intercropped with beans in alternate rows had statistically inferior dry matter compared to maize sown in the rest of the patterns, whose dry matter yields were statistically similar. Dry matter of maize plants significantly increased with N application at all sampling times. Dry matter of bean plants was not significantly affected by the planting patterns, but N application significantly increased this parameter. Planting patterns had no significant effect on Leaf area indices of both maize and bean plants, but this parameter was significantly increased with N application in maize plants.

Planting patterns and nitrogen application had a significant effect on maize grain yield in both seasons. The

interaction between the planting patterns and N levels was significant in the first season. At 0 and 50 Kg N/ha, maize intercropped with beans in the same hole significantly out-yielded maize sown in the rest of the patterns; whereas sole maize and maize intercropped with beans in the same row, whose yields were statistically similar, gave significantly higher grain yield than maize intercropped with beans in alternate rows. At 100 and 150 Kg N/ha, sole maize had grain yield that was non-significantly higher than those of maize intercropped with beans in the same row or same hole, but statistically higher than that of maize intercropped with beans in alternate rows. In the second season, at all N levels, there were no significant differences among the planting patterns except at 0 and 50 Kg N/ha where maize intercropped with beans in the same hole significantly out-performed maize intercropped with beans in alternate rows. Maize intercropped with beans in the same hole did not significantly respond to application of more than 50 Kg N/ha whereas maize sown in the rest of the patterns did not significantly respond to application of above 100 Kg N/ha. Both planting patterns and N levels had a significant effect on the number of kernels per cob-row, 100-kernel weight and cob-length, but had no effect on the number of rows per cob. Planting patterns had no significant effect on bean yields, but N application significantly increased this parameter.

Based on these results, it was concluded that increased intimacy between maize and bean plants in an intercrop system increased maize yields only under low N levels.

CHAPTER ONE:

1.0 INTRODUCTION

1.1 Merits of Intercropping

Recent world food shortages and prospects of inadequate supplies in future have prompted accelerated interest in methods for increasing food production. This is particularly the case in developing countries where the demand for food and agricultural products is expected to double in the year 2000, with crops expected to provide 77% of the food requirements (FAO, 1981).

Food scarcity often observed in many developing countries has led to the common belief that traditional food production systems of the tropics are inefficient. However, studies on the productivity of traditional tropical systems have shown that in terms of energy return, these systems are more efficient than some mechanised systems of the temperate regions (Cox, 1975). Other studies (Andrews, 1972; Fisher, 1976; Osiru and Willey, 1972; Nadar, 1984) have also shown that mixed cropping is usually more productive than pure cropping in the tropics.

With the decline in farm size as a result of population pressure in most developing countries, the most likely method of increasing crop output is by increasing yields from each unit of land harvested by intensification of production. One of the oldest and commonest method of intensification of production in most parts of Africa is by mixed cropping or intercropping where two or more crops are grown at the same time on the same area of land (Finlay, 1975). Farmers, therefore, manage more than one crop at a time in the same field so that crop intensification is in both time and space dimensions (Andrews and Kassam, 1976). Depending on local agroclimatic variation, 50 to 80% of rainfed crops are planted as intercrops in different parts of the developing countries (Aiyer, 1949; Mathur, 1963; Jodha, 1977).

A number of reasons have been advanced for the superiority of intercropping. They include:

i. Where legumes are grown with grasses, the grasses may benefit from the nitrogen fixed by the companion legume (Agboola and Fayemi, 1972; Trenbath, 1974).

ii. Provision of varied foods over several months with balanced nutrition (Finlay, 1975; Narang *et al.*, 1969).

iii. Greater as well as more even spread of employment (Mathur, 1963; Baker, 1975; Andrews and Kassam, 1976).

iV. Minimization of risk against insects, diseases, weather and price fluctuations (Aiyer, 1949; Anon, 1960; Mukiibi, 1976).

V. Protection of soil from water and wind erosion and direct sunlight (Finlay, 1975; Narang *et al*, 1969).

Vi. Better utilization of the environmental resources by plants of different root systems, nutrient requirements, heights, etc. (Andrews, 1972; Willey, 1979; Willey and Osiru, 1972). The practice of mixed cropping or intercropping thus reflects the traditional wisdom of the subsistence farmers as applied to their cropping decisions.

1.2 The case of Intercropping maize and beans.

In the past, because researchers had little interest in intercropping, little research on intercropping was carried out in Africa. Intercropping was considered a primitive practice that would give way to sole cropping in the course of agricultural development (Willey, 1979). However, in recent times, there has been accelerated interest in intercropping because of the reluctance of most African farmers to adopt technology of food production systems based on sole cropping borrowed from the temperate large scale practices. The Kenyan small scale farmers are no exception. They have persistently grown their food crops mixed and the practice has even spread to the large scale farms and into the cash crops that were grown strictly as sole crops. As in most African countries, intercropping often involves a cereal and a legume, with the cereal being considered as the main crop. This is mainly because, in most cases, the cereal is the main food source and its yield is much higher than that of the legume (Willey, 1979).

Maize (*Zea mays* L.) is the most important cereal crop in both high and medium potential areas of Kenya (Chui, 1987), and 70-90% of the total maize production comes from small scale farms ranging in size from 0.2 to 0.8 ha (Ackello and Odhiambo, 1986). With the current rate of population growth estimated at 3.7% per annum (Anon, 1989), an annual maize production growth rate of 4.7% would be required to meet the demand for maize in the year 2,000 (Anon, 1986c). However, farmers' yields are low with an average of 1.9 tonnes per ha due to rainfall fluctuations, low soil fertility and poor crop husbandry (Onyango, 1987). This underscores the need to improve production especially in small scale farms through, among other things, improved intercropping systems and fertilizer use practices.

In Kenya, common bean (*Phaseolus vulgaris* L.) is the most important pulse crop in the medium and high potential areas (Keya *et al.*, 1979), and as a food crop, it is second only to maize in acreage (Schonherr and Mbugua, 1976). Common bean is found grown in mixtures with food and cash crops such as maize, sorghum, pigeon peas, cassava, coffee and cotton. However, it is grown mostly in mixtures with maize (Schonherr and Mbugua, 1976), which has been found to greatly reduce its yields to as low as 32% of the sole crop (Chui and Nadar, 1984). Maize-bean mixtures are found in all small scale areas at medium altitude which include western, central and eastern parts of Kenya. Dry beans consist of 22% protein and is rich in amino acids tryptophan and lysine (Purseglove, 1968) and therefore plays an important role as a potential source of low cost, readily available protein. Cereal-legume (bean) mixtures contain proteins of superior nutritive value as they mutually supplement amino acids as compared with those of either cereal or legume proteins alone. Grain legumes become more important in those vegetarian diets that depend primarily on cereals and root crops.

1.3 Justification of This Study

Of all nutrients, nitrogen is perhaps the most important nutrient requirement for maize production. Unfortunately, commercial nitrogen fertilizers are very expensive and out of reach of most small scale farmers. Alternative sources of nitrogen, therefore, need to be sought.

Use of legumes such as beans in intercropping systems can serve as N source which is within the reach of most small scale farmers. Documented evidence indicates that tropical legumes are capable of excreting nitrogen during growth (Agboola and Fayemi, 1972) or releasing it during decomposition of decaying roots and nodules (Janny and Kletter, 1965; De, 1980; Poth *et al.*, 1986). Nitrogen needs of a cereal intercropped with legumes were reported to be less than for sole cropping due to transfer of some of the fixed nitrogen by the legume to the associated cereal during the growing season (Willey, 1979). To exploit this alleged beneficial effect of legumes, the best spatial arrangement of intercrops need to be investigated since the spatial arrangement is one of the major factors influencing the performance of intercrops through its effects on edaphic interactions and light penetrations into the canopies of both shorter and taller components. Hence, a relevant question is how intimate intercrops should be (Willey, 1979). Studies by Chui and Nadar (1984) showed that the beneficial effects of beans on maize in an intercrop system was positively associated with the spatial arrangements. In their study, they observed that intercropping maize and beans in the same hole had higher maize yields than intercropping maize and beans in the same row which in turn out-yielded intercropping maize and beans in alternate rows. However, this study did not consider the influence of nitrogen levels on the observed legume benefits and therefore did not establish whether the benefits were due to nitrogen made available to the companion cereal crop or other factors. A clear demonstration of the existence of interaction between the spatial arrangements of intercrops and nitrogen fertilizers may help in rationalization of N-fertilizer rates.

This study was conceived with the following objectives:

1. to investigate the effect of increased proximity between maize and beans in an intercrop system on maize growth and yield.
2. to examine the interaction between applied nitrogen fertilizer and interspecific proximity between maize and beans in an intercrop system.

CHAPTER TWO:

2.0 LITERATURE REVIEW

2.1 Effect of Intercropping on Growth and Yield of Intercrops.

Cereal-legume intercrop performance has received considerable attention from several workers. Whereas most studies have shown substantial yield advantages of intercropping (Ahmed and Rao, 1982), there have been cases with no worthwhile advantage (Crookston and Hill, 1979; Wahua and Miller, 1978).

Studies on cereal/bean mixtures have been well described in literature. Willey and Osiru (1972) observed that maize/bean intercropping was 38% more productive than sole cropping in Uganda. The higher productivity of the intercrop was attributed to better utilization of growth resources, particularly light. In Tanzania, Enyi (1973) found that interplanting beans in sorghum or maize led to reductions in leaf area indices, fresh weight yields at anthesis, straw yield at harvest and grain yields of cereals. He attributed the reduction in maize LAI to the high rate of nutrient absorption by the interplanted beans that coincided with that of cereals. Spurling (1973), however, reported no deleterious effect on maize yield by interplanting beans in maize. Owuor (1977), working in Kenya, concluded that maize/bean mixtures planted early in the season at the same time were highly productive. Hasselbach (1978), working in Thika, Kenya, observed that interplanting of even one row of beans affected maize yield and reduced bean yields by 49% as compared with sole beans. Mafra *et al.* (1981) observed that beans were more competitive than cowpea when intercropped with sorghum or corn and lowered sorghum yields by 56% and that of corn by 32%. Francis *et al.* (1982) in their studies, reported a yield advantage of 30% in the dry season and 39% in the wet season by intercropping maize and beans. Stewart (1982), at Katumani, Kenya, indicated that intercropping of maize and beans is only advantageous when rainfall exceeds 325 mm.

Results at IITA (IBADAN) during 1972-1975 showed that intercropping maize with cowpeas resulted in 15% higher maize yields in 1973 but not in 1974. It was further noted that intercropping maize with cowpeas reduced cowpea branching, nodule weight and seed yield. Nadar and Faught (1984) reported that intercropping maize with cowpeas without nitrogen fertilizer resulted in substantially better returns than from maize alone. From further investigations, Nadar (1984) reported that maize yield in a maize/cowpea intercrop were reduced by 46% to 57%, mainly due to a severe reduction in average ear weight.

In maize/groundnut mixture studies, Edje (1982) noted that groundnut growth vigour and seed yields were significantly reduced when grown in association with maize. However, maize yield and yield components were appreciably not affected. The groundnut LAI was significantly reduced by 50% and that of maize taken at 11 weeks after planting was not significantly affected, being 4.74 for maize monoculture and a mean of 4.06 for maize grown in association. The groundnut variety 'Manipinta' which had the highest yield (2,700 Kg/ha) in monoculture also had the highest yield (600 Kg/ha) when grown in association with maize while 'Malimba' had the lowest yield in both cropping systems, 1,300 and 300 Kg/ha in monoculture and in association, respectively.

Das and Mathew (1980), cited by De (1982), in their study on maize/black gram mixtures, found that the yield of maize intercropped with black gram was 3.67 t/ha compared to 3.13 t/ha from maize grown alone. This increase was equivalent to about 40 Kg N/ha applied to maize. This finding supports the thesis of direct transfer of nitrogen from legumes to cereals in intercropping. In other studies, Singh (1981) observed sorghum yield increases of 20, 17, 27, 34, 12 and 8% when grown in association with green gram, black gram, grain cowpea, fodder cowpea, groundnut and soybean, respectively, under rainfed conditions.

Dalal (1974) studied the association of legumes and non-legumes and found that intercropping maize with pigeon pea in alternate rows significantly reduced the grain yield of maize but not of pigeon peas. Tarhalkar and Rao (1981) reported that intercropping sorghum with long duration pigeon peas caused less reduction in sorghum yield than intercropping with short duration pigeon peas. Natarayan and Willey (1981) observed a significant reduction in pigeon pea LAI when pigeon pea was intercropped with sorghum. They attributed the reduction in LAI to severe competition for moisture suffered by the legume component of the crop. Nadar (1984) reported that pigeon pea growth was considerably reduced, but the pigeon pea plants were able to compensate after the harvest of the intercrop maize and produced yields equivalent to 80%-100% of the sole crop.

In studies on intercropping of sorghum with soybeans, Singh (1977) showed 84% yield increase in sorghum intercropped with soybean as compared with sole crop. Cordera and MacCollumn (1979) observed a 20% increase in total productivity from intercropping maize with soybeans. They attributed the high productivity to the longer leaf area duration of the intercrop system. Makena and Doto (1982) reported significant reduction in number of productive pods per plant, 200 -seed weight and soybean yield as a result of intercropping with cereal crops. Chui and Nadar(1984) observed similar results in maize/soybean intercrops.

2.2 Effect of Planting Patterns on Growth and yield of component crops in intercrops.

It has often been suggested that to get maximum benefits from any complementary effects, crops should be as intimately associated as possible, and there have been reports which have supported this contention (Andrews, 1972; IRRI, 1973). But there also have been reports of no effects (Evans, 1960) and others where increasing intimacy has decreased yield (Pendleton *et al.*, 1963).

Hasselbach and Ndegwa (1982) demonstrated that increasing inter-row distance of maize decreased maize yield; however beans compensated for the loss. Bean yields decreased by 42% compared with best pure stand yield if maize was planted at the recommended inter-row distance (44,000 plants/ha). Maize planted at 125 cm inter-row distance(27,000 maize plants/ha) allowed beans to produce 90% of the best pure stand and was the most promising treatment regarding Land equivalent ratio (LER). Chui and Nadar (1984) studied the effect of spatial arrangements on the yield of maize/bean intercrops and reported that intercropping maize and beans in alternate rows reduced maize yields by 33% mainly due to a decrease in ear weight of 29%. Intercropping maize and beans in the same hole and in alternate holes on the same row without applied nitrogen increased maize yield by 27% and 7%, respectively. Intercropping reduced bean yields by 67% due to reduced plant growth and pod set. They further noted that the association of beans with maize in different spatial arrangements under low fertility conditions indicated that the extent of beneficial effect was positively associated with the proximity of the two intercrops. However, Chui (1988) reported contrasting results.

He observed that intercropping beans and maize in the same row and beans between two maize rows increased total grain yield by 14% and 22% in the first season and by 16% and 29% in the second. Intercropping maize and beans in the same row and a row of beans between two maize rows resulted in a bean reduction of 51 and 56% in one season and 61 and 64% in the other, respectively. He further noted that cropping systems had no significant effect on bean total dry matter (TDM) at 40 days after planting but had a significant one on maize TDM with beans intercropped with maize in the same row providing greater depressive effect on maize TDM than beans intercropped between two maize rows. In studies of intercropping maize or sorghum with soybeans, Singh *et al.* (1973) obtained low yields of soybean when intercropped with maize in narrow rows. The reduction in yield was, however, less when intercropped with maize under wide spaced rows. The maize yields were enhanced by 5 to 12% over monocrop levels (2,800 to 3800 Kg/ha) by intercropping with soybean in alternate single and double rows. Dalal (1977) found that maize yields were reduced by 15 and 17% under 0 and 100 Kg N/ha when intercropped in the same row with soybean, whereas soybean yield reduced by 90 and 75% by intercropping with maize in the same row and in alternate rows. Motha and De (1980) reported that maize yields were not affected by intercropping with soybeans, but sorghum yields were reduced. When a plant population of 65,000 plants per ha was maintained, no significant differences in maize yields occurred whether the rows were 60 or 120 cm apart. May and Misangu (1982) reported that intercropping maize and soybean or cowpea in the same hole resulted in consistently larger grain yields than intercropping in alternate holes on the same row. They suggested that these advantages occurred through stimulation of additional nitrogen by fixation or the creation of a better environment. Nyambo *et al.* (1982) studied the influence of planting combination and planting configurations on three cereals (maize, sorghum, millet) intercropped with two legumes (soybean, green gram) and observed that sole cereal gave higher yields than cereal intercropped with legumes in the same row which in turn out-performed cereal intercropped with legumes in alternate rows.

Mongi *et. al.* (1982) studied the influence of intercropping methods on foliar NPK contents and yields of maize and cowpeas and found no significant differences in grain yield and dry matter between maize intercropped with cowpeas in the same hole and maize intercropped with cowpeas in alternate rows. But intercropping in the same hole significantly increased the N content of maize ear leaves, whereas the foliar P and K contents of maize were not affected by any of the intercropping methods. Nadar (1984) intercropped maize with cowpeas in three spatial arrangements: in the same row 15 cm apart or seeds of both crops planted in the same hole or in alternate rows and reported that maize intercropped with cowpea in the same row gave the highest grain yield followed by maize intercropped with cowpea in the same hole which in turn out-yielded maize intercropped with cowpea in alternate rows. Monocrop maize had higher yields than maize intercropped with cowpea in alternate rows.

Evans (1960) studied the effects of crop arrangements on yield of maize or sorghum intercropped with groundnut and found no significant differences between yields of maize or sorghum intercropped with groundnut whether grown in alternate-row or within-the-row arrangements. In contrast, Bodade (1964) suggested that there was more benefit in mixing crop species in the same row than planting them in the same ratio in adjacent rows. In fact, the author observed more yield advantage when groundnut was intercropped with sorghum in the same row than when intercropped in alternate rows. Osiru and Kibira (1981), however, did not find any significant differences between these arrangements in sorghum/pigeon pea and finger millet/groundnut mixtures.

2.3 Nitrogen Availability, Uptake and Utilization by Plants.

Nitrogen found in the soil is classified as inorganic or organic. The inorganic forms of nitrogen include NH_4^+, NO_3^-, NO_2^-, N_2O, NO and elemental N. However, from the stand point of soil fertility, NH_4^+, NO_3^- and NO_2^- are of great importance. The organic forms of soil nitrogen occur as consolidated amino acids or proteins, free amino acids, amino sugars and other unidentified compounds (Tisdale and Nelson, 1966). Up to 90% of the total nitrogen in soils is estimated to be in organic matter, although in some cases significant amounts exist as NH_4^+ bound to clay colloids (Runge, 1983: cited by Salisbury and Ross, 1986).

Plants absorb most of their nitrogen in the forms of NH_4^+ and NO_3^-. The amounts of these two ions available to the crop roots depend largely on the amounts supplied as commercial nitrogen fertilizer and released from the reserves of the organically bound soil N. Mineralization of organic matter plays an important role in supplying inorganic nitrogen to the crops. The first major step in mineralization is the conversion of organic nitrogen to NH_4^+ by heterotrophic soil microbes in a process known as ammonification. In warm moist soils, with near neutral pH, NH_4^+ is further oxidised by bacteria to NO_3^- within a few days of its formation or its addition as fertilizer in a process known as nitrification. Conversion of NH_4^+ into NO_3^- is a two step process in which ammonia is first converted to nitrite and then to nitrate.

Conversion to nitrite is effected largely by a group of obligate autotrophic bacteria known as *Nitrosomonas*, whereas conversion from nitrite to nitrate is effected by *Nitrobacter* which is also a group of obligate autotrophic bacteria (Tisdale and Nelson, 1966; Salisbury and Ross, 1986).

In many acidic soils or poorly aerated soils, nitrifying bacteria are less abundant or active, so NH_4^+ becomes a more important nitrogen source than NO_3^-. Flora indigenous to such soils encounter little or no NO_3^-. When these species are cultivated they may still exhibit a distinct preference for NH_4^+-N (Pate, 1980) and display a marked intolerance to NO_3^--N (Hansen and Pate, 1987: cited by Pate and Farquhar, 1988). On the other hand, most cultivated soils have their available N in the form of NO_3^- due to the rapid nitrification of ammonia released from decaying organic matter or ammoniacal fertilizer (Black, 1968; Salisbury and Ross, 1986). Many plants utilize NO_3^- and may also utilize NH_4^+, although they suffer various impairments when only ammonium furnishes nitrogen (Black, 1968).

Both NO_3^+ and NH_4^+ are absorbed by inducible, energetically dependent uptake mechanisms (Pate and Atkins, 1983). Whereas NH_4^+ is toxic and hence must be assimilated into organic compounds immediately upon absorption by the root, NO_3^- can enter into the storage pools of root and shoot, or alternatively be reduced at or close to the site of uptake by an inducible nitrate reducing system. In non-photosynthetic tissues, NADH derived from glycolysis, mitochondria dehydrogenases, or the pentose phosphate pathway provides reductant (Abrol *et al.*, 1983); while in the light, NO_3^- may be assimilated at essentially no cost using surplus photosynthetically generated reductant (Smirnoff and Stewart, 1985). Nitrate reduction occurs in two steps, the first being mediated by nitrate reductase and nitrite reductase both nitrate inducible (Jackson, 1978: cited by Franco and Munns, 1982). Once ammonium has been produced it is assimilated *via* glutamine synthetase and glutamate synthase under normal low NH_4^+ concentrations, and possibly *via* glutamase dehydrogenase under high NH_4^+ concentrations (Franco and Munns, 1982).

Nitrogen is a constituent of proteins, purines and many coenzymes and therefore an interference with protein synthesis and hence growth is the major biochemical effect of nitrogen deficiency (Epstein, 1972; Hewitt and Smith, 1974; Mengel and Kirkby, 1979). Lack of nitrogen leads to reduced photosynthesis which in turn causes a nitrogen deficient plant to lack not only amino acids but also the machinery for synthesis of the necessary carbohydrates and carbon skeletons. Plants deprived of nitrogen show decreased cell division, expansion and elongation, prolonged dormancy and therefore, delaying the swelling of buds in some plants (Frank, 1965; Bartholomew and Clark, 1965).

2.4 Nitrogen Fixation by Legumes

Nitrogen fixation is a process by which atmospheric N_2 is reduced to NH_4^+. This process requires a source of electrons, protons and numerous ATP molecules in the presence of nitrogenase enzyme (Salisbury and Ross, 1986). About 15% of the nearly 20,000 species in the leguminosae family have been examined for N-fixation, and approximately 90% of these have root nodules in which N-fixation occurs (Allen and Allen, 1981: cited by Salisbury and Ross, 1986).

Bacteria of the genus *Rhizobium* are responsible for N-fixation in legumes. *Rhizobia* are aerobic bacteria that persist saprophytically in the soil until they infect a root hair or a damaged epidermal cell. After infection, they penetrate the cytoplasm and cause proliferation of tissues and eventually form a mature root nodule containing a non-motile bacterium (bacteroid) within which N-fixation occurs (Hubbell, 1981; Graham, 1984; Salisbury and Ross, 1986).

Variation in ability to fix N_2 in legumes occurs both between and within species. Variations are caused by host controlled traits such as nodule initiation, development and function. Layzell *et al.*, cited by Graham (1982), found cowpeas to expend less energy in nodule maintenance and respiration than lupine, while Sen and Weaver (1980), cited by Graham (1982), found that the specific nodule activity of *Arachis hypogea* nodules was greater than that of cowpeas. Variation in ability to fix N_2 in symbiosis with *Rhizobium* between cultivars of the same species has been demonstrated in clover, soybeans, beans, cowpeas and Vicia (Graham, 1984).

Nitrogen fixation requires a source of photosynthate and energy is also required for development and maintenance of nodules. In fact, recent studies indicate that photosynthate supply is the primary factor limiting N fixation by legumes (Havelka *et al.*, 1982). A number of traits each affect carbohydrate supply to nodules. Among them is time varieties take to flower and mature. Hardy *et al.* (1973), cited by Graham (1984), demonstrated that early flowering soybean lines tended to fix less N_2 than those from later maturity group. This is presumably because of competition between developing pods and nodules (Graham, 1984). N_2 fixation has been significantly enhanced by a photoperiod-induced delay in flowering (Day and Graham (unpublished data), cited by Graham, 1982). Leaf area duration may also be important. Wynne *et al.* (1982), in studies with peanuts, found that 70 to 75% of the variation in nodulation and N_2 fixation found in eight peanut cultivars could be attributed to differences in leaf area duration. In beans, high N_2 fixation were found to be associated with late maturity and climbing habit (Rennie and Kemp, 1983).

Environmental factors which influence N_2 fixation include phosphorus, calcium, potassium, micronutrients, moisture content, temperature and acidity of the soil. P-deficiency is the most important single factor for N_2 fixation and legume production. It has been shown that plants dependent on N_2 require more P than plants using mineral N (Freire, 1984; Cadisch *et al.*, 1989). This need reflects the vital role of P in energy transfer and the large quantities of energy required for reduction of N_2 to NH_4^+ (Salisbury and Ross, 1986). Most legumes dependent on N_2 fixation also have high requirements of Mo, S, Cu, Co, K and Ca (Collins and Duke, 1981; Salisbury and Ross, 1986; Cadisch *et al.*, 1989).

Soil acidity influences N_2 fixation by direct and indirect effects on the bacteria and on the host. Variations occur between species and within species with respect to tolerance to acid soils. *Phaseolus vulgaris*, for example, are adapted to non-acidic or slightly acidic soils of high fertility (Freire, 1984).

Graham and Halliday (1977) reported that soil temperature is the major limiting factor for beans in tropical and subtropical areas.

It has been reported that nitrogenase was inhibited reversibly by moderate deficits of water, but severe water stress caused irreversible damage (Bergersen, 1977). Water stress was found to cause severe inhibition of nitrogenase activity and nodule respiration in *Glycine max*, and a number of other legumes. Recovery of nitrogen fixing ability was found to be dependent on the severity of the stress, but complete recovery was not observed from severely stressed nodules. The degree of recovery was also related to nodule morphology (Sprent, 1976; Sprent, 1981: cited by Venkatswarlu *et al.*, 1990).

2.5 Effect of Nitrogen on Growth and yield of Intercrops

The component crops in an intercropping system have different nutritional requirements and their growth patterns change with time. The fertilizer needs of an intercropped cereal may, therefore, be increased, unaltered, or reduced compared to those of the sole crop depending on the crops involved. In maize/legume intercrop system, for example, maize requires high amounts of nitrogen for good yield (Drysdale, 1965); whereas grain legumes require large quantities of nitrogen but since they satisfy most of their needs by symbiotic N-fixation they have to take up N from the soil in the early stages of their development (Hagin and Turker, 1982).

Kurtz *et al.* (1952) reported that if competition occurs between the maize crop and an intercrop it is primarily for water and nitrogen. They indicated that fertilizer nitrogen reduces the competition between intercrops and maize.

Janny and Kletter (1965) observed that the beneficial effect of intercropping with legumes can either be due to nitrogen excreted by the legume during growth or to N released during decomposition of decaying roots and nodules. They further noted that cereals may benefit indirectly since legumes do not compete with cereals for N owing to variations in their rooting patterns. De (1980) reported that some amount of nitrogen from legume root decay may be taken up by the associated crops during the growing season. However, Henzel and Vathis (1977) did not establish direct evidence of quantitatively significant transfer of nitrogen from legume plants to non-legume while the legume plants were growing actively.

Agboola and Fayemi (1972) showed that tropical legumes are capable of excreting nitrogen during growth and non -legume crop yields were increased when intercropped with a legume compared to yield when monocropped. They observed no response of maize to application of 50 Kg N/ha in maize -legume association. The maize yield was high in both fertilized and unfertilized plots interplanted with legumes whereas maize yields were lower from plots with neither legume nor fertilizer and intercropping with maize reduced legume yield. Willey and Osiru (1972), working with maize/bean mixtures and sorghum/ bean mixtures, found large intercropping advantages with application of 130 Kg N/ha. Valle (1975) in maize/bean mixture studies, reported highest maize yields with application of 46 Kg N/ha whereas in beans the positive effect was noted up to 30 Kg N/ha. Pontoja *et al.* (1978) found that nitrogen was the nutrient that was most affected in maize/bean intercrops. They further observed that nitrogen increased protein content of both plants, and that the best time of applying N was one third at planting and two thirds, 30 days after planting. Cecilia *et al.* (1982) found that maize/bean mixtures responded differently to nitrogen and phosphate fertilizer at two trial sites, but the highest yields were obtained from sowing the two crops along the same row. Uriyo *et al.* (1982), in Tanzania, reported that in acid soils calcium ammonium nitrate fertilizer was the most favoured source of nitrogen for maize/bean mixtures resulting in increases of both intercrops. Faris *et al.* (1983) showed that sorghum/bean intercrop system yielded more grain than the monocrop system, even with application of fertilize

Remison (1978), in maize/cowpea studies, found that the competitive relationships between maize and cowpea in the proportion of 1:1 was unchanged by N or P application. The author further observed that maize responded to N and P when grown alone, but responded to P when grown with cowpea. Ahmed and Gunasema (1979) observed that application of 60 and 120 Kg N/ha depressed yields of cowpea intercropped with maize due to increased competition. In contrast, Kalra and Damla (1979), cited by Davis *et al.* (1986), demonstrated in 173 farms in Nigeria that fertilizer has a beneficial effect on farmers' maize/cowpea and sorghum /cowpea intercrops. Fertilizer gave a higher value- to-cost ratio than any other improved practice. Dancette (1981) found that N-application increased straw yields of sole and mixed crop millet but had no effect on cowpea yield.

In maize/soybean studies, Finlay (1975) reported increased maize yields with application of N and P, but soybean yields did not. Liboon and Harwood (1975) in a similar study found that LER fell from 1.47 at zero N/ha to 1.11 at 120 Kg N/ha. They further noted that nitrogen application of 60 Kg N/ha stopped N-fixation resulting in lower LER values. Chui and Nadar (1984) reported that application of N-fertilizer significantly increased the yield of maize intercropped with soybean by 91 and 40%, and of maize monocrop by 97 and 49% in the two different seasons. They attributed the yield increase to increased ear-weight, 100-kernel weight and harvest index. Intercropped soybean yield was significantly reduced, and they attributed this to reduction in number of leaves, LAI and dry matter accumulation at seed-filling. The largest LER in maize/soybean intercrops where no N was applied was 1.34 and where N was applied it was 1.14.

2.6 Effect of Nitrogen on Growth and Yield of Sole Maize.

Nitrogen is an important nutrient requirement of maize production for optimum production. Drysdale (1965) reported that a total of 57 Kg N was required to produce a 227 Kg /acre maize crop in Kenya.

Nitrogen application has been reported to positively influence the leaf area development. Maizlish *et al.* (1980) observed that besides accelerating root growth, progressive increases in N also increased leaf area index. Pearman *et al.* (1979) made similar observations on the effect of N on leaf area. However, Nunez and Kamprath (1969) reported that increasing nitrogen rates from 112 to 280 Kg/ha had no effect on leaf area, but the efficiency of a given area in producing grain was higher as nitrogen rates increased .

Maize response to N-fertilizer application depends on the prevailing soil or environmental conditions. Shukla (1972) reported that maize yield was highly correlated with the total nitrogen content of the soil and also found that maize did not respond to nitrogen fertilizer application on soils with relatively high total nitrogen (0.32%). Oesligle *et al.* (1976) did not obtain any significant maize yield response to application of nitrogen fertilizer on a soil which was planted to annual food crops for the first time. Broadbent (1980) suggests that substantial quantities of residual nitrogen would reflect over-fertilization and/or insufficient water supply for the crop during its growing season in previous years.

Time and method of nitrogen application have been reported to influence the response of maize to nitrogen. Stevenson and Baldwin (1969) reported that under Ontario conditions, spring fertilizer application produced greater grain yields than autumn application, but there was no difference between pre-planting and side dressing methods of application. Rhoads *et al.* (1978) observed that applying fertilizer after plant emergence produced 30% more grain than pre-planting application. Rudert and Locassio (1979) studied the effect of nitrogen source, rate and time of N application. They found that during a wet 1967 season, total yield was 65% with N applied as ammonium sulphate than as calcium nitrate. Total yields increased linearly from 6.1 to 9.3 metric tons /ha with an increase in N rate. During the wet season, application of split rather than single application as calcium nitrate increased yield. During the dry season, timing of nitrogen application had no effect on yield with either N source. In a separate study, Bandel *et al.* (1980) found that maize yields were significantly higher in response to ammonium nitrate application than N application in urea forms. Papanicoloan *et al.* (1985) found that N fertilization had a positive effect on maize yield. They reported that the incorporation method of N application was superior to others in pot experiments with a similar trend in the field experiments. Obiero (1991) working at Kabete, Kenya observed that time of N application had no influence on maize performance; however, N application positively influenced maize performance.

Thurman *et al.* (1980) found a significant increase in maize yields with increasing N-fertilization on a highly weathered soil. Average maximum grain yield of 6.1 metric tons/ha resulted from application of 203 Kg N/ha. Application of nitrogen to maize after emergence produced about 30% more maize yield than preplanting application.

Sharma (1978) and Sharma *et al.* (1979) from experiments conducted under the all India maize improvement project indicated that maize varieties behave differently to higher levels of plant population and fertility. Local varieties tolerated the higher plant population (75,000 plants/ha) and 75-125 Kg N/ha, while hybrids and composites did not respond to above 60,000 plants/ha but responded to N levels. Bhopal and Singh (1989) in studies in Itimachal Pradesh, India found a significant response of maize to N (90 Kg N/ha). The optimum fertilizer rate was 90 Kg N, 60 Kg P_2O_5 and 30 Kg K_2O/ha.

In Kenya, Marimi (1975) concluded from the results of a one season fertility study that the maize cultivar (Katumani composite B) was more responsive to soil moisture levels than to applied nitrogen. This may have been due to the masking effects of the already existing soil nitrogen residue rather than to the cultivars genetic make up. Ikombo (1984), while studying the effect of N-fertilizer application under semi-arid conditions in Kenya reported lower maize yields with application of low N-rates (40 Kg N/ha). He attributed this to the creation of high osmotic pressure by the readily soluble N fertilizer applied, the consequent withdrawal of water from the rooting zone creating moisture stress. Odhiambo (1989) working at Kabete, Kenya observed slight increases in grain yield with application of N-fertilizer.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was conducted at the University of Nairobi's Field Station farm, Kabete, located on latitude $1^{0}15'$ South and longititude $36^{0}44'$ East, and an altitude of about 1800 m. The soils are well drained, very deep, dark reddish brown to dark red, friable clay with acid humic top soil (humic NITOSOLS), developed from Limuru Trachite (Michieka, 1977). The soils were sampled and analysed for nutrients in both field experiments prior to planting (appendices A and B). This area receives an average annual rainfall of about 1000 mm with a monthly maximum temperature of $23^{0}C$ and a minimum of $12^{0}C$ (Anonymous, 1985). Appendix C shows the weather data during the experimental period.

The first season's experiment was performed between early November, 1991 and early April, 1992 while the second season's experiment was performed between mid-March and mid-September, 1992.

3.2 Experimental Design and Treatments

In both experiments, a 4 x 4 factorial structure was laid out in a completely randomized block design with three replicates. The treatments comprised four levels of nitrogen (N): 0, 50, 100 and 150 Kg N/ha and four planting patterns (PP): sole maize, maize and beans intercropped in alternate rows, maize and beans intercropped as alternating plants in the same row and maize and beans intercropped in the same hole. Maize variety Embu 512 and bean variety GLP-2 were used in the experiments. The experimental plots measured 5.25 m x 4

m. Nitrogen was applied in the form of calcium ammonium nitrate (CAN) topdressed along maize rows at six weeks after emergence. In the treatments on planting patterns, it was assumed, as is always the case with small scale farmers, that maize was the main crop with beans serving as a secondary and supplementary crop. The maize was therefore maintained at the spacing of 75 cm x 25 cm which is recommended for maize monocrop. This gives a plant population of 53,333 plants per hectare. To provide for the treatment in which a maize plant and a bean plant were planted in the same hill, beans were also maintained at the same population of 53,333 plants per hectare. This meant that the spacing of beans was same as that for maize where they were planted in the same hill. Where maize and beans were planted in the same row, within row spacing for beans was halfway (about 12.5 cm) between two neighbouring maize plants along the same row. In the treatment of alternating maize and bean rows, the spacing for beans was same as that for maize which meant that a row of beans was halfway (about 37.5 cm) between two maize rows.

3.3 Crop Husbandry

The plots were ploughed and harrowed to obtain a moderate tilth in the seed bed. Furrows 75 cm apart, were then made and triple superphosphate fertilizer was applied at a rate of 20 Kg P per ha and thoroughly mixed with the soil. Two seeds were planted per hill for each crop along the furrows. Two weeks after emergence, the seedlings were thinned to one per hill for each crop. The bean seedlings were then sprayed with Dimethoate 40% EC at a rate of 1 litre in 500 litres of water per ha for control of Bean fly on the aerial parts of plants. This was repeated at weekly intervals up to the beginning of flowering. Thereafter Benomyl was applied at the rate of 20 g per 20 litres of water two days after every application of Dimethoate for control of Bean rust and other fungal diseases. Four weeks after emergence, Stalk borer granules (25 gms Carbaryl/Kg) were applied to the maize crop at the rate of 0.2 g per plant for the control of Maize stalk borer. The plots were kept weed free throughout the experimental period using hand hoes and pangas.

3.4 Measurements and Observations

The parameters measured included: leaf area development, biomass development, grain yield and yield components.

3.4.1 Plant Growth and Biomass Development

Sampling for these measurements began 9 weeks after emergence (WAE) and continued after every two weeks until 13 and 19 weeks after emergence for beans and maize, respectively. At each sampling time, five plants of each crop component were sampled from the outer rows, excluding the guard rows, of each plot. One row was sampled at a time. The leaves were separated from the shoots for the measurements of leaf area (LA) using a LI-COR automatic LA Integrator (Model LI-3100, LI-cor. Inc., Lincoln, Nebraska). The leaf area index (LAI) was then determined. The plant components (except the roots) of each crop were chopped and dried in the oven at 80 °C for 48 and 72 hours for beans and maize respectively, then the total shoot dry matter taken.

3.4.2 Seed Yield and Yield Components

At the time of full maturity three middle rows of maize occupying 5.6 m^2 per experimental plot were harvested for grain yield determination. Of the 30 plants sampled per plot, 15 were used to determine the mean number of rows per cob, mean number of kernels per cob- row, and mean cob-length. 100-kernel weight was obtained by weighing 100 dry kernels from each plot sample.

In case of beans, an area of 7.5 m^2 within the three middle rows was harvested for grain yield determination. Of the 40 plants sampled per plot, 20 were used to determine the mean number of pods per plant, mean number of seeds per pod and 100-seed weight. Maize and bean yields were adjusted to a moisture content of 15 and 14%, respectively, using 200 seeds which were dried to a constant weight.

3.5 Data Analysis

Analysis of Variance (ANOVA) was computed in respect of each of the growth and yield parameters, and the mean separations were done using Duncan's multiple range test as described by Steel and Torrie (1980). Correlations among all the parameters taken for the maize crop were also performed.

CHAPTER FOUR:

4.0 RESULTS

4.1 Effect of Planting Patterns and N Levels on Biomass Accumulation (g/plant) of Maize and Bean Plants.

Over both seasons, planting patterns had no significant effect on shoot dry weight of maize plants taken at all sampling times except at 15 and 19 WAE in the first season and at 19 WAE in the second season (tables 1a - 5b). In all the cases where planting patterns significantly influenced the dry matter of maize plants, maize intercropped with beans in alternate rows had statistically lower dry matter than sole maize, maize intercropped with beans in the same row and maize intercropped with beans in the same hole, whose dry matter values were not statistically different from one another. Over both seasons, N application had a significant effect on the dry matter of maize plants at all sampling times. At 9 WAE, over both seasons, application of 100 and 150 Kg N/ha caused a significant increase in dry matter; however, there were no significant differences between levels 0 and 50 Kg N/ha and among levels 50, 100 and 150 Kg N/ha (tables 1a and 1b). At 11 WAE, in the first season, application of 100 and 150 Kg N/ha gave significantly higher dry matter than zero N level and 50 Kg N/ha, whose dry matter values were not significantly different. There was no significant difference between levels 100 and 150 Kg N/ha (table 2a). In the second season, at both 11 and 13 WAE, dry matter significantly increased with increasing N levels except with application of more than 100 Kg N/ha (tables 2b and 3b). A similar trend was observed in dry matter taken at 13 WAE in the first season except that there was no significant difference between application of 50 and 100 Kg N/ha (table 3a). At 15 WAE, dry matter significantly increased with increase in N levels except with application of more than 100 and 50 Kg N/ha in the first and second season, respectively (tables 4a and 4b). Over both seasons, at 19 WAE, dry matter significantly increased with increasing N levels; however, no such increase was observed with application of more than 100 Kg N/ha (tables 5a and 5b). Over both seasons, the interaction between the planting patterns and N levels was not significant, at all sampling times. However , mean separation tests performed at 19 WAE in both seasons and at 15 WAE in the first season, showed that differences between the planting patterns varied with N levels and the planting patterns responded differently to increasing N levels (tables 4a, 5a and 5b). At 0 Kg N/ha, over both seasons at 19 WAE and over the first season at 15 WAE, sole maize, maize intercropped with beans in the same row and maize intercropped with beans in the same hole had statistically similar dry matter values which were significantly higher than that of maize intercropped with beans in alternate rows. Similar results were observed at 50 Kg N/ha for dry matter taken at 19 WAE, but there was no significant difference between sole maize and maize intercropped with beans in alternate rows in the first season, and among sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows, in the second season. At the same N level (50 Kg N/ha), no significant differences were observed among planting patterns for dry matter taken at 15 WAE in the first season. At 100 and 150 Kg N/ha, over both seasons for dry matter taken at 19 WAE and over the first season for dry matter taken at 15 WAE, no significant differences were observed among the planting patterns. At 19 WAE, in both seasons, and at 15 WAE, in the first season, dry matter of sole maize significantly increased with application of 100 and 150 Kg N/ha, although there was no significant difference between these N levels. Dry matter of maize intercropped with beans in alternate rows taken at 19 WAE, in both seasons, and at 15 WAE, in the first season, significantly increased with increasing N levels except with application of above 100 and 50 Kg N/ha, respectively. In the same row arrangement, at 19 WAE, in the first season, maize dry matter significantly increased with application of above 50 Kg N/ha. However, there was no significant difference between 0 and 50 Kg N/ha, 50 and 100 Kg N/ha and between 100 and 150 Kg N/ha. In the second season, at the same sampling time, application of 100 and 150 Kg N/ha significantly increased the dry matter, but there was no significant difference between levels 0 and 50 Kg N/ha, and between levels 100 and 150 Kg N/ha. On the other hand, dry matter of maize intercropped with beans in the same hole taken at 19 WAE, in both seasons, and dry matter of maize intercropped with beans in the same row taken at 15 WAE, in the first season, significantly increased with application of above 50 Kg N/ha, but there was no significant difference between levels 0 and 50 Kg N/ha and among levels 50, 100 and 150 Kg N/ha. The average dry matter per plant was higher in the second season than in the first season at all sampling times.

Planting patterns had no significant effect on dry matter of bean plants taken at 9, 11 and 13 WAE in both seasons (Tables 6a- 8b). However, beans intercropped with maize in the same hole performed better than beans intercropped with maize in the same row which was in turn better than beans intercropped with maize in alternate rows, especially at low

N-levels (0 and 50 Kg N/ha). Over both seasons, N application significantly increased the dry matter at all sampling times (tables 6a- 8b). At 9 WAE, in the first season, application of 100 Kg N/ha significantly increased dry matter relative to 0 Kg N/ha, but there were no significant differences among levels 0, 50 and 150 Kg N/ha. At both 11 and 13 WAE, in the first season, application of N caused a significant increase in the dry matter; however, there were no significant differences among levels 50, 100 and 150 Kg N/ha. Similar observations were made in the second season, but there was no significant difference between levels 0 and 50 Kg N/ha (7a, 7b, 8a, and 8b). The interaction between the planting patterns and N-levels had no significant effect on dry matter in both seasons. The dry matter values obtained in the second season were generally superior to those obtained in the first season, at all sampling times.

Table 1a: Effect of planting patterns (PP) and nitrogen (N) levels on dry matter of maize plants (g/plant) at 9 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	27.2	28.6	30.1	30.1	29.0
Alternate row	24.1	26.1	28.8	29.6	27.2
Same row	27.3	28.7	29.7	29.8	28.9
Same hole	28.4	28.7	29.7	29.8	29.2
N-means	26.8[a]	28.0[ab]	29.6[b]	29.8[b]	

Table 1b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 9 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	28.4	30.0	32.5	32.7	30.9
Alternate row	26.1	29.4	31.3	31.4	29.6
Same row	28.3	30.0	31.8	32.3	30.6
Same hole	29.0	30.3	31.9	32.6	31.0
N-means	28.0[a]	29.9[ab]	31.9[b]	32.3[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 2a: Effects of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 11 weeks after emergence (season one)

Planting patterns	Nitrogen levels (Kg N/ha)				
	0	50	100	150	PP-means
Monocrop	82.1	85.3	98.8	100.6	91.7
Alternate row	78.0	81.4	94.6	99.6	88.4
Same row	82.7	85.3	97.1	100.5	91.4
Same hole	83.2	86.3	97.5	100.0	91.8
N-means	81.5[a]	84.6[a]	97.0[b]	100.2[b]	

Table 2b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 11 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha)				
	0	50	100	150	PP-means
Monocrop	84.5	89.0	98.6	99.5	92.9
Alternate row	80.3	86.3	94.8	96.7	89.5
Same row	84.2	88.3	97.6	98.0	92.0
same hole	86.1	89.4	97.1	98.1	92.7
N-means	83.8[a]	88.3[b]	97.0[c]	98.1[c]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 3a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 13 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	147.8	161.2	173.2	177.5	164.9
Alternate row	143.1	154.5	165.1	169.4	158.0
Same row	148.0	161.8	170.5	174.3	163.7
Same hole	155.1	164.6	171.3	174.6	166.4
N-means	148.5[a]	160.5[b]	170.0[bc]	174.0[c]	

Table 3b: Effects of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 13 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	139.8	164.5	184.7	189.0	169.5
Alternate row	130.3	149.9	171.5	176.3	157.0
Same row	140.6	165.5	177.8	182.0	166.5
Same hole	155.7	167.9	179.9	180.3	171.0
N-means	141.6[a]	162.0[b]	178.5[c]	181.9[c]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 4a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 15 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	193.9^{a}_{y}	203.0^{a}_{x}	229.1^{b}_{x}	233.9^{b}_{x}	215.0_{y}
Alternate row	160.2^{a}_{x}	188.2^{b}_{x}	207.3^{b}_{x}	211.5^{b}_{x}	191.8_{x}
Same row	194.3^{a}_{y}	198.6^{ab}_{x}	220.3^{b}_{x}	222.0^{b}_{x}	208.8_{y}
Same hole	197.7^{a}_{y}	204.1^{a}_{x}	218.7^{a}_{x}	220.3^{a}_{x}	210.2_{y}
N-means	186.5^{a}	198.5^{b}	218.9^{c}	221.9^{c}	

Within each row, means followed by the same superscript (a,b,c), and within each column, means followed by the same subscript (X,y), are not significantly different at 5% probability, according to Duncan's multiple range test.

Table 4b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 15 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	197.7	214.1	227.9	230.1	217.5
Alternate row	180.1	197.5	213.8	218.4	202.5
Same row	196.8	214.0	220.6	221.1	213.1
Same hole	199.5	215.7	220.7	221.9	214.5
N-means	193.5^{a}	210.3^{b}	220.8^{b}	222.9^{b}	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 5a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 19 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	246.7^{a}_{y}	269.3^{a}_{xy}	316.5^{b}_{x}	319.4^{b}_{x}	288.0_{y}
Alternate row	203.7^{a}_{x}	240.4^{b}_{x}	295.8^{c}_{x}	303.1^{c}_{x}	260.0_{x}
Same row	251.2^{a}_{y}	279.2^{ab}_{y}	303.3^{bc}_{x}	314.4^{c}_{x}	287.0_{y}
Same hole	261.0^{a}_{y}	292.4^{ab}_{y}	303.3^{b}_{x}	309.0^{b}_{x}	291.4_{y}
N-means	240.7^{a}	270.3^{b}	304.7^{c}	311.5^{c}	

Table 5b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants at 19 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	253.7^{a}_{y}	273.0^{a}_{xy}	319.8^{b}_{x}	323.5^{b}_{x}	292.5_{y}
Alternate row	216.7^{a}_{x}	248.0^{b}_{x}	299.2^{c}_{x}	306.7^{c}_{x}	267.7_{x}
Same row	256.3^{a}_{y}	275.7^{a}_{xy}	305.0^{b}_{x}	318.3^{b}_{x}	288.8_{y}
Same hole	268.3^{a}_{y}	294.0^{ab}_{y}	308.3^{b}_{x}	316.7^{b}_{x}	297.5_{y}
N-means	248.8^{a}	273.3^{b}	308.1^{c}	316.3^{c}	

Within each row, means followed by the same superscript (a,b,c), and within each column, means followed by the same subscript (X,y), are not significantly different at 5% probability, according to Duncan's multiple range test.

Table 6a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of bean plants at 9 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	9.0	9.6	10.3	9.9	9.9
Same row	9.2	9.8	10.5	10.0	9.9
same hole	9.4	10.1	10.5	10.0	10.0
N-means	9.2[a]	9.8[ab]	10.4[b]	10.0[ab]	

Table 6b: Effect of planting patterns and nitrogen levels on dry matter (g/plant)of bean plants at 9 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	9.9	10.2	10.4	10.3	9.9
Same row	9.9	10.4	10.6	10.3	9.9
Same hole	10.1	10.5	10.5	10.3	10.0
N-means	10.0	10.4	10.5	10.3	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 7a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of bean plants at 11 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	18.3	19.5	20.6	19.9	19.6
Same row	19.0	20.6	21.1	20.4	20.2
Same hole	20.0	20.9	21.2	20.3	20.6
N-means	19.1[a]	20.3[b]	21.0[b]	20.2[b]	

Table 7b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of bean plants at 11 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	19.5	20.5	21.3	21.2	20.6
Same row	19.6	21.0	22.3	22.0	21.2
Same hole	20.1	21.2	22.4	22.0	21.4
N-means	19.7[a]	20.9[ab]	22.0[b]	21.7[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 8a: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of bean plants at 13 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	19.3	21.1	21.9	21.3	20.9
Same row	20.0	21.3	22.2	21.5	21.3
Same hole	21.2	22.3	22.2	21.3	21.8
N-means	20.2[a]	21.6[b]	22.1[b]	21.4[b]	

Table 8b: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of bean plants at 13 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	19.9	21.8	22.6	22.2	21.6
Same row	21.0	22.3	22.9	22.3	22.1
Same hole	22.0	22.6	23.0	22.3	22.5
N-means	21.0[a]	22.2[ab]	22.8[b]	22.3[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

4.2 Effect of Planting Patterns and Nitrogen Levels on LAI of Maize and Bean Plants..

Over both seasons, planting patterns had no significant effect on LAI of maize plants taken at all sampling times (tables 9a-12b). However, maize intercropped with beans in alternate rows tended to give lower LAI values than maize sown in the rest of the patterns at all N levels; whereas maize intercropped with beans in the same hole tended to give the highest LAI at 0 and 50 Kg N/ha. N application significantly increased the LAI of maize plants taken at all sampling times (tables 9a, 9b, 10a, 10b, 11a, 11b, 12a,and 12b). Over the first season, LAI of maize plants significantly increased with increasing N levels except with application of above 50 and 100 Kg N/ha at 9 and 11 WAE, respectively. At 13 and 15 WAE, application of 100 and 150 Kg N/ha significantly increased LAI relative to 0 and 50 Kg N/ha, whose LAI values were statistically similar. There was also no significant difference between levels 100 and 150 Kg N/ha. Over the second season, at 9, 11 and 13 WAE, application of 100 and 150 Kg N/ha significantly increased LAI; however, no significant differences were observed between levels 0 and 50 Kg N/ha and among levels 50, 100 and 150 Kg N/ha. At 15 WAE, application of N significantly increased the LAI, but there was no significant difference between 50 and 100 Kg N/ha, and between 100 and 150 Kg N/ha. Over both seasons, at all sampling times, the interaction between the planting patterns and N levels was not significant although maize intercropped with beans in the same hole performed better than the rest of the patterns at zero N level compared to higher N levels. The average LAI values were generally higher during the second season than in the first season at all sampling times.

Planting patterns had no significant effect on LAI of bean plants taken at 9 and 11 WAE during both seasons (13a, 13b, 14a and 14b). Similarly, N application did not significantly influence the LAI values over both seasons; however, N application tended to improve this parameter (13a-14b). The interaction between the planting patterns and N levels was not significant in both seasons, at all sampling times. LAI values obtained in the first season were smaller than those obtained in the second season.

Table 9a: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 9 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	2.67	2.77	2.80	2.82	2.77
Alternate row	2.47	2.62	2.67	2.73	2.62
Same row	2.52	2.75	2.80	2.80	2.72
Same hole	2.58	2.77	2.78	2.79	2.73
N-means	2.56[a]	2.73[b]	2.76[b]	2.79[b]	

Table 9b: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 9 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.00	3.20	3.30	3.40	3.20
Alternate row	2.80	3.10	3.20	3.30	3.10
Same row	3.10	3.20	3.30	3.30	3.20
Same hole	3.10	3.30	3.30	3.30	3.30
N-means	3.00[a]	3.20[ab]	3.30[b]	3.30[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 10a: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 11 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.73	3.95	4.25	4.33	4.07
Alternate row	3.65	3.84	4.08	4.13	3.93
Same row	3.75	3.99	4.12	4.29	4.04
Same hole	3.93	3.97	4.15	4.16	4.05
N-means	3.77[a]	3.94[b]	4.15[c]	4.23[c]	

Table 10b: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 11 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	4.17	4.43	4.80	4.93	4.58
Alternate row	3.83	4.27	4.63	4.67	4.35
Same row	4.17	4.43	4.67	4.77	4.51
Same hole	4.33	4.53	4.67	4.73	4.57
N-means	4.13[a]	4.42[ab]	4.69[b]	4.78[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 11a: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 13 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.49	3.68	3.93	3.97	3.77
Alternate row	3.44	3.60	3.76	3.79	3.65
Same row	3.52	3.70	3.86	3.87	3.74
Same hole	3.68	3.76	3.88	3.89	3.80
N-means	3.53[a]	3.69[a]	3.86[b]	3.88[b]	

Table 11b: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 13 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.83	4.17	4.50	4.60	4.28
Alternate row	3.47	4.00	4.33	4.50	4.08
Same row	4.00	4.17	4.40	4.50	4.27
Same hole	4.17	4.27	4.40	4.50	4.34
N-means	3.87[a]	4.15[ab]	4.41[b]	4.53[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 12a: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 15 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	2.78	2.92	3.31	3.33	3.09
Alternate row	2.73	2.84	3.09	3.12	2.95
Same row	2.80	2.93	3.24	3.31	3.07
Same hole	2.90	2.97	3.26	3.30	3.11
N-means	2.80[a]	2.92[a]	3.23[b]	3.27[b]	

Table 12b: Effect of planting patterns and nitrogen levels on Leaf area index of maize plants at 15 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.33	3.73	4.00	4.13	3.80
Alternate row	2.87	3.60	3.93	4.03	3.61
Same row	3.50	3.73	3.93	4.03	3.80
Same hole	3.77	3.80	4.00	4.07	3.91
N-means	3.37[a]	3.72[b]	3.97[bc]	4.07[c]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 13a: Effect of planting patterns and nitrogen levels on leaf area index of bean plants at 9 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	0.47	0.48	0.50	0.50	0.49
Same row	0.48	0.49	0.50	0.50	0.49
Same hole	0.49	0.50	0.50	0.50	0.50
N-means	0.48	0.49	0.50	0.50	

Table 13b: Effect of planting patterns and nitrogen levels on leaf area index of bean plants at 9 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	0.49	0.50	0.51	0.51	0.50
Same row	0.50	0.51	0.52	0.51	0.51
Same hole	0.50	0.51	0.52	0.51	0.51
N-means	0.50	0.51	0.52	0.51	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 14a: Effect of planting patterns and nitrogen levels on leaf area index of bean plants at 11 weeks after emergence (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	0.58	0.61	0.65	0.66	0.63
Same row	0.60	0.66	0.68	0.67	0.65
Same hole	0.60	0.68	0.69	0.67	0.66
N-means	0.59	0.65	0.67	0.67	

Table 14b: Effect of planting patterns and nitrogen levels on leaf area index of bean plants at 11 weeks after emergence (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	0.63	0.68	0.73	0.72	0.69
Same row	0.65	0.70	0.75	0.73	0.71
Same hole	0.70	0.73	0.77	0.73	0.73
N-means	0.66	0.70	0.75	0.73	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

4.3 Effect of Planting Patterns and Nitrogen Levels on Grain Yield and Yield components of Maize and Bean plants.

4.3.1 Maize Yield and Yield Components

4.3.1.1 Grain Yield

Over both seasons, planting patterns had a significant effect on maize grain yield (tables 15a and 15b). Maize intercropped with beans in alternate rows had significantly lower grain yield than sole maize, maize intercropped with beans in the same row and maize intercropped with beans in the same hole, whose maize yields were not statistically different. Similarly, N application significantly influenced the grain yield in both seasons (tables 15a and 15b). This parameter significantly increased with increasing N levels except with application of above 100 Kg N/ha. The interaction between the planting patterns and N levels was significant in the first season. A similar, but non-significant effect was observed in the second season. Over the first season, at 0 and 50 Kg N/ha, maize intercropped with beans in the same hole significantly out-yielded maize sown in the rest of the patterns; whereas sole maize and maize intercropped with beans in the same row, whose yields were statistically similar, gave significantly higher grain yield than maize intercropped with beans in alternate rows. In the second season, at the same N levels, maize intercropped with beans in the same hole had higher, though no-significant, yields than sole maize and maize intercropped with beans in the same row, whose yields were not significantly different from that of maize intercropped with beans in alternate rows. Maize intercropped with beans in the same hole, however, statistically out-yielded maize intercropped with beans in alternate rows. At

100 and 150 Kg N/ha, in the first season, sole maize had grain yield that was non-significantly higher than that of maize intercropped with beans in the same row or same hole, but statistically higher than that of maize intercropped with beans in alternate rows. In the second season, at the same N levels, there were no significant differences among all the planting patterns. Over both seasons, maize intercropped with beans in the same hole did not significantly respond to application of more than 50 Kg N/ha; whereas sole maize, maize intercropped with beans in alternate rows and maize intercropped with beans in the same row did not significantly respond to application of more than 100 Kg N/ha. The average grain yields were 5.87 and 7.74 t/ha in the first and second season, respectively.

Table 15a: Effect of planting patterns and nitrogen levels on grain yield (t/ha) of maize plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha)				
	0	50	100	150	PP-means
Monocrop	4.75^{a}_{y}	5.56^{b}_{y}	6.86^{c}_{y}	6.90^{c}_{y}	6.02_{y}
Alternate row	4.08^{a}_{x}	4.87^{b}_{x}	6.22^{c}_{x}	6.29^{c}_{x}	5.37_{x}
Same row	4.80^{a}_{y}	5.69^{b}_{y}	6.50^{c}_{xy}	6.60^{c}_{xy}	5.90_{y}
Same hole	5.53^{a}_{z}	6.21^{b}_{z}	6.47^{b}_{xy}	6.53^{b}_{xy}	6.18^{b}_{y}
N-means	4.78^{a}	5.58^{b}	6.51^{c}	6.58^{c}	

Table 15b: Effect of planting patterns and nitrogen levels on grain yield (t/ha) of maize plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha)				
	0	50	100	150	PP-means
Monocrop	5.40^{a}_{xy}	7.37^{b}_{xy}	9.03^{c}_{x}	9.50^{c}_{x}	7.83_{y}
Alternate row	4.67^{a}_{x}	6.67^{b}_{x}	8.00^{c}_{x}	8.83^{c}_{x}	7.04_{x}
Same row	5.60^{a}_{xy}	7.43^{b}_{xy}	8.77^{c}_{x}	9.17^{c}_{x}	7.74_{y}
Samehole	6.63^{a}_{y}	8.37^{b}_{y}	9.00^{b}_{x}	9.33^{b}_{x}	8.33_{y}
N-means	5.58^{a}	7.46^{b}	8.70^{c}	9.21^{c}	

Within each row, means followed by the same superscript (a,b,c), and within each column, means followed by the same subscript (s) (X,y,z), are not significantly different at 5% probability level, according to Duncan's multiple range test.

4.3.1.2 Yield Components

Planting patterns had a significant effect on cob-length, number of kernels per cob row and 100-kernel weight of maize plants in both seasons (tables 16a-18b). Over the first season, sole maize, maize intercropped with beans in the same row and maize intercropped with beans in the same hole were statistically similar, but significantly superior to maize intercropped with beans in alternate rows (tables 16a, 17a and 18a). In the second season, similar observations were made except that there were no significant differences among cob-lengths of sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows and between number of kernels per cob-row of maize intercropped with beans in the same row and maize intercropped with beans in alternate rows (tables 16b, 17b and 18b). N application, on the other hand, significantly influenced cob-length, number of kernels per cob-row and 100-kernel weight in both seasons (tables 16a-18b). An increase in these yield components with increasing N levels was observed, but this increase was not significant with application of more than 100 Kg N/ha. The interaction between the planting patterns and N levels did not have a significant effect on cob-length, number of kernels per cob-row and 100-kernel weight in both seasons; however, mean separation tests showed that planting patterns responded differently to varying levels of N and differences among them also varied with N levels. At 0 Kg N/ha, over the first season, the average cob-length of maize intercropped with beans in the same hole was statistically similar to that of maize intercropped with beans in the same row, but significantly higher than those of sole maize and maize intercropped with beans in alternate rows. The latter two were also statistically similar. At the same N level and season, the average cob-length of maize intercropped with beans in the same row was statistically similar to that of sole maize, but significantly superior to that of maize intercropped with beans in alternate rows. Over both seasons, at 0 and 50 Kg N/ha, the number of kernels per cob-row of maize intercropped with beans in the same hole was statistically similar to those of sole maize and maize intercropped with beans in the same row, but significantly higher than that of maize intercropped with beans in alternate rows. However, sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows had statistically similar number of kernels per cob-row (tables 17a and 17b). Similar results were observed with respect to cob-length at 0 and 50 Kg N/ha in the second and first season, respectively. At 0 Kg N/ha, over the first season, and at 0 and 50 Kg N/ha, over the second season, sole maize, maize intercropped with beans in the same row and maize intercropped with beans in the same hole, whose kernel weights were statistically similar, had 100-kernel weights that were significantly higher than that of maize intercropped with beans in alternate rows. A similar observation was made at 50 Kg N/ha in the first season except that there was no significant difference between sole maize and maize intercropped with beans in alternate rows. Over both seasons, at 100 and 150 Kg N/ha, no significant differences in cob-length, number of kernels per cob-row and 100-kernel weight were observed among all the planting patterns. At 50 Kg N/ha, in the second season, similar results were observed with respect to cob-length

Over the first season, cob-length of sole maize, number of kernels per cob-row of sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows and 100-kernel weight of maize intercropped with beans in alternate rows significantly increased with increase in N levels except with application of more than 100 Kg N/ha. In the same season, cob-length of maize intercropped with beans in alternate rows showed a similar response to N application except that levels 50 and 100 were statistically similar. In the first season, cob-length of maize intercropped with beans in the same row and number of kernels per cob-row of maize intercropped with beans in the same hole, and in the second season, number of kernels per cob-row of sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows significantly increased with increase in N levels; however, no such increase was observed with application of above 50 Kg N/ha. Cob-length of maize intercropped with beans in the same hole did not significantly respond to application of N in both seasons; whereas 100-kernel weight and number of rows per cob-row of maize intercropped with beans in the same hole did not significantly respond to N application in the first and second season, respectively. Application of 100 and 150 Kg N/ha caused a significant increase in cob-length of sole maize and maize intercropped with beans in alternate rows and 100-kernel weight of maize intercropped with beans in the same row in the second season and both seasons, respectively; however, there were no significant differences between these N levels and 50 Kg N/ha. In the second season, cob-length and 100-kernel weight of maize intercropped with beans in the same row and maize intercropped with beans in the same hole, respectively, significantly increased with application of 150 Kg N/ha, but there were no significant differences among levels 0, 50 and 100 and between levels 100 and 150 Kg N/ha. Observations made in the second season showed that application of 100 and 150 Kg

N/ha significantly increased 100-kernel weight of sole maize and maize intercropped with beans in alternate rows; however, there was no significant difference between levels 0 and 50 Kg N/ha and between levels 50 and 100 Kg N/ha. The average cob-length, number of kernels per cob-row and 100-kernel weight were higher in the second season than in the first season.

The effect of planting patterns and N levels and their interaction on the number of rows per cob was not significant in both seasons (tables 19a and 19b). The average number of rows per cob in the first season was 12.0 compared to 11.8 in the second season.

Table 16a: Effect of planting patterns and nitrogen levels on cob-length (cm) of maize plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	17.2^{a}_{xy}	19.2^{b}_{xy}	20.6^{c}_{x}	20.8^{c}_{x}	19.3_{y}
Alternate row	16.3^{a}_{x}	18.4^{b}_{x}	19.5^{bc}_{x}	19.9^{c}_{x}	18.5_{x}
Same row	18.3^{a}_{yz}	19.5^{b}_{xy}	20.2^{b}_{x}	20.3^{b}_{x}	19.6_{y}
Samehole	19.2^{a}_{z}	20.0^{a}_{y}	20.2^{a}_{x}	20.2^{a}_{x}	19.9_{y}
N-means	17.8^{a}	19.3^{b}	20.1^{c}	20.3^{c}	

Table 16b: Effect of planting patterns and nitrogen levels on cob-length (cm) of maize plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	18.4^{a}_{xy}	21.0^{ab}_{x}	22.8^{b}_{x}	23.3^{b}_{x}	21.4_{xy}
Alternate row	16.0^{a}_{x}	18.7^{ab}_{x}	21.3^{b}_{x}	22.3^{b}_{x}	19.6_{x}
Same row	18.7^{a}_{xy}	21.0^{ab}_{x}	22.3^{ab}_{x}	23.0^{b}_{x}	21.3_{xy}
Same hole	20.2^{a}_{y}	22.3^{a}_{x}	22.7^{a}_{x}	23.0^{a}_{x}	22.1_{y}
N-means	18.3^{a}	20.8^{b}	22.3^{c}	22.9^{c}	

Within each row, means followed by the same superscript (a,b,c), and within each column, means followed by the same subscript (s) (X,y,z), are not significantly different at 5% probability level, according to Duncan's multiple range test.

Table 17a: Effect of planting patterns and nitrogen levels on Kernels per cob-row of maize plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	36.0^{a}_{xy}	37.5^{b}_{xy}	40.1^{c}_{x}	40.3^{c}_{x}	38.5_{y}
Alternate row	35.0^{a}_{x}	36.6^{b}_{x}	39.4^{c}_{x}	39.6^{c}_{x}	37.7_{x}
Same row	36.3^{a}_{xy}	38.0^{b}_{xy}	39.9^{c}_{x}	39.9^{c}_{x}	38.5_{y}
Same hole	37.3^{a}_{y}	39.0^{b}_{y}	39.8^{b}_{x}	40.0^{b}_{x}	39.0_{y}
N-means	36.2^{a}	37.8^{b}	39.8^{c}	40.0^{c}	

Table 17b: Effect of planting patterns and nitrogen levels on Kernels per cob-row of maize plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	36.0^{a}_{xy}	40.2^{b}_{xy}	43.7^{b}_{x}	44.2^{b}_{x}	41.0_{y}
Alternate row	34.0^{a}_{x}	38.7^{b}_{x}	40.7^{b}_{x}	41.7^{b}_{x}	38.8_{x}
Same row	36.3^{a}_{xy}	40.5^{b}_{xy}	41.7^{b}_{x}	43.3^{b}_{x}	40.5_{xy}
Same hole	40.0^{a}_{y}	43.0^{a}_{y}	43.2^{a}_{x}	43.3^{a}_{x}	42.4_{y}
N-means	36.6^{a}	40.6^{b}	42.3^{c}	43.1^{c}	

Within each row, means followed by the same superscript (a,b,c), and within each column, means followed by the same subscript (s) (X,y,z), are not significantly different at 5% probability level, according to Duncan's multiple range test.

Table 18a: Effect of planting patterns and N levels on 100-kernel weight (g) of maize plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	36.3^{a}_{y}	38.0^{a}_{xy}	40.5^{b}_{x}	40.6^{b}_{x}	38.9_{y}
Alternate row	32.4^{a}_{x}	36.2^{b}_{x}	38.3^{c}_{x}	38.9^{c}_{x}	36.5_{x}
Same row	37.0^{a}_{y}	38.9^{ab}_{y}	39.5^{b}_{x}	39.6^{b}_{x}	38.8_{y}
Samehole	37.8^{a}_{y}	39.6^{a}_{y}	39.5^{a}_{x}	39.5^{a}_{x}	39.1_{y}
N-means	35.9^{a}	38.2^{b}	39.5^{c}	39.7^{c}	

Table 18b: Effect of planting patterns and nitrogen levels on 100-kernel weight (g) of maize plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	38.1^{a}_{y}	40.7^{ab}_{y}	43.3^{bc}_{x}	45.0^{c}_{x}	41.8_{y}
Alternate row	34.4^{a}_{x}	37.0^{ab}_{x}	40.0^{bc}_{x}	41.7^{c}_{x}	38.5_{x}
Same row	38.7^{a}_{y}	41.3^{ab}_{y}	43.0^{b}_{x}	44.0^{b}_{x}	41.8_{y}
Samehole	40.0^{a}_{y}	42.0^{ab}_{y}	43.3^{ab}_{x}	44.0^{b}_{x}	42.3_{y}
N-means	37.8^{a}	40.3^{b}	42.4^{c}	43.7^{c}	

Within each row, means followed y the same superscript (a,b,c), and within each column, means followed by the same subscript (s) (X,y,z), are not significantly different at 5% probability level, according to Duncan's multiple range test.

Table 19a: Effect of planting patterns and nitrogen levels on number of rows per cob of maize plants (season one)

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	12.0	12.0	11.9	12.0	12.0
Alternate row	12.1	12.2	12.0	12.0	12.1
Same row	11.9	11.9	12.1	12.0	12.0
Same hole	12.0	12.1	11.9	12.0	12.0
N-means	12.0	12.1	12.0	12.0	

Table 19b: Effect of planting patterns and nitrogen levels on number of rows per cob of maize plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	11.5	11.5	11.7	12.0	11.7
Alternate row	11.9	11.9	12.0	12.0	12.0
Same row	11.8	11.6	11.7	12.0	11.8
Same hole	11.6	11.8	11.7	12.1	11.8
N-means	11.7	11.7	11.8	12.0	

4.3.2 Bean Yield and Yield Components

4.3.2.1 Grain Yield

The effect of planting patterns on grain yield of bean plants was not significant in both seasons even though beans intercropped with maize in the same hole yielded higher than beans intercropped with maize in the same rows which in turn had slightly higher seed yields than beans intercropped with maize in alternate rows (tables 20a and 20b). On the other hand, N application had a significant effect on seed yields during both seasons (tables 20a and 20b). Relative to zero N level, application of 50, 100 and 150 Kg N/ha caused a significant increase in seed yield. There were no significant differences among levels 50, 100 and 150 Kg N/ha. The interaction between the planting patterns and N levels had no significant effect on seed yield in both seasons, although the differences among the planting patterns generally decreased with increasing N levels. For example, at zero N level beans intercropped with maize in the same hole out-yielded beans intercropped with maize in alternate rows by 5.6 and 4.7% compared to 0.6 and 0.9% at 150 Kg/ha, in the first and second season, respectively. The average seed yield was 616 Kg/ha in the first season and this was numerically lower than 694 Kg/ha in the second season.

Table 20a: Effect of planting patterns and nitrogen levels on grain yield (Kg/ha) of bean plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	578	603	632	619	608
Same row	582	619	637	622	615
Same hole	612	623	636	623	624
N-means	591 [a]	615 [b]	635 [b]	621 [b]	

Table 20b: Effect of planting patterns and nitrogen levels on grain yield (Kg/ha) of bean plants (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	652	684	701	699	684
Same row	665	702	709	703	695
Same hole	684	708	709	705	702
N-means	667 [a]	698 [b]	706 [b]	702 [b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

4.3.2.2 Yield Components

Over both seasons, planting patterns had no significant effect on number of pods per plant, number of seeds per pod and 100-seed weight although beans intercropped with maize in the same hole tended to produce higher number of pods per plant, number of seeds per pod and 100-seed weights than beans intercropped with maize in the same row or in alternate rows (tables 21a-23b). Over both seasons, N application had a significant effect on number of pods per plant and 100-seed weight (tables 21a, 21b, 23a and 23b). Application of 50, 100 and 150 Kg N/ha caused a significant increase in number of pods per plant in both seasons and 100-seed weight in the first season, but there were no significant differences among these N levels. In the second season, application of 100 Kg N/ha caused a significant increase in 100-seed weight; however, there were no significant differences among levels 0, 50 and 150 Kg N/ha and levels 50, 100 and 150 Kg N/ha. N application generally increased the number of seeds per pod although the increase was not significant . The interaction between the planting patterns and N levels had no significant effect on number of pods per plant and 100-seed weight in both seasons. The average number of pods per plant, number of pods per pod and 100-seed weight were higher in the first season than in the second season.

Table 21a: Effect of planting patterns and nitrogen levels on number of pods per plant (season one).

Planting patterns	Nitrogen levels (Kg N/ha)				PP-means
	0	50	100	150	
Alternate row	6.6	7.0	7.4	7.3	7.1
Same row	6.7	7.3	7.5	7.3	7.2
Same hole	7.0	7.4	7.6	7.3	7.3
N-means	6.8[a]	7.2[b]	7.5[b]	7.3[b]	

Table 21b: Effect of planting patterns and nitrogen levels on number of pods per plant (season two).

Planting patterns	Nitrogen levels (Kg N/ha)				PP-means
	0	50	100	150	
Alternate row	7.5	8.5	9.1	9.0	8.5
Same row	8.0	8.7	9.3	9.0	8.8
Same hole	8.7	9.3	9.5	9.0	9.1
N-means	8.1[a]	8.8[b]	9.3[b]	9.0[b]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 22a: Effect of planting patterns and nitrogen levels on number of seeds per pod of bean plants (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Monocrop	3.2	3.5	3.7	3.5	3.5
Alternate row	3.3	3.6	3.7	3.6	3.6
Same row	3.4	3.8	3.8	3.6	3.7
N-means	3.3	3.6	3.7	3.6	

Table 22b: Effect of planting patterns and nitrogen levels on number of seeds per pod (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	3.5	3.8	3.9	3.8	3.8
Same row	3.6	3.8	3.9	3.9	3.8
Same hole	3.7	3.9	4.0	4.0	3.9
N-means	3.6	3.8	3.9	3.9	

Table 23a: Effect of planting patterns and nitrogen levels on 100-seed weight (g) of beans (season one).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	46.3	49.3	50.3	50.0	49.0
Same row	47.0	49.7	50.7	50.0	49.4
Same hole	49.3	50.7	51.3	49.7	50.3
N-means	47.5[a]	49.9[b]	50.8[b]	49.9[b]	

Table 23b: Effect of planting patterns and nitrogen levels on 100-seed weight (g) of beans (season two).

Planting patterns	Nitrogen levels (Kg N/ha) 0	50	100	150	PP-means
Alternate row	49.0	51.3	52.3	52.0	51.2
Same row	50.3	52.0	53.0	52.3	51.9
Same hole	51.3	53.0	53.8	52.3	52.6
N-means	50.2[a]	52.1[ab]	53.0[b]	52.2[ab]	

Means followed by the same letter (s) are not significantly different at 5% probability level according to Duncan's multiple range test.

4.5 Interrelationships between Parameters associated with Growth and Yield of Maize

Over both seasons, the correlation between maize grain yield and LAI (13 WAE), dry matter (19 WAE), cob-length, kernels per cob-row and kernel weight was positive and highly significant (tables 24a and 24b). There were, however, negligible correlations (positive or negative) between grain yield and number of rows per cob.

The number of rows per cob had small non-significant correlations (positive or negative) with other yield components, dry matter and LAI. Over the first season, correlations among cob-length, number of kernels per cob-row, number of rows per cob, 100-kernel weight, dry matter and LAI were positive and significant. Similar observations were made in the second season except that the correlation between LAI and number of kernels per cob-row was not significant.

Table 24a: Correlation coefficients between different parameters associated with growth and yield of maize (season one).

	Yield (t/ha)	Leaf area index	Dry matter (g/plant)	Rows cob^{-1}	Cob-lenght (cm)	Kernels cob^{-1}
Yield (t/ha)						
Leaf area index	0.4784**					
Dry matter (g/plant)	0.9053**	0.4600**				
Rows cob^{-1}	-0.0096	-0.1723	-0.0981			
Cob-lenght (cm)	0.8307**	0.4317**	0.7360**	0.0477		
Kernels cob-row $^{-1}$	0.8766**	0.2065	0.7416**	0.1359	0.8173**	
100-kernel weight	0.8140**	0.3901*	0.7174**	0.1059	0.6948**	0.6894**

Table 24b: Correlation coefficients between different parameters associated with growth and yield of maize (season two).

	Yield (t/ha)	Leaf area index	Dry matter (g/plant)	Rows cob^{-1}	Cob-lenght (cm)	Kernels cob^{-1}
Yield (t/ha)						
Leaf area index	0.5459**					
Dry matter (g/plant)	0.8499**	0.5522**				
Rows cob^{-1}	0.0800	0.1515	0.0563			
Cob-lenght (cm)	0.6905**	0.4820**	0.6962**	-0.0445		
Kernels cob-row $^{-1}$	0.7816**	0.5150**	0.7293**	0.2208	0.6798**	
100-kernel weight	0.7931**	0.4760**	0.7913**	-0.0518	0.6558**	0.6106**

*, ** significant at 0.05 and 0.01 probability levels.

CHAPTER FIVE

5.0 Discussion.

In both seasons, planting patterns had a significant effect on maize grain yield. Under low N levels (0 and 50 Kg N/ha), intercropping maize and beans in the same hole had significantly higher grain yields than the rest of the patterns, whereas intercropping maize and beans in alternate rows had significantly the lowest yields. The maize increases due to intercropping maize and beans in the same hole may be attributed to N excreted by the legume during growth or to N released during the decomposition of decaying legume roots and nodules (Janny and Kletter, 1965; Agboola and Fayemi, 1972; De, 1980). In fact, recent studies based on ^{15}N analysis of soil in the root zone of the legume indicate that N contribution from the N-rich legume root and nodule material may be substantial (Poth *et al.*, 1986). The fact that maize intercropped with beans in the same hole had much higher yields than maize intercropped with beans in the same row and this in turn had higher yields than maize intercropped with beans in alternate rows, strongly suggests that the amount of N contribution by beans in an intercropping system was influenced to a large extent by the proximity of the intercrop roots. Martin and Snaydon (unpublished), cited by Snaydon and Harris (1981), studied the effects of N supply on relative yield totals of barley and beans, separating the effects of above- and below-ground interactions using partitioned boxes, and observed yield advantages only when the roots interacted. Trenbath (1974) also observed that mingling of legume and non-legume roots has beneficial effects. Another possible factor which may have caused the differences among the intercropping systems is the differences in intensity of competition for N between the legume and the cereal in these systems which may have influenced legume N-fixation. Thompson (1977), cited by May and Misangu (1982), and Willey (1979) have suggested that depletion of nitrogen by the cereal intercropped with a legume causes an increase in N-fixation observed as a stimulation of nodule number and weight. Similar observations were made by Rerkasem *et al.* (1985) who found that intercropping of maize and rice bean increased N-fixation due to competition for soil N by the maize. Competition for N by maize intercropped with beans in the same hole may have depleted N at the roots of beans enhancing N-fixation and hence, N available for the maize intercrop. On the other hand, competition for N by maize intercropped with beans in alternate rows may not have caused a serious depletion of N at bean roots to enhance adequate N-fixation. Several field experiments have also supported the beneficial effects of increasing the intimacy between cereals and legumes in an intercrop system. Bodade (1964) obtained more sorghum yield when sorghum was mixed with groundnuts in the same row than in adjacent rows. Nyambo *et al.* (1982) reported higher yields when cereals (maize, sorghum, millet) were intercropped with legumes (soybean, green gram) in the same row than in alternate rows. Nadar (1984) reported significantly higher maize yield when maize was intercropped with beans in the same row than when it was intercropped with beans in alternate rows at row spacings of 75 and 90 cm. May and Misangu (1982) observed that intercropping maize and soybeans or cowpea in the same hole gave higher yields than intercropping maize and beans in the same row. Mongi *et al.* (1982) observed significantly higher N content of maize ear leaves when maize was intercropped with cowpeas in the same hole than in alternate rows or when grown as a sole crop. Nadar (1984) reported that whereas intercropping maize and beans in alternate rows greatly reduced maize yields, intercropping maize and beans in the same row and in the same hole increased maize yields by 7% and 27%, respectively. Nadar (1984) observed similar results in maize/cowpea intercrops, but maize intercropped with cowpea in the same row had higher yields than maize intercropped with cowpea in the same hole.

At higher N levels (100 and 150 Kg N/ha), the advantage of intercropping maize and beans in the same hole disappeared possibly because of reduced N-fixation or N was not limiting any more. It has been established that high nitrate-N in the soil depresses N-fixation (Herridge, 1982a) and this is accomplished through inhibition of attachment of *Rhizobia* to root hair, abortion of infection thread, slowing of nodule growth, inhibition of fixation within established nodules, and more rapid senescence of the nodule when either No_3^- or NH_4^+ is added (Noel *et al.*, 1982). Significant differences in dry matter among the planting patterns occurred earlier in the first season than in the second season possibly because of the lower soil available N in the first season than in the second season (appendices A and B). The general decrease in the depressive effect of beans on maize at high N levels, when maize was intercropped with beans in alternate rows, could be explained by reduced competition for N between these crop components at these N levels. This is because crop legumes are known to utilize substantial amounts of soil nitrate during growth (Harper and Gibson, 1984), and under limiting N conditions may compete with associated crop (Kurtz *et al.*, 1952)). Legumes have also been reported to utilize mineral N in preference to forming nodules and fixing N_2 (Allos and Bartholomew, 1959).

The effect of planting patterns on cob-length, 100 kernel weight, number of kernels per cob-row and dry matter taken at 19 WAE in both seasons and at 15 WAE in the first season was significant. Effect of planting patterns on Leaf area index followed a similar trend, although the effect was not significant. The trend in the differences in the planting patterns, with respect to these parameters, was similar to that observed in maize yield. This suggests that planting patterns influenced grain yield through their effect on these parameters. This contention is supported by the positive and significant (p=0.01) correlations observed between these parameters and maize yield. Obiero (1991) observed similar results. Ebong and Wahua (1991) also reported a positive and significant correlation between maize yield and numbers of kernels per cob-row. Hoen and Andrew (1959) identified the primary yield components of maize as the number of cobs plant^{-1}, number of grain rows cob^{-1}, number of grains row^{-1} and weight of 100 grains. Planting patterns had no effect on the number of rows per cob in both seasons.

In case of beans, the effect of planting patterns on yield was not significant in both seasons. However, intercropping maize and beans in the same hole generally out-performed intercropping maize and beans in the same row which in turn performed slightly better than intercropping in alternate rows, especially at zero N level. The superiority of intercropping maize and beans in the same hole, under low N levels, may have been due to enhanced N-fixation caused by depletion of N by the maize crop as suggested earlier. Such enhanced N-fixation in the same hole may be interpreted to mean that the legume itself also benefits. May and Misangu (1982) also observed higher cowpea or soybean yields when maize was intercropped with these legumes in the same hole than when they were intercropped with maize in the same row. The effect of planting patterns on yield components and growth parameters of beans was not significant. However, the trend in these parameters was similar to that of the bean yields, suggesting that the planting patterns influenced bean yield through their influence on these parameters. Haag *et al.* (1978) reported that the main, effect of high fertility levels was to enhance the role of pods per plant and single seed weight in influencing seed yield.

Over both seasons, N application significantly increased maize grain yield. Rault and Masood (1977) observed that increasing N rates led to increased rates of grain filling and they attributed this to the adequate supply of the building block materials during the critical period of grain development. Studies on response of maize to N in maize/legume intercrops (Evans, 1960: Willey and Osiru, 1972: Finlay, 1975: Uriyo *et al.*, 1982: Chui and Nadar, 1984) and in maize sole crops have all shown that N application appreciably increases maize grain yield. Sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows showed high and similar response to N application. Most results (Wahua and Miller, 1978; Ahmed and Gunasema, 1979; Nambiar *et al.*, 1983; Reddy *et al.*, 1983) showed that sole and intercropped cereal responded similarly to applied N, and this gives little support to the belief that grain legumes in intercropping might benefit the associated cereal during the growing season. Maize intercropped with beans in the same hole, in this experiment, however, showed less response to N application than sole maize, suggesting that N was less limiting when maize was intercropped with beans in the same hole. The finding in this study, therefore, supports the assertion that legumes provides available N fixed to the non-legume when grown in association. A similar observation was made by Agboola and Fayemi (1972) who found no response of maize to application of above 50 Kg N/ha when maize was intercropped with a legume.

The observations made with respect to maize yields in this study are of great importance to our small scale farmers operating under low nitrogen conditions. It may be advisable for this group of farmers to intercrop maize and beans in the same hole so as to derive the beneficial effects of N-fixation by the bean plant. Significant differences in dry matter of maize plants among planting patterns occurred after beans had been harvested. This could have been due to N released by the decomposing root and nodule material of bean plants. If this was the case, then maize and beans should be planted at the same time in the same hole in an intercrop system.

Bean yields increased with increasing N levels up to 50 Kg N/ha. Studies on response of sole beans to N-fertilizer application (Cardosso *et al.*, 1978: Haag *et al.*, 1978; Keya *et al.*, 1982) have all found significant increases in bean yields with application of N-fertilizer. Uriyo (1982) and Chui (1988) in maize/bean intercrops, also observed increases in bean intercrop yields with N application. Kalra and Ganguar (1980) in maize-cowpea mixtures, found that application of 80 and 120 Kg N/ha gave larger seed yields of cowpea than 40 Kg N/ha. Crop legumes are known to utilize substantial amounts of soil nitrate during growth (Harper and Gibson, 1984), and may compete for N when intercropped with a non-legume (Kurlz *et al.*, 1952).

Application of N significantly increased the cob-length, number of kernels per cob row and 100-kernel weight. Similar increases in cob-length and number of kernels per cob-row and seed size with N application have been reported by other workers (Yoshida, 1972: cited by Hocking *et al.* 1984; Hongo, 1991). Chui and Nadar (1984) reported increased 100-kernel weight with N application. Increases in cob-length with N application, on the other hand, has been reported by Odhiambo (1989). The response of these parameters to N application was similar to the response of yield to N application. This implies that nitrogen increases maize yield through its effect on these parameters. The positive and significant correlations between these parameters and maize yield support this contention. Obiero (1991) also observed positive correlations between these parameters and maize yield. The number of rows per cob, however, was not significantly affected by N application suggesting that this component is probably genetically controlled. Hongo (1991) made a similar observation. This is also reflected in the fact that the correlations between this parameter and other yield components, leaf area index, dry matter and yield was generally very low.

The number of pods per plant of bean plants was significantly increased by N application in both seasons. Increases in number of pods per plant in sole beans with N application have been reported by several workers (Asif and Greig, 1972; Barke, 1978; Haag *et al.*, 1978; Delbert *et al.*, 1982; Mack, 1983). Chui (1988) also observed increases in the number of pods per plant of beans intercropped with maize with N application. N application generally improved the number of seeds per pod, but the effect was not significant. Haag *et al.* (1978) reported a significant increase in seed weights of sole beans at high fertility levels. Chui (1988) also observed increases in number of seeds per pod of beans intercropped with maize with N application. Nitrogen application caused a significant increase in 100-seed weight in the first season. Similar increases in sole bean 100-seed weight with N application have been reported (Haag *et al.*, 1978). Chui (1988) also reported such increases in beans intercropped with maize with N application. The significant increases in bean yields observed with N appplication could have been mainly caused by the significant increases in number of pods per plant and 100-seed weight of bean plants. Haag *et al.* (1978) reported that the main effect of high fertility levels was to enhance the role of pods per plant and single seed weight in influencing seed yield.

N applicaton caused a significant increase in dry matter in both seasons, at all sampling times. Similar and contrasting results have been reported elsewhere. Thomas and Thorne (1975) found that application of nitrogen caused an increase in dry matter of spring wheat (*Triticum aestivum* L.). Rego (1981) reported increases in fodder yields of sole sorghum and sorghum intercropped with pigeon pea in alternate rows. In contrast, Chui (1988) did not observe any significant increases in dry matter of sole maize or maize intercropped with beans in alternate rows or same rows. Andrew and Eck (1983) reported that increased N application increased the chlorophyll level of sweet corn leaves in water stressed and unstressed plants. They translocated the increase in chlorophyll content into increased photosynthetic efficiency and a subsequent increase in total dry matter observed. Similarly, N application significantly increased the dry matter of bean plants in both seasons. Molina (1975) reported that dry matter production of 6 bean cultivars increased with N application. Dean and Clark (1980) found significant increases in dry matter in black bean (*Phaseolus vulgaris* L.) from application of N fertilizer, although N-fertilization consistently depressed N-fixation. In contrast, Chui (1988) observed no significant increases in dry matter of sole beans, beans intercropped with maize in alternate rows and beans intercropped with maize in the same row with application of N-fertilizer.

N application significantly increased leaf area index of maize plants at all sampling times. Maizlish *et al.* (1980) and Pearman *et al.* (1979) have also reported increases in LAI values with application of N. Thorne and Watson (1955), observed that early N application increased LAI to a maximum whereas late application delayed senescence. The increase in leaf area with N application may be attributed to the role of nitrogen in plant growth and development. Nitrogen plays an active role in the development of new cells, resulting in their growth, enlargement and elongation (Bartholomew and Clark, 1965; Frank, 1965; Black, 1968). Leaf area index, in most cases, responded less to N application than grain yield, suggesting that the efficiency of a given leaf area in producing grain may have improved with N application. Nunez and Kamprath (1969) reported that increasing N rates from 112 to 280 Kg N/ha had no significant effect on leaf area, but the efficiency of a given area in producing grain was higher as N rates increased. The significant increases in leaf area index was reflected in the dry matter, grain yield and yield components. This is further supported by the significant and positive correlations between leaf area and these parameters. Nitrogen application may have increased the number of kernels per cob-row by providing a good supply of photosynthates. Fuch (1968), cited by Tollenar (1977), concluded that the assimilation surface available to the plant at tassel initiation determined the number of kernel initiations laid down. Cooper (1977), cited by Remison (1978), reported a positive correlation between the amount of manufactured carbohydrates and Leaf area. The amount of carbohydrates manufactured is dependent on the rate of photosynthesis per unit area which is influenced by leaf chlorophyll. A positive correlation between the leaf chlorophyll and leaf area exists (Obiero, 1991), and there also exists a positive correlation between leaf chlorophyll and leaf photosynthetic rate (Buttery and Buzzel, 1977), and according to Edmeades and Daynard (1979), leaf photosynthetic rate has a powerful influence on grain yield especially at the silking stage.

In case of beans, N application had no significant effect on leaf area index, although it slightly improved this parameter. Late application of N may have been the cause of the insignificant response observed. Thorne and Watson (1955) observed that early N application increased LAI to a maximum whereas late application delayed senescence. The fact that dry matter and grain yield significantly increased with N application, suggests that N application increased the efficiency of bean leaf areas in producing photosynthates rather than greater light interception. Nunez and Kamprath (1969) reported increased efficiency of a given leaf area in producing dry matter for grain filling with higher N rates as a result of increased chlorophyll content in the leaves.

The higher dry matter, leaf area indices and yield components observed in the second season, in both beans and maize, may be attributed to the higher amounts of rain during the march rains. Intercropping maize and beans, irrespective of the intercropping system, tended to be more productive during the second season than in the first season. This could have been due to reduced competition for water in the second season which received more rain than the first season (appendix C). Kurtz *et al.* (1952) reported that if competition occurs between the maize crop and the intercrop it is mainly for nitrogen and water.

Conclusions.

The results of this study, demonstrated the superiority of intercropping maize and beans in the same hole, with respect to maize yields, under low N levels (0 and 50 Kg N/ha). At these N levels (0 and 50 Kg N/ha), this intercropping system produced superior yields compared to the rest of the patterns; however, at higher N levels (100 and 150 Kg N/ha), the yield of this system slightly decreased below that of the monocrop system. Bean yields were slightly better in this intercropping system than in the others. This finding is of great importance to the small scale farms, which are characterised by low fertility conditions because of lack of the necessary inputs. This group of farmers should therefore intercrop maize and beans in the same hole so that they can exploit the potential N made available to the maize crop by the bean crop.

The beneficial effects of beans to maize was found to be positively associated with the proximity of the roots of the maize and bean intercrops. This was demonstrated by the fact that under low N levels, maize intercropped with beans in the same hole out-performed maize intercropped with beans in the same row which in turn had superior yields over maize intercropped with beans in alternate rows. The advantage of increasing the intimacy between maize and bean intercrops may have occurred either through the mingling of the intercrop roots which allowed contact of maize roots with the N excreting points of the beans or the stimulation of additional nitrogen fixation as a result of increased competition for N by the maize crop.

N-fertilizer significantly increased grain yield of both maize and bean intercrops, although maize was more responsive to N application. The fear that large quantities of N required by maize may cause excessive vegetative growth of beans intercropped with maize has, therefore, been allayed by this study. In fact, the optimum N requirement of maize (100 Kg N/ha) also gave the largest grain yields of beans. The recommended N-fertilizer for maize sole crop can, therefore, be safely used in maize/bean intercropping systems. Sole maize, maize intercropped with beans in the same row and maize intercropped with beans in alternate rows showed high and similar response to increasing N levels, whereas maize intercropped with beans in the same hole showed much lower response to N levels, further strengthening the contention that intercropping maize and beans offers substantial benefits in terms of nitrogen made available to the maize crop.

Recommendations For Further Research.

1. Studies should be conducted using the optimal N levels suggested in this study to determine the optimal levels of phosphorous since this element is known to be limiting in most tropical soils and also plays an important role in N-fixation.

2. Different varieties of beans should be planted in the various intercropping arrangements under the various N levels adopted in this study with a view of exploiting any potential differences in N-fixation or tolerance to NO_3^- that may exist among them.

3. Inoculation studies should also be undertaken to determine whether inoculation influences the performance of the intercropping systems adopted in this experiment.

4. Studies on light interception, nodulation and plant nutrient analysis should be undertaken in order to establish the cause of the advantage of intercropping maize and beans in the same hole.

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Appendices

Appendix A: Soil test results (season one)

	Soil pH					Me/100 g/soil				ppm
	H_2O	$CaCl_2$	%N	%C	C:N	K	Na	Ca	Mg	P
Depth										
0-30 cm	6.2	5.5	0.20	2.03	9:1	1.00	0.04	15.4	2.70	4.1
30-60 cm	6.2	5.5	0.20	1.80	10.2:1	1.00	0.05	14.9	2.50	4.2

Appendix B: Soil test results (season two)

	Soil pH					Me/100 g/soil				Ppm
	H_2O	$CaCl_2$	%N	%C	C:N	K	Na	Ca	Mg	P
Depth										
0-30 cm	6.2	5.5	0.27	3.00	11:1	1.00	0.04	13.4	4.00	5.5
30-60 cm	6.2	5.5	0.28	2.95	10.5:1	1.00	0.05	13.2	4.00	5.1

Appendix C: Weather data during the experimental period

Year	Month	Total rainfall (cm)	Temperature (^{0}C)	
			Max.	Min.
1991	October	21.6	25.0	13.0
1991	November	199.4	22.7	13.5
1991	December	50.7	22.8	13.3
1992	January	4.7	24.0	12.8
1992	February	70.2	26.6	13.2
1992	March	5.6	26.2	14.2
1992	April	401.7	24.3	14.8
1992	May	216.5	22.5	13.4
1992	June	20.6	21.3	12.4
1992	July	29.4	19.9	11.3
1992	August	3.8	19.7	10.5
1992	September	16.3	22.9	11.5

Appendix 1a: Analysis of Variance (ANOVA) table for dry matter of maize plants at 9 Weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	4.185		
Nitrogen levels (N)	3	75.141	25.047	3.272^{*}
Planting patterns (PP)	3	32.233	10.744	$1.403^{n.s.}$
N x PP	9	17.500	1.944	$0.254^{n.s.}$
Error	30	229.681	7.656	
C.V. 9.7%				

Appendix 1b: ANOVA table for dry matter of maize plants at 9 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	3.225		
Nitrogen levels (N)	3	142.499	47.500	5.720^{**}
Planting patterns (PP)	3	14.447	4.816	$0.580^{n.s.}$
N x PP	9	5.790	0.643	$0.077^{n.s.}$
Error	30	249.129	8.304	
C.V. 9.4%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 2a: ANOVA table for dry matter of maize plants at 11 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	117.820		
Nitrogen levels (N)	3	3026.321	1008.774	41.964 **
Planting patterns (PP)	3	93.929	31.310	1.302 $^{n.s.}$
N x PP	9	28.741	3.193	0.133 $^{n.s.}$
Error	30	721.179	24.039	
C.V. 5.4%				

Appendix 2b: ANOVA table for dry matter of maize plants at 11 weeks after emergence (season two).

Source	d.f.	SS	Ms	F
Blocks	2	23.339		
Nitrogen levels (N)	3	1729.789	576.596	14.519 **
Planting patterns (PP)	3	85.832	28.611	0.720 $^{n.s.}$
N x PP	9	20.032	2.226	0.056 $^{n.s.}$
Error	30	1191.408	39.714	
C.V. 6.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 3a: ANOVA table for dry matter of maize plants at 13 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	25.760		
Nitrogen levels (N)	3	4030.812	1343.604	8.024 **
Planting patterns (PP)	3	481.517	160.506	0.959 n.s.
N x PP	9	706.604	78.512	0.469 n.s.
Error	30	5023.570	167.452	
C.V. 7.9%				

Appendix 3b: ANOVA table for dry matter of maize plants at 13 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	1727.720		
Nitrogen levels (N)	3	12233.377	4077.792	13.910 **
Planting patterns (PP)	3	1415.817	471.939	1.610 n.s.
N x PP	9	702.164	78.018	0.266 n.s.
Error	30	8794.497	293.150	
C.V. 10.3%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 4a: ANOVA table for dry matter of maize plants at 15 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	1353.545		
Nitrogen levels (N)	3	10785.519	3595.173	17.642**
Planting patterns (PP)	3	3819.657	1273.219	6.248**
N x PP	9	1031.058	114.562	0.562$^{n.s.}$
Error	30	6113.388	203.780	

C.V. 6.9%

Appendix 4b: ANOVA table for dry matter of maize plants at 15 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	254.800		
Nitrogen levels (N)	3	6476.966	2158.989	5.662**
Planting patterns (PP)	3	1544.629	514.876	1.350$^{n.s.}$
N x PP	9	385.726	128.575	0.337$^{n.s.}$
Error	30	11439.094	381.303	

C.V. 9.2%

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 5a: ANOVA table for dry matter of maize plants at 19 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	5232.867		
Nitrogen levels (N)	3	38671.747	1290.582	35.952**
Planting patterns (PP)	3	7276.562	2425.521	6.765**
N x PP	9	4144.780	460.531	1.284$^{n.s.}$
Error	30	10756.485	358.530	
C.V. 6.7%				

Appendix 5b: ANOVA for dry matter of maize plants at 19 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	60.371		
Nitrogen levels (N)	3	34530.059	11510.020	28.513**
Planting patterns (PP)	3	6212.576	2070.859	5.130**
N x PP	9	3851.835	427.982	1.060$^{n.s.}$
Error	30	12110.333	403.678	
C.V. 7.0%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 6a: ANOVA table for dry matter of bean plants at 9 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.927		
Nitrogen levels (N)	3	6.679	2.226	2.088 n.s.
Planting patterns (PP)	2	0.487	0.240	0.225 n.s.
N x PP	6	0.656	0.109	0.018 n.s.
Error	22	23.461	1.066	
C.V. 10.5%				

Appendix 6b: ANOVA table for dry matter of bean plants at 9 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	2.470		
Nitrogen levels (N)	3	1.476	0.492	0.882 n.s.
Planting patterns (PP)	2	0.157	0.076	0.136 n.s.
N x PP	6	0.109	0.018	0.032 n.s.
Error	22	12.283	0.558	
C.V. 7.3%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 7a: ANOVA table for dry matter of bean plants at 11 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	6.142		
Nitrogen levels (N)	3	15.868	5.289	2.988*
Planting patterns (PP)	2	6.537	3.269	1.840 n.s.
N x PP	6	2.138	0.356	0.201 n.s.
Error	22	39.094	1.777	
C.V. 6.7%				

Appendix 7b: ANOVA table for dry matter of bean plants at 11 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	6.000		
Nitrogen levels (N)	3	28.036	9.345	5.008**
Planting patterns (PP)	2	4.134	2.067	1.126 n.s.
N x PP	6	0.666	0.111	0.060 n.s.
Error	22	40.374	1.835	
C.V. 8.6%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 8a: ANOVA table for dry matter of bean plants at 13 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	15.251		
Nitrogen levels (N)	3	18.368	6.123	5.452^{**}
Planting patterns (PP)	2	4.291	2.146	$1.911^{n.s.}$
N x PP	6	3.821	0.637	$0.567^{n.s.}$
Error	22	36.739	1.123	
C.V. 5.3%				

Appendix 8b: ANOVA table for dry matter of bean plants at 13 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	4.802		
Nitrogen levels (N)	3	19.132	6.377	3.800^{*}
Planting patterns (PP)	2	3.552	1.776	$1.058^{n.s.}$
N x PP	6	2.313	0.386	$0.230^{n.s.}$
Error	22	36.911	1.678	
C.V. 5.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 9a: ANOVA table for leaf area index of maize plants at 9 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.028		
Nitrogen levels (N)	3	0.384	0.128	4.267"
Planting patterns (PP)	3	0.135	0.045	$1.500^{n.s.}$
N x PP	9	0.029	0.003	$0.100^{n.s.}$
Error	30	0.911	0.030	
C.V. 3.5%				

Appendix 9b: ANOVA table for Leaf area index of maize plants at 9 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.087		
Nitrogen levels (N)	3	0.665	0.221	$2.278^{n.s.}$
Planting patterns (PP)	3	0.143	0.048	$0.495^{n.s.}$
N x PP	9	0.950	0.106	$1.093^{n.s.}$
Error	30	2.900	0.097	
C.V. 3.0%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 10a: ANOVA table for leaf area index of maize plants at 11 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.020		
Nitrogen levels (N)	3	1.574	0.523	12.163**
Planting patterns (PP)	3	0.149	0.050	1.163 n.s.
N x PP	9	1.303	0.017	0.395 n.s.
Error	30	3.149	0.043	
C.V. 5.2%				

Appendix 10b: ANOVA table for Leaf area index of maize plants at 11 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.355		
Nitrogen levels (N)	3	3.119	1.040	3.540*
Planting patterns (PP)	3	0.407	0.136	0.464 n.s.
N x PP	9	0.264	0.029	0.099 n.s.
Error	30	8.785	0.293	
C.V. 12%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 11a: ANOVA table for Leaf area index of maize plants at 13 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.020		
Nitrogen levels (N)	3	0.846	0.282	6.558**
Planting patterns (PP)	3	0.189	0.063	1.465$^{n.s.}$
N x PP	9	0.081	0.009	0.209$^{n.s.}$
Error	30	1.290	0.043	
C.V. 7.1%				

Appendix 11b: ANOVA table for Leaf area index of maize plants at 13 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.165		
Nitrogen levels (N)	3	3.324	1.108	5.682**
Planting patterns (PP)	3	0.496	0.165	0.846$^{n.s.}$
N x PP	9	0.513	0.057	0.292$^{n.s.}$
Error	30	5.861	0.195	
C.V. 10.4%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 12a: ANOVA table for Leaf area index of maize plants at 15 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.012		
Nitrogen levels (N)	3	1.871	0.624	13.160**
Planting patterns (PP)	3	0.200	0.067	1.404 n.s.
N x PP	9	0.050	0.017	0.348 n.s.
Error	30	1.422	0.047	
C.V. 7.1%				

Appendix 12b: ANOVA table for Leaf area index of maize plants at 15 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.218		
Nitrogen levels (N)	3	3.503	1.168	10.336**
Planting patterns (PP)	3	0.561	0.187	1.655 n.s.
N x PP	9	0.822	0.091	0.805 n.s.
Error	30	3.375	0.113	
C.V. 8.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 13a: ANOVA table for leaf area index of bean plants at 9 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.0016		
Nitrogen levels (N)	3	0.0031	0.0010	1.000 n.s.
Planting patterns (PP)	2	0.0006	0.0003	0.300 n.s.
N x PP	6	0.0007	0.0001	0.100 n.s.
Error	22	0.0210	0.0010	
C.V. 6%				

Appendix 13b: ANOVA table for leaf area index of bean plants at 9 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.0005		
Nitrogen levels (N)	3	0.0021	0.0007	0.778 n.s.
Planting patterns (PP)	2	0.0005	0.0003	0.333 n.s.
N x PP	6	0.0001	0.00001	0.111 n.s.
Error	22	0.0194	0.0009	
C.V. 5.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 14a: ANOVA table for leaf area index of bean plants at 11 weeks after emergence (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.0057		
Nitrogen levels (N)	3	0.0270	0.00901	1.723 n.s.
Planting patterns (PP)	2	0.0099	0.0049	0.944 n.s.
N x PP	6	0.0038	0.0006	0.120 n.s.
Error	22	0.1151	0.0052	

C.V. 11%

Appendix 14b: ANOVA table for leaf area index of bean plants at 11 weeks after emergence (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.0018		
Nitrogen levels (N)	3	0.0391	0.0130	1.502 n.s.
Planting patterns (PP)	2	0.0097	0.0049	0.559 n.s.
N x PP	6	0.0026	0.0004	0.051 n.s.
Error	22	0.1909	0.0087	

C.V. 7.6%

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 15a: ANOVA table for grain yield of maize plants (season one)

source	d.f.	SS	MS	F
Blocks	2	1.363		
Nitrogen levels (N)	3	25.961	8.654	95.099 **
Planting patterns (PP)	3	4.535	1.512	16.615 **
N X PP	9	2.598	0.289	3.178 *
Error	30	2.729	0.091	
C.V. 5.1%				

Appendix 15b: ANOVA table for grain yield of maize plants (season two)

source	d.f.	SS	MS	F
Blocks	2	0.252		
Nitrogen levels (N)	3	94.129	31.376	58.104 **
Planting patterns (PP)	3	10.162	3.387	6.272 **
N X PP	9	2.965	0.329	0.610 n.s.
Error	30	16.202	0.540	
C.V. 9.5%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 16a: ANOVA table for cob-length of maize plants (season one).

source	d.f.	SS	MS	F
Blocks	2	1.734		
Nitrogen levels (N)	3	48.399	16.133	33.195**
Planting patterns (PP)	3	12.777	4.259	8.763**
N X PP	9	9.367	1.041	2.142 n.s.
Error	30	14.566	0.486	
C.V. 3.6%				

Appendix 16b: ANOVA table for cob-length of maize plants (season two).

source	d.f.	SS	MS	F
Blocks	2	0.570		
Nitrogen levels (N)	3	151.582	50.527	11.470**
Planting patterns (PP)	3	39.482	13.161	2.988*
N X PP	9	13.836	1.537	0.349 n.s.
Error	30	132.157	4.405	
C.V. 9.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 17a: ANOVA table for number of kernels per cobrow (season one).

Source	d.f.	SS	MS	F
Blocks	2	2.575		
Nitrogen levels (N)	3	116.157	38.719	44.45**
Planting patterns (PP)	3	13.849	4.616	5.30**
N X PP	9	9.029	0.997	1.145 n.s.
Error	30	26.125	0.871	
C.V. 2.4%				

Appendix 17b: ANOVA table for number of kernels per cob-row of maize plants (season two).

Source	d.f.	SS	MS	F
Blocks	2	7.047		
Nitrogen levels (N)	3	320.522	106.841	19.647**
Planting patterns (PP)	3	83.626	27.887	5.128**
N X PP	9	35.626	3.958	0.728 n.s.
Error	30	163.140		
C.V. 5.7%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 18a: ANOVA table for 100-kernel weight of maize plants (season one).

Source	d.f.	SS	ms	F
Blocks	2	4.570		
Nitrogen levels (N)	3	109.947	36.64	18.799**
Planting patterns (PP)	3	55.206	18.402	9.442**
N x PP	9	27.638	3.071	1.576 n.s.
Error	30	58.484	1.949	
C.V. 3.9%				

Appendix 18b: ANOVA table for 100-kernel weight of maize plants (season two).

Source	d.f.	SS	MS	F
Blocks	2	2.588		
Nitrogen levels (N)	3	240.289	80.096	21.926**
Planting patterns (PP)	3	124.749	41.583	11.383**
N X PP	9	13.415	1.491	0.408 n.s.
Error	30	109.586	3.653	
C.V. 4.8%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 19a: ANOVA table for number of rows per cob of maize plants (season one).

source	d.f.	SS	MS	F
Blocks	2	1.07		
Nitrogen levels (N)	3	0.042	0.014	0.084 n.s.
Planting patterns (PP)	3	0.046	0.015	0.090 n.s
N X PP	9	0.235	0.026	0.156 n.s.
Error	30	5.017	0.167	
C.V. 3.4%				

Appendix 19b: ANOVA table number for rows per cob of maize plants (season two).

source	d.f.	SS	MS	F
Blocks	2	0.265		
Nitrogen levels (N)	3	0.901	0.300	0.472 n.s.
Planting patterns (PP)	3	0.542	0.181	0.285 n.s
N X PP	9	0.420	0.047	0.074 n.s.
Error	30	19.082	0.636	
C.V. 6.8%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 20a: ANOVA table for grain yield (Kg/ha) of bean plants (season one).

Source	d.f.	SS	ms	F
Blocks	2	168.389		
Nitrogen levels (N)	3	9315.667	3105.222	6.986 **
Planting patterns (PP)	2	1461.056	730.528	1.644 n.s.
N x PP	6	1351.166	228.194	0.507 n.s.
Error	22	9778.278	444.467	
C.V. 3.4%				

Appendix 20b: ANOVA table for grain yield (Kg/ha) of bean plants (season two).

Source	d.f.	SS	ms	F
Blocks	2	182.166		
Nitrogen levels (N)	3	8782.750	2927.583	3.763 *
Planting patterns (PP)	2	1808.666	904.333	1.162 n.s.
N x PP	6	777.334	129.556	0.166 n.s.
Error	22	17115.834	777.992	
C.V. 4.0%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 21a: ANOVA table for number of pods per plant of beans (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.107		
Nitrogen levels (N)	3	2.812	0.937	5.713 "
Planting patterns (PP)	2	0.482	0.241	1.469 n.s.
N x PP	6	0.209	0.035	0.213 n.s.
Error	22	3.613	0.164	
C.V. 5.6%				

Appendix 21b: ANOVA table for number of pods per plant (season two).

Source	d.f.	SS	ms	F
Blocks	2	20.107		
Nitrogen levels (N)	3	7.303	0.937	4.063 "
Planting patterns (PP)	2	2.810	0.241	2.346 n.s.
N x PP	6	1.199	0.035	0.334 n.s.
Error	22	13.184	0.164	
C.V. 11.5%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 22a: ANOVA table for number of seeds per pod of bean plants (season one).

Source	d.f.	SS	ms	F
Blocks	2	0.167		
Nitrogen levels (N)	3	1.156	0.385	2.655 n.s.
Planting patterns (PP)	2	0.191	0.096	0.950 n.s.
N x PP	6	0.009	0.002	0.020 n.s.
Error	22	3.200	0.145	
C.V. 10.5%				

Appendix 22b: ANOVA table for number of seeds per pod of bean plants (season two).

Source	d.f.	SS	ms	F
Blocks	2	0.037		
Nitrogen levels (N)	3	0.568	0.189	2.739 n.s.
Planting patterns (PP)	2	0.154	0.077	1.116 n.s.
N x PP	6	0.014	0.002	0.029 n.s.
Error	22	1.523	0.069	
C.V. 6.9%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

Appendix 23a: ANOVA table 100-seed weight of bean plants (season one).

Source	d.f.	SS	ms	F
Blocks	2	4.480		
Nitrogen levels (N)	3	51.417	17.139	4.714 "
Planting patterns (PP)	2	10.055	5.028	1.383 n.s.
N x PP	6	9.500	1.583	0.435 n.s.
Error	22	80.000	3.636	
C.V. 3.9%				

Appendix 23b: ANOVA table for 100-seed weight of bean plants (season two).

Source	d.f.	SS	ms	F
Blocks	2	15.861		
Nitrogen levels (N)	3	40.937	13.645	2.186 n.s.
Planting patterns (PP)	2	10.551	5.276	0.846 n.s.
N x PP	6	3.389	0.565	0.091 n.s.
Error	22	137.293	6.241	
C.V. 4.8%				

n.s.= Not significant

*, **= Significant at 0.05 and 0.01 probability levels respectively.

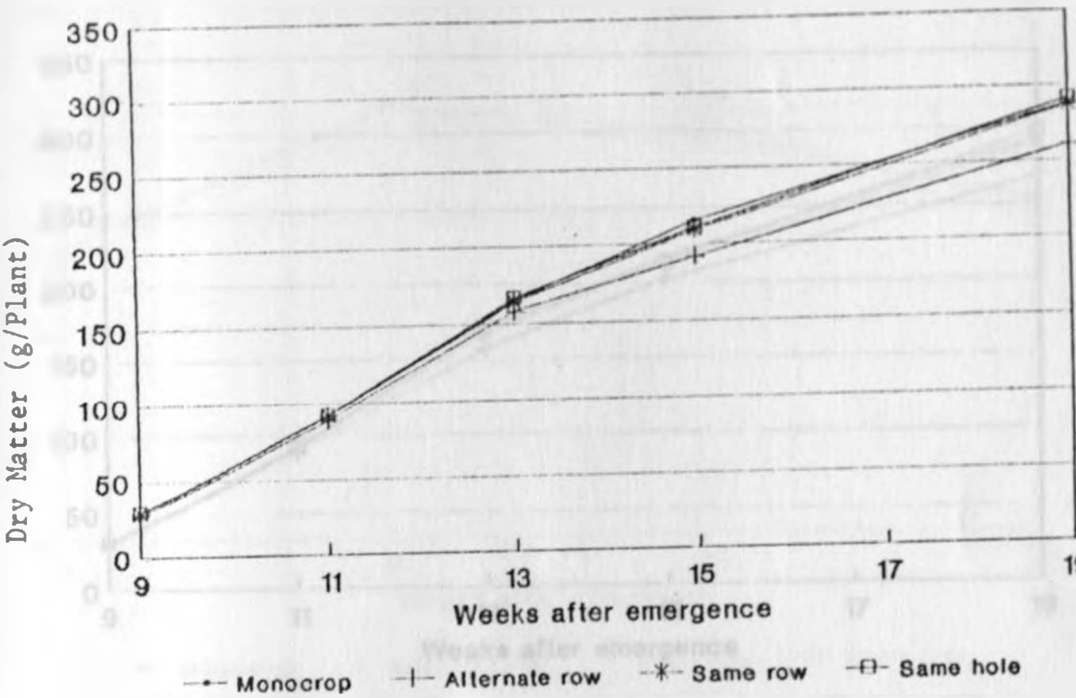

Figure 1: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants (season one).

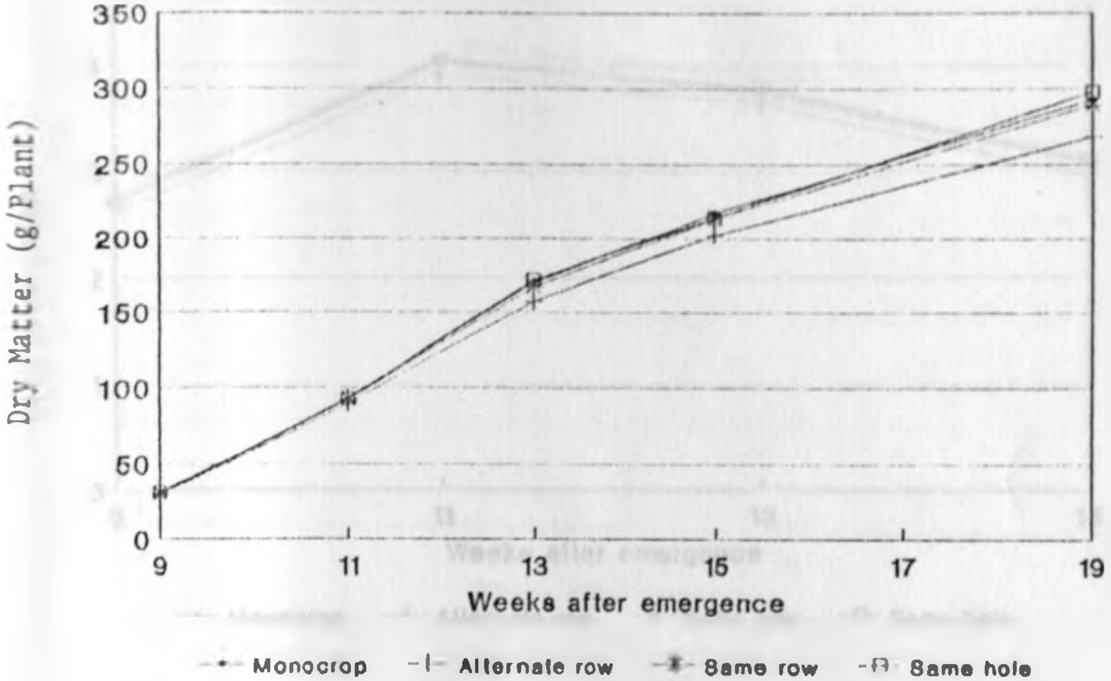

Figure 2: Effect of planting patterns and nitrogen levels on dry matter (g/plant) of maize plants (season two).

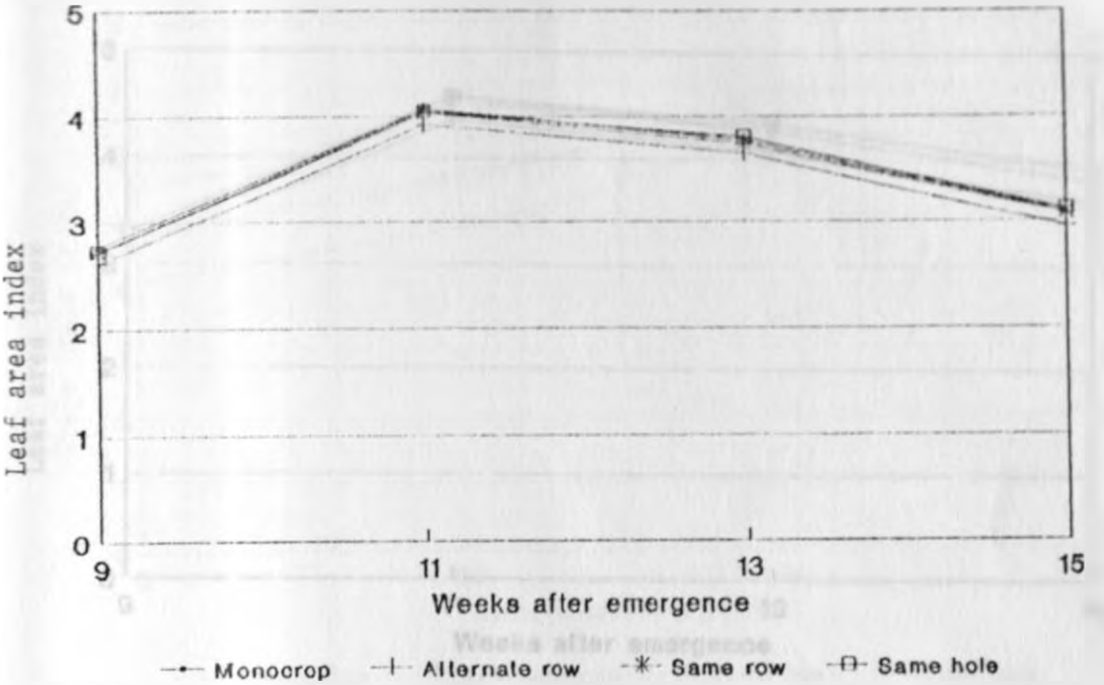

Figure 3: Effect of planting patterns and nitrogen levels on leaf area index of maize plants (season one).

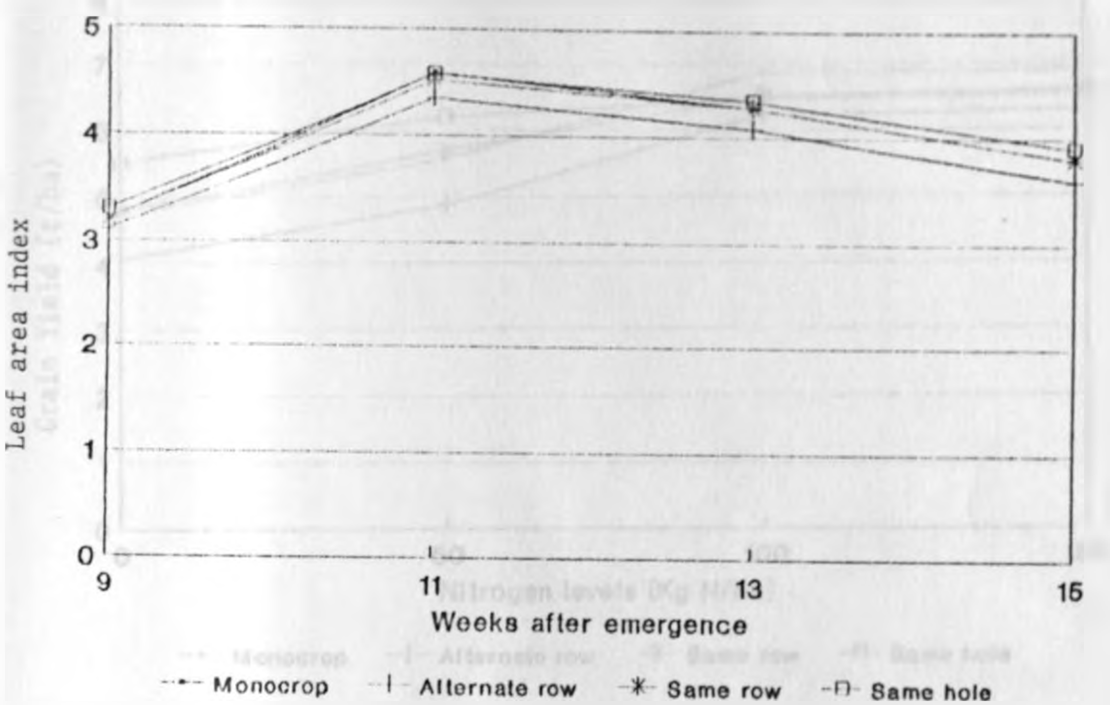

Figure 4: Effect of planting patterns and nitrogen levels on leaf area index of maize plants (season two).

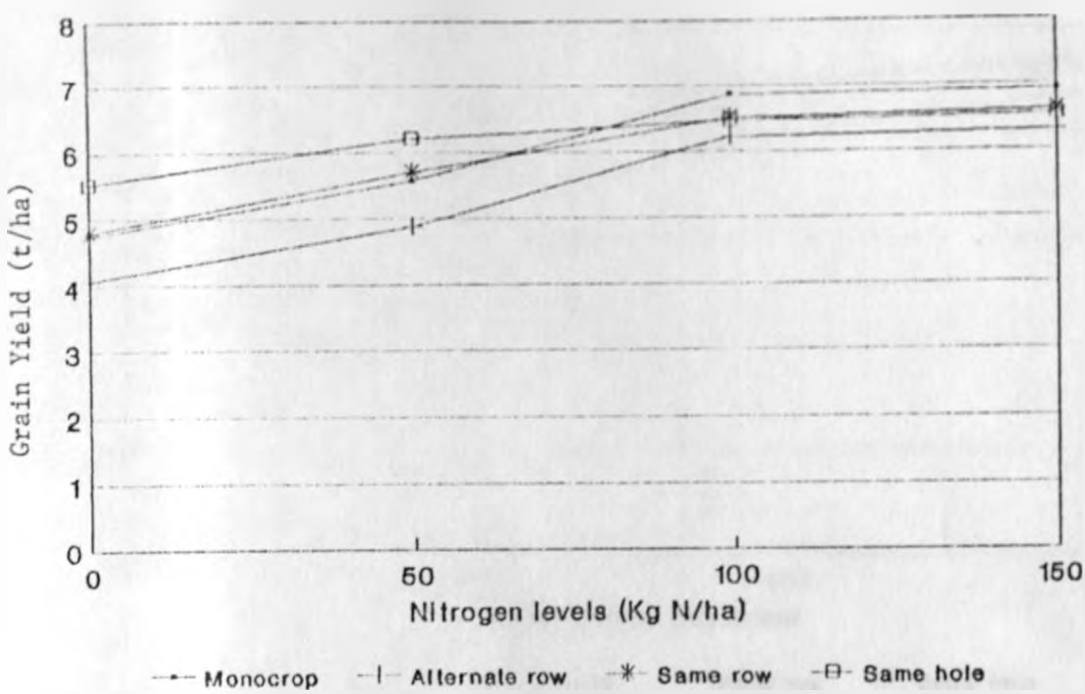

Figure 5: Effect of planting patterns and nitrogen levels on grain yield (t/ha) of maize plants (season one).

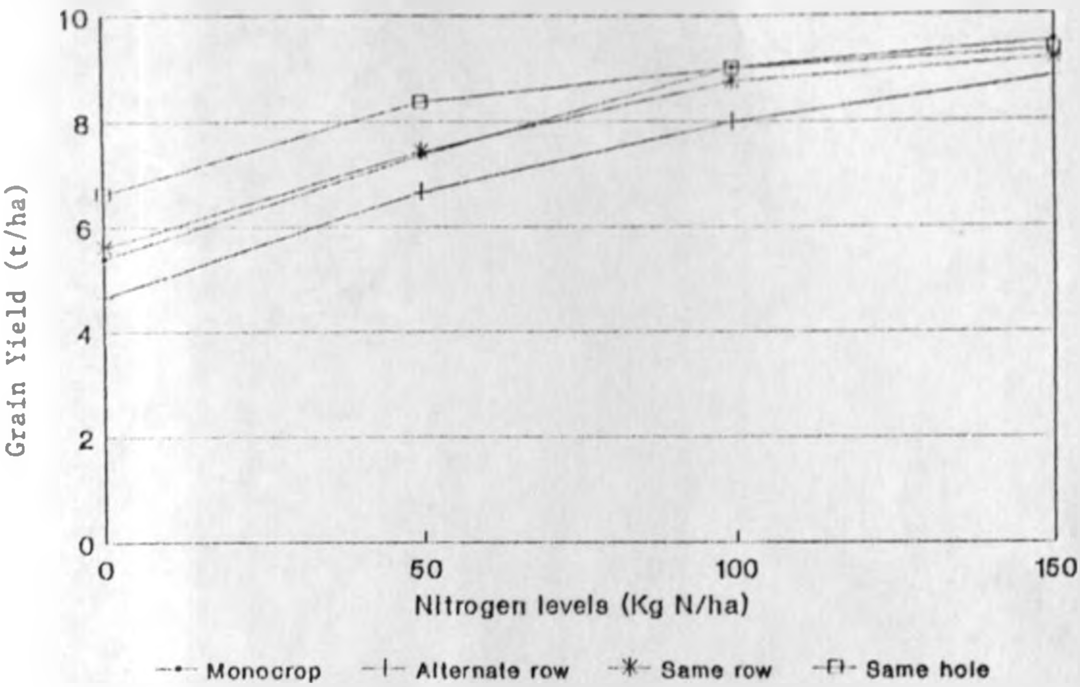

Figure 6: Effect of planting patterns and nitrogen levels on grain yield (t/ha) of maize plants (season two).