EFFECTS OF BEAN PLANTING DENSITY AND PLANTING TIME ON GROWTH AND YIELDS OF MAIZE AND BEANS IN AN INTERCROPPING SYSTEM

BY

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DECLARATION

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

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

_______________ Date 20/12/96

Prof. J.O. Nyabundi

DEDICATION

This thesis is dedicated to my children , Javan, Joyce and Victor who gave me the moral support I needed to finish my work.

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ABSTRACT.

Intercropping is a farming practice that has recently received attention from agronomists as a means of improving land use efficiency.

This study was conducted to determine whether manipulating bean density and planting time could have any effects on the growth and final yield of intercropped maize and beans. The effects of bean density and planting time on bean nodulation , soil nitrogen levels, growth and final yields of maize and beans under intercropping system was investigated at the University of Nairobi, Kabete campus field station, on reddish brown nitosol clay.

Increasing bean density increased bean height but lowered bean biomass significantly during both seasons. Increasing bean density to three or more plants per hill significantly reduced bean nodulation. Planting beans two weeks after maize increased nodulation significantly. There was high nitrogen levels in the soil at flowering time in treatments where beans were planted two weeks before maize as compared to where beans were planted two or four weeks after maize.

Increasing bean density increased bean yields. There was an increase of 116% and 126% in bean yields in treatments having four bean plants per hill compared to those treatments having one bean plant per hill, during the 1993/94 and 1994/95 seasons respectively. The treatments having four bean plants per hill also had the highest land equivalent ratio (LER) of 1.3 in season one and 1.6 in season two. High LER of 1.3 in season one and 1.7 in season two were also obtained in treatments where beans were planted two weeks before maize.

Results during the 1993/94 and 1994/95 seasons showed that bean planting density and time significantly affected the general development of both maize and beans. However, the two factors did not significantly affect the final yields of maize, though that of bean was significantly affected. During the 1993/94 season, beans planted two weeks before maize had the highest yield (1134.4 kgs/ha), compared to treatments where beans were planted at the same time with maize (784.4 kg/ha), two weeks after maize (723.3 kg/ha) and four weeks after maize (402.9 kg/ha) respectively. Beans planted four weeks after maize had the lowest yields. The trend was similar during the 1994/95 season.

From the results it shows that it is more advantageous to plant beans before maize in order to obtain higher bean yields. Upto four bean plants per maize plant can be planted to achieve higher bean yields without affecting maize yield.

CHAPTER ONE

1.0 INTRODUCTION

1.1 IMPORTANCE OF INTERCROPPING IN KENYA

Traditionally, agricultural systems in Kenya are based on growing of crops in mixtures. For most of the small scale farmers, it is necessary that a variety of crops should be grown to allow for a varied diet. The farmer sees mixed cropping as a means of ensuring this diversification. This farming system has been practised for many years and will continue to be practised primarily because population pressure on arable land continue to reduce the land available for each family.

Diets of high nutritive value can be achieved by intercropping in subsistence farming. This is of practical importance in the developing world where diets are deficient in proteins. In Kenya about 80% of the agricultural population derive their diet from mixed cropping subsistence agriculture (Ministry of Agriculture, 1985). This indicates that more research should be redirected in order to promote and recognise the place of mixed cropping systems in Kenya and other developing countries.

The Kenyan small scale farmers have persistently grown their food crops in mixed cropping systems and the practise has even spread to large scale farms and into the cash crops that were formerly 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 and its yield is much higher than that of the legume (Willey,1979).

Intercropping may be one way of increasing land productivity (Cordero and McCollum, 1979). Fisher (1977) reported that mixed cropping of annual crops in tropical regions is a more efficient means of using available land than the pure stands. The level of agricultural productivity in the humid tropics is greatly dependent upon rainfall and solar energy, the low level of solar energy during the rainy months lower yields and this can be offset by intercropping (Gomez and Gomez, 1983). Intercropping also results in better utilization of the environmental resources by plants of different root systems, nutrient requirements, heights and structure (Willey, 1979). Where legumes are grown with the grasses, the grasses may benefit from the nitrogen fixed by the companion legume (Agboola and Fayemi, 1971, Trenbath, 1974).

In any intercropping system the farmer is interested in the land use efficiency. There are a number of methods designed for evaluating the respective intercrop yields and comparing them with the sole crop yields. The common methods include the land equivalent ratio (LER) and area by time equivalent ratio (ATER). LER is the ratio of the area needed under sole cropping to one of intercropping at the same management level to give an equal amount of yield (Willey, 1979). LER was further defined by Mead (1986) as:-

$$\frac{\text{Yield of 'a' in mixture}}{\text{Yield of 'a' in monocrop}} + \frac{\text{Yield of 'b' in mixture}}{\text{Yield of 'b' in monocrop}} = L_a + L_b$$

A value of LER greater than one indicates an overall biological advantage of intercropping. The two components of the total index, La and Lb represent the efficiency of yield production of each crop when grown in a mixture, relative to sole crop performance. Martin, *et al* (1990) reported that LER accounts for potential yield differences of component crops in an intercrop by comparing each crop to itself in monocrop and then summing up the ratios.

1.2 INTERCROPING MAIZE AND BEANS

Intercroping cereals with low canopy legumes is widely practised throughout the tropical world and to a limited extent in some temperate regions. Maize/bean mixture is a predominant cropping system in Central and South America and parts of East Africa, where rainfall ranges from 700mm – 1500mm, spread over a period of four to five months (Francis *et al,* 1982). Both crops are usually planted at the beginning of the rainy season. Where the cropping season is longer, another crop may be planted with residual moisture.

In Kenya, maize (*Zea mays*) is the most important staple cereal for over 90% of the population and is grown in most of the arable parts of the country. The bulk of the production comes from the small scale subsistence farmers. Its popularity arises from its higher yield potential compared to the indigenous cereals in areas with satisfactory rainfall.

The common bean *(Phaseolus vulgaris L)* is the most important grain legume for human consumption in the world. Of the world production of 8.3 million tonnes, 16% is produced in Africa. Bean production is widely distributed in East Africa, being important in all agricultural areas, except at the coast. It is estimated that between 500,000 and 700,000 hectares are covered by beans annually in Kenya (GoK, 1989). As a food crop, beans rank second to maize in Kenya and are grown mainly in intercropping systems by small scale farmers (MoA, 1985). The *per capita* consumption of beans in Kenya has been estimated at 20kg (Mukunya, 1994). This indicate that beans have a substantial contribution to the nutritional balance of the diets of millions of Kenyans, whose purchasing powers do not allow sufficient consumption of animal proteins. Dry beans consist of 22% protein and is rich in amino acids tryptophan and lysine (Purseglove, 1968). The beans therefore play an important role as a potential source of low cost, readily available protein.

Common beans, like other members of the Leguminosae family, have rhizobia in the root nodules, which contribute to the nitrogen nutrition of the bean crop. Thus in intercropping systems involving beans, the other crops in the system may benefit from the nitrogen fixed by beans. Maize is commonly mixed with beans or grown as a sole crop. De Groot (1979) reported that maize is the stronger competitor in the mixture with yields at the same level as in monoculture of maize.

1.3 JUSTIFICATION

Maize *(Zea mays)* is the main subsistence crop in Kenya and it is grown in most agricultural areas in the country. Nitrogen is an important nutrient required for maize production and needs to be supplied in some form, in order to obtain economic maize production.

Due to the high cost of commercial nitrogen fertilizers, most subsistence farmers cannot afford them. On the other hand the large inputs of fertilizer nitrogen and intensive cultivation required by corn, cause soil degradation and environmental damage. The alternative is to rotate legumes and cereals or to intercrop them, thus providing the necessary nitrogen and increasing the dietary protein without affecting the soil. Agboola and Fayemi (1971) reported that legumes such as beans are capable of excreting nitrogen into the soil. The nitrogen can be released either during the growing period or during the decomposition of decaying roots and nodules (Janny and Kletter, 1965). Nitrogen needs of a cereal intercropped with legume were reported to be less than for sole cropping, due to transfer of some of the fixed nitrogen by the legume to the associated cereals during the growing season (Chemining'wa and Nyabundi, 1994).

Eaglesham *et al* (1981) reported that maize grown in association with cowpea in western Nigeria did not respond to fertilizer nitrogen and the ^{15}nitrogen results indicated a nitrogen excreation by cowpea. In another experiment, Akobundu (1980) reported that intercropped maize responded to only 60kg nitrogen ha^{-1} while sole maize responded to 120kg nitrogen ha^{-1} thereby showing nitrogen benefit from the legume. A similar observation was made by Kang, et al (1981) in the case of intercropping of maize in established rows of *Leucaena leucocephala* in alley cropping. The nitrogen excretion by an intercropped legume gives significant benefit to the associated crop only on conditions of low soil mineral nitrogen status (Eaglesham *et al* 1981; Chemining'wa and Nyabundi, 1994). Nitrogen deficient soils often confront farmers in tropical countries where fertilizers are unavailable. So an understanding of the factors influencing nitrogen excretion by mixed cropped legumes may lead to significant increases in associated cereal yields in low fertility conditions.

Some research work (Chemining'wa and Nyabundi, 1994; Chui and Nadar, 1984) has been done on the effects of planting patterns and effects of different inertcrops on yields. However little has been done on the effects of planting time of various legumes. Chui and Nadar (1984) 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. Chemining'wa and Nyabundi (1994) showed that planting beans in the same hole with maize, increased maize yields under conditions of low soil nitrogen but they used a ratio of only one bean plant per maize plant leading to low population of beans and hence low bean yields. Hasselbach and Ndegwa (1982) also showed that planting beans earlier than maize increased both bean and maize yields but they used alternate row and mixed intercropping. Based on the above findings this project was conceived to establish whether increasing the bean density per hole would have any effect on both maize and bean yields. It is also important to establish the best time for planting the legumes in an intercropping system in order to obtain maximum benefit for the associated cereals and thus give better yields.

1.4 OBJECTIVES.

i) to investigate the effects of bean density on yield of maize and bean intercropped in the same hill.

ii) to establish the most appropriate planting time for beans relative to maize, planted in the same hill under intercropping system.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. EFFECTS OF INTERCROPPING ON INTERCROP YIELDS

Intercropping is the growing of two or more crops simultaneously on the same field. The crops are not necessarily sown at exactly the same time and their harvest times may be quite different, but they are usually simultaneous for a significant part of their growing period. This distinguishes it from relay cropping in which growing periods only briefly overlap (Willey, 1979).

Interplanting crops may provide increased production or improved cultural conditions for crop establishment (Beste, 1976). Altieri, *et al* (1987) reported that one main reason why farmers throughout the world choose to use polycultures is that frequently more yield can be harvested from a given area, than when the crops are sown in separate patches. However, some researchers have argued that, high land equivalent ratio values for mixtures of crops with different maturation periods inflate the apparent efficiency of using polycultures, since several shortduration crops may be grown sequentially over the same period of time as a polyculture (Heisbisch and McCollum, 1987).

Intercropping results in higher yield per given season due to more efficient use of the environmental factors, especially where the component crops differ in their resource use and where they complement each other
(Willey, 1979, Singh; 1979) Other important factors that could lead to high yields include, better leaf cover providing protection against soil erosion. Diseases and pests may not spread as rapidly in mixtures because of differential susceptibility to pests and pathogens and because of enhanced abundance and efficiency of natural enemies, (Altieri, *et al,* 1987). Mixtures provide an insurance against total crop failures especially in areas subject to frost, floods or drought. They further reported that polycultures composed of species with spatially complementary rooting patterns can exploit greater volume of soil and have more access to relatively immobile nutrients like phosphorus. Mixtures also result in more efficient use of light, water and other nutrient requirements.

In legume/cereal mixtures fixed nitrogen from the legume is available to the cereals, thereby improving the nutritional quality of the mixture (Izaurralde *et al* 1990). Janny and Kletter (1965) observed that the beneficial effect of intercropping with legume can either be due to nitrogen excreted by the legumes during growth or to nitrogen released during decomposition of decaying roots and nodules. They further noted that the cereals may benefit indirectly, since legumes do not compete with them for nitrogen, owing to variations in their rooting patterns. Norman (1977) reported that cereal/legume mixture is the common form of intercropping practised by most farmers in Nigeria. The advantage of the system is due to the possible increase in availability of nitrogen to the mixed population through fixation by legumes (Fisher, 1977). When fertilizer nitrogen is limited, biological nitrogen fixation (BNF) is the major source of nitrogen in legume/cereal mixed cropping systems. The soil nitrogen use patterns of component crops depend on the nitrogen source and legume species. Nitrogen transfer from legume to cereal increases the cropping systems yield and efficiency of nitrogen use, (Fujita, *et al*, 1992).

The notable crop associations include maize, sorghum, millet with legumes such as soybean, groundnut, beans, mungbeans, cowpea and others. In such associations there are complementary effects between species due to spatial differences in canopy heights and rooting patterns (Willey,1979). Allen and Obura (1983) reported that intercropping systems gave higher yields than the respective monoculture over a wide range of agroclimatic conditions. Because of the higher yields the risks were less with intercropping (Rao and Morgado, 1984). Improved stability of yield is one of the major reasons why intercropping continues to be an extremely important practice in many developing areas of the world (Rao and Willey, 1980). Trenbath (1974) suggested that yield compensation may occur between polyculture component crops, so that failure of one component is offset by increased yields of the other component(s).

Yield variability of cereal/legume mixtures can be less than for monoculture, thus the likelihood of having nothing to eat or sell is apparently less when crop mixtures are used (Altieri, *et al*, 1987). Francis and Sander (1977) working with maize and beans and Rao and Willey (1980) working with sorghum and pigeon peas found that the probability of exceeding a specified disaster income level was greater for polycultures than for monoculture.

The effects of intercropping can either be negative or positive depending on the intercrops used, especially the legume component. Enyi (1973) reported that maize intercropped with either beans or cowpeas had lower yields than maize intercropped with pigeon peas, probably because the high rates of nutrient absorption by the two legumes coincided with uptake of the maize crop, whereas the greatest nutrient demand by pigeon peas occurred after maize had been harvested. Hasselbach (1978) observed that the interplanting of even one row of beans affected maize yield and maize competition reduced bean yields by 49% compared to pure stands.

Another 43% yield reduction of beans was noted by Hasselbach and Ndegwa (1982). Enyi (1973) reported that intercropping reduces leaf area index (LAI) in maize and sorghum, this results in lower fresh weight yields. Beans and cowpeas had a greater effect than pigeon peas. Nadar (1984) reported that maize yields in maize/cowpeas intercrop were reduced by 46% to 57%, mainly due to a severe reduction in average ear weight. It was further noted that intercropping maize with cowpea reduced cowpea branching. The taller component species in an intercrop usually shade the shorter species. Consequently, the shorter component crop yield reductions, in an intercrop system are generally greater than for the taller component.

Willey (1979) reported that yield advantage in intercropping occurs only when component crops differ in their use of growth resources in such a way that they complement each other. He further stated that for maximizing the advantage the degree of complementarily (temporal and spatial) needs to be maximized by selecting crops with minimum or no inter-crop competition. Wanki and Fawusi (1982) reported that varietal selection is an important consideration when planning the intercropping. Mutual shading by component crops especially the taller cereals, reduce biological nitrogen fixation (BNF) and yield of the associated legume. Light interception by the legume can be improved by selecting a suitable plant type and architecture. Planting pattern and population at which maximum yield is achieved also vary among component species and environments (Fujita, et al, 1992).

Singh (1981) reported a yield increase of 10.7% in sorghum intercropped with soybean compared with sole sorghum. However the maximum yield increase was caused by fodder cowpea followed by grain cowpea, green gram and black gram respectively. In maize/bean mixtures, yields of mixtures were higher by 38% than in pure stands, while in the dwarf sorghum/bean mixtures, higher yields of upto 55% in mixtures were recorded compared to pure stands (Osiru and Willey,1977). In studies on intercropping of sorghum with soyabeans, there was 84% yield increase in sorghum intercropped with soyabeans as compared to sole crop (Singh, 1977) cited by Cheminig'wa (1992). The maize/pigeon peas mixtures can be managed similarly to sorghum/pigeon peas mixtures to realise yield advantages from 44% to 80%. Dalal (1974) reported that there can be a 56% advantage for mixed planting of maize and pigeon peas, but an 83% advantage for alternate row intercropping over sole cropping.

2.2. EFFECTS OF PLANTING DENSITY AND PATTERN ON INTERCROP YIELDS.

Many farmers reduce the planting density of the various crop components in an intercropping system, this usually reduce the yield of the components of the respective intercrops as compared to pure stands. Nadar (1984) reported that high population of either maize or beans decrease the potential yield of the component crops per thousand plants, while per unit area, the yield increases. Yunussa (1989) observed that, in most cases the beneficial effects of intercropping are not realised by the farmers because they often plant their crops at suboptimal densities.

In a maize/beans intercropping, maize yield increased with an increase in population density. The optimum plant combination were 40,000 maize plants and 120,000 bean plants per hectare when sown together (Pal *et al,* 1993). In another experiment, Evans (1961) reported that mean yields of sorghum increased significantly with increased sorghum populations, while there were highly significant and appreciable reductions in maize yields as populations were reduced in intercropping systems. Under tropical conditions, maize yield are not significantly affected by increasing bean population, but bean yields are increased significantly due to an increase in pod number per unit land area. However, Margado, (1992) reported that increasing maize density reduce nodulation of beans roots.

Plant population density has been reported to change the response of sorghum to intercropping (Wahwa and Miller, 1977). Similar results were reported for intercropping maize and beans (Willey and Osiru, 1972; Fisher, 1977). High densities in mixtures have been reported to result in large crop yield increases. Under intercropping conditions, the number of days to 50% flowering increased as plant density increased (Fawusi *et al*, 1982). Pal *et al,* (1993) observed that yields of component crops in the intercropping system vary significantly with the components population density. The authors reported that for maximum productivity of sorghum or maize intercropped with soybeans, optimum population of one component crop plus one-third optimum population of the companion crop is recommended, depending on which crop is regarded as the main/minor crop.

In sole maize increasing plant density, increased plant height, number of cobs/m2 and dry matter yield. Average number of kernels per cob was decreased but there was no significant effect of weight of individual kernels (Mandimba, *et al,* 1993). The best yield advantages occur at higher plant population levels. According to Dewit (1960) cited by Lima and Lope (1979), this situation takes place when the individual species utilize slightly different parts of the environment. For many intercropping situations it is believed that better use of resources are made and yield advantages maximized when total population are greater than the optimum for their component sole crops (Yayock, 1979).

Cropping patterns also determine the effectiveness of intercropping. In an experiment where maize and beans were planted together on the same hill, maize yields were 27% higher than those of the sole crop. Agboola and Fayemi (1971) reported that when the maize and beans were 15cm apart in the same row, the yield increase was only 7% but when planted in alternate rows maize yield was lower than that of the sole crop. This is an indication that the excreted nitrogen was almost immobile and that the maize could not benefit from it if the sight of excretion was more than 15cm away from the maize plant.

Chui and Nadar (1984) noted that the association of beans with maize in different spartial arrangements under low fertility conditions indicated that the extent of beneficial effect was positively associated with the proximity of the two intercrops. May and Misangu (1982) further reported that intercropping maize and soybeans or cowpeas in the same hill resulted in consistently larger grain yields than intercropping in alternate hills on the same row. Cheminig'wa (1992) also showed that grain yields of beans planted with maize in the same hill were higher than when planted in alternate holes in the same row. The intensity of the interaction between the component crops depends upon the extent of interplant contact between the individuals of the different components (Chui and Nadar, 1984).

A factor of major importance in the performance of intercrops, therefore is their spartial arrangement, which affect the edaphic interaction and light penetration into the canopies of both taller and shorter components (Chui and Nadar, 1984). The question of intimacy is almost pertinent where legume contribution to the cereal crop is desired because mingling of legumes and cereal roots has been reported to have beneficial effects (Trenbath, 1974). Grouping of crop rows of diverse heights could be advantageous as more solar radiation would be available to the dwarf crop. This has led to the concept of paired row planting (Singh, 1979, 1981; De *et al*, 1978). It should however be pointed out that the planting pattern lacks the interspecific intimacy that often enhances crop complementarity.

Reddy *et al* (1980) reported that using paired rows increased yields of base crops by between 8.2% and 12.2% in corn in winter and rainy seasons respectively where an increase in yield of sorghum was 44% suggesting that paired row planting was preferable to conventional equidistant planting. They further noted that intercropping in a paired row system helps to increase the economic returns per unit area and time besides making better use of available resources in semi arid tropics.

2.3 EFFECTS OF PLANTING TIME ON MAIZE AND BEAN YIELDS

The planting time of component crops in an intercropping system determines the degree of competition and thus the resulting yields. In order to avoid labour peak constraints during cropping season, Hasselbach and Ndegwa

(1982) suggested that it would be desirable to plant component crops at different times. Beans were planted four weeks before maize, at the same time as maize and one week after maize. It was observed that upto 43% reduction in bean yields could be attributed to interplanted maize over a wide range of mixed cropping trials. They further reported that planting beans one month before maize resulted, not only in the highest total yield per unit area but also in the bean yields. In rainfed cropping system it may not be very practicable to plant beans one month before maize due to unareliablity of rainfall but it is possible when irrigation is used.

In another study Willey and Osiru (1972) used a replacement series of pure maize, two-thirds maize/one-third beans, one-third maize/two-thirds beans and pure beans. They noted that yields of mixtures were upto 25% higher than could be achieved by growing the crops separately, but they further observed that the advantages decreased markedly with delayed planting of beans. At a population mixture, consisting of two-thirds maize/one-third beans, the yield advantage decreased from 20% when beans were planted at the same time with maize to only 2% when beans were planted four weeks after.

Osiru (1974) examined the relative importance of temporal and spatial aspects by delaying the sowing of beans so that the growth patterns of the component crops were closely synchronised. In maize/bean mixtures advantages declined from an average of 23% for simultaneous sowing to an average of 6.3% when the beans were sown one month after maize. In

Sorghum/bean mixtures the comparable effect was a decline of 33% to 10.6%. In another study, Owuor (1977) reported that in a maize/bean mixture, when beans were planted early or at the same time with maize then the bean yields were improved.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE.

A field experiment was conducted over two seasons at the University of Nairobi's Kabete Field Station to study the effect of bean density and bean planting time on growth and yield of maize and beans. The site lies, on latitude 1^0 15' South, longitude 36^0 44' East at an altitude of approximately 1800m above sea level. The area received an annual rainfall of 910.1mm in 1993 and 1020.2mm in 1994. During the experimental period in the two seasons the area had adequate soil moisture, which was supplemented by irrigation whenever moisture was limiting. In season one the maximum temperature was 20.5 ^{0}C and minimum 12.5 ^{0}C, while in season two the maximum temperature was 19.6 ^{0}C and minimum 11.3 ^{0}C. This gave a temperature range of 8.0 ^{0}C and 8.3 ^{0}C in the two seasons respectively. The first season's experiment was carried out between September 1993 and March 1994, while the second season's experiment was carried out between November 1994 and May 1995.

The soils are well drained very deep dark red friable clay, classified as humic nitosols developed from Limuru tracytes parent rock (Michieka, 1977). The soils have moderate organic carbon in the top soil and base saturation is below 50%. The pH range lies between 5.0 and 6.0, the soils are adequately supplied with bases but generally low in phosphorus (Michieka, 1977). Prior to planting in each season the experimental plots were planted to densely broadcast sole maize to deplete the soil of as much nitrogen as possible.

3.2 EXPERIMENTAL TREATMENT AND DESIGN.

Maize hybrid 512 and bean variety GLP –2 were used. In all treatments maize was planted at the same time and maintained at the recommended pure stand spacing of 75cm x 25cm giving maize plant population of 53,333 plants per hectare. In all the intercropping treatments, maize and beans were planted in same hill. There were four levels of planting time for beans namely: beans planted two weeks before maize (2 WBM),beans planted with maize (0 WBM), beans planted two weeks after maize (2 WAM) and beans planted four weeks after maize (4 WAM). In treatments where beans were planted after maize, the bean seed were pressed into the soil by hand approximately 5cm, equally spaced, around the maize plant. The bean planting density treatments comprised one bean plant per maize plant (53,333 bean plants per hectare), two bean plants per maize plant (106,666 bean plants per hectare), three bean plants per maize plant (159,999 bean plants per hectare) and four bean plants per maize plant (213,332 bean plants per hectare). These bean planting densities have been abbreviated elsewhere in text as 1 BP/hill, 2BP,3BP and 4BP/hill respectively.

The pure bean treatment was planted at the same spacing (75cm x 25cm) as the intercropping beans with four plants per hill. It therefore had the same bean population and clumping pattern as the highest intercropped density. It is significant that the population was within the range recommended for pure beans though with different clumping arrangement. The pure bean plants were planted for each treatment of bean planting time in order to separate any environmental effects of time of planting from those of interspecific competition.

At the same time a parallel crop of pure beans spaced at 46.9cm x 10cm with one plant per hill was planted. This gave approximately same plant population as the clumped pure beans (75cm x 25cm with four plants per hill), but was representative of the recommended practice.

The experiment was arranged in 4 x 4 factorial structure laid out as completely randomized block design with three replicates. Experimental plots measured 4.5m x 3.5m.

3.3. GENERAL CROP HUSBANDRY

The field was ploughed and harrowed using a disc plough and harrow respectively, to obtain a moderate tilth in the seed bed. The trash was removed and the area levelled to avoid the effect of depressed areas in the site. The plots were then marked out and furrows made 75cm apart in the plots. Triple Super Phosphate was applied to the furrows at a rate of 20kg P/ha and thoroughly mixed with soil before planting The seeds were placed along the furrows at an interval of 25cm, at the appropriate time. The number of bean seeds also varied depending on the treatment. In all the treatments an extra seed was planted and thinning was done 15 days after emergence, this was done to ensure the correct number of bean plants per hill. The bean plants varied from one to four plants per hill. For maize, two seeds were placed per hole and thinned to one plant per hole, 15 days after emergence. For the 46.9cm x 10cm pure beans, the furrows were made 46.9cm a part and the seeds placed at an interval of 10cm along the furrow.

Before planting the seeds were dressed using malathion 50% (a broad spectrum contact organophosphate) at the rate of 10g per kilogramme of seed to control cutworms and beanfly (*Melanogromyza* spp). Starting from one week after emergence the young bean seedlings were sprayed with Dimethoate 40%EC (systemic insecticide/arcaricide) at a dilution rate of one litre in 500 litres of water per hectare to control bean fly on the aerial parts of the plants. This was done at weekly intervals upto flowering stage.

After flowering Ambush (systemic insecticide) was sprayed at weekly intervals, at the dilution rate of 100mls per 20 litres of water to control flower eating insects. Two days after every spray of insecticides, Benomyl (a systemic fungicide) was sprayed at the dilution rate of 20g per 20 litres of water to control bean rust and other fugal diseases. Four weeks after emergence of maize, Bullock (systemic pyrethroid insecticide) was applied to the funnel of each maize plant at the rate of 0.2g/plant for the control of maize stalk borer. The plots were kept weed free manually and irrigation was applied as needed. The two crops were harvested by hand at maturity, 110 days for beans and 150 days for maize. Bean and maize yields were then adjusted to 14% and 15% moisture content respectively, by sun drying.

3.4 EXPERIMENTAL MEASUREMENTS AND OBSERVATIONS

The parameters measured included plant growth and biomass of maize and bean plants at two weeks intervals starting from week eight. Bean nodule numbers and weight were also monitored on the first four bean biomass sampling episodes. The final grain yield of both maize and beans was also taken at harvesting. Soil nitrogen in the rooting zone was determined at maize flowering time and at maize harvesting time. The soil samples were taken from all the plots which were exposed to the various treatments and then compounded according to bean planting time, thus resulting in four soil samples. Before planting during the two seasons composite soil samples were taken at random from the experimental site at a depth of 30cm. Soil pH was measured using a glass electrode, while the nitrogen content was determined using the Kjeldahl method. The Kjeldahl distillates were collected in 0.1N. H_2SO_4 and the excess acid was back titrated with 0.1N NaOH. The organic carbon content was determined using the Walkley –Black procedure which measure active/decomposable organic matter in the soil.

3.4.1 PLANT GROWTH AND BIOMASS DEVELOPMENT

Sampling for biomass development began eight weeks after emergence of maize and continued after every two weeks until fourteen weeks after emergence for maize. For beans the sampling period lasted from four weeks after emergence to ten weeks after emergence. At each sampling episode, plants of each crop component falling within 1m length were harvested. The sampling was done systematically and sequentially starting with outer rows. This was necessary to avoid creation of too many gaps within the field. Both maize and bean plants were cut at ground level. The bean roots were subsequetly carefully dug out and washed to reveal the nodules. The heights of both maize and bean plants were taken and the nodules also counted. The plants were then chopped and put in bags, the nodules were put in envelopes. The plant materials were oven dried at 80^0 C to constant weight, after which the dry matter and the nodule weight were taken.

3.4.2. GRAIN YIELD

At the end of the season thirty maize plants were sampled at random from the three centre rows of each plot for grain yield determination. All the bean plants falling within the same centre rows were harvested from each plot. The maize and bean crops were shelled and threshed respectively then the resulting grains were sun dried before weighing. The weights were obtained for each plot separately, after which averages for the respective treatments were obtained and extra polated to give yields per hectare for both maize and bean respectively

3.5. DATA ANALYSIS

Analysis of variance (ANOVA) and appropriate statistical tests of significance were applied to the data. The data was analysed using the general linear models (GLM) procedure of statistical analysis system (SAS) (SAS Institute, 1988). The GLM was chosen in this case, because the data set had some missing values, due to the cropping system used and the fact that data from each crop was analysed separately. The mean separations were done using Duncan's Multiple range test as described by Steel and Torrie (1980). The level of significance used for the test was 5%.

3.6 SOIL ANALYSIS

Soil samples from the experimental site were analysed before planting, in order to determine the nitrogen content and the amount of organic matter in the soil. At maize flowering and harvesting times more soil samples were taken for analysis of nitrogen and carbon contents. The soil samples were taken from all the plots which were exposed to the various treatments and then compounded according to the time of planting beans, resulting in four soil samples.

CHAPTER FOUR

4.0 RESULTS

4.1 SOIL CHEMICAL PROPERTIES

Results of soil analysis are shown (tables 1B and 1C). The soil nitrogen content before planting was 0.2% and the carbon content was 2.57%. At maize flowering time the plots where beans were planted two weeks before maize had the highest nitrogen content. On the other hand, the plots where beans were planted four weeks after maize had the lowest nitrogen content at maize flowering time but the highest nitrogen content at harvesting time.

Table 1A: ANALYSIS OF SOIL NITROGEN AND CARBON BEFORE PLANTING

Soil	pH		
H_2O	$CaCl_2$	% N	%C
6.8	5.94	0.2	2.57

Table 1B: ANALYSIS OF SOIL NITROGEN AND CARBON AT MAIZE FLOWERING TIME.

	Soil H_2O	Ph $CaCl_2$	% N	%C
2 WBM	6.30	5.10	0.30	2.33
0 WBM	6.30	5.00	0.29	2.56
2 WAM	6.30	5.00	0.26	2.71
4 WAM	5.63	5.10	0.22	2.79

Table 1C: **ANALYSIS OF SOIL NITROGEN AND CARBON AT MAIZE HARVESTING TIME.**

	SOIL H_2O	pH $CaCl_2$	% N	%C
2 WBM	6.82	6.04	0.31	3.28
0 WBM	6.78	5.89	0.34	3.32
2 WAM	6.91	6.14	0.38	3.94
4 WAM	5.99	6.12	0.39	4.05

2 WBM - Beans planted two weeks before maize
0 WBM - Beans planted with maize on the same date
2 WAM - Beans planted two weeks after maize
4 WAM - Beans planted four weeks after maize

4.2 EFFECT OF BEAN PLANTING DENSITY AND TIME ON MAIZE HEIGHT

Bean planting density and time significantly affected maize height eight weeks after emergence of maize during season one (Table 2A). Planting beans two weeks before maize significantly reduced maize height compared to planting the beans two and four weeks after maize respectively. Planting three or less beans in the same hill with maize had no significant effect on maize height as compared to pure maize however, increasing the number of beans to four plants per hill significantly reduced maize height compared to pure maize.

During the second season (Table 2B) time of planting beans had no significant effect on maize height eight weeks after maize emergence compared to pure maize. Planting three or four beans per hill with maize, significantly reduced maize height.

Between similar treatments maize plants were shorter during season two compared to season one. The same trend was observed during sampling at fourteen weeks after maize emergence in both seasons.

Table 2A: **Effect of Bean Planting Density and Time on Maize height (cm) at Eight weeks after emergence of Maize (season one)**

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	113.0	-	-	113.0^{A}
1BP/hill	88.9	103.3	122.2	120.0	108.6^{A}
2BP/hill	84.0	102.7	118.1	107.6	103.1^{A}
3BP/hill	78.3	101.1	117.3	97.2	93.5^{AB}
4BP/hill	70.9	99.0	108.7	95.6	95.5^{B}
PLANTING TIME - MEANS	80.5^{B}	103.8^{AB}	116.6^{A}	105.1^{A}	

C.V. -24.6% SE $\pm$ 3.4

Table 2B: **Effect of Bean Planting Density and Time on maize height (cm) at Eight weeks after emergence of Maize (season two)**

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	73.5	-	-	73.5^{A}
1BP/hill	66.8	66.3	72.8	68.8	68.7^{A}
2BP/hill	66.7	65.0	63.2	62.7	64.4^{AB}
3BP/hill	66.2	59.5	62.7	62.5	62.7^{B}
4BP/hill	65.8	58.3	60.0	54.7	59.7^{B}
PLANTING TIME - MEANS	66.4^{A}	64.5^{A}	64.7^{A}	62.2^{A}	

C.V. - 16.1% S.E. $\pm$ 1.5

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

1BP/hill - 1 bean plant/hill
2BP/hill - 2 bean plants/hill
3BP/hill - 3 bean plants/hill
4BP/hill - 4 bean plants/hill

2WBM - 2 weeks before maize
OWBM - same time with maize
2WAM - 2 weeks after maize
4WAM- 4 weeks after maize

Table 2C: Effect of Bean Planting Density and Time on maize height (cm) at Fourteen weeks after emergence of Maize (season one)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	236.7	-	-	236.7^{A}
1BP/hill	187.3	218.2	259.2	248.3	228.3^{A}
2BP/hill	171.2	193.3	236.7	210.2	202.8^{B}
3BP/hill	155.8	188.3	231.7	202.5	194.6^{B}
4BP/hill	137.5	170.8	217.7	200.0	181.5^{B}
PLANTING TIME - MEANS	163.0^{B}	201.5^{A}	236.3^{A}	215.3^{A}	

C.V. - 21.3% S.E. $\pm$ 6.1

Table 2D: Effect of Bean Planting Density and Time on maize height (cm) at Fourteen weeks after emergence of Maize (Season two)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	223.3	-	-	223.3^{A}
1BP/hill	182.7	216.0	260.0	250.7	229.8^{A}
2BP/hill	188.3	216.0	234.7	241.3	220.1^{A}
3BP/hill	187.3	208.0	227.0	220.7	210.8^{A}
4BP/hill	180.0	205.7	215.0	219.7	205.1^{A}
PLANTING TIME - MEANS	187.1^{B}	213.8^{A}	234.2^{A}	233.1^{A}	

C.V - 16% S.E. $\pm$ 4.9

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

1BP/hill - 1 bean plant/hill
2BP/hill - 2 bean plants/hill
3BP/hill - 3 bean plants/hill
4BP/hill - 4 bean plants/hill

2WBM - 2 weeks before maize
0WBM - same time with maize
2WAM - 2 weeks after maize
4WAM- 4 weeks after maize

4.3 EFFECT OF BEAN PLANTING DENSITY AND TIME ON MAIZE BIOMASS

Bean planting density and time significantly affected maize biomass eight weeks after maize emergence during season one (Table 3A). Planting two or more bean plants per hill significantly reduced maize biomass as compared to pure maize . However planting one bean plant per hill had no significant effect on biomass. Planting of beans two weeks before maize significantly reduced maize biomass as compared to planting two and four weeks after maize respectively.

During season two (Table 3B) planting beans two weeks before maize significantly reduced maize biomass. The highest biomass was obtained where beans were planted four weeks after maize. Planting three or four bean plants per hill with maize significantly reduced maize biomass.

A similar trend was observed during sampling done, on maize biomass, twelve weeks after maize emergence in season one (Table 3C). However in season two (Table 3D) both bean planting time and density had no significant effect on maize biomass. In both season one and two maize in treatments where beans were planted two and four weeks respectively after maize had higher biomass as compared to treatments where beans were planted two weeks before maize. The maize plant in treatments having four bean plants per hill had the lowest biomass accumulation at all sampling times during both seasons.

Table 3A: Effects of Bean Density and Planting Time on Maize Dry Weight (g/plant) Eight weeks after emergence of Maize, (season one).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	63.8	-	-	63.8^{A}
1BP/hill	35.0	48.2	94.0	67.9	61.3^{A}
2BP/hill	19.6	47.4	65.1	54.1	46.6^{B}
3BP/hill	18.3	47.0	51.7	50.9	42.0^{B}
4BP/hill	15.2	37.4	50.5	45.6	37.2^{B}
PLANTING TIME - MEANS	22.0^{C}	48.8^{B}	65.3^{A}	55.6^{AB}	

C.V - 21% S.E. ± 4.1

Table 3B: Effect of Bean Planting Density and Time on maize Dry weight at (g/plant) Eight weeks after emergence of Maize (season two)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	21.5	-	-	21.5^{A}
1BP/hill	8.0	20.5	17.5	28.9	$18.^{A}$
2BP/hill	5.0	11.5	16.4	26.5	$14.^{AB}$
3BP/hill	3.8	10.1	14.2	23.6	12.9^{B}
4BP/hill	3.6	6.5	12.9	15.1	9.5^{B}
PLANTING TIME - MEANS	5.1^{C}	14.1^{B}	15.2^{AB}	23.5^{A}	

C.V - 21% S.E. ± 1.4

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

1BP/hill - 1 bean plant/hill	2WBM	- 2 Weeks before maize	
2BP/hill - 2 bean plants/hill	OWBM	- Same time as Maize	
3BP/hill -3 bean plants/hill	2WAM	- 2 Weeks after Maize	
4BP/hill - 4 bean plants/hill	4WAM	- 4 Weeks after Maize	

Table 3C: **Effect of Bean Planting Density and Time on Maize Dry Weight (g/ plant) Twelve weeks after emergence of Maize (season one)**

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	116.8	-	-	116.8^{A}
1BP/hill	82.8	113.0	94.9	173.8	116.1^{A}
2BP/hill	50.4	86.7	91.0	115.7	85.9^{B}
3BP/hill	46.8	63.5	89.1	101.1	75.1^{B}
4BP/hill	43.0	62.7	68.1	73.6	61.9^{B}
PLANTING TIME - MEANS	53.4^{C}	88.5^{B}	85.8^{B}	116.0^{A}	

C.V. - 20% S.E. ± 4.4

Table 3D: **Effect of Bean Planting Density and Time on Maize Dry Weight (g/ plant) Twelve weeks after emergence of Maize (season two)**

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	95.9	-	-	95.9^{A}
1BP/hill	83.6	94.8	97.6	95.0	92.7^{A}
2BP/hill	83.1	85.8	94.0	93.6	86.2^{A}
3BP/hill	79.5	84.3	91.0	90.2	86.3^{A}
4BP/hill	79.9	81.4	90.5	82.4	83.3^{A}
PLANTING TIME - MEANS	81.3^{A}	88.4^{A}	93.3^{A}	90.3^{A}	

C.V. - 11% S.E. ± 1.3

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

1BP/hill - 1 bean plant/hill	2WBM	- 2 Weeks before maize
2BP/hill - 2 bean plants/hill	0WBM	- Same time as Maize
3BP/hill -3 bean plants/hill	2WAM	- 2 Weeks after Maize
4BP/hill - 4 bean plants/hill	4WAM	- 4 Weeks after Maize

4.4 EFFECTS OF BEAN PLANTING DENSITY AND TIME ON BEAN HEIGHT.

Planting beans two weeks after maize significantly increased bean height compared to planting beans two weeks before maize, at the same time with maize and four weeks after maize during season one (Table 4A). Planting three or four bean plants per hill together with maize significantly increased bean height compared to pure beans.

In season two (Table 4B) planting beans two or four weeks after maize significantly reduced bean height compared to planting beans two weeks before or at the same time with maize respectively. Increasing bean density to four beans per hill significantly increased bean height as compared to the rest of bean planting density treatments.

Bean density and planting time had similar effect on bean height during both seasons.

Table 4A: Effect of Bean Planting Density and Time on Bean height (cm) Ten weeks after Bean emergence (season one)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	31.1	27.4	36.2	29.2	31.0^{B}
1BP/hill	31.4	30.4	44.2	30.1	34.0^{B}
2BP/hill	32.5	30.8	46.5	33.1	35.7^{AB}
3BP/hill	33.5	32.1	46.7	39.8	38.0^{A}
4BP/hill	35.4	35.29	49.1	40.1	40.0^{A}
PLANTING TIME - MEANS	32.8^{B}	31.2^{B}	44.5^{A}	34.4^{B}	

Table 4B: Effect of Bean Planting Density and Time on Bean height (cm) Ten weeks after Bean emergence (season two)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure bean	33.4	30.7	19.5	25.0	27.2^{B}
1BP/hill	29.5	26.2	25.8	25.0	26.6^{B}
2BP/hill	35.3	31.6	26.0	27.5	30.1^{B}
3BP/hill	37.4	33.0	27.3	29.7	31.9^{B}
4BP/hill	41.9	35.5	36.2	30.2	36.0^{A}
PLANTING TIME - MEANS	35.5^{A}	31.4^{A}	27.0^{B}	27.5^{B}	

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

1BP/hill - 1 bean plant /hill 2WBM - 2 weeks before maize
2BP/hill - 2 bean plants/hill 0WBM - same time as maize
3BP/hill -3 bean plants/hill 2WAM - 2 weeks after maize
4BP/hill - 4 bean plants/hill 4WAM - 4 weeks after maize

4.5 EFFECTS OF BEAN PLANTING DENSITY AND TIME ON BEAN BIOMASS

Planting time and density of beans significantly affected bean biomass. During season one planting beans two and four weeks after maize reduced bean biomass as compared to planting beans two weeks before and at the same time with maize (Table 5A). The highest significant bean biomass was obtained when beans were planted two weeks before maize. Increasing bean density to three or four plants per hill with maize significantly reduced bean biomass compared to pure bean stand.

In season two, (Table 5B) time of planting beans significantly affected bean biomass. Beans planted two or four weeks after maize had signifcantly lower biomass compared to those planted two weeks before or at the same time with maize respectively. Increasing bean density to two, three or four bean plants per hill also reduced the biomass.

A similar trend was observed in both seasons, however during the second season the bean plants, planted four weeks after maize had the lowest biomass.

Table 5A: Effects of Bean Planting Density and Time on Bean Dry weight (g/plant) Ten weeks after bean emergence- (season one)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	26.1	15.2	13.2	10.1	16.2^{A}
1BP/hill	19.5	14.9	12.6	4.6	12.9^{A}
2BP/hill	19.4	13.2	6.3	4.0	10.7^{AB}
3BP/hill	18.3	9.9	5.2	3.9	9.3^{B}
4BP/hill	13.0	9.6	4.0	3.8	7.6^{B}
PLANTING TIME - MEANS	19.3^{A}	12.5^{B}	8.3^{C}	5.3^{C}	

Table 5B: Effects of Bean Planting Density and Time on Bean Dry weight (g/plant) Ten weeks after bean emergence- (season two)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	14.2	20.2	8.0	3.9	11.6^{A}
1BP/hill	14.0	17.0	6.7	3.1	10.2^{A}
2BP/hill	12.8	9.7	6.7	2.3	7.9^{B}
3BP/hill	12.0	8.0	6.6	2.0	7.2^{B}
4BP/hill	10.8	6.6	5.1	1.6	6.0^{B}
PLANTING TIME - MEANS	12.8^{A}	12.3^{A}	6.6^{C}	2.6^{C}	

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

1BP/hill - 1 bean plants/hill   2WBM - 2 weeks before maize
2BP/hill - 2 bean plants/hill   0WBM - same time as maize
3BP/hill -3 bean plants/hill   2WAM - 2 weeks after maize
4BP/hill - 4 bean plants/hill   4WAM - 4 weeks after maize

4. 6 EFFECTS OF BEAN PLANTING DENSITY AND TIME ON NODULES PER PLANT

Bean planting time and density significantly affected bean nodulation. During season one intercropping beans and maize in the same hill significantly increased bean nodulation over pure stand of beans. However, nodulation decreased with increase in the number of beans per hill. The bean plants in treatments having one or two plants per hill had the highest number of nodules. Planting beans two weeks or four weeks after maize increased bean nodulation (Table 6A).The lowest and highest bean nodulation was obtained in treatments where beans were planted at the same time with maize and two weeks before maize respectively.

During season two (Table 6B) the bean plants in the treatment having four plants per hill with maize, registered low nodulation which was not significantly different from pure beans.The bean plants planted two weeks before maize during the second season had the lowest number of nodules per plant.

The trend in both seasons was similar and the bean plants in the pure bean treatment had the lowest number of nodules per plant.

Table 6A: Effects of Bean planting Density and Time on Nodule/Plant

Ten weeks after emergence of Beans - (season one.)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	18.0	9.0	15.0	13.0	14.0[C]
1BP/hill	65.0	16.0	27.0	30.0	35.0[A]
2BP/hill	60.0	15.0	26.0	26.0	32.0[A]
3BP/hill	30.0	13.0	17.0	20.0	20.0[B]
4BP/hill	23.0	13.0	15.0	18.0	17.0[BC]
PLANTING TIME - MEANS	39.0[A]	13.0[C]	20.0[B]	21.0[B]	

Table 6B: Effects of Bean planting Density and Time on Nodule/Plant Ten weeks after emergence of Beans - (season two)

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	4.0	9.0	19.0	16.0	12.0[C]
1BP/hill	20.0	37.0	30.0	40.0	32.0[A]
2BP/hill	9.0	36.0	28.0	35.0	27.0[B]
3BP/hill	7.0	34.0	23.0	27.0	23.0[B]
4BP/hill	5.0	18.0	20.0	18.0	15.0[C]
PLANTING TIME - MEANS	9.0[B]	27.0[A]	24.0[A]	27.0 [A]	

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

1BP/hill - 1 bean plants/hill   2WBM - 2 weeks before maize
2BP/hill - 2 bean plants/hill   0WBM - same time as maize
3BP/hill -3 bean plants/hill   2WAM - 2 weeks after maize
4BP/hill - 4 bean plants/hill   4WAM - 4 weeks after maize

4.7 EFFECTS OF BEAN PLANTING DENSITY AND TIME ON MAIZE AND BEAN YIELDS.

4. 7. 1: MAIZE YIELDS.

Bean planting time had a significant effect on final yield of maize in season one (Table 7A). Beans planted two weeks before maize had a signifcant depressing effect on maize yields compared to other treatments where beans were planted at the same time with maize, two weeks and four weeks after maize respectively. The resulting yields in the last three treatments had no significant difference from one another. Likewise interplanting beans in the same hill with maize had a significant depressing effect on maize yield as compared to pure maize treatment.

During season two both bean planting time and density did not have any significant effect on the final maize yield (Table 7B). The maize yields during this season were generally higher than in season one.

Table 7A: EFFECTS OF BEAN PLANTING DENSITY AND TIME ON MAIZE YIELDS (Kg/ha) (season one).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	8592.5	-	-	8592.5^{A}
1BP/hill	5694.8	6554.1	6945.1	6554.1	6437.0^{B}
2BP/hill	5967.4	7198.5	7277.0	7952.5	7098.8^{B}
3BP/hill	3994.1	6173.3	6459.2	6802.9	5857.4^{B}
4BP/hill	3994.1	5810.3	6459.2	6459.2	5680.7^{B}
PLANTING TIME - MEANS	4912.6^{B}	6865.7^{A}	6785.1^{A}	6942.2^{A}	

C.V. - 24%   S.E. $\pm$ 219.1

Table 7B: EFFECTS OF BEAN PLANTING DENSITY AND TIME ON MAIZE YIELDS (Kg/ha) (season two).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure maize	-	9067.0	-	-	9067.6^{A}
1BP/hill	9244.0	7911.0	9067.0	9422.0	8911.0^{A}
2BP/hill	9333.0	8800.0	9511.0	9867.0	9378.0^{A}
3BP/hill	9067.0	8533.0	8622.0	8889.0	8778.0^{A}
4BP/hill	7911.0	8445.0	8267.0	7733.0	8089.0^{A}
PLANTING TIME - MEANS	8889.0^{A}	8551.0^{A}	8867.0^{A}	8978.0^{A}	

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

1BP/hill	- 1 bean plant /hill	2WBM	- 2 weeks before maize
2BP/hill	- 2 bean plants/hill	0WBM	- same time as maize
3BP/hill	-3 bean plants/hill	2WAM	- 2 weeks after maize
4BP/hill	- 4 bean plants/hill	4WAM	- 4 weeks after maize

4.7.2:- BEAN YIELD

During season one, planting time had a significant effect on final bean yield (Table 8A). The yields decreased as the planting time was delayed with those planted four weeks after maize giving the lowest yields. The bean plants planted two weeks before maize had the highest significant yield.

Bean planting density also had a significant effect on resulting yields. Increased bean density significantly increased the yields, with treatments having four bean plants per hill giving the highest yields,which were comparable to pure bean stand.

The trend was similar in season two (Table 8B). There were higher yields in season two as compared to season one.

Table 8A: **EFFECTS OF BEAN PLANTING DENSITY AND TIME ON BEAN YIELDS (Kg/ha) (season one).**

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	1600.4	1150.2	870.1	812.1	1108.2^{A}
1BP/hill	634.9	500.6	587.1	180.8	475.9^{C}
2BP/hill	690.9	742.2	740.5	236.5	670.0^{BC}
3BP/hill	1426.4	895.3	740.5	414.6	869.2^{AB}
4BP/hill	1515.3	1001.1	825.0	779.7	1030.3^{A}
PLANTING TIME - MEANS	11734.6^{A}	857.9^{B}	752.6^{B}	484.7^{C}	

C.V. - 29.5% S.E. ± 65

Table 8B: EFFECTS OF BEAN PLANTING DENSITY AND TIME ON BEAN YIELDS (Kg/ha) (season two).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
Pure beans	3214.1	3112.3	2240.3	1400.2	2491.0^{A}
1BP/hill	1739.7	1180.2	1098.3	3991.5	1002.4^{C}
2BP/hill	2419.0	1659.0	1210.1	583.8	1468.0^{BC}
3BP/hill	2531.2	2391.3	1834.6	575.5	1833.2^{AB}
4BP/hill	53060.3	3099.7	2134.7	786.4	1270.3^{A}
PLANTING TIME - MEANS	2592.9^{A}	2288.5^{AB}	1703.6^{B}	747.5^{C}	

C.V. 26.9% S.E. ±143.7

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

1BP/hill - 1 bean plant /hill — 2WBM - 2 weeks before maize
2BP/hill - 2 bean plants/hill — 0WBM - same time as maize
3BP/hill -3 bean plants/hill — 2WAM - 2 weeks after maize
4BP/hill - 4 bean plants/hill — 4WAM - 4 weeks after maize

4.8: EFECTS OF BEAN PLANTING DENSITY AND TIME ON LAND EQUIVALENT RATIO (LER)

The yield obtained from from the intercropped treatments were evaluated using the Land Equivalent Ratio (LER). Both bean planting time and planting density had a significant influence on the resulting LER as shown by ANOVA (Appendices 14 and 15)

Highest LER Values were obtained from treatments where beans were planted two weeks before maize and where there were four bean plants per hill (Table 9A and 9B). Generally the LERs in season two were higher than in season one.

During both seasons treatments where there was only one bean plant per hill had the lowest LER, however they still had yield advantage over monocropping. Planting time of beans had no significant effect on LER during season one.

Table 9A: EFFECTS OF BEAN PLANTING DENSITY AND TIME ON LAND EQUIVALENT RATIO (LER) (season one).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
1BP/hill	1.1	1.1	1.1	0.9	1.0^{C}
2BP/hill	1.3	1.1	1.3	1.1	1.3^{AB}
3BP/hill	1.4	1.2	1.2	1.1	1.2^{B}
4BP/hill	1.4	1.3	1.3	1.2	1.3^{A}
PLANTING TIME - MEANS	1.3^{A}	1.2^{A}	1.2^{A}	1.3^{A}	

Table 9B: EFFECTS OF BEAN PLANTING DENSITY AND TIME ON LAND EQUIVALENT RATIO (LER) (season Two).

BEAN PLANTING DENSITY	BEAN PLANTING TIME				PLANTING DENSITY MEANS
	2WBM	0WBM	2WAM	4WAM	
1BP/hill	1.5	1.2	1.3	1.2	1.3^{B}
2BP/hill	1.7	1.5	1.4	1.4	1.5^{A}
3BP/hill	1.7	1.6	1.5	1.3	1.5^{A}
4BP/hill	1.7	1.8	1.5	1.3	1.6^{A}
PLANTING TIME - MEANS	1.7^{A}	1.5^{AB}	1.4^{BC}	1.3^{C}	

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

1BP/hill - 1 bean plants/hill	2WBM	- 2 weeks before maize
2BP/hill - 2 bean plants/hill	OWBM	- same time as maize
3BP/hill -3 bean plants/hill	2WAM	- 2 weeks after maize
4BP/hill - 4 bean plants/hill	4WAM	- 4 weeks after maize

CHAPTER FIVE

5.0 DISCUSSION

Increasing bean density from one plant to four plants per hill did not significantly affect maize yields, but bean yields increased with increased bean density. Morgado (1992) reported that under tropical conditions maize yields are not affected by increasing bean population, but bean yields are increased due to increased pod numbers per unit area. Pal *et al* (1993) reported that yield of component crops in intercropping system vary significantly with component crop density. In this experiment there was an increase of 116% and 126% in the bean yields in treatments having four bean plants per hill compared to treatments having one bean plant per hill in the two seasons respectively. The said treatments also had the highest LER of 1.3 and 1.7 respectively and thus giving the best yield advantage. Increasing the plant density increased bean plant height, in treatments having two, three or four bean plants per hill respectively, but the dry weight of the plants was decreased.

The relative planting time of the component crops in an intercropping system determines the degree of competition and thus resulting yields. In this study bean planting time was staggered over six weeks; this significantly affected the resulting bean yields but had no effect on the final maize yields. Beans planted two weeks before maize had the highest yields as compared to those planted at the same time with maize, two weeks after maize and one month after maize. There was a significant reduction in bean yields as the planting time was delayed and yield decrease was also observed in pure beans. Those planted one month after maize had the lowest yields. There was a yield reduction of 64.5% and 76% in the two seasons respectively as compared to the beans planted two weeks before maize.

Hasselbach and Ndegwa (1980) reported that planting beans four weeks before maize gave the best yield results for beans. Willey and Osiru (1972) observed that the intercropping advantages decreased markedly with delayed planting of beans. Osiru (1974) reported a yield advantage decrease from 20% when beans were planted at the same time with maize to only 2% when beans were planted four weeks after. Similarly Osiru (1974) reported that in maize/bean mixtures yield advantages declined from an average of 23% for simultaneous sowing to an average of 6.3% when beans were sown one month after maize. Planting beans four weeks after maize, not only affected beans in the intercrop treatments but even the beans in pure stands had reduced yields. Despite the weekly spraying and other crop husbandry measures taken, the late planted beans still had more problems with insects and diseases. In view of this it is advantageous to plant beans early in the season because the bean plants escape several diseases which occur late in the season and at the same time it is also good for the maize plants which benefit from the early fixed nitrogen, especially where farmers do not use nitrogen fertilizers.

The soil nitrogen analysis results prove that the beans planted two weeks before maize were able to fix nitrogen earlier than the later planted beans. At maize flowering time the soil samples from plots in which beans were planted two weeks before maize had the highest nitrogen content and those where beans were planted four weeks after maize had the lowest nitrogen content. At harvesting time the reverse was true.

These results suggest that the fixed nitrogen coming from treatments in which beans were planted two weeks before maize was more exhaustively used than from the treatment in which beans were planted four weeks after maize. Planting of beans before maize depressed growth of maize plants early in the season but the maize plants pulled up after the maturity of the beans resulting in no yield loss in season two. In season one the maize plants in this treatment recorded significantly lower yields, however in both seasons the high bean yields associated with planting beans before maize produced the highest field productivity as reflected in LER values. Where the beans were planted late, their growth was significantly affected due to the shading by the already established taller component crop and the competition for the available nutrients, which affects their biological nitrogen fixing ability, Fujita *et al* (1992).

The nitrogen excretion by an intercropped legume gives significant benefit to the associated crop only on conditions of low soil mineral nitrogen status (Eaglesham *et al* 1981). In this experiment the low mineral nitrogen condition was created by first using pure maize to exhaust the soil nitrogen in the experimental site. Cheminig'wa (1992) reported that the superiority of intercropping maize and beans in the same hole under low nitrogen levels may have been due to enhanced nitrogen-fixation caused by depletion of nitrogen by the maize crop.

CHAPTER SIX

6.0 CONCLUSION

From the observations made and results obtained in this study, it can be concluded that it is beneficial to plant beans earlier than maize in intercropping systems because it results in higher yields from both component crops.

Most farmers in the tropical countries rely on rainfed agriculture and it may not be very possible to plant beans at the beginning of the rains and wait for two or four weeks before planting maize as this would adversely affect maize yields; farmers in areas where irrigation is possible should plant beans earlier than maize but those depending on rainfed agriculture should plant maize and beans together at the beginning of the season for maximum utilization of the rain water. In this study, planting the component crops at the same time gave the second best combined yields.

Nitrogen deficient soils often confront farmers in tropical countries where fertilizers are relatively expensive.So an understanding of the factors influencing nitrogen fixation by mixed cropped legumes may lead to significant increases in associated cereal yields in low fertility conditions. The observations made with respect to yields in this study are of great importance to the small scale farmers who in most cases cannot afford to purchase the nitrogen fertilizers.

The results in this study further demonstrate that it is beneficial to increase the bean density in order to obtain higher bean yields and the total yield per unit area. It should however be noted that such increases in bean density may increase intra-species competition among the bean plants, so the resulting bean seed yield may be more but of poor quality. In this study, the best combination which was used without sacrificing either the yield or seed quality was two bean plants and one maize plant per hill. Nevertheless, Nuh (1996) reported that inoculation of bean seeds with Rhizobium bacteria increased yield of both maize and beans in intercropped situations. Such results indicated that nitrogen fixation may still limit yield development in intercropped beans. It would be interesting to examine the interaction of increased bean: density and inoculation, such interaction may conceivably change the optimal bean; maize density ratio under intercropped conditions.

RECOMMENDATIONS FOR FURTHER RESEARCH

Intercropping is a very important farming practice in Kenya and I wish to recommend the following:-

1. Interaction between bean density and nitrogen fertilizers/Rhizobium inoculation should be examined

2. It is clear from the results of this study that the earlier the beans are planted, the higher the bean yields. Results of Chemining'wa and Nyabundi (1994) indicated that only dead and decomposing bean roots and root nodules released the fixed nitrogen for the benefit of the maize plants. From this observation it is suggested that a study should be conducted using different bean varieties having different maturity durations, to establish the best bean variety to use in the various parts of the country having different rain patterns, considering that beans and maize will have to be planted at the same time.

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APPENDICES

APPENDIX 1: WEATHER DATA DURING THE EXPERIMENTAL PERIOD.

YEAR	MONTH	TOTAL RAINFALL (MM)	TEMPERATURE	
			MAXIMUM	MINIMUM
1993	Oct.	45.4	25.6	13.5
1993	Nov.	101.1	21.1	14.4
1994	Dec.	107.6	23.4	13.6
1994	Jan	9.9	26.0	13.0
1994	Feb	92.8	26.9	12.5
1994	Mar	59.1	26.5	14.4
1994	Apr	247.0	22.8	14.0
1994	May	114.3	22.1	14.0
1994	Jun	19.8	21.7	12.0
1994	Jul	19.3	21.2	11.7
1994	Aug	53.6	27.5	12.0
1994	Sep	3.4	23.9	12.3
1994	Oct	87.8	25.0	14.3
1994	Nov	245.5	22.9	11.3
1994	Dec	67.7	23.1	13.8
1995	Jan	15.1	25.3	12.7
1995	Feb	116.8	26.2	13.0
1995	Mar	168.2	24.1	14.0
1995	Apr	109.7	24.0	15.1
1995	May	210.3	23.2	11.6

APPENDIX 2: ANALYSIS OF VARIANCE FOR MAIZE HEIGHT - (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	4417.9	2209.0	6.8	NS
TIME	3	22832.4	7610.8	23.6	0.000***
DENSITY	3	6960.8	2320.3	7.2	0.0009***
TIME x DENSITY	9	1048.3	116.5	0.4	NS
ERROR	30	9677.1	322.6		
TOTAL	47	44936.6			

CV = 11.3%   SE $\pm$ 4.5

APPENDIX 3: ANALYSIS OF VARIANCE FOR MAIZE HEIGHT (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	151.2	75.6	0.5	NS
TIME	3	4235.9	1412.0	9.4	0.0002***
DENSITY	3	2944.0	981.3	6.5	0.016***
TIME x DENSITY	9	455.7	50.6	0.3	NS
ERROR	30	4522.8	150.8		
TOTAL	47	12309.7			

CV = 9.2%   SE $\pm$ 2.3

NS = NOT SIGNIFICANT

*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 4: ANALYSIS OF VARIANCE FOR MAIZE DRY WEIGHT (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	1079.6	539.8	1.5	NS
TIME	3	16259.3	5419.8	14.7	0.0000***
DENSITY	3	8986.6	2995.5	8.1	0.00004***
TIME x DENSITY	9	379.0	42.1	0.1	NS
ERROR	30	11066.6	368.8		
TOTAL	47	37771.1			

CV = 25.7% SE ± 4.1

APPENDIX 5: ANALYSIS OF VARIANCE FOR MAIZE DRY WEIGHT (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	204.5	102.3	2.0	NS
TIME	3	3236.4	1078.8	21.1	0.0000***
DENSITY	3	1480.5	493.5	9.7	0.0001***
TIME x DENSITY	9	185	20.6	0.4	NS
ERROR	30	1531.2	51.1		
TOTAL	47	6637.7			

CV = 11.8% SE ±1.7

NS = NOT SIGNIFICANT

*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 6: ANALYSIS OF VARIANCE FOR MAIZE YIELD (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	6915701.9	3457850.9	2.6	NS
TIME	3	31040809.9	10346936.6	7.8	0.0005***
DENSITY	3	14788694.4	4929564.8	3.7	0.0218**
TIME x DENSITY	9	4326456.2	480717.4	0.4	NS
ERROR	30	39718058.7	1323935.3		
TOTAL	47				

CV = 18.4%   SE ± 219.1

APPENDIX 7: ANALYSIS OF VARIANCE FOR NODULE WEIGHT (SEASON ONE

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	9681859.3	4840929.6	3.1	NS
TIME	3	2234837.2	744945.7	0.5	NS
DENSITY	3	10223400.4	3407800.1	2.2	NS
TIME x DENSITY	9	5221948.9	580216.5	0.4	NS
ERROR	30	46734794.7	1557826.5		
TOTAL	47	74096840.5			

CV = 14.6%   SE ± 181.1

NS = NOT SIGNIFICANT

** = SIGNIFICANT AT 5% PROBALITY LEVEL
*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 8: ANALYSIS OF VARIANCE FOR BEAN HEIGHT (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	5.8	2.9	0.2	NS
TIME	3	656.6	218.9	12.1	0.000***
DENSITY	4	519.1	129.8	7.28	0.0002***
TIME x DENSITY	12	67.3	7.2	0.3	NS
ERROR	38	685.1	0.3	0.84	
TOTAL	59	1933.8			

CV = 12.8% SE ± 0.7

APPENDIX 9: ANALYSIS OF VARIANCE FOR BEAN HEIGHT (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	108.9	54.3	6.2	NS
TIME	3	3193.5	157.7	121.4	0.0000***
DENSITY	4	630.9	3.1	18.0	0.0000***
TIME x DENSITY	12	37.4	8.8	0.4	NS
ERROR	38	333.1			
TOTAL	59	4303.5			

CV = 10.9% SE ± 1.1

NS = NOT SIGNIFICANT

*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 10: ANALYSIS OF VARIANCE FOR BEAN DRY WEIGHT (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	71.4	35.7	4.5	NS
TIME	3	736.8	245.6	31.1	0.0000***
DENSITY	4	263.0	65.8	8.3	0.0001***
TIME x DENSITY	12	74.8	6.2	0.8	NS
ERROR	38	300.1	7.9		
TOTAL	59	1446.0			

CV = 32.2%   SE ± 0.6

APPENDIX 11: ANALYSIS OF VARIANCE FOR BEAN DRY WEIGHT (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	9.6	4.8	2.3	NS
TIME	3	838.8	279.6	132.6	0.0000***
DENSITY	4	148.2	37.1	17.6	0.0000***
TIME x DENSITY	12	54.7	4.6	2.2	NS
ERROR	38	80.1	2.1		
TOTAL	59	1131.5			

CV = 21.7%   SE ± 0.6

NS = NOT SIGNIFICANT

*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 12: ANALYSIS OF VARIANCE FOR BEAN YIELD (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	877320.2	438660.1	4.9	NS
TIME	3	3235803.2	1078601.1	12.0	0.0000***
DENSITY	3	2085730.3	695243.4	7.7	0.0006***
TIME x DENSITY	9	614808.2	68312.0	0.8	NS
ERROR	30	2707733.4	90257.7		
TOTAL	47	9521395.2			

CV = 29.5%   SE ± 65

APPENDIX 13: ANALYSIS OF VARIANCE FOR BEAN YIELD (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
BLOCK	2	344437.4	172218.7	0.5	NS
TIME	3	23378386.5	7792795.5	20.5	0.0000***
DENSITY	3	8999074.1	2999691.4	7.9	0.0005***
TIME x DENSITY	9	2480942.1	275660.2	0.7	NS
ERROR	30	11388554.3	379618.5		
TOTAL	47				

CV = 26.9%   SE ± 143.7

NS = NOT SIGNIFICANT

*** = SIGNIFICANT AT 1% PROBABILITY LEVEL

APPENDIX 14: ANALYSIS OF VARIANCE FOR LAND EQUIVALENT RATIO (LER) (SEASON ONE)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
TIME	3	0.12081875	0.04027292	18.03	0.0000***
DENSITY	3	0.172867875	0.05762292	25.79	0.0000***
ERROR	9	0.2010625	0.00223404		
TOTAL	15	0.31379375	580216.5		

CV = 12% SE ± 0.04

APPENDIX 15: ANALYSIS OF VARIANCE FOR LAND EQUIVALENT RATIO (LER) (SEASON TWO)

SOURCE	DF	SS	MS	F-VALUE	Pr>F
TIME	3	0.34106875	0.11368958	12.37	0.0000***
DENSITY	3	0.17656875	0.05885626	6.40	0.0000***
ERROR	9	0.08270625	0.00918958		
TOTAL	15	0.60034375			

CV = 14% SE ± 0.1

*** = SIGNIFICANT AT 1% PROBALITY LEVEL.