EFFECT OF INOCULATION AND VARYING BEAN DENSITIES ON BIOMASS AND YIELD OF INTER CROPPED MAIZE AND BEANS

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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DEDICATION

To my beloved mother, Dahabo Egal, and my father, late Mohamed Hassan.

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ABSTRACT

Nitrogen is often the most essential nutrient for maize production, particularly with respect to biomass accumulation, leaf area index and grain yield. However, commercial fertilizers as a source of nitrogen, are becoming increasingly expensive and out of reach of most small scale farmers in the developing countries. To obtain a cheaper alternative source of nitrogen, field experiments were conducted at the University of Nairobi's Faculty of Agriculture farm to investigate the effect of rhizobial inoculation of beans on growth and yield of maize and beans at various bean densities inter-cropped with maize in the same hill and to examine the inter action between inoculation and density of beans inter cropped with maize in same hill.

Two inoculation levels and four bean densities were tested in a factorial experiment laid out in a completely randomised block design with three replicates. The inoculation consisted of non-inoculated and inoculated treatments of beans. The varying bean densities were: One bean plant per hill, two bean plants per hill, three bean plant and four bean plants per hill. Each planting hill also carried one maize plant. Maize variety, Embu (H_{512}) and bean variety GLP-2 were used.

Both bean and maize plants were sampled during the growing season to determine the dry matter yield as well as the nodule number on the bean plants. At the end of the growing cycle, yield and yield components were measured. Soil samples were collected from the hills to determine the percent soil nitrogen in the hills at maize flowering (12 WABE), maize maturity (24 WABE) and one month after maize harvest (28 WABE).

In almost all parameters,results showed that the inoculated treatments were statistically not different from the non inoculated treatments. Bean grain yield increased with increasing bean density while maize yield decreased with increasing bean density. Yield components per plant of both maize and beans decreased with increasing bean density. The increasing bean density did not significantly affect the percent soil nitrogen at all stages of soil sampling. The interaction between inoculation and bean density treatments was not significant.

CHAPTER ONE

INTRODUCTION

1.1 Prevalence and importance of intercropping in the tropics.

Intercropping or mixed cropping is defined as mixing or interplanting of a number of different crops on the same piece of land at the same time. This practice is believed to be centuries old and traditionally very common in many parts of the tropics Intercropping is the most popular crop production system used in subsistence tropical agriculture (willey 1979) It is widely practised among farmers in Asia and Africa (Andrews and Kassam, 1979) Depending on the agroculimatic variations, 50-80 percent of rainfed crops are planted as intercrops in different parts in the developing countries. (Norman, 1974, Jodha, 1977)

The persistence and prevalence of intercropping is mainly attributed to a number of reasons which include Increased efficiency in the utilization of environmental factors (light,water, nutrients etc), more efficient utilization of labour, reduction of the adverse effects of diseases,pests and weeds, insurance against crop failure,higher gross returns and protection of the soil against erosion

Despite the widespread use of intercropping in traditional farming systems of tropical America, Asia and Africa, the scientific principles underpinning the practice are little understood so far (Banta and Harwood, 1975) For example, there are complex interspecific, intervarietal and interplant interactions (competition, allelopathy etc) that occur in intercropping This depends on the effect of various factors such as the effect of plant species, plant density and spacing, planting patterns, canopy types, root systems, differential demands on environmental factors at different growth stages (Trenbath 1974) Many recent investigations have shown that intercropping can give susbtantial yield advantages The four main physiological reasons for such advantages would appear to be that when grown together, the component crops compete each other and make better total use of environmental resources than when grown separately Although the yield of one or both crops in the intercrop is lower than their respective pure stands There is However, an obvious need for better understanding of the competitive effects between component crops and their respective ecological requirements under various environmental conditions

There is now a cumulative body of knowledge that shows that the yield of one or both crops in the intercrop is lower than their respective pure stands (Agboola and Fayemi 1971; Willey and Osiru, 1972. Enyi, 1973) Although it may not be possible to eliminate such reductions in the yield of the component crops, there should be an attempt to improve the system to approach the theoretical and potential values in such cereal-legume intercrops An economic survey of Machakos area of eastern Kenya (M O A 1981) reported that almost all farmers practice mixed cropping, especially during the main rains However, cereal plus legume intercropping systems which are most prevalent in these areas do not necessarily give the best returns in terms of yield because farmers do not generally select the most compatible crop varieties and husbandry practices

Maize and beans seem to be compatible to an extent, as they have different plant heights as well as rooting depth and patterns Hence a mixture of the two species can lead to an efficient utilization of the environmental resources However, according to the observation of some researchers, nitrogen transfer can be there when non-legume is planted with a legume but the legume suffers drastically due to competition exerted on it by the non-legume For instance, intercropping of beans with maize in population density level of 1 1 resulted in the reduction of bean yield by 36% less than an equal bean population in monocrop (Nadar, 1980) This bean yield reduction was attributed to the reduction in the number of pods per plant due to the competition effect exerted by the maize This implies that there could be a population level where the competition effect between the two species is at minimum Therefore there is need to identify the most appropriate population level for the two species when intercropped

1.2 Global importance of maize as stable food crop and its demands for nitrogen.

With regard to production and cultivation area, maize is the most important cereal crop in the world after rice and wheat In Kenya, It occupies a much larger area than any other crop and is grown by nearly any small scale cultivator in the country It is Therefore obvious that maize holds the key position in Kenya's nutrition, agriculture and economy, Allan (1971)

Maize has a high demand for Nitrogen Maize production is limited by nitrogen deficiency more often than by that of any other nutrient A number of workers have reported nitrogen has a considerable effect on the quality of the maize grain Zuber et al (1954) cited by Berger (1962), found that application of 134 5 kg N/ha raised the crude protein content of the grain from 7 25 to 8 83 percent in the first year and from 7 12 to 10 27% in the following year The protein content of the green parts of the maize plant were appreciably affected It has also been observed in several studies that both the average ear size and the number of ears per plant were increased by nitrogen applied to maize For instance, Krantz and Chandler (1954) cited by Berger (1962) found that the average ear size was increased by 17 percent whereas the number of ears was increased by 41 percent when the rate of fertilizer application was increased from 22 kg to 191 kilogram N/ha

1.3 Bean (*Phaseolus vulgaris L.*)

Bean is one of the most common legume crops interplanted in different cropping systems in Kenya In the developing countries such as Kenya where animal protein is too expensive for regular consumption by low income groups, beans and other pulses containing considerable amount of protein of high nutritional quality assume an eminent role as a potential source of low cost readily obtainable protein The importance of legumes mainly lies in their actual and potential values as source of plant protein for human consumption Beans play a considerable role in the maintenance of the soil fertility through nitrogen fixation Beans are known to nodulate without inoculation when grown in many Kenyan soils, presumably adding nitrogen biologically fixed to the soil. Keya (1975) however, found that bean rhizobia were lacking in some soils of Kenya He reported good nodulation and increased seed yields of beans when appropriate commercial inoculants were used in friable Kikuyu loam soil of pH 6.2 that lacked bean rhizobia

Lopes (1974) reported that efficiently nodulated common bean plants can fix nitrogen under field conditions as rates equivalent to its nitrogen requirement. De Souza (1969) has obtained similar finding to that of Lopes (1974), in that sufficiently nodulated *P.vulgaris* could fix adequate nitrogen to meet its nitrogen requirement Nuh (1996) has shown that inoculation has increased the yield of beans as well as the associated maize crop

However, reports from different investigators indicate that response of *p. vulgaris* to inoculation varies from place to place and from variety to variety Chui and Nadar (1983) for instance reported that bean nodule response to inoculation varied, ranging from a case of decreasing nodule number to a case of substantially increasing nodulation Amare A and Birhanu Abegaz (1985), showed that the agronomic characterstics of *Phaseolus vulgaris* were not affected by inoculation.

1.4 Intercropping beans with maize

When legumes are intercropped with non-legumes, the intercrop yield is often expected to exceed that of either components grown alone and the relative yield total (RYT) may exceed 1.5 (Trenbath, 1974) This is attributed to the fact that the two components do not compete for nitrogen which is often the most limiting soil nutrients In addition, the yield of the non-legumes may further be increased if the period of intercropping is sufficiently continued to more than 3-6 months when the nitrogen fixed by the legume can be available and benefitted by the associated non-legume Among some of the important considerations that affect the productivity of such a mixture is the ability of the legume component to fix nitrogen This property is best accomplished in situations which meet the following conditions The presence of the nitrogen fixing microrganism (Rhizobia), its population density and effectiveness,The specificity between the rhizobium strain and the host legume species The environmental factors affecting the growth of the host legume plant and the rhizobia and the duration of the growth period of the two components in the mixture to help the utilization of the fixed nitorgen from the legume to the cereal

1.5 Justification

Nitrogen is believed to be the most essential nutrient for maize production, particularly in the respects of biomass accumulation, leaf area index and grain yield Unfortunately commercial fertilizers are becoming increasingly expensive and out of reach of most small scale farmers in the developing countries A cheaper alternative source of nitrogen therefore need to be sought Legumes such as beans can be a cheap source of nitrogen which is relatively accessible for the small scale farmers when intercropped with cereal Tropical legumes are capable of excreting nitrogen during growth (Agboola and Fayemi, 1972) or relasing it during decomposition of decaying roots and root nodules (Janny and Kleter, 1955). Cereals intercropped with legumes demand less nitrogenous fertilizer than when planted as a sole crop. This is due to the transfer of some nitrogen fixed by the legumes to the associated cereals during the growing season (Willey 1979) To utilize the nitrogen fixed by the legumes effectively, several other factors are worth considering, such as the spatial arrangements of the intercrops, inoculation of the legume seeds with nitrogen fixing Rhizobium Spp as well as the various density levels of the legume to be planted with cereal A recent work carried out by Cheminig'wa (1992) showed that increasing intimacy between maize and beans enhanced the yield of maize without any effects on the beans (Nuh (1996) has shown that beneficial effects of beans observed by Chemining'wa (1992) can be further enhanced by inoculation of the beans using the right rhizobium strains In both experiments, the yield of beans remained low because of the low densities used Adhiambo (1996) has shown that yield of beans can be increased by increasing density of the bean component in the maize /bean intercrop. This study was conceived with the following objectives

1.6 Objectives

1 To investigate the effect of inoculation on the growth and yield of maize and beans at various bean densities intercropped with maize in same hill

2 To examine the interaction between inoculation and density of beans intercropped with maize in same hill

CHAPTER TWO

LITERATURE REVIEW

2.1 The effect of intercropping on growth and yield of intercrops.

The environment existing in a cereal legume intercropped plot has received a considerable amount of attention. Chemining'wa, (1992) reported yield increase in maize without any effect on beans in 1:1 ratio of the intercrops under different levels of nitrogen. The benefits of intercropping were enhanced by increased intimacy so that maize and bean planted in same hill gave highest yields. Willey and Osiru (1972) observed that maize/beans intercropping was 3% more productive than that of sole cropping in Uganda. The higher productivity of the intercropping was attributed to a better utilization of the growth resources particularly light. Cordere and Mecollum (1979) realized 20-40% increase in total production in intercropping maize with soyabeans. They related the higher productivity to the longer leaf area durations of the intercrop. May and Misangu (1980) found that intercropping maize and cowpeas or soyabeans in the same hill resulted in consistently larger grain yields than intercropping in alternate hills. They suggested that these yield advantages may have occurred through the stimulation of additional nitrogen fixation or creation of a better soil environment. Singh (1979) reported 8-34% sorghum yield increases in sorghum legume intercrop systems over sole crop. Lima and Lopes (1979) reported total grain yield increase of beans and maize due to the population levels. Giri *et al* (1980) reported that intercropping pigeonpea with mung in 2:1 ratio did not significantly affected the yield of pigeon pea in comparison to sole cropping, while intercropping with pearl millet in all ratios (1:1, 2:2) reduced grain yield of pigeon pea. Legume intercrops such as mung, soybean and groundnut did not interfere with the normal growth of pigeonpea while quick growing pearl-millet competed with pigeonpea. This reduction in yield was attributed to the shading effect of millet foliage on pigeonpea. Similar results on pigeonpea with cereals such as sorghum and maize were reported earlier by Saraf *et al* (1975) cited by Giri *et al (1980)*. They further noted that pigeonpea yield was not adversely affected by intercropping of mung, urd, cowpea and soyabean because they are short in stature, and exert less competition for light and available moisture Chui and Nadar (1983) observed that reduction of intimacy between maize and soybean by widening rows of maize diminished interspecific competition This was revealed by increased soyabean leaves per plant by 27 and 39%, leaf area index by 38% and 46% and phytomass by 35 to 77%. In maize-cowpea intercrop, cowpea competed strongly with the maize component and maize yields in the intercrop were reduced by 46 to 57% mainly due to a severe reduction in average ear weight, H M Nadar,(1983)

Other literature however, indicate that the effect of intercropping can be either negative or positive depending on the intercrops used especially the legume component Enyi (1973) reported that maize intercropped with either bean or cowpeas had lower yields than maize intercropped with pigeonpeas, probably because the peak nutrient requirement phase of the two legumes coincided with that of the maize crops whereas the greatest nutrient demand by pigeon peas occurred after maize had been harvested A 43% reduction of bean yields was noted by Hasselbach and Ndegwa (1980) Nadar (1984) reported that maize yields in maize/cowpea 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 in an intercrop usually shades the shorter species Consequently, the shorter component experiences greater yield reduction than the taller component in an intercrop system

Janny and Kletter (1955) observed that the beneficial effect of intercropping with legumes can either be due to the nitrogen excreted by the legume during growth or to the nitrogen released during decomposition of decaying roots and nodules They further noted that cereals may benefit indirectly, since legumes do not compete for the nitrogen, owing to variations in their rooting patterns Chowdhury and Misangu (1979) reported that intercropping greatly decreased the dry matter content and grain yield of chickpea but had no effect on yield of sorghum

2.2 Effects of planting densities on intercrop yields.

In many cases, the potential beneficial effects of intercropping are not achieved as farmers often plant their crops at suboptimal densities (Yunusa 1969). High populations of either maize or beans decrease potential yield of the component crops per thousand plants, while per unit area the yield increases Nadar (1984). Evans (1960) 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

Plant population density has been reported to change the response of sorghum to intercropping (Wahua and Miller, 1978) Similar results were reported for intercropping maize and beans (Willey and Osiru, 1972) High densities in mixture 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. Fausi, *et al* (1982). In a study on maize response to row spacing and population densities Nadar (1983) reported that two plants per hill yielded significantly higher than one plant per hill The yield was correlated with the population However, bean response to population change in the sole crop was not significant It yielded almost the same when planted at either 1 or 2 plants per hill Nadar (1983) Adhiambo (1996) observed that bean density does not affect maize yield, She further noted that bean yield increased with bean density

W De Grootg (1979) observed that when interplanting one row of beans, bean yields were 50% of those of the pure stand and maize yields reached 65% of the pure stand For two rows of interplanted these figures were 68 and 50% respectively, giving the same LER He suggested two rows of beans to be planted between maize for the wet areas of Western Kenya

Silva and Costa (1986) reported that an intercropping of varying bean and maize densities, bean yields tended to decrease as the maize population increased This decrease was attributed to the reduction in the number of pods per plant beans Number of seeds per plant did not differ with the different associations

2.3 The effect of inoculation on legume growth and yield

Inoculation of legumes has received a considerable attention with most studies showing substantial advantages even though cases of no worthwhile advantages have also been reported Sakala (1985) observed that use of rhizobium inoculant in combination with 20 kg N per ha increased yield of beans Nuh (1996) found that inoculation enhanced the beneficial yield effects of both beans and intercropped maize. Hegazi and Metwallly (1985) reported that inoculation has significantly increased the yield of soybean Results in pot experiment indicated that inoculation of cowpeas with rhizobium stimulated nodulation effectively and increased dry matter production, seed yield, crude protein and nitrogen content (Rotimi 1972, Deshmukh and Joshi, 1973 cited by K Mulongoy 1985) Chowdhury (1975) observed that inoculation had significantly increased nodulation and grain in soybean Seed inoculation with exotic strains of rhizobium increased pigeon peas grain yield significantly over non inoculated controls, particularly in soils whose mineral nitrogen levels were reduced by incorporation of coconut fibre and bagasse (Quilt and Dalal 1979 cited by Kurmar Rao1990) Badr el Din and Moawad (1988) reported that inoculation of *rhizobium leguminosarium* significantly increased plant dry weight, N_2 content of lentil and faba bean plants over uninoculated controls Taylor *et al* (1983) reported that inoculation with *R. phaseoli* produced significant increases in nodualtion, nitrogenase activity and plant growth Inoculation in the absence of nitrogen fertilizer doubled seed yields Vencatasamy (1984) observed that different *P. vulgaris* cultivars produced different nodule fresh weights with the same *R. phaseoli* strain The higher nodule weights were associated with higher percentage increases in the nitrogen content of plant tops which suggests that the efficiency of nitrogen fixation is also determined by the host genotype However, cases of no beneficial effects of inoculation have been reproted. for example Souza (1968, cited by Njeri 1984) reported that nodulation surveys conducted in East Africa showed that the indigenous legume species such as *phaseolus vulgaris* did not benefit from inoculation Trinick (1982) reported that if the inoculation strain cannot compete with the indigenous rhizobia for the nodule sites there may be no benefit from inoculation Singleton and Tavarer (1986) observed that inoculation is rarely beneficial if populations of effective compatible rhizobium are already there One of the challenges in research on improvement of N_2 fixation has been the poor nodulation of *Phaseolus vulgaris* in the field Garaham (1981)

2.4 The concept of nitrogen fixation in legumes

The recognition that exploitation of the atmospheric dinitrogen by legumes is due to the presence of the bacteria in root nodules, began over a century ago (Hellriezel and Willfanth 1988, cited by Giller 1991) This group of bacteria is collectively referred to as rhizobia It includes all bacterial species that induce and infect nodules on roots and on stems of plants of the family leguminousae The Genus Rhizobium comprises the three recognized fast growing species *R.Leguminosarum, R Loti and R Meliloti*, (Jordan, 1984) Rhizobia could be present in the soil as free living bacteria in which case they are referrred to as indigenous rhizobia, or can be introduced deliberately to the soil through inoculation

The symbiotic association or living together of legumes and the bacteria of genus rhizobia provides the major symbiotic source of fixed nitrogen in agricultural soils Rhizobia invade the root hairs and the cortical ceil ultimately inducing the formation of nodules that serve as a home for the organisms Some recent molecular biology experiments have shown that a major component of the initial interaction between a legume and its compatible rhizobium strain consist of stimulation of biochemical activity in the rhizobial strains by flavoniod and isoflavoniod molecules in the plant root exudates These compounds stimulate the activity of nod (nodulation) genes, that is, genes whose products are required for the nodulation at the congeta legume host There is some specifity in this interaction as different flavoniod and isoflevoniod compounds from different legumes have been shown to activate the nod genes of their compatible rhizobia preferentially (Peters *et al*, Kosslack *et al* 1987, Horvath *et al* 1987 cited by Giller 1991)

However this stimulation is by no means completely specific as exudates from incompatible legume species can often activate the nod genes of a given rhizobium strain to some degree (Spaink *et al* 1987) Recent evidence demonstrated that exact specifity arises at the latter part of the interaction at least in the case of *R.. Melilon* One of the functions of the *R meliloti* nod genes is to synthesise a nodulation signal, a small carbohydrate called in this case NodRm-1, which is recognised only by the compatible legume species. *medicago sativa* Therefore, a given rhizobium species will inoculate some legumes but not others

This specifity of interaction is the basis for classifying rhizobia and their host plants into seven so called cross inoculation groups Legumes that can be inoculated by a given Rhizobium species are included in the same cross inoculation group Thus *Rhizobium phaseoli* inoculates *phaseoli vulgari* (dry beans), phaseoli coccinues (runner bean)

2.5 Methods of legume seed inoculation.

Legume seed inoculation is considered in two parts namely seed inoculation in which the inoculant is directly applied to the seed before sowing and seed bed inoculation in which the seed is sown without inoculation but the inoculant is applied to the seed bed

seed inoculation:

a) **Dusting or dry inoculation**. This is the simplest method of inoculation as it involves the application of the mere inoculant to the seed immediately before sowing or to sprinkle on the seed in the seed box Some of the inoculant adheres to the seed by lodging in the scratches and the irregularities on the seed coat However, this method is said to be the least efficient method as much of the inoculant is shed particularly during passage of the seed through machinery Dusting or dry inoculation is still in use but cannot be recommended

b) **Slurry inoculation.** In this method the inoculant is applied to the seed as a suspension in water in order to increase the amount of inoculant adhering to the seed. alternatively the inoculant can be mixed with a moistened seed The seed must be dried before sowing without direct sunlight, but as certain proportion of the inoculant is lost as seeds dries, using adhesives in the slurry such as household sugar (10% solution), gum arabic 10% soultuon or methyl cellulose (15%) may help more inoculant to adhere to the seed coat. Caution is important to avoid samples of gum arabic which contain preservatives lethal to rhizobia. This method is particularly suitable for inoculating grain legumes when sowing small areas

c) **Seed pelleting**. The advantages of this method include protection of the inoculant rhizobia against rhizobiotoxic substances contained in some legume seed coats, unfavourable physical and chemical conditions in soils, competition from soil microflora, the effects of acid fertilizer and against seed harvesting ants. pelleting makes aerial sowing of inoculated seed feasible and ensures better survival of the rhizobia when delays between inoculation and sowing are unavoidable. Seed pelleting is particularly suitable for small seeded group of legumes to be sown in soils in contact with acid fertilizers

Seed bed inoculation.

In certain situations application of inoculant directly to the seed may not be an efficient means of inoculation, such as

1- When the use of seed dressings of fungicides and insecticides all of which have some antagonistic effect on the rhizobia are unavoidable

2- When a large area of grain legumes is to be sown and due to the seed size, large volume of seed makes the other methods of inoculation more difficult

3- The seed coats of some legumes contain substances toxic to rhizobia

4- Some legumes such as soybean lift the seed coat. The seed coat comes out of the soil during emergence so that the rhizobia on the seed coat are not deposited in the soil. In such circumstances an alternative means of inoculation can be

(d) **Solid inoculant:** is made by coating solid granulated material with peat inoculant in an adhesive Suitable adhesives include a 25% aqueous solution of gum arabic with no preservatives or a 5% solution of methlycellulose. Tenacity of the adhesive solution can be improved by chilling overnight. Peat inoculants is thoroughly stirred into the adhesive and this suspension poured on to the seeds and mixed together until all seeds appear evenly coated The seeds should be dried by spreading in a thin layer When dry and any lumps have been broken up the material can be ready for use

Solid inoculant is particularly suitable to the inoculation of numerous small samples of legume seed, e g plant breeder's lines, where conventional inoculation of each sample separately would be tedious and time consuming

(b) **Liquid inoculation:** a peat culture of rhizobia (frozen and concentrated) is mixed into a paste with water, diluted to a slurry, then added to a water-filled tank prior to spray application Any equipment previously used for toxic chemicals should be avoided to ensure the survival and the viability of the rhizobia An excellent nodulation can be obtained by spraying inoculation into the row beside or beneath the seed

CHAPTER THREE

MATERIALS AND METHODS

3.0 EXPERIMENTAL SITE

Two experiments were conducted at the field station of the University of Nairobi, Upper Kabete. Campus The area lies at an altitude of 1940m asl, latitude 1° 14' 20"s to 1 15" and longitudes 36 44 E to 36° 45 20" There are two rainy seasons namely long rain season which lasts from March to May contributing an average seasonal rainfall of 505 6mm, and the short rain season which prevails from October to December with an average seasonal rainfall of about 285 2 mm The monthly min and max temperatures being 12°C and 23°Crespectively This is a temperature range of 22°C Anonymous (1985)

The soils are well drained very deep, dark red friable clays classified as humic nitosols

3.1 Experimental design and treatments

In both experiments, a 2x4 factorial experiment laid out in a completely randomised block design with three replications was used The treatments comprised the following two factors -

(i) **Inoculation, (I)** comprised of inoculated (I_1) and non-inoculated (I_0) groups of beans The beans were inoculated with rhizobium 446 Num strain from Mircen project, department of Soil Science, University of Nairobi The inoculation process followed the recommendations of the Mircen project as described below

1- A table spoonful of sugar was mixed with 300 ml of water

2- The solution was sprayed on the seeds of beans (15Kg)

3- After all seeds were moistened, the inoculant was evenly scattered on the seeds and then thoroughly mixed to make sure that the seeds were well coated with the inoculant

4- Inoculated seeds were planted in wet soil immediately after inoculation

5- To avoid contamination, the non-inoculated seeds were planted first

(v) Bean Density

This factor comprised of four levels of bean density

One bean plant per hill denoted as D1

Two bean plants per hill denoted as D2

Three bean plants per hill denoted as D3

Four bean plants per hill denoted as D4

Maize variety H512 and bean variety GLP2 were used in the experiments The experimental plots measured 4.5m x 4m The spacing was 75 between rows and 25 cm between plants in same row for both maize and beans since both crops were planted in the same hill This provided a plant population of 53,333 plants in the treatments which were having one bean plant per hill For treatments of two bean plants per hill, the population was 106,660 bean plant per hectare For those treatments of three bean plant per hill, the population was 16000 bean plant per hectare and or those of four bean plants per hill, the population was 213,332 bean plants per hectare Prior to planting of the experiment, maize was densely planted with no nitrogenous fertilizer applied on the experimental site to deplete soil nitrogen Soil nitrogen content of the site was determined at the planting time for each season

3.2 Treatment combination

Levels	D1	D2	D3	D4
Io	IoD1	IoD2	IoD3	IoD4
I_1	I_1D1	I_1D2	I_1D3	I_1D4

3.3 General crop husbandry

The field was ploughed and harrowed so as to obtain a moderate tilth. All plant residues were cleared to ensure field hygiene. Plots were measured accurately and clearly marked out before planting. Triple super phosphate (46% P_2O_5) was applied to the furrows at the rate of 20 kgs/ha and thoroughly mixed with the soil before planting. Two maize seeds were planted per hill and thinned to one plant per hill at two weeks after emergence. For beans more seeds were planted for each treatment to be thinned to the required number of bean plants per hill according to population level of the respective treatments. Before planting the seeds were dressed using malathion 50% at the rate of 10 g per kg of seeds to control such pests like cutworms. Starting from one week after emergence, the bean plants were sprayed with insecticide Dimethoate 40% at weekly intervals to control beanfly on the aerial parts upto flowering stage. After flowering another insecticide (ambush) was sprayed at weekly intervals to control flower eating insects. Two days after every spray of insecticides, the crop was sprayed with fungicide to control bean rust and other fungal diseases. Four weeks after emergence of maize, stalkborer granules were applied to control maize stalkborer. Weed control was carried out manually. In the events of water stress due to shortage of rains, sprinkle irrigation was used to prevent moisture stress.

3.4 Experimental measurements and the analysis

(1) Nodule count for beans (per plant)

Four hills in one meter inside the first line next to the guard row of each plot were carefully uprooted together with the maize plant during the flowering time of beans. The shoot part of the bean was cut out and left for the bean biomass determination, the root part was carefully separeated out and washed to count the number of nodules per plant.

(2) Biomass of beans at flowering stage

The same shoot parts of the bean samples collected for the nodule count were dried under 70c° to a constant weight for determination of bean biomass.

(3) Biomass of maize at flowering

Four maize hills in one meter inside of the first line next to the guard row of each plot were carefully uprooted The samples were dried to constant weight to determine the dry matter weight per plant maize

(4) Grain yield of Beans and Maize

The three most interior lines of each plot were harvested for grain yield of each intercrop component (maize and beans) A sub-sample of 20 plants was picked randomly from the plants of the three lines To determine the number of seeds per pod and the number of pods per plant as well as the number of seeds per crop and the number of cobs per plant maize

(5) 100 grain weight for each intercrop (maize and beans)

Ten sub-samples of 100 grains per treatment were picked randomly from the yield of the three lines for each plot yield. the sub -samples have been pooled and weighted to determine 100 grain weight of each intercrop.

(6) Soil nitrogen content before planting

Soil samples were collected from the site by zigzag method of sampling at a depth of 0-30 cm to determine the soil nitrogen content before planting of each season

(7) Soil nitrogen content in the hills at maize flowering and maize maturity.

Three soil samples were picked from each hill (0-30 cm) by the time the maize samples were being uprooted for maize biomass at flowering and at physiological maturity (hard dough stage) Then, all samples from the four hills were mixed thoroughly in order to obtain one homogenous soil sample for each plot The samples were analyzed to determine the per cent soil nitrogen content in the hills.

(8) <u>% Soil nitrogen content in the hills one month after harvesting</u>

At the time of harvesting four planting hills in the central part of each plot were marked with stakes The plots were thereafter kept weed-free for a period of one month at the end of which soil samples were collected from a depth of 0-30 cm of each hill for determination of soil nitrogen content.

Data Analysis

Collected data were subjected to analysis of variance (ANOVA) and, where treatment effects were detected, mean separation was done using Duncanc multiple range test (P=0.05)

CHAPTER FOUR

RESULTS

4.1 Effects of inoculation and varying bean densities on Biomass of beans/plant and /hill

Over both seasons inoculation had no significant effect on the beans dry matter per plant (Table 1A - 1B) or per hill (Table 2A - 2B), but increasing bean density had significant effect on bean dry matter at both levels (Table 1a-2b) In both seasons bean dry matter per plant decreased with increase in bean density with no significant difference between the means of treatments having two, three and four bean plants per hill (Tables 1a-1b). Bean dry matter per hill conversely increased with increase in bean density with a significant difference among all treatment levels of density (Tables 2a-2b)

4. 2 The effect of inoculation and varying bean density on the number of nodules per plant (FIVE WABE)

Over both seasons inoculation had no significant effects on the number of nodules per plant Unlike inoculation, bean density had highly significant effects on the number of nodules per plant (Table 3a-3b). Generally the number of nodules per plant decreased with increasing bean density In the first season experiment, there was no significant difference between the treatments having one bean plant, two bean plants and three bean plants per hill of varying bean densities, but in the second season, there was no significant difference between the treatment means of three bean plants and four bean plants per hill of varying bean density

In both seasons, the number of nodules decreased with increase in bean density (Table 3a-3b)

The effect of inoculation and varying bean density on Biomass of heans (g/plant).

Table 1 (a) Season one

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	60.83	42.79	34.89	37.37	43.95
Inoculated	54.43	39.33	37.33	34.41	41.38
Bean density Means	57.62[a]	41.06[b]	36.11[b]	35.86[b]	

C.V 6.85%

S.E 3.87

Table 1 (b) Season Two

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	49.52	30.07	29.47	30.80	35.99
Inoculated	53.46	38.09	32.78	28.79	38.29
Bean density Means	51.49[a]	36.08[b]	31.13[b]	29.84[b]	

C.V 10.72%

S.E 5.36

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

The effect of inoculation and varying bean density on Biomass of beans (g/ per hill).

Table 2 (a) Season one

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	60.80	85.57	104.65	149.18	100.05
Inoculated	54.43	78.65	113.06	137.61	95.93
Bean density Means	57.62^{d}	82.11^{c}	108.86^{b}	143.40^{a}	

C.V 15.99%

S.E 3.94

Table 2 (b) Season Two

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	49.52	68.14	108.39	123.50	87.39
Inoculated	53.46	76.83	98.35	115.14	85.95
Bean density Means	51.49^{d}	72.50^{c}	103.37^{b}	119.32^{a}	

C.V 14.36%

S.E 3.08

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

The effect of inoculation and varying bean density on the number of nodules/plant

Table 3 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	27.70	18.33	22.40	13.80	20.56
Inoculated	20.20	21.17	17.98	13.43	18.22
Means	24.45^{a}	20.70^{a}	19.75^{a}	13.62^{b}	

C.V. 17.79%

S.E. 1.98

Table 3 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	19.33	12.00	13.33	12.67	14.33
Inoculated	7.00	17.67	10.33	10.67	13.92
Means	18.17^{a}	14.84^{ab}	11.83^{b}	11.67^{b}	

C.V. 25.85%

S.E. 2.10

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

4.3 Effect of inoculation and varying bean densities on grain yield and yield components of beans

(A) Grain yield:

In both seasons inoculation had no significant effect on the grain yield of beans but increasing bean density had a highly significant effect on this parameter (Table 4a–4b)

In both experiments grain yields of beans increased with the increase in bean density. In both seasons, the highest yield was obtained from the treatments having four bean plants per hill and the lowest from the treatments with one bean plant per hill(Table 4a–4b)

(B) Yield components:

(i) Number of pods per plant

Over both seasons the number of bean pods per plant significantly decreased with increasing bean planting density but inoculation had no significant effect on this variable. (Table 5a- 5b)

In the first season, the number of pods per plant decreased with the increase in bean planting densities with no significant difference between the means of the treatments having three bean plants and four bean plants per hill (Table 5a). In the second season the number of pods per plant had the same trend except that no significant difference occurred between the treatments having two bean plants per hill, three bean plants per hill and four bean plant

Per hill (Table5)

The effect of inoculation and varying bean density on grain yield of beans (t/ha)

Table 4 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	7 9	9 0	10 4	12 0	9 8
Inoculated	8.2	8 9	10 7	12 9	9.9
Means	8 0[d]	9.0[c]	10.5[b]	12 0[a]	

C V 10 30%

SE 25 78

Table 4 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non inoculated	4 0	5 0	5.8	7 0	5 4
Inoculated	4 3	5 1	6 1	7 1	5 6
Means	4 1[d]	5 0[c]	6 0[b]	7.0[a]	

C V 5 31%

S E 16 98

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

The effect of inoculation and varying bean density on the number of pods per plant.

Table 5 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	11 70	8 93	7 72	5 59	8 49
Inoculated	10 63	10 02	8 27	7 83	9.19
Means	$11\ 67^{a}$	$9\ 48^{b}$	$8\ 00^{c}$	$6\ 71^{d}$	

C V 11 26

S E 0.57

Table 5 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	10 87	8 98	6 68	5 75	8 07
Inoculated	8 82	7 02	6 97	6 97	7 45
Means	$9\ 85^{a}$	$8\ 00^{b}$	$6\ 83^{b}$	$6\ 35^{b}$	

C V 16 42%

S E 0 73

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

(ii) **Number of seeds per pod**

In the first season experiment, inoculation had no significant effect on the number of seeds per pod, unlike inoculation, bean varying density had significant effect on the number of seeds per pod This means that there was a significant difference between the treatment having one bean plant per hill and those having two, three and four bean plants per hill(Table 6a)

However, in the second season experiment, neither inoculation nor bean density had any significant effect on the number of seeds per pod (Table 6b)

(iii) 100 seed weight

Over both seasons, inoculation had no significant effect on 100 seed weight of beans but bean density had a highly significant effect on it (Table 7a-7b) In both seasons, 100 seed weight of beans decreased with increase in bean density although there was no significant difference between the treatments having three bean plants and four bean plants per hill in season one, (Table 7a) In the second season, bean densities had the same trend except that there was no significant difference between the treatments having one bean plant per hill and those having two bean plants per hill. (Table 7b)

The effect of inoculation and varying bean density on the number of seeds per pod

Table 6 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	4 62	4 48	4 60	3 72	4 36
Inoculated	5 10	3 72	3 37	3 76	3 98
Means	4 86[a]	4.10[b]	3.99[b]	3.74[b]	

C V 10 51%

S E 0 26

Table 6 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	4 47	4.30	4 23	3 92	4 23
Inoculated	4 63	3 81	3 69	3 70	3 96
Means	4 55[a]	4 06[a]	3 96[a]	3 81[a]	

C.V 17.37%

S.E 0 42

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

The effect of inoculation and varying bean density on 100 grain weight of beans

Table 7(a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	45 55	40 42	39 35	40 71	41 51
Inoculated	44 45	38 82	35 31	33 17	37.96
Means	45 04[a]	39 62[ab]	37.33[b]	36 94[b]	

C V 7 84%

S E 3 23

Table 7(b) Season two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non inoculated	38 37	36 75	39 04	36 52	37 67
Inoculated	42.30	42 83	37 44	34 65	39.30
Means	40 34[a]	39.79[a]	38 24[ab]	35 59[b]	

C V 7 15%

S E 3 02

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

4.4 Effect of inoculation and varying bean densities on Biomass of maize at flowering (two weeks after bean harvest - Twelve WAEM)

Over both seasons inoculation had no significant effect on dry matter of maize at flowering but bean density had significant effect on this variable only in the first season of this experiment table (8a-8b).

In both seasons dry matter of maize indicated a decreasing trend with increase in bean density In the first season, the treatment bearing one bean plant per hill had significantly higher maize biomass than the other maize density treatments which were, however not significantly different from one another The decreasing trend was also clear though not significantly so in the second season

4.5 Effect of inoculation and varying bean densities on grain yield and yield components of maize.

(A) Grain yield:

Inoculation had no significant effect on grain yield of maize in either season but increasing bean density had significant effects on grain yield of maize over both seasons (Table 9a-9b). Generally, in both seasons maize grain yields decreased with increase in bean density and the highest yield was obtained from the treatment having one bean plant per hill

In the first season, there was no significant difference between the means of the treatments having two bean plants, three bean plants and four bean plants per hill (Table 9a) but in the case of the second season, there was no significant difference between treatments of one bean plant per hill and two bean plants per hill Similarly, there was no significant difference between the treatments of three bean plants and four bean pants per hill (Table 9b)

The effect of inoculation and varying bean density on Biomass of maize at flowering (g\ plant).

Table 8(a) Season one

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	102.50	98.79	96.44	85.74	95.87
Inoculated	119.04	104.44	84.23	88.15	98.97
Bean density Means	110.77^{a}	101.62^{b}	90.34^{b}	86.94^{b}	

C.V 17.32%

S.E 9.32

Table 8(b) Season two

Inoculation	Bean Density levels				Inoculation
	D1	D2	D3	D4	Means
Non Inoculated	89.71	85.92	72.57	69.05	79.31
Inoculated	82.33	83.85	81.81	77.00	81.29
Bean density Means	86.02^{a}	84.89^{a}	77.19^{a}	73.10^{a}	

C.V 23.02%

S.E 10.67

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

The effect of inoculation and varying bean density on grain yield of maize (t/ha)

Table 9(a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	7.5	5.3	5.1	4.5	5.6
Inoculated	6.8	6.1	5.2	5.0	5.8
Means	7.2^a	5.7^b	5.1^b	4.8^b	

C.V 14.53%

S.E 3.57

Table 9 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	5.9	5.3	5.4	4.2	5.2
Inoculated	6.2	5.2	4.3	4.6	5.1
Means	6.0^a	5.3^b	4.9^b	4.4^b	

C.V 6.62%

S.E 4.01

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

(B) Yield components of beans:

(i) Number of cobs per plant:

Over both seasons inoculation had no significant effect on the number of cobs per plant(Table 10a-10b) Unlike inoculation, bean density had significant effect on this prameter in the first season of the experiment This means that only the treatments having two bean plants and those having three bean plants were significantly different(Table 10a) In the second season experiment, the factor had no significant effect on the number of cobs per plant maize, but the prameter generally decreased with increasing bean density (Table 10b)

(ii) Number of kernels per cob: In both experiments, inoculation had no significant effect on the number of kernels per cob (Table 11a)

Regarding to bean density, the factor had significant effects on the number of kernels per cob over both seasons (Table 11a-11b) In the first season for instance, there was no a significant difference between the treatments having one bean plant per hill and those having two bean plants per hill (11a) In the case of the second season, there was no significant difference between the treatments having three bean plants per hill and those of four bean plants per hill (Table 11b)

The effect of inoculation and varying bean density on the number cobs per plant maize

Table 10 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	1.16	1.07	1.14	1.03	1.10
Inoculated	1.23	1.13	1.08	1.00	1.11
Means	1.20^{a}	1.10^{b}	1.11^{b}	1.02^{c}	

C.V 6.54%

S.E. 1.05

Table 10 (b) Season two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	1.06	1.05	1.05	1.00	1.00
Inoculated	1.13	1.10	1.06	1.05	1.10
Means	1.10^{a}	1.08^{a}	1.06^{a}	1.03^{a}	

C.V 5.31%

S.E. 1.093

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

The effect of inoculation and varying bean density on number of kernels per cob

Table 11 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	329 67	353 78	319 63	267.35	317 61
Inoculated	344 80	297 88	285 64	293 91	305 36
Means	337 24^{a}	325 83^{a}	302 64^{ab}	280 63^{b}	

C.V 8 93%

S E 16 06

Table 11(b) Season two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	345 38	299 40	269 10	256 97	292 71
Inoculated	347 05	319.20	293 97	286 13	311.59
Means	346 22^{a}	309 30^{ab}	281.65^{b}	271 55^{b}	

C V 7 27%

S E 12 82

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

(iii) 100 grain weight of maize: In the first season, neither inoculation nor bean density had any significant effect on 100 grain weight of maize (Table 12a). However, in the second season experiment, bean varying density had significant effect on 100 grain weight of maize with no significant difference between the means of the treatments having three bean plants and four bean plants per hill

In both seasons, 100 grain weight of maize decreased with increase in bean varying density (Table 12a-12b)

The effect of inoculation and varying bean density on 100 grain weight (g) of maize

Table 12(a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	44 17	42 57	37 16	33 42	39 81
Inoculated	39 70	36 06	39 30	37 69	38 19
Means	41 94^{a}	39 32^{a}	38 36^{a}	36 38^{a}	

C V 8 30%

S.E 1 85

Table 12(b) Season two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	37 91	35 14	35 65	35 55	36 06
Inoculated	41 82	39 35	34 64	32 62	37 11
Means	39 87^{a}	37 35^{b}	35 15^{c}	34.09^{c}	

C V 4 55

S E 0 97

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

4.6 Effect of inoculation and varying bean density on percent soil nitrogen in the hills at maize flowering, maturity and one month after harvesting

Over both seasons inoculation had no significant effect on percent soil nitrogen in the hills at all soil sampling episodes (Tables 13a -15 b). Bean density variations also had no significant effects on percent soil nitrogen in the hills at all soil sampling episodes (Table 13a-15b)

The effect of inoculation and varying bean densities on percent soil nitrogen in the hills at maize flowering/ (Two weeks after bean harvest and twelve WABE)

Table 13a (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	0 32	0 32	0 24	0 22	0 28
Inoculated	0.19	0 22	0.22	0 28	0 23
Means	0.26[a]	0 27[a]	0.23[a]	0 25[a]	

C V 21.33%

S E 0 07

Table 13 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D 2	D3	D4	
Non Inoculated	0 36	0 35	0 43	0 31	0 36
Inoculated	0 30	0 35	0 31	0.36	0.34
Means	0 33[a]	0 35[a]	0 37[a]	0 34[a]	

C V 19.54%

S E 0 04

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

The effect of inoculation and varying bean densities on percent soil nitrogen in the hills at maize maturity/ (14 weeks after bean harvest -24 (WABE))

Table 14 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	0.26	0.45	0.48	0.38	0.39
Inoculated	0.27	0.34	0.43	0.64	0.41
Means	0.27^a	0.40^a	0.46^a	0.51^a	

C V 27.33%

S E 0.11

Table 14 (b) Season Two

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	0.25	0.23	0.25	0.24	0.25
Inoculated	0.26	0.27	0.26	0.23	0.26
Means	0.26^a	0.27^a	0.26^a	0.25^a	

C V 11.15%

S E 0.02

Means followed by the same letter are not significantly different °% probability level according toDuncan's multiple range test

The effect of inoculation and varying bean densities on percent soil nitrogen in the hills one month after maize harvesting (18 weeks after bean harvest- 28 WABE)

Table 15 (a) Season one

Inoculation	Bean Density levels				Means
	D1	D2	D3	D4	
Non Inoculated	0 24	0 28	0 31	0 30	0 28
Inoculated	0 29	0 23	0 27	0 26	0 27
Means	0 27^{a}	0 26^{a}	0 29^{a}	0 29^{a}	

C.V 23 01

S E 0 012

Table 15 (b) Season Two

Inoculation	**Bean Density levels**				Means
	D1	D2	D3	D4	
Non Inoculated	0 28	0 31	0 25	0 32	0 29
Inoculated	0.32	0 24	0 35	0.29	0.30
Means	0.30^{a}	0 28^{a}	0 30^{a}	0.31^{a}	

C.V 17 11

S E 0.01

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

CHAPTER FIVE

DISCUSSION

Lack of beneficial significant effects of inoculation on the yields of intercropped beans and maize (tables 4a-4b, 9a-9b) may be attributed to the presence of the indigenous rhizobia in the soil which could compete with the introduced strain for the nodule sites and thus masked the effect of the inoculation The presence of nodules on the uninoculated bean treatments provide an obvious evidence that indigenous rhizobia had been there before planting This is further supported by the observation that there was no difference in nitrogen content between the hills of inoculated and non-inoculated treatments The native rhizobia may be available in the soils in large numbers relative to the introduced strain and would conceivably be better established Therefore, the introduced strain may not be able to out-perform it in the competition for the limited substrates and space These results support earlier observations that inoculation is rarely beneficial if the population of effective compatible rhizobia are already present in the soil (Singleton and Tavares, 1986, Trinick, 1982) Results of the soil analysis for percent soil nitrogen content in the hills of both inoculated and uninoculated treatments, (Tables 13a-15b) suggest that both the indigenous and the introduced strains of rhizobia were ineffective as the respective means of the two inoculation levels were very low and not significantly different Furthermore, the number of nodules on both inoculated and uninoculated treatments (Table 3a - 3b) were generally low indicating that the symbiotic performance was poor One of the challenges of research on improvement of N_2 fixation in grain legumes has been the poor nodulation of *Phaselus vulgaris* in the field (Graham 1981) souza (1968) reported that nodulation surveys conducted in East Africa have shown that the indigenous legume species such as *Phaseolus vulgaris* did not benefit from inoculation

Results of the dry matter and the yield component of both intercrops have consistently shown no beneficial effect of inoculation suggesting that the symbiotic performance was low Amare and Birhanu (1984) observed that inoculation did not significantly affect the grain yield of *Phaseolus vulgaris* or P app in general They further noted that it did not affect the other yield components such as pods per plant, seeds per pod and pod length

In regard to the effects of increasing bean densities from one to four bean plants per hill on the growth and yield of beans and maize inter-crops, the factor has significantly affected the yield of maize over both seasons of the experiment (Table 9a-9b) As shown in those tables, maize yields decreased as the proportion of bean plants in the hills with maize increased This decrease in the yield of maize may be attributed to the response of maize to increasing bean density Like the other cereals, maize response to plant population density partly occurs as a reduction in the number, size and length of the vegetative parts of the maize crop (root, leaves and inter-nodes) and partly occurs in the yield component parts of the maize plant by reducing the number of flowers, cobs and seeds initiated, or aborting (death/abscision) before maturity Clements et al This, subsequently results in the reduction of the mean seed weight and hence low grain yield of maize per unit area In this experiment, the results, of the maize dry matter (Table 8a-8b), grain yield (Table9a-9b) and yield components (Table 10a-10b,11a-11b,12a-12b) tended to decrease with increasing bean density These results, are in agrement with those found by Wiley and Osiru (1972), Aidar (1978) cited by Lima and Lopez (1979)

According to the results of the yield components of beans per plant, dry matter of beans per plant and the nodule number per plant all of the said parameters tended to decrease with the increasing bean density This implies that the mechanism by which plant population density affects the growth and yield of beans is similar to the one of the maize crop. Clements *et al* (1929) cited by Harper (1977) found similar results to these

However, in this experiment, bean grain yield increased with the increasing density This increase may be associated with the increasing number of pods per hill Adhiambo (1996) oberved that bean yields increase with increase in bean density Pal *et al* (1993) reported that yield of component crops in intercropping system vary significantly with component crop density Lima and Lopez (1979) reported that bean yields increased with increase in the proportion of bean plants in the mixture Increasing bean density did not significantly affect the percent soil nitrogen in the hills at all episodes of soil sampling -maize flowering, maize maturity and one month after maize harvesting- (Table 13a-15b,). These results can be attributed to the low symbiotic performance in this experiment which may be caused by the inefficiency of the rhizobia population as there have been no significant difference between the inoculation means indicated in almost all the tables of the various variables described earlier in chapter four. This inefficiency of the rhizobia population may be explained by some environmental constraints including physical, chemical and biological constraints. High temperatures can prevent nodulation or if nodualation does occur can inhibit the activity of nitrogen fixation in legumes (Day *et al* 1978). Conversely, cool temperatures lead to delayed development of plants, including delays in the formation of nodules, and so decreased rates of nitrogen fixation. Grazing of rhizobia in soil by protozoa has been shown to reduce the population of rhizobia in soil (Danso *et al* 1975).

For different species the processes of infection, nodule development, and fixation, usually have different maximum, optimum and minimum temperatures Haque and Jutzi (1985) Working with temperate species *Trifolium susterranum*, Mayer and Anderson (1959) demonstrated that a moderately high temperature of 30°C inhibited symbiotic Nitrogen fixation, and concluded that similar temperatures might limit nitrogen production by legumes in tropical regions

Both photoperiod and light intensity have been reported to affect nodulation and nitrogen fixation Gibson (1977). The effect of light on nitrogen fixation can be associated with variations in the host plant photosynthesis. In this experiment for instance, maize was intercropped with beans, therefore the cereal intercrop might have shaded the legume by intercepting the light intensity and hence suppressing the photosynthetic activity of the bean intercrop, which in turn might have resulted in the low symbiotic performance indicated in the results of almost all the variables measured in this experiment. Allan *et al* (1975) observed similar results

Generally, the results in this study further demonstrate that it is beneficial to increase the bean density in order to obtain higher bean yield and the total yield per unit area. it should however be noted that such increase in bean density may increase intra-species competition among the bean plants, so the resulting bean yield may be more but of poor quality. In this study, the best combination which was used without sacrificing either the yield or the seed quality was two bean plants and one maize plant per hill

CONCLUSIONS AND RECOMMENDATIONS

1. In all parameters, results have shown that inoculated treatments were not significantly different form the non inoculated treatments

2. Yield components per plant of both maize and beans decreased with increasing bean density

3. Maize grain yield decreased with increasing bean density significantly

4. Bean grain yield significantly increased with increasing bean density

5. Increasing bean density did not significantly affect the percent soil nitrogen at all stages of soil samping

6. Interaction between inoculation and varying bean density was statistically not significant

Recommendation for further research:

1. This study has shown that inoculation has no effect growth of inoculated beans and presumably nitrogen fixation. Other workers such as Chemming'wa and Nyabudi (1994) show that beans planted in close proximity with maize plants benefitted the maize in condition of low nitrogen. Detailed, well controlled lab experiments should therefore be conducted to establish the beneficial nature of beans to maize when planted in close proximity

2. Bean yield increased with increasing bean density. It is, however envisaged that this response will be influenced by availability of soil based plant growth factors such as moisture and mineral nutrients. Further studies should therefore be conducted to evaluate this response under conditions of limited soil water plants nutrients

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APPENDIX 1A **Analysis of Variance for the Biomass of beans per plant**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	1314.778	657.389	14.615	0.004***
Inoculation	1	101.601	101.601	2.260	0.155 ns
Density	3	2372.554	8124.185	180.617	0.000***
Inoculation X Density	3	337.920	112.620	2.504	0.1016
Error	14	629.723	44.980		
Total	23	26756.616			

APPENDIX 1 B **Analysis of Variance for Biomass of beans per plant**

(SEASON two)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	298.234	149.117	1.731	0.213ns
Inoculation	1	15.682	15.682	0.182	0.676 ns
Density	3	16773.684	5591.228	64.917	0.00 ***
Inoculation X Density	3	363.242	121.081	1.406	0.283 ns
Error	14	1205.805	86.129		
Total	23	18656.647			

APPENDIX 2 A **Analysis of Variance for Biomass of beans per hill (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	513.633	256.816	5.510	0.0172*
Inoculation	1	36.927	36.927	0.792	0.388 ns
Density	3	1879.524	626.508	13.443	0.002***
Inoculation X Density	3	66.127	22.042	0.473	0.706 ns
Error	14	652.578	46.606		
Total	23	3148.688			

APPENDIX 2B **Analysis of Variance for the Biomass of beans per hill (season two)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	212.544	106.272	3.737	0.050ns
Inoculation	1	31.488	31.488	1.107	0.310 ns
Density	3	1779.055	593.108	20.853	0.000***
Inoculation X Density	3	39.117	13.039	0.458	0.716 ns
Error	14	398.129	28.438		
Total	23	2460.333			

APPENDIX 3A Analysis of Variance for the number of nodules per plant beans (season one)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	30.754	15.377	1.301	0.303ns
Inoculation	1	37.625	37.625	3.184	0.096ns
Density	3	327.781	109.260	9.248	0.001**
Inoculation X Density	3	92.419	30.806	2.607	0.928ns
Error	14	165.411	11.815		
Total	23	653.990			

APPENDIX 3 B Analysis of Variance for the number of nodules per plant beans (season two)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	57.484	28.742	2.224	0.145ns
Inoculation	1	1.042	1.042	0.081	0.781 ns
Density	3	168.792	56.264	4.355	0.023 *
Inoculation X Density	3	74.792	24.931	1.929	0.171ns
Error	14	180.891	12.921		
Total	23	483.00			

APPENDIX 4A Analysis of Variance for grain yield of beans (season one)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	6116.75	3058.37	7.21	0.0071**
Inoculation	1	293.580	293.588	0.692	0.410ns
Density	3	251463.079	83821.026	197.490	0.000***
Inoculation X Density	3	459.023	153.008	0.36	0.873ns
Error	14	5942.030	424.431		
Total	23	264274.461			

APPENDIX 4B Analysis of Variance for grain yield of beans (season two)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	2258.57	1124.28	1.30	0.30 ns
Inoculation	1	2283.65	2283.65	2.65	0.13 ns
Density	3	269283.30	89761.10	103.98	0.000***
Inoculation X Density	3	289.29	96.43	0.11	0.95ns
Error	14	12085.80	863.27		
Total	23	286190.61			

APPENDIX 5A Analysis of Variance for the number of pods per plant.

(season one)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	25.716	12.858	9.019	0.003**
Inoculation	1	2.516	2.516	1.764	0.205 ns
Density	3	77.335	25.778	18.081	0.000***
Inoculation X Density	3	6.058	2.19	1.10	0.28ns
Error	14	19.960	1.426		
Total	23	131.485			

APPENDIX 5B Analysis of Variance for the number of per plant (season two)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	2.001	1.000	0.617	0.553ns
Inoculation	1	2.667	2.667	1.643	0.221 ns
Density	3	44.479	14.826	9.138	0.001**
Inoculation X Density	3	11.741	3.914	2.412	0.110 ns
Error	14	22.716	1.622		
Total	23	83.603			

APPENDIX 6A **Analysis of Variance for number of seeds per pod (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	7.082	3.541	10.14	0.0020**
Inoculation	1	0.818	0.818	2.312	0.151ns
Density	3	4.191	1.391	3.90	0.031
Inoculation X Density	3	2.698	0.899	2.544	0.098ns
Error	14	4.950	0.3542		
Total	23	19.739			

APPENDIX 6B **Analysis of Variance for the number of seeds per pod (season two)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	6.809	3.405	6.459	0.103 *
Inoculation	1	1.411	1.411	2.678	0.124 ns
Density	3	2.758	0.919	1.744	0.204 ns
Inoculation X Density	3	2.086	0.695	1.319	0.308 ns
Error	14	7.380	0.527		
Total	23	20.444			

APPENDIX 7A **Analysis of Variance for 100 grain weight of beans (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	291.614	145.807	6.971	0.008**
Inoculation	1	73.815	73.815	3.529	0.081 ns
Density	3	247.606	82.535	3.946	0.031*
Inoculation X Density	3	42.159	14.053	0.672	0.583ns
Error	14	292.836	20.917		
Total	23	948.029			

APPENDIX 7B **Analysis of Variance for 100 grain weight of beans (season two)**

Source	DF	SS	MS	F vale	Pr P
Replication	2	370.623	185.311	24.339	0.000***
Inoculation	1	21.414	21.414	2.812	0.116 ns
Density	3	83.670	27.890	3.663	0.039*
Inoculation X Density	3	63.049	21.016	2.760	0.0813 ns
Error	14	106.693	7.614		
Total	23	645.348			

APPENDIX 8A **Analysis of Variance for Biomass of maize (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	96.935	48.467	0.186	0.832ns
Inoculation	1	166.374	166.374	0.638	0.478 ns
Density	3	2549.920	849.973	3.26	0.054*
Inoculation X Density	3	1624.879	541.626	2.078	0.149 ns
Error	14	3649.506	260.679		
Total	23	8087.611			

APPENDIX 8 B **Analysis of Variance for Biomass of maize (season two)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	120.895	60.447	0.177	0.840ns
Inoculation	1	23.384	23.384	0.068	0.797 ns
Density	3	692.040	230.680	0.675	0.581 ns
Inoculation X Density	3	291.240	91.080	0.384	0.836 ns
Error	14	4782.636	341.617		
Total	23	5910.19			

APPENDIX 9A **Analysis of Variance for grain yield of maize (season one)**

Source	DF	SS	MS	F vale	Pr P
Replication	2	1707408.333	853704.167	2.640	0.106ns
Inoculation	1	60000.000	60000.000	0.1856	0.6732ns
Density	3	9280133.333	3093377.778	9.568	0.0011**
Inoculation X Density	3	846400.000	282133.333	0.872	0.4785ns
Error	14	4526191.667	323299.405		
Total	23	16420133.333			

APPENDIX 9 B **Analysis of Variance for grain yield of maize (season two)**

Source	DF	SS	MS	F vale	Pr P
Replication	2	1057275.00	528637.5	3.407	0.0623ns
Inoculation	1	16016.667	16016.667	0.1032	0.7527ns
Density	3	4379250.00	1459750.00	9.408	0.0012**
Inoculation X Density	3	1216450.00	405483.333	2.6133	0.923 ns
Error	14	2172258.333	155161.309		
Total	23	8841250.00			

APPENDIX 10A **Analysis of Variance for the number of cobs/plant (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	0.076	0.038	10.443	0.002***
Inoculation	1	0.0004	0.0004	0.012	0.740ns
Density	3	0.101	0.034	9.295	0.001***
Inoculation X Density	3	0.021	0.007	1.951	0.168 ns
Error	14	0.051	0.004		
Total	23	0.2495			

APPENDIX 10B **Analysis of Variance for the number of cobs/plant (season two)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	0.095	0.048	14.879	0.0003**
Inoculation	1	0.013	0.013	3.940	0.0671 ns
Density	3	0.018	0.006	1.856	0.184 ns
Inoculation X Density	3	0.002	0.597	0.206	0.890 ns
Error	14	0.045	0.0032		
Total	23	0.172			

APPENDIX 11A Analysis of Variance for the number of kernels per cob (season one)

Source	Df	SS	M	F vale	Pr>P
Replication	2	1475.14	737.57	0.93	0.42 ns
Inoculation	1	2141.18	2141.18	2.69	0.12 ns
Density	3	20144.18	6714.73	8.44	0.0019**
Inoculation X Density	3	654.76	218.25	0.27	0.84 ns
Error	14	1138.30	795.59		
Total	23	33626.56			

APPENDIX 11 B Analysis of Variance for the number of kernels per cob (season two)

Source	Df	SS	MS	F vale	Pr>P
Replication	1	1231.449	615.725	1.249	0.3168ns
Inoculation	2	5296.996	5296.996	10.746	0.005**
Density	3	24075.524	8025.175	16.281	0.000***
Inoculation X Density	3	5075.559	1691.866	3.432	0.047*
Error	14	6900.866	492.919		
Total	23	42580.434			

APPENDIX 12A **Analysis of Variance for 100 seed weight of maize (season one)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	7.658	3.829	0.371	0.697ns
Inoculation	1	15.698	15.698	1.520	0.238 ns
Density	3	95.788	31.929	3.092	0.062*
Inoculation X Density	3	93.262	31.087	3.010	0.66ns
Error	14	144.580	10.327		
Total	23	356.985			

APPENDIX 12B **Analysis of Variance for 100 seed weight of maize (season two)**

Source	DF	SS	MS	F vale	Pr>P
Replication	2	49.734	24.867	8.790	0.003 **
Inoculation	1	6.141	6.141	2.171	0.163 ns
Density	3	117.559	39.186	13.852	0.000***
Inoculation X Density	3	56.198	18.732	6.622	0.005*
Error	14	2.291	0.161		
Total	23	64.426			

APPENDIX 13A Analysis of Variance for percent soil Nitrogen in the hills at maize flowering/ two weeks after bean harvest-Twelve WABE

(Season one).

Source	Df	SS	MS	F vale	Pr P
Replication	2	0.016	0.008	0.507	0.613ns
Inoculation	1	0.014	0.013	0.857	0.370ns
Density	3	0.004	0.001	0.093	0.963ns
Inoculation X Density	3	0.031	0.010	0.659	0.591ns
Error	14	0.221	0.0168		
Total	23	0.286			

APPENDIX 13 B Analysis of Variance for percent soil Nitrogen in the hills at maize flowering/ three weeks after bean harvest-thirteen WABF

(Season two)

Source	DF	SS	MS	F vale	Pr P
Replication	2	0.437	0.219	6.099	0.012 ns
Inoculation	1	0.004	0.004	0.105	0.751 ns
Density	3	0.193	0.0645	1.799	0.194 ns
Inoculation X Density	3	0.120	0.040	1.116	0.376 ns
Error	14	0.502	0.036		
Total	23	1.257			

APPENDIX 14A Analysis of Variance for percent soil Nitrogen in the hills at maize harvesting/ 3.5 months after bean harvest -24 WABE (Season one)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	0.005	0.025	0.542	0.593 ns
Inoculation	1	0.007	0.007	1.430	0.252 ns
Density	3	0.006	0.002	0.048	0.750ns
Inoculation X Density	3	0.026	0.009	1.890	0.178 ns
Error	14	0.065	0.005		
Total	23	0.109			

APPENDIX 14 B Analysis of Variance for percent soil Nitrogen in the hills at maize harvesting/ 3.5 months after bean harvest -24 WABE. (Season two).

Source	DF	SS	MS	F vale	Pr>P
Replication	2	0.004	0.002	2.414	0.612 ns
Inoculation	1	2.042	2.042	0.269	0.587 ns
Density	3	0.002	5.042	0.665	0.364 ns
Inoculation X Density	3	0.003	8.708	1.149	0.3637ns
Error	14	0.012	7.577		
Total	23	0.019			

APPENDIX 15A **Analysis of Variance for percent soil nitrogen in the hills at one month after maize harvesting –18 weeks after bean harvesting -28 WABE**

(Season one)

Source	DF	SS	MS	F vale	Pr>P
Replication	2	0.01	0.0048	1.617	0.233 ns
Inoculation	1	0 1042	00.1042	0.036	0.851 ns
Density	3	0 004	0 001	0.431	0.734ns
Inoculation X Density	3	0 003	8 819	0 297	0 827 ns
Error	14	0 042	0.0029		
Total	23	0 058			

APPENDIX 15 B **Analysis of Variance for percent soil nitrogen in the hills at one month after maize harvesting -18 weeks after bean harvesting -28 WABE**
(Season two)

Source	DF	SS	MS	F vale	Pr P
Replication	2	0.013	0.007	4.019	0 042*
Inoculation	1	0 004	0 001	2 474	0 138 ns
Density	3	0.002	0.057	0.353	0 788ns
Inoculation X Density	3	0 01[illegible]	0 005	3 071	0 062 ns
Error	14	0 02	0 002		
Total	23	0.056			

Appendix A Soil Test (season one)

	Soil PH				Me/100 g				ppm
Depth	H_2O	$CaCl_2$	%N	%C	K	Na	Ca	mn	P
0-30	6.2	5.80	0.33	2.45	4.25	1.45	4.5	2.92	5.00

Appendix B Soil Test (season two)

	Soil PH				Me/100 g				ppm
Depth	H_2O	$CaCl_2$	%N	%C	K	Na	Ca	mn	P
0-30	6.5	4.90	0.37	3.1	3.0	0.9	9.5	3.0	11.0

Appendix C Weather data during the experimental period

Year	Month	Total rainfall (mm)	Temperature (°c)	
			Min	Max
1996	March	110 1 mm	14 7	25.3
1996	April	91 1 mm	14 4	23 7
1996	May	89 3	14.4	22.4
1996	June	51 2	12.8	20.7
1996	July	35 6	11 1	20 0
1996	August	36 6	10 3	21 5
1996	September	37 0	11 9	23 6
1996	October	1 3	1 3	24 9
1996	November	209.7	13 8	22 1
1996	December	2 6	13 1	23 6
1997	January	4 7	13 3	25.6
1997	Febuary	0 0	12.8	28 0
1997	March	29 2	14 6	26 4
1997	April	541 2	14.3	23.3
1997	May	105 8	13.5	21 9