

THE EFFECT OF VARIED SOIL NITROGEN LEVELS ON THE YIELD
AND NUTRIENT UPTAKE OF INTERCROPPED BEANS AND MAIZE
AT VARIED CROP PROPORTIONS

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ABSTRACT

Intercropping is a traditional practice that has been in existence in developing countries for many years for a number of reasons. These include: Increased productivity per unit area; efficient use of limited resources such as land, labour, nutrients, light, time and water; reduction in pest damage due to diseases, insects and weeds; greater yield stability due to reduced risks; and economics of better use of land, labour, and capital or management of resources.

A field experiment was carried out in East Ithaca (Cornell University, New York) in 1990 and 1991 growing seasons to determine if by altering proportions and population of beans and maize, a cropping system can be designed to produce more under limiting conditions. Three nitrogen levels of 0, 80 and 160 kg N/ha and five crop proportions of sole maize, sole beans, 75% maize + 25% beans, 50% maize + 50% beans and 25% maize + 75% beans were the treatments planted in a split-plot design. The bean cultivar used was Ruddy (red kidney, bush beans) and the maize cultivar was Pioneer 3925. Two bean rows were planted between two maize rows.

Intercropping greatly increased dry matter accumulation per plant of beans and maize (gm/plant), and therefore, total dry matter in kg/ha. At the same time, nutrient uptake (kg/ha) was greatly improved by intercropping although nutrient concentrations in most instances were more in sole crops than intercrops.

In 1990 and 1991 growing seasons, intercropping reduced incidence of Japanese and Mexican bean beetles compared to sole beans. Japanese

and Mexican bean beetles decreased with decrease in bean proportions in the systems.

Intercropped maize and beans were more efficient than sole crops in utilizing available resources with high land equivalent ratios (LER) values both under low and high maize population cropping systems. LER values decreased with increase in applied N fertilizer in both years.

Total yield per hectare or combined yield of both beans and maize per hectare increased with increase in maize proportions while total income decreased with increase in maize proportions in both years. In 1990, intercrops produced higher income than sole crops. In 1991 under low maize population cropping system, sole beans produced the highest income although not significantly different from 75% bean proportion.

Protein production was also affected by crop proportions and N fertilization. Intercropped beans produced a higher amount of protein both in 1990 and 1991 growing seasons than sole beans. Sole maize in 1990 produced more protein than intercropped maize, and in 1991 under both low and high maize population cropping systems, intercropped maize produced higher protein than sole maize.

BIOGRAPHICAL SKETCH

The author was born in Nebbi, Uganda, on March 1, 1961. He obtained his primary and secondary education in the northern part of Uganda. He obtained a Bachelor in Agriculture (crop science as a major with soil fertility as a minor) from Makerere University, Kampala, Uganda in June, 1985 with an Upper second class degree with honors. In 1986 he was employed by the Ministry of Agriculture, Research Department and posted to Serere research station where he was assigned to work on beans as an agronomist. One year later, he moved to Kawanda research station in Kampala to continue his work with the Uganda National Bean Program (UNBP) in collaboration with CIAT (International Center for Tropical Agriculture) scientists. Since then, he has been working at Kawanda research station.

The author came to the United States in August, 1989 to pursue a Master degree in vegetable crops with a minor in soil fertility with specific interest in intercropping of beans and maize.

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CHAPTER ONE

INTRODUCTION

Many farmers in developing countries faced with constraints to crop production imposed by either limited land resources or limited labour, intensify production by using multiple cropping systems. In these systems, two or more crops are grown together in the same field, for most part of the growing seasons, or in sequence. Multiple cropping is subdivided into two main categories: (a) intercropping and (b) sequential cropping. Intercropping is the growing of two or more crops in the same field per year simultaneously while, sequential cropping is the growing of two or more crops in the same field per year but in sequence.

Peasant farmers practice intercropping due to a number of reasons (Lamberts, 1980, 1983; Francis, 1989). The main reasons for practicing intercropping include increased productivity and greater yield stability due to reduced risk; efficient use of limited, available resources like water, land, labour, light, time and nutrients; reduction in pest damage caused by diseases, insect pests and weeds; and economics of better resource utilization.

Intercropping a non-legume crop with a legume crop is one of the many cropping systems prevalent in the tropical and sub-tropical countries. It has been observed that the yields of both crops may be reduced when intercropped compared with their yields when grown in pure stands, although the combined yield may be higher than when either crop is grown alone (Okigbo and Greenland, 1976).

Although intercropping has been practiced for generations, the detailed study of intercropping is just a few decades old and a lot still remains unclear about intercropping system. Very little work has been done in connection with soil fertility problems and yet this is very important in relation to proper managing of soils in the areas where intercropping is practiced. For example, in Uganda, farmers usually plant field beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) as intercrops at very high population densities without giving much thought to the nutritional status of the soil. This is made worse by the fact that beans are harvested by uprooting whole plants and carried away from the fields without returning the crop residues to the same field. For maize, only the cobs are harvested and the rest of the residues remain in the field. Therefore, the distant fields from home are mined of the nutrients which are instead used in compound gardens as mulch leading to better soil fertility. Thus fertility level decreases as one moves away from the home gardens to distant gardens. This poses a lot of problems to our soils in developing countries as farmers are not in position to apply artificial fertilizers either because they are not available or they are too expensive for farmers to afford. There seems to be indications by a number of researchers that intercrops do accumulate more nutrients (kg/ha) than sole crops (Chui, 1988; Ofori and Stern, 1986; and Wahua, 1983). If this is the case, then a better cropping system must be devised in order to avoid mining of the soils of the nutrients available and maintain high production of the crops.

But it is clear that as we put in more crops in a system, the more complex the research work becomes compared to dealing with a single

crop. This seems to be the reason why very little so far has been done in connection with intercropping.

The primary objective of the present research work was to determine whether by altering proportions and population of field beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.), a cropping system could be designed to produce more under limiting conditions of the rural peasant farmers. I also wanted to determine the effect of altering crop proportions of beans and maize in a replacement series under different soil fertility levels on the nutrient uptake of the two crops and crude protein accumulation. Therefore, we need to design a system which will produce adequate yield inspite of the low fertility status of the soils, regardless of the cause of the soil fertility. The experiment involved comparison of total yield and yield components, nutrient contents of the plants, crude protein accumulation by the crops and total income from the crops as affected by altering crop proportions and population of the crops.

CHAPTER TWO

LITERATURE REVIEW

2.1. TERMINOLOGY

The practice of growing many crops on the same field either simultaneously or sequentially has been a tradition of many people in developing countries. Many researchers have used terms like 'polyculture', 'mixed cropping' 'intercropping', 'crop association', 'multiple cropping', etc to mean the growing of more than one crop in the same field. Over years, there has been an urgent need to standardize these terms and define them correctly. The first attempt to standardize them was made by Andrews and Kassam (1976). Table 2.1 presents the recently published version of the definitions by Francis (1986) that are in common use and widely accepted these days, and other definitions used in connection with multiple cropping systems.

Multiple cropping system is the general term for all cropping patterns where more than one crop is cultivated on a field in one year. From the table, multiple cropping system has two main divisions: 'Intercropping' and 'sequential cropping' with subdivisions under the two main categories.

Intercropping systems are themselves distinguished by the spatial arrangement of the component crops. "Row" cropping is used when crops are planted in alternate rows, while "mixed cropping" is used when no specific spatial arrangement can be distinguished. "Strip" cropping is the

growing of two or more crops simultaneously in strips. This allows the use of large field equipment. "Relay" cropping is when two or more crops are

Table 2.1. Definitions and Terminology in Common usage with Multiple cropping systems

Multiple cropping: The intensification of cropping in temporal and spatial dimensions; growing two or more crops on the same field in one year

Sequential cropping: Growing two or more crops in sequence on the same field per year; crop intensification is only in the time dimension; there is no intercrop competition

Double cropping: Growing two crops per year in sequence

Triple cropping: Growing three crops per year in sequence

Quadruple cropping: Growing four crops per year in sequence

Ratoon cropping: Cultivation of crop regrowth after harvest, although not necessarily for grain

Intercropping: Growing two or more crops simultaneously on the same field; crop intensification is in both the temporal and spatial dimensions; there is intercrop competition during all or part of the crop growth

Mixed Intercropping: Growing two or more crops simultaneously with no distinct row arrangement

Row Intercropping: Growing two or more crops simultaneously; one or more crops are planted in rows

Strip Intercropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically

Relay Intercropping: Growing two or more crops simultaneously during part of the life cycle of each; a second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest

Cropping Index: $\text{Number of crops grown per year on a given area of land} \times 100$

Cropping pattern: Yearly sequence and spatial arrangement of crops or crops and fallow on a given area

Cropping system: Cropping patterns used on a farm and their interactions with farm resources, other farm enterprises, and available terminology that determine their make up

Monoculture: Repetitive growing of the same sole crop on the same land

Sole crop: One crop variety grown alone in pure stand at normal density

Land Equivalent Ratio (LER): Ratio of the area needed under sole cropping to that under intercropping at the same management level to give an equal amount of yield; LER is the sum of the fractions of the yields of the intercrops related to their sole crop yields

Competition effect: Competition of intercropped species for light, nutrients, water, carbon dioxide, and other growth factors

Table 2.1. Contd.

<u>Complementary effect:</u>	Effects of one component on another that enhance growth and productivity, as compared to competition
<u>Component crops:</u>	Individual crop species that are part of the multiple crop system
<u>Component technology:</u>	Procedure for growing each component crop
<u>Interplanting:</u>	All types of seeding or planting a crop into a growing stand; used especially for annual crops grown under stands of perennial crops
<u>Over yielding:</u>	Production of component crops in an intercrop that is higher than the sum of appropriate monoculture crops; this is a LER greater than unity
<u>Spatial arrangement:</u>	Physical or spatial organization of component crops in a multiple cropping system.

planted in the same field but not on the same date. One crop is usually planted some days after the first crop has been planted.

Associated with multiple cropping are other terms that are used to describe or evaluate multiple cropping systems as given in Table 2.2. These terms are becoming increasingly important because of the interests that researchers are taking in describing in detail what multiple cropping systems involve. Since farmers have persisted in the use of multiple cropping system, an in-depth knowledge of the system will be of great help in improving crop production.

2.2. IMPORTANCE OF INTERCROPPING

Intercropping a non-legume crop with a legume crop has been practiced by peasant farmers in sub-tropical and tropical countries for centuries. Although it has been observed that the yields of both crops are reduced when intercropped compared with their yields when they are

grown in pure stands, the combined yield may be higher than either crop grown alone. Lamberts (1980) reviewed in detail the reasons for continued use of multiple-cropping.

Table 2.2. Other related terminology connected with multiple cropping systems

<u>Crop diversification</u> :	Planting various crops on the same farm which may or may not be interplanted (Lynam et al., 1986).
<u>Competitive Ratio (CR)</u> :	Measure of intercrop competition which indicates the number of times which one component crop is more competitive than the other (Willey and Rao, 1980).
<u>Interference</u> :	Overall deleterious effects of one plant on another; encompasses both competition and allelopathy (Trenbath, 1974).
<u>Competition</u> :	Process in which the reaction of a plant upon the habitat reduces the level of some other necessary factors to the detriment of some other plant sharing the same habitat (either simultaneously or sequentially) (Trenbath, 1974).
<u>Interspecific competition</u> :	Competition between plants of different species such as weeds-crop competition, maize-beans (Trenbath, 1974)
<u>Intraspecific competition</u> :	Competition between plants of the same species, for example, a study of growth and development as a function of density in monoculture (Donald, 1963).
<u>Intraplant competition</u> :	Competition between the parts of a single plant (Donald, 1963).
<u>Income Equivalent Ratio (IER)</u> :	The ratio of the area needed under sole cropping to produce the same income as one hectare of intercropping at the same management level. IER is the conversion of LER into economic terms (Andrews and Kassam, 1976).
<u>Monetary Advantage (MA)</u> :	Same as IER.
<u>Area Equivalent Ratio (AER)</u> :	The ratio of the actually cultivated farm area to the sum of the equivalent sole crop area of each crop involved (Andrews and Kassam, 1976).

Briefly, the summary for continued use of multiple-cropping systems includes increased yield advantage, better use of resources, reduction in pest damage and socioeconomic reasons.

2.2.1. Yield advantage and resource use

Lamberts (1980, 1983) extensively covered this topic so only a brief description will be given here. Intercropping leads to increased productivity or yield advantages where the combined yield in intercropping is higher than the yields of the sole crops. There is better use of available resources such as land, labor, time, water and nutrients. Also, there is even distribution of labor, and the practice allows farmers to combine many cultural operations at the same time, and there is generation of employment. There is better use of water especially in dry areas where rainfall is scarce, and the possibilities for irrigation are limited.

2.2.2. Reduction in pest damage

In this context, 'pests' refers to diseases, insect pests and weeds, which are of primary importance in reducing yield.

(i) Diseases: Several authors have indicated the importance of crop mixtures or multiple-cropping in decreasing disease attack compared to monoculture, especially if the pest attacks only one particular crop in the mixture (Fisher, 1979; Francis et al., 1976; Trenbath, 1976). In multiple cropping system, species diversity allows mixtures of both susceptible and resistant (non-host) plants, thus increasing the distance from one host plant to another which may reduce colonization and spread of the disease (Altieri and Liebman, 1986). In some cases, due to the microclimate modifications imposed by crop association, increased relative humidity and shade may favour the incidence of certain diseases such as angular leaf spot and wilt in common beans (Palti, 1981). This type of situation,

however, can be offset by including non-host plants in the mixture (Power, 1989).

Sumner et al. (1981) noted that the effects of crop mixtures on diseases are that "they buffer against disease losses by delaying the onset of the diseases, reducing spore dissemination, or modifying microenvironmental conditions such as humidity, light, temperatures, and air movement. Certain associated plants can function as repellants, antifeedants, growth disrupters, or toxicants. In the case of soil borne pathogens, some plant combinations may enhance soil fungistasis and antibiosis through indirect effects on soil organic matter contents".

Browning (1975) indicated that so long as the pathogen/host/environment relationship is understood in a particular cropping system, the use of mixed cropping and genetic diversity may be a possibility in controlling diseases.

(ii) Insect pests: Altieri and Liebman (1986), Francis (1986) Lamberts (1980), and Power (1989) discussed this topic in detail with a lot of examples in which insect pests were less prevalent in multiple cropping systems than sole crops.

Hasse and Litsinger (1981) indicated that "insects may have difficulty finding suitable host plants in an intercrop due to the presence of other non-host plants, to camouflage of the preferred host, to changes in the texture or color of the total background, to masking of a chemical attractant, or to presence of a repellent from a non-host plant. Even if the insect finds the host, there may be interference with reproduction and survival due to non-host crop plants, or there may be differences in either the microclimate or the natural enemy population in the intercrop compared to a sole crop environment".

Wrubel (1984) noted that the population of Japanese beetles were lower on soybeans in maize/soybean intercrop than on the sole crop of soybeans. He attributed the low abundance of the beetles to the shading effect of the soybeans by the maize plants. Similar finding was reported by Gethi and Khaemba (1985) where intercropping cowpea and maize reduced damage caused by the legume pod borer, *Maruca testulalis*, in Kenya. Risch et al. (1983) in a review of literatures on 198 insects that attack crops reported that 53% showed lower abundance in multiple cropping than sole crops, 18% were more abundant in mixtures, 9% showed no difference, and 20% were variable in their response.

(iii) Weeds: Altieri and Liebman (1986) indicated a number of factors that could be manipulated to reduce weeds in an intercropping system. These are mostly cultural practices which can be easily applied by a farmer.

- Crop density where legumes can be used as cover crops to reduce weeds. Common beans sown between rows of cassava was very effective in reducing weeds with similar effect on the yield of cassava as continued manual weeding (CIAT, 1980). Similar effect may apply to cereal-legume combination.

- Spatial arrangement and the relative proportion of the component crops are manipulated in such a way that the component crops capture maximum available resources compared to the weeds (Shetty and Rao, 1979). They observed in their study that the weed suppressing power of pearl millet and groundnuts depended more on the relative proportion of the two crops. In a 1:3 pearl millet/groundnut row arrangement, weeds were more suppressed than in other row arrangements.

- Crop species where different species possess different abilities to suppress weeds (Shetty and Rao, 1979; Robinson and Dunham, 1954).

Other factors like soil moisture, weed density, weed community, herbivores and pathogens may be important in the intercrop-weed relationship (Altieri and Liebman, 1986).

2.2.3. Socio-economics and other advantages involving greater yield stability due to reduced risks of losses to pests; economics of better use of land, labour, and capital or management resources have been discussed in detail by Bradfield (1986), Lamberts (1980) and Lynam et al. (1986), and therefore, will not be repeated here.

On the other hand, when two or more crops are planted together, yields of all the component crops are not always increased. It was reported that the yield of beans (*Phaseolus vulgaris* L.) was substantially reduced by intercropping with maize at CIAT (International Centre for Tropical Agriculture) (Francis, 1978; Francis et al., 1978). Simultaneous planting of bush beans and maize reduced bean yield to 52% of monocrop on average, and with climbing beans to only 31% of monocrop. Total LERs (defined in table 2.1) of both crops, however, were higher than one. Generally, there is reduction in legume yields with only slight changes in yields of the cereals grown in association with them (Dalal, 1974; Fisher, 1977b; Wahua and Miller, 1978a; Willey and Osiru, 1972). Rego (1979) reported a decline in sorghum yield when intercropped with pigeon pea, or when intercropped with cowpea (Enyi, 1973). In most cases, the total LERs are greater than one. But low LERs are most likely to occur in cases where crops are attacked by pests or very low fertility soils are used (Martin and Snaydon,

1982), or when planting of one component crop is delayed too much (Francis et al., 1982).

Researchers have also indicated that intercropping experiments are more complex and difficult to manage than monoculture (Willey, 1979b). Intercropping experiments are also difficult to mechanize because of the different crops that are planted in the same field which may require different field operations.

In the present research work, we are trying to put the mentioned advantages into perspective and see how manipulating crop proportion in intercropping and varying fertility levels may affect the advantages.

2.3. PLANT DENSITY AND SPATIAL ARRANGEMENTS, RELATIVE PLANTING TIME, AND CHOICE OF CROPS AND CULTIVARS

In intercropping systems, the initial decision a farmer makes is in regard to plant density, spatial arrangements, relative planting time and the choice of crops and cultivars to include in the system. As reported by Martin and Snaydon (1982), these agronomic practices determine the success of an intercropping system, the interaction between the component crops and the use of available, limiting resources in relation to the pure stand. However, an improper decision about these agronomic practices may lead to losses of yield advantages in terms of land equivalent ratio (LER).

2.3.1. Plant density and spatial arrangement

Plant density and spatial arrangements are very important because they determine interactions and interferences within a given plant population. Steiner (1984) made the following observations:

"___ optimum density can be increased in all intercropping systems where the interference between neighboring plants is less than in sole crops, that is, where intercrop competition is less than intracrop competition. Population increases are most likely to cause increases in yield where there are large temporal differences in growth patterns of the components ___".

Baker (1979b) carried out a study on the effect of plant-population change in crop mixtures, and he noted that yield advantage from intercropping is due to some response to "reduced" plant population because of complementarity in space, time or both. He also indicated that, considering the length of the growing season and the difference in plant size, the yield of an intercrop may be further increased by increasing plant population. But it is also clear that increasing plant population increases the incidence of interference between neighboring plants such that the yield per plant is reduced. But because of species diversity in an intercropping system, the response to population increase may not be uniform as compared to sole crops. Baker (1979a) working on a mixture of 75- and 85- day sorghum varieties found that there was increased yield per unit area due to higher yield per plant when the two cultivars were grown together at high population compared to the sole crops. He gave an example of a millet intercrop where millet yield increased from 0.151 kg/plant in sole crop millet to 0.218 kg/plant in a millet-maize intercrop and up to 0.314 kg/plant in a millet-maize-sorghum intercrop. There was

no significant effect on maize or sorghum yield. Therefore, he concluded, a high overyield of crops could be obtained by increasing the plant populations within an intercrop system. The intercrop populations used here were higher than the sole crop population of millet, and millet population was optimum for all three cases. Most likely, increase in millet yield per plant was due to better utilization of the available resources or better spatial arrangements or both, resulting into high LER.

In regard to Baker's finding, Huxley and Maingu (1978) noted earlier that, even if higher yield could be obtained by increasing crop population in intercropping system, different crops respond differently to population increase. Therefore, yield advantage calculation should be made between intercrop and sole crop at their respective optimum population. Only when this is attained, can a farmer realise the benefit of an intercrop compared to sole crop.

But the overall yield in intercropping systems is determined by the component crop populations which determine how much of the total yield is contributed by each crop in the intercrop system (Steiner, 1984). This final contribution to the overall yield is determined by the relative competitive ability (defined in Table 2.2) of the component crops which is not a constant or a quantifiable function for any given crop. In most cases, this relative competitive ability will depend on the actual population of the component crops. " All component crops become relatively more competitive if they form a large proportion of the total population; and dominant crops become more dominant when the total population increases" (Willey, 1979b).

In the face of this argument, the yield of a crop will depend on how far it can maintain that yield in the presence of its neighboring plants. It

is clear from the above points that the yield per unit area (Y) is a function of yield per plant (y) and the number of plants (P) in a unit of land area. A shift in population density will shift yield per plant depending on the direction of the shift, that is, the yield may increase, decrease or remain constant. Generally, most crops will increase their grain yield per plant in response to reduced population, and individual plant productivity declines as each plant has to share a limited supply of resources when population is increased (Baker, 1979b; Donald, 1963; Marx, 1966). From Donald's work of 1963, dry matter accumulation per plant at the early stages of growth is linear regardless of the population density. Competition becomes obvious at the high population density first for light, and later for other resources until growth is stopped. Biomass yield remains constant after reaching a certain maximum density with no further increase in total biomass yield with increasing density as shown in Figure 2.1a. The grain yield per unit land area increases with increase in density and reaches a maximum and then drops down with further increase in density (Fig. 2.1b).

In a number of cases, yield per plant has decreased both at the low and high plant population densities, and Donald (1963), gives the following review to effect of the changing plant population:

"___ the great seed weight and number of seeds per inflorescence at intermediate densities are due to the varying time of incidence of interplant and intraplant competition. At the widest spacing, competition is absent during the early stages of growth. Flower primordia are laid down by each plant in large numbers. As growth proceeds, interplant competition becomes progressively operative, until when flowering and seed setting occur the load of inflorescences is so great as to lead to competition among the inflorescences themselves and thereby to reduce the efficiency of seed production in the individual inflorescence. This loss of efficiency at the widest spacing shows in reduced numbers of seeds per inflorescence and reduced seed size

compared with somewhat denser stands. Thus, intraplant competition may be at low densities ____"

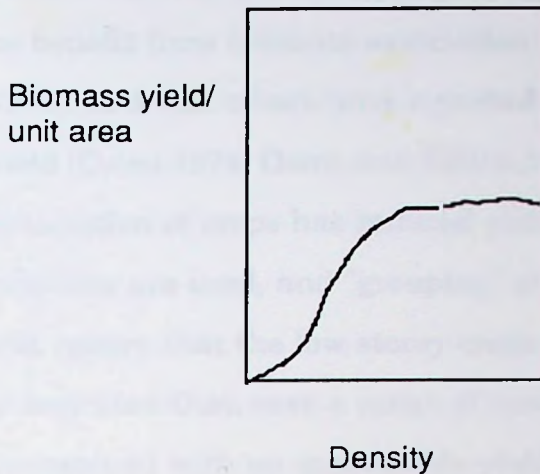


Figure 2.1a

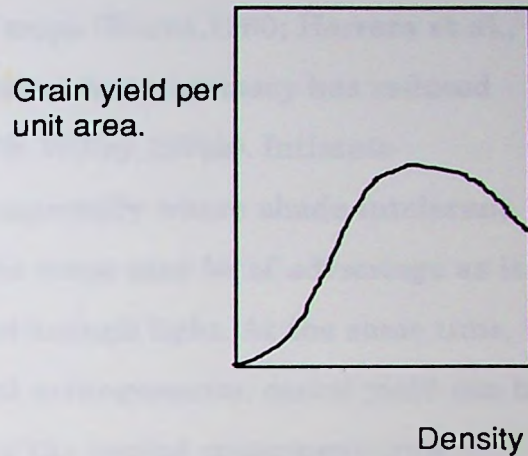


Figure 2.1b

Figure 2.1. Total biomass and grain yields of crops in response to increasing density.

What researchers have found indicates that as long as the interference between plants in an intercropping system is less than that of sole crops, a high population of the intercrop may be used. But for the case of this research we are carrying out, the nature of interference is not clear, and therefore the need to use optimum plant population density of each crop for the intercrop as described in the methodology. Also, we are trying to see if change of component densities under a range of soil fertility levels will affect their response in a replacement series.

Another important issue in intercropping is the "spatial arrangement" defined by Willey (1979b) as "the pattern of distribution of plants over the ground, which determines the shape of the area available to the individual plants". Many researchers have indicated the benefit of

intimate association of crops as a means of improving crop yield (Andrews, 1972; Dalal, 1974; 1977; IRRI, 1973) while others have reported no benefit from intimate association of crops (Evans, 1960; Herrera et al., 1975), and still others have reported cases where intimacy has reduced yield (Osiru, 1974; Osiru and Kibira, 1979; Willey, 1979b). Intimate association of crops has reduced yield especially where shade intolerant cultivars are used, and "grouping" of the crops may be of advantage as it will ensure that the low storey crops get enough light. At the same time, it is indicated that, over a range of spatial arrangements, cereal yield can be maintained with an appreciable yield of the second component crop (Singh, 1977). Crop arrangements in intercropping systems which allow for maximum utilization of available resources may give high yield.

"Grouping" of crops in a mixture can be of great advantage when tall crops are combined with short ones (Steiner, 1984). For example, at CIAT (International Centre for Tropical Agriculture) (CIAT, 1978), an experiment was carried out where cassava was interplanted with legumes at two cassava spacings of 1m x 1m and 2m x 0.5m to maintain constant population of both treatments. The 2m x 0.5m cassava spacing allowed 2-3 rows of legumes to be planted between cassava rows, and a much higher yield of the legume was achieved by this spacing compared to the 1m x 1m cassava spacing, with no significant difference in the yield of cassava between the two spacings. In India, grouping of the cereals helped increase the yield of the second component crop, soybeans, with no apparent yield loss in the cereal (sorghum) (De, 1980). De also reported a second experiment where maize population was maintained at 60,500 plants/ha at spacings of either 60cm or 120cm apart. The 120cm spacing

allowed 3 rows of soybean between 2 rows of maize, resulting in LER increase of 54%.

Total dry matter production for a maize/bean intercrop may be significantly affected by the spatial arrangement of the two crops. Planting the two crops in the same row reduced total dry matter of the intercrop by 36.5% at 40 days after planting, and by 24.4% at maturity (Chui, 1988). Planting the two crops in alternate rows only reduced the total dry matter production of the intercrop by 29.4% at 40 days after planting and 11.6% at maturity. Mixtures of pigeon peas and sorghum gave high LER when grown in alternate rows than when planted in the same row, and this was true for 4 different plant populations of the two crops (Osiru and Kibira, 1979). They related this to better nutrient utilization as roots were better distributed than the roots being in the same row. Similarly, Martin and Snaydon (1982) in studying the effect of planting pattern in barley (*Hordeum sativum*) - field beans (*Vicia faba*) mixture compared monocultures of both crops, alternate-row arrangement and within-row arrangement of the mixtures. They noted that, when the two crops were grown in alternate rows, the LER was 1.85 compared to when the crops were grown using the within-row arrangement (1.53), and this was when the mixture included more barley than beans. According to them, the grain yield of beans was less than expected and that of barley greater than expected when in within-row mixtures. Both beans and barley yielded more than expected in alternate-row mixtures ($p < 0.05$). They concluded that the nature of competition between the species in an intercrop depended more on the optimum spatial arrangement. Reducing the competition effect by growing the crops in alternate rows often increases yield of the component crops.

It should be noted that plant arrangement is often the result of trying to save time and labour in planting and weeding, and psychological satisfaction of planting a "large area" or lack of seeds (Edje, 1981). Experience with farmers in Eastern Africa shows that maize is planted in rows which can be up to 1m x 1m but 3-4 seeds per hill (personal experience). The overall population density is almost the same as when they are planted using the recommended spacing. Beans are planted either in rows or broadcast. Farmers usually drop 2-3 seeds of beans in small holes made by using a stick. Some plant both maize and beans in the same hole. To make the work go even faster, some farmers take a mouthful of bean seeds and as they make a hole they drop the seeds and cover them straight. These methods of planting help reduce labor needs. Although yields may be better if plants are grown in alternate rows, with individual plants spaced apart, it is a lot easier to plant 3-4 seeds per hill and have a wider gap which makes weeding much easier than when planted close together. Yield is reduced by planting so many seeds in the same hole especially under poor soil fertility but this has not been proved to be significantly different from the modern method of planting in rows under good soil fertility management. The reduction in yield results from intense competition between the plants as they occupy a small area. Where soil condition is not favorable, yield may be significantly reduced. Despite the efforts to introduce modern row planting of crops, farmers still practice their own methods of planting.

Therefore, considering planting pattern in an intercropping system, it is important to optimize the complementarity of the component crops so that utilization of the available resources in the environment is maximized. This optimization appears to occur most often in alternate

row arrangements, and for this reason, we choose this planting pattern in the present research.

2.3.2. Relative planting time

Relative planting time is mostly determined by the type of cropping system that prevails in an area (mixed cropping, relay cropping, alley cropping, etc) and the agroclimatic factors .

In an experiment carried out at Makerere University farm (Kabanyolo, Kampala, Uganda) by Willey and Osiru (1972) using mono beans and mono maize, $2/3$ maize + $1/3$ beans, $1/3$ maize + $2/3$ beans (replacement series) at three plant populations of 2.8, 5.6, 11.1 'plant units' / sq.m., in a split-plot design, yields of the mixtures were up to 25% higher than when the crops were grown separately. The advantages of the mixtures declined markedly with delay in planting date of the beans. The yield advantage of the mixture at population one (2.8 'plant units' / sq.m.) dropped from 20% when beans and maize were planted at the same time to only 2% when beans were planted 4 weeks after planting maize. This trend was similar for the other two plant populations used (5.6 and 11.1 'plant units'/sq.m.). Willey and Lakhani (1976) reported a similar finding with sorghum/bean mixture where the yield advantage declined from an average of 33.1% with simultaneous planting to 10.6% with a month's delay in planting of beans after the sorghum in a mixture.

Francis et al. (1986) indicates that the purpose of adjusting planting date is to ensure that component crops have adequate moisture and temperature for germination, avoid the extremes in temperature that could cause stress and difficulty in setting and maturing seeds, and

minimize other unfavorable conditions during the whole growing season. This is a decision that a farmer faces when he thinks of when to plant component crops in a mixture considering that these species may require different cultural managements. Willey (1979b) reported that, " the greater the difference in maturity and growth factor demands of the crop components, either because of genetic differences or manipulation of planting dates, the more opportunity for greater total exploitation of growth factors and overyielding, that is, a total production greater than monoculture of each crop ".

Francis (1989) stated that a crop in a mixture if given a head start will, in most cases, be the more competitive than the others planted late. In experiments carried out at CIAT (Colombia), Francis (1978) and Francis et al. (1982) reported the achievement of a higher yield of beans when beans were planted early, but this resulted in reduced yield of the maize. The reverse was true where early planting of maize favoured high maize yield and low bean yield. He attributed the change in yield of the crops to the effect of early high competition and shading by the earlier planted component crop. Wien and Smithson (1979) found that delaying cowpea planting for 30 to 40 days after cereals (sorghum or millet) in an intercrop reduced cowpea yield to a very low level. However, cowpea yield increased with over 40 days' delay in cowpea planting after the cereals, as long as the growing season was long enough to allow the cowpea to mature.

Therefore, the decision on when to plant component crops in a mixture will largely depend on what objectives the farmer has, and the economic return from the crops as well as the length of the growing season (Francis, 1978). In case where necessity dictates the early

establishment of one crop component, early planting of that crop may be advisable. Otherwise, simultaneous planting avoids giving one species an initial advantage over the other. All the effects of planting dates indicate how important shading is to the understorey crops and how early competition may be of importance in reducing yield of the component crops in a mixture. That is why in the present experiments, simultaneous planting was chosen in order to avoid giving one crop an early start.

2.3.3. Choice of crops and cultivars in mixtures

Choice of crops for intercropping is determined by a number of factors including where and when planting is done, physical factors (soil conditions, temperature, stress, moisture regimes), social factors (personal tastes, use of the products, and transportation), economic factors (prevailing prices and costs of production), pests and cropping patterns, and greater or less competitive ability (Jana and Sekao, 1976; Lamberts, 1983; Rao et al., 1979; Smith and Francis, 1986).

Willey (1979b) pointed out that the objective of proper crop selection is to reduce intercrop competition, and maximize complementary effects between the different intercrop components in order to increase yield. He also observed that the extent of any selection should be in regard to whether the crop is dominant or dominated in the intercrop; the tallness of the component crops which determines the amount of light that a lower component crop in the storey gets during the process of growth.

Multiple cropping system is more diverse genetically than monoculture, the complexity ranging from multiline varieties to highly complex combinations of cultivars as seen in tropical Asia and Africa

(Harwood and Price, 1976; Jensen, 1952; Okigbo and Greenland, 1976).

This represents a wide spectrum of genetic diversity both within and among species which is important in selecting varieties for multiple cropping system. Therefore, cultivar selection for multiple cropping systems is complex because of the environmental diversity, the number of species involved and the interactions among crop species which may cause variation in agronomic management of the system (Finlay, 1976; Smith and Francis, 1986). Wien and Smithson (1979) suggested that screening a wide range of pure lines in the multiple cropping system to identify traits that are important and easily adaptable to the system is essential.

Smith and Francis (1986) indicated that there are three groups of factors which affect selection for multiple cropping system, namely: genetic diversity, genetic traits of importance to consider in the selection and the breeding methodology. Some important phenotypic traits that should be considered for multiple cropping system are:

- **Crop maturity:** Combinations of crops with different maturity periods can maximize resource use and lead to compensation by the late maturing crop. Rao and Willey (1980) indicated that a mixture of pigeonpeas and cereals yielded more pigeonpeas than the pure stand of pigeonpeas as the maturity periods between the two crops increased. He reported a similar finding for a millet/sorghum intercrop where combining late maturing sorghum with early maturing millet or the reverse were more productive than when the maturity periods were similar. The late maturing crop yielded well due to compensation after harvest of the early maturing crop, therefore, increasing total productivity of both crops. Similarly, Willey and Lakhani (1976) reported high total yields of both crops for maize/bean and

sorghum/bean mixtures when the components varied greatly in maturity periods. Andrew (1972) suggested that combining early and late maturing crops increased their capacities to use the environmental growth factors efficiently due to the temporal differences in demands between the component crops.

- **Photoperiod sensitivity** is desirable in some situations. For example, in a maize-sorghum intercropping, it allows for close adjustment of crop cycles to rainfall distribution as flowering in some sorghum varieties is affected by photoperiod (Smith and Francis, 1986). This permits flowering and maturity to occur during favorable periods of the season. Photoperiod insensitivity, on the other hand, allows flexibility in cropping system, and can permit a number of harvests sequentially per year as in a double or triple cropping system.

- **Plant morphology:** Reducing the shading or competitive effect of a dominant crop by reducing its height in most cases allows increased productivity of the subordinate crop especially if the subordinate crop is shade sensitive (Davis et al., 1984). Soybeans in association with short maize yielded more than when combined with tall maize variety (Thomson et al., 1976). But benefits may also be attained by planting crops in mixtures that are morphologically and physiologically of contrasting habits (Baker, 1979; Donald, 1963; Lingegouda, 1972; Osiru and Kibira, 1979). Francis (1978), working on the association of three bean types with maize in Colombia found that planting maize with bush beans (type I) and semi-climbing beans (types II and III) simultaneously had very little effect on maize. Planting maize with climbing beans (type IV) greatly reduced maize yield. When other tall cereal crops were combined with sorghum, the yield of sorghum was more reduced than when it was

combined with short cereal varieties (Rao and Willey, 1980). Therefore, the relative morphology and yield of individual crops in mixtures are influenced by the presence of other crops in the mixture, densities and spatial arrangements of the component crops (Francis, 1978). Herrera and Harwood (1973) indicated that "most successful combinations used in intercroppings have crops that have widely different leaf canopies (short crops growing under tall ones) creating different strata of leaf concentrations giving a more efficient utilization of incident light. Also, this builds up a rough canopy architecture allowing good wind turbulence that will give a good distribution of carbon dioxide for photosynthetic process and hence, increase the dry matter production".

- **Root systems** : Not much has been reported on but crops vary in their needs for water and nutrients, and this may be important in intercropping. It may be advantageous to mix crops of different root systems (shallow and deep rooted crops) so that resource exploitation is maximized (Willey, 1979b).

- **Stress tolerance**: Selection of cultivars adapted to a wide range of environmental conditions may allow for flexibility in planting dates if many crops are planted together (Smith and Francis, 1986). The sensitive cultivars are planted when conditions are optimum and the less sensitive ones are planted later if resources are limiting in the environment.

- **Density response**: Knowledge of the response of each crop cultivar to increasing density can allow greater flexibility in the design of multiple cropping systems (Francis et al., 1976). It is important to note that individual crop densities do affect yield, and therefore, optimum density for each crop is important to know if one is to avoid interplant competition and at the same time maximize yield (Smith and Francis, 1986).

Consideration should be given to genotype response of each crop to density as was shown for maize/cassava intercrops (Ezumah et al., 1990; Ezumah, 1990).

- **Insect and disease resistance:** This was discussed in an earlier section (Section 2.2.2) and examples were cited of how crop mixtures might affect pest population build up in mixtures.

When all the above factors are considered, it is evident that a clear breeding methodology for crop mixtures is difficult to find and very costly and time consuming to handle. If there is a genotype x cropping system interaction, then one may have to test a number of cultivars of one or more crops in each cropping system, thereby increasing the cost (Smith and Francis, 1986).

2.4. SOIL FERTILITY MANAGEMENT IN INTERCROPPING

With the improvement in cereal genotypes, low soil fertility in many cereal production areas has become a constraint to cereal production both in sole cropping and intercropping (Baker and Blamay, 1985). This is due to the nature of soils in the tropical and sub-tropical areas where intercropping is important. Sanchez et al. (1982) and Steiner (1984) enumerated a number of reasons for the rapid decline of soil fertility in the tropics and sub-tropics, and pointed out that intercropping of legumes may be a possible solution to the rapid decline in soil fertility. The issues they considered to be responsible for soil deterioration were:

(1) Low inherent fertility of most soils, that is, low effective cation exchange capacity (CEC), low inherent nutrient status,

- (2) rapid decomposition of organic matter due to high temperature and humidity which is accelerated by tillage and ploughing,
- (3) soil erosion and loss of nutrients through leaching which is favoured by the high intensity rain,
- (4) leaching of basic cations due to low base saturation and low soil pH, and lastly,
- (5) loss in water holding capacity due to low organic matter content.

They concluded that the practice of crop mixtures or multi-storey cropping could provide a nearly continuous soil cover, thus preventing overheating of the soil and protect the soil from heavy rain impact and soil erosion. Since two or more crops are included in crop mixtures, the dense and diversified root systems could reduce leaching of nutrients. Steiner (1984) indicates that this has been proven to work well in some dry areas of W. Africa where sorghum and pigeonpeas are planted together. The pigeonpeas protect the soil during the dry season against insolation and wind erosion, and improve soil fertility by symbiotic nitrogen fixation and phosphorus uptake by their deep roots.

But the issues of importance under intercropping systems are:

- (1) The associated crops usually have different nutritional demands, their peak periods of demands may not coincide, and their response to the various nutrients vary (Steiner, 1984),
- (2) cereals usually need large amounts of nitrogen while nodulation in legumes is suppressed by heavy nitrogen application (Beverly and Jarrell, 1984; Haynes, 1980; Sorensen and Penas, 1978; Steiner, 1984),
- (3) increased removal of nutrients by the intercrops may lead to soil nutrient depletion unless this is off-set by increased fertilizer application (Dalal, 1974; Kassam and Stockinger, 1972; Steiner, 1984),

(4) dominant crops may become even more dominant after nitrogen application and suppress the dominated crops with eventual reduction in grain yield, although the reverse may be possible in case of intercrops involving cereals only (Donald, 1963), and

(5) consideration has to be given to the varieties to include in the mixture because local varieties may give the best relative yields at low fertility while improved varieties may respond better to high fertility levels (Francis et al., 1978; Graham and Scott, 1983; Ofori and Stern, 1987; Santos, 1977).

2.4.1. The effect of nitrogen on yield of crops and protein content of grains

Component crops in intercrops differ in their response to applied nitrogen in respect to the different cereal/legume combinations, and thus affect their efficiencies (Ahmed and Rao, 1982; Boucher, 1986). But Palada and Harwood (1974) noted that intercrops make more efficient use of nitrogen than sole crops with high dry matter accumulation.

Application of nitrogen to legume/non-legume intercrops tend to reduce LER values, and LER values generally decrease as the N rates increase. This has been proven for some cereal and legume combinations. In a maize/cowpea association, the grain yield of maize increased with increase in nitrogen level both in sole and intercrop systems (Baker and Blamey, 1985; Ezumah et al., 1987; Ofori and Stern, 1986; Remson, 1978). The yield of cowpea declined with increasing nitrogen application depending on the cultivar used. The intercropping efficiency in terms of LER declined with increasing levels of nitrogen following the trends in cowpea yields. Similar results were reported for maize/soybean and

maize/mungbean intercrops (Chang and Shibles, 1985a and 1985b; Chui and Shibles, 1984), a maize/groundnuts intercrop (Searle et al., 1987), and a sorghum and chickpea intercrop (Chowdhury and Misangu, 1979). In contrast, sorghum yield has also been reported to decline when intercropped with pigeonpeas or cowpeas or beans over a range of nitrogen levels (Enyi, 1973; Rego, 1979). The yields of the companion legumes remained unchanged in case of beans and cowpeas, and that of pigeon peas was improved. The drop in LER values with increasing nitrogen application is a clear indication of the relative advantage of intercropping under low fertility levels compared to high fertility levels. But this does not indicate that intercropping is only advantageous under low fertility management. Intercropping can be successfully intensified and managed under high fertility management. The LER values of legume/non-legume intercrops decrease because of the shading effect by the dominant non-legume crop and the negative influence of nitrogen fertilizer on symbiotic nitrogen fixation (Steiner, 1984).

On the other hand nitrogen application to mixtures may increase the yield of all the component crops with resulting high LER values with increasing nitrogen levels. Lathwell and Evans (1961) reported that the yield of soybean intercropped with maize was closely associated with the amount of nitrogen accumulated in the plant. According to him, nitrogen application at bloom stage of soybeans increased yield by more than 20%. A similar finding was reported by Kalra and Gangwar (1980). They found that 80 and 120 kg N per ha gave larger seed yields of cowpeas in the intercrop than 40 kg N per ha with increasing yield of the cereal with increase in nitrogen application. This resulted in higher LER.

An uncommon situation is where nitrogen application has no significant effect on the component crops in the mixture. Chui (1988) observed that applied nitrogen increased yield of beans by 14% in sole beans and 5% in intercropped beans although the yields were not significantly different from one another. The applied nitrogen did not increase total grain yield of either crop (maize or beans) nor LER significantly. Maize seed yield was not significantly affected by the applied nitrogen or cropping system at 130 kg N/ha of the applied nitrogen. He attributed this lack of response to high initial nitrogen level in the soil used.

The effect of intercropping and nitrogen fertilization on seed protein content is not straight forward, although alternate planting of crops in the mixture may improve the protein contents of the component crops. Wahua and Miller (1978b) indicated that percentage seed protein of soybeans was unaffected by intercropping with sorghum or nitrogen levels applied. But maize and pigeon peas grown in mixture and in alternate rows produced the maximum protein per hectare per week (Dalal, 1974). Maize in monoculture produced the maximum grain yield per ha per week, while pigeonpea grown in monoculture produced minimum yields and protein per ha per week. This shows how important plant arrangements and intercropping are in determining the nutritional status of the grains produced, and therefore, accumulation of nutrients.

Cultivar effects may interfere with performance of legume crops in intercropping systems in response to nitrogen. Ezumah et al. (1978) noted that there were interactions between cowpea cultivars and N rates used. Non-nodulating cowpea cultivars responded well to N application while the yields of nodulating cultivars were reduced with increasing N rates. It

is, therefore, important to choose proper cultivars to include in intercropping systems if the system is to utilize the applied nitrogen efficiently.

Most of the already cited cases of responses of sole and intercrop legumes to nitrogen application, the dry matter increase brought about by nitrogen fertilization was not necessarily converted to grain yield (Chowdhury and Misangu, 1979; Ezumah et al., 1987; Russell and Calwell, 1989). But for the pigeon pea/cereal intercrop, the dry matter increase of pigeon peas due to nitrogen application was converted to seed yield, and there was close correlation between dry matter and seed yield (Rego, 1979).

Little seems to be known about the effect of varying the proportions of the component crops in crop mixtures on protein and yield of the component crops. There is indication that N may increase protein content of crops in intercropping systems but this remains to be determined.

2.4.2. The effect of N and shading on nodulation of legumes

High dosage of N has been known to severely reduce nodulation in beans or legumes in general, especially where phosphorus level is very low or is limiting (Awonaike et al., 1980; Baker and Blamey, 1985; Beverley and Jawell, 1984; Graham and Scott, 1983; Ssali and Keya, 1986). Nitrogen also causes reduction in the number of nodules per plant, nitrogenase activity and dinitrogen fixation by legumes depending on the host genetics and the cultivars of the legume in question.

Shading has also been indicated to affect fixation in legumes depending on the legume. In tropical areas, intercropping of tall cereals

or crops with under storey legumes is very common. Shading reduced cowpea N fixation drastically in maize/cowpea intercrop (Chang and Shibles, 1985 a). It was also noted that total nodule activity (TNA) was low for bush beans, cowpeas and soybeans at 27% sun (Eriksen and Whitney, 1984). Except for bush beans at 27% sun, shading caused 34% average reduction in dry matter and grain yields, 50% reduction in the TNA and 76% reduction in nodule mass in the legumes. Bush beans were less sensitive to shading than the other two legumes. At 27% sun, shading never had significant effect on TNA and dry matter yield of bush beans. Similarly, Wahua and Miller (1978 a) reported that shading accelerated loss of TNA and reduced yield of soybeans. But whether there is significant effects of N and shading in a maize/bean association with varied proportions of the component crops is still to be determined.

Shading may also be important for some plant protein needs. Shading in cowpeas was reported to reduce the available energy for N remobilization, and therefore, decreased protein yield (Littleton et al., 1979). In contrast, shading increased protein content and reduced yield and oil content in soybeans (Wahua and Miller, 1978a). Nitrogen application usually causes heavy leaf production in component crops, in which case the taller component crop can cause shading to under-storey crop. It may indirectly influence the amount of N in the plant through nitrogen fixation, and therefore, one needs to consider the shading effect in an intercropping situation. Alternate planting pattern of the component crops may, however, allow enough sunlight to the legume and allow photosynthesis without affecting bean yield drastically.

2.4.3. Nitrogen effect on nutrient uptake in sole and intercrop systems.

The available evidence indicates that intercrops make more efficient use of N and take up more nutrients than the sole crops especially when they are planted in alternate rows. Intercrops have been reported to respond positively to N application by increasing nutrient uptake more than sole crops in proportion to the dry matter accumulation (Chui, 1988). Nitrogen concentration (percentage) was higher for beans than for maize up to 40 days after planting. Beans had relatively higher concentrations of nitrogen, phosphorus (P), magnesium (Mg), and calcium (Ca) than maize during flowering and pod filling stages in all cropping systems irrespective of N fertilizer levels. Beans planted in the same row as maize took up less nutrients than beans planted in alternate rows. Total nutrient uptake (kg/ha) was more for intercropped system than sole crop systems. Nutrient uptake for both beans and maize increased with increase in N levels. Sorghum grain yield and nutrient uptake increased markedly with N fertilization responding similarly to applied N in the sole and intercrop systems, and the same was true for the maize crop (Baker and Blamey, 1985; Bhangoo and Albritton, 1972; Chang and Shibles, 1985a; Forde, 1976; Ofori and Stern, 1986; Santos, 1977; Wahua, 1983). Similar reports were by Kassam and Stockinger (1972) for a sorghum/millet intercrop, and Suryatna and Harwood (1976) and Palada and Harwood (1974) for maize/rice and maize/soybean intercrops respectively. Total dry matter and nutrient uptake were more for mixtures than sole crops.

Wahua (1983) introduced the concept of Nutrient Supplementation Index (NSI) (the ratio of total nutrient uptake in the mixture and sole crop by the species concerned) to aid the study of crop mixture fertilization. This

was based on the same principles as those of relative yield totals. The uptake of nutrients (kg/ha) is determined at the time of maximum demand which lies between anthesis and mid-grain filling stages of development. This is then used as a basis for fertilization formulation. It is reported in percentage, the calculated percentage is an additional amount of fertilizer on top of what is required by the sole crops to fertilize the mixture. For example, a calculation of 12.5% as in LER calculation for a mixture of maize and beans means that to satisfy the requirements of both crops in a mixture, an additional 12.5% of that required by sole crop maize is needed. Therefore, NSI may be an easier way to formulate fertilization schedules for mixed cropping situations regardless of the component crops (detailed explanation given by Wahua, 1983).

Whether nutrient uptake and accumulation are affected by the proportion of component crops in the mixture is not clear and this is what the present research is to determine.

2.5. DESIGN AND EVALUATION OF INTERCROPPING EXPERIMENTS

This topic was discussed at length by Lamberts (1983) in her thesis work on experimentation in intercropping systems. Main issues will be briefly mentioned here in connection with design and evaluation of intercropping experiments.

Farmers usually grow crops in mixtures to satisfy several objectives. Willey (1979a) indicated that there is overwhelming evidence for the possibility that intercropping can provide high yield advantages compared to sole cropping. But less is currently understood about the

design and analysis of intercropping experiments, although there is a growing appreciation in this direction (Willey, 1979a, 1985). Mead and Willey (1980) listed three main ways in which intercrops may be viewed by a farmer and how the performance of the intercrops may be assessed:

(a) "Where the component crops are equally acceptable to the farmer and there are no constraints which determine that both have to be grown".

Therefore, intercropping advantage is assessed by the amount by which the combined intercrop yield exceeds that of the higher-yielding sole crop.

(b) "Where a farmer wishes to produce a full yield of a main crop (that is, as much as in sole cropping) and some additional yield of a second crop as a bonus". Here, the yield of the major crop is important and this is easily compared to the sole crop.

(c) "Where there are needs to grow more than one crop whether intercropped or not, to spread labour peak, to reduce marketing risks, or to satisfy different dietary requirements". The advantage is when 2 or more crops intercropped produce more yield than when grown separately. This is a very common objective to most farmers who practice intercropping.

It has to be noted that due to the many objectives attached to intercropping, when analyzing intercrop data, there is no single straight forward way of analysis and some situations may require a number of different methods of analysis (Reddy and Chetty, 1984). I will briefly describe some underlying aspects of designing experiments and some of the various methods used in analyzing intercrop data.

2.5.1. Designing intercropping experiments

Two main types of intercropping experiments have been conducted to date: "Additive experiments" and "replacement experiments" (Chang and Shibles, 1985a). In additive experiments the density of one crop is maintained constant and that of one crop is varied. In substitutive or replacement series experiments the proportions of the species involved, for example, A and B in the mixture, are varied while the overall density $A+B$ is maintained constant. The choice of which of these two ways of investigating intercropping systems used depends on the objectives of the research. In general, if one is interested in comparing maximum productivity of the mixture to the maximum monoculture productivity, the use of replacement series is advisable. Replacement series avoid bias because both mixtures and monocultures are at the same total population. But if the interest is on maximum carrying capacity of the land, then additive experiments may be appropriate. In our case, the interest is maximum production of the mixture at the same total population as monocultures.

Mead and Stern (1979, 1980) noted that little emphasis has been placed on the problems of designing intercropping experiments. In their work, they put forward the following five aspects of intercropping experimentation which require thought:

1. The need to define the objectives of an experimental program precisely, and to attempt to satisfy these objectives through a sequence of specific experiments,
2. The extent to which intercropping experiments should involve monocrop plots,

3. The need to investigate the effects of many factors and their interactions at an early stage of an experimental program,
 4. The large size of many intercropping experiments, which therefore require efficient use of available space and careful control of experimental error, and
 5. Problems of sampling within experimental plots, particularly in experiments examining the detailed growth patterns of intercrops.
- These aspects of intercropping are thoroughly discussed in their papers including the use of blocks, selection of designs, and the advantages and disadvantages of the designs in carrying out intercropping experiments. Since our interest is in comparing total productivity of mixtures and monocultures at the same total population, and particularly considering the objectives of the current research, we chose the 'substitutive experimental method' in a split-plot design as explained in the methodology.

2.5.2. Analysis of intercropping systems

Many ways are available to evaluate the advantages of intercropping experiments, and I will briefly consider the following: (a) LER, (b) Competitive Ratio (CR), and (c) yield stability and economics.

(i) Land Equivalent Ratio (LER)

LER as was defined by Francis (1986) is a common way of evaluating the advantage of an intercropping system compared to sole cropping. Mead (1979), Mead and Willey (1980), and Willey (1985) all indicated that LER is a useful measure in providing standardized basis so that crops can be added to form "combined" yields, and the LERs can be compared

between different situations and even different crop combinations. The LER can also be taken as a measure of the relative yield advantage over sole crop, for example, LER of 1.2 indicates a yield advantage of 20% compared to sole crops. Willey (1979a) also noted that comparisons between individual LERs (LA and LB) can be a very useful indication of the competitive effects between the two crops.

LER is computed as (Mead and Willey, 1980):

$$\text{LER} = \text{LA} + \text{LB} = \frac{Y_a}{S_a} + \frac{Y_b}{S_b}$$

where: LA and LB = LERs for individual crops A and B

Y_a and Y_b = individual crop yields of crops A and B in mixtures

S_a and S_b = their yields as sole crops at optimum populations.

Although LER is a very useful measure of intercrop advantage, it may give wrong impression of yield values of the system. Since it is defined as a ratio, large values may be obtained just because of large yields of intercropping yet it is also possible to get large values due to small yields in the corresponding sole crops (Mead and Willey, 1980). It is, therefore, important to understand the nature of the experiment being carried out and use the most appropriate method to analyze the results.

Huxley and Maingu (1979) indicated that all intercrop yields should be compared with the sole crop at its optimum population and spacing. This is to avoid over- or underestimating the advantages of the intercrop

systems compared to sole crops. In a case of an experiment designed to examine the advantage of intercropping at different levels of fertility, it is important and appropriate to standardize any given intercrop yield with respect to the sole crop yield at the same fertility level (Mead and Willey, 1980; Riley, 1984; Oyejola and Mead, 1982). This is the way that will be used for the current research to calculate the LER of the intercrop system at each fertility level.

(ii) Competitive Ratio (CR)

CR indicates the number of times by which one component crop is more competitive than the other (Willey and Rao, 1980). They noted that CR can be useful in: (a) comparing the competitive ability of different crops, (b) identifying which plant characters are associated with competitive ability and correlate these to yield, and (c) determining what competitive balance between components is most likely to give maximum yield advantage.

CR can be calculated as below (Willey, 1979 a):

$$CRa = \frac{Yab}{Yaa \times Zab} + \frac{Yba}{Ybb \times Zba}$$

where: CRa= competitive ratio of species a

Yaa = pure stand yield of species a

Ybb = pure stand yield of species b

Yab = mixture yield of species a (in combination with b)

Yba = mixture yield of species b (in combination with a)

Zab = plant proportion of species a (in mixture with b)

expressed as a proportion of the total in the mixture

Z_{ba} = plant proportion of species b (in mixture with a)

expressed as a proportion of the total in the mixture

L_a = component LER of species a in the mixture

L_b = component LER of species b in the mixture.

The above may also be written as:

$$CR_a = \left\{ \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}} \right\} \times \frac{Z_{ba}}{Z_{ab}}$$

$$= \frac{L_a}{L_b} \times \frac{Z_{ba}}{Z_{ab}}$$

The CR, therefore, becomes simply the ratio of the individual LERs of the two component crops, but correcting for the proportions in which the crops were initially sown (Willey, 1979a). The component crop with the higher CR is the dominant one. To determine if there is a yield advantage of mixing the crops, the product of CRs for the crops in each system also called the Coefficient (K) is formed. If the Coefficient (K) is >1 there is a yield advantage, if $K=1$ there is no difference, and if $K<1$ there is a yield disadvantage (Willey, 1979 a).

It is important in the present research to determine the CR between the different crop components in the system and see how the CRs are affected by soil fertility variation, and therefore, determine the best combination of crop proportions for each fertility level.

(iii) Yield stability and economics

Yield stability is determined by the genetic potential of a crop, the crop's tolerance to stress, population density, planting patterns, competitive effect between component crops and soil fertility (Chowdhury, 1979; Rao and Willey, 1979; Rao et al., 1979). Therefore, in-depth studies of these factors which involve transgressive yielding ability of crops could further enhance stability, productivity, and profitability of intercropping system (Rao et al., 1979).

Available evidence suggests that intercropping gives higher and more dependable gross return per ha than sole crops (Norman, 1974), and high gross return per unit of peak-labour use (Jodha, 1979; Norman, 1974). Rao and Willey (1979) also noted that mixtures provide insurance against risks even under aberrant weather, and therefore, give stable returns (Rao and Willey, 1979). They attributed this to compensation of one component crop when the other fails or grows poorly due to pests, diseases, etc in the mixture.

Net returns from mixtures depend on the prices of the component crops, and therefore, the proportions of the crops in the mixture (Francis and Sander, 1978; Rao and Willey, 1979). Francis and Sander (1978) evaluated intercrop and monocrop systems of beans and maize over a range of prices and they found that mono beans were more profitable over a wide range of relative prices if the farmer used an intensive package of technology. On the other hand, risk was higher in the monoculture beans than in mixtures. Therefore, the probability of maintaining a consistent income with relatively lower investment was highest for maize/bean mixture depending on the relative prices and cost of production of the component crops (Francis and Sander, 1978; Lynam et al., 1986).

As LER is not enough to show profitability of an intercrop, it is important to attach monetary value to the system and calculate the Income Equivalent Ratio (IER) or Monetary Advantage (MA). IER or MA is defined as the ratio of the area needed under sole cropping to produce the same gross income as one ha of intercropping at the same management level. This expresses the relative advantage indicated by the LER as an absolute monetary advantage, and assumes that the ratio of the crops in the system is the exact ratio that is required by the farmer (Willey, 1979a). MA of an intercrop tells a farmer whether he is losing or gaining from the system and how stable the system is from year to year, and location to location. It is very vital to consider all these methods of evaluating intercrop system if one is to make a valid conclusion from his research work. In the current work being reported, most of these methods have been used to arrive at a meaningful conclusion about the intercrop and monocrop comparison.

CHAPTER THREE

MATERIALS AND METHODS

3.1. General background.

The field experiment was carried out in field N1 of Fruit and Vegetable Science Department (Cornell University, New York) at E. Ithaca in the growing seasons of 1990 and 1991. The soil was Arkport fine, sandy loam soil (weak gray-brown podzolic soil) having chemical properties indicated in Table 3.1 for both 1990 and 1991 growing seasons. Soil samples (0-30 cm layer) were taken prior to planting during both seasons, and air-dried and ground to pass through a 2-mm sieve. This was then analyzed for pH, available nutrients, organic matter (OM) and cation exchange capacity (CEC). In both years, the same field was used for the experiment. The field had very low OM and available nitrogen but adequate level of other nutrients needed for proper plant growth.

Soil samples were taken before planting season of 1991 to determine if residual effects of nitrogen remained after the 1990 treatments. Results of the analysis confirmed that there was no significant difference between the different blocks that received nitrogen in 1990 growing season.

Originally, this same field was planted to sweet corn/bean and sweet corn/bean/potato intercrops in 1988, and sweet corn and garden vegetables in 1989. In 1989, the field received 784 kg/ha of N-P-K or 13-13-13 of N-P₂O₅-K₂O (100 kg N/ha, 43 kg P/ha, and 85 kg K/ha).

Measurements were taken for factors for which plants were most likely to compete including light and nutrients especially the macro-nutrients (N, P, K, Ca and Mg). No measurements were made to determine the occurrence of competition for water between maize and beans, or to determine the water status of the soil.

Table 3.1. Chemical properties of surface soil (0-30 cm layer) used in the maize-bean intercropping experiment at E. Ithaca, Cornell University (New York) in 1990 and 1991 growing seasons.

Soil chemical properties	1990	1991
Soil pH in 0.01 M CaCl ₂ (1:)	6.65	6.32
Organic matter, % OM	2.42	1.94
Available NO ₃ , mg/kg of soil	4.63	6.41
Available P mg/kg of soil	30.05	23.90
Available K mg/kg of soil	187.50	156.00
Available Ca mg/kg of soil	722.25	675.00
Available Mg mg/kg of soil	37.80	32.30
Available Fe mg/kg of soil	1.03	1.90
Available Al mg/kg of soil	11.33	13.20
Available Mn mg/kg of soil	5.83	15.00
Available Zn mg/kg of soil	-0.08	-0.40
Available Cu mg/kg of soil	-0.33	-0.40
CEC, cmol / kg		6.45

3.2. Soil analysis

Soil analysis was done by the Department of Soils, Crops and Atmospheric Science (SCAS), Cornell University. Soil pH was determined on a 1:1 (by volume) soil :water. Available nutrients (major and minor nutrients) were extracted with Morgan's solution, 10% sodium acetate in 3% acetic acid buffered to pH 4.8, using a 1:5 (by volume) soil:solution ratio. K, Mg, Ca, Mn, Fe, Al and Zn were determined by atomic absorption. P, NO₃-N and NH₄-N were determined colorimetrically by stannous chloride reduction, automated hydrazine reduction, and phenate hypochlorite methods respectively.

Organic matter (OM) was determined by loss of ignition (LOI) method. The soil was first air-dried, and later dried at 50° C for one hour, then ignited at 500° C for two hours. To calculate the %OM, the LOI was converted to OM by the formula: $(0.7 \times \text{LOI}) - 0.23 = \% \text{ OM}$ (equation is only valid up to 6% OM). Cation Exchange Capacity (CEC) was determined by extraction with a solution of barium chloride / triethanolamine buffered at pH 8.0 followed by titration of the excess base (the units, cmol (+) / kg, stand for centimoles of ion charge per kg of soil, and are equivalent to units of milliequivalents per 100 gm). The results of 1990 and 1991 soil analyses are compiled in Table 3.1.

3.3. Experimental design and treatments

Experimental design and treatments were identical in both years, except for additional set of treatments involving high maize population in 1991. The experiment consisted of three nitrogen levels (0, 80 and 160 kg

N/ha) simulating low, medium and high fertility levels respectively, and five crop proportions. These were arranged in a split-plot design with four replicates. Nitrogen (N) levels were the main plots and crop proportions were the sub-plots. Sub-plots measuring 8m x 4.5m (replicates 1 and 4 in 1990) and 8m x 2.7m (replicates 2 and 3 in 1990, and all replicates in 1991) had rows oriented in the north-south direction. The five crop proportions in 1990 included:

- (1) Sole crop of maize at 37,000 plants/ha.
- (2) Sole crop of beans at 166,667 plants/ha.
- (3) 75% of sole maize + 25% of sole beans,
- (4) 50% of sole maize + 50% of sole beans,
- (5) 25% of sole maize + 75% of sole beans.

These were combined in a replacement series to maintain the same total land use area. The assumption was that the sole crop populations of the two crops were the maximum populations for the area and varieties of crops used in the experiment.

In 1991, we had all the above crop proportions except 50% of sole maize + 50% of sole beans which was left out. In addition to the four crop proportions of 1990, we had a new set of crop proportions involving sole maize population of 55,000 plants/ha but maintaining the same population of beans as was for 1990 treatments. This gave a total of 8 crop proportions as below:

- (1) Sole maize at 55,000 plants/ha (high population : 90cm x 20cm spacing)
- (2) Sole maize at 37,000 plants/ha (low population : 90cm x 30cm spacing)
- (3) Sole beans at 166,667 plants/ha. (60cm x 10cm spacing)
- (4) 25% of sole beans + 75% of sole maize (high maize population)
- (5) 25% of sole beans + 75% of sole maize (low maize population)

(6) 50% of sole beans + 50% of sole maize (high maize population)

(7) 75% of sole beans + 25% of sole maize (high maize population)

(8) 75% of sole beans + 25% of sole maize (low maize population).

The early-maturing maize cultivar, Pioneer 3925, and bush red kidney beans, cultivar Ruddy, were used in the experiment.

Nitrogen treatments remained the same in both years. On June 5th, 1990 and June 2nd, 1991, the field plots were fertilized with half the amount of ammonium nitrate fertilizer used in the trial (40 or 80 kg N/ha) by broadcasting on the randomized blocks. The bean and maize seeds were planted on June 6th, 1990 and June 3rd, 1991. Maize was machine planted at 90cm x 30cm in 1990, 90cm x 10 cm in 1991 while beans were hand planted at 60cm x 10 cm between the two maize rows. Each plot of 8m x 4.5m had 6 maize rows with 10 bean rows such that two bean rows were between two maize rows, and plots of 8m x 2.7m had 4 maize rows and 6 bean rows intercropped. Bean rows were about 15cm from each maize row on either side.

The second half of the fertilizer was applied four and half weeks after planting by broadcasting when maize plants were beginning rapid growth (at knee height). The fertilizer was incorporated into the soil while weeding using a hoe.

Thinning was done manually on the 25th and 26th of June both in 1990 and 1991 growing seasons to achieve the desired plant populations.

3.4. Weed control

Four days after planting, pre-emergence herbicide, metolachlor, (Dual) was applied at the rate of 1.68 kg active ingredient/ha. Hand

weeding was done once during the time of second fertilizer application in both years. Occasionally, weeds that appeared in some plots were hand pulled.

3.5. Plant canopy height measurement

Maize height (with leaves stretched) was recorded at 4, 6, 7 and 9 weeks after planting (1990) and 5, 6, 7 and 9 weeks after planting (1991). Bean heights (to the last growing points) were recorded at 4 and 6 weeks after planting (1990) and 5 and 6 weeks after planting (1991). Measurements were taken on plants in the two central rows and 5 plants were marked in each row for the measurement (a total of 10 plants per plot of either beans or maize were used). The same plants were used for height measurements at all dates.

3.6. Light interception

PAR (photosynthetically active radiation) was recorded at 7 and 9 weeks after planting both in 1990 and 1991 growing seasons. PAR was measured using a Sunfleck Ceptometer (Decagon Devices Inc., Pullman, Washington 99163, USA). To find the amount of light intercepted by intercropped maize, the ceptometer was placed on top of the maize canopy and then on the bean canopy. The difference between the readings was recorded as the amount of light intercepted by maize, and was expressed as a percentage of incident PAR. The ceptometer was then placed at ground level under the beans and the difference between the above bean and above ground readings was the amount of light intercepted by beans.

For sole crops of either maize or beans, the ceptometer readings were taken above the crops and below the crops at ground level.

3.7. Chlorophyll content measurement

Chlorophyll content of both maize and bean leaves was recorded at 44 and 65 days after planting using the chlorophyll meter, Minolta SPAD-502 (Minolta Camera Co., Ltd. 3-13, 2-chome, Azuchi-machi, Chuo-Ku, Osaka 541, Japan). The SPAD-502 determines the relative amount of chlorophyll present in a plant leaf by measuring the transmittance of the leaf in the red and infra-red wavelength regions. Using the 2 transmittances, the meter calculates a numerical SPAD value which is proportional to the amount of chlorophyll present in the leaf.

In each plot, 30 readings were taken from 6 different plants of either beans or maize. An average of the 30 readings was recorded as the amount of chlorophyll present for each crop in each plot.

3.8. Plant sampling for dry weight determination and plant nutrient analysis

Plant samples were taken at 42 (stage of rapid plant growth) and 63 (after tasseling in maize and at pod filling stage in beans) days after planting (DAP) and at maturity (to determine seed harvest index and nitrogen harvest index). The samples were taken at random from each plot and at sampling time, a total of 5 bean or 3 maize plants were taken. The samples were chopped into pieces, bagged and placed in the oven at 60° C to dry for a period of 3 days. Dry weights of the dry samples were

recorded at each sampling date. Parts of the samples were ground for plant nutrient analysis.

Plant samples were analyzed for nutrient contents by Fruit and Vegetable Science Department, Cornell University. Macro and micro nutrients were analyzed by the Standard Dry Ash method which included running the samples through ICP analysis (Inductively Coupled Argon Plasma Atomic Emission Spectrometer). Two to four hundred mg of a ground sample were weighed into a quartz test tube. The sample was dry ashed for 6 hours at 450° C in a muffle furnace using an aluminium rack. The ashed samples were cooled, 0.25 ml of 30% hydrogen peroxide added, then reacted at 450° C for two hours. About 0.5 ml of 37% hydrochloric acid was then added to dissolve the ash. In one hour, a diluent of 9.5 mls of distilled water containing 4.0µg of yttrium (Y), an internal standard, was added with sufficient force to mix the sample. After the sediment had settled, the sample solution was then run on the ICP to determine the nutrients.

Nitrogen analysis (ammonium based nitrogen) was by the Micro Kjeldahl method. One hundred mg of dry, ground sample was digested with 3 mls of concentrated sulfuric acid and 1 ml of 30% hydrogen peroxide at 300° C for three hours using an aluminum block digester. After cooling, 1 ml of hydrogen peroxide was added to the sample which was then heated for a minimum of two hours. The sample was cooled and diluted to 50 mls with distilled water. Only 0.15 ml of the diluted sample was then added to 2 mls solution of 8.5% sodium salicylate and 0.03% sodium nitroferricyanide. Color development was initiated by adding 2 mls of a solution of 1.5 g/l sodium dichloroisocyanurate and 48 g/l sodium hydroxide. Color was allowed to develop for one hour. This solution was

further diluted with 20 mls of distilled water, mixed thoroughly and read at 660 nm on a Bausch and Lomb Spectronic 710 (Spectronic 1001 Plus, Milton Roy, USA), using a 10 mm flow through cell.

3.9. Harvesting

Beans and maize from the two central rows of 7m each were harvested. Beans were harvested by uprooting whole plants and placed in gunny bags. Dry maize cobs from the field were husked and placed in gunny bags to dry. The number of maize plants harvested and total number of cobs per plot were noted to determine the number of cobs per maize plant as affected by the treatments. The harvested materials were then spread in the greenhouse until dry. Additional samples of 6 bean plants were harvested for pods per plant and seeds per pod determinations.

Afterwards, the beans were machine threshed and maize machine shelled. Moisture content of the seeds was recorded and determinations of seed yield per plot, seed yield per plant or yield per hectare were made at 8% moisture content for beans and 12% moisture content for maize. Two hundred seeds from each plot of both crops were weighed to determine if there was any significant treatment difference. Shelling percentage (seed weight/cob weight ratio) was calculated on all maize samples. Seed samples were then taken to the laboratory for nutrient analysis, and determination of protein contents of seeds were made based on the formula $\%N \times 6.25 = \% \text{ Crude Protein}$.

3.10. Other observations

This included pest damage assessment, time taken by maize to reach 50% tasseling, time taken by beans to reach 50% flowering and maturity periods in both maize and beans. Pest assessment was made by counting the number of bean plants damaged by Japanese and Mexican bean beetles in the two central rows of beans at flowering time. The number of damaged plants was then recorded as percentage of insect damage by considering the total number of all bean plants in the two central rows. Later on as the damage increased, a number of Japanese beetle traps with pheromones were placed in the field. No insecticides were used in the experiments.

Beans were considered mature when over 50% of the pods turned yellow (a stage that farmers in Uganda would start collecting fresh beans to cook). On the other hand, maize was considered mature when the tip of the cobs were just beginning to show signs of drying.

3.11. Statistical analysis and other analyses

Analyses of variance were performed on all the variables for both years except that the effects of maize on bean yield under low and high maize population cropping systems were not statistically analysed so as to compare the two. Yields per ha were analysed separately as indicated in Appendix A: Tables 2 and 3. Combined yields were not statistically compared between the 2 years due to the method of analysis used (Appendix A: Table 4). Treatment means and graphs were all used in reporting results. Mean yields across the four replicates of both sole and

intercropped systems were used to calculate land equivalent ratios (LER, defined as the relative area of pure crops that would be required to produce the yields obtained by intercropping; Francis, 1986) and competitive ratios (CR), the ratio of the individual LERs of the two crops after correcting for the proportions in which the crops were sown initially (Willey and Rao, 1980).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Weather conditions: Rainfall and temperatures in 1990 and 1991 growing seasons

Rainfall amount for 1990 and 1991 growing seasons are as indicated in Table 4.1. There was plenty of rain during the early part of 1990 growing season compared to 1991, and therefore, no irrigation was necessary since the rain was well distributed. In 1991, we had to apply irrigation twice early in the season to supplement the erratic rainfall that occurred at this time which was very low and practically left the soil very dry. Rainfall continued to be well distributed through out the growing season of 1990 compared to 1991 and this had dramatic effects on yield of the crops.

Table 4.1. Rainfall amount (mm) and temperatures (°C) at E. Ithaca during 1990 and 1991 growing seasons .

Months	1990		1991	
	rainfall	temp. (°C)	rainfall	temp. (°C)
June	60.2	18.6	27.2	19.3
July	99.1	20.6	100.6	20.8
August	111.5	19.5	66.0	20.6
September	78.0	15.1	80.5	14.6
October	180.1	11.0	56.1	10.6
Total	528.9		330.4	

In 1991 temperatures were higher than in 1990, and therefore, most likely there was more evaporation from the soil (Table 4.1). There was plenty of rain by August to October in 1990 but 1991 remained warm and dry.

Crop emergence during 1991 growing season was very much affected by the weather condition experienced leading to uneven emergence of the crops although the start of emergence was the same in both 1990 and 1991 growing seasons. Maize emerged seven days after planting and beans emerged eight days after planting in both years. At crop emergence, the crops were attacked by birds but to avoid this we had aluminium foils placed across the field.

4.2. Crop heights of sole and intercropped beans and maize as affected by crop proportions and N fertilization

Both beans and maize heights responded linearly to increase in crop proportions in 1990 and 1991 under low maize population cropping system with decreased heights as crop proportions decreased (Tables 4.2 and 4.3). There was no significant differences in bean height from 50% bean proportion to sole crop of beans both at 4 and 6 weeks after planting (WAP) in 1990 and at 6 WAP in 1991 (low maize population cropping system). At 5 WAP in 1991 under low maize population cropping system, crop proportion had no significant effect on bean height (Table 4.3).

On the other hand, under high maize population cropping (55,000 maize plants/ha), bean height was not significantly affected by crop proportions both at 5 and 6 WAP (Table 4.4), and there was no clear trend of height development in relation to crop proportions though intercropped

Table 4.2. The effect of crop proportions on bean and maize heights in sole and intercropped systems 4 and 6 WAP (beans), and 4, 6, 7 and 9 WAP (maize), 1990.

Crop proportions	4 WAP		6 WAP		7 WAP	9 WAP
	beans	maize	beans	maize	maize	maize
25%	18.4 a	83.3 a	46.4 a	129.2 a	172.2 a	229.8 a
50%	19.2 ab	85.5 b	49.1 b	138.2 b	187.0 b	243.1 b
75%	20.2 b	86.9 b	49.2 b	142.8 c	196.3 c	256.9 c
Sole crop	20.2 b	89.4 c	50.6 b	154.3 d	214.5 d	276.0 d
^a Stat.sig.						
linear	**	***	***	***	***	***
quadratic	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, **, NS significant at 0.1%, 1%, or not significant respectively.

beans looked thicker and more branched. Under high maize population cropping system, maize plants showed similar positive response to crop proportion as in 1990 and 1991 under low maize population cropping system (Table 4.4). At all stages of growth, sole crops of beans and maize grew much taller than the intercrops in both 1990 and 1991 growing seasons. This confirms the earlier report of Francis et al (1982) who found increased bean heights with increase in bean density due to high competition within sole beans for light.

There was no significant difference in maize height development between 1990 and 1991 seasons but beans in 1991 were much shorter than beans in 1990 (almost half the height achieved in 1990). The dry and warm weather conditions of 1991 could have been responsible for the slow growth

Table 4.3. The effect of crop proportions on bean and maize heights in sole and intercropped systems 5 and 6 WAP (beans), and 5, 6, 7 and 9 WAP (maize) under low maize population cropping system, 1991.

Crop proportions	5 WAP		6 WAP		7 WAP	9 WAP
	beans	maize	beans	maize	maize	maize
25%	18.6	100.0 a	28.2 a	139.5 a	186.1 a	213.0 a
75%	19.3	104.5 b	29.7 ab	150.4 b	197.1 b	221.2 a
Sole crop	19.4	112.9 c	31.1 b	166.1 c	216.1 c	242.3 b
^a Stat.sig.						
linear	NS	***	*	***	***	***

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, *, NS significant at 0.1%, 5% or not significant respectively.

Table 4.4. The effect of crop proportions on bean and maize heights in sole and intercropped systems 5 and 6 WAP (beans) and 5, 6, 7 and 9 WAP (maize) under high maize population cropping system, 1991.

Crop proportions	5 WAP		6 WAP		7 WAP	9 WAP
	beans	maize	beans	maize	maize	maize
25%	19.3	103.5 a	29.9	145.4 a	190.7 a	215.8 a
50%	19.9	103.7 a	31.1	146.6 ab	192.6 ab	218.3 a
75%	19.6	105.6 a	29.6	152.2 b	197.5 b	223.3 ab
Sole crop	19.4	113.4 b	31.1	163.3 c	209.7 c	231.9 b
^a Stat.sig.						
linear	NS	***	NS	***	***	***
quadratic	NS	**	NS	*	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, **, * and NS significant at 0.1%, 1%, 5% or not significant respectively.

of beans and the lack of difference in maize height of intercropped maize at 9 WAP. Intraspecific competition among beans or maize could have caused increase in height of sole maize or beans seen in 1990 and 1991. For the high maize population cropping system of 1991, increased population of maize increased competition in the systems.

N fertilization significantly affected bean height at 4 WAP, but at 6 WAP, N had no significant effect on bean height in 1990 (Table 4.5). In 1991, N fertilization had no significant effect on bean heights at 5 and 6 WAP both under low and high maize population cropping systems as shown in Tables 4.6 and 4.7 respectively.

Table 4.5. The effect of N fertilization on bean and maize heights at 4, 6, 7 and 9 WAP averaged across sole and intercropped systems, 1990.

Nitrogen (kg/ha)	4 WAP		6WAP		7WAP	9 WAP
	beans	maize	beans	maize	maize	maize
0	18.5 a	83.8	47.2	134.6 a	178.2 a	236.4 a
80	20.5 b	86.8	49.8	143.9 b	199.1 b	261.0 b
160	19.5 ab	88.2	49.6	144.8 b	200.2 b	257.0 b
^a Stat.sig.						
linear	NS	NS	NS	*	**	**
quadratic	**	NS	NS	NS	*	**

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

Table 4.6. The effect of N fertilization on bean and maize height 5, 6, 7 and 9 WAP averaged across sole and intercropped systems under low maize population cropping system, 1991.

Nitrogen (kg/ha)	5 WAP		6 WAP		7 WAP	9 WAP
	beans	maize	beans	maize	maize	maize
0	18.6	103.4 a	29.2	145.8 a	192.0 a	223.7
80	19.3	104.5 a	28.4	151.1 a	199.8 ab	221.3
160	19.4	109.6 b	30.9	159.1 b	207.5 b	231.5
^a Stat. sig.						
linear	NS	*	NS	**	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

Table 4.7. The effect of N fertilization on bean and maize heights 5, 6, 7 and 9 WAP averaged across sole and intercropped systems under high maize population cropping system, 1991.

Nitrogen (kg/ha)	5 WAP		6 WAP		7 WAP	9 WAP
	beans	maize	beans	maize	maize	maize
0	19.5	101.9 a	30.6	143.1 a	184.6 a	216.2
80	19.6	108.8 b	30.0	154.7 b	202.0 b	220.7
160	19.5	109.1 b	30.7	158.6 b	207.2 b	230.8
^a Stat. sig.						
linear	NS	NS	NS	**	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

Maize responded linearly to N application increasing in height with increase in N fertilization level in both years except at 4 WAP (1990) and 9 WAP (1991 under both low and high maize population cropping systems) where no response to N occurred as indicated in Tables 4.5, 4.6 and 4.7, respectively. There was no response to fertilizer N apparently beyond 80 kg N/ha for both years. One possible reason for lack of response to fertilizer N in 1990 could have been due to low population of maize used. In 1991, dry and warm weather and high population of maize could have limited the N response.

4.3. The effects of N fertilization and crop proportions on dry matter yield of beans and maize in sole and intercropped systems

Dry matter yield of beans (gm/plant) at 42 days after planting (DAP) was not significantly affected by crop proportions in 1990, and 1991 under high maize population cropping system although there was tendency for more dry matter accumulation with reduction in bean proportions in the systems (Tables 4.8 and 4.10, respectively). At the same sampling date in 1991, dry matter yield of beans under low maize population cropping system was significantly increased as crop proportion was reduced (Table 4.9).

In 1990, at 63 DAP and maturity, bean dry matter yield (gm/plant) was significantly increased as crop proportion was reduced (Table 4.8). The intercropped beans were much thicker and more branched than sole beans. Crop proportion had no significant effect on bean dry matter yield at 63 DAP under low and high maize population cropping systems in 1991 (Tables 4.9 and 4.10).

Under high maize population cropping system in 1991, crop proportion only significantly affected dry matter yield of beans at maturity (Table 4.10). Sole beans accumulated more dry matter than intercropped beans though there was no significant difference between 25% and 50% bean crop proportions and sole beans.

Maize dry matter (gm/plant) was significantly affected by crop proportions at all sampling dates in both years except for maize under low maize population cropping system at maturity in 1991 (Tables 4.9). At 42 DAP, there was increase in maize dry matter yield with increasing maize proportion (sole maize accumulated more dry matter than

Table 4.8. The effect of crop proportions on bean and maize dry matter accumulation (gm/plant) at 42 and 63 DAP and at maturity in sole and intercropped systems, 1990.

Crop proportions	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
25%	24.3	37.2 a	69.7 b	118.3 a	85.8 b	336.7 b
50%	22.0	39.7 a	65.5 b	137.0 b	74.5 a	374.6 b
75%	21.5	44.5 b	53.6 a	130.0 ab	71.2 a	323.3 a
Sole crop	21.7	49.5 c	54.2 a	155.8 c	67.3 a	350.8 b
^a Stat. sign.						
linear	NS	***	**	***	**	*
quadratic	NS	NS	NS	NS	NS	NS
cubic	NS	NS	NS	**	NS	**

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.9. The effect of crop proportions on bean and maize dry matter accumulation (gm/plant) at 42 and 63 DAP and at maturity in sole and intercropped systems under low maize population cropping system, 1991.

Crop proportions	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
25%	15.6 b	34.0 a	25.6	127.7 a	25.4	265.6
75%	13.5 a	37.5 a	25.1	132.3 a	26.6	242.4
Sole crop	14.1 a	45.0 b	26.9	152.8 b	27.0	259.7

^a Stat. sig.

linear	*	***	NS	**	NS	NS
quadratic	*	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance,

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.10. The effect of crop proportions on bean and maize dry matter accumulation (gm/plant) at 42 and 63 DAP and at maturity in sole and intercropped systems under high maize population cropping system, 1991.

Crop proportions	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
25%	14.2	37.0 a	26.0	141.2 b	25.6 ab	265.9 b
50%	13.8	35.8 a	24.9	124.3 a	22.5 ab	218.7 a
75%	14.2	35.3 a	22.9	115.5 a	21.9 a	210.4 a
Sole crop	14.1	40.7 b	26.9	120.8 a	27.0 b	207.8 a
^a Stat. sign.						
linear	NS	*	NS	***	NS	***
quadratic	NS	**	NS	**	*	**

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

intercropped maize) in both 1990 and 1991 growing seasons (Tables 4.8, 4.9 and 4.10 respectively). Sole maize accumulated more dry matter per plant than intercropped maize from 42 DAP till maturity at which time there was a cubic response to crop proportions in 1990 and 1991 under low maize population cropping system (Tables 4.8 and 4.9).

At maturity, there were no significant differences between sole maize and 50% and 25% maize proportions in 1990 (Table 4.8). This was primarily due to increased number of ears of intercropped maize at maturity compared to sole maize although intercropped maize remained short.

Maize under high maize population cropping system in 1991 had a reverse trend at 63 DAP and at maturity where sole maize accumulated less dry matter than intercropped maize (Table 4.10). This could have been due to increased competition between maize plants coupled with dry weather condition experienced in 1991 growing season.

As maize accumulated more dry matter in the intercrop, beans on the other hand accumulated less dry matter in 1990 and 1991 under low maize population cropping system. In 1991 under high maize population cropping system, there was quadratic effect on bean dry matter accumulation at maturity and a similar tendency at 63 DAP (Table 4.10). This seems to coincide well with competitive abilities of the two crops which tend to increase with decrease in crop proportions for both maize and beans.

Combined or total dry matter yield (kg/ha) of beans and maize at 42 DAP was significantly affected by crop combinations in 1990 and 1991 under low maize population cropping system (Tables 4.11 and 4.12). In both cases, dry matter yield increased with increase in bean proportions in the systems. Sole beans accumulated more dry matter than the intercrops and sole maize but the intercrops had higher combined total dry matter yield than sole maize. At 63 DAP, crop combinations had similar effect on combined dry matter yield as was at 42 DAP in 1990 and the reverse was true in 1991 under both cropping systems (Tables 4.11, 4.12, 4.13). Under low and high maize population cropping systems, combined dry matter yield increased significantly with increase in maize proportions and this continued up to maturity which was also similar in 1990 at crop maturity (Tables 4.11, 4.12 and 4.13).

Table 4.11. The effect of different crop combinations on total dry matter accumulation (kg/ha) of sole and intercropped maize and beans, 1990.

Crop combinations	42 DAP	63 DAP	Maturity
Sole maize	1825.0 a	5768.5 a	12993.8 b
75% maize + 25% beans	2250.3 b	6514.1 a	12557.6 b
50% maize + 50% beans	2570.7 b	7993.6 b	13147.7 b
25% maize + 75% beans	3032.9 c	7800.4 b	12298.5 ab
Sole beans	3611.8 d	9033.4 c	11222.2 a

Statistical significance

linear	***	***	**
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Means followed by a common letter are not significantly different at 5% level using LSD.

***, NS significant at 0.1% or not significant, respectively.

Table 4.12. The effect of different crop combinations on total dry matter accumulation (kg/ha) of sole and intercropped maize and beans under low maize population cropping system, 1991.

Crop combinations	42 DAP	63 DAP	Maturity
Sole maize	1668.4 a	5659.7 b	9618.7 d
75% maize + 25% beans	1694.6 a	4740.1 a	7792.7 c
25% maize + 75% beans	1997.4 b	4326.1 a	5783.4 b
Sole beans	2345.8 c	4478.5 a	4502.8 a

Statistical significance

linear	***	***	***
quadratic	*	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

***, *, NS significant at 0.1, 5% or not significant, respectively.

Table 4.13. The effect of different crop combinations on total dry matter accumulation (kg/ha) of sole and intercropped maize and beans under high maize population cropping system, 1991.

Crop combinations	42 DAP	63 DAP	Maturity
Sole maize	2237.1	6645.4 c	11430.4 e
75% maize + 25% beans	2048.8	5846.4 b	9745.0 d
50% maize + 50% beans	2129.1	5442.4 b	7869.3 c
25% maize + 75% beans	2283.6	4804.8 a	6394.4 b
Sole beans	2345.8	4478.5 a	4502.8 a
<u>Statistical significance</u>			
linear	NS	***	***

Means followed by a common letter are not significantly different at 5% level using LSD.

***, NS significant at 0.1% or not significant, respectively.

Nitrogen fertilization improved dry matter yields of beans significantly in 1990 and in low maize population in 1991 (Tables 4.14 and 4.15). Dry matter yield of beans increased linearly with increase in applied nitrogen fertilizer. This confirms the work of Chui (1988) who stated that N fertilization promoted vegetative growth in beans.

Under high maize population cropping system in 1991 (Table 4.16), N fertilization had no significant effect on bean dry matter yield at all stages of sampling although there was tendency for dry matter to increase at 160 kg N/ha.

In general, maize responded linearly to N fertilization at all stages of growth with increased dry matter accumulation (gm/plant) as N fertilizer level was increased both in 1990 and 1991 growing seasons (Tables 4.14, 4.15 and 4.16, respectively). In all cases of maize response to

N fertilizer, there was no significant increase in dry matter accumulation beyond 80 kg N/ha. On the other hand, combined dry matter yield (kg/ha) increased linearly with increase in applied N fertilizer with no significant effect only at 63 DAP in 1991 under both cropping systems (Tables 4.17, 4.18 and 4.19). Dry and warm weather experienced at tasseling in 1991 was responsible for lack of proper N use by beans and maize at 63 DAP. Therefore, unfavourable weather at critical growth stage of the crops may be detrimental for proper crop growth.

Table 4.14. The effect of N fertilization on dry matter accumulation (gm/plant) of beans and maize at 42 and 63 DAP and at maturity averaged across sole and intercropped systems, 1990.

Nitrogen (kg/ha)	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
0	19.8 a	40.2 a	55.9 a	115.9 a	69.3	301.3 a
80	23.2 b	42.6 ab	61.2 ab	144.3 b	76.6	379.7 b
160	24.2 b	45.2 b	65.1 b	145.7 b	78.3	380.6 b
^a Stat. sign.						
linear	**	**	*	***	NS	***
quadratic	NS	NS	NS	**	NS	**

Means followed by a common letter are not significantly different at 5% level using LSD.

^a statistical significance.

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.15. The effect of N fertilization on dry matter accumulation (gm/plant) of beans and maize averaged across sole and intercropped systems at 42 and 63 DAP and at maturity under low maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
0	13.2 a	34.2 a	21.3 a	130.5	21.2 a	233.4 a
80	14.2 ab	38.5 ab	26.5 ab	134.4	27.5 ab	248.4 a
160	15.7 b	43.8 b	29.7 b	148.0	30.3 b	285.9 b
^a Stat. sig.						
linear	*	**	*	NS	*	**
quadratic	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

**, *, NS significant at 1%, 5% or not significant respectively.

Table 4.16. The effect of N fertilization on dry matter accumulation (gm/plant) of beans and maize at 42 and 63 DAP and at maturity averaged across sole and intercropped systems under high maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP		63 DAP		Maturity	
	beans	maize	beans	maize	beans	maize
0	13.6	32.9 a	23.7	108.9 a	22.3	191.5 a
80	13.7	38.0 b	23.3	125 ab	22.5	228.6 ab
160	14.9	40.6 b	28.5	142.1 b	28.0	257.0 b
^a Stat. sign.						
linear	NS	**	NS	**	NS	*

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

Table 4.17. The effect of N fertilization on total dry matter yield (kg/ha) of maize and beans averaged across sole and intercropped systems at 42 and 63 DAP and at crop maturity, 1990.

Nitrogen (kg/ha)	42 DAP	63 DAP	Maturity
0	2441.1 a	6688.5 a	11195.9 a
80	2685.8 ab	7753.0 b	12880.8 b
160	2847.5 b	7824.7 b	13255.2 b

Statistical significance

linear	*	**	**
quadratic	NS	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

**, *, NS significant at 1%, 5%, or not significant, respectively.

Table 4.18. The effect of N fertilization on total dry matter yield (kg/ha) of maize and beans averaged across sole and intercropped systems at 42 and 63 DAP and at maturity under low maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP	63 DAP	Maturity
0	1742.3 a	4477.0	6243.5 a
80	1921.9 ab	4708.4	6779.5 a
160	2115.4 b	5218.0	7750.1 b

Statistical significance

linear	*	NS	**
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Means followed by a common letter are not significantly different at 5% level using LSD.

**, *, NS significant at 1%, 5% or not significant, respectively.

Table 4.19. The effect of N fertilization on total dry matter yield (kg/ha) of maize and beans averaged across sole and intercropped systems at 42 and 63 DAP and at maturity under high maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP	63 DAP	Maturity
0	2043.6 a	4932.9	6986.5 a
80	2197.6 ab	5368.7	8007.5 ab
160	2399.0 b	6059.8	9029.0 b

Statistical significance

linear

*

NS

*

Means followed by a common letter are not significantly different at 5% level using LSD.

*, NS significant at 5% or not significant, respectively.

Searle et al. (1981) reported a similar finding where N fertilization significantly improved dry matter accumulation of maize in maize/cowpea and maize/groundnut intercrops.

It would seem that although weather was a factor in reducing N usage in 1991 growing season, population pressure from the high maize density was partially relieved by N additions as indicated by the results of 1991 under low and high maize population cropping systems (Tables 4.15 and 4.16, respectively).

4.4. Leaf chlorophyll content of beans and maize in sole and intercropped systems as affected by N fertilization and crop proportions

Tables 4.20 and 4.21 show the chlorophyll content of bean and maize leaves at 42 and 65 DAP in 1990, 63 DAP in 1991 under low and high maize population cropping systems and the effect of N fertilization on chlorophyll contents, respectively.

At 42 DAP, bean leaf chlorophyll content decreased with increasing bean proportions and maize leaf chlorophyll increased with increasing maize proportions in the systems. This indicates how intense intraspecific competition was within the bean crop as population of beans in the system increased. The result here shows that there is less interspecific than intraspecific competition for available nitrogen which determines the green color of crop leaves (chlorophyll).

Maize showed a reverse trend to that of beans at 42 DAP (Table 4.20). There was more chlorophyll in sole maize than intercropped maize. Low maize proportion had the lowest amount of chlorophyll because beans established themselves first than maize and where the proportion of beans was high, they were very close to maize. This could have induced N deficiency in the low maize proportion.

In 1991, chlorophyll measurement was taken only once at 63 DAP as indicated in table 4.20. Under low maize population cropping system in 1991, crop proportion had no significant effect on both beans and maize leaf chlorophyll content although the amount of chlorophyll increased with increasing proportions of either beans or maize (sole crops had more

Table 4.20. The effect of crop proportion on bean and maize chlorophyll content in sole and intercropped systems in 1990, 1991 (A) under low maize population cropping and 1991 (B) under high maize population cropping systems.

Crop	1990				1991(A)				1991(B)			
	42 DAP		65 DAP		63 DAP		63 DAP		63 DAP		63 DAP	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	40.5 b	46.8 a	37.8	47.7 a	38.6	52.9	38.5 a	52.0 b	38.6 a	51.3 ab	37.5 a	51.5 ab
50%	39.9 ab	48.4 ab	37.3	51.0 a	--	--	38.6 a	51.3 ab	38.6 a	51.3 ab	37.5 a	51.5 ab
75%	39.9 ab	50.0 b	38.3	51.4 a	39.6	53.0	37.5 a	51.5 ab	37.5 a	51.5 ab	40.3 b	49.5 a
Sole crop	38.9 a	52.4 c	37.4	60.0 b	40.3	55.3	40.3 b	49.5 a	40.3 b	49.5 a	40.3 b	49.5 a
a Stat. sign.	*	***	NS	***	NS	NS	NS	*	NS	*	NS	NS
linear	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant respectively.

chlorophyll than intercropped plants). There was significant difference caused by crop proportions under high maize population cropping in 1991 (Table 4.20). Bean leaf chlorophyll increased with increase in crop proportion with sole beans significantly higher than intercropped beans. Due to intraspecific competition within maize plants with increased maize population, the low bean proportion crops may have suffered from lack of nitrogen leading to their low chlorophyll content.

Maize under the high maize population cropping of 1991 showed a reverse trend to that of 1990 and 1991 under low population cropping system (Table 4.20). Chlorophyll content of maize leaves under the high population increased with decrease in maize proportion with sole maize having the lowest amount of chlorophyll compared to intercropped maize. This was mainly due to the high population of maize leading to intense competition for the available nitrogen with less interspecific competition than intraspecific competition.

At 65 DAP, beans showed no significant difference in the amount of chlorophyll in their leaves regardless of the crop proportions in 1990 (Table 4.20). At this time, beans were fully manufacturing their own N from their root nodules in the no N plots such that all crop proportions were in position to get enough N to support their systems with no significant difference between them. It was also the time when beans were nearing end of pod filling stage and most of the leaves were beginning to drop and some had turned yellow due to old age. The amount of chlorophyll was, therefore, reduced at this stage compared to 42 DAP.

Only sole maize showed significant difference in the amount of chlorophyll from the rest of the crop proportions at 63 DAP and this was

Table 4.21. The effect of nitrogen fertilization on chlorophyll content of beans and maize leaves averaged across sole and intercropped systems in 1990, 1991 (A) under low maize population cropping and 1991 (B) under high maize population cropping.

Nitrogen (kg/ha)	1990				1991(A)		1991(B)	
	42 DAP		65 DAP		63 DAP		63 DAP	
	beans	maize	beans	maize	beans	maize	beans	maize
0	38.3 a	45.0 a	37.8 ab	43.8 a	38.2 a	49.7 a	38.0	42.0 a
80	40.5 b	50.5 b	36.5 a	55.0 b	39.8 ab	55.5 b	38.8	52.9 b
160	40.9 b	52.6 c	38.7 b	58.7 c	40.7 b	56.1 b	39.4	55.7 b
a Stat. sign.	**	***	NS	***	*	*	NS	**
linear								
quadratic	*	*	*	**	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * NS significant at 0.1%, 1%, 5% or not significant respectively.

just after tasseling in 1990 (Table 4.20). Maize had more chlorophyll at this time than was at 42 DAP. This could have been the period of maximum chlorophyll accumulation and utilization of applied N fertilizer by maize coinciding with maximum increase in maize heights and dry matter yield in 1990.

Both beans and maize generally showed significant linear response of chlorophyll content to N application at 42 and 65 DAP in 1990 and at 63 DAP in 1991 under both cropping systems (Table 4.21). Maize was significantly different at all N levels in 1990. But in 1991, in all cases of significant response to N, there was no significant response beyond 80 kg N/ha as shown in Table 4.21. The trend of chlorophyll amount in response to N application seems to indicate that beans even at low N are capable of supplying their own N to support their systems as much as beans that are planted in N-applied plots. The results also indicate a much higher response of maize to N applied in 1990 than in 1991 which can be due to weather and or population increase of maize used in 1991.

4.5. Nutrient concentrations in intercropped beans and maize as affected by crop proportions and N fertilization

Crop proportions (CP) had no significant effect on bean nutrient concentrations at 42 DAP in 1990 (Table 4.22). P and Ca concentrations were more or less constant regardless of crop proportions. In 1991 at the same sampling date (42 DAP), CP had significant effects on bean P, K, and Ca concentrations under low maize population cropping, and bean N, P and K under high maize population cropping (Tables 4.23 and 4.24). In all

Table 4.22. The effect of crop proportions on bean and maize nutrient concentration 42 days after planting (DAP) in both sole and intercrop systems, 1990.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	3.5	2.4 a	4.5	4.7 a	0.4	0.4 a	1.9	0.39 a	0.32	0.14 a
50%	3.5	2.3 a	4.5	4.7 a	0.4	0.4 a	1.9	0.38 a	0.33	0.14 a
75%	3.6	2.4 ab	4.6	4.9 ab	0.4	0.5 b	1.9	0.39 a	0.33	0.15 a
Sole crop	3.5	2.6 b	4.6	5.1 b	0.4	0.5 b	1.9	0.41 b	0.34	0.16 b
a Stat. sign.										
linear	NS	**	NS	**	NS	***	NS	**	NS	**
quadratic	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

***, **, * NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.23. The effect of crop proportions on bean and maize nutrient concentration 42 days after planting in sole and intercrop systems under low maize population cropping, 1991.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	3.2	2.9	3.8 a	3.6	0.37 a	0.44	2.3 b	0.44	0.40	0.18
75%	3.4	2.8	4.1 b	4.0	0.40 b	0.42	2.2 a	0.41	0.40	0.18
Sole crop	3.5	2.8	4.3 c	3.8	0.41 b	0.45	2.3 ab	0.42	0.41	0.18
a Stat. sign.										
linear	NS	NS	***	NS	***	NS	NS	NS	NS	NS
quadratic	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, * NS significant at 0.1%, 5% or not significant respectively.

Table 4.24. The effect of crop proportions on bean and maize nutrient concentrations in sole and intercropped systems at 42 days after planting (DAP) under high maize population cropping, 1991.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	3.2 a	2.8	3.8 a	3.7	0.38 a	0.42	2.2	0.45	0.40	0.19
50%	3.3 ab	2.8	4.2 b	3.8	0.40 ab	0.40	2.1	0.38	0.40	0.17
75%	3.3 ab	2.7	4.1 ab	3.9	0.40 ab	0.42	2.3	0.41	0.40	0.19
Sole crop	3.5 b	2.7	4.3 b	3.9	0.41 b	0.42	2.3	0.42	0.41	0.18

a Stat. sign.

linear

quadratic

cubic

*

NS

**

NS

*

NS

NS

NS

NS

NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

cases of significant responses, nutrient concentrations increased with increase in crop proportions (sole beans had higher concentrations of nutrients than intercropped beans) (Tables 4.23 and 4.24, respectively).

In 1990, maize nutrient concentrations were significantly affected by crop proportions at 42 DAP but there was no significant CP effect on nutrient concentrations in 1991 under both low and high maize population cropping systems (Tables 4.22, 4.23 and 4.24). All maize nutrient concentrations in 1990 increased with increase in crop proportions with sole maize having higher concentration of nutrients than intercropped maize (Table 4.22).

Beans had higher concentrations of N, Ca and Mg than maize and almost the same concentrations of P and K as maize in 1990 and 1991 under both low and high maize population cropping systems (Tables 4.22, 4.23 and 4.24, respectively).

At 42 DAP, N fertilization significantly affected bean N, Ca and Mg concentrations in 1990 and 1991 under high maize population cropping system, and bean N, P and K concentrations under low maize population cropping system in 1991 (Tables 4.25, 4.26, 4.27). In all cases, N fertilization improved bean nutrient uptake with no significant response beyond 80 kg N/ha in both years. Maize N, K, Ca and Mg concentrations were significantly affected by N fertilization in 1990 (Table 4.25). Under low maize population cropping system in 1991, N fertilization significantly affected only N uptake by maize with no significant difference between 80 and 160 kg N/ha (Table 4.26). But under high maize population cropping systems in 1991, N fertilization significantly increased all maize nutrient uptake (Table 4.27).

Table 4.25. The effect of different N fertilizer levels on nutrient concentrations of beans and maize averaged across sole and intercropped systems 42 days after planting, 1990.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	3.3 a	2.0 a	4.4	4.7 a	0.4	0.5	1.7 a	0.35 a	0.30 a	0.13 a
80	3.6 b	2.5 b	4.7	4.9 ab	0.4	0.4	1.9 b	0.40 b	0.33 b	0.15 b
160	3.7 b	2.8 c	4.6	4.9 b	0.4	0.4	2.0 b	0.43 c	0.35 b	0.16 c
a Stat. sign. linear	**	***	NS	*	NS	NS	**	***	**	**
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

***, **, * NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.26. The effect of N fertilization on nutrient concentrations of beans and maize averaged across sole and intercrop systems 42 DAP under low maize population cropping, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	3.2 a	2.5 a	3.8 a	3.6	0.37 a	0.43	2.1	0.36 a	0.38	0.17
80	3.4 b	2.9 b	4.1 ab	3.9	0.38 ab	0.42	2.3	0.43 b	0.42	0.18
160	3.5 b	3.1 b	4.3 b	3.9	0.41 b	0.45	2.4	0.47 b	0.42	0.19
^a Stat.sign.										
linear	*	***	*	NS	*	NS	NS	***	NS	NS
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant respectively.

Table 4.27. The effect of different N fertilizer levels on nutrient concentrations of beans and maize averaged across sole and intercropped systems at 42 days after planting, under high maize population cropping, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	3.0 a	2.4 a	3.9	3.6 a	0.39	0.39 a	2.0 a	0.38 a	0.37 a	0.15 a
80	3.4 b	2.9 b	4.1	3.8 ab	0.39	0.42 b	2.3 b	0.46 b	0.42 b	0.19 b
160	3.6 b	2.9 b	4.2	4.0 b	0.41	0.43 b	2.4 b	0.42 ab	0.43 b	0.20 b
a Stat sign.										
linear	**	***	NS	*	NS	*	***	*	*	***
quadratic	NS	**	NS	NS	NS	*	NS	**	NS	*

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

***, **, * , NS significant at 0.1%, 1%, 5% or not significant respectively.

At 42 DAP, all maize nutrients showed increased uptake by maize with increase in applied N fertilizer. This seems to indicate that competition for nutrients in maize starts very early in the process of growth compared to beans. Beans on the other hand had higher concentrations of N, Ca and Mg than maize plants at all crop proportions irrespective of fertilizer level. This happened to be the start of bean flowering. Chui (1988) reported a similar finding with intercropped maize and beans (additive series) where beans had higher concentrations of N, P and Ca at bean flowering and pod filling stage. But there was a higher accumulation of K in maize in 1990 and P in 1991 under both low and high population cropping systems. This agrees with the finding of Hanway (1962) that K accumulation in maize takes place early in the season.

At 42 DAP, bean K and maize Mg concentrations in 1990, and bean K and Ca concentrations in 1991 under low maize population cropping system showed significant CP x N fertilization interactions. Beans increased their uptake of K at 80 kg N/ha and then dropped down at 160 kg N/ha for 25%, 50% and 75% bean proportions (Figure 4.1). Sole beans continued to take up K linearly with increase in N fertilization. Application of 80 kg N/ha improved bean growth which allowed beans to take up more K. As N fertilization was increased to 160 kg N/ha, maize in the intercrops became more competitive than beans, and therefore, increasing interspecific competition left the intercropped beans to suffer at the high N level as shown in Figure 4.1. Application of N fertilizer reduced intraspecific competition in the sole beans and that is why K uptake increased with increase in applied N.

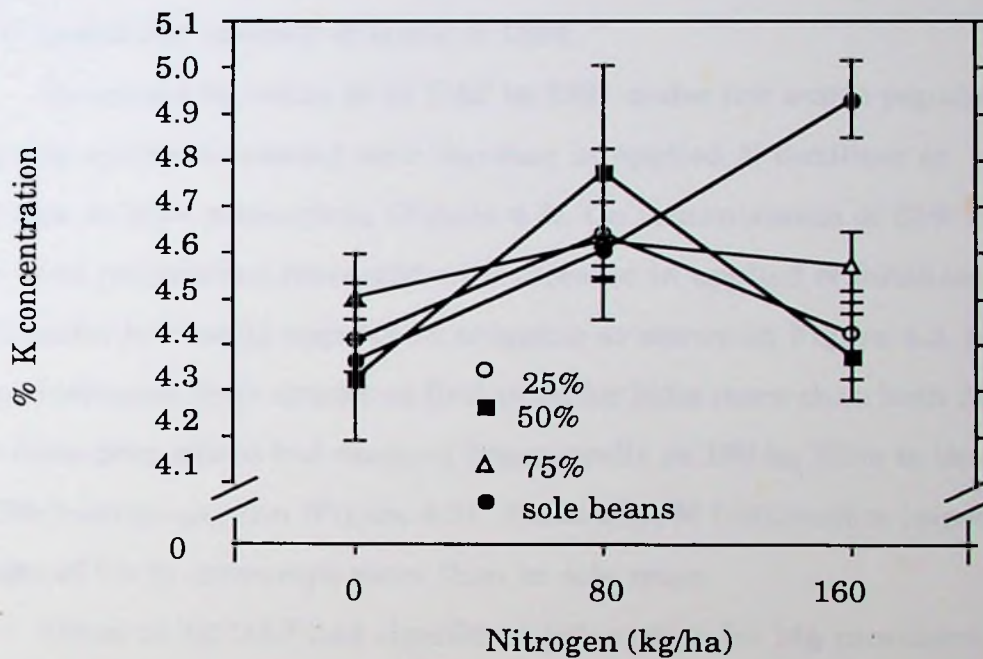


Figure 4.1. The effect of crop proportions and N fertilization interaction on % bean K concentration at 42 DAP in sole and intercropped systems, 1990.

Bean K uptake under low maize population cropping in 1991 (same maize and bean population as in 1990) showed similar trends for all crop proportions compared to 1990 except 75% bean proportion (Figure 4.2). K uptake by beans at 42 DAP in 1990 increased with increase in applied N fertilizer and increase in bean proportions. Bean proportion at 25% had very low K concentration at 0 N level which increased drastically at 80 kg N/ha to the level of sole beans (Figure 4.2). The dry weather of 1991 could have caused this reversal of trend in 1991.

Ca uptake by beans at 42 DAP in 1991 under low maize population cropping system increased with increase in applied N fertilizer or decrease in bean proportions (Figure 4.3). Ca concentration of 25% and 75% bean proportions increased with increase in applied N fertilizer in 1991 under low maize population cropping as shown in Figure 4.3. Sole beans increased their uptake at first at 80 kg N/ha more than both 25% and 75% bean proportions but dropped dramatically at 160 kg N/ha to the level of 75% bean proportion (Figure 4.3). Generally, N fertilization improved uptake of Ca in intercrops more than in sole crops.

Maize at 42 DAP had significant interaction for Mg concentration in 1990 (Figure 4.4). In all cases of crop proportions, maize Mg uptake increased with increase in applied N fertilizer or increase in maize crop proportions (Figure 4.4). Maize at 50% proportion showed no response to N at 80 kg N/ha but later increased its uptake significantly at 160 kg N/ha. Sole maize, 25% and 75% maize proportions all increased their uptake of Mg at 80 kg N/ha and 160 kg N/ha although the increase by 75% maize proportion at 160 kg N/ha was very slight as indicated in figure 4.4. There

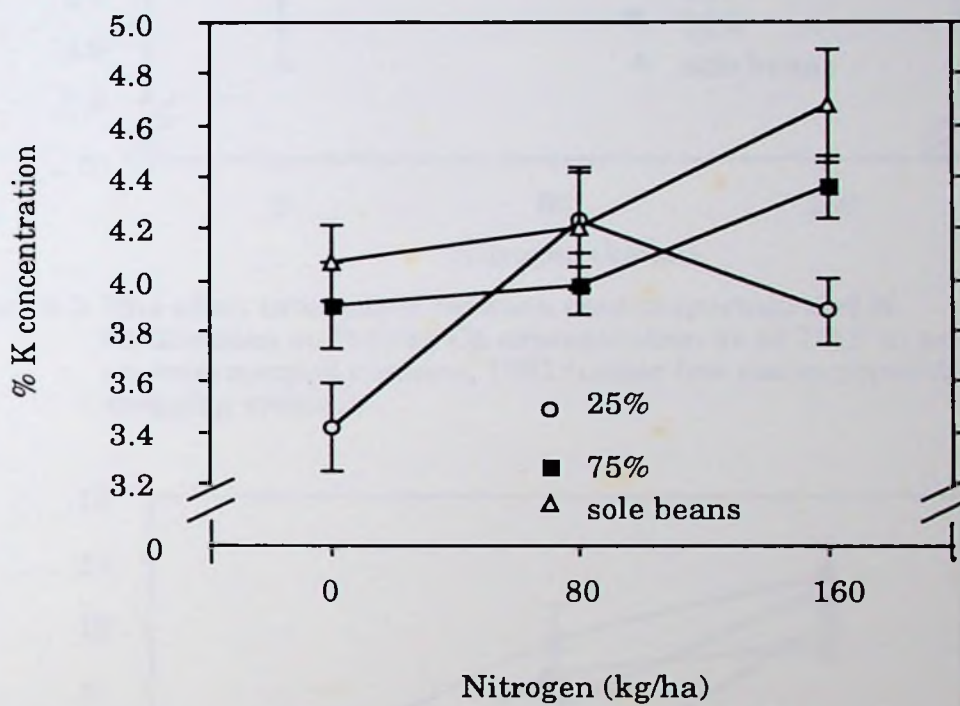


Figure 4.2. The effect of crop proportions and N fertilization interaction on % bean K concentration at 42 DAP in sole and intercropped systems, 1991 (under low maize population cropping system).

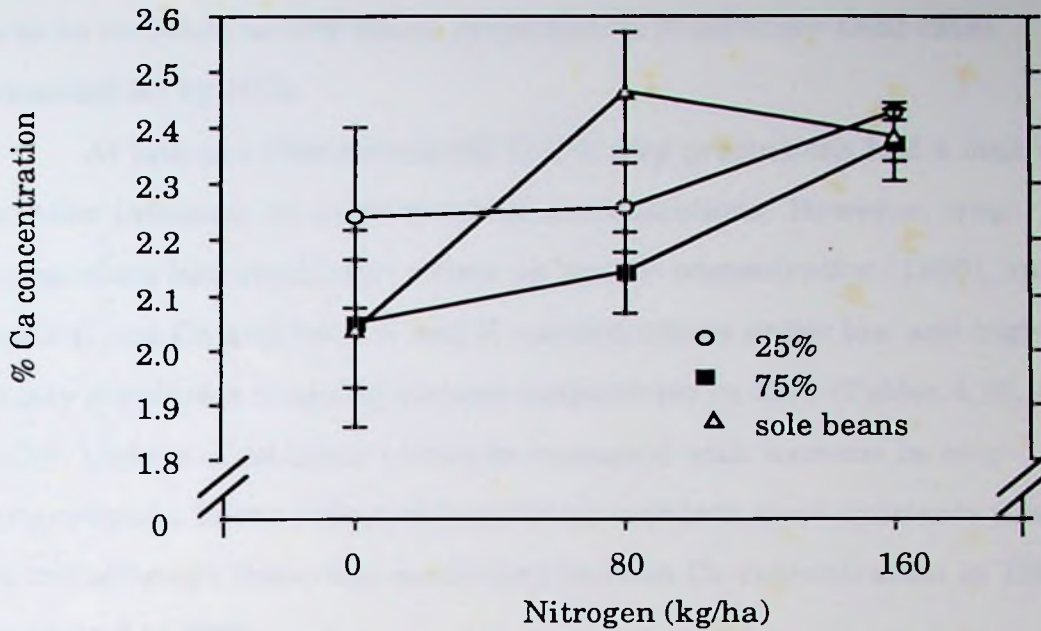


Figure 4.3. The effect interaction between crop proportion and N fertilization on % bean Ca concentration at 42 DAP in sole and intercropped systems, 1991 (under low maize population cropping system).

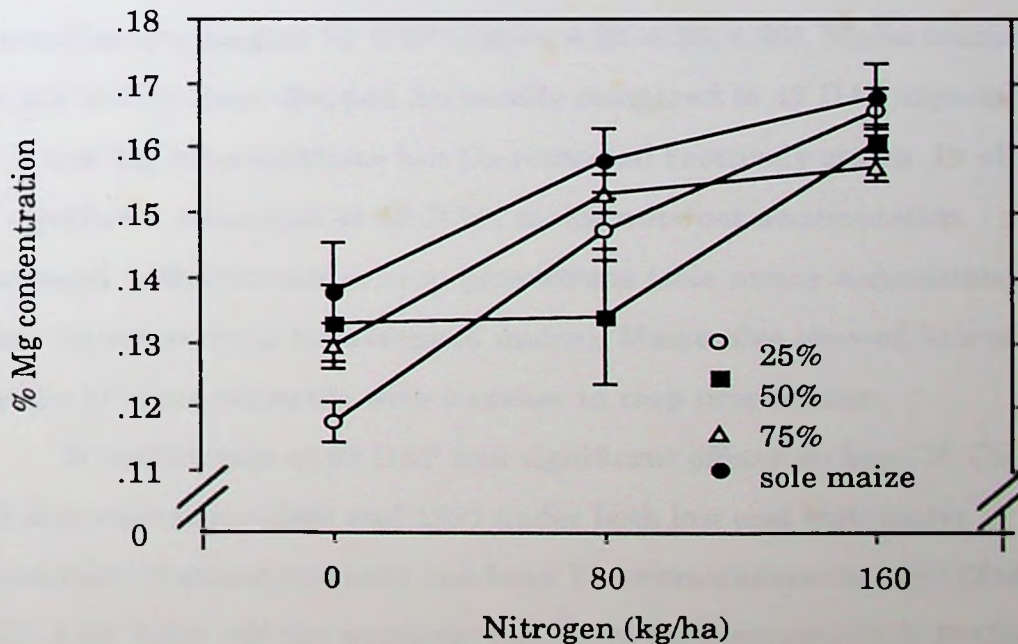


Figure 4.4. The effect of crop proportions and N fertilization interaction on % maize Mg concentration at 42 DAP in sole and intercropped systems, 1990.

was no response of 50% maize proportion to N fertilizer until rates exceeded 80 kg N/ha.

At late pod filling stage (63 DAP), crop proportions had a much smaller influence on plant nutrient concentrations. However, crop proportions had significant effects on bean P concentration (1990), and bean K and Ca and bean N and K concentrations under low and high maize population cropping systems respectively in 1991 (Tables 4.28, 4.29, 4.30). Uptake of all these nutrients increased with increase in crop proportions. Beans still continued to accumulate more nutrients than maize although there was much drop in bean Ca concentration in 1991 compared to 1990.

Crop proportions had significant effects on maize N and P concentrations (1990), maize P concentration (1991 under low maize population cropping), and maize K concentration (1991 under high maize population cropping) at 63 DAP (Tables 4.28, 4.29, 4.30). Maize nutrient uptake at this stage dropped drastically compared to 42 DAP especially N, P, K and Mg concentrations but Ca remained relatively stable. In all cases of significant responses at 63 DAP, maize nutrient accumulation increased with increase in crop proportions (sole maize accumulated more nutrients than intercropped maize). Maize also showed increased uptake of other nutrients with increase in crop proportions.

N fertilization at 63 DAP had significant effects on bean N, Ca and Mg concentrations (1990 and 1991 under both low and high maize population cropping systems) and bean K concentrations in 1990 (Tables 4.31, 4.32, 4.33). All the nutrients increased with increase in N fertilization

Table 4.28. The effect of crop proportions on nutrient concentrations of beans and maize in sole and intercropped systems 63 days after planting, 1990.

Crop proportions	<u>% Nitrogen</u>		<u>% Potassium</u>		<u>% Phosphorus</u>		<u>% Calcium</u>		<u>% Magnesium</u>	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	3.2	2.2 a	3.0	1.7	0.35 a	0.36 ab	2.3	0.50	0.34	0.1
50%	3.4	2.3 a	3.1	1.8	0.37 ab	0.35 a	2.3	0.51	0.33	0.1
75%	3.4	2.3 a	3.1	1.8	0.37 ab	0.34 a	2.2	0.50	0.34	0.1
Sole crop	3.4	2.7 b	3.0	1.7	0.38 b	0.38 b	2.2	0.51	0.32	0.1
<u>a Stat. sign.</u>										
linear	NS	**	NS	NS	*	NS	NS	NS	NS	NS
quadratic	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

**, *, NS significant at 1%, 5% or not significant respectively.

Table 4.29. The effect of crop proportions on nutrient concentrations of beans and maize in sole and intercropped systems under low maize population cropping system, 1991.

Crop proportions	<u>% Nitrogen</u>		<u>% Potassium</u>		<u>% Phosphorus</u>		<u>% Calcium</u>		<u>% Magnesium</u>	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	2.7	1.9	2.8 a	2.1	0.32	0.29 b	1.6 a	0.4	0.30	0.15
75%	2.8	1.8	2.7 a	2.2	0.33	0.28 ab	1.5 a	0.4	0.30	0.14
Sole crop	2.9	1.9	3.0 b	2.1	0.35	0.27 a	1.7 b	0.5	0.32	0.13
a <u>Stat. sign.</u>	NS	NS	**	NS	NS	*	*	NS	NS	NS
linear	NS	NS	**	NS	NS	*	*	NS	NS	NS
quadratic	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

**, *, NS significant at 1%, 5%, or not significant respectively.

Table 4.30. The effect of crop proportions on nutrient concentrations of beans and maize in sole and intercropped systems 63 DAP under high maize population cropping system, 1991.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	2.7 ab	1.8	2.8 a	2.0 a	0.24	0.30	1.6	0.41	0.31	0.13
50%	2.7 a	1.7	2.8 ab	2.1 ab	0.34	0.27	1.5	0.42	0.30	0.14
75%	2.8 ab	1.6	3.0 bc	2.2 b	0.36	0.27	1.7	0.42	0.30	0.15
Sole crop	2.9 b	1.7	3.0 c	2.3 b	0.35	0.27	1.7	0.44	0.32	0.14
a Stat. sign.										
linear	*	NS	**	**	NS	NS	NS	NS	NS	NS
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

**, *, NS significant at 1%, 5%, or not significant respectively.

Table 4.31. The effect of different N fertilizer levels on nutrient concentrations of beans and maize averaged across sole and intercropped systems 63 DAP, 1990.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	3.2 a	1.9 a	2.9 a	1.7	0.35 a	0.33 a	2.0 a	0.5 a	0.28 a	0.09 a
80	3.3 ab	2.5 b	3.1 b	1.8	0.39 b	0.36 ab	2.3 b	0.5 a	0.34 b	0.10 a
160	3.5 b	2.8 c	3.1 a	1.8	0.37 ab	0.38 b	2.3 b	0.6 b	0.38 c	0.12 b

a Stat. sign.

linear

*

**

NS

NS

**

*

*

**

quadratic

NS

NS

NS

NS

*

NS

NS

*

NS

NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance.

***, **, * NS significant at 0.1%, 1%, 5%, or not significant respectively.

Table 4.32. The effect of N fertilization on nutrient concentrations of beans and maize averaged across sole and intercropped systems, 63 DAP under low maize population cropping system, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	2.7 a	1.7	2.7	2.1	0.33	0.30 b	1.4 a	0.4	0.27 a	0.14
80	2.8 ab	1.9	2.8	2.2	0.33	0.27 a	1.6 b	0.5	0.32 b	0.14
160	3.0 b	2.0	3.0	2.1	0.34	0.26 a	1.8 b	0.4	0.33 b	0.13
a Stat. sign.										
linear	*	NS	NS	NS	NS	**	**	NS	**	NS
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

**, *, NS significant at 0.1%, 5% or not significant respectively.

Table 4.33. The effect of N fertilization on nutrient concentrations of beans and maize averaged across sole and intercropped systems 63 DAP under high maize population cropping system, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	2.6 a	1.4 a	2.8	2.1	0.34	0.28	1.4 a	0.38 a	0.27 a	0.13 a
80	2.8 b	1.8 b	2.9	2.2	0.35	0.27	1.6 b	0.41 ab	0.32 b	0.14 a
160	3.0 b	2.0 b	3.0	2.2	0.35	0.28	1.9 c	0.50 b	0.33 b	0.15 b
a Stat. sig. linear	**	**	NS	NS	NS	NS	***	*	***	*
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * , NS significant at 0.1%, 1%, 5% or not significant respectively.

with significant differences at all levels of applied N fertilizer for Ca (LSD = 0.05) in 1990 (Table 4.31), and Mg in 1991 under high maize population cropping system (Table 4.33).

Maize responded linearly to N fertilization for maize N, P, Ca and Mg concentrations in 1990 with increase in all these nutrients with increasing N fertilizer level (Table 4.31). In 1991 under low maize population cropping system, N fertilization had significant effect only on maize P concentration which concentration decreased with increase in applied N fertilizer (Table 4.32). It seemed beans took up more P than maize especially with increase in N fertilizer improving bean growth but reducing uptake by maize. The same trend was apparent for maize P under high maize population cropping system in 1991 (Table 4.33). N fertilizer also had significant effect on maize Ca and Mg concentration in 1991 under high maize population cropping system. The amount of Ca and Mg absorbed by maize increased with increase in applied N fertilizer.

There were significant CP x N fertilization interactions for maize P concentration in 1990 and 1991 under low maize population cropping system at 63 DAP (same maize and bean population in 1990 and 1991) (Figures 4.5 and 4.6, respectively). In 1990, maize P uptake at 63 DAP increased with increase in N fertilization especially at 50% and 75% maize crop proportions (Figure 4.5). Maize at 25% proportion decreased its P uptake at 80 kg N/ha and then increased at 160 kg N/ha. Sole beans increased their uptake of P at 80 kg N/ha and then dropped at 160 kg N/ha. By increasing N fertilizer level to 160 kg N/ha, competition for P by beans was reduced or maize growth was improved in the intercropped systems such that better root development allowed more uptake of P by intercropped

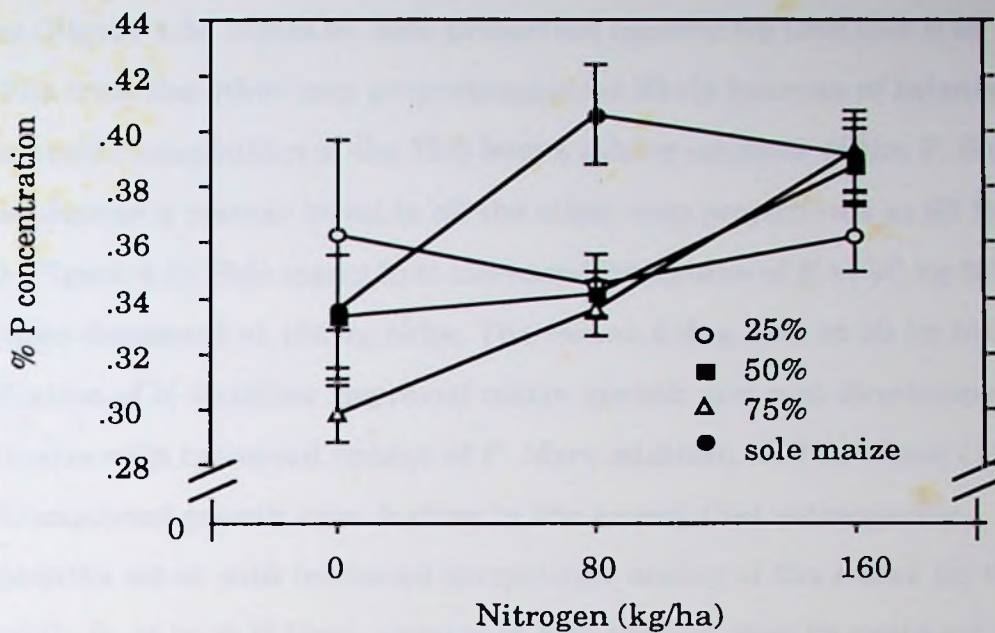


Figure 4.5. The effect of crop proportions x N fertilization interaction on % maize P concentration at 63 DAP in sole and intercropped systems, 1990.

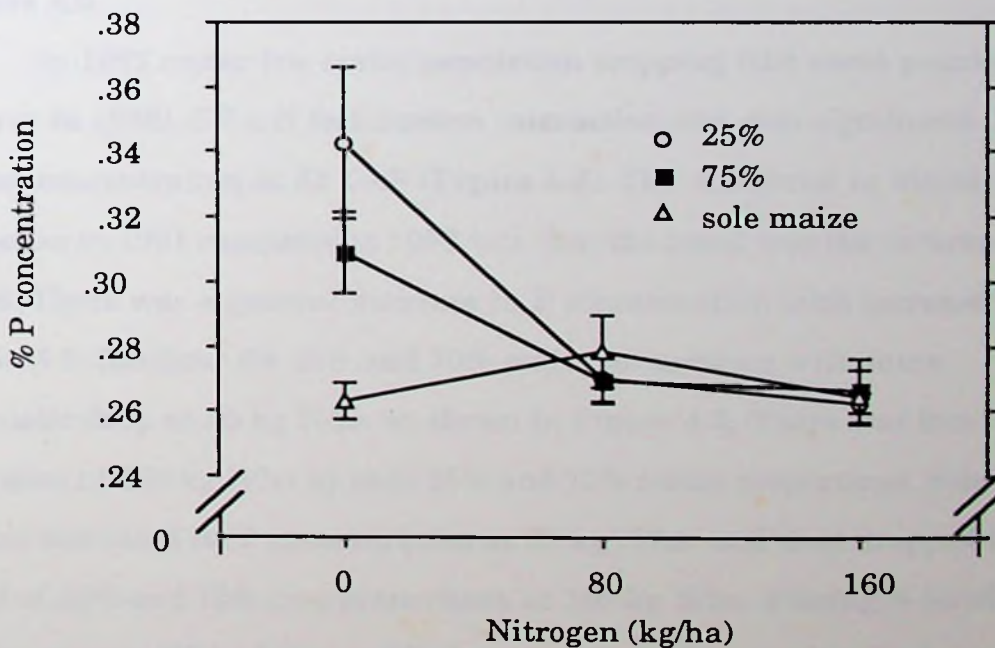


Figure 4.6. The effect crop proportion x N fertilization interaction on maize P concentration at 63 DAP in sole and intercropped systems, 1991 (under low maize population cropping).

maize (Figure 4.5). Maize at 25% proportion apparently took less P at 160 kg N/ha than the other crop proportions most likely because of intense intraspecific competition of the 75% beans taking up more of the P. Sole maize showed a reverse trend to all the other crop proportions at 63 DAP in 1990 (Figure 4.5). Sole maize first increased its uptake of P at 80 kg N/ha and then decreased at 160 kg N/ha. The reason being that at 80 kg N/ha, application of N fertilizer improved maize growth and root development in sole maize with increased uptake of P. More addition of N fertilizer (160 kg N/ha) improved growth even further to the extent that intraspecific competition set in with increased competitive ability of the maize for the immobile P. At high N level, amount of P in the soil may be could not cope with the rapid growth of the sole maize leading to reduced uptake and low concentration of P in sole maize tissues at 160 kg N/ha as indicted by Figure 4.5.

In 1991 under low maize population cropping (the same population as was in 1990), CP x N fertilization interaction was also significant for maize concentration at 63 DAP (Figure 4.6). The difference in maize response in 1991 compared to 1990 was that the trend was the reverse of 1990. There was a general decrease in P concentration with increase in applied N fertilizer for 25% and 75% maize proportions with more dramatic drop at 80 kg N/ha as shown in Figure 4.6. There was less decrease at 160 kg N/ha by both 25% and 75% maize proportions. Sole maize increased its P concentration at 80 kg N/ha and then dropped to the level of 25% and 75% crop proportions at 160 kg N/ha. Placing N fertilizer in the system (80 kg N/ha) might have reduced N production by beans from their nodules which then caused them to compete for the applied N. Dry weather of 1991 might have reduced the efficiency of N utilization by

maize resulting into poor uptake of P by maize. The same explanation applies to N use at 160 kg N/ha. Sole maize had low P concentration at 0 N level because of poor maize growth since N was lacking. Addition of 80 kg N/ha to some extent improved maize growth, probably root system leading to improved P uptake by maize. More addition of N (160 kg N/ha) might have improved growth even further leading to increased intraspecific competition and reduced uptake of P by maize at the high N level (Figure 4.6). This was aided by the dry weather experienced in 1991. Dry weather effect can clearly be seen by comparing P uptake in 1990 and 1991 as indicated in Figures 4.5 and 4.6, respectively.

At crop maturity, crop proportions significantly affected bean Ca (1990), N (1991 under low maize population cropping system), and bean N and P (1991 under high maize population cropping system) (Tables 4.34, 4.35, 4.36). Bean Ca concentration in 1990 showed more uptake by 50% and 75% bean proportions than sole beans and 25% bean proportion (Table 4.34). Intraspecific competition among sole beans and 75% maize proportions could have caused the observed effects on sole beans and 25% bean proportion respectively. The rest of the nutrients in 1990 showed no specific trend in regard to crop proportions.

In 1991 under both low and high maize population cropping systems, beans increased their uptake of N and P with increase in crop proportions (Tables 4.35 and 4.36, respectively). Sole beans accumulated more N than intercropped beans and the same was true for P under high maize population cropping system. Under both low and high maize population cropping systems, 75% bean proportion accumulated less nutrients than other crop proportions due to competition within beans

Table 4.34. The effect of different crop proportions on bean and maize nutrient concentrations in sole and intercropped systems at crop maturity, 1990.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	2.3	1.2 a	2.3	1.0 b	0.25	0.36 ab	3.4 ab	0.21 b	0.20	0.12 a
50%	2.3	1.3 b	2.4	0.9 b	0.24	0.39 b	3.5 b	0.19 b	0.19	0.14 b
75%	2.3	1.2 a	2.4	0.8 a	0.25	0.34 a	3.5 b	0.17 ab	0.18	0.13 ab
Sole crop	2.4	1.4 b	2.3	0.7 a	0.26	0.37 ab	3.3 a	0.14 a	0.21	0.14 ab
<u>a Stat. sign.</u>										
linear	NS	NS	NS	***	NS	NS	NS	**	NS	NS
quadratic	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
cubic	NS	*	NS	NS	NS	*	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * , NS significant at 0.1%, 1%, 5%, or not significant respectively.

Table 4.35. The effect of crop proportions on nutrient concentrations of beans and maize in sole and intercropped systems at crop maturity under low maize population cropping, 1991.

Crop proportions	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	2.6 a	1.7 b	2.3	1.2 a	0.31	0.28	2.0	0.39	0.32	0.13
75%	2.4 a	1.5 a	2.4	1.3 ab	0.29	0.26	2.2	0.39	0.31	0.12
Sole crop	2.8 b	1.5 a	2.5	1.4 b	0.33	0.26	2.1	0.39	0.31	0.12
a Stat. sign.										
linear	*	***	NS	*	NS	NS	NS	NS	NS	NS
quadratic	**	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * , NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.36. The effect of crop proportions on nutrient concentrations of beans and maize in sole and intercropped systems at maturity under high maize population cropping system, 1991.

Crop proportions	<u>% Nitrogen</u>		<u>% Potassium</u>		<u>% Phosphorus</u>		<u>% Calcium</u>		<u>% Magnesium</u>	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
25%	2.6 a	1.6 c	2.5	1.3	0.30 a	0.31 b	2.0	0.45 b	0.31	0.14
50%	2.4 a	1.4 b	2.5	1.3	0.29 a	0.26 a	2.1	0.37 ab	0.31	0.13
75%	2.6 a	1.3 a	2.4	1.3	0.33 ab	0.23 a	2.2	0.35 a	0.31	0.12
Sole crop	2.8 b	1.4 ab	2.5	1.4	0.33 b	0.24 a	2.1	0.40 ab	0.31	0.13
a Stat. sig.	**	***	NS	NS	*	***	NS	NS	NS	NS
linear										
quadratic	*	**	NS	NS	NS	*	NS	*	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * , NS significant at 0.1%, 1%, 5% or not significant respectively.

themselves (intraspecific competition) and from the very competitive 25% maize proportion (interspecific competition). This is also indicated by the high N and P uptake by the 25% maize proportion at maturity under both low and high maize population cropping systems in 1991 (Tables 4.35 and 4.36, respectively).

At maturity crop proportions had significant effects on maize N, K, P and Ca (1990), N and K (1991 under low maize population cropping system), and N, P and Ca (1991 under high maize population cropping system) (Tables 4.34, 4.35, 4.36). Maize N and Mg concentrations showed no significant difference between 50% maize proportion and sole maize in 1990 (Table 4.34). This could have been due to better crop arrangement at 50% maize proportion and the reliable rainfall received in 1990. K and Ca concentrations of maize decreased with increase in maize proportions in 1990. Maize at 25% proportion accumulated more P and Ca than other crop proportions. This might have been due to its slow growth and delay in maturity such that when beans matured in the intercrop, maize was in position to use the available P and Ca as these happened to be less mobile.

On the other hand, there was increase in maize N, P, Ca and Mg with decrease in crop proportions in 1991 under both low and high maize population cropping systems (Tables 4.35 and 4.36 respectively). Maize K increased with increase in crop proportions which agreed with Hanway's finding of 1962 that maize accumulated K early in the season without change later in the season. The change in N, P, Ca and Mg concentrations in 1991 could better be explained by the dry weather experienced in 1991 which increased competition for the available resources especially intraspecific competition. Generally, maize nutrient concentration at maturity was lower than at 63 days after planting except for P which was

more or less constant in 1990 and 1991 growing seasons.

N fertilization had significant effects on bean Ca and Mg concentrations in 1990, bean N in 1991 under low maize population cropping, and bean N, Ca and Mg in 1991 under high maize population cropping (Tables 4.37, 4.38 and 4.39, respectively). In all cases, bean nutrient accumulation increased with increase in N fertilization.

There were significant N effects on maize N and K concentrations in 1990, N, P, K and Mg in 1991 under low and high maize population cropping systems respectively (Tables 4.37, 4.38, 4.39). Maize at maturity showed similar response as beans with increase in nutrient uptake with increasing N fertilization except for P and Mg which decreased with increase in N fertilization in 1990 and 1991 under both cropping systems. Maize showed less response at high population to applied N perhaps due to weather condition and population pressure in 1991.

At crop maturity, there were significant CP x N interactions for maize Ca concentration (1990) (Figure 4.7), and maize N and P concentrations in 1991 under low maize population cropping (same population as in 1990) (Figures 4.8 and 4.9). In 1990, maize Ca concentration increased when 80 kg N/ha was applied and less increase was apparent at 160 kg N/ha for 75% maize proportion and sole maize (Figure 4.7). Maize at 25% proportion decreased its Ca uptake at 80 kg N/ha and later increased at 160 kg N/ha. Beans probably relaxed its uptake of N at high level leading to improvement of maize growth and therefore, more Ca uptake by 25% maize proportion. In general, maize Ca concentration increased with decrease in maize proportions or increase in applied N fertilizer except for 25% maize proportion.

Table 4.37. The effect of varied N fertilizer levels on percentage nutrient concentrations of beans and maize averaged across sole and intercropped systems at crop maturity, 1990.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	2.4	1.2 a	2.3	0.77 a	0.26	0.38	3.2 a	0.15	0.15 a	0.15
80	2.4	1.3 b	2.4	0.83 ab	0.25	0.37	3.4 ab	0.18	0.20 b	0.14
160	2.2	1.3 b	2.4	0.92 b	0.24	0.34	3.6 b	0.20	0.24 c	0.12

^a Stat. sign.										
linear	NS	***	NS	*	NS	NS	*	NS	***	NS
quadratic	NS	*	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance.

***, *, NS significant at 0.1%, 5% or not significant respectively.

Table 4.38. The effect of N fertilization on nutrient concentrations of beans and maize averaged across sole and intercropped systems at crop maturity under low maize population cropping system, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	2.4 a	1.3 a	2.3	1.2 a	0.31	0.28 b	1.8	0.36	0.28	0.14 b
80	2.5 a	1.6 b	2.4	1.3 ab	0.30	0.26 ab	2.1	0.38	0.33	0.11 a
160	2.9 b	1.7 b	2.5	1.5 b	0.32	0.26 a	2.4	0.43	0.33	0.12 a
a Stat. sign.	**	***	NS	*	NS	*	NS	NS	NS	*
linear										
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, * NS significant at 0.1%, 1%, 5% or not significant respectively.

Table 4.39. The effect of N fertilization on nutrient concentrations of beans and maize averaged across sole and intercropped systems at crop maturity under high maize population cropping system, 1991.

Nitrogen (kg/ha)	% Nitrogen		% Potassium		% Phosphorus		% Calcium		% Magnesium	
	beans	maize	beans	maize	beans	maize	beans	maize	beans	maize
0	2.3 a	1.2 a	2.4	1.1 a	0.30	0.28	1.8 a	0.36	0.27 a	0.15
80	2.5 a	1.5 b	2.5	1.4 b	0.31	0.25	2.1 ab	0.41	0.33 b	0.12
160	2.9 b	1.6 b	2.5	1.3 ab	0.33	0.26	2.4 b	0.41	0.34 b	0.13
a Stat. sig. linear	**	**	NS	NS	NS	NS	*	NS	***	NS
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	**	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

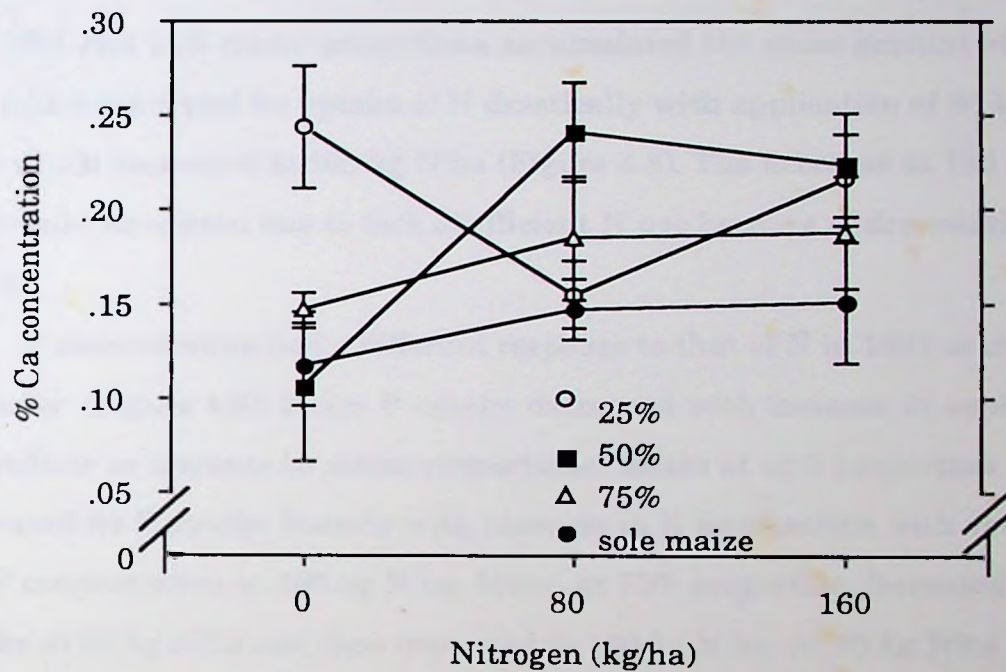


Figure 4.7. The effect of crop proportions x N fertilization interaction on maize Ca concentration at maturity in sole and intercropped system, 1990.

In 1991 under low maize population cropping system at maturity, N fertilizer application improved N uptake by 25% and 75% maize proportions (Figure 4.8). Maize N concentration increased with increase in applied N or decrease in maize crop proportions. At low N level, 25% maize had the highest concentration of N which was significantly different from 75% maize proportion and sole maize. But at 160 kg N/ha, both 25% and 75% maize proportions accumulated the same amount of N. Sole maize increased its uptake of N drastically with application of 80 kg N/ha which decreased at 160 kg N/ha (Figure 4.8). The decrease at 160 kg N/ha could have been due to lack of efficient N use because of dry weather in 1991.

P concentration had a different response to that of N in 1991 at crop maturity (Figure 4.9). Maize P uptake decreased with increase in applied N fertilizer or increase in maize proportions. Maize at 25% proportion decreased its P uptake linearly with increase in N fertilization with very low P concentration at 160 kg N/ha. Maize at 75% proportion decreased its uptake at 80 kg N/ha and then increased at 160 kg N/ha. At 80 kg N/ha 25% bean proportion might have competed seriously for the immobile P being very competitive leading to a drop in 75% maize proportion P uptake. For 75% maize proportion and sole maize, increased uptake at 160 kg N/ha could have been due to increased competitiveness of maize at the high N level.

Again dry weather was a main factor in the response of both beans and maize to applied N fertilizer in 1991 although population pressure under high maize population cropping in 1991 also contributed to the observed effects under the high maize population cropping system. But

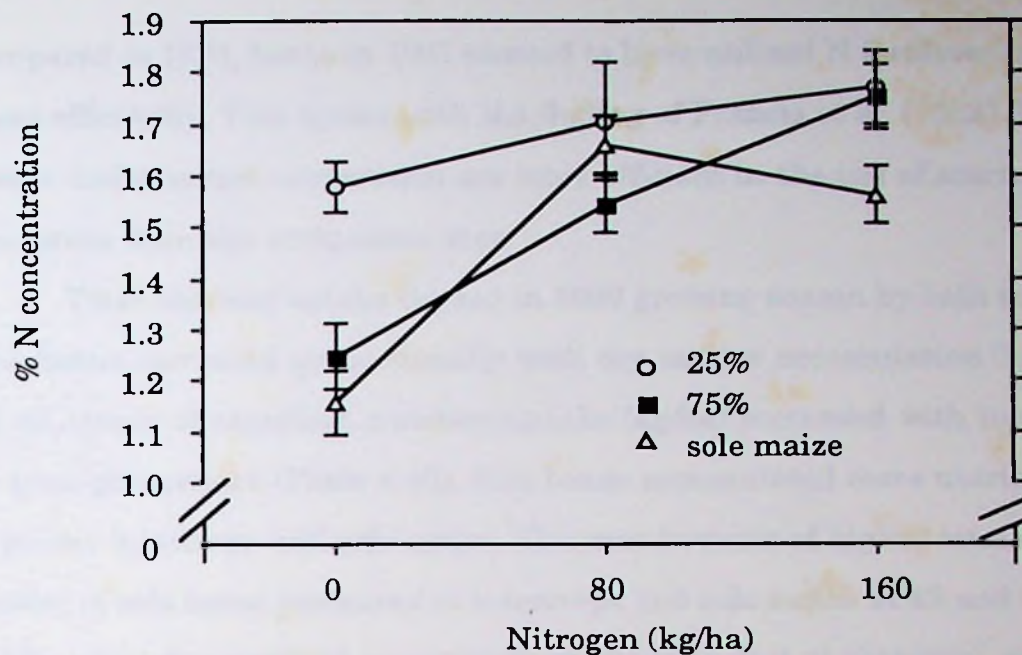


Figure 4.8. The effect of crop proportion x N fertilization interaction on maize N concentration at crop maturity in sole and intercropped systems, 1991 (low maize population cropping).

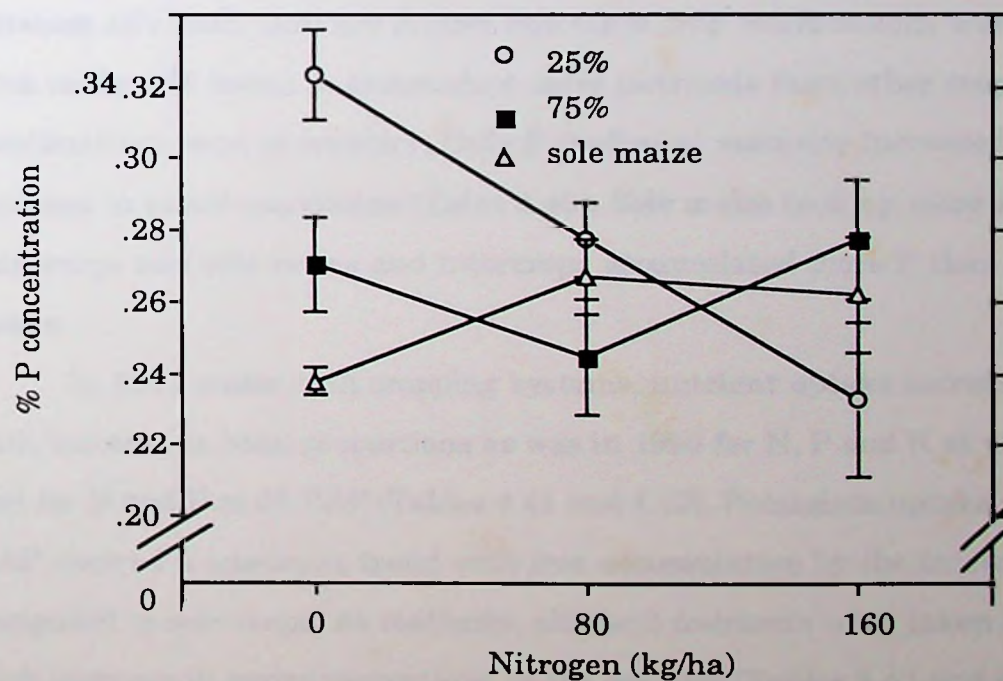


Figure 4.9. The effect of crop proportion x N fertilization interaction on maize P concentration at maturity in sole and intercropped systems, 1991 (low maize population cropping system).

compared to 1990, beans in 1991 seemed to have utilized N fertilizer much more efficiently. This agrees with the finding of Francis et al. (1982) that beans under severe competition are more efficient in the use of scarce resources than the companion crop.

Total nutrient uptake (kg/ha) in 1990 growing season by both maize and beans increased proportionally with dry matter accumulation (kg/ha). At all stages of sampling, nutrient uptake (kg/ha) increased with increase in bean proportions (Table 4.40). Sole beans accumulated more nutrients than the intercrops and sole maize. This was because of higher total dry matter of sole beans compared to intercrops and sole maize at 42 and 63 DAP and higher nutrient concentrations of beans. But at maturity, sole beans accumulated less total dry matter (kg/ha) than intercrops and sole maize but still maintained high nutrient concentration. The difference between sole bean total dry matter and other crop combinations was slight. This made sole beans to accumulate more nutrients than other crop combinations even at maturity. Only P (kg/ha) at maturity increased with increase in maize population (Table 4.40). Sole maize took up more P than intercrops and sole beans and intercrops accumulated more P than sole beans.

In 1991 under both cropping systems, nutrient uptake increased with increase in bean proportions as was in 1990 for N, P and K at 42 DAP and for N and P at 63 DAP (Tables 4.41 and 4.42). Potassium uptake at 63 DAP showed a quadratic trend with less accumulation by the intercrops compared to sole crops. At maturity, all the 3 nutrients were taken more with increase in maize proportions in the systems (Tables 4.41 and 4.42). This was due to very low total dry matter accumulation (kg/ha) by beans reducing its total nutrient uptake in the systems.

Table 4.40. The effect of different crop combinations of beans and maize on nutrient uptake (kg/ha) at 42 and 63 DAP and at maturity, 1990.

a Crop combinations	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
Sole maize	46.9 a	8.8 a	92.4 a	157.8 a	21.9 a	98.9 a	176.3 a	48.3 d	96.1 a
75%M+25%B	66.0 b	9.6 ab	105.8 ab	177.9 a	22.6 a	153.0 b	191.8 a	39.1 bc	152.2 b
50%M+50%B	82.3 c	10.5 b	117.1 b	244.1 b	29.5 b	214.2 c	231.4 b	41.4 c	214.1 c
25%M+75%B	105.7 d	12.4 c	139.2 c	245.7 b	28.8 b	224.5 c	249.6 bc	34.5 ab	245.1 d
Sole beans	128.4 e	14.7 d	167.5 d	305.0 c	34.5 c	271.4 d	262.9 c	29.5 a	249.9 d
^b Stat. sign.									
linear	***	***	***	***	***	***	***	***	***
Quadratic	NS	*	NS	NS	NS	NS	NS	NS	**

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Crop combinations where M is maize and B is beans

^b Statistical significance,

***, **, *, NS significant at 0.1%, 1%, 5% or not significant, respectively.

Table 4.41. The effect of different crop combinations of maize and beans on nutrient uptake (kg/ha) at 42 and 63 DAP and at maturity under low maize population cropping system, 1991.

a Crop combinations	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
Sole maize	47.2 a	7.5 ab	63.4 a	109.0 a	15.3	120.7 ab	141.0	24.7 c	136.9 b
75%M+25%B	50.6 a	6.7 a	67.2 a	95.5 a	13.8	110.4 a	131.3	21.1 b	115.1 ab
25%M+75%B	66.8 b	8.0 b	79.8 b	110.0 ab	13.9	111.1 a	123.0	16.4 a	110.0 a
Sole beans	81.5 c	9.5 c	101.9 c	129.6 b	15.6	136.7 b	128.4	15.1 a	110.9 a
b Stat. sign.									
linear	***	***	***	*	NS	NS	NS	***	*
quadratic	*	***	*	*	NS	*	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Crop combinations where M is maize and B is beans.

b Statistical significance,

***, *, NS significant at 0.1%, 5% or not significant, respectively.

Table 4.42. The effect of different crop combinations of maize and beans on nutrient uptake (kg/ha) at 42 and 63 DAP and at maturity under high maize population cropping system, 1991.

a Crop combinations	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
Sole maize	61.5 a	9.4 bc	86.9 a	115.5 ab	18.4 b	150.9 b	164.1 b	28.2 c	161.2 c
75%M+25%B	58.9 a	8.3 a	79.8 a	109.5 a	16.6 ab	133.5 ab	143.2 a	22.8 b	137.6 b
50%M+50%B	64.8 ab	8.5 ab	84.7 a	115.1 ab	16.1 ab	130.7 a	132.0 a	21.1 b	122.0 ab
25%M+75%B	72.3 b	9.2 abc	90.6 a	116.2 ab	15.7 a	124.0 a	129.3 a	20.3 b	110.8 a
Sole beans	81.5 c	9.5 c	101.9 b	129.6 b	15.6 a	136.7 ab	128.4 a	15.1 a	110.9 a
b Stat. sign.									
linear	***	NS	**	*	*	NS	***	***	***
quadratic	*	*	*	NS	NS	*	NS	NS	NS
cubic	NS	NS	NS	NS	NS	NS	NS	*	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Crop combinations where M is maize and B is beans.

^b Statistical significance,

***, **, *, NS significant at 0.1%, 1%, 5% or not significant, respectively.

In general, N fertilization increased nutrient accumulation (kg/ha) (linear response) at all stages of sampling (Tables 4.43, 4.44 and 4.45). There was more nutrient accumulation in 1990 compared to 1991 growing seasons. N fertilization had no significant effect on P uptake at maturity in 1990 and at 63 DAP in 1991 (Tables 4.43, 4.44 and 4.45). Ground cover by beans in the intercrops could have acted as a mulch to retain moisture in the intercrops aiding nutrient use during the dry and warm weather conditions of 1991 as compared to sole crops.

4.6. Light interception by beans and maize as affected by N fertilization and crop proportions in sole and intercropped systems

The percentage light interception by beans and maize depended primarily on how closely the plants were planted in the systems. Figures 4.10 (1990), 4.11 (1991 under low maize population cropping system) and 4.12 (1991 under high maize population cropping system) indicate the percentage light interception by beans at 42 and 63 DAP in 1990 and 42 and 56 DAP in 1991 growing seasons. Obviously, sole beans intercepted a greater proportion of the incoming light than intercropped beans as the intercropped beans were being shaded by maize. Bean response to shading appears to be low compared to other legumes. Most likely the planting arrangement allowed enough light to reach the understorey beans which allowed photosynthesis to proceed well.

Maize showed the same trend as beans at both periods of light measurements in both 1990 (Figure 4.13) and 1991 under low and high maize population cropping systems (Figures 4.14 and 4.15, respectively). Beans both in sole and intercropped systems intercepted much higher

Table 4.43. The effect of nitrogen fertilization on total nutrient uptake (kg/ha) averaged across all crop combinations of maize and beans at 42 and 63 DAP and at maturity, 1990.

Nitrogen (kg/ha)	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
0	71.1 a	10.4 a	110.7 a	187.0 a	23.2 a	167.4 a	199.9 a	35.6	170.7 a
80	87.6 b	11.3 ab	126.8 b	235.0 b	29.5 b	201.6 b	230.6 b	40.4	196.2 b
160	99.0 b	11.9 b	135.6 b	256.2 b	29.7 b	208.2 b	236.8 b	39.7	207.4 b
<u>a Stat. sign.</u>									
linear	**	*	**	***	**	**	***	NS	***
quadratic	NS	NS	NS	NS	NS	*	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance,

***, **, * NS significant at 0.1%, 1%, 5% or not significant, respectively.

Table 4.44. The effect of N fertilization on total nutrient uptake (kg/ha) averaged across all crop combinations of maize and beans at 42 and 63 DAP and at maturity under low maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
0	51.9 a	7.0 a	66.7 a	93.7 a	13.9	106.6 a	101.4 a	17.3 a	97.2 a
80	62.0 ab	7.7 a	77.6 ab	108.7 ab	14.2	118.4 b	131.3 b	18.7 a	112.5 a
160	70.7 b	9.1 b	89.9 b	130.6 b	15.8	134.1 c	160.1 c	22.1 b	145.0 b
^a Stat. sign.	**	**	**	*	NS	**	***	**	***
linear									

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance,

***, **, * NS significant at 0.1%, 1%, 5% or not significant, respectively.

Table 4.45. The effect of N fertilization on total nutrient uptake (kg/ha) averaged across all crop combinations of maize and beans at 42 and 63 DAP and at maturity under high maize population cropping system, 1991.

Nitrogen (kg/ha)	42 DAP			63 DAP			Maturity		
	N	P	K	N	P	K	N	P	K
0	56.9 a	8.0 a	77.1 a	92.7 a	14.9	117.1 a	106.3 a	19.0	102.3 a
80	69.1 b	9.1 ab	89.4 b	118.0 ab	16.1	132.5 ab	138.1 ab	20.7	136.8 ab
160	78.1 b	10.1 b	100.7 c	142.2 b	18.6	157.2 b	175.9 b	24.9	147.6 b
^a Stat. sign. linear	**	**	***	*	NS	*	*	NS	*

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance,

***, **, * , NS significant at 0.1%, 1%, 5% or not significant, respectively.

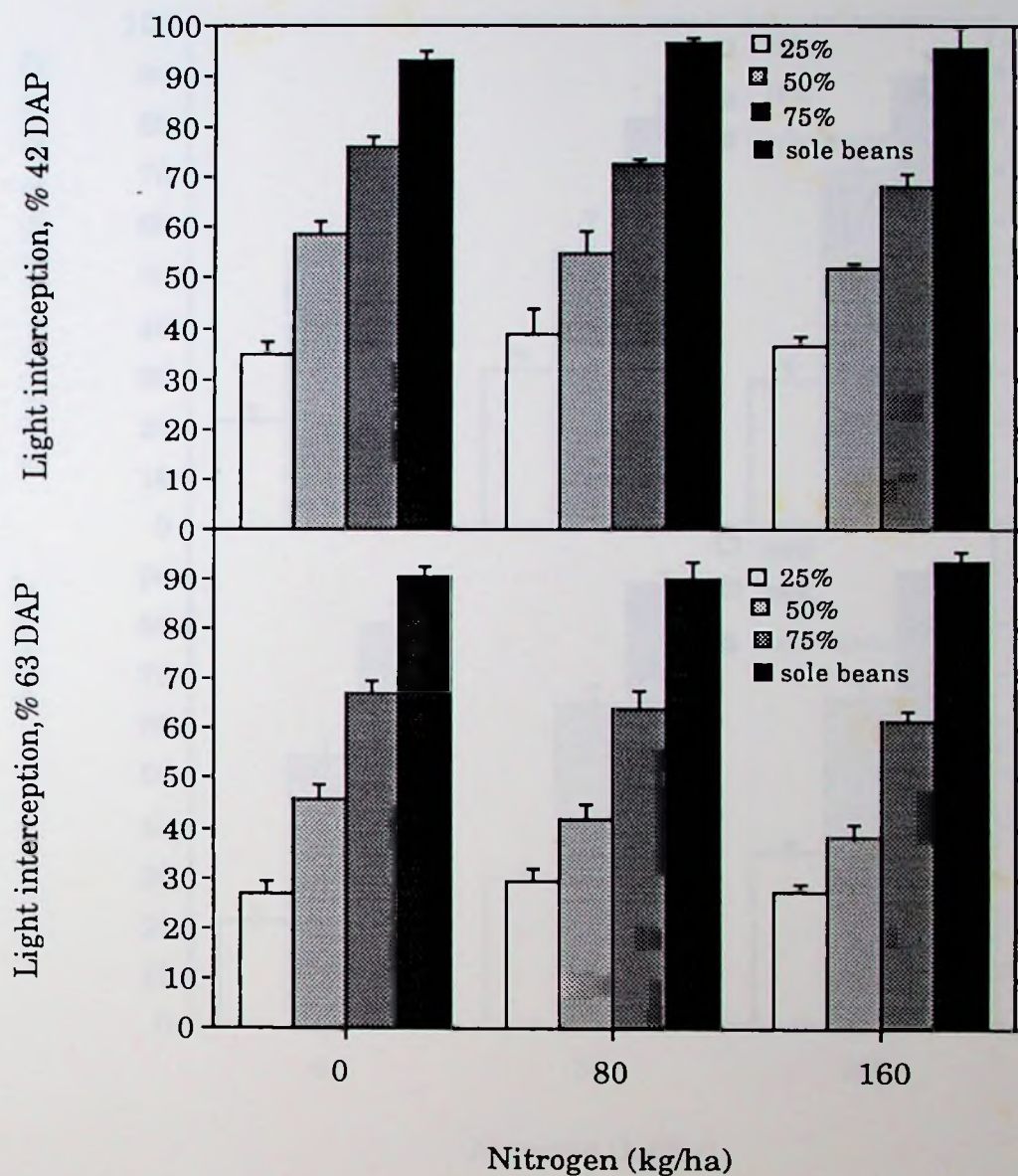


Figure 4.10. The effects of crop proportions and N fertilization on percentage light interception by beans at 42 and 63 DAP in sole and intercropped systems, 1990 (τ Standard error of the means).

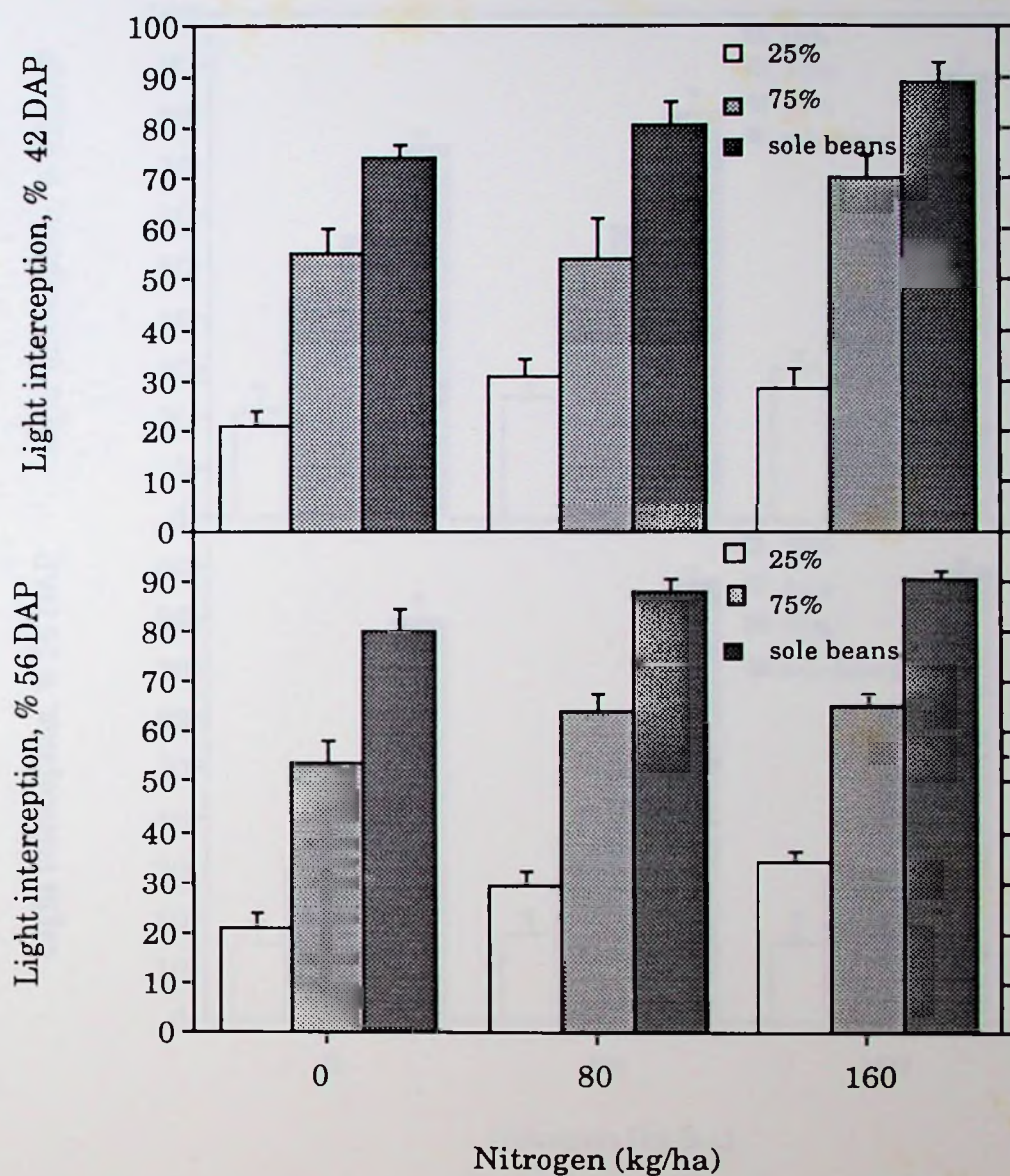


Figure 4.11. The effects of crop proportions and N fertilization on percentage light interception by beans at 42 and 56 DAP in sole and intercropped systems under low maize population cropping, 1991 (T Standard error of the means).

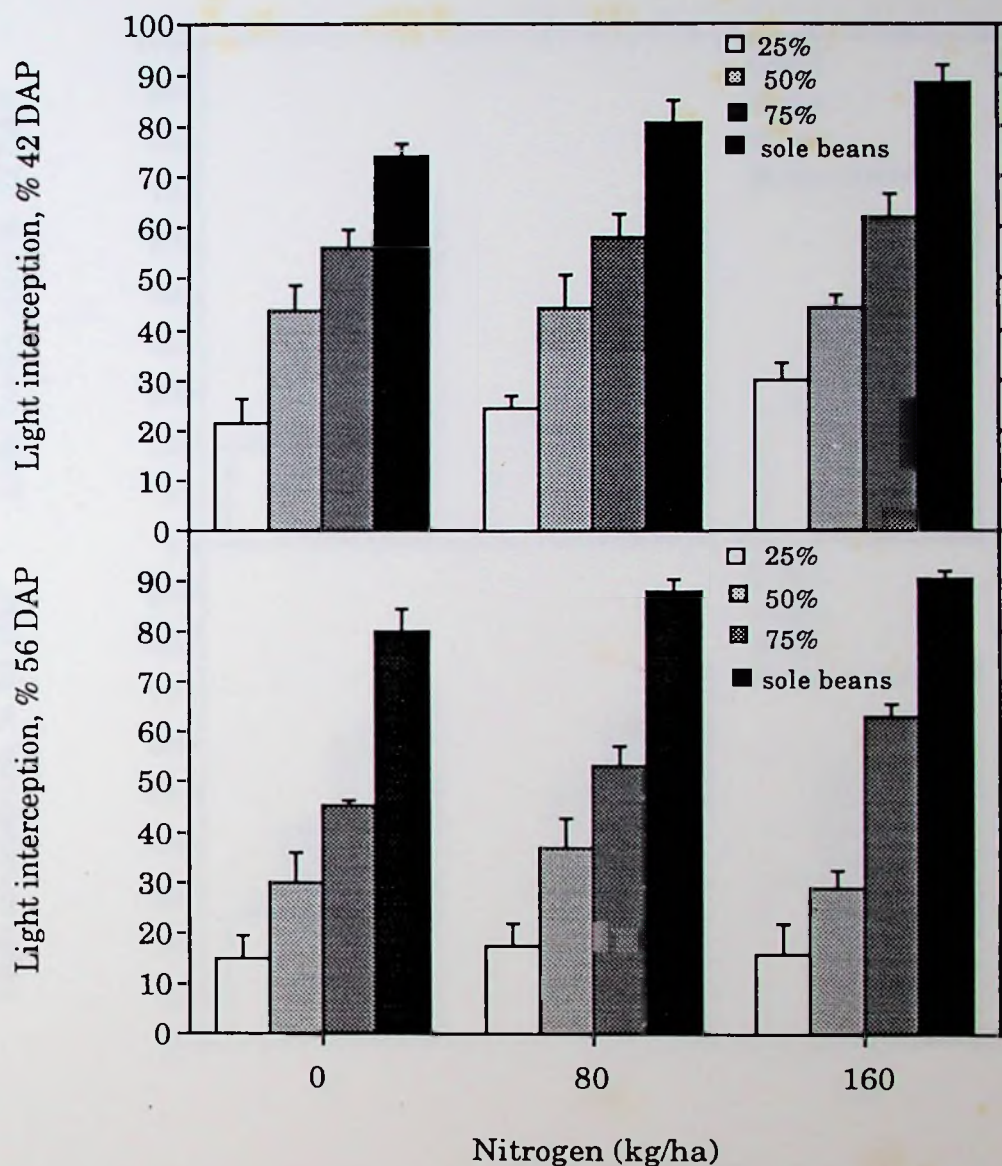


Figure 4.12. The effects of crop proportions and N fertilization on percentage light interception by beans at 42 and 56 DAP in sole and intercropped systems under high maize population cropping, 1991 ($\uparrow$ standard error of the means).

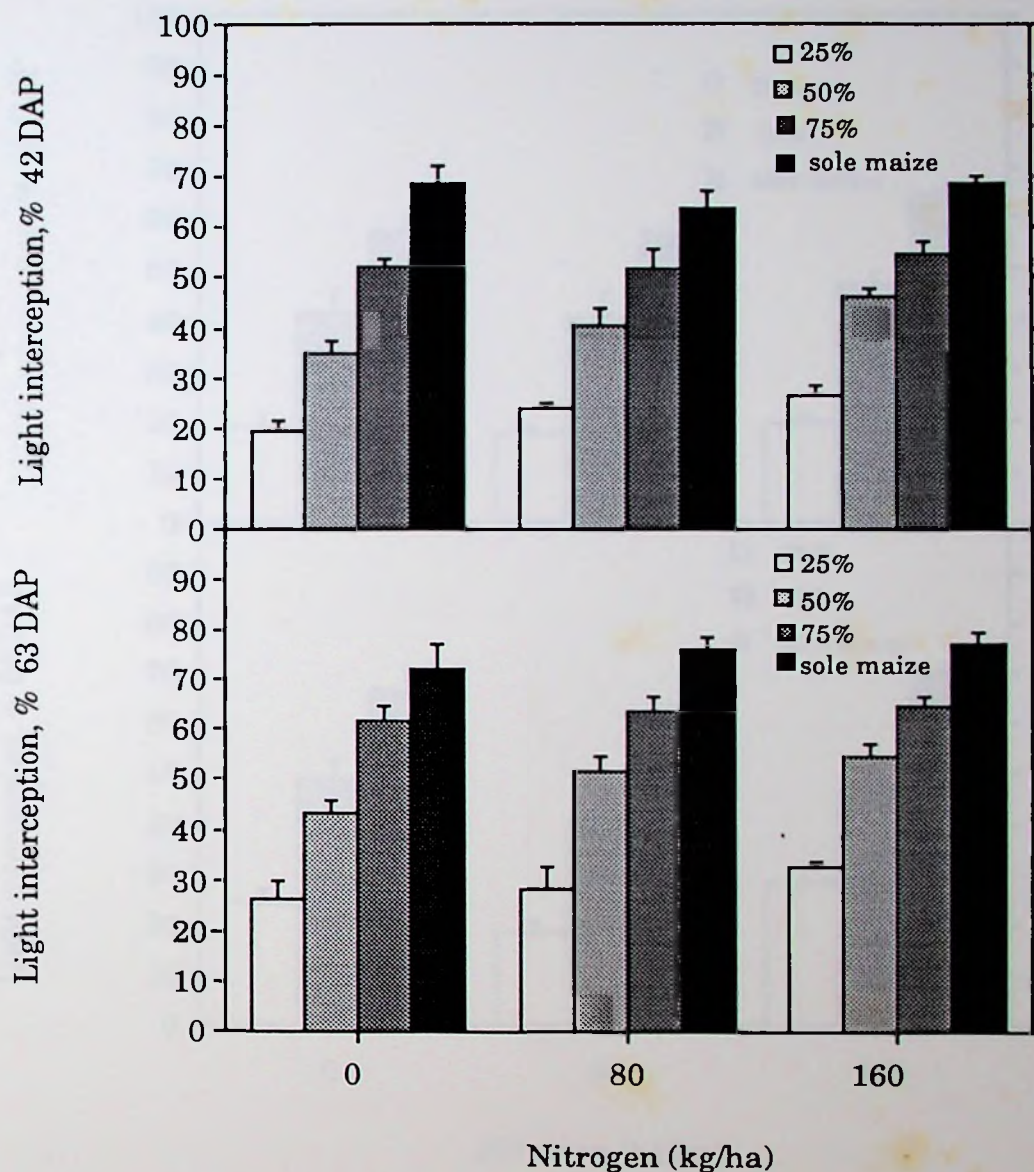


Figure 4.13. The effects of crop proportions and N fertilization on percentage light interception by maize at 42 and 63 DAP in sole and intercropped systems, 1990 († Standard error of the means).

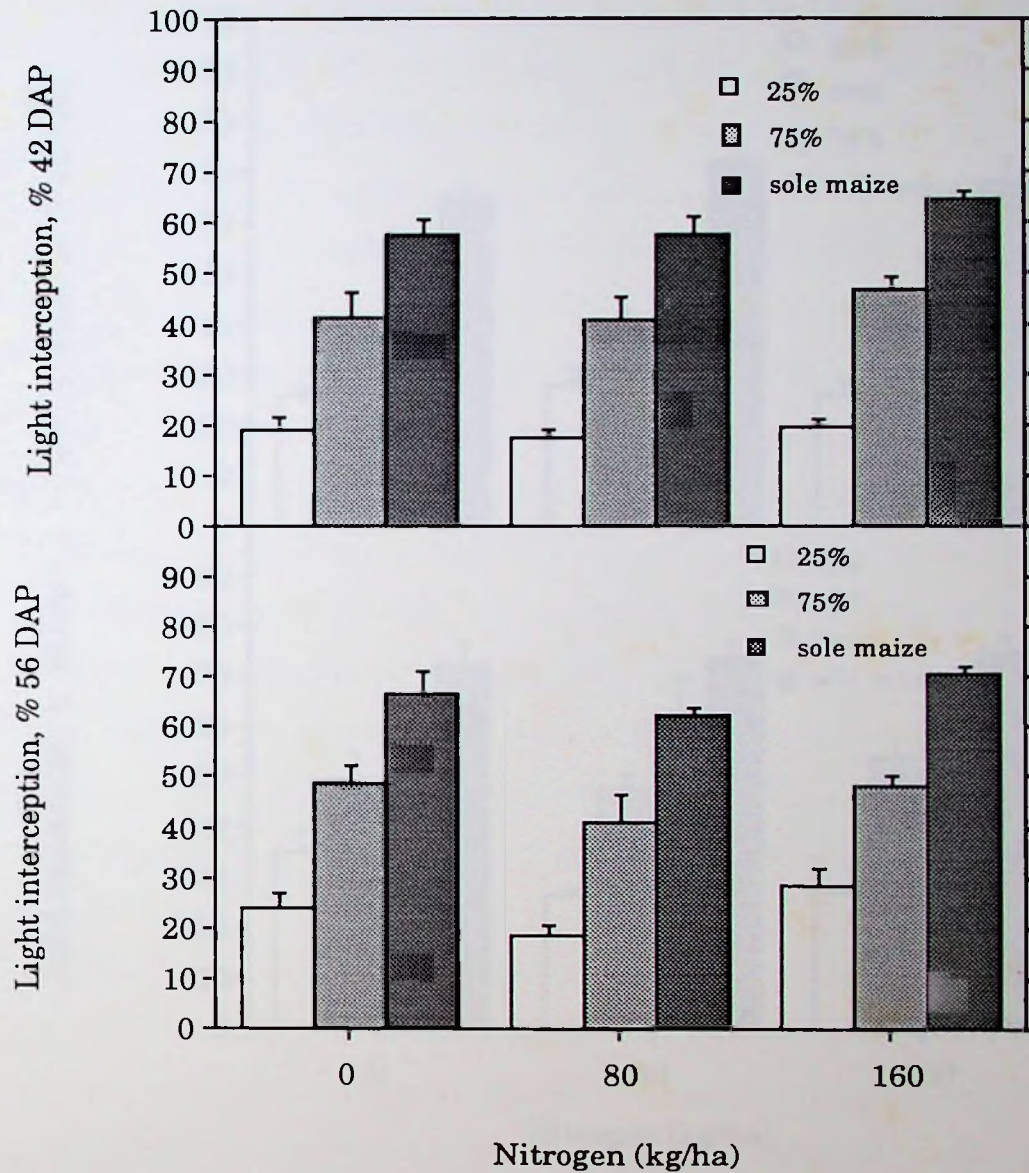


Figure 4.14. The effects of crop proportions and N fertilization on percentage light interception by maize at 42 and 56 DAP in sole and intercropped systems under low maize population cropping, 1991 ($\bar{\text{J}}$ standard error of the means)

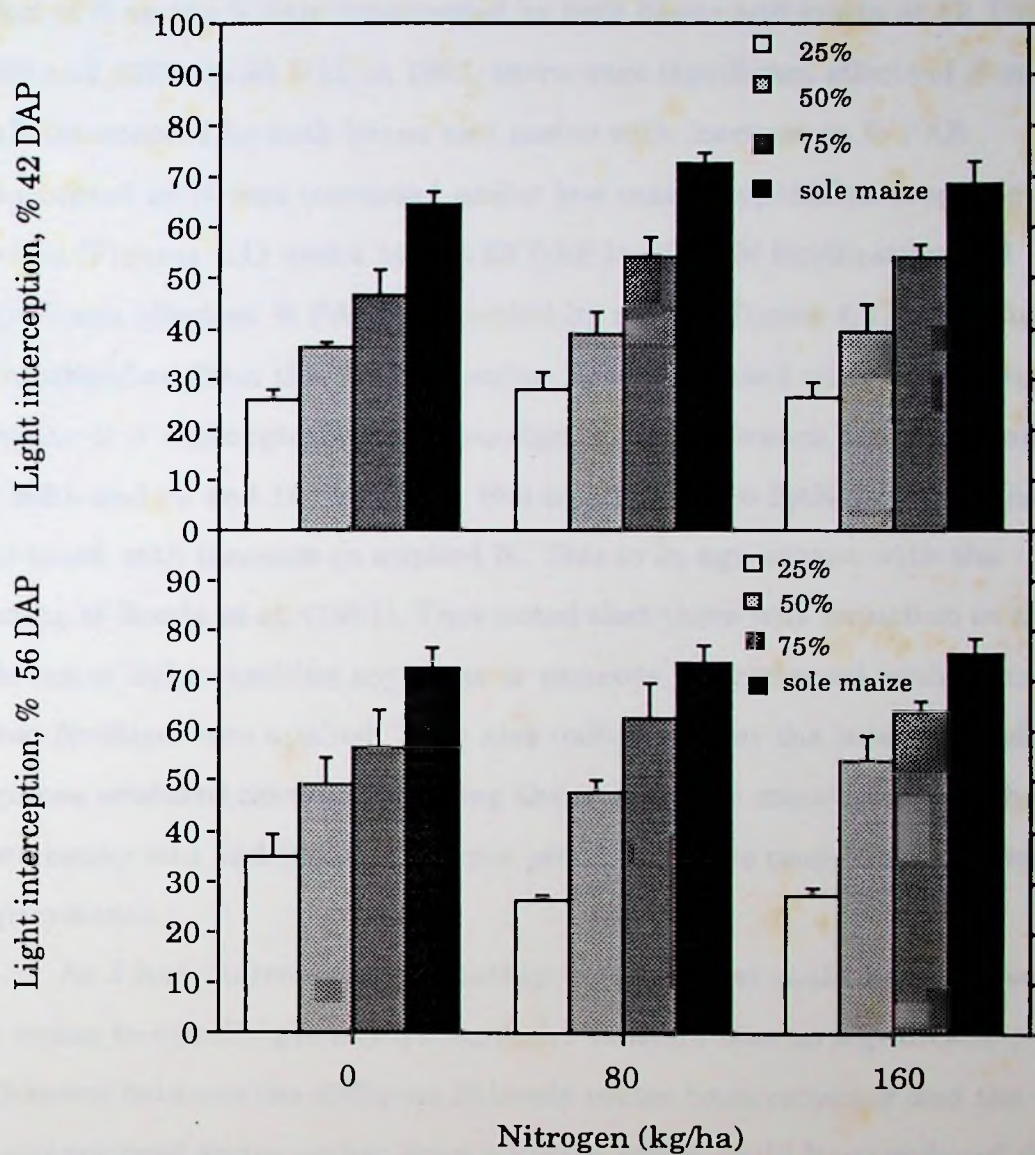


Figure 4.15. The effects of crop proportions and N fertilization on percentage light interception by maize at 42 and 56 DAP in sole and intercropped systems under high maize population cropping, 1991 ($\bar{\text{T}}$ standard error of the means).

proportion of the incoming PAR than maize at the same proportions in both years. From the figures, one would see that there was no significant effect of N on the % light intercepted by both beans and maize at 42 DAP in 1990 and 1991. At 56 DAP in 1991, there were significant effects of N on % PAR intercepted by both beans and maize with increase in % PAR intercepted as N was increased under low maize population cropping system (Figures 4.11 and 4.14). At 63 DAP in 1990, N fertilization had significant effect on % PAR intercepted by maize (Figure 4.13). Amount of light absorbed from the total incoming light increased with increasing amount of N although there was no significant difference between 0 and 80 kg N/ha and 80 and 160 kg N/ha. But in all cases, % PAR seemed to have increased with increase in applied N. This is in agreement with the finding of Searle et al. (1981). They noted that there was reduction in the amount of light reaching soybeans or peanuts intercropped with maize when fertilizer was applied. They also indicated that the intercropped legumes etiolated markedly making them as tall as monocrops but they were heavy and had higher yield per plant than sole crops (additive series experiment).

As I had indicated, the planting arrangement could have allowed for beans to equally get enough sunlight as there was no significant difference between the different N levels under bean cropping and the use of replacement series rather than additive series could have reduced the effect of intercropping on light absorbed by beans. Eriksen and Whitney (1984) showed that bush beans were less affected by shading than cowpeas and soybeans with maximum yield at 70% sun. Therefore, under intercropping with low maize population, we would expect beans to do even better.

Obviously, N improved maize growth but never affected interception of light by beans at 63 DAP in 1990. But the whole idea is that the light which could have been wasted if maize is planted alone gets trapped by beans under the maize leading to proper utilization of the available light for maximum production.

In both growing seasons, total light interception was highly affected by the different crop combinations in the systems. Light was better intercepted as bean proportions increased in the systems. In 1990, intercrops intercepted more light than sole crops at 42 and 63 DAP (Figure 4.16). But at 42 DAP, intercrops involving 50% and 75% beans, although intercepted more light than the rest of the crop combinations, were not significantly different from sole beans. At 63 DAP, all intercrop combinations were not significantly different from sole beans but significantly different from sole maize.

In 1991, under low maize population cropping system, sole beans intercepted more light than the rest of the crop combinations except at 42 (0 and 160 kg N/ha) and 56 DAP (160 kg N/ha) where the intercrop of 25% maize + 75% beans intercepted more light than sole beans or other crop combinations (Figure 4.17). Under high maize population cropping system, intercrops intercepted more light at 0 and 80 kg N/ha (42 DAP) and 160 kg N/ha (56 DAP) although at other N levels, intercrops were not significantly different from sole beans (Figure 4.18). All intercrop combinations were not significantly different from one another and intercrop combinations involving 50% and 75% beans were not significantly different from sole beans.

N fertilization had significant effect on light interception by the different crop combinations in 1990 at 42 DAP, and in 1991 under low

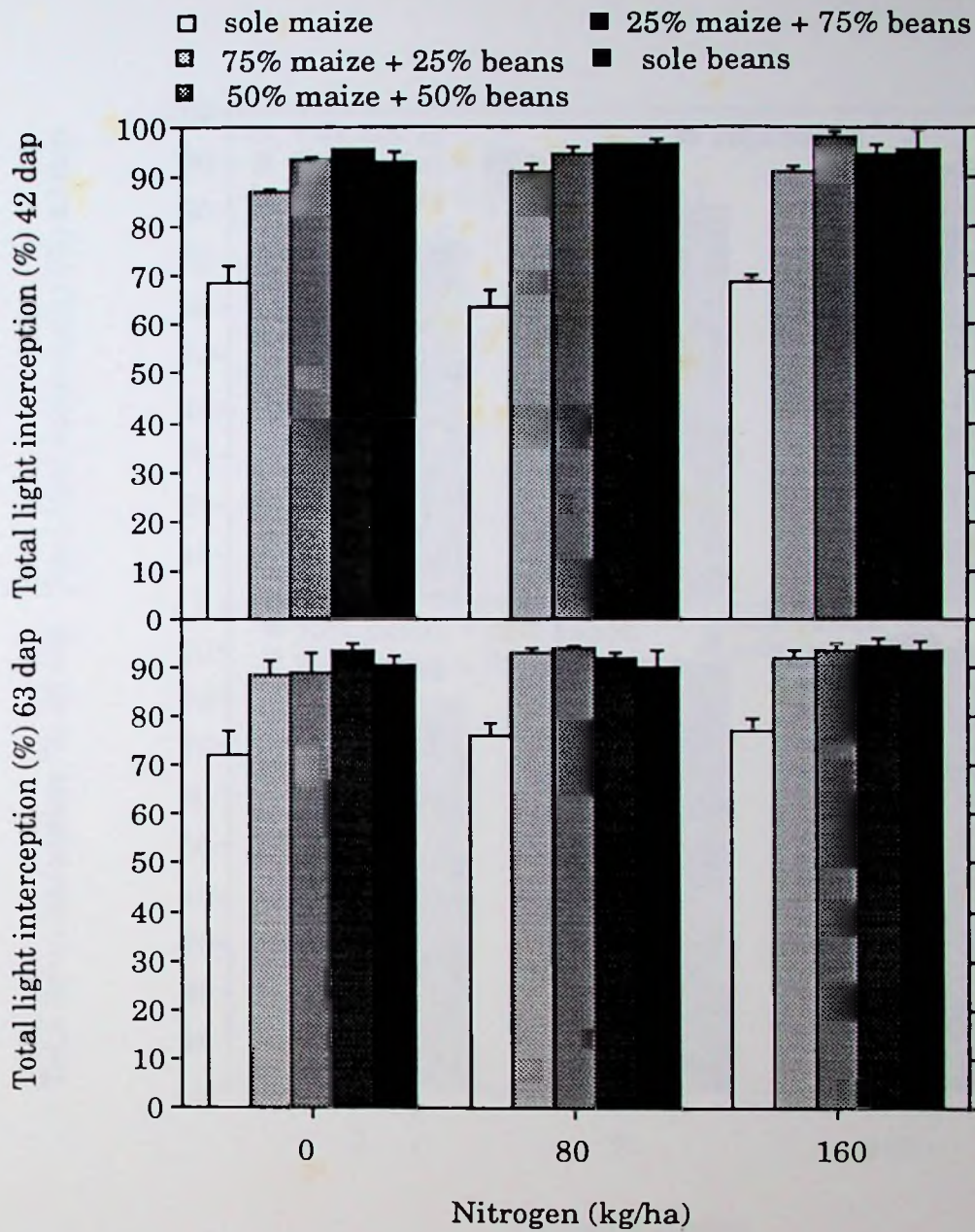


Figure 4.16. The effect of crop combinations of beans and maize on total light interception (% PAR) at 42 and 63 DAP in 1990.

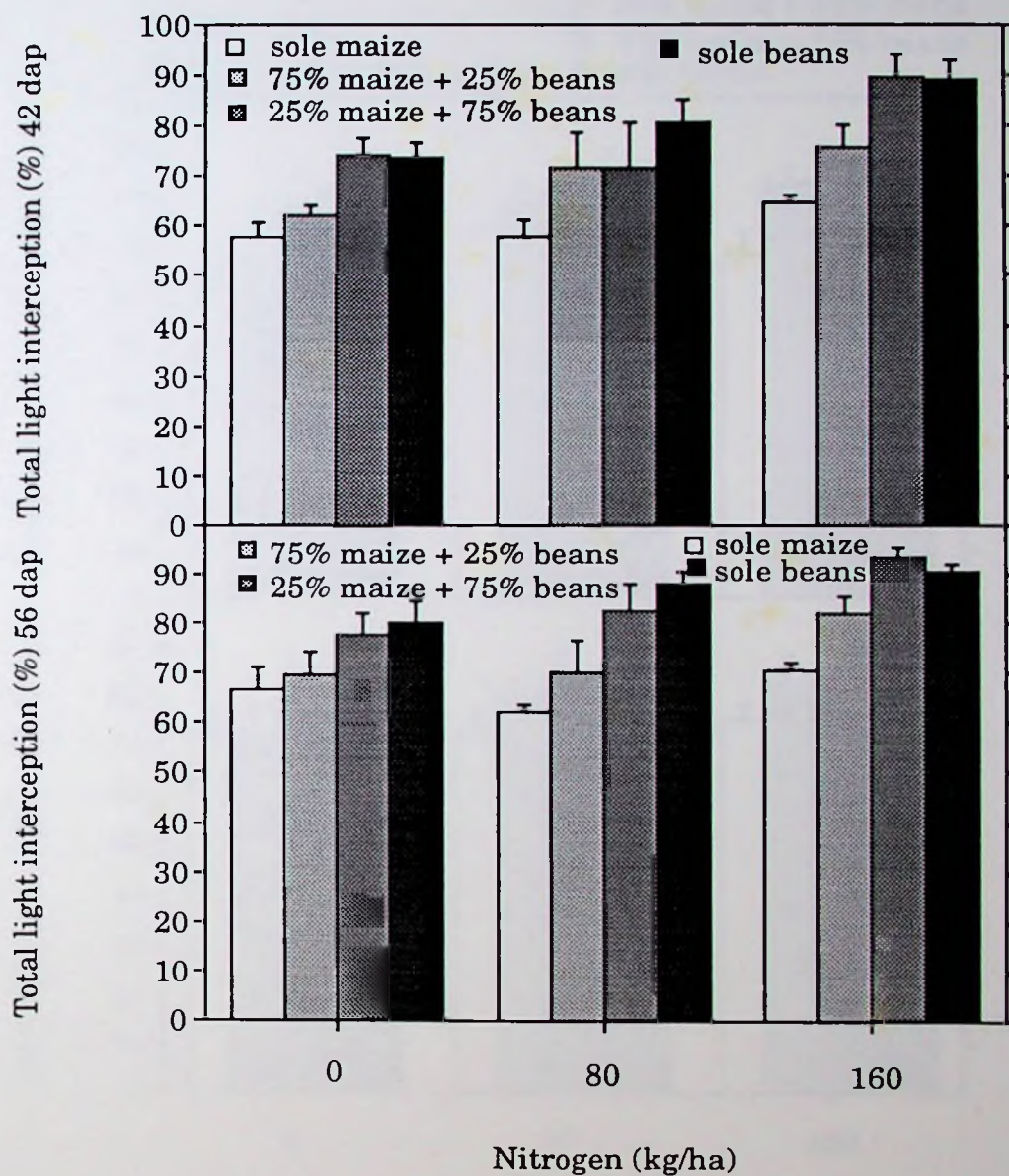


Figure 4.17. The effect of crop combinations of beans and maize on total light interception (% PAR) at 42 and 56 DAP under low maize population cropping system, 1991.

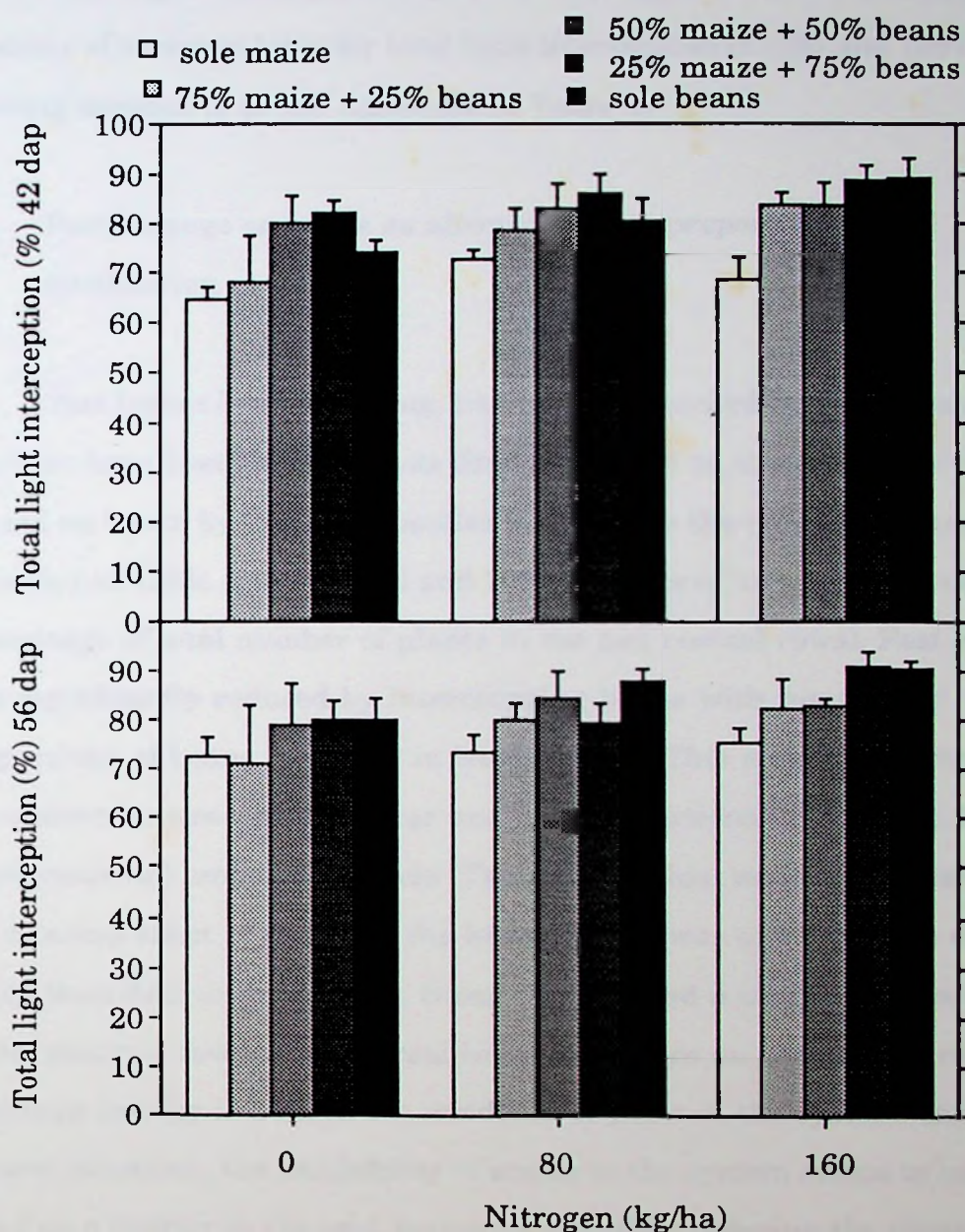


Figure 4.18. The effect of crop combinations of beans and maize on total light interception (% PAR) at 42 and 56 DAP under high maize population cropping system, 1991.

maize population cropping system at 42 and 56 DAP (Figures 4.16 and 4.17). Total light interception improved with application of N fertilizer. Analysis of variance table for total light interception in 1990 and 1991 growing seasons is at the Appendix A: Table 1.

4.7. Pest damage on beans as affected by crop proportions and N fertilization

Just before bean flowering, beans were attacked by Japanese and Mexican bean beetles. There was dramatic effect on the amount of damage caused on beans by these two beetles in regard to the cropping system as indicated in Table 4.46 for 1990 and 1991 (number of infected plants as a percentage of total number of plants in the two central rows). Pest damage was significantly reduced by intercropping beans with maize, with lowest proportions of beans resulting in least damage. This significant linear correlation between pest damage and crop proportions held true in both years under all cropping systems (Table 4.46). This, most likely, was due to the shading effect of maize on the beans. There was more damage on sole beans than intercropped beans. Stoop (1986) noted a similar response of insect pests in cowpea and cereal intercrop where an increase in cowpea intercrop density increased the incidence of pests in the system. In the present situation, the availability of maize in the system seems to have acted as a barrier to the pest movements further reducing the damage in intercrops especially intercropping involving high maize proportions. The results seem to agree with the finding of Wrubel (1984) that Japanese beetles were lower on soybeans in maize/soybean intercrop than on sole

Table 4.46. The effect of bean proportions on the damage caused on beans by Japanese and Mexican bean beetles in sole and intercropped systems, 1990 and 1991 growing seasons.

Bean proportions	<u>% pest damage on beans</u>		
	1990	1991 (A)	1991 (B)
25%	2.4 a	1.2 a	0.9 a
50%	6.2 ab	----	3.4a
75%	9.7 bc	9.1 b	6.6 b
Sole beans	12.9 c	15.8 c	15.0 c

^c Statistical sign.

linear	***	***	***
quadratic	NS	NS	*
cubic	NS	----	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a 1991 under low maize population cropping.

b.1991 under high maize population cropping.

^c Statistical significance

***, *, NS significant at 0.1%, 5% or not significant respectively.

A low maize population cropping

B high maize population cropping

soybeans. He attributed his finding to the fact that shading reduced population of Japanese beetles in soybeans and maize intercrop.

Maize acting as a barrier in the intercrop also agrees with the finding of Hasse and Litsinger (1988) who postulated that in an intercropping situation, maize would prevent insect movements to the intercropped beans so long as the maize crop is not a host to the pest in question. There was even more reduction in pest damage under the high maize population cropping of 1991 (Table 4.46) still confirming the finding that shading might be a more determining factor in the control of these pests in intercropping.

Nitrogen had no significant effect on pest damage on beans although there was more damage in the 80 kg N/ha plots than the 0 and 160 kg N/ha plots in 1990, and a tendency for the damage to increase with reduction in the amount of applied nitrogen under both low and high maize population cropping systems in 1991. This seems not to agree totally with the finding of Auclair (1963), that pest damage would increase with increase in N fertilizer application. But due to the high damage that was being caused by the pests, we had to place traps in the field at various location which could have been responsible for some of the effects seen. Still the effect of crop proportions could not be doubted at this time.

4.8. Tasseling in maize and maturity in beans and maize as affected by N fertilization and crop proportions

Sole maize tasseled and matured much earlier than intercropped maize in both 1990 and 1991 growing seasons under both low and high maize population cropping systems (Table 4.47). There were significant

Table 4.47. The effect of crop proportions on the number of days to tasseling and maturity in maize in sole and intercropped systems in 1990, 1991 under low maize population cropping (A) and 1991 under high maize population cropping (B).

Maize	1990		1991 (A)		1991 (B)	
proportions	tasseling	maturity	tasseling	maturity	tasseling	maturity
25%	55.9 d	107.7 b	52.7 b	92.8 c	53.2 b	91.5 c
50%	54.8 c	106.8 b	--	--	53.3 b	88.5 b
75%	53.8 b	100.8 a	52.9 b	88.3 b	52.6 ab	86.3 a
Sole crop	51.9 a	103.4 a	50.7 a	84.8 a	52.1 a	85.4 a
^a Stat. sig.						
linear	***	***	***	***	***	*
quadratic	*	NS	NS	NS	NS	NS
cubic	NS	NS	--	--	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant respectively.

linear trends for both days to tasseling and maturity in maize in regard to crop proportions (Table 4.47). As maize proportion was reduced in the system, tasseling and maturity were delayed. It seems competition between maize and beans occurs much earlier in the season than intraspecific competition leading to delayed growth, tasseling and maturity in maize as maize proportion is reduced in the systems. Beans showed no significant difference in flowering and maturity regardless of the crop proportions in 1990 and 1991 growing seasons under both low and high maize population cropping systems (results not shown).

Low N delayed tasseling while high N level increased rate of tasseling in maize in 1990 and 1991 under low maize population cropping (Table 4.48). Under the high maize population cropping of 1991, N fertilization had no significant effect on tasseling although the trend was towards delayed tasseling with reduction in N fertilization (Table 4.48). It seems a certain dry matter accumulation was necessary in maize in order to tassel. Intercropping subjected the maize to competition for the available N by beans at early stages of growth, slowing down growth and delaying tasseling and maturity. Also considering the effect of N on maize under low and high maize population cropping systems, the increase in maize population coupled with dry weather of 1991 may have been responsible for the lack of significant effect of N on maize tasseling under the high maize population cropping system. Beans took the advantage of the available N and put on more vegetative growth leading to delayed maturity as indicated in Table 4.48. The higher the amount of N applied, the longer the beans took to mature regardless of the cropping systems.

Table 4.48. The effect of N fertilization on days to tasseling in maize and maturity in beans in sole and intercropped systems in 1990, 1991 under low maize population cropping (A) and 1991 under high maize population cropping (B) systems.

Nitrogen (kg/ha)	1990		1991 (A)		1991 (B)	
	maize tasseling	bean maturity	maize tasseling	bean maturity	maize tasseling	bean maturity
0	55.7 b	80.3 a	53.0 b	71.4 a	53.4	72.3 a
80	53.7 a	83.9 b	52.5 ab	78.3 b	52.9	78.8 b
160	52.9 a	86.5 b	51.4 a	84.2 c	51.9	83.1 c
^a Stat. sig. linear	***	**	*	***	NS	***
quadratic	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, **, *, NS significant at 0.1%, 1%, 5% or not significant respectively.

4.9. The effects of crop proportions and N fertilization on seed yield

There was a highly significant linear response of bean yield per ha to increasing bean proportion in the systems in 1990 and 1991 under both low and high maize population cropping systems as indicated in Table 4.49. This was similar to the finding made by Osiru and Willey (1972), and Willey and Osiru (1972) in a sorghum/bean and maize/bean mixtures in Uganda where crop yields responded linearly to increase in crop population in replacement series experiments.

Maize responded in the same way as beans to increasing crop proportion in the system with low yield at low maize crop proportion as shown in Table 4.49 for 1990 and 1991 under low and high maize population cropping systems. There were significant linear responses of maize yield to increasing maize proportions in the systems in both years. Percentage maize yield increase from one proportion to another also decreased with increasing proportions just as was in beans.

Bean yield per ha was not significantly affected by N fertilization in both years (Table 4.50). This agrees with Chui's finding of 1988 where N had no significant effect on bean monocrop yield per ha in Tanzania. The current result being reported and that of Chui are contradicted by the work of Keya et al., (1982) who reported bean response to 80 kg N/ha in monocrop with yield increase from 2,555 to 3,482 kg/ha at Embu in Kenya although they reported no response of beans to N in Uganda. Soil type, soil nutrient status, weather condition and crop management all seem to be important in determining crop response to applied N. This clearly indicates the lack of response of beans to applied N in terms of yield and also that beans are capable of supplying their own N when need arises with yield equally as

high as plots that may receive N. Despite the fact that they may use available N if supplied, it may not cause any significant change in bean yield or yield may be reduced if weather condition is not favorable as in low maize population cropping system of 1991. There was high variation in yield of beans in 1991 growing season compared to 1990 (coefficient of variations of 57.33 and 57.20 for low and high maize population cropping systems, respectively and 19.35 for 1990). The analysis of variance table is

Table 4.49. The effect of crop proportions on the yield of beans and maize (kg/ha) in sole and intercropped systems in 1990 and 1991 growing seasons.

Crop proportions	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
25%	1004.2	1600.0	413.9	744.6	392.4	1039.6
50%	1603.9	3003.5	--	--	715.6	1585.0
75%	2244.0	3719.4	1074.6	1757.0	1052.0	2036.3
Sole crop	2907.2	5258.3	1486.1	2428.7	1468.1	2601.6
^a Stat. sig.						
linear	***	***	***	***	***	***
quadratic	NS	NS	NS	NS	NS	NS
cubic	NS	**	--	--	NS	NS

1991 (A) intercropping under low maize population (37,037 plants/ha),
1991 (B) intercropping under high maize population (55,000 plants/ha).

^a Statistical significance

***, **, NS significant at 0.1%, 1% or not significant, respectively.

indicated in the Appendix A: Table 2.

Maize, on the other hand, responded linearly to applied N increasing its yield with increase of applied N although there was no significant difference between 80 and 160 kg N/ha in 1990 (Table 4.50).

There was no significant response of maize to applied N in 1991 under both low and high maize population cropping systems. Maybe the area used was fertile enough to the extent that further increase in N never caused any significant increase in yield or the population of maize used in the trial was too low to effectively utilize the available N in 1990 growing season. In the 1991 growing season, the dry weather could have been a

Table 4.50. The effect of N fertilization on beans and maize yields (kg/ha) averaged across sole and intercropped systems in 1990 and 1991 growing seasons.

Nitrogen (kg/ha)	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
0	1860.5	2878.3 a	925.2	1543.3	877.0	1483.6
80	1913.5	3711.7 b	1025.0	1584.2	911.4	1861.4
160	2045.4	3727.9 b	1006.4	1802.9	947.0	2136.3
^a Stat. sig. linear	NS	***	NS	NS	NS	NS
quadratic	NS	*	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant, respectively.

factor in the low response of maize to applied N fertilizer and the high population of maize used might have increased competition to the extent that yield was reduced under high maize population cropping system. There was a lot of variability in the yield of maize in both years as shown by

the analysis of variance table and coefficient of variations (Appendix A: Table 3).

Although competitive abilities of the two crops changed drastically with changes in crop proportions and N fertilization, there was generally less change in yield per ha of intercrops compared to sole crops due to N fertilization and CP as shown in Figures 4.19, 4.20 and 4.21 for 1990 and 1991 under low and high maize population cropping systems, respectively. Beans produced over-yielding (yield above the expected yield if there was no competition between the two crops) at 0 and 80 kg N/ha for all intercropped situations, but at 160 kg N/ha there was over-yielding in beans only when bean proportion was reduced to below 50% bean proportion in 1990 (Figure 4.19). Maize showed slight over-yielding at 25% proportion under no N application. There was over-yielding in maize at 80 kg N/ha for 50% maize proportion, and any maize proportion below 75% at 160 kg N/ha in 1990 (Figure 4.19). From the figure, it can be seen that maize responded to applied N while beans showed no response to the applied N.

In 1991, under the high maize population cropping (Figure 4.21), beans and maize both showed over-yielding at 0 N. The reason for over-yielding of intercropped maize at this low nitrogen level could have been due to the low yield of sole maize making the intercropped maize more advantageous. At 80 kg N/ha, there was over-yielding on the part of maize all through while beans at proportion above 25% showed under-yielding. Maize also showed over-yielding at points below 75% maize proportion and beans showed no over-yielding at all points and under-yielding at points beyond 50% beans at 160 kg N/ha in 1991.

Total yield (combined yield) of both beans and maize together (kg/ha) depended primarily on how much maize was in the system. Combined

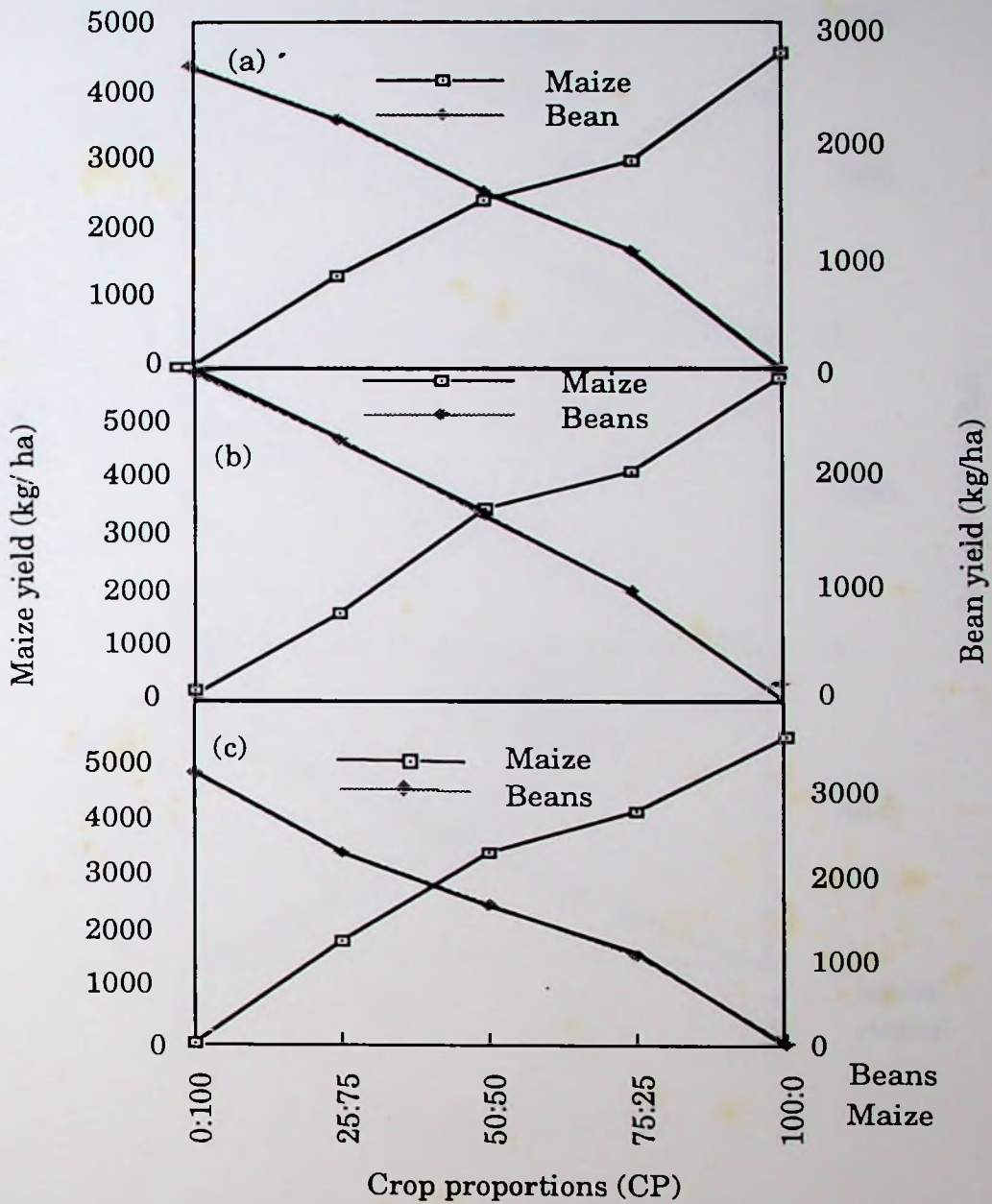


Figure 4.19. Yields of beans and maize (kg/ha) in sole and intercropped systems at (a) 0 N/ha, (b) 80 kg N/ha and (c) 160 kg N/ha in a replacement series, 1990.

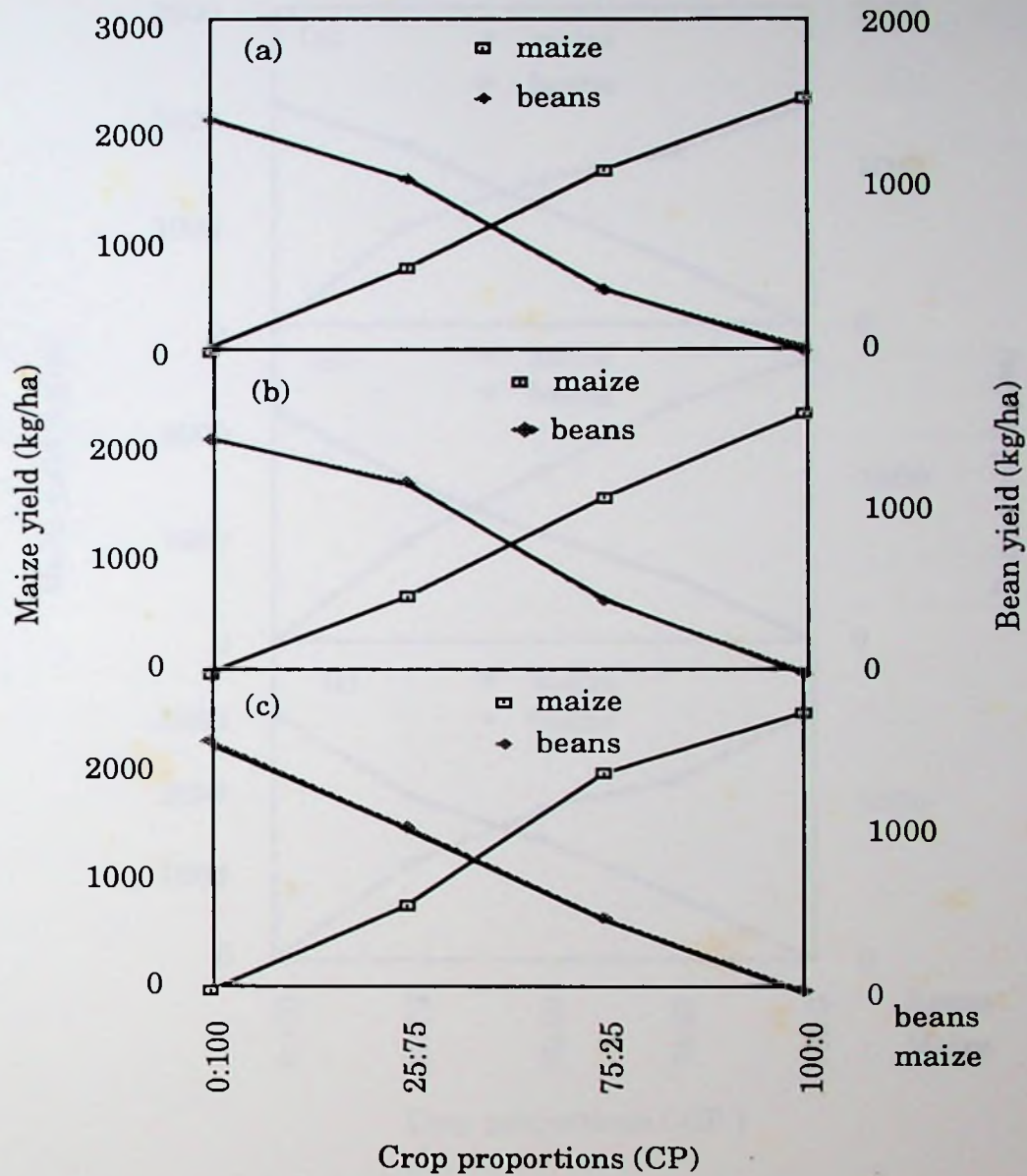


Figure 4.20. Yields of beans and maize (kg/ha) in sole and intercropped systems at (a) 0 kg N/ha, (b) 80 kg N/ha, and (c) 160 kg N/ha under low maize population cropping (37,000 maize plants/ha as sole crop) in a replacement series diagram, 1991.

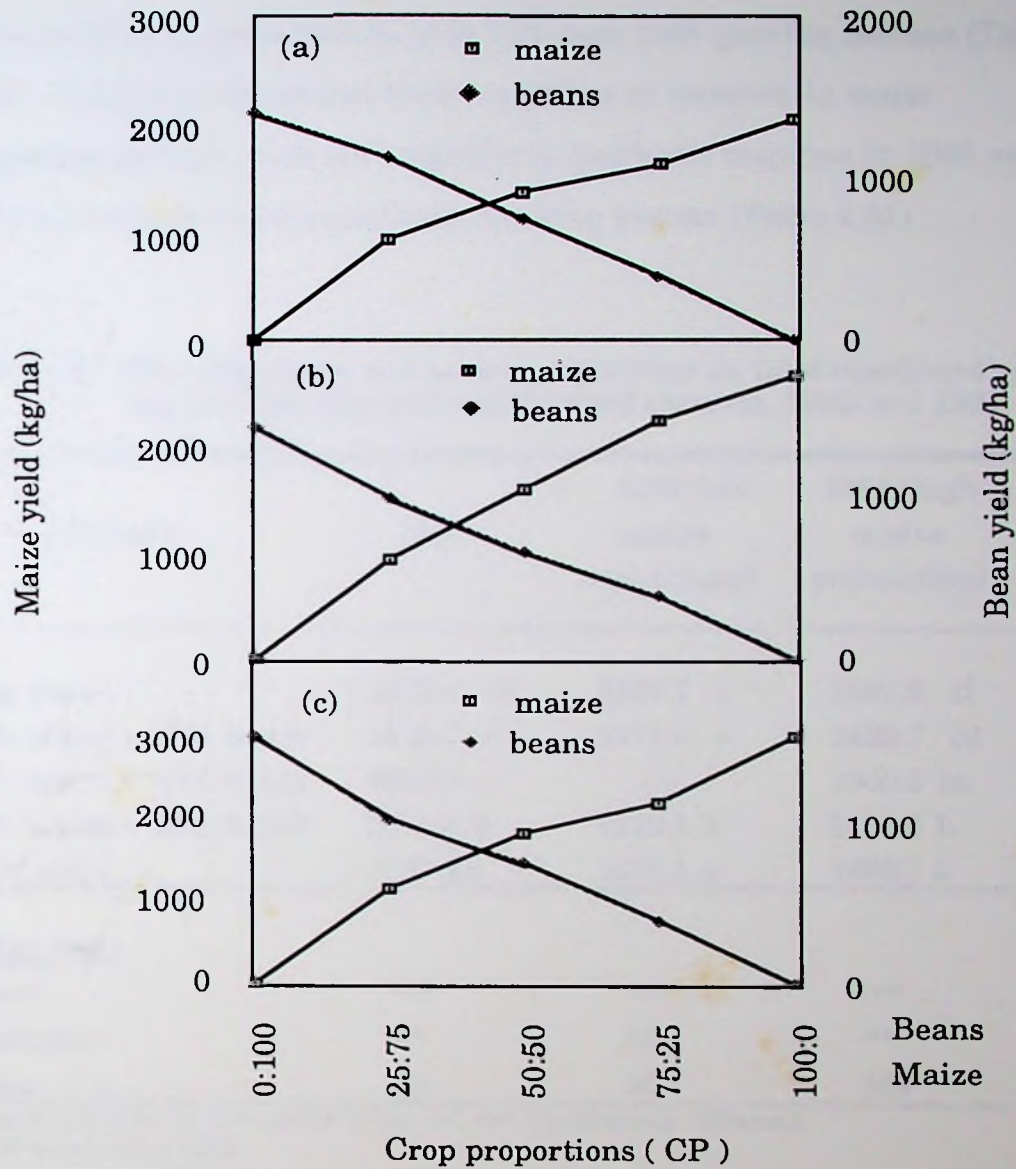


Figure 4.21. Yields of beans and maize (kg/ha) in sole and intercropped systems at (a) 0 kg N/ha, (b) 80 kg N/ha and (c) 160 kg N/ha under high maize population cropping system (55,000 plants/ha as sole maize) in a replacement series diagram, 1991.

yield increased with increase in maize proportion and decreased with increase in bean proportion in both 1990 and 1991 growing seasons (Table 4.51). There was significant linear response to increase in maize proportion in both years and significant quadratic response in 1990 and 1991 under high maize population cropping system (Table 4.51).

Table 4.51. The effect bean and maize proportions on total (combined) yield (kg/ha) both sole and intercropped systems, 1990 and 1991.

Treatments	1990	1991 (low maize population)	1991 (high maize population)
Sole maize	5258.3 d	2428.7 c	2601.6 d
75% maize + 25% beans	4723.7 c	2171.0 c	2428.7 cd
50% maize + 50% beans	4607.3 c	----	2300.6 bc
25% maize + 75% beans	3875.8 b	1819.2 b	2091.6 b
Sole beans	2907.2 a	1476.1 a	1468.1 a
^a Stat. sign.			
linear	***	***	***
quadratic	**	NS	**
cubic	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, **, NS significant at 0.1%, 1% or not significant respectively.

N fertilization significantly increased total (combined) yield (kg/ha) in 1990 and not in 1991 (Table 4.52). Combined yield increased with increase in applied N fertilizer indicating a much better N use in 1990

compared to 1991. There was no significant CP $\times$ N interaction for combined yield (kg/ha) in 1990 but a significant CP $\times$ N in 1991 under high maize population cropping system (Appendix A: Table 4). There was better total yield with more N addition although N had no significant effect under the high maize population cropping system of 1991. Table 4 also indicates low variability in combined yield for 1990 (CV of 23.29), but higher variability for 1991 growing seasons (CV of 27.13 and 34.44 for low and high maize population cropping systems, respectively).

Table 4.52 The effect of N fertilization on combined yield (kg/ha) averaged across sole and intercropped systems of beans and maize in 1990 and 1991 growing seasons.

Nitrogen (kg/ha)	1990	1991 (low maize population)	1991 (high maize population)
0	3791.1 a	1851.4	1916.0
80	4442.0 b	1963.1	2190.8
160	4618.7 b	2106.7	2434.2
^a Stat. sign.			
linear	***	NS	NS
quadratic	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, NS significant at 0.1% or not significant, respectively.

4.10. Competition between beans and maize as affected by crop proportions and N fertilization

The relationships between competitive abilities of maize and beans in intercropped systems are shown in Figures 4.22 and 4.23 for 1990 and 1991 under high maize population cropping systems, respectively. From the figures, it can be clearly seen that for both beans and maize, competitive abilities of the two crops increased with decrease in the crop proportions. This is indicated by reduction in chlorophyll content, (high maize population cropping system) (Table 4.20), and dry matter accumulation with increase in crop proportions (Tables 4.8, 4.9 and 4.10). Therefore, competition was more intense within crops than between the crops. The competition effect caused reduction in yield per plant with increase in crop proportions. Under high maize population cropping system, intercrops accumulated more nutrients than sole crop of maize still confirming less interspecific competition as compared to intraspecific competition. Donald (1963) noted that yield per plant declined with increase in plant density, and intraspecific interference increased with increasing density with reduced yield per plant.

Beans and maize had different responses to N in terms of their competitive abilities. Figures 4.24 and 4.25 illustrate the changes in bean and maize competitive abilities with increasing N levels in 1990 and 1991 (high maize population cropping system) growing seasons. From figures 4.24 and 4.25, increasing N level, at whatever crop proportions used in the system, increased maize's competitive ability while that of beans was decreased with N application. Beans competed less with maize as more N was available. At the same time, maize growth was enhanced by N

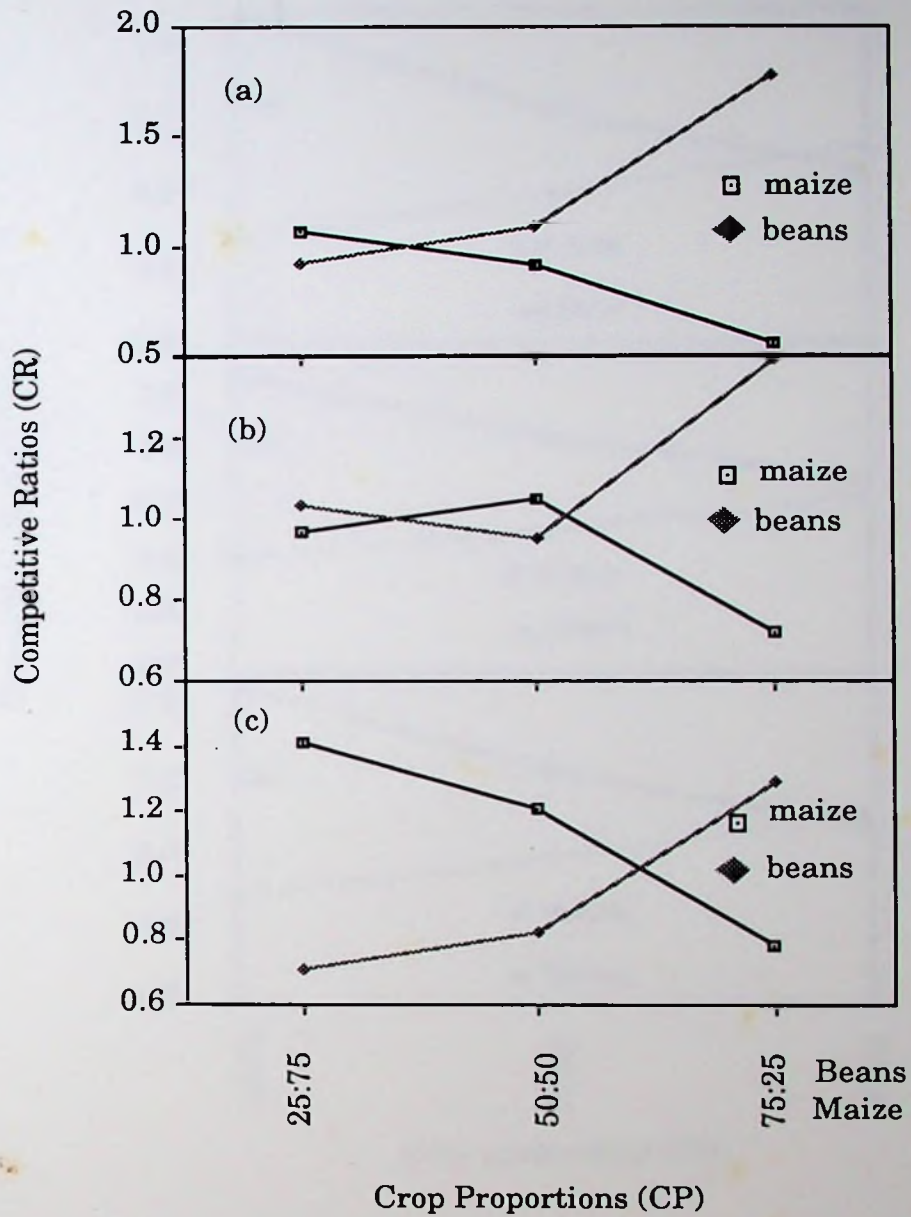


Figure 4.22. Relationships between competitive ratios for yield with change in crop proportions of maize and bean intercropped at (a) 0 nitrogen, (b) 80 kg N/ha, and (c) 160 kg N/ha, 1990.

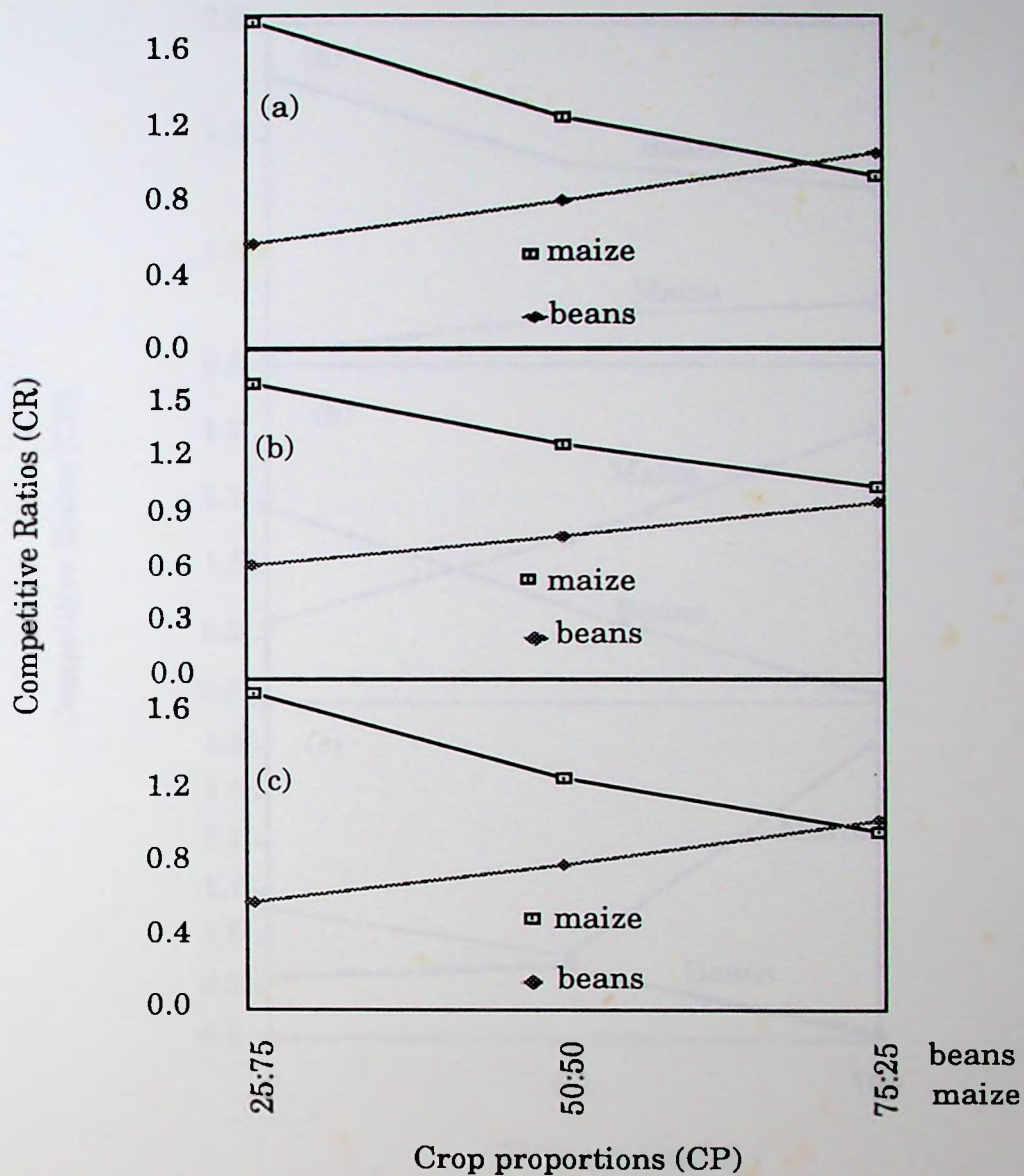


Figure 23. The relationships between competitive ratios for yield with change in crop proportions of bean and maize intercrops at (a) 0 kg N/ha, (b) 80 kg N/ha and, (c) 160 kg N/ha under high maize intercropping (55,000 plants per ha. sole maize), 1991.

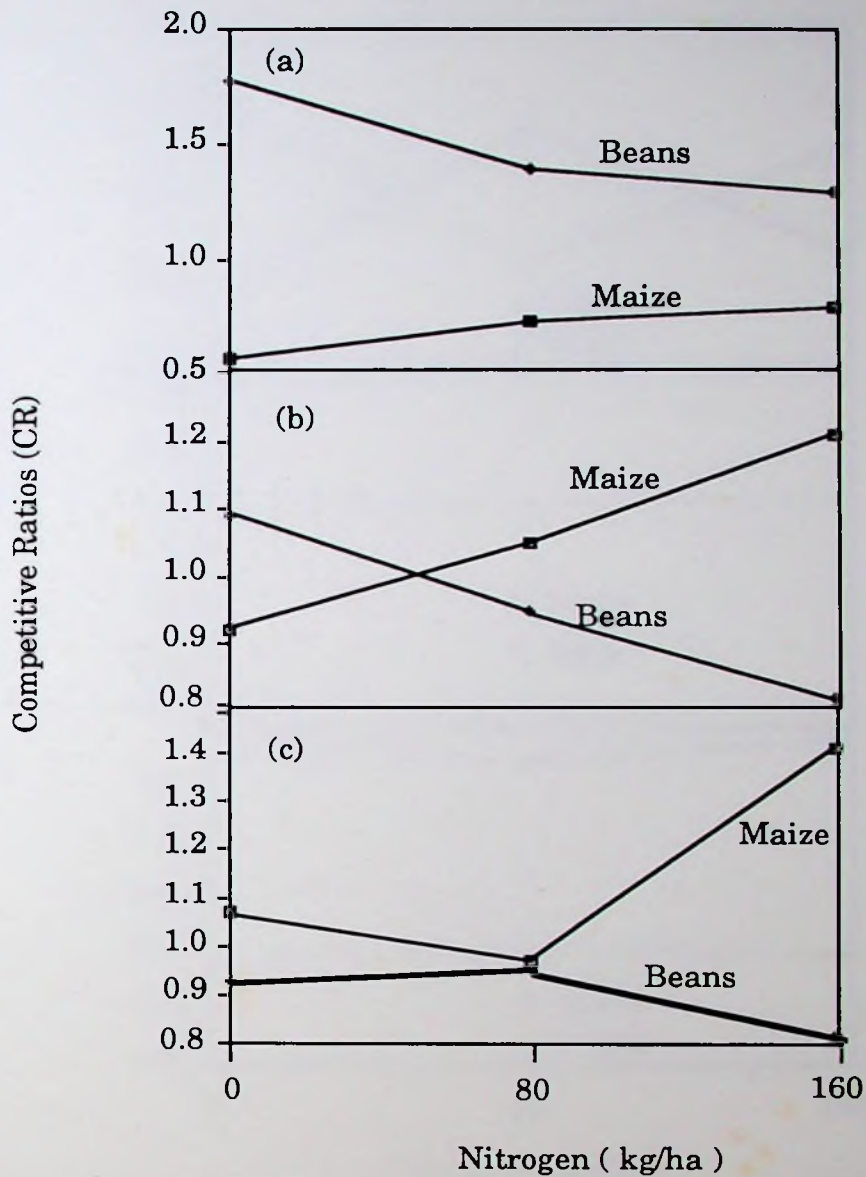


Figure 4.24. Relationships between competitive ratios for yield with change in nitrogen fertilization of intercropped maize and beans at different crop proportions; (a) 75% maize + 25% beans, (b) 50% maize + 50% beans and (c) 25% maize + 75% beans, 1990.

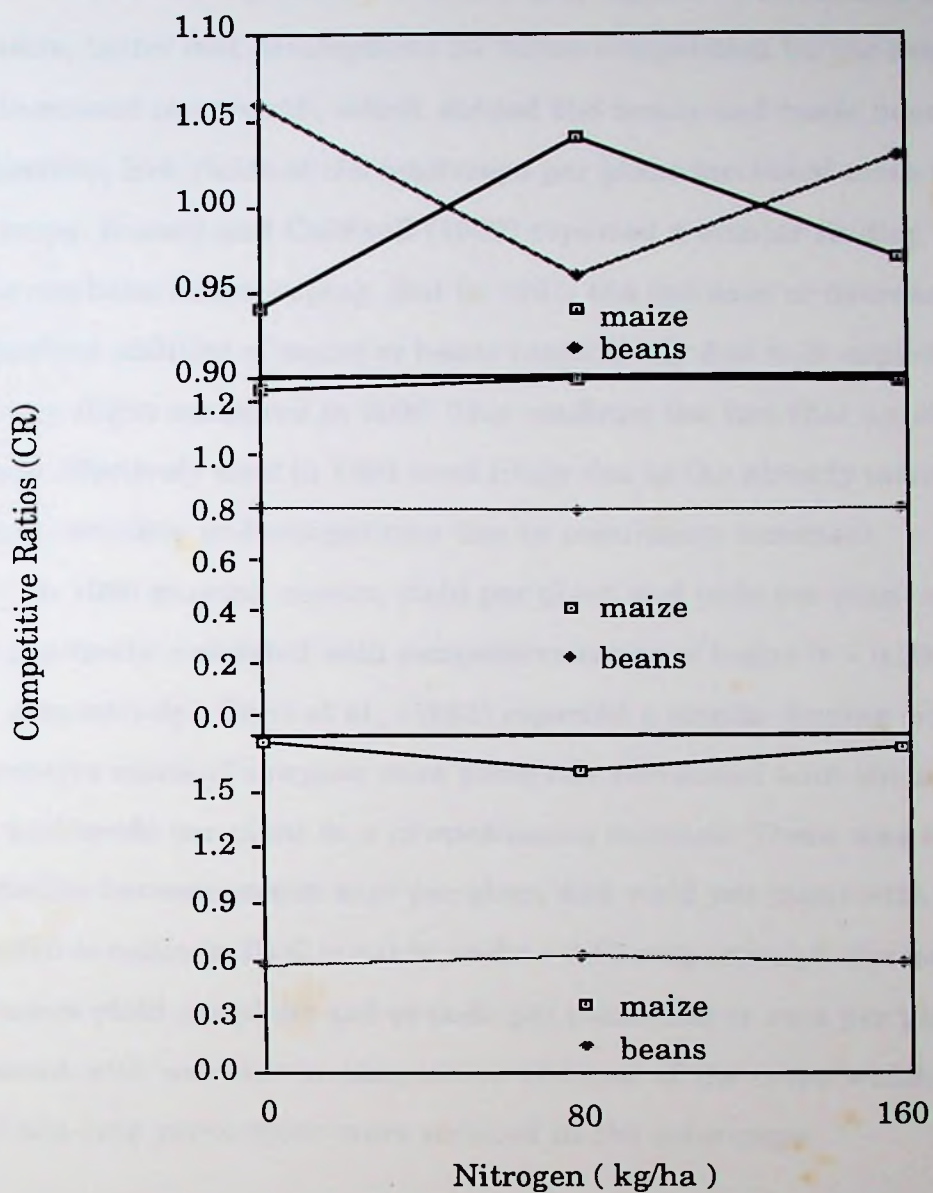


Figure 4.25. Relationships between competitive ratios for yield with change in nitrogen fertilization of intercropped maize beans at different crop proportions; (a) 75% maize + 25% beans, (b) 50% maize + 50% beans, and (c) 25% maize + 75% beans under high maize population cropping system, 1991.

application which might have caused better uptake of nutrients, and therefore, better root development for better competition for the available N and increased top growth, which shaded the beans and made beans less competitive. But yields of the intercrops per plant increased more than the sole crops. Russell and Caldwell (1989) reported a similar finding for maize /soybean intercropping. But in 1991, the increase or decrease in competitive abilities of maize or beans respectively due to N application was very slight compared to 1990. This confirms the fact that applied N was not effectively used in 1991 most likely due to the already mentioned reasons (weather and competition due to population increase).

In 1990 growing season, yield per plant and pods per plant of beans were positively correlated with competitive ratios of beans ($r = 0.99$ and $r = 0.99$ respectively). Faris et al., (1983) reported a similar finding where the competitive ratios of cowpeas were positively correlated with the number of pods and seeds per plant in a cowpea/maize mixture. There was also correlation between maize ears per plant and yield per plant with maize competitive ratios in 1990 ($r = 0.95$ and $r = 0.82$ respectively). For both beans and maize yield per plant and or pods per plant and or ears per plant increased with increase in competitive abilities of the crops which was when the crop proportions were reduced in the intercrops.

4.11. The effects of crop proportions and N fertilization on bean yield components

Crop proportions had significant linear effects on bean seed number per pod in 1991 under both low and high maize population cropping systems and so significant effect on seed weight (200 seed weight) in both

1990 and 1991 (Table 4.53). In 1991 under both low and high maize population cropping systems, the number of bean seeds increased with decrease in bean proportions.

N fertilization had significant linear effects on bean seed weight in 1990 and maize seed weight in 1991 under high maize population cropping system (Table 4.54) and no significant effect on bean seed number per pod. Seed weight increased with increase in applied N fertilizer. Due to poor weather condition of 1991, seed weights were about half the weights attained in 1990 growing season.

Therefore, in 1991 the number of seeds attained determined yield per plant with positive correlation with yield per plant ($r = .81$) under low maize population cropping but a negative one in 1990 ($r = -.98$). Seed weight was high for 50% bean proportion in 1990 which could have been responsible for the high protein content of the 50% bean proportion seeds that year.

The number of bean pods per plant was significantly affected by crop proportions in 1990 (Figure 4.26a). The number of pods per plant increased with decrease in bean proportions. There was no significant crop proportion effect on bean pods per plant under low and high maize population cropping systems in 1991. The number of pods produced determined yield per plant in 1991 under the high maize population cropping system.

There were both linear and quadratic effects of crop proportions on bean yield per plant in 1990 (Figure 4.26b). Yield per plant decreased with increase in bean proportions in the systems. The decrease in yield per plant was much higher from 25% to 50% bean proportions, and thereafter, much less drop in yield per plant with increase in bean proportions in

Table 4.53. The effect of crop proportions on the number of bean seeds per pod, and 200 seed weight of beans and maize in sole and intercropped systems in 1990, 1991 (A) and 1991 (B) under low and high maize population cropping systems.

Crop proportion	Seeds per pod			200 seed weight (gm)					
	1990		1991 (A)		1991 (B)		1990		
	beans	beans	beans	beans	beans	beans	beans	maize	maize
25%	3.9	4.1 b	3.9 b	78.2	49.8	70.6	31.2 b	71.2	31.3 c
50%	4.2	--	3.9 ab	80.2	50.4	--	--	70.6	27.6 b
75%	4.2	3.9 ab	3.9 ab	79.4	48.7	71.6	29.0 a	69.6	26.1 a
Sole crop	4.2	3.7 a	3.7 a	79.4	50.1	67.4	27.8 a	67.4	25.6 a
^a Stat. sig. linear	NS	*	*	NS	NS	NS	**	NS	***
quadratic	NS	NS	NS	NS	NS	NS	NS	NS	**
cubic	NS	--	NS	NS	NS	--	--	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, **, * NS significant at 0.1%, 1%, 5% or not significant, respectively.

Table 4.54. The effect of N fertilization on 200 seed weight (gm) of beans and maize averaged across sole and intercropped systems in 1990, and 1991 under low (A) and high (B) maize population cropping systems.

Nitrogen (kg/ha)	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
0	77.2 a	49.8	69.0	28.8	68.6	25.8 a
80	78.3 a	50.1	68.6	29.4	69.6	28.5 b
160	82.5 b	49.3	72.0	29.7	71.0	28.7 b
^a stat. sig.						
linear	***	NS	NS	NS	NS	*
quadratic	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant respectively.

1990. In 1991 growing season, there was no significant effect of crop proportions on yield per plant but still 25% bean proportion produced higher yield than the rest of the proportions. Our finding seems to relate to that of Osiru and Willey (1972) and Willey and Osiru (1972). They found that yield per plant of beans in a replacement series increased with decrease in bean proportion in the intercrop. There were positive correlations between number of pods per plant and yield per plant in 1990 and 1991 under low maize population cropping with $r = .99$ and $r = .88$ respectively. There was a negative correlation under high maize population cropping ($r = -.31$). It would seem that 25% bean proportion

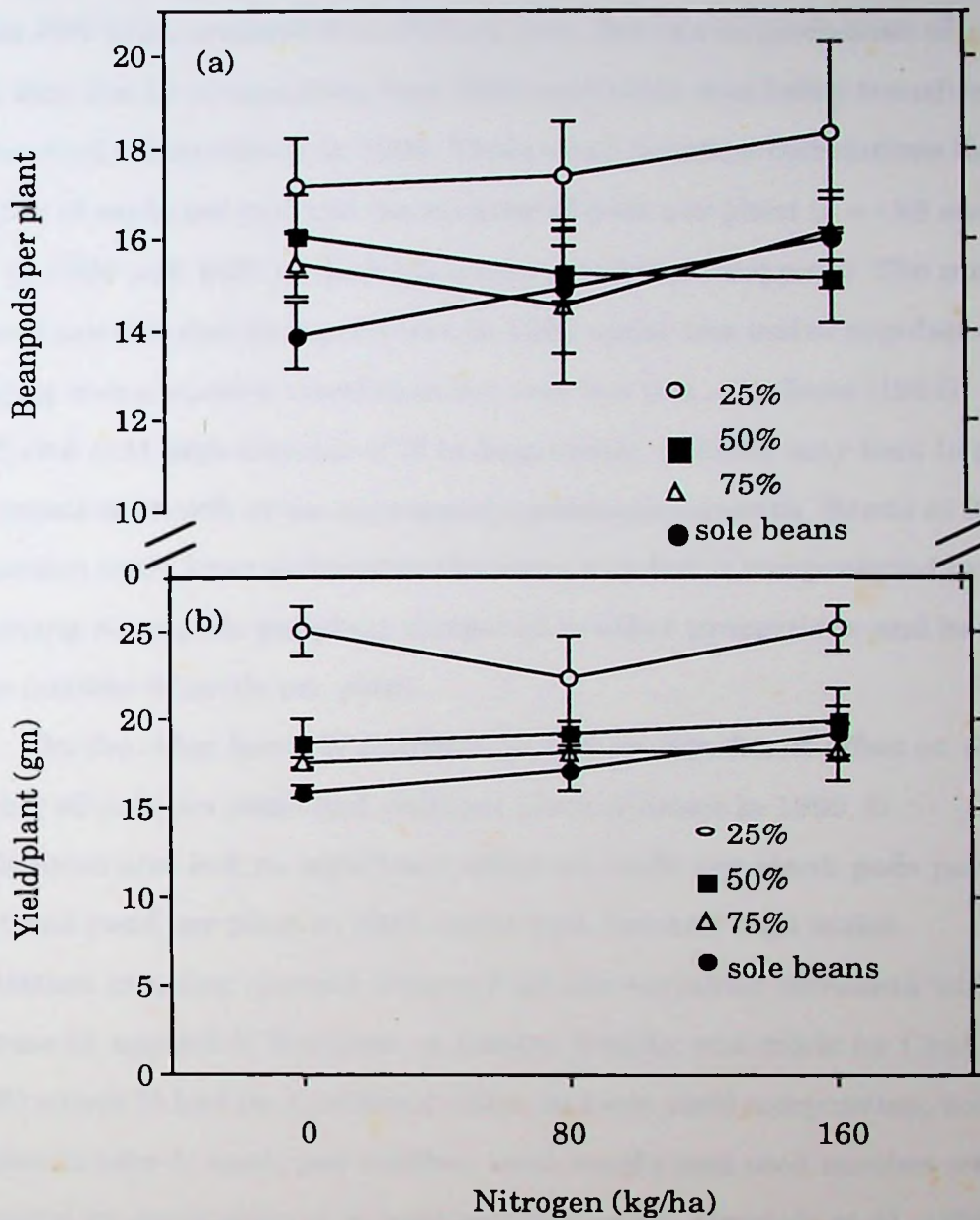


Figure 4.26. The effects of crop proportions and N fertilization on (a) the number of pods per plant and, (b) yield per plant of beans in sole and intercropped systems, 1990 (τ standard error of the means).

although producing light seeds managed to attain high yield per plant because of its high number of pods per plant. The production of light seeds by the 25% bean proportion could have been due to overproduction of pods such that due to competition, very little assimilate was being transferred for proper seed maintenance in 1990. There were negative correlations for number of seeds per pod and the number of pods per plant ($r = -.98$ and $r = -.94$ in 1990 and 1991 under high maize population cropping). The number of seeds per pod and pods per plant in 1991 under low maize population cropping was a positive correlation but very low ($r = .44$). Saito (1982) concluded that high amount of N in bean/maize mixture may lead to a lot of vegetative growth at the expense of reproductive growth. Beans at 25% proportion could have suffered in the same way but it compensated by producing more pods per plant compared to other proportions and had the same number of seeds per plant.

On the other hand, N fertilization had no significant effect on the number of pods per plant and yield per plant of beans in 1990. N fertilization also had no significant effect on seeds per plant, pods per plant and yield per plant in 1991 under both low and high maize population cropping systems although all the variables increased with increase in applied N fertilizer. A similar finding was made by Chui, (1988) where N had no significant effect on bean yield components, but relative to zero N level, pod number, seed weight and seed number were improved by application of N (replacement series). Graciela et al., (1981) noted that N fertilization might not have significant effect on bean yield components or seed yield if stress occurred at a critical stage of bean growth. Observation in our trial in 1991 indicated that dry weather started

a few weeks after planting which was more emphasized at bean flowering stage leading to lack of proper N use by beans.

Appendix A: Table 5 indicates the analysis of variance table (ANOVA) for bean yield per plant as affected by N fertilization and crop proportions for both years. There was high variation in 1991 growing season compared to 1990.

4.12. The effects of crop proportions and N fertilization on maize yield components

Crop proportion had no significant effect on seed weight in 1990 but significant effect in 1991 under both low and high maize population cropping systems (Table 4.53). Maize seed weight increased with decrease in maize proportions with intercropped maize producing much heavier seeds. This may be indicating better resource use by intercropped maize compared to sole maize. There were also significant linear effects of maize proportions on the number of ears per plant in 1990 (Figure 4.27a) and ears per plant and yield plant in 1991 under both low and high maize population cropping systems (Figures 4.28a and 4.29a). The number of ears decreased with increasing maize proportions, and the lowest was at 75% maize proportion in 1990 and the same trend was true for maize in 1991 growing seasons. No significant differences between 25% and 50% maize proportions and 75% maize proportion and sole maize in 1990. For all the measured variables in 1991, maize yield components increased with decrease in crop proportions under low and high maize population cropping systems. High positive correlations existed between ears per plant and yield per plant ($r = .97$) in 1990 and in 1991 $r = .99$ both under

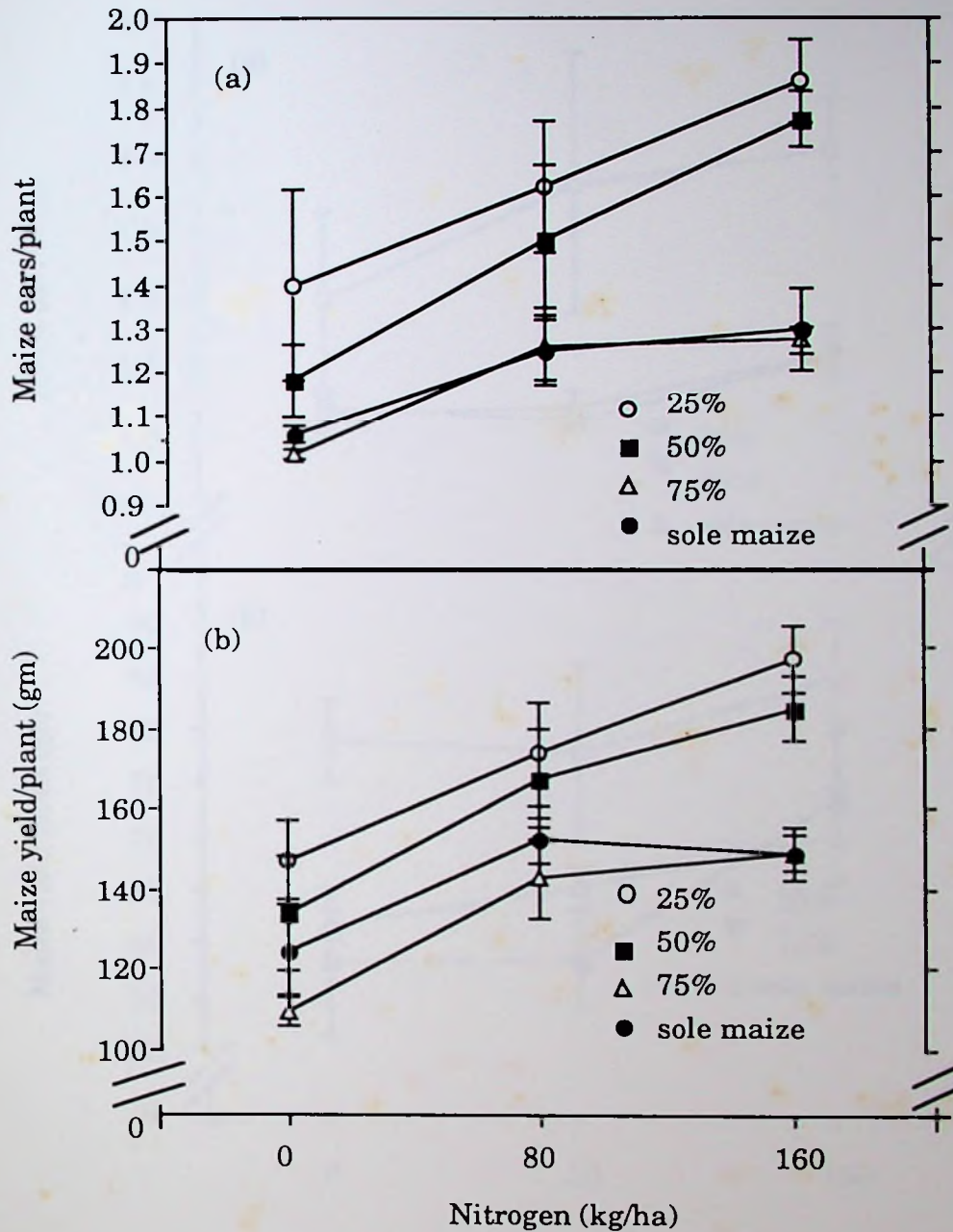


Figure 4.27. The effects of crop proportions and N fertilization on (a) number of ears per plant, and (b) maize yield per plant in sole and intercropped systems, 1990 ($\bar{x}$ standard error of the means).

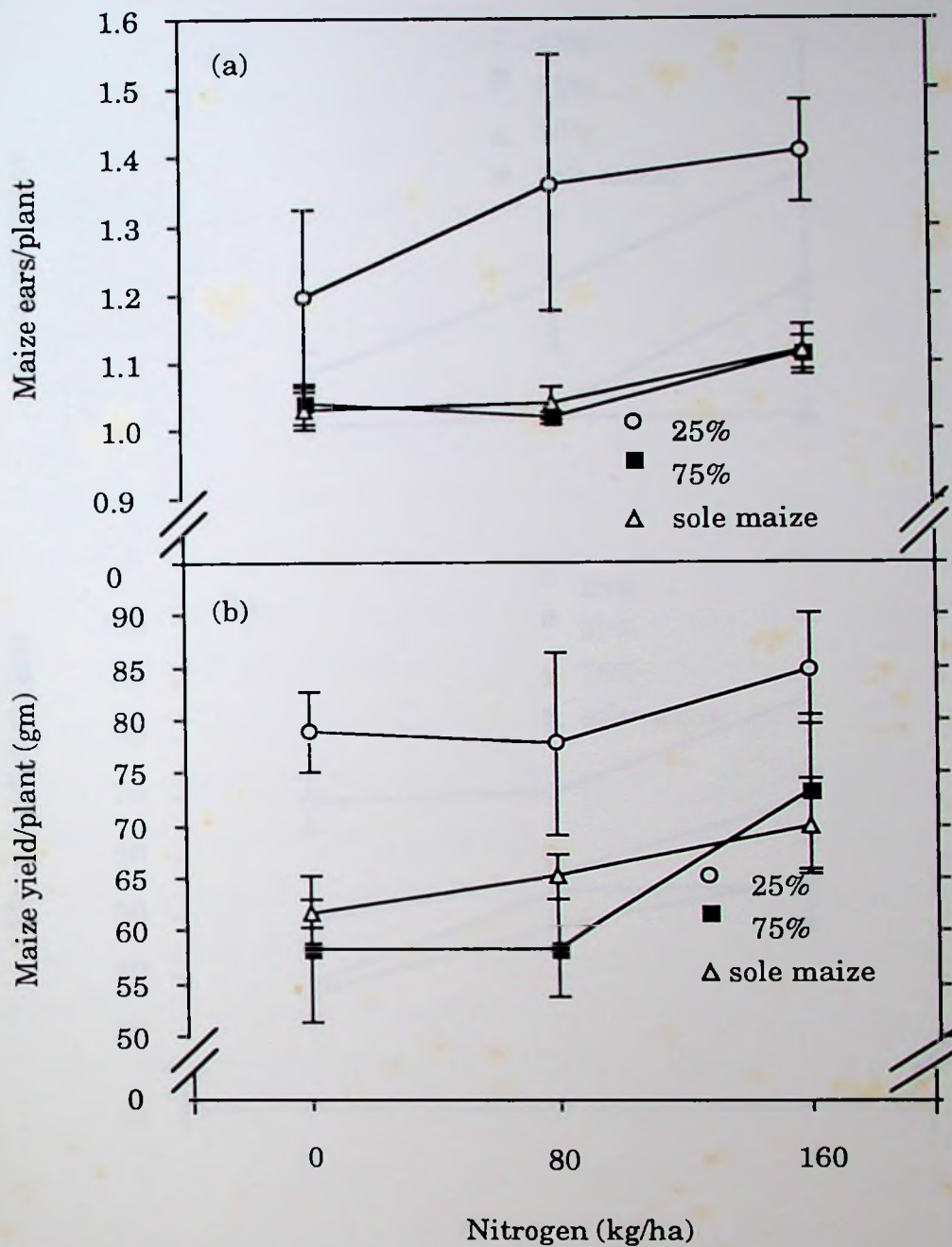


Figure 4.28. The effects of crop proportions and N fertilization on (a) maize ears per plant, and (b) maize yield per plant in sole and intercropped systems under low maize population cropping system, 1991 (standard error of the means).

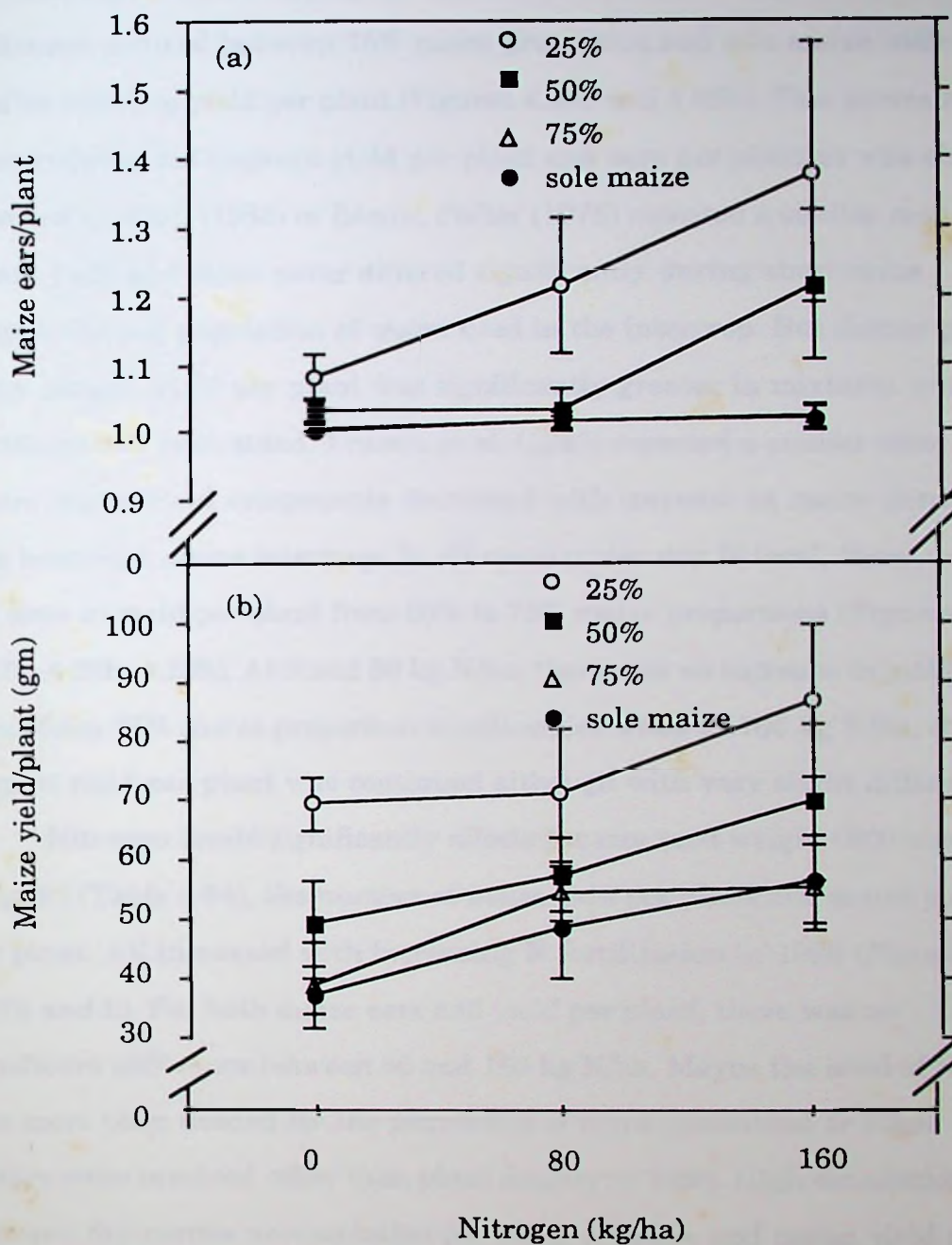


Figure 4.29. The effects of crop proportions and N fertilization on (a) the number of maize ears per plant, and (b) maize yield per plant in sole and intercropped systems under high maize population cropping system, 1991 (τ standard error of the means).

low and high maize cropping systems. In 1991 also, no significant difference occurred between 75% maize proportion and sole maize with similar effect on yield per plant (Figures 4.28b and 4.29b). This proves that intercropping did improve yield per plant and ears per plant as was also reported by Chui (1988) in Kenya. Fisher (1976) reported a similar case where yield per plant never differed significantly during short rains despite the low population of maize used in the intercrop. But during good rainy season, yield per plant was significantly greater in mixtures with potatoes than pure stand. Francis et al. (1983) reported a similar case where maize yield components decreased with increase in maize density in a bean and maize intercrop. In all cases under any N level, there was a big drop in yield per plant from 50% to 75% maize proportions (Figures 4.27b, 4.28b, 4.29b). At 0 and 80 kg N/ha, there was an increase in yield per plant from 75% maize proportion to sole maize while at 160 kg N/ha, the drop in yield per plant was continued although with very slight difference.

Nitrogen levels significantly affected maize seed weight (200 seed weight) (Table 4.54), the number of maize ears per plant and maize yield per plant. All increased with increasing N fertilization in 1990 (Figure 4.27a and b). For both maize ears and yield per plant, there was no significant difference between 80 and 160 kg N/ha. Maybe the level of N was more than needed for the population of crops considered or other factors were involved other than plant density in 1990. High correlation between dry matter accumulation per plant of maize and maize yield per plant ($r = 0.71$) existed at maize maturity. The dry matter accumulated during the process of growth was converted to grain yield in maize. Maize at 25% proportion, although produced nearly 2 cobs per plant, only one cob per plant was of big size. In 1991 under low and high maize population

cropping systems, N fertilization had no significant effect on ears per plant and yield per plant. Wahua (1983) noted that maize kernel number and mean grain weight of maize were significantly influenced by application of N fertilizer although this was under favorable weather condition.

High variation was observed in yield per plant under high maize population cropping system in 1991 (CV = 34.42) and low variability in 1990 (CV = 19.11) and under low maize population cropping system (CV = 18.96). ANOVA table for maize yield per plant is in Appendix A; Table 6.

4.13. Yield advantages of mixing beans and maize

Relative yields (RY) of beans at all crop proportions decreased with increasing N levels and the reverse was true for maize except for 25% maize proportion at 80 kg N/ha where the RY was lower than at 0 Kg N/ha in 1990 (Table 4.55). This agrees with the trend noted by Russell and Caldwell, (1989) in maize/soybean intercrop. LERs for 25% maize + 75% beans decreased with increasing N application, while the LER values for 50% maize + 50% beans increased with increasing N application (Table 4.55). The LER values for 75% maize + 25% beans at first decreased and then increased at the high N level. The increase in LERs were mostly due to the increase in the yield of maize in response to applied N fertilizer. Maize at 50% proportion and 50% beans had higher LER values at all N levels indicating some mutual sharing of resources or benefits of intercropping. It could be that the plant arrangement was optimum to allow for better capture of resources or there was less interspecific and intraspecific competition at the two crop proportions as indicated by their

Table 4.55. The effects of varied soil N levels and crop proportions on bean and maize relative yields and total LERs in sole and intercropped systems, 1990.

a Treatments		Relative Yields		Total
		beans	maize	^b LER
Sole beans,	N0	1.00	--	1.00
75B + 25M,	N0	0.83	0.30	1.13
50B + 50M,	N0	0.58	0.54	1.12
25B + 75M,	N0	0.39	0.67	1.07
Sole maize,	N0	--	1.00	1.00
Sole beans,	N1	1.00	--	1.00
75B + 25M,	N1	0.80	0.29	1.09
50B + 50M,	N1	0.57	0.55	1.12
25B + 75M,	N1	0.33	0.70	1.03
Sole maize,	N1	--	1.00	1.00
Sole beans,	N2	1.00	--	1.00
75B + 25M,	N2	0.72	0.33	1.05
50B + 50M,	N2	0.52	0.62	1.14
25B + 75M,	N2	0.33	0.76	1.09
Sole maize,	N2	--	1.00	1.00
Standard error				0.04

^a N0, N1, N2 represent 0, 80 and 160 kg N/ha respectively, and B and M are percent proportions of beans and maize, respectively in the intercrops.

^b Land Equivalent Ratio (LER).

competitive abilities and RY values in Figure 4.22 and Table 4.55, respectively for 1990 growing season.

In 1991, the relative yield of beans under the high maize population cropping decreased with increasing N application while under the low maize population cropping, bean relative yield first increased at 80 kg N/ha and then decreased at 160 kg N/ha (Table 4.56). Maize on the other hand had increased relative yield values at 80 kg N/ha and then decreased at 160 kg N/ha except for 25% maize proportion which decreased at 80 kg N/ha and then increased again at 160 kg N/ha under the high maize population cropping (Table 4.56). Under low maize population cropping, the relative yield of maize first decreased at 80 kg N/ha and then increased at 160 kg N/ha (Table 4.56). This could have been due to the changing competitive abilities of these crops with change in N levels.

In 1991, LERs were highest under no N application indicating that beans/maize intercrops were more advantageous even under low N and dry weather as experienced during the growing season (Table 4.56). This could have been due to large yields of intercropping or small yields of corresponding sole crops due to competition as was explained by Mead and Willey, 1980. But it confirms the finding of Ahmed and Rao (1982) that intercropping advantage (LER) decreases with increasing rate of applied N fertilizer. This contradicts the finding of Waghmare and Singh (1984) that higher LER and net returns are achieved at maximum N levels (120 kg N/ha) than at low N level.

Under low maize population cropping system, the advantage of intercropping was not as under high maize population cropping system. LERs were not significantly different in 1991 under low maize population cropping system (Tables 4.56 and 4.57). Similar to our results for 25%

Table 4.56. The effects of varied N levels and crop proportions on bean and maize relative yields and total LERs in sole and intercropped systems under low and high maize population cropping systems, 1991.

a Treats.	b Relative yield		Total LER	c Relative yield		Total d LER
	beans	maize		beans	maize	
Sole beans, N0	1.00	--	1.00	1.00	--	1.00
75B + 25M N0	0.76	0.32	1.08	0.84	0.47	1.31
50B + 50M, N0	--	--	--	0.53	0.66	1.19
25B + 75M, N0	0.26	0.71	0.97	0.28	0.77	1.05
Sole maize, N0	--	1.00	1.00	--	1.00	1.00
Sole beans, N1	1.00	--	1.00	1.00	--	1.00
75B + 25M, N1	0.79	0.30	1.09	0.68	0.37	1.05
50B + 50M, N1	--	--	--	0.46	0.61	1.07
25B + 75M, N1	0.29	0.67	0.96	0.28	0.88	1.16
Sole maize, N1	--	1.00	1.00	--	1.00	1.00
Sole beans, N2	1.00	--	1.00	1.00	--	1.00
75B + 25M, N2	0.71	0.30	1.01	0.66	0.40	1.06
50B + 50M, N2	--	--	--	0.42	0.64	1.06
25B + 75M, N2	0.30	0.80	1.10	0.29	0.75	1.04
Sole maize, N2	--	1.00	1.00	--	1.00	1.00
Standard error			NS			0.04

a N0, N1, N2 represent 0, 80 and 160 kg N/ha respectively, and B and M are percent proportions of beans and maize respectively in the intercrops.

b Relative yields and LERs under low maize population (37,000 plants/ha).

c Relative yields and LERs under high maize population (55,000 plants/ha).

d Land Equivalent Ratio (LER).

Table 4.57. The effects of crop combinations on total land equivalent ratios of sole and intercropped systems in 1990 and 1991.

Crop combinations	1990	1991 (A)	1991 (B)
Sole maize	1.00 a	1.00	1.00 a
75% maize + 25% beans	1.06 ab	1.01	1.08 ab
50% maize + 50% beans	1.13 c	----	1.11 b
25% maize + 75% beans	1.09 bc	1.06	1.14 b
Sole beans	1.00	1.00	1.00
<u>Statistical significance</u>			
linear	NS	NS	NS
quadratic	***	NS	***

1991 (A) Low maize population cropping system

1991 (B) High maize population cropping system

***, **, NS significant at 0.1%, 1% or not significant, respectively.

beans + 75% maize at 0 and 80 kg N/ha in 1991 under low maize population cropping system, Fisher (1976) indicated that no yield advantage from bean/maize mixture was apparent under low rainfall condition . Dry weather at maize's critical growth period was the limiting factor in his experiment, as occurred in the 1991 trial, in which a dry spell was experienced at tasseling. LERs (Land Equivalent Ratios) were significantly affected by crop combinations in 1990 and 1991 under the high maize population cropping system (Table 4.57; Appendix A: Table 7). There was no significant effect of N fertilization on LER values . Intercrop combinations were significantly different from the sole crops (Table 4.57).

It should also be noted that there were consistently higher LER values in intercropping than sole crops in 1990 and 1991 growing seasons with the exception of 25% beans + 75% maize at 0 and 160 kg N/ha under low maize population cropping in 1991 (Tables 4.55 and 4.56, respectively). Russell and Caldwell (1989) and Faris et al., (1983) reported similar findings of higher LER values for intercropped maize/soybeans and maize/beans than sole crops respectively. But in general intercropping gives much higher LER values than sole crops. Francis et al. (1982) noted high yield advantage of intercropping beans and maize of up to 65% over the single crop alternative (LER of 1.65).

4.14. Crop proportions and N fertilization effects on seed protein content, maize shelling percentage, and seed and N harvest indices

There was no significant effect of N fertilization and crop proportions on bean seed protein content in 1991 both under low and high maize population cropping systems although there were significant

differences between the different crop proportions (LSD .05) under high maize population cropping system (Table 4.58). There was better accumulation of crude protein under intercropping than sole cropping both in 1990 and 1991 growing seasons. In 1990, 50% bean proportion had significantly higher amount of crude protein than the rest of the crop proportions (Table 4.58). The reason for high crude protein accumulation by 50% bean proportion is not clear. Maybe there was less competition at this proportion or the available resources were being well distributed. But the high weight per seed of 50% bean proportion indicates a much better distribution of growth factors. Bean intercrop at 25% bean proportion in 1991 under high maize population cropping system produced the highest amount of protein at 0 N level indicating the efficiency of N conversion into protein by intercrops than sole crops. This confirms the earlier report of Francis et al. (1982) who indicated that bean intercrops produced much higher protein than sole crops.

Maize grain protein content was not affected by CP in 1990 although the trend seems to indicate that sole maize was better than intercrop maize and significant CP x N interactions in 1991 under both low and high maize population cropping systems.

Variation in N fertilization had significant effect on bean and maize crude protein in 1990, and maize in 1991 under both low and high maize population cropping systems (Table 4.59). Bean and maize crude protein increased with increase in applied N fertilizer.

Figures 4.30 and 4.31 indicate the significant interactions between CP and N fertilization for maize seed protein content in 1991 under low and high maize population cropping systems respectively. In both cases, there was a general increase in maize seed protein content with

Table 4.58. The effect of crop proportions on bean and maize seed protein contents and maize shelling percentage in sole and intercropped systems in 1990 and 1991 under low (A) and high (B) maize population cropping systems..

Crop proportion	% Crude seed protein				Shelling %	
	1990		1991 (A)	1991 (B)	1990	1991 (A)
	beans	maize	beans	beans	maize	maize
25%	25.0 a	9.8	27.1	26.3	83.9 a	82.6
50%	26.4 b	10.6	--	25.4	84.6 b	--
75%	24.6 a	10.5	26.6	27.1	84.3 ab	81.5
Sole crop	24.7 a	10.7	26.1	26.1	83.9 a	82.7

^a Stat. sig.

linear	NS	NS	NS	NS	NS	NS
quadratic	NS	NS	NS	NS	*	NS
cubic	*	NS	--	NS	NS	--

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

*, NS significant at 5% or not significant, respectively.

Table 4.59. The effect of N fertilization on bean and maize seed protein contents and maize shelling percentage averaged across sole and intercropped systems in 1990 and 1991 under low (A) and high (B) maize population cropping systems.

Nitrogen (kg/ha)	% Crude seed protein				Shelling %	
	1990		1991 (A)	1991 (B)	1990	1991 (A)
	beans	maize	beans	beans	maize	maize
0	24.2 a	10.0	26.1	25.6	84.4	84.1 b
80	25.2 ab	10.3	26.0	26.0	82.3	81.5 b
160	26.2 b	10.8	27.6	27.3	83.9	81.2 a
^a Stat. sig. linear	*	NS	NS	NS	NS	*
quadratic	NS	NS	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

*, NS significant at 5% level or not significant respectively.

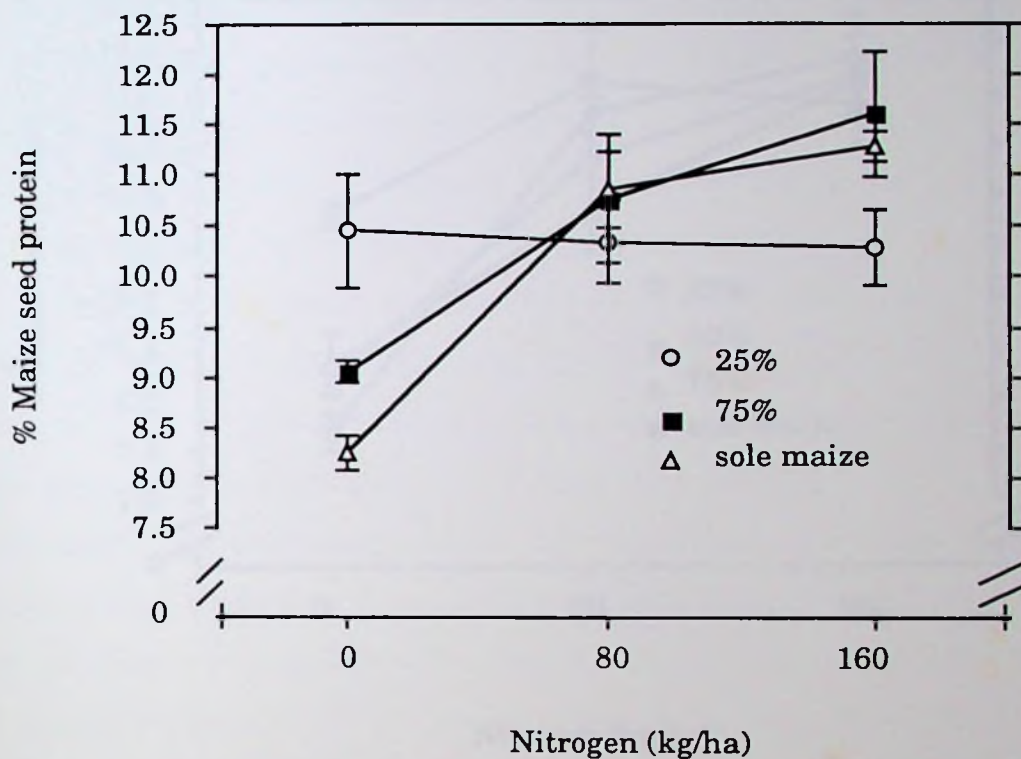


Figure 4.30. The effects of crop proportions x N fertilization interactions on maize seed protein content under low maize population cropping system, 1991 (standard error bars shown on the graph).

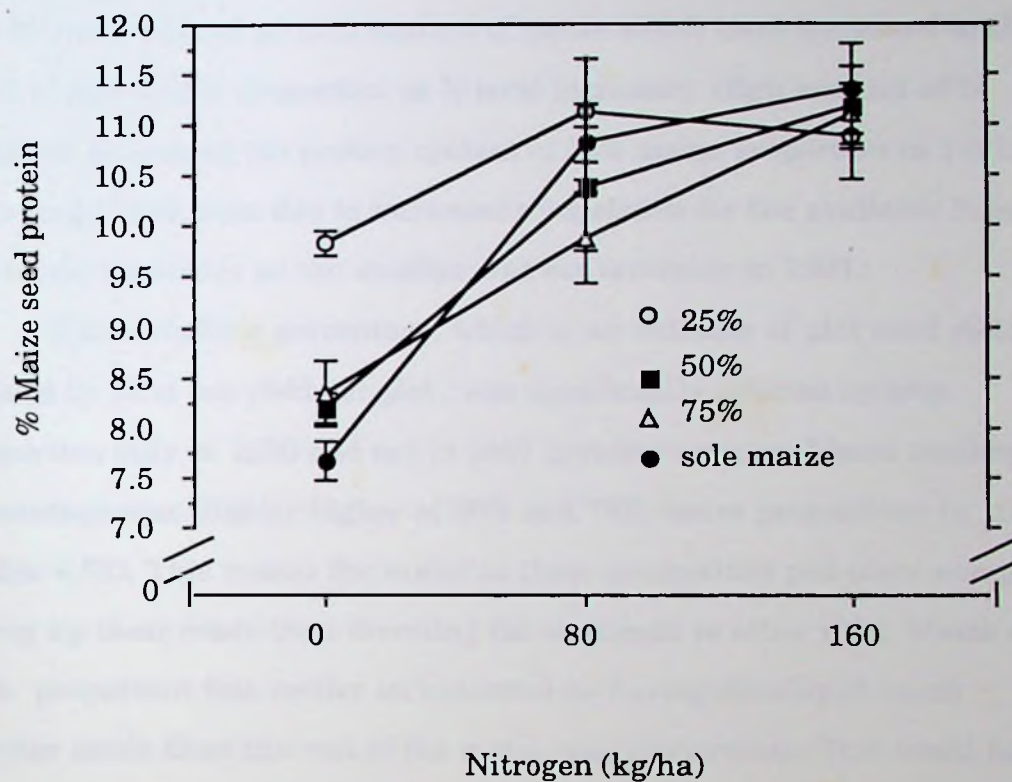


Figure 4.31. The effects of crop proportions x N fertilization interaction on maize protein content under high maize population cropping system, 1991 (standard error bars are as shown).

increasing fertilizer N. Maize at 25% proportion had the highest amount of protein at 0 N level indicating a more efficient use of available N than sole crops. The lower the proportion of maize in the system, the more crude protein they accumulated at low N while increasing maize proportion at low N level reduced protein content of maize which later increased to the level of 25% maize proportion as N level increased. High amount of N fertilizer decreased the protein content of 25% maize proportion in 1991. This could have been due to increased competition for the available N by the beans especially as the weather was not favorable in 1991.

Maize shelling percentage, which is an outcome of plot seed yield divided by total cob yield per plot, was significantly affected by crop proportion only in 1990 and not in 1991 growing seasons. Maize shelling percentage was slightly higher at 50% and 75% maize proportions in 1990 (Table 4.58). This means the maize at these proportions put more energy in filling up their seeds than diverting the nutrients to other uses. Maize at 50% proportion was earlier on indicated as having developed much heavier seeds than the rest of the maize crop proportions. This could have been responsible for its high shelling percentage. This means for the current experiment, the 50%/50% bean/maize proportion is a better plant arrangement to reduce interplant competition at late growth stages than other crop proportions.

N fertilizer application had significant effect only on maize shelling percentage in 1991 under low maize population cropping (Table 4.59). In all cases, maize shelling percentage decreased with increase in applied N fertilizer. There was more dry matter being put in other part of the cob than the seeds due to N fertilization.

In 1991 under high maize population cropping system, there was significant CP x N interaction for maize shelling percentage (Figure 4.32). Maize proportions at 25% and 50% had higher shelling percentages than 75% maize proportion and sole maize at 0 N level (Figure 4.32) indicating efficient use of N by intercrops than sole crop. As N application was increased, the lower maize proportions (25% and 50%) had reduced shelling percentage at 80 kg N/ha and later on increased at 160 kg N/ha. This could have been due to the fact that N application encouraged vegetative growth at the expense of seed production, therefore, resulting in low shelling percentage. The high proportion maize (75% and sole maize) had increased shelling percentage at 80 kg N/ha with sole maize continuing to increase at 160 kg N/ha while 75% maize proportion dropped off to the level of 50% maize proportion as shown in Figure 4.32. This seems to indicate that at high maize proportion there is intense intraspecific competition which is reduced by application of N fertilizer.

Bean and maize seed harvest indices were significantly affected by crop proportions in 1990 and 1991 under both population cropping systems except bean seed harvest index in 1990 (Table 4.60). In all cases, seed harvest indices decreased with increase in crop proportions of either beans or maize. This was due to increased pods and yield per plant or increased ears and yield per plant with decrease in crop proportions either beans or maize respectively. Wahua (1983) dealing with maize/cowpea intercrop using additive series found no significant effect of intercropping on maize seed harvest index but Spitters (1983) indicated that seed harvest index was positively affected by reduction in plant density, and therefore, by interplant competition. Our result seems to support Spitter's finding.

N fertilization had no significant effect on both beans and maize harvest indices in 1990 and 1991 growing seasons. But there was high

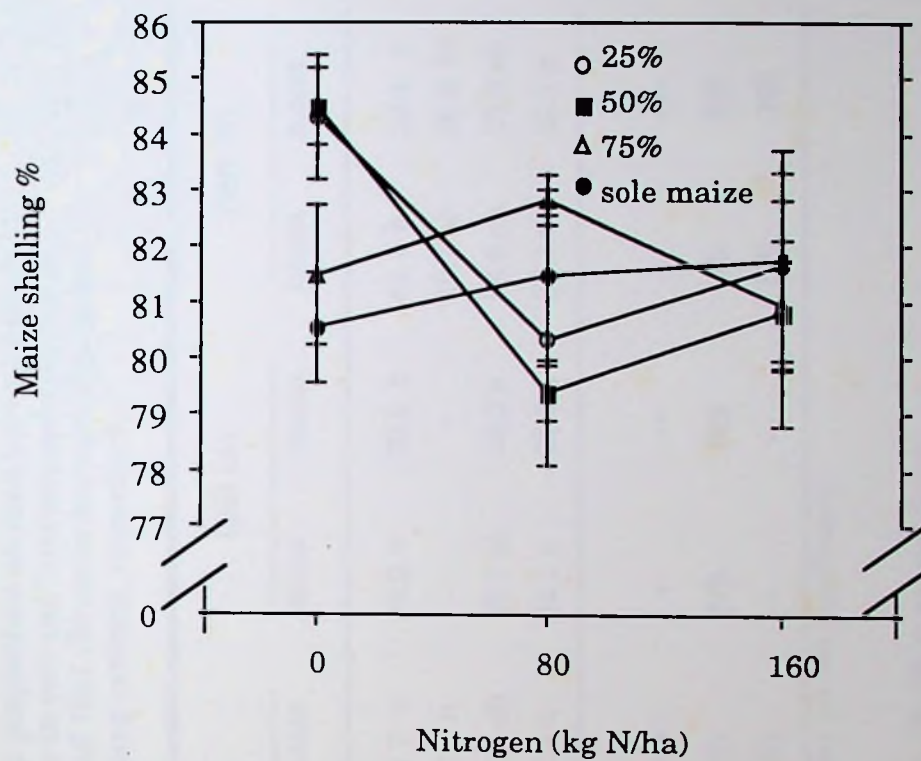


Figure 4.32. The effects of crop proportions x N fertilization interaction on maize shelling percentage under high maize population cropping system, 1991 (standard error bars are shown in the figure).

Table 4.60. The effect of crop proportions on seed harvest indices of beans and maize in sole and intercropped systems in 1990, 1991 (A) and 1991 (B) under low and high maize population cropping systems, respectively.

Crop proportion	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
25%	28.8	47.7 c	40.9 b	30.5 b	41.1 b	28.4 c
50%	26.5	43.3 b	--	--	40.7 ab	26.4 bc
75%	25.7	41.4 ab	35.1 ab	26.3 a	38.6 ab	23.2 ab
Sole crop	26.6	40.4 a	32.1 a	25.5 a	32.1 a	22.7 a
^a Stat. sig. linear	NS	***	*	**	*	***
quadratic	NS	NS	NS	NS	NS	NS
cubic	NS	NS	--	--	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, *, NS significant at 0.1%, 1%, 5% or not significant, respectively.

tendency for seed harvest indices to decrease with increase in applied N fertilizer.

Nitrogen harvest index, which is the percentage of seed N to total plant N at maturity, was not significantly affected by crop proportion in 1990, but crop proportion had significant linear and quadratic effects in 1991 under both cropping systems (Table 4.61). Intercropped beans in 1991 had higher N harvest indices than sole beans with no significant difference between the different intercrop proportions.

Application of N fertilizer significantly affected bean N harvest indices in 1991 under both cropping systems but not in 1990 (Table 4.62). Nitrogen harvest index decreased with increase in applied N fertilizer. This means N is more effectively transferred to the seeds than the vegetative parts of the plants at low N level especially when the weather condition is unfavorable.

Maize N harvest indices were higher for intercropped than sole crop maize in 1990. In 1991, it increased with increasing maize proportion in low maize population cropping system (Table 4.61). There was no significant effect of crop proportions on N harvest index of maize under the high maize population cropping in 1991. But under both cropping systems of 1991, sole maize and 75% maize proportion were not significantly different from one another (LSD: 0.05) instead great difference from 25% maize proportion existed.

N fertilization seems to have affected N harvest index of maize significantly in 1990 and not in 1991 (Table 4.62). Nitrogen harvest indices of maize increased with reduction in applied fertilizer N. Total plant N from the zero N plots was low but seed N showed no significant difference between the different N levels. Obviously, the maize crop at 0 N level

Table 4.61. The effect of crop proportions on nitrogen harvest indices of bean and maize in sole and intercropped systems in 1990, 1991 (B) under low and high maize population cropping systems, respectively.

Crop proportion	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
25%	50.4	39.8 ab	62.7 b	49.6 a	62.3 b	51.4 a
50%	49.1	36.3 a	--	--	63.5 b	52.5 ab
75%	43.2	43.6 b	63.6 b	52.6 b	63.0 b	55.0 b
Sole crop	45.0	37.0 a	59.5 a	52.7 b	59.5 a	53.4 ab
^a Stat. sig. linear	NS	NS	*	**	*	NS
quadratic	NS	NS	*	NS	*	NS
cubic	NS	**	--	--	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

**, *, NS significant at 1%, 5% or not significant, respectively.

Table 4.62. The effect of N fertilization on N harvest indices of beans and maize averaged across sole and intercropped systems in 1990, 1991 (A) and 1991 (B) under low and high maize population cropping systems, respectively.

Nitrogen (kg/ha)	1990		1991 (A)		1991 (B)	
	beans	maize	beans	maize	beans	maize
0	46.2	46.1 b	63.3 b	52.9	63.8 b	53.2
80	44.3	36.1 a	62.1 ab	51.1	62.1 ab	53.7
160	50.2	35.1 a	60.4 a	51.1	60.1 a	52.3
^a Stat. sig. linear	NS	***	*	NS	*	NS
quadratic	NS	*	NS	NS	NS	NS

Means followed by a common letter are not significantly different at 5% level using LSD.

^a Statistical significance

***, *, NS significant at 0.1%, 5% or not significant, respectively.

diverted more N to the seeds rather than to vegetative growth resulting into high N harvest index. This indicates that intercrops do make efficient use of N even at low N level than sole crops. As more N is added to the system, there is more vegetative growth with less N accumulation in the seeds.

4.15 The effects of crop proportions and N fertilization on total income

The proportions at which the crops were planted and the price of each crop had significant effect on the total income that a farmer could get out of each cropping system. In 1990, intercropping beans and maize produced much higher income than sole maize cropping (Table 4.63). Growing a monocrop of beans gave equal income to that produced by intercropping. Intercropping with 50% or 75% bean proportion produced the highest total income than sole crops. This was due to the fact that maize grain price was only 180 Uganda shillings per kg and bean grain was at 400 Uganda shillings per kg.

In 1991, total income under low maize population cropping system increased with increase in bean proportions (Table 4.63). Sole beans produced the highest income which was not significantly different from 75% beans + 25% maize system. Under high maize population cropping system, 75% beans + 25% maize produced the highest total income per ha compared to other crop proportions (Table 4.63). Beans tend to more expensive than maize grains all the time and the price of bean grain is double the price of maize grain. One can get more money by selling maize fresh in towns but this involves transport which is very expensive. The income being reported is general in most places in the country.

Total income increased with increase in applied nitrogen fertilizer in 1990 and there was no significance in 1991 (Table 4.64). Therefore, a small farmer would be better off intercropping than sole cropping with high income, low cost of production and reduced risk of crop failure.

Table 4.63. The effect of intercropping on total income per ha in Uganda shillings in 1990, 1991 under low (A) and high (B) maize population cropping systems (1000 Uganda shillings = 1 US \$).

Crop proportions	1990	1991 (A)	1991 (B)
sole maize	946.5 a	437.2 a	468.3 a
75% maize + 25% beans	1071.2 b	481.8 ab	523.5 ab
50% maize + 50% beans	1182.2 c	---	571.5 bc
25% maize + 75% beans	1198.3 c	563.9 bc	607.9 c
sole beans	1162.9 bc	590.4 c	587.2 bc
a Stat. sign.			
linear	***	***	***
quadratic	**	NS	NS
cubic	NS	NS	NS

The figures are in Uganda shillings ('000).

Means followed by a common letter are not significantly different at 5% level using LSD.

a Statistical significance

***, **, NS significant at 0.1%, 1% or not significant, respectively.

Francis and Sanders (1978) reported that risk was higher in sole crops than in intercrops. They also noted that over a range of prices, monocrop beans was more profitable than others only if a farmer was able to introduce intensive package of technology. But considering the high risk and investments in monocrops, intercropping beans and maize would be

much more profitable than sole cropping. Therefore, a small subsistence farmer would be better off using intercropping to maintain low cost of production and greater income stability, and minimize risk. As put forward by Francis (1986), net income advantage from intercropping appear to be secondary to risk reduction. This seems to be true with most

Table 4.64. The effect of nitrogen fertilization on the total income averaged across sole and intercropped systems in 1990, 1991 under low (A) and high (B) maize population cropping systems in Uganda shillings (1000 Uganda shillings = 1 US \$)

Nitrogen (kg/ha)	1990	1991 (A)	1991 (B)
0	1009.8 a	485.9	505.3
80	1132.1 b	523.9	548.7
160	1191.3 b	545.2	602.6
Statistical significance			
linear	***	NS	NS
quadratic	NS	NS	NS

Figures are in Uganda shilling ('000).

Means followed by a common letter are not significantly different at 5% level using LSD.

***, NS significant at 0.1% or not significant respectively.

subsistence farmers even in Uganda. But Norman (1974) presented evidence that intercropping in northern Nigeria was a mean of reducing variability in net income while Abalu (1976) showed that 2-crop patterns had a lower variance in net income than sole crops in northern Nigeria.

CHAPTER FIVE

GENERAL DISCUSSION

When two or more crops are grown together in the same field simultaneously (intercropping), there is usually intense interspecific competition for light, water, and nutrients which may limit the advantages of an intercropping system (Ofori and Stern, 1987). The results of these two years of work indicate a high possibility of increasing yields of beans and maize in an intercropping system by changing the population densities of the two crops as soil N level is varied and reduce the competition. There seems to be better utilization of available resources by the intercrops compared to the sole crops. Previous report had indicated no difference in light interception by monocrop beans and mixed bean-maize plantings in additive series (Fisher, 1979). Our data indicated that although intercropped beans or maize intercepted less PAR than monocropped beans or maize (Figures 4.10, 4.11, 4.12, 4.13, 4.14 and 4.15) in both years, total light interception was higher in intercropped maize and beans than sole crops in 1990 (Figure 4.16). In 1991 under low maize population cropping system, sole beans intercepted more light than the intercrops and sole maize (Figure 4.17), and under high maize population cropping system, intercrops intercepted more light during the early part of the crop growth (Figure 4.18). Combined yield (kg/ha) on the other hand did not show a positive response to total light intercepted by the crops. Sole maize which intercepted less total light in both years had the highest total yields (kg/ha) than other crop combinations (Table 4.51). Yield per plant did show a positive response to total light intercepted by the two crops in the intercrops

where yield per plant increased with decrease in crop proportions or increase in total light intercepted by the two crops in 1990 (Figures 4.26b and 4.27b for beans and maize, respectively). Intercropped beans or maize produced more yield per plant than sole cropped beans or maize. This agreed with the finding of Eriksen and Whitney (1984) who indicated that bush beans were less affected by shading than cowpeas or soybeans and bush beans had maximum yield at 70% shade compared to cowpeas or soybeans. From our data, we would say that intercropping increased light interception that could have been wasted if the crops were planted as sole crops. Gardiner and Craker (1981) noted that there was decreased light reflection in maize-bean intercrop and increased light interception in the intercrop, although the quantity of light available to the bean canopy was decreased as maize population was increased.

From our experiment, we can conclude that there is better distribution of resources in intercrops than in sole crops because of the high dry matter accumulated per plant (gm) by the intercrops compared to sole crops (Table 4.8 for 1990 and Table 4.10 for maize in 1991 under high maize population cropping system). But total dry matter yield (kg/ha) was low for intercrops than sole beans and higher than sole maize early in the season (Tables 4.11, 4.12 and 4.13) which changed at maturity time with more dry matter yield of sole maize than other crop combinations. Intense, early competition from beans in the intercrops, reduced maize dry matter in the intercrops than the sole maize while beans increased their dry matter accumulation in the intercrops (on per plant basis) (Tables 4.8, 4.9 and 4.10). Dry matter increase of beans could have been due to better light distribution and other resources or the effect of the shading by maize as indicated earlier. The intense competition in intercropped maize was also

indicated by substantially delayed tasseling and maturity in intercropped maize compared to sole maize (Table 4.47), reduced leaf chlorophyll content (Table 4.20), and lower leaf N content in 1990 and 1991 except at crop maturity in 1991 where intercrops had higher leaf N (Tables 4.35 and 4.36). By applying N fertilizer, competition for resources was reduced leading to more dry matter accumulation (kg/ha) (Tables 4.17, 4.18 and 4.19), more nutrient uptake by both crops (kg/ha) (Tables 4.43, 4.44 and 4.45) and shorter period of time to tasseling and maturity (Table 4.48). Chui and Shibles (1984), Davis and Garcia (1983) and Wanki et al. (1982) working on maize-soybean, maize-climbing beans and maize-cowpea intercrops respectively, indicated substantially delayed maize tasseling and silking in intercrops compared to sole maize. But the delayed maturity in intercropped maize led to better dry matter accumulation and yield per plant in 1990 and 1991 growing seasons and higher nutrient accumulation in 1991 compared to sole maize in our experiment.

Nutrient accumulation (kg/ha) was affected by crop combinations in both years (Tables 4.40, 4.41 and 4.42). Total nutrient uptake in 1990 was determined by the density of beans in the system where intercrops accumulated less nutrients than sole beans but higher amount than sole maize except for P uptake at maturity (Table 4.40). Nutrient uptake in 1991 increased with increase in bean density only early in the season but later increased with increase in maize density (Tables 4.41 and 4.42). Nutrient uptake per ha followed a similar trend as dry matter yield per ha in both years. Therefore, the yellowing in intercropped maize before tasseling in 1990 and 1991 under low maize population cropping system was due to competition from beans for N which started early in the season. In 1991, leaf yellowing was more in sole maize under high population due to

population pressure and intraspecific competition for N than in the intercrops as indicated by low chlorophyll content of sole maize (Table 4.20). The intercrop combinations in 1991 which involved higher bean proportions, the beans could have retained moisture by acting as cover crops which aided in the use of the available N compared to sole maize and the combination involving 25% beans.

Competition for nutrients between legumes and cereal intercrops may also delay development and productivity (Wahua, 1983). According to our data, where no N was applied, growth was delayed and productivity was low. A number of researchers have indicated the need for high soil N for better cereal growth (Hikam et al., 1991; Baker and Blamey, 1985). Therefore, applying N fertilizer reduces competition for this element in the intercrops improving yield of the crops. Total yield per ha (kg) in 1990 was improved by N fertilization and not in 1991 (Table 4.52). This seems to indicate that N was not efficiently used in 1991 compared to 1990 growing season. In terms of yield advantage as measured by land equivalent ratios (LERs), productivity was highest in intercropped systems than sole cropped systems at low soil N level (Tables 4.55 and 4.56), which could have been due to low yield of the sole crops or better yield of the intercrops. Intercrops were significantly different from the sole crops (Table 4.57) and N fertilization had no significant effect on LER values (Appendix A: Table 7). A possible explanation may also be more bean yield due to reduced shading as less N was available to allow better growth of maize (Ofori and Stern, 1987) or resources were being maximally utilized by the intercrops (Willey, 1979b). This advantage decreased with increase in applied N fertilizer especially under poor weather condition of 1991.

Better yield of intercropped beans compared to sole beans could also

be attributed to reduced damage on beans by Japanese and Mexican bean beetles (Table 4.46). Intercropping with maize acted as a barrier to the movement of these pests (Hasse and Litsinger, 1988) or the maize plants in the intercrops provided shade to the beans making the environment unsuitable for survival of the beetles (Wrubel, 1984). Because of the reduced damage, yield per plant of beans increased in the intercrops compared to sole beans.

Efficient use of nutrients by intercrops and high dry matter accumulation and better light interception by the intercrops led to improved bean seed protein content in 1990 and both bean and maize seed protein content in 1991 under dry weather condition compared to sole crops (Table 4.58). Efficient use of resources is also indicated by the high seed harvest indices of the intercrops compared to sole crops (Table 4.60), and high N harvest indices for the intercrops than the sole crops (Table 4.61) except for maize in 1991 where sole maize had higher N harvest indices than the intercrops. There were also higher yield per plant (both maize and beans), and maize ears per plant and bean pods per plant in intercrops than the sole crops. This points to the fact that resources were better utilized under intercropping than sole cropping.

The high productivity under intercropping because of better utilization of light, water, nutrients and other resources being well shared also means higher net return from intercrops than sole crops (Norman, 1974; Francis, 1986; Francis and Sander, 1978). Our data indicated higher gross return from intercropping than sole cropping although sole beans produced equally high gross income as intercrops especially under the low maize population cropping system in 1991 (Table 4.63). Gross income also increased with increase in applied fertilizer N (Table 4.64). Therefore, the

practice of intercropping may prove more profitable with less risk and more stable yield than sole cropping.

CHAPTER SIX

CONCLUSIONS

In conclusion, intercropping was much more efficient in utilizing the available resources than sole cropping for most of the important yield components studied. Although intercropping had less dry matter yield (kg/ha) than sole crops in most cases (Tables 4.11, 4.12 and 4.13), and lower nutrient uptake (kg/ha) than sole beans in 1990 (Table 4.40) and sole beans and later sole maize in 1991 (Tables 4.41 and 4.42), still intercrops were more advantageous than sole crops in terms of LERs (Tables 4.55, 4.56 and 4.57). This means that the intercrops used the available resources more efficiently than sole crops. Intercropping efficiency was also indicated by high dry matter accumulation per plant and more nutrient uptake per plant from intercrops than sole crops. Nutrient uptake increased with increase in applied N fertilizer. On per plant basis, the lower the proportion of beans and maize, the higher the accumulation of dry matter and nutrients (gm/plant) at maturity due to better yield components. Therefore, the density combination under a given soil fertility level which requires the least amount of resources devoted to intercropping but which confer the most benefit may be considered the optimum combination for that particular soil fertility level.

Intercropping also leads to reduction in pest damage. This was indicated by reduction in the damage by Japanese and Mexican bean beetles in intercropping systems compared to sole crops (Table 4.46). This means reduction in the cost of production, and therefore, increased yield per unit area. Farmers in developing countries do not apply pesticides on

field crops in most cases and the use of intercropping is one way to deal with pest problems and at the same time increase yield without any additional cost of production.

Beans and maize yield components including number of pods per plant, maize ears per plant and yield per plant were higher in intercrops than sole crops. This indicates a more efficient distribution of resources within intercrops than sole crops for better production. It indicates also that there is over-yielding in intercrops compared to sole crops. Intercrops produced higher land equivalent ratio (LER) values than sole crops except under the dry weather of 1991 where including a higher proportion of maize was not profitable (Tables 4.55 and 4.56). Much higher LER was at low N level than at high N level. Intercropping beans and maize at low N level is effective in utilizing the available resources properly. The advantage of intercropping seems to be expressed better under low N level even when weather conditions are bad.

Intercropping beans and maize tends to improve on shelling percentage of maize (Table 4.58), seed harvest indices (Table 4.60), and nitrogen harvest indices of both beans and maize (Table 4.61). This means the crops are in better position to effectively convert the nutrients absorbed to produce seeds. Protein content was also much better under intercropping than sole cropping and high values were observed under dry weather condition of 1991 (Table 4.58). Intercrops are in position to convert nitrogen to protein effectively even when the weather situation is not so good.

Intercropping also produced more gross income than sole cropping although sole beans produced equally high gross income as the intercrops (Table 4.63). Sole crops with high risk involved need a lot of investment

which most peasant farmers are not in position to do. Therefore, by intercropping, a farmer reduces the risks and at the same time improves on his income which may be much more stable than from sole crops.

But what does this mean to a peasant farmer in Uganda who survives by intercropping beans and maize at all times? First, it will be to a farmer's advantage to plant low proportion of beans at high soil fertility and high proportion of beans at low soil fertility level. This does not mean that a farmer cannot plant high population of beans at high soil fertility level but for maximum production, low proportion of beans will be of an advantage. These proportions of beans and maize tend to coincide with the point of equal competition between the two crops which is just below 50% in case of beans and just over 50% in case of maize under good soil fertility and weather conditions as was in 1990 (Figure 4.22).

Secondly, it will be of no benefit to a farmer to plant high population of the two crops if there is high risk of poor weather as is commonly experienced in the north-eastern part of Uganda. There would be no justification for this action as our results of 1990 and 1991 indicated.

Thirdly, a farmer is much better off intercropping than sole cropping if the weather condition is bad or if the population of the crops accidentally happens to be high. Because of better resource utilization in intercropping, yield is most likely to be high in intercropping than in sole crops under the bad weather situation.

In the future, serious studies in connection with intercropping should include; (a) study of interaction components below ground in an intercropped system, (b) competition studies involving a number of different nutrients like N, P, K, Ca and Mg, (c) proper timing of fertilizer N application in intercropped systems, and (d) screening varieties with

respect to soil fertility problems. The screening process should involve testing N efficient maize lines for bean intercropping, and (c) time of N application in an intercropping situation.

In summary,

- (1) Intercropping was more efficient in utilizing the available resources than sole crops as indicated by high LERs which decreased with increase in applied N fertilizer,
- (2) Intercrops do reduce pest damage which leads to reduced cost of production,
- (3) Reduced risk from weather failure or pest damage by intercropping and better resource utilization means better yield from intercropped beans and maize, and therefore, higher net return from intercrops than sole crops
- (4) If intercrops are going to take up large amount of nutrients from the soil as sole crops (kg/ha), then we need proper soil management under intercropping situations just as for sole crops. High nutrient removal coupled with residue removal at harvesting (noting the high N harvest indices of intercropped maize and beans) may be more harmful to the soil than sole cropping. Therefore, returning crop residues to field where they were removed and proper crop rotation may be a solution to avoid soil nutrient depletion especially under the farmers' situation in developing countries.

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APPENDIX A
ANALYSIS OF VARIANCE (ANOVA) TABLES

Table 1. ANOVA table for total light interception (PAR) as affected by the different crop combinations and N fertilization in 1990, 1991 (A) under low maize population cropping and 1991 (B) under high maize population cropping system.

Source	a df	b df	1990		1991 (A)		1991 (B)	
			42 DAP	63 DAP	42 DAP	56 DAP	42 DAP	56 DAP
			c ms	ms	ms	ms	ms	ms
Block (B)	3	3	6.11	41.88	341.28	116.02	297.47	235.03
Nitrogen (N)	2	2	24.44	60.13	693.68	517.66	380.36	292.16
N linear	1	1	48.84*	114.58	1296.68*	935.28*	694.21	577.16
N quadratic	1	1	0.05	5.68	90.68	100.04	56.79	4.47
N x B	6	6	7.65	56.34**	141.61*	116.35*	155.71**	318.92***
Crop combinations (CC)	4	3	1795.13***	694.70***	1107.30***	1050.23***	503.96***	280.87**
CC linear	1	1	4573.21***	1439.36***	3161.73***	2961.04***	1089.62***	1418.57***
CC quadratic	1	1	2289.57***	1092.42***	146.65	103.25	24.75	545.76***
CC cubic	1	1	313.31***	174.73**	13.68	86.40	2.49	24.93
CC quartic	1	-	4.42	72.28*	---	---	15.70	7.94
CC x N	8	6	18.20	9.71	53.27	48.25	47.86	38.90
Residual	35	27	17.27	14.76	42.42	43.07	42.02	57.88
d CV			13.20	9.20	18.10	15.30	13.40	13.30

a Degrees of freedom for 1990 and 1991(B) under high maize population cropping system

b Degrees of freedom for 1991(A) under low maize population cropping system

c Mean square

d Coefficient of variation.

Table 2. ANOVA for bean yield (kg/ha) as affected by crop proportions and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c m s	1991 (A) m s	1991 (B) m s
Block (B)	3	3	272490.34	4.320E5	4.870E5
Nitrogen (N)	2	2	144985.23	33788.96	6107.59
N linear	1	1	273400.36	39511.97	2.27
N quadratic	1	1	16570.09	28065.96	12190.93
N x B	6	6	137982.64**	3.000E5***	3.440E5***
Crop proportions (CP)	3	2	8.067E6***	3.410E6***	2.570E6***
CP linear	1	1	2.419E7***	6.670E6***	7.686E6***
CP quadratic	1	1	12148.88	1.430E5	42944.76
CP cubic	1	-	181.21	----	227.38
CP x N	6	4	66295.49	19641.35	14340.21
Residual	27	18	38077.50	62291.06	50029.29
^c CV			19.35	57.33	57.20

^a Degrees of freedom for 1990 and 1991 under high maize population croppingsystem

^b Degrees of freedom for 1991 under low maize population cropping system

^c Mean square

^d Coefficient of variation.

Table 3. ANOVA for maize yield (kg/ha) as affected by crop proportions and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c m s	1991 (A) m s	1991 (B) m s
Block (B)	3	3	9.448E5*	29013.62	1.315E6
Nitrogen (N)	2	2	3.376E6**	2.378E5	1.554E6
N linear	1	1	5.775E6***	404282.64	3.046E6
N quadratic	1	1	9.775E5*	63296.41	38778.53
N x B	6	6	1.521E5	99850.55	5.576E5***
Crop proportions (CP)	3	2	2.546E7***	8.625E6***	5.225E6***
CP linear	1	1	7.494E7***	1.702E7***	1.559E7***
CP quadratic	1	1	98950.14	232195.56	3.696
CP cubic	1	-	1.271E6**	-----	41297.07
CP x N	6	4	125940.77	47757.21	1.607E5
Residual	27	18	114913.08	55464.69	1.016E5
^d CV			41.70	45.52	44.29

^a Degrees of freedom for 1990 and 1991 under high maize population cropping system

^b Degrees of freedom for 1991 (A) under low maize population cropping system

^c Mean square

^d Coefficient of variation.

Table 4. ANOVA for total (combined) yield (kg/ha) of beans and maize as affected by crop combinations (CC) and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c m s	1991 (A) m s	1991 (B) m s
Block (B)	3	3	5.005E5	4.492E5	2.636E6
Nitrogen (N)	2	2	3.738E6**	2.621E5	1.266E6
N linear	1	1	6.849E6	5.214E5	2.522E6
N quadratic	1	1	6.259E5	2.697E3	4.495E3
N x B	6	6	1.753E5	3.620E5*	1.378E6***
Crop combinations (CC)	4	3	9.819E6***	2.070E6***	2.318E5***
CC linear	1	1	3.616E7***	6.181E6***	8.138E6***
CC quadratic	1	1	1.925E6**	2.187E4	8.010E5**
CC cubic	1	1	5.591E5	6.312E3	2.530E5
CC quartic	1	-	2.895E5	-----	6.244E3
CC x N	8	6	1.448E5	5.890E4	1.930E5*
Residual	35	27	1.831E5	1.062E5	8.408E4
dCV			23.19	27.13	34.44

^a Degrees of freedom for 1990 and 1991 under high maize population cropping system

^b Degrees of freedom for 1991 under low maize population cropping system

^c Mean square

^d Coefficient of variation.

Table 5. ANOVA for bean yield per plant (gm) as affected by crop proportions and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c m s	1991 (A) m s	1991 (B) m s
Block (B)	3	3	30.51	43.52	39.72
Nitrogen (N)	2	2	9.92	5.31	0.76
N linear	1	1	14.20	6.53	4.5E-4
N quadratic	1	1	5.64	4.08	1.53
N x B	6	6	13.07*	22.82***	28.01***
Crop proportions (CP)	3	2	110.91***	6.20	2.55
CP linear	1	1	271.41***	7.60	2.06
CP quadratic	1	1	56.69***	4.80	5.38
CP cubic	1	-	4.62	----	0.15
CP x N	6	4	4.24	2.18	0.67
Residual	27	18	3.78	2.93	2.92
d CV			20.97	34.79	32.41

^a Degrees of freedom for 1990 and 1991 under high maize population cropping system

^b Degrees of freedom for 1991 under low maize population cropping system

^c Mean square

^d Coefficient of variation.

Table 6. ANOVA for maize yield per plant (gm) as affected by crop proportions and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c m s	1991 (A) m s	1991 (B) m s
Block (B)	3	3	1721.56*	121.45	1268.06
Nitrogen (N)	2	2	7380.10**	350.29	1205.70
N linear	1	1	13535.84**	569.90	2406.27
N quadratic	1	1	1224.36	130.68	0.56
N x B	6	6	290.36	143.66	516.35***
Crop proportions (CP)	3	2	3943.22***	1041.19**	1992.60***
CP linear	1	1	9061.54***	1322.52**	5183.61***
CP quadratic	1	1	1609.02**	759.86*	722.98**
CP cubic	1	-	1245.30*	----	5.75
CP x N	6	4	174.02	36.83	49.34
Residual	27	18	204.24	109.04	85.47
d CV			19.11	18.96	34.42

^a Degrees of freedom for 1990 and 1991 under high maize population cropping system

^b Degrees of freedom for 1991 under low maize population cropping system

^c Mean square

^d Coefficient of variation

Table 7. ANOVA for LERs as affected by crop combinations (CC) and N fertilization in 1990, and 1991 (A) and (B) under low and high maize population cropping systems, respectively.

Source	^a df	^b df	1990 ^c ms	1991 (A) ms	1991 (B) ms
Block (B)	3	3	0.044*	0.012	0.007
Nitrogen (N)	2	2	0.001	0.001	0.032
N linear	1	1	0.001	0.002	0.059
N quadratic	1	1	0.002	0.001	0.004
N x B	6	6	0.008	0.016	0.026
Crop combinations (CC)	4	3	0.037***	0.010	0.048*
CC linear	1	1	0.001	0.002	0.004
CC quadratic	1	1	0.138***	0.014	0.153**
CC cubic	1	1	0.004	0.014	0.017
CC quartic	1	-	0.004	----	0.012
CC x N	8	6	0.002	0.010	0.023
Residual	35	27	0.006	0.020	0.016
dCV			9.36	12.49	13.36

^a Degrees of freedom for 1990 and 1991 under high maize population cropping system

^b Degrees of freedom for 1991 under low maize population cropping system

^c Mean square

^d Coefficient of variation