THE GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.) AND SOYABEANS (*GLYCINE MAX*. (L) MERRILL) GROWN AS INTERCROPS

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ABSTRACT

The effect of plant population maize (Zea mays L.) cultivar (Pioneer 3901) and AMT and Matara cultivars of soyabeans (Glucine max (L) Merill) grown together in an intercropping system was studied. In the experiment three rows of maize were sown at populations of 6, 8, 10 plants/m^2 and three rows of soyabeans were planted between the rows of maize at either 50 or 75 plants/m^2 replacing one of the three rows of maize.

Plants were sampled for vegetative analysis during the growth of the crops and at final harvest. Total dry matter, grain yield and the componentsof yield and leaf area index were deterimend.

Grain yield of maize increased from 794 to 1522 g/m^2 as the population of maize increased. However the yield of the maize was not affected by either the cultivar or the populations of the soyabeans grown among it.

Grain yield and the component of yield of the intercropped soyabeans were not affected when population of maize in the mixture was increased. Matara produced higher yields than AMT when grown with maize and this was associated with production of more grain per plant and larger seeds. As the plant population of the soyabeans was increased the grain yield of Matara increased and up to 336.9 g/m^2 was obtained, however the yield of AMT was not affected by a similar increase in plant population, possibily Matara had greated temporal difference and was more competative than AMT when grown in the mixture.

Three methods were used to evaluate the yield of intercropped plots. These were the seed yield summed for both crops, Land Equivalent Ratio (LER) and a yield ratio based on maize. Although the results obtained depended on the method used all the three methods indicated intercropping could be more advantageous than growing maize and soyabeans as pure stands. All the three methods indicated that the highest yield was obtained when the highest population of maize was combined with the highest population of soyabeans. Higher yields were obtained when Matara rather than AMT was grown in the intercropped plots.

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INTRODUCTION

In many agricultural areas the amount of unused land which can be brought into production is limited, so of total agricult-ural production is to be increased, agriculturists must concentrate on in-provements to production per unit areas.

The introduction of new methods of production have not always met with ready acceptance by many subsistance farmers and small holders, who generally represent the greater of the farming population in develop-ing countries, whose farming systems are not able to accomodate the higher level or risk involved. For these farmers yield increases may occur with inmprovement of traditional farming ventures such as inter-cropping.

This avenue of research has often been overshadowed by the research effort of manoculture farming and consequently progress has not been dramatic.

Soyabeans (Glucine max) and Maize (Zea mays) are both crops which feature in tropical agriculture system and which are able to be grown successfully in temperate areas such as New Zealand, and were therefore selected as the component crops of this intercropping study.

Because the use of environmental resources in likely to be differenct from that of the monocrop situation when both crops are grown together simultaneously, environmental factors also must be monitored in order to asses value on intercropping.

With these broad objectives the present study was conducted at Massey University over 1983/84 summer to investigate the following aspect of intercropping soyabeans and maize.

1. To study the growth and yield response of maize and soyabeans to population in mixture.

2. To determine the combination of maize and cultivar of soyabeans that gives the highest yield advantage in the given intercropping pattern.

3. To obtain some information on the yield advantage for intercropping of maize and soyabeans.

Chapter One

REVIEW OF THE LITERATURE

1.1 Introduction

There are many systems of land use currently used by farmers to make their land productive. Crops are not always grown sequentially, but may be sown before previously sown crop has been harvested, or intermingled with another crop so that they both occuply the ground simulteneously. Exact classification is difficult, but the following terms have been recognised (Table 1.1).

Table 1.1. System of multiple land use.

Polyculture	-	A very general term used by Kass (1976) to describe mixed cropping or mixed intercropping, interplanting, interculture and relay planting.
Multiple cropping	-	Grwoing more than one crop on the same piece of land in a year (Dalrmple, 1971; Harwood, 1975; Andrews and Kassam, 1976).
Interplanting	-	Blanting short term annual crops amongst long term annual or biennial crops during the early stages of development of longer term crop (Ruthenberg, 1972).
Interculture	-	Arable crops grown under perennial crops (Ruthenberg, 1971).
Relay culture	-	The sowing of seeds or seedlings of a subsequent crop before the harvest of the first crop (Ruthenberg, 1971).
Mixed cropping	-	Growing two or more crops simultaneously and with no apparent arrangement into

rows, so that the crops are intermingled (Ruthenberg, 1971), Harwood, 1976).

Intercropping - Growing two or more crops simultaneously in row (Andrews and Kassam, 1976; Ruthenberg, 1971).

The term 'intercropping' is therefore used to describe a system in which more than one useful crop is grown simultaneously in the same area of land in one cropping season. This review will concentrate on the intercropping of maize and soyabeans, but will draw upon evidence from other crops where necessary.

1.2. The objectives and occurance of intercropping

The objective of intercropping are many and varied and depend on the location, scale and needs of the grower. In some cases the aim may be to miximise the yields of the main crop, often a cereal, and any additional production which comes from interplanted crops is viewed as profit (Rao and Willey, 1980), in other cases the farmer may be able to achieve higher yields from the crops when they are grown together than when they are grown alone (Fordham, 1983). However the scale of the operation may also influence the objective of thóse undertaking intercropping. For example when rubber and oil palm are grown as a large scale as plantation crops a creeping legume may be grown between the trees to control weeds or to the improve the level of soil nitrogen. But when rubber and oil palm are grown by a smallholder, crops may be planted between them to supplement food production, or to provide revenue during the early years before commercial yields are obtained from the rubber or oil palm treees.

Melon (Cococunthis vulgaris) may be grown as living mulch in melon-maize mixture to give effective weed control (Wahua, 1984), and implementation of this is being considered in Nigeria (Akobunda, 1981, IITA, 1979).

Another objective of intercropping is to minimize the risk of crop failure (Aiyer, 1949) and this is a common and frequently found objective of small farmers (Francis, 1985). Other objectives of intercopping are to reduce soil erosion (Norman, 1973), ensure a regular supply of food (Ruthenberg, 1980), and to make more efficient use of natural resouces (Willey, 1979a).

Many investigators have stressed the importance of intercropping in the tropics (Miracle, 1967, Wabster, 1966; Meads and Rilley; 1981); Beets, 1982; Pinchinat et al. 1975; Okigbo and Greenland, 1975). Dalrymple (1971) surveyed the occurance of multiple cropping systems in the tropics, and concluded that the practice of multiple cropping is wide spread. It is estimated that 98 percent of cowpeas (probably the most important legume grown in Africa) is grown in association with other crops (Anon, 1972). Francis and Flor (1985) estimated that in the tropical parts of Latin America, 60 percent of maize is grown in association with other crops. It is estimated that 5 to 6 percent of rice and 70 to 80 percent of other crops are grown in mixture in Indonesia (FAO, 1973), and in Taiwan 5 percent of sweet potato is relayed with rice (Chih Kung, 1975).

The systems of multiple land use adopted by farmers depend on the crops being grown and the aims and objectives of the farmer and are therefore very diverse. For example multi-story cropping is practical with coconut which lets sufficient light through its fronds so that shade tolerant plants can be grown beneath. These shade crops are frequently grown in the early years of the plantation before the coconuts produce an economic yield (Fordham, 1983, Nelliat et al. 1974).

In Malaysia, for example, coconut is grown on a substantial proportion of the country's cultivated land, most of which is managed by smallhoders. Most of the farmers benefit by the adoption of intercropped perennials such as cocoa, banana, pineapple, coffee, cloves, or annuals such as maize, chilli, cabbage, cauliflower, tomato and shallot (Denamany et al., 1980).

An alternative to the above system is to interplant fast growing, early maturing annuals crops, for example beans of soyabeans, between slower growing, longer term, annual crops, such as maize. This enables the fast maturing crop to exploit the natural resource available during the establishment of the slower growing crop. When these crops have matured, conditions again become more favourable for the growth of the remaining crop. This form of intercropping is particularly prevalent in regions having a single wet season (Fordham, 1983), and may be suitable in temperate regions where the wet season or summer period is too short to accommodate growth of succesive crops. For example maize is grown throughout the wet season in Central America, and beans are planted as the maize approaches physiological maturity and they then mature during the dry period (Delsligle et al., 1981).

In areas where the growing season is sufficiently long it may possible to intercrop two fast growing crops in succession with a third full season crop. Andrew (1974) described a system tried in Nigeria in which a long season cereal (Sorghum vulgare) was interplanted with a short maturing cereal (Pennistum millet or maize) followed by cowpeas.

Because of its dependence on hand labour, intercropping is not frequently practised in developed countries where labour is not readily available or is costly. However different species may still be intercropped in separate blocks so that the plants are sufficiently close to afford them some mutual benefit. This practice allows the use of machinery (Beets, 1982; Fordham, 1983). Strip intercropping in the USA is an example of this.

1.3. The effect of enviromental factors on successful intercropping

Most of the observations on the effect of climatic changes on intercropping involve crops grown in the tropics during wet and dry seasons. Maize-legume mixture have been found to be most advantageous when grown in dry seasons while maize-rice systems, on the other hand, more advantageous in wet season (IRRI, 1974). In the Philippines, Paner (1975) found that several legumes (mungbeans, peanut, and soyabeans) yielded more if planted one week before the harvest of maize grown during the dry season but there was no effect on the yield when the crops were planted during the wet season. This probabaly occured because plants grown during the wet season made more growth, so that competition between the plants was increased, as Reddy and Chaterjee, (1973) have suggested.

Intercropping systems are more common in dry areas and generally perform better in dry condition (Andrew and Kassam, 1975, Johda, 1976) perhaps because this system of land use makes more efficient use of water (Gupta and Mathia, 1961; Beet, 1976; Baldy, 1964; Willey, 1979). Ayer (1949) reported that the rooting depth of the component crop were different and other workers have suggested that the water use of these crops is different.

A number of authors have maintained that the crop with a shallow rooting system is forced to grow deeper roots becuase of competition with the other crop (Baldy, 1964; Whittington and O'Brian, 1968; IRRI, 1972; Fisher, 1976; Willey, 1979). It may thus be able to use water lower in the soil profile and be better able to sustain drought (Trenbath, 1974; Andrew, 1972). The same argument was used by Kassam and Stockinger (1973) who noted that sorghum plants in a millet-sorghum mixture were smaller and transpired less, and hence made a smaller demand on soil moisture than sorghum grown as a sole crop. Paner (1975) found that water consumption was greater in crops grown in mixture than in plants grown separately, and the total yield was also greater in the mixture. He concluded that intercropping made efficient use of moisture than did monocropping.

However, there is also evidence which indicates that because of high total consumptive use of water intercropping is not benificial in dry seasons. Singh (1973) got better results from a sorghum and soyabeans mixture in a wet year than in a dry year. Prine (1960) observed that maize intercropped with sorghum and soyabeans appeared to suffer more from drought than a monoculture of maize grown at the same time.

Light energy is instantly available to the plant and it must be used instantaneously and cannot be stored except as photosynthetically produced carbohydrate. When the canopy of one component of an association is set higher than that of another, the taller canopy intercepts the greater share of light. However the tall maize allows more light to reach the under-story crop. Francis (1976) reported that when the species were intercropped, normal size maize had less effect on yields of bush and climbing beans than dwarf maize and the attributed this to more intense competition for light when the beans were grown with the dwarf maize than with the of tall maize.

1.4 The effect of plant species and plant tupes on intercropping

Certain species such as cotton, peanut, and maize appear to perform much more succesfully in combination with other crops than do other plants (Kass, 1979). The most common combinations of species reported in the literature are those of a legume and non-legume, often a cereal (Beets, 1982). Although the relative yields in the mixture depend on the plants involved, many workers have reported that the yield of the legume in a cereal-legume mixture is reduced significantly (Willey and Osiru, 1972; Wahua and Miller, 1978; Dalal, 1974; Fisher, 1977; Beets, 1977).

The height of each plant component crop can influence the success of intercropping ventures. Reducing the shading or competative effect of a dominant cereal by selecting for shorter cultivars may increase the productivity of lower story crops (Andrew, 1972 & 1974; Davis et al. 1984). However evidence of the effect of plant height is conflicting. Graham and Lessma (1966) reported yields of shorter sorghums were lower than those of taller sorghum when grown as sole crops, in spite of greater light interception by the former, and yet Tarholkar and Rao (1975) reported that the shorter sorghum was better when intercropping in India, compared to traditional tall, late varieties. Bean yields were reported to be lower when the crop was planted together with dwarf maize than when it was planted with tall maize (Francis et al., 1976). In another study rice yields were much lower when intercropped with taller maize (IRRI, 1974).

The types of legume plant also has a significant influence on the performance of the taller cereal in the mixture. A deteminate growth pattern and medium to short plant habit appear to be desirable for some legumes (IRRI, 1972; Catedral and Lantican, 1978). A short-duration determinate soyabeans was more productive in intercropping than long-duration indeterminate cultivars (Tarholker and Rao, 1975). An erect determinate cowpea cultivar had less influence on maize than indeterminate ones (Wien and Nangju, 1976). The yield of tall hybrid maize grown with a determinate bush did not differ from that obtained from monocropped maize but when the same maize was grown with climbing beans, yield was reduced 37 percent (Francis et al. 1982).

As indicated above, the morphology of a plant can have a singificant effect on its effectiveness as a component of an intercropping system. Francis et al. (1876) listed the following characteristic which are desirable if two species are to be grown together:-

1. Insensitivity to photoperiod which will allow cultivars to be planted at any time during the year and give flexibility to the system so that planting can be made outside the traditional periods.

2. Early maturity which allows opportunities for designing pattern for intercrops with more crops per unit of time, either by adding a short-cycle legume after a main cereal crops, or planting them on the same day.

3 Short plants with erect leaf growth which allows light to reach the under-storey crop. These plants should be resistant to lodging.

4. Resposiveness to changes in populations which allows populations of the crops grown in the mixture be altered according to the current economic return, so that the best combination of crops giving the highest return may be grown.

1.5. The effect of cultural factors on intercropping

Crop yield is a function of yield per plant and the number of plants per unit area. In commercial agricultural production 'the crop' is normally a community of individual plants (Donald,1963) which all affect the plants nearby and in return all suffer some competition. Under these conditions yield per plant is relatively low, but since the number of plant per unit area is high, the total yield per unit area may also be high (Beets, 1982).

The role of the total population of plants and the effect of the proportion of each component species on the yield of intercropped plants have been reviewed by Willey (1979). Intercropping systems have been studied using a Replacement Model, where a proportion of one crop is substituted for a proportion of the other or, less frequently, an Additive Model is used where the population of one plant remains constant while an increasing number of plants of the second crop and planted amongst it (See Section 1.6).

In intercropping the densities of individual crops influence the yield and the yield component of each species, but recent results by Cartel et al. (1983) have suggested that a wide range of combinations of crop densities may give similar total yield and gross returns. However IRRI (1973) reported that the total yield obtained were higher when maize and rice were grown at a high maize population than with a low population of maize. The total yield obtained also increased as the population of the rice interplanted amongst the maize was increased. This suggested that each component of an intercropping system should be sown at its optimun plant population.

When the population of one species of an association is reduced, and the population of the other crop in the association increased the total yield may not be affected, but one crop may contributed more to the total yield (Willey and Osiru, 1972).

Studies of cereal-legume intercrops by many workers have indicated that the cereals can be grown over a wide range of spatial arrangements and appreaciable increases in legume yields can be achieved (Kassam 1972; Osiru and Willey, 1972; Wahua and Miller; 1978; Willey; 1979, Tariah and Wahua, 1985).

Investigations into these intercrops have generally shown that at equivalent populations, yields are higher when crops are arranged in rows rather than when both species are scattared randomly over the plot (Shannon and Lawson, 1975; Sayarifudin et al.; 1975). This may be due to better distribution of light within the canopy (Gooding, 1965). Dalai (1974) also found that levels of soil N were higher when maize and pigeon pea were intercropped rather than mixed cropped which he attributed to the inhibition of nodulation and nitrogen fixation in the pigeon pea when it was grown in close association with maize.

However when the rows of a component crop are arranged more closely the yield per m^2 may increase. Herrera and Harwood (1974), for example, found that the yield of maize grown at 1.4 m spacings between rows of rice, were higher than when the rows of maize were 2.8 m apart.

The spatial arrangment of the rows of plants within the intercropped plants may also influence the yield and yield components. As the plant species become more separated the advantages of intercropping are reduced (Andrew, 1972); Harrera and Harwood, 1974; Beets, 1982) since the interaction between the plant species may be reduced (IRRI, 1975). Generally planting single alternate rows of two crops gives grenter yield advantages for intercropping than other planting patterns (Beets, 1982), but the results depend on the morphology of the two species grown together. Greater yields of maize planted with various legumes (bush or pole beans, dwarf pigeon beans) in alternate rows were reported by IITA (1975) as compared to with planting these crops in bands of four wide. Chao (1975) reported that maize yields were higher when a row of maize was planted for every five rows of soyabeans.

1.6. Methods of eveluating intercropping

Reserach into intercropping is generally undertaken to determine whether this system of farming is more advantageous than growing crops in monocultures. There are a number of methods which can be used to compare the yields of crops grown alone or in mixtures. Haizel (1974) described the following methods:

1. Additive methods where the population of crop a is maintained at that comparable to the sole plots, and additional plants of species b are grown amongst them.

2. Substitutive method, where the total plant population in pure stands and in the mixture is the same.

3. And replacement series, where a certain number of plants of one crop species is regarded as being equivalent to a single plant of the other crops species and this relationship is used to determine the populations in the mixture.

Serious objections can be raised to the use of each of these methods. The additive method will probably result in populations in the crop mixture being too high (Donald, 1963) and any increase in yields obtained from the mixture may be attributable only to the higher plant population. Replacement experiments avoid this bias because the mixture and monoculture have the same total populations (De Wit, 1960). But the decision that one plant of one species is equivalent to a number of plants of another species is often completely arbitary, although a competive index may be calculated after suitable experimentation using the method described by Donald (1963). It is unlikely that plants grown in mixture derived from substitutive methods will be grown at populations which have proved to the optimum when the crops were grown as monocultures.

Nonetheless the additive method has been used by Agboola and Fayemi (1971), Evan adn Breedharan (1962) and Rao and Willey (1980; and the substitutive method by Anthony and Willimott (1957), Grimes (1962) and Dalai (1974); while the replacement series was used by Willey and Osiru (1972) and Osiru and Willey (1972).

While the methods of combining crop species have their shortcoming, there are a number of methods used to evaluate the yields obtained from intercropping plants and the effects of one component crop on other crops in the mixture, and there is much debate in the literature to the use of these.

Analysing yield of intercrops

Donald (1963) suggested that the simplest method of eveluating the yield of intercropped crops is to take the means of yields of the plants grown as pure stands, i.e. the mean of crops A and B, and compare it to the total yield obtained from the mixture. However because the two crops grown together are often dissimilar (e.g. coconuts and peanuts) the results obtained for most parameters are usually meaningless although yield may be assessed in this way. However when the two crops produce a similar product such as oats and barley grown for grain, or have similar usage such as rye grass and clover grown for forage the yields can be compared by this way.

Evan (1960) recommended that the yields of the two crops grown in mixtures be compared on an area basis and compared with the yield of each crops grown on half the area as pure a stand. This method, however, assumes that in the mixture the two crops were planted in equal proportions and this may not occur in the farmer's fields because the objectives for intercropping may be different. Despite this objection intercropping was most frequently evaluated by comparing the yield obtained with the yield obtained from half-hectare blocks of the crops grown as pure stands (Andrew, 1972). This method was later superseded by a method developed by van den Bergh (1968) and since then it has been adopted by others

(IRRI, 1974, 1975, Haizel, 1974; Pinchinat and Oelslighe, 1974 Francis et. al., 1975, Sastrawinata, 1976; Crookston, 1976). This method consisted of dividing the yield of each crop in the mixture by its yield in pure stand to obtain what van de Bergh (1968) called the 'relative yield'. The relative yields of each component crop is summed to obtain the 'relative yield total' (RYT), which is the yield obtained from a unit area of the intercrop relative to the yield obtained from the monocrop. This term was replaced by the term Land Equivalent Ratio (LER) by IRRI in 1974 and is defined as the amount of land area needed as monocrop to produce the same amount of yield as one hectare of intercropping (Mead and Willey, 1980; Bantilan and Harwood, 1973; deWit and van Den Bergh, 1965). If the LER is greater than one the yields obtained from the mixture are greater than those obtained from the separate sole crops and therefore intercropping is more beneficial than growing the crops seprately.

Land equivalent Ratio is amongst the method most frequently used methods to measure the biological efficiency of intercropping (Rilley, 1984; Willey, 1979). It not only shows the yield advantage or disadvantage of intercropping but the magnitude of this and can be adapted to situations where mixtures of more than two crops are grown and it is not restricted only to replacement experiment (Mead and Riley, 1981). However, because it is an index, LER gives no indication of absolute yields. Willey (1985) argued that the calculation of biological efficiency is not meant for practical evaluation of crop yields, and suggested the yield level associated within a given advantage or efficiency could be indicated by providing the yield of the sole crop on which the LER calculation is based.

Analysing plant competition

Other methods of determining whether intercropping is more advantageous than growing crops in monocultures have been derived from studies of plant competition. De Wit (1960) proposed a Relative Crowding coefficient and this was later examined by Hall (1974a, 1974b) who assumed that the mixture formed a replacement series. The yield of each crops grown in the mixture can be expressed relative to the yield obtained from a monocrop. In mixture of any proportion of two species, (a and b), the relative crowding coefficient of a is calculated as:

$$RCC_a = \frac{Mix_a}{(Sole_a - Mix_a)} \quad X \quad \frac{Sown_b}{Sown_a}$$

Where: RCC_a is the relative crowding coefficient of species a.

Mix_a and $sole_a$ are the yields of species grown as a mixture and a sole crop.

$Sown_a$ and $Sown_b$ are the sown proportion of species a and b in the mixture.

When the product of the coefficients of the two species is greater than one there is an advantage in intercropping. However this relative crowding coefficient does not give indication of the magnitude of the yield advantage.

William (1967) and McGilchrist (1965) development an analysis of replacement series experiments to measure the competitive abilities of species a relative to species b when they were sown in any proportion in mixture. McGilchrist and Trenbath (1971) developed this concept and proposed and Aggressivity Index. The Aggressivity of b in the mixture relative to a is calculated as:

$$A_b = \frac{Y_a}{S_a \text{ X } Sown_a} \quad \frac{Y_b}{S_a \text{ X } Sown_a}$$

Where: A_b is aggressivity of species b

Y_a and Y_b are the yields of species a and b in the mixture

S_a and S_b are the yields from pure stand,

$Sown_a$ and $Sown_b$ are the sown proportions of species a and b

The dominant species is indicated by a positive value and the greater the difference in agressivity index of the two crops the bigger the difference in the competitive ability of the two crop in the mixture will be. The major objection to this index is that it does not indicate the yield advantages of intercropping the two species.

Another method used to evaluate intercropping is the calculation of a Competitive Index as proposed by Donald (1963). This is the product of two equivalance factors of the two species in the mixture. The equivalence is the number of plants of species and which is equally competative to one plant of species b. Should a species have an equivalence factor of less than one it is more competitive in the intercrop than when it is a grown in the mixture. A Competitive Index of less than one indicates no advantage in mixing the crops. Willey (1979a) argued that though the concept is good, its practical use is limited in that the sole crops have to be planted at a range of plant population so that the equivalent plant number can be estimated.

A 'Competative Ratio' was proposed by Willey and Rao (1980) to quantify the degree of competition between component crops in an intercropping situation. This is simply a ratio of the individual Land equivalent Ratios of the two component crops, but corrected for the proportion of the crop initially sown. It indicates not only the competitive ability of each species but shows the relative productiivty of each species in the mixture. The main advantage of the index over other quantitative measures of competition, is that it can be applied to both additive and replacement experiments.

Although these indices have been derived from studies of plant competition between pasture species, the above indices have been used in the analysis of intercropping experiments and they give some indication of the advantages or disadvantages of mixing crops (Willey, 1979 a & b). Some dominated most research into competition (Mead and Stern, 1979). Mead and Riley (1981) in their comprehensive review of the methods available for analysis of data from intercropping experiments point out that there is no single straight forward method which is universally appropriate. Hence, Mead and Stern (1979) concluded that more than one analysis should be applied to intercropping data.

1.7. Advantages and disadvantages of intercropping

The advantages of intercropping have been reported by a number of workers (Andrew, 1972; Willey and Osiru, 1972; Willey, 1979) while other investigators claimed that sole cropping offered better production (Crookston, 1976) or yield stability (Harwood and Price, 1975) or affected the levels of pests and diseases within the crop or its fertilizer requirements.

Crop yields

In many parts of the world, maize is frequently intercropped with various legume species. Increases in the yield of maize have been reported in situation where the legume component has contributed to the nitrogen balance in the soil. For example, Fayemi (1971, 1972 a & b) found that in the absence of artifical fertilizer the yield of maize increased when it was intercropped with any of three different legumes (cowpea, calapogan, and greegram). Many other workers reported similar increases in the yield of maize when it was intercropped with other legumes such as soyabeans, African yambean, bush bean and lima bean (Pinchinat and Oelsligle, 1974; Singah et al., 1973). However there have many reports of mains yield being decreased in intercropping with velvetbeans (Mucuna sp.) (Viegas et al.,1960), with soyabeans (Glycine max)(Crookston, 1976), with cowpeas (Vigna ungiculata) (IITA, 1975).

In many cases the yield of each species has been reduced by intercropping (Donald,1963; Trenbath, 1974; Ahmed and Rao, 1981), and the yields of legumes were more affected than those of maize when they were grown together (Beets, 1982).

Comparisons between intercropping and monocropping are commonly based upon a Land Equivalent Ratio (LER) which is extensively used by IRRI (1974) and research during recent years has provided increasing evidence that a substantial yield advantage can be obtained from intercropping. Ahmed and Rao (1981) reported LER values up to 2.0 obtained from intercropped maize and soyabeans grown at various locations in their multi-location study. Several other investigators also reported LER values ranging from 1.2 to 1.6 (Alexander and Genter, 1962; Beste, 1978; Mokta and De, 1980; Sarifudin et. al., 1974). Combinations of values maize and beans have achieved LER values of 2 but, as can be seen from the summary of values presented in Table 1.2, LER values in the range 1.1 to 1.5 are more typical.

It can be seen from this table that LER values greater than one have been reported from many parts of the world and indicate that intercropping maize with legumes can prove successful.

Table 1.2. LER of maize intercropped with various legume crops at different locations.

Intercrop grown with maize	LER	Reference
Bean (Phaseolus vulgaris)	1.47	Francis et el., (1977), Columbia.
"	1.20	Oelsligle et. al., (1977) Costa Rica
"	1.20	Fisher, (1978), Kenya
Cowpea (Vigna sinensis)	1.53	Vandemeer et. al.,(1983), Mexico
"	1.41	Wahua et al., (1981), Nigeria
Soyabeans (Glycine max)	1.44	Francis et al., (1977), Columbia
"	1.02	Radke and Hagston, (1977), USA

Several investigators have evaluated the labour utilization and economic return of intercropping and monocropping of component crops (Norman et al., 1970; IRRI, 1973, 1974; Baker and Norman, 1975; Sastrawinata, 1976). In maize-legume systems, studies of the economic value of intercropping showed that maize planted at 60 cm x 30 cm spacings with a single row of soyabeans planted between tha maize rows was more profitable than pure maize planted at similar spacing (Narang, et al., 1969). Willey and Osiru (1972) reported that at the price ratio of maize to beans of 1:6 or 1:4, the mixture was more profitable than either maize or soyabeans grown as monocrops.

When grown with legumes, intercropped maize is often more profitable when the crops is grown as a monocrop because there is less need for nitrogen fertilizer which reduces the cost of production (Singh et al., 1974i IRRI, 1974; Oelsligle, 1974). The low level of nitrogen fertilizer required in this system would certainly be of great advantage to subsistance farmers in the tropics who usually apply little or no fertilizer.

However because of changes in the relative price of the products the economic evaluation of intercropping might be valid only at the time the evaluation is made. Thus Vanderneer et al., (1983) demostrated that when price of cowpeas at the lowest price the mixing of maize and the price of cowpeas presented an economic advantages but did not shows any advantage when the price was inflated to 50% of the lowest price.

Stability of yield

In many tropical countries agriculture is often carried out by small farmers, often at subsistence level. The main concern of these small farmers is to assure that the yields obtained are sufficient for their needs and stable from one season to another (Ruthernberg, 1980).

Growing plants as intercrops appears to suit them well because if one crop should fail, yields can still be harvested from tht other crop in a intercrop is reduced perhaps because of drought, temperature, or insects and diseases specific to that crop the other crop will compensate by using the available growth resource so that the yield obtained from this crop may be more than expected. Willey (1979) pointed out that this type of compensation is not possible if the crop are grown separately.

Many workers have examined the stability of yields from intercropping by combining several experiments over several years and analysing them using regression and have demonstrated that yields of intercrops were more stable than those of sole cropped plants (Rao and Willey, 1980 & 1981; Francis and Sanders, 1978). However several crops can be grown concurrently as monocultures so that the risk of crop failure is spread and there is some stability of total farm production. Even so Francis, (1985) has suggested that the gains are lower than those obtained from intercropping.

The chance of total crop failure is often lower in intercropped situations than in monocultures because, either environmental condition favour one crop, or differences in the suceptibility of different species to adverse conditions occur (Prine, 1960). Petil and Karaddi (1969) reported that cotton and peanut grown as intercrops were most profitable in years in which excessive raintall practically destroyed the cotton crop. Because of the chance of crop failure, Singh et al., (1973) even recomended that soyabeans should always be planted in mixtures. They reasoned that in India the chances of crop failure from virus and rust are so likely that the presence of an associated crop in the mixture could prevent a total loss.

Harwood and Price (1976) doubted the yield was more stable when plants were intercropped but based their hypothesis on results of an experiment which maize and rice were grown together for only one year. They pointed out that failure in a component crop often occur after considerable intercrop competation has occured so that the failed crop might still reduce the yield of the surviving crop. Harwood and Price conculuded that there was no real benefit to intercropping and the aim of intercropping should be to diversify crop production rather than to provide stability of yield. They suggested that crop failures at any stage during the growth could be overcome by replanting, but their evidence was based on a limited number of combination of crops (maize-mungbean, maize-rice, and maize-soyabeans) in which both crops generally had similar growth cycles and climatic requirements. Cases of drought cited by others (Andrews, 1972; CIMYYT, 1974) have generally occured too late in the season to be offset by replanting.

It is concluded that workers who measured yields from intercroppimg over several years generally found them to be more stable than those obtained from monocultures.

Nitrogen production

The main justification for choosing to grow legume and non legume species as intercrops is that the legumes may supply biological nitrogen to the non legume crop, thus reducing the need for artificial fertilizer or reducing the demand on organic nitrogen released by mineralization. Schilling (1965) found that at two sites in Senegal the total nitrogen of millet and sorguhm was increased by intercropping with peanuts. Other workers showed high nitrogen production in maize-pigeon peas (Dalal, 1974), or maize soyabeans mixture (Satrawinata, 1976) than when either crop was grown alone.

When a legume is involved in intercropping it is always possible that the nitrogen it fixes might be available to concurrently or subsequently grown crops (Agboola and Fayemi, 1972). In another experiment these workers showed tha over successive cropping seasons the legume they grew increased that nitrogen content of the top 30 cm of the soil by 23-30 kg/ha, and that this benefit the maize crop in the association. Further experiments showed that cowpeas released more soluble nitrogen through decomposition of crop residues.

The incidence of pest and diseases

The level of pests and diseases in plants grown together in intercropping systems has been reported to be lower than if the crops are grown as monocrops (Evan, 1969; Ruthenberg, 1971; Apple, 1972; Norman, 1974). For example in the Philippines interplantings peanut (Arachis hypogaea) in maize at maize population of 20000 to 40000 plants per hectare reduced the infestation of maize borer (Ostrinia furnacalis) (IRRI, 1973 & 1974). The research workers suggested that the occured because the peanut provided a better habitat for the spider (Hucosa spp.) which prayed upon the maize borers. However growing low populations of maize as monocrops also reduced the infestation of maize borer although not as much as by intercropping with peanut or soyabeans (Sastrawinata, 1976). Other workers reported that incidence of halo blight, common mosaic, anthracnose, angular leaf spot diseases were lower as were the number of armyworm and leaf beetles when maize and beans were grown in mixture (Rheenen et al. 1981; Altieri et al.1978).

Several mechanisms have been suggested to account for this reduction in the incidence of pests and diseases.

1. The spread of disease in reduced because the distance between suceptible plants is increased, and the presence of the second crop may act as a physical barrier between infected plants (Ayer, 1949; Chiang, 1978).

2. One species may serve as a 'trap crop' for a disease of pest to which the other plant is suceptible (Ayer, 1949; Trenbath, 1974).

3. Bilogical control of insects may be promoted because one species may provide a better habitat for the predators of the pests and these conditions may continue longer if the second crop is slow maturing so that the number of predators may increase (Litzinger and Moody, 1976; IRRI, 1973 & 1974).

Perrin (1977) discussed these mechanisms in his review and concluded that these effects will occur when insects are diverted either from one component crop to another which is less suceptibale, or when insects are actually repelled from the intercrops.

There are cases where intercropping has given rise to a increase in the incidence of pests and diseases. Van de Bergh (1968) suggested that one component of an intercropping system may carry viruses not harmful to itself but destructive to the associated species. Willey and Osiru (1972) noted that an attack of gall midges on beans pods (Phseolus vulgaris) seemed to be worse in mixtures of beans and maize because the mixture provided a more humid and shady environment. IRRI (1973) also reported an increase in the incidence of soyabean rust in suceptible varieties when it was interplanted. The disease became worse when the population of maize in the mixture was increased.

Other workers have reported that the incidence of leaf disease (cercopora leaf spot and rust) was increased in mungbean intercropped with maize (IRRI, 1974), and in peanuts grown with maize (IITA, 1975), and white mould and bean rust was increased in beans grown with maize (Van Rheenen et al. 1981). Ayer (1949) suggests a number of ways by which intercropping may increase the incidence pests and diseases:-

1. As the amount of cultivation of the soil is likely to be reduced when crops are grown as mixture reduce the soil aeration may be reduced so that less soil is exposed to light which favours the build up of the pathogen.

2. Greater shading by the associated species may increase the humidity and thus favour the spread of fiseases.

3. The associated species may serve as alternative host for pest and diseases.

4. and the residues of the first harvested crop may remain in the field as a source of inoculum for the later harvested crop.

There appear to be fewer differences between manoculture and intercropping in the incidence of plant diseases (Francis, 1985).

Mechanization

One of the main disadvantages of growing crops in mixture is the differences in maturation, height, nutrient requirements, suceptibility to pests and diseases and the final used of the end produced which make mechanisation difficult, and this is often cited as one of the main reasons against the use of intercropping. Intercropping of soyabeans and maize in southern U.S.A. declined because of this difficulty and because specific practices and mechanisation for monoculture were developed (Prine, 1960). However mechines can still be used in this system, especially for land preparation. While modern practices in developed countries may reduce the benefits of intercropping, it still offers considerable advantages in less developed countries where the use of machinery and chemicals remain low and labour is readily available. In these countries it is often desirable to use labour intensive production methods, rather than labour saving, mechanised techniques.

CHAPTER TWO

MATERIALS AND METHODS

2.1. Experimental layout

In order to investigate the effects of plant density on the yield of intercropped plants, an experiment was set up in 1983 on the No. 1 dairy farm at Massey University. Three populations of maize, cultivar Pioneer 3901 and two populations of two soyabeans cultivars (Matara and AMT) were combined in a 3x2x2 factorial experiment using a split plot design. The main plots were the three maize plots, and the four subplots were made up of combinations of soyabean cultivars and plant populations.

A nominal nine rows of maize were sown in each plot at 75 cm spacing but in each plot the second, fourth and sixth rows of maize were replaced by three rows of soyabeans, 25 cm apart, so that each intercropped plot contained a total of six rows of maize and nine rows of soyabeans (Figure 2.1). The maize was sown at 6, 8, 10 plants/m^2, and the soyabeans at 50 and 75 plants/m^2. Three plots of maize and two populations of each of the cultivars of soyabean were sown in areas adjacent to the experimental area at populations equivalent to those used in the intercropped plots so that estimate of monocrop yields could be obtained.

A path one metre wide was left between the subplots to allow easy access to the plots during the growth of the crops. After all the treatments were sown the area around the whole experiment was sown with the maize at 25 cm row spacings.

2.2. Cultural practices

The site, a Manawatu fine sandy loam, was chosen because it was considered to be well suited to maize growing. The experimental area was ploughed and rolled on the 14 october, and the soil was further cultivated on the 23 November with one pass of both power and dutch harrow. Three hundred kilogram of 30 percent potassic super and five kilograms thimet per hectare were broadcasted the day before sowing.

Germination tests made in the laboratory indicated that the germination of the seed was as follows: Maize cv Pioneer 3901, 98%;

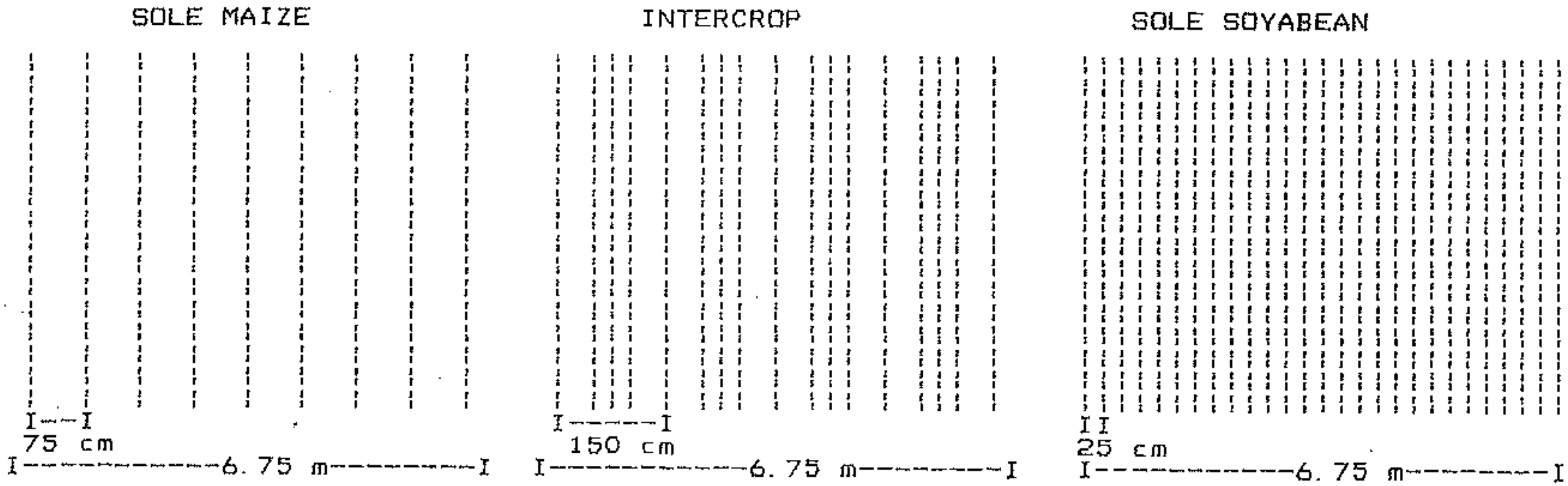

Figure 2.1: Plot size and planting pattern in the sole cropped and intercropped plots.

Soyabean cv AMT 99%; Soyabean cv Matara 98%. The soyabeans were inoculated the day before sowing with a commercial strain of Rhizobium japonicum marketed as a granular peat and then kept in a cool room until planting.

A small plot cone seeder was chosen to drill the crops because it was considered to sow small amounts of seed more accurately than a conventional drill. The amount of seed needed to sown each row of maize of soyabeans within each plot was calculated and preweighed before sowing and the drill was calibrated to distribute these seeds evenly over the 16 m rows making up each of the subplots.

On 24 November the main plots were sown. Two rows of maize were sown 1.5 m apart during each pass of the drill. The following day the spacing of the coulters was altered so that three rows of soyabeans could be sown at 25 cm spacings between the rows of maize at 25 cm spacing and the drill was again driven over the plots.

Alachlor at 1.7 kg a.i. per ha. was applied to the plots immediately after sowing to control weeds. The weeds which later grew in the plots following this pre-emergents treatment were hoed, and those growing between the blocks were cut by tractor-monunted mower in February.

A large flock of wild ducks discovered the experimental site on 3 December, just as the maize was beginning to emerge and they pulled up the germinating maize plants and ate the seeds. This caused considerable damage to the rows of maize, but the ducks ignored the emerging soyabean seedlings. Various measures were taken to control the ducks but they were largely ineffective and presoaked maize seeds were resown in the damaged plots during this period using a hand operated Masterplanter. The ducks left the area by 9 December and did not return so that the resown maize was not damaged as it germinated.

When 50 percent of the maize was silking plants were side dressed with urea at 100 kg per hectare but fertilizer was not applied to the soyabeans plots.

2.3 Sampling of vegetative material during growth

There were six sequential harvests carried out at intervals during the growing season. The first destructive harvest was made on 6 November, 44 days after sowing. A quadrat of 1.125 m^2 was taken across two rows of maize and three rows of soyabeans from the central rows of the first eight metres of each plot. A guard area of 2 m was left at the margin of each subplot and a length of 0.5 m was left around the areas previously sampled when subsequent vegetative harvest were made. An area of 1.125 m^2 was also sampled from each of the areas of maize and soyabeans grown as monocrops along side the experimental area.

As the season progressed and the plants grew bigger a large amount of material was harvested at each sampling so that harvesting frequently took two days to complete. The maize plants in each sample were cut to ground level and taken to a cool room within the laboratory and the following day the soyabean plants within each area were sampled. In the laboratory the number of plants were counted, the number of tillers and branches recorded and the height of each plant measured. The plants were then divided into leaf and stem fractions. At the fifth harvest both the maize and soyabeans plants had begun to flower and the amount of reproductive tissue on each was also determined. The plant components were dried in a forced draught oven at 80^{o}C for 48 to 96 hours before dry weight determinations were made.

At each harvest the leaf area of the soyabeans and maize plants were measured with a Li-cor leaf area meter and the leaf area index calculated. The leaf area of the lamina taken drom the main stems and the tillers of maize plants was measured separately, while in soyabeans the area of the leaf and petiole was measured. Young unexpanded leaves were not spread before being passed through the machine, so that only the photosynthetic area of exposed tissue was measured. The photosynthetic area of other parts of the plants were not measured. After the fourth harvest plants began to senesce and the leaves with more than 50 percent senenscent tissue were not measured.

2.4 Final Harvest

The final harvest of the maize and soyabeans was made in early May 1984 when the presence of a black layer within the maize cob indicated that the crop had physiologically matured. Both soyabean cultivars had matured earlier (Matara in late March, Amt in April) but stood in the field without damage until the maize was ready for harvest.

The harvest area of 5.0 m^2 was taken from the central rows of the 8 m portion of the plots not previously sampled and again this sample was of two rows of maize and three rows of soyabeans. Because of the size of the crop, sampling was again carried out over two days. At harvest the number of plants and tillers was recorded and ten randomly selected plants were harvested and transported to the laboratory. Grain yield, the components of yield, plant height and total dry matter were measured. The cobs on the plants remaining in the sampled area were counted, harvested, oven dried and used to determine the total grain yield of the area.

Twenty soyabean plents were randomly selected from the sample and transported to laboratory for similar analysis. The rest of soyabean plants in the sample area were counted, harvested and threshed and oven dried to determine the total grain yield of the area.

2.5 Light measurement

Light interception was estimated from measurement of photosynthetically active radiation measured over the range 400-700 mm on a portable light meter (L-135) placed within the canopied of one replicate of the experiment and within the sole crops. The incident light was monitored above, below and within the canopies between 12.00 noon and 1.00 PM the day before each harvest.

The sensor of the meter was mounted on a two and half metre pole and could be slid along its length. The light reading was raken by placing the pole first in the row of maize, and then in the soyabeans between the rows of maize (Figure 2.2). The sensor was moved up the pole to the height of the maize canopy, then lowered down the pole to ground level. In the soyabeans, the readings were taken at the top of the soyabean canopy and at ground level. In the monocrops the readings were taken in a similar manner above and at groung level.

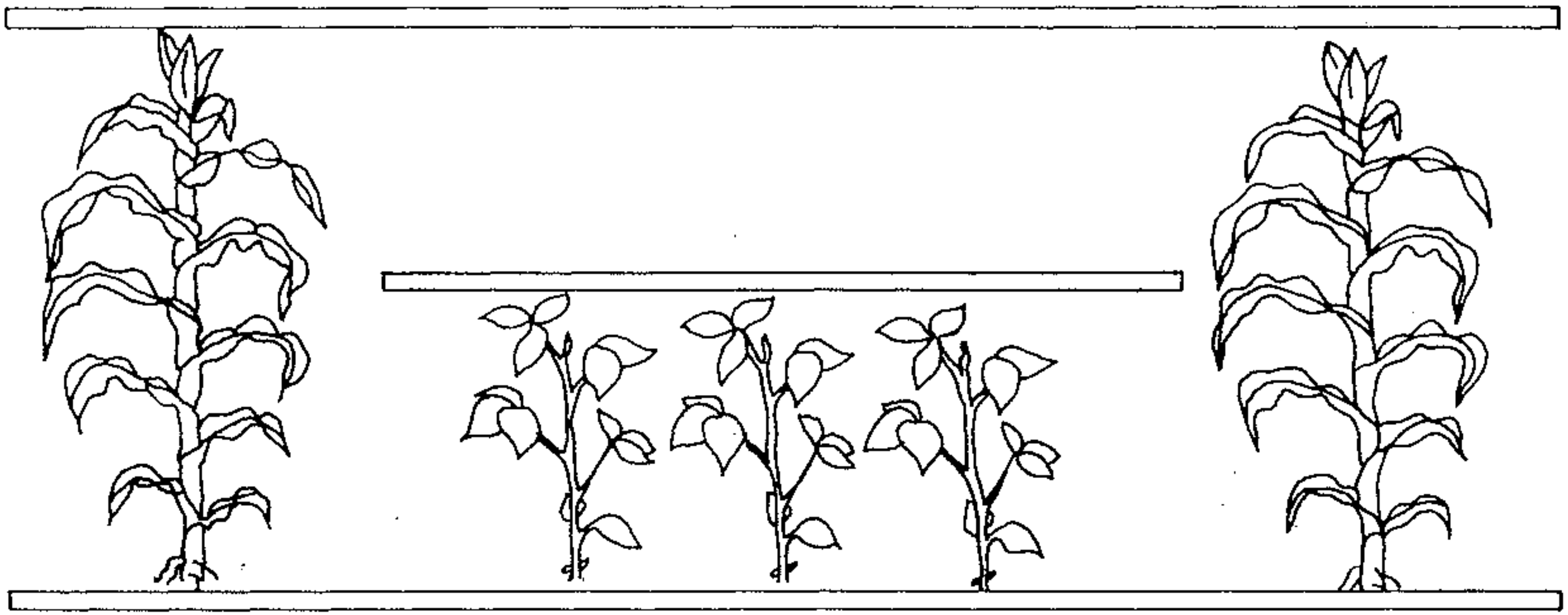

Figure 2.2: Positions for light measurement in the intercropping plots. The horizontal bars indicate the heights at which light measurements were made.

2.6 Methods of calculation

i) Combining yields of maize and soyabeans

The methods was first used by Willey and Osiru (1972). The total yield of the maize and soyabeans grown as intercrops is compared with the yields obtained from a similar area of sole crops - in this case two thirds maize, one third soyabeans (Figure 2.1).

ii) Land Equivalent Ration (LER)

Using the notation of Mead and Willey (1980), Land Equivalent Ration can be calculated with the following formula:

$$LER = LER_a + LER_b$$

$$= \frac{Y_a}{S_a} + \frac{Y_b}{S_b}$$

Where: LER_a and LER_b are the Land Equivalent Ratios of the individual intercrop components

Y_a and Y_b are the crop yields of the individual crops grown together in the intercrop.

S_a and S_b are the yields of the crops grown as sole crops.

The highest yields obtained from sole crops of maize and soyabeans are used to calculate the total LER.

iii) The ratio of summed grain yield to that of maize

The method was first used by Chiu and Shibles (1984) and is calculated using the formula:

$$YR = \frac{Y_t}{Y_m}$$

Where: YR is the ratio between the combined yields of the intercropped plots.

Y_t is the total yield of maize and soyabeans in the intercrop.

Y_m is the yield of monocropped maize.

This method is based upon the assumption that maize is the main crop, and the combining of crops is only considered to be succesful if no loss in the yield of maize occur as the result of adding the second crop. The second crop is therefore seen to provide additional rather than compensatory yield.

The highest grain yield obtained from the sole crop population of maize is used as a reference point.

iv) Competitive ration (CR)

Willey and Rao (1980) developed a method of calculating competitive ratio using the formula:

$$CR_a = \frac{LER_a}{LER_b} \times \frac{Z_b}{Z_b}$$

Where: CR_a is the Competitive Ratio for crop a

Z_a and Z_b are the ratio between the areas within the intercropped plots sown with each crop.

LER_a and LER_b are the Land Equivalent Ratios of the Individual intercrop components.

In this experiment, two thirds of the area was allocated to maize and one third to soyabeans (Figure 2.2).

Chapter Three

RESULTS

3.1 Climate

The monthly rainfall recorded at the experimental site over the 1983/84 growing season was similar to that recorded at the Palmerston North D.S.I.R. Grasslands Division's meteorological station, 0.9 Km away. The season was generally drier than usual and the mean daily air temperature was lower than usual during the period November to February but higher than normal during the remainder of the growing season (Table 3.1).

Table 3.1. Average daily rainfall and temperature recorded during the 1983/84 growing season.

Monthly rainfall (mm)				Mean daily temperature (C^{o})		
Eaperimental Site	D.S.I.R 1983-84 season	Longterm average 1928-80	Deviation from normal	Longterm average 1928-80	D.S.I.R. 1983-84 season	Deviation from normal
Nov -	54	78	-24	14.2	13.8	-0.4
Dec 59	68	94	-26	16.6	15.5	-0.9
Jan 39	35	79	-44	17.3	16.2	-1.1
Feb 82	91	67	+24	17.6	17.1	-0.5
Mar 99	114	69	+45	16.4	17.5	+1.1
Apr 38	39	81	-42	13.9	14.1	+0.2
May 94	96	89	+7	10.9	11.1	+0.2

3.2 Plant growth and development

Maize

The maize plants emerged ten days after sowing, but some plots were damaged by ducks. When these plots were resown it was not possible to retain the original seeding rates, and the plant populations were higher than originally planned. Both the early sown maize and the resown plants grew well and 56 days after sowing these plants were visually difficult to distinguish. There were no problems with plant disease or insect infestation. Some maize plants died during the growing season so that the plant number counted at final harvest were lower than those taken at emergence (Table 3.2). The results reported here have been calculated using plant counts taken at final harvest.

Table 3.2: Plant population of maize at emergence and final harvest

Plant Population	Expected population at sowing (plants/m²)	Plants counted at emergence (plants/m²)	Plant populaation at harvest (plants/m²)
Mixture:			
D1	6	8.4b	5.6c
D2	8	9.0b	9.0b
D3	10	13.0a	11.9a
LSD		3.20	1.01
Sole crop:			
D1	6	6.0	5.7
D2	8	9.0	8.7
Maize	10	12.0	11.5

Values not followed by the same differ at p=0.05

Some maize plants produced tillers but many tillers were weak and spindly and died during later growth so that by the final harvest there were only, on average, 0.2 tillers per plant.

Maize plants grew to be over 2.0 m in height and this was not significantly affected by maize population or the cultivars of soyabean planted amongst them, but height was slightly increased when the population of soyabeans planted among the maize was increased (Table 3.3).

Table 3.3: Effect of maize population, cultivars and population of soyabeans on the height of maize at final harvest.

	Plant height (m)
Maize population	
D1	2.20a
D2	2.31a
D3	2.33a
LSD	0.182
Soyabean cultivars:	
Amt	2.27a
Matara	2.29a
Soyabeans population:	
SI	2.22b
S2	2.34a
LSD	0.089
Interactions	-

Values not followed by the same letter differ at p=0.05

In both the intercropped and monocropped maize plots the first tassels began to emerge 63 days after sowing, and the number of tasseling plants appeared to be higher at higher populations.. The first silks appeared 77 days after sowing.

Soyabeans

Both soyabean cultivars emerged seven days after sowing. Not all the soyabean seeds planted germinated and plant populations were lower than orginally planned (Table 3.4). Like the maize, some soyabean plants died during the growing season and so that the counts taken at final harvest were lower those taken earlier.

Table 3.4: Plant population of soyabeans at emergence and final harvest

Soyabean population	Expected population at sowing (plants/m²)	Plant counted at emergence (plants/m²)	Plant population at harvest (plants/m²)
Mixture:			
SI	50	48.9a	44.4b
S2	75	67.1b	60.9a
LSD		5.66	5.62
Sole crop:			
S1	50	45.0	43.2
S2	75	64.0	60.0

Values not followed by the same letter differ at p=0.05

Some nodules were noted on roots of soyabean seedling 21 days after emergence. Forty four days after sowing half of the soyabean plants in all plots in the mixture had nodulated as had about 35 percent of soyabean plants grown alone. More Matara plants appeared to be nodulated than AMT plants and most of the sampled plants then had between 15 and 20 nodules per plant.

When soyabeans were grown in association with maize, plants averaged 1.3 branches per plant compared with 2.2 branches per plant on each monocultured plant. When grown in association with maize Matara plants produced fewer branches than AMT but in both cultivars the number of branches decreased when the population of soyabeans was increased.

The height of both cultivars of soyabean increased as the population of soyabeans was increased. Matara plants were taller than those of AMT and the population of maize had no effect on the height of the soyabean plants (Table 3.6). When grown in association with maize Matara plants produced the first flower 69 after sowing, but AMT plants began to flower 14 days later.

The leaves of the soyabeans plants began to yellow 90 days after sowing and in the monocroped plots had completely abscissed 141 days after sowing, but senescence was delayed by about 20 days when soyabeans were grown amongst maize. On 23 March the leaves remaining on plants within an area of per m^2 were scored on a one to ten scale (1 = leaves fully retained, 10 = no leaf).

Averaged over all treatments, the soyabeans plants in intercropped plots had an average score of about 4.4, while soyabeans in the sole plots had a score of 2.2. AMT retained more leaves (8.7) and had more leaf cover than Matara (0.7) (Table 3.5). The population of maize had no effect on leaf abscision of leaves of the soyabeans in the mixture.

Table 3.5. The effect of the population of maize, cultivars and population of soyabeans on the plant height, number of branches, leaf abcission and lodging of soyabeans.

	Plant height (cm)	Number of branches per plant	Leaf-fail (Score at 141 days)	Lodging (Score at 141 days)
Maize population				
D1	82.7a	1.7b	5.1a	3.9a
D2	83.8a	2.0a	5.8a	3.5a
D3	81.4a	1.8b	5.5a	2.9a
LSD	48.41	0.25	0.53	1.25
Soyabean Cultivars				
AMT	80.0b	2.2a	1.7b	1.5b
Matara	85.5a	1.5b	9.3a	5.4a
Soyabean population				
S1	79.8b	2.3a	5.9a	2.0b

(continue Table: 3.5)

	Plant height (cm)	Number of branches per plant	Leaf-fail (Score at 141 days)	Lodging (Score at 141 days)
S2	85.6a	1.3b	5.0b	4.9a
LSD	4.10	0.32	0.21	1.50
Interactions	-	-	-	-
Sole				
Soyabeans (S2)	80.0	2.2	0.0	1.0

Values not followed by the same letter differ at p=0.05.

Towards the end of the podding period, both cultivars of soyabeans lodged when they grown between the rows of maize, however no lodging occured in the soyabeans grown as a sole crop. The amount of lodging was also scored on a 1 to 10 scale (1 : no lodging, 10 : fully lodged). Matara lodged more than AMT but lodging tended to decrease as the population of maize in the mixture increased (Table 3.5).

3.3 Dry matter yield

Maize

When the population of maize in the association was increased from 5.6 to 11.9 plants per m^2 the dry weight of each maize plant decreased, but the total dry matter increased from 1.63 to 2.89 Kg/m^2 (Table 3.6). Neither the population nor cultivar of soyabeans had any effect on the dry weight of the maize plants. Maize grown at heigher populations yielded more total dry matter per m^2 than when plants were grown at lower populations (Figure 3.1), and the differences largely occured early in the growing season. Neither the cultivars of soyabeans nor the population of soyabeans had any effect on the total dry matter accumulated by the maize in the mixture (Figure 3.2).

Table: 3.6 The effect of maize population and cultivars and population of soyabeans on total dry matter, yield and harvest index of maize.

	Dry matter per plant (g/plant)	Dry matter (Kg/m^2)	Grain yield (g/m^2)	Grain yield from tillers (g/m^2)	Harvest index (%)
Maize population					
D1	291.0a	1.63c	794a	307a	48.9a
D2	253.1b	2.26b	1185b	199b	52.0a
D3	242.4c	2.89a	1522c	30b	52.7b
LSD	21.72	0.240	151.9	125.3	2.81
Soyabeans cultivars:					
AMT	257.4a	2.21a	1144a	173a	51.0a
Matara	267.6a	2.31a	1190a	185a	51.1a
Soyabeans population:					
S1	255.1a	2.25a	1167a	164a	51.4a
S2	271.7a	2.27a	1167a	194a	51.1a
LSD	18.30	0.161	160.6	64.2	1.81
Interactions	-	-	-	-	-
Sole crop:					
D1	285.5		830		51.0
D2	270.4		1200		51.0
D3	282.0		1750		52.0

Values not followed by the same letter differ at p=0.05

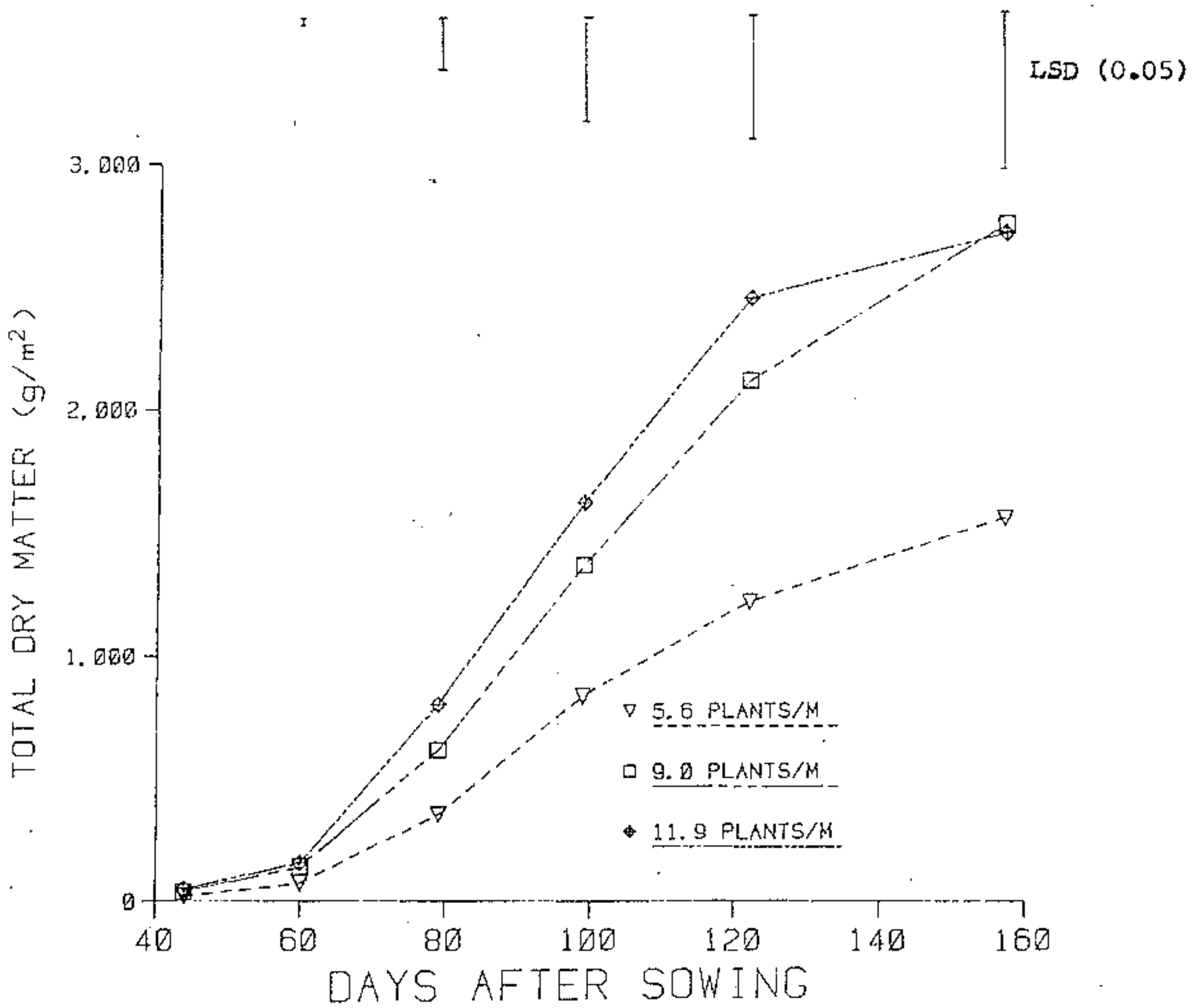

Figure 3.1: The effect of maize population on the total dry matter of maize accumulated during the growing season.

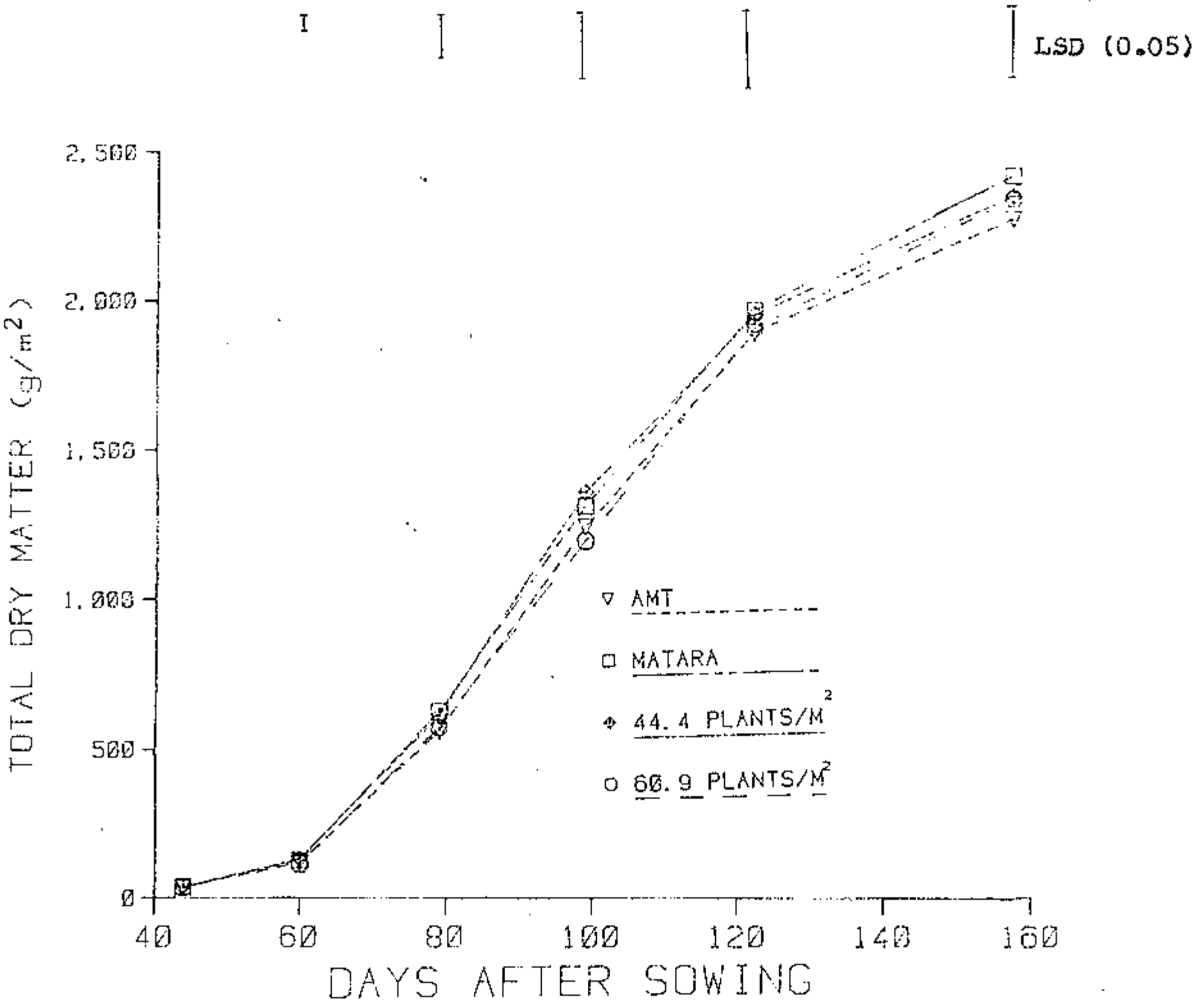

Figure 3.2: The effect of cultivars and population of soyabeans on the total dry matter of maize accumulated during the growing season.

When the population of maize in the association was increased from 5.6 to 11.9 plants per m^2 the grain yield of maize increased linearly from 0.794 to 1.522 Kg/m^2 but was not affected by the population of cultivar of soyabeans (Table 3.6). The relationship was described by the following equation:

$$y_m = 186.\ 5 + 110.9\ x \quad (r=0.94,\ p=0.05,\ n=48) \quad \ldots\ldots \quad (3.1)$$

Where: y_m is grain yield per m^2

x is the population of maize in the intercrop.

Fitting a quadratic equation did not increase the amount of variation accounted by the plant population. Although the yield of maize from all density treatments in the association appeared to be lower than that of the sole crop, this was based upon a single quadrat of 4.5 m^2.

Many of the tillers which survived until final harvest produced cobs which were often huskless or contained grain and tassel-like structures, and almost all of these ears suffered bird damage or broke off during field drying so they did not contribute greatly to final harvest. However some of these tillers did produce normal ears and 38 percent of the grain yield obtained from plants at population 5.6 plants per m^2 came from tillers (Table 3.6). The number of tillers produced by each maize plant, the yield obtained from each tiller and the weight of a hundred seeds were all reduced as the population of maize in the mixture was increased (Table 3.7).

The harvest index of the maize crop increased when the population of maize increased but was not affected by the cultivar or the population of soyabeans. Maize plants grown alone had a similar harvest index.

Table: 3.7 The affects of population of maize and the cultivars and popilation of soyabeans on the yield components of maize.

	Total Yield (g/plant)	Number of tillers per plant	Number of ears per plant	Number of seeds per ear	100 grain weight (g)
Maize population					
D1	141.9a	0.50a	1.01a	466a	29.91a
D2	131.2b	0.24b	1.01 a	454a	28.53b
D3	127.2b	0.04	1.02a	457a	27.86b
LSD	11.9	0.114	1.03	27.30	0.88
Soyabean cultivars:					
Amt	131.9a	0.26a	1.00a	458.3a	28.8a
Matara	136.5a	0.25a	1.01a	459.4a	28.8a
Soyabeans population					
S1	134.2a	0.23a	1.01a	451.4a	28.3a
S2	134.2b	0.28a	1.03a	466.3a	29.2a
LSD	7.30	0.10	0.13	17.2	1.30
Interactions	-	-	-	-	-

Values not followed by the same letter differ at p=0.05.

Soyabeans

Matara plants were larger (13.4 g/plant) than those of AMT (10.2 g/plant) and plants size in both cultuvars was reduced as the population of soyabeans was increased but was not affected by the population of maize (Table 3.8). Soyabeans plants tended to be larger when they were grown as sole crops but again this estimate is based upon a single quadrat of 4.5 m^2 taken at final harvest.

Early in the season there was little difference in the total dry matter of both cultivars, but by the end of the growth period Matara and accumulated more total dry matter than AMT (Figure 3.3). However the dry matter yields (g/m^2) of these soyabeans grown amongst maize was not affected by the population of maize throughtout the growth of the crop (Figure 3.4).

Grain yields of the soyabeans were not affected by the population of maize (Table 3.8). However there was a significant interaction between the cultivar and the plant population. In Matara the grain yield rose as plant population was increased and yield of 336 g/m^2 was obtained. However in AMT the grain yield was not affected by similar increase in plant population. A similar interaction between cultivar and population was shown when the harvest index was calculated (Table 3.9).

Table: 3.8 The effect of maize population and cultivars and population of soyabeans on total dry matter, grain yield and harvest index of soyabean.

	Total dry matter per (g/plant)	Total dry matter (g/m^2)	Grain yield of soyabens (g/m^2)	Harvest Index (%)
Maize population				
D1	12.0a	599a	266.0a	44.6a
D2	12.3a	570a	273.6a	45.4a
D3	11.0a	596a	255.5a	43.2a
LSD	1.35	69.9	24.34	3.60

(continued Table 3.8)

	Total dry matter per (g/plant)	Total dry matter (g/m^2)	Grain yield of soyabeans (g/m^2)	Harvest Index (%)
LSD	1.35	69.9	24.34	3.60
Soyabean cultivars:				
Amt	10.2b	546b	215.5a	39.2b
Matara	13.4a	630a	314.5b	50.1a
Soyabeans Population:				
S1	13.1a	564a	260.8a	46.2a
S2	10.4b	612b	269.5a	43.1a
LSD	1.49	49.9	23.2	12.40
Interactions	-	-	Cv X S*	Cv X 8*
Sole Crop:				
Soyabean	14.3		412.9	48

Values not dollowed by the sama letter differ at p=0.05.

* significant at p=0.05.

Table: 3.9. The effect of cultivars and population of soyabeans on the grain yield and harvest index of soyabeans.

	Yield (g/m^2)		Harvest Index	
	Soyabean population		Soyabean population	
	S1	S2	S1	S2
Soyabean cultivars:				
Amt	229.2	201.9	42.0	36.4
Matara	292.5	336.6	50.5	49.7
LSD	32.81		3.51	

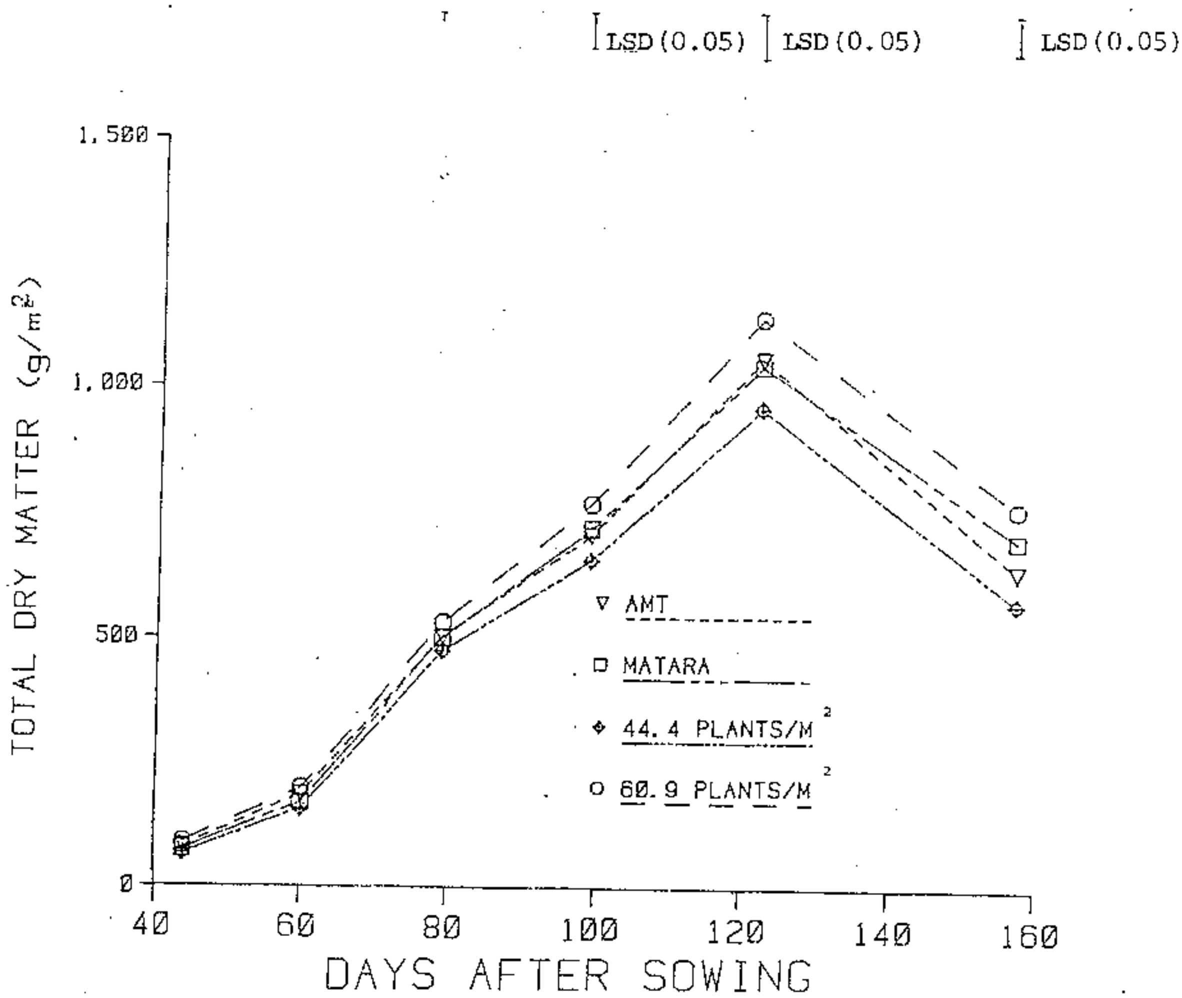

Figure 3.3: The effect of the soyabeans cultivars and the population on soyabeans on the total dry matter of soyabeans accumulated during the growing season.

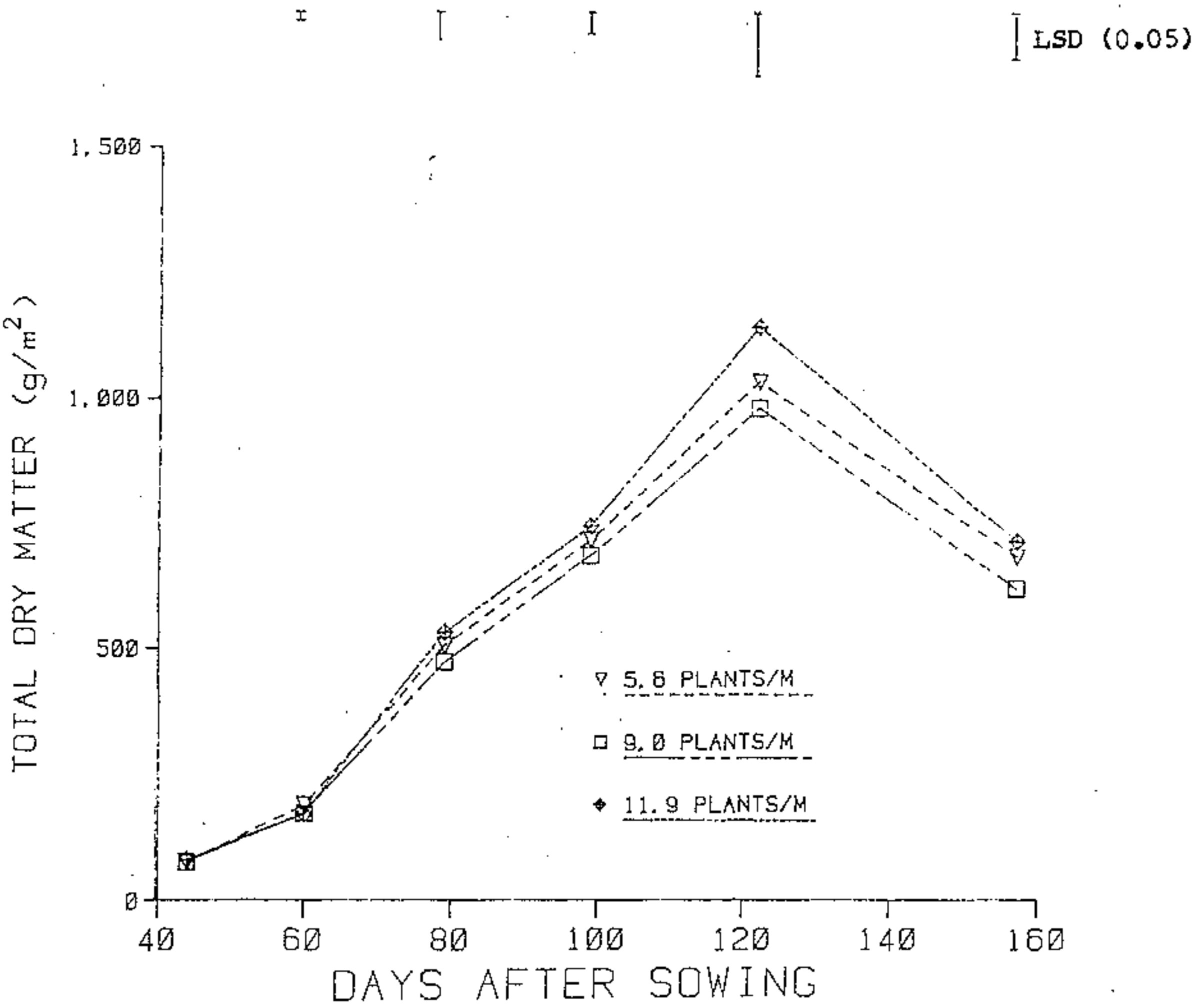

Figure 3.4: The effect of the maize population on the total dry matter of soyabeans accumulated during the growing season.

Grain yields of up to 5.4 g per plant were obtained from soyabeans. The number of pods on each plant was reduced as the population of maize was increased, however this had no effect on the other component of soyabean yield (Table 3.10). More grain was obtained from Matara than from AMT, and the individual seeds were larger although all other components of yield were the same (Table 3.10).

Table: 3.10. Effect of maize popuplation and cultivars and population of soyabeans on yield components of soyabeans.

	Total yield per plant (g)	Number of pod per plant	Number of seed per pod	100 grain weight (g)
Maize population				
D1	5.47a	19.9a	1.7a	17.0a
D2	5.68a	19.5a	1.7a	17.1a
D3	5.03a	17.7b	1.7a	15.9a
LSD	0.70	1.4	0.18	1.42
Soyabean cultivars:				
Amt	4.1b	18.9a	1.6a	13.4b
Matara	6.7a	19.3a	1.8a	19.8a
Soyabean population				
S1	6.1a	21.1a	1.7a	17.2a
S2	4.7b	16.9b	1.7a	16.3a
LSD	0.79	2.40	1.90	1.18
Interactions	-	-	-	-
Sole crop: soyabean				

Value not followed by the same letter differ at p=0.05.

3.4. Estimation of yields from intercropped plots

Three methods were used to calculate yields from intercropped plots (summation of yields, LER, and yield ratio) and results are shown in Table 3.11. The highest grain yields obtained from the monocrop maize and monocrop soyabeans were used as comparison for all these methods. These were 1750 g per m^2 from maize at 11.5 plants per m^2 and 412 per m^2 g per m^2 at 60 plants per m^2 of soyabeans.

Summation of yields of component crops

When the grain yield of the maize and soyabean components of each plot were summed, total grain yields up to 1785 g per m^2 were obtained (Table 3.11) and yield could be described by the following equation:

$$Y_t = 477 + 108x \; (r^2=0.88,\ p=0.05,\ n=48) \ldots\ldots.. \quad (3.2)$$

where: Y_t is the total grain yield obtained from maize and soyabeans

X is the population of maize in the mixture.

Although the population of soyabeans had no effect, Matara contributed more to the combined grain yield than did AMT.

Land Equivalant Ration (LER)

As the population of maize in the mixture increased the LER also increased and this was mainly associated with increases in the maize component of the LER (Table 3.11). As in the previous method of calculation, Matara contributed more to the total combined yield of the intercrop than did AMT. There was a significant interaction between cultivar and population of soyabeans which indicated that the yield advantage from intercropping increased when the population of Matara was increased but no such an increase was observed when the population of AMT was increased.

The yield ratio

The Ratio of the combined yield from intercropped plots to the total yield of monocropped maize was first calculated by Chui and Shibles (1984). When the population of maize grown in the mixture was increased, Table: 3.11. Three methods of estimating the effect of maize population, cultivars and population of soyabeans on total grain yield of the intercropped plots.

	Summation of yields (Kg/m^2)	Estimation of LER			Ratio of combined yields
		LER of the maize component	LER of the soyabean component	Total LER	
Maize population					
D1	1060c	0.45c	0.64a	1.09c	0.61a
D2	1450b	0.68b	0.64a	1.32b	0.83b
D3	1785a	0.87a	0.64a	1.51a	1.02a
LSD	163.2	0.08	0.06	1.128	0.17
Soyabean cultivars:					
Amt	1359b	0.68a	0.52b	1.20b	0.77b
Matara	1504a	0.71a	0.76a	a.47a	0.86a
Soyabeans population					
S1	1427b	0.70a	0.63a	1.33a	0.82a
S2	1427b	0.69a	0.65a	1.34a	0.82a
LSD	161	0.092	0.06	0.16	0.058
Interactions	-	-	Cv x S*	Cv x S*	

	Population of soyabean					
	S1	S2	S1	S2	S1	S2
Soyabean cultivars:						
AMT	0.67	0.64	0.55	0.49	1.22	1.13
Matara	0.66	0.70	0.71	0.81	1.37	1.51
LSD	0.086		0.082		0.117	

	Summation of yields
Sole Crop:	
1:2 Sown proportion of maize and soyabeans	1304

Value not followed by the same letter differ at p=0.05

* Significant at p=0.05.

the ratio between the summed yield of the intercrop and the grain yield of the sole crop maize increased (Table (3.11), and the relationship could be described as:

$$Y_r = 0.3 + 0.06\,x \quad (r=0.92, p=0.05, n=48) \ldots\ldots (3.3)$$

where = Y_r is the ratio of the total grain yield of the intercrop
x is the population of maize in the mixture.

Substitution in the equation will give a ratio greater than one when the population of maize is increased beyong 11 plants per m^2. The highest ratio obtained from the experiment was 1.06 which was obtained from plots in which the maize was grown at 12 plants per m^2 and Matara at 61 plants per m^2.

As in the previous calculations the highest ratio was obtained when maize was grown in association with Matara and growing AMT or changing the population of soyabean plant did not increase the ratio.

3.5. Competition between maize and soyabean plants

The Competative Ratio (CR) indicates how much one crop out yields the other, and hence provides and estimate how much more competitive it is in the mixture. This ratio has recently been proposed by Willey and Rao (1980).

Maize was more competitive than soyabeans (Table 3.12), and when maize was planted at about 12 plants per m^2 the yield was 3.12 times that of soyabeans. Matara was more competative than AMT so that it was grown amongst maize it yielded more than AMT. The cultivars and populations of soyabeans had no effect on the competitive ability of either maize or soyabeans in the mixture.

3.6. Leaf area indices and light interception

The leaf area index of maize was increased markedly when the population of maize in the intercrop was increased, and reached a maximum of 6.1 99 days after sowing (Figure 3.5). Neither the cultivar nor the population of soyabeans had any effect upon the leaf area index of maize grown in the mixture (Figure 3.6). The maize plants grown in the mixture and alone remained photosynthetically active until the onset of frost in early May.

Table: 3.12. The effect of maize population, cultivars and population of soyabeans on the competitive ratio of maize and soyabeans.

	Competitive ratio of maize	Competitive ratio of soyabeans
Maize population		
D1	1.49c	0.72a
D2	2.27b	0.47b
D3	3.12a	0.38c
LSD	0.559	0.096
Soyabean cultivars:		
Matara	2.72a	0.45a
Amt	1.85b	0.60b
Soyabean population		
S1	2.21a	0.52a
S2	2.28a	0.52a
LSD	0.33	0.072
Interaction	-	-

Values not followed by the same letter differ at $p=0.05$.

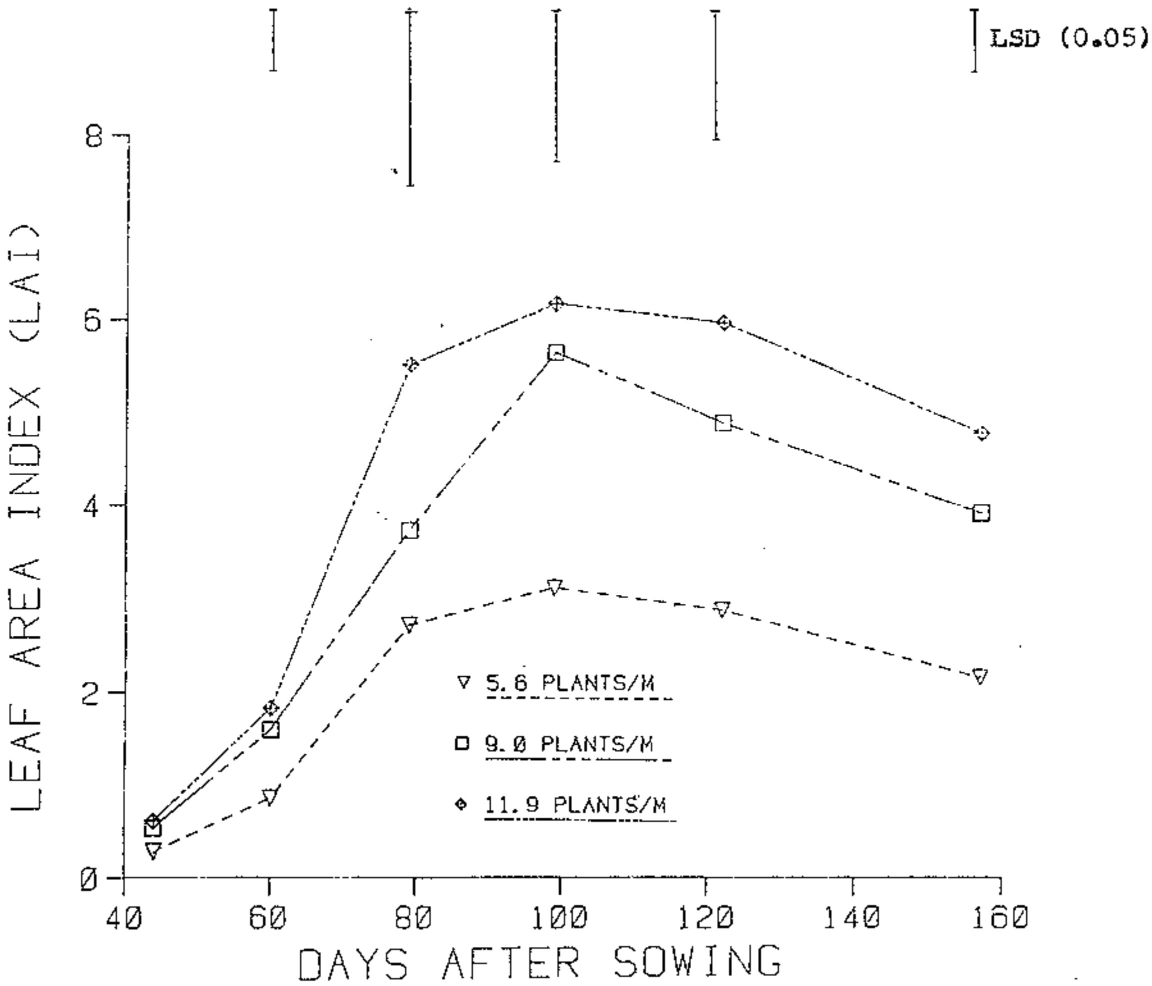

Figure 3.5: The effect of maize population on the leaf area index of the intercropped maize.

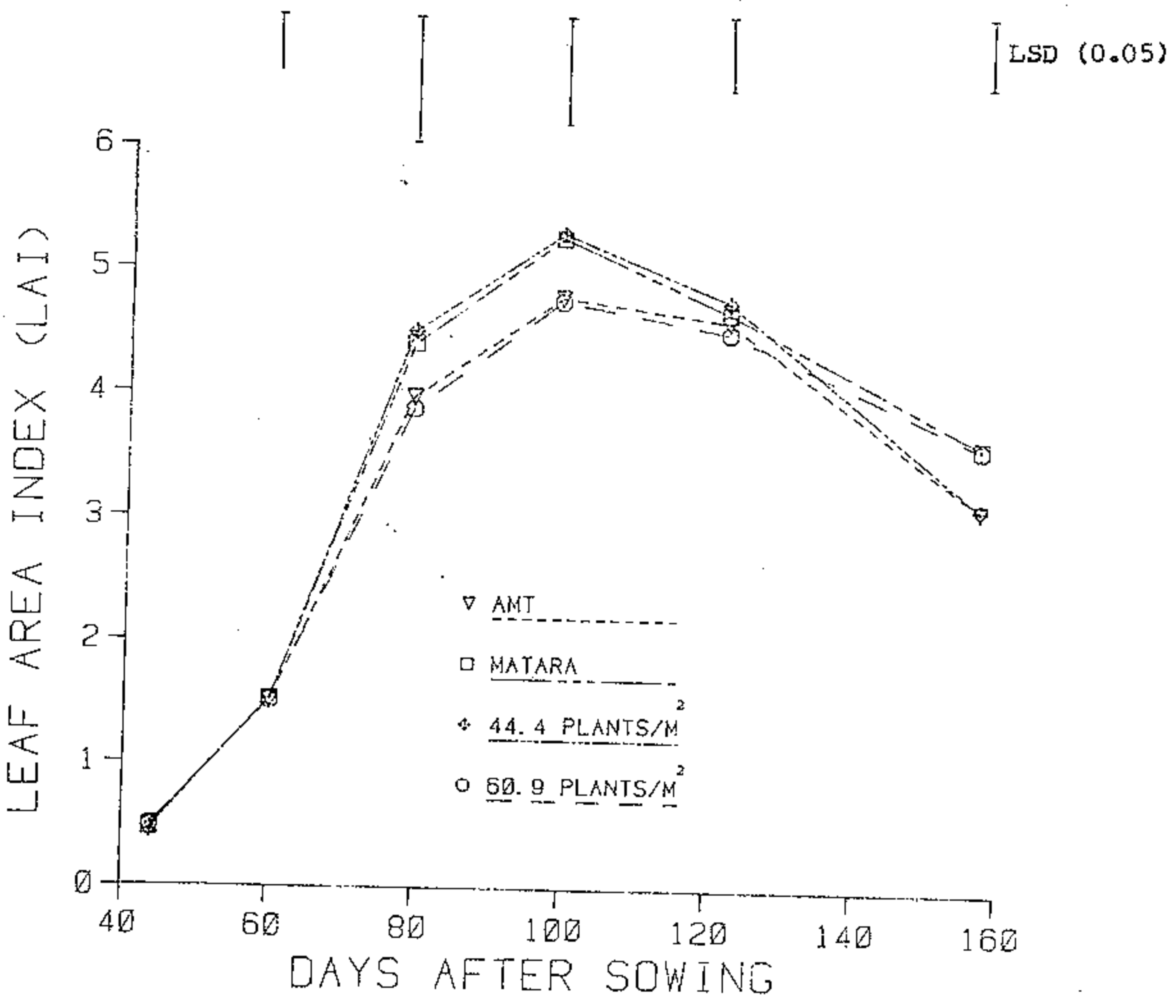

Figure 3.6: The effect of the cultivars and populations of soyabeans on the leaf area index of the intercropped maize.

The leaf area index of Matara was higher than that of AMT, and 99 days after sowing attained a maximum measured value of 5.83 compared with a leaf area index of 4.73 for AMT. Both cultivars of soyabean lost their leaves earlier when grown as sole crops than they did when grown amongst maize. As AMT retained its leaves more than 14 days longer than Matara the difference in the leaf area index of the two cultivars increased towards the end of the growing season. The population of maize had no effect on the leaf area index of the soyabeans, except towards the end of the growing season when the leaf area index of the soyabeans was reduced as the population increase (Figure 3.7) because the soyabeans grown at high populations of maize tended to have higher leaf fall (Table 3.5).

The measurement taken in the intercropped plots between the rows of maize indicated that the amount of light received at the top of soyabean canopy was not reduced as the population of maize was increased (Table 3.13). However as the season progressed and the maize grew, less light was recorded at the top of soyabean canopy. Very little of the light reaching the top of maize or soyabean canopies reached ground level, although some light did get through once the leaves fell from the soyabean plants.

Table: 3.13: Light attenuation in soyabean-maize intercrop canopy

	Light within the crop canopy (% of incident light)			
Days after sowing	Maize population	Top of maize	Top of soyabeans	ground level
94	D1	100	80.0	0.0
	D2	100	81.0	0.0
	D3	100	82.0	0.0
119	D1	100	52.7	2.3
	D2	100	54.7	0.3
	D3	100	51.6	0.0
149	D1	100	50.3	18.0
	D2	100	50.5	12.0
	D3	100	48.9	0.9

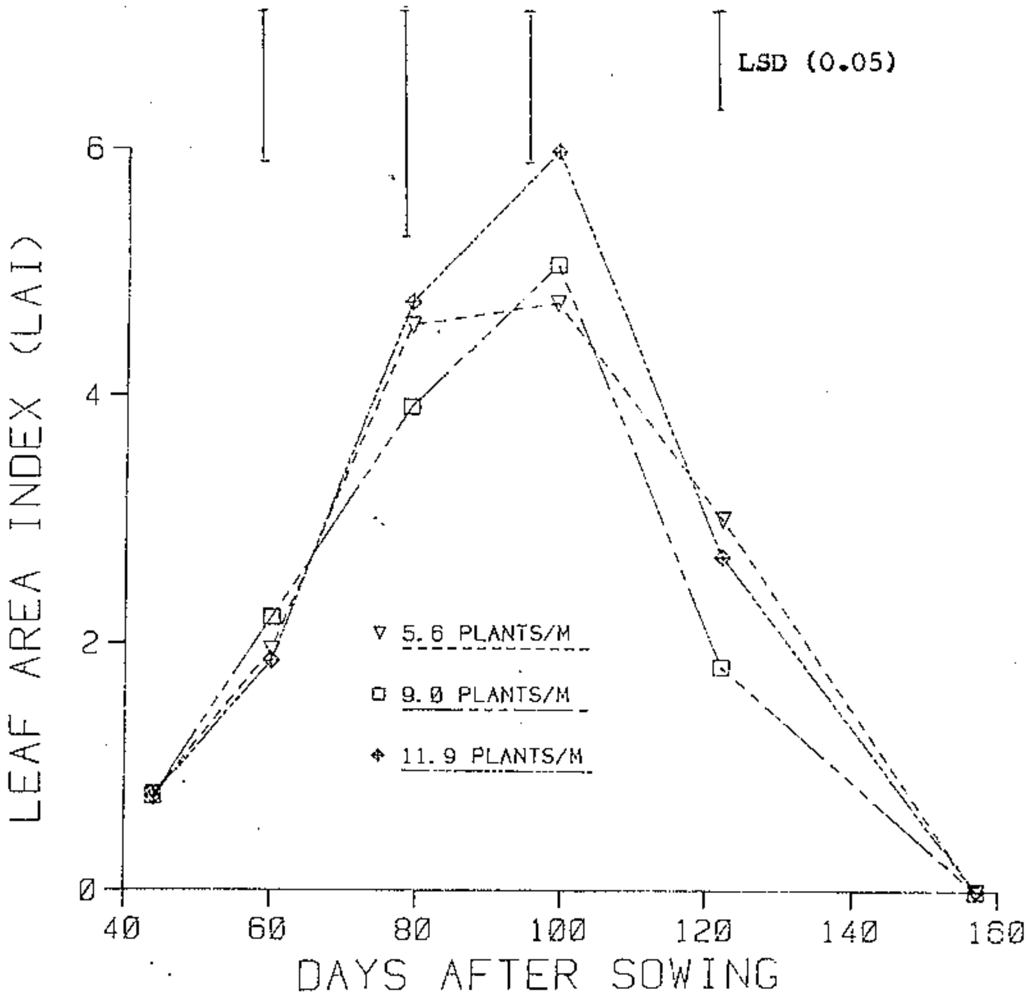

Figure 3.7: The effect of the population of maize on the leaf area index of intercropped soyabeans.

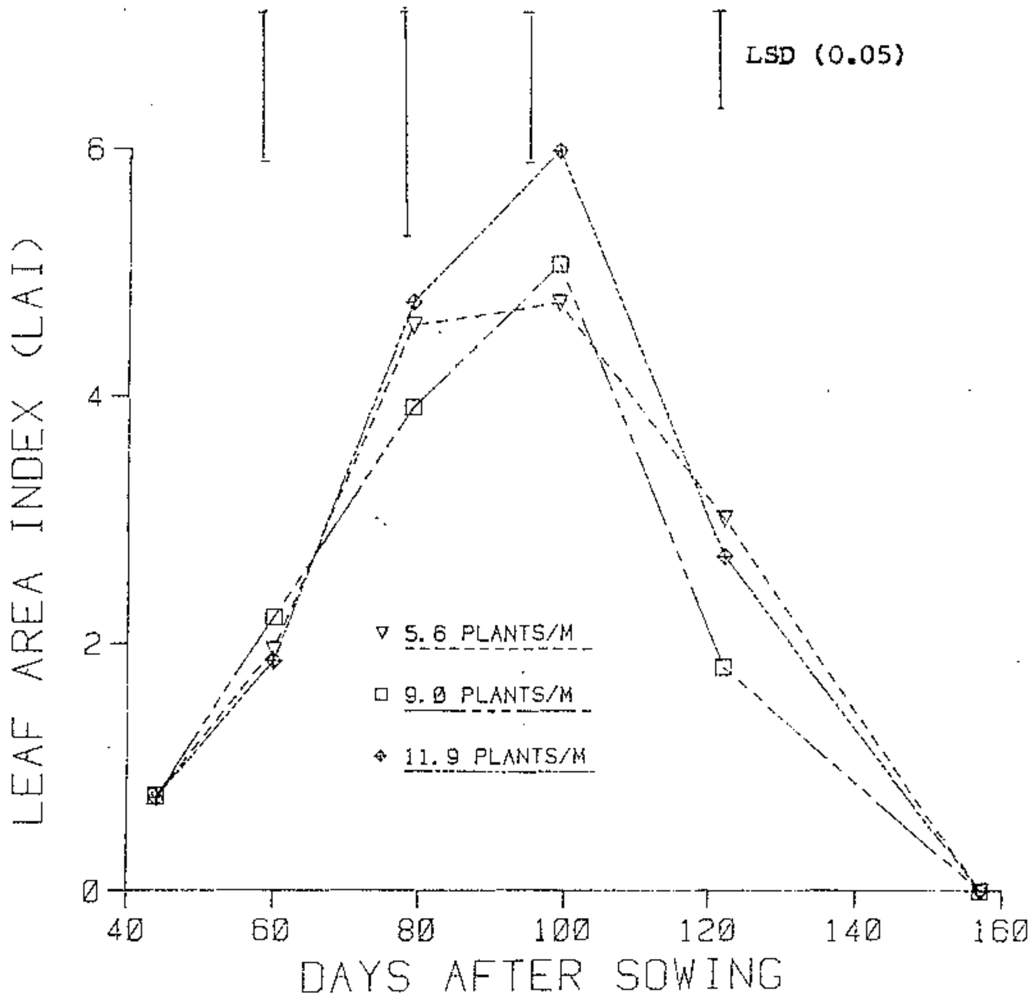

Figure 3.7: The effect of the population of maize on the leaf area index of intercropped soyabeans.

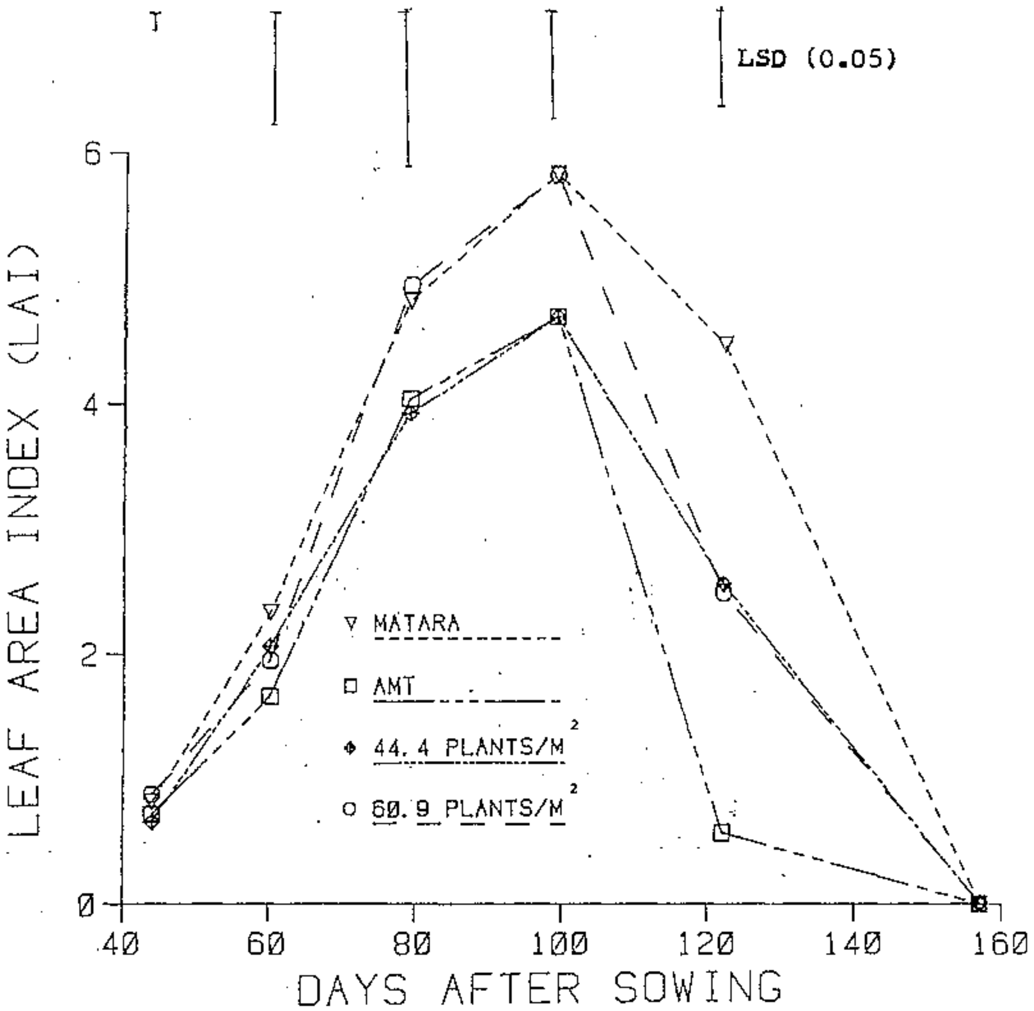

Figure 3.8: The effect of the cultivars and population of soyabeans on the leaf area index of intercropped soyabeans.

CHAPTER FOUR

DISCUSSION

4.1. Yield and growth of soyabeans and maize

The damage to the maize plants brought by the ducks and the subsequent resowing undoubtely altered the plant populations from those originally planned (Table 3.2) but although the final populations were higher than planned the anticipated differences in treatment population were maintained. Although no visible differences in plant size were apparent 56 days after sowing the differences in the growth of the original and resown plants may have masked the differences in the growth and yield of maize plants grown with soyabeans.

Comparisons between intercropped and sole cropped plots may not be statistically valid because the sole plots were not included in the designed experiment but were grown along side the experimental area and were not replicated. At harvest only one sample was taken from the sole crop plots so that no estimate of the variance of these yields is available. Nevertheless the yields obtained from intercropped and monocropped plots provide a good estimate of the production of the plots because a large area of each crop (4.5 m^2) was taken at harvest. The calculation of Land Equivalent Ratio (LER) and the yield ratio was not affected by this experimental design because the yields from the sole crop plots are used as a constant in the calculation.

The favourable summer temperatures and adequate rainfall over the growing season, which was supplement by irrigation meant that both crops grew well and grain yields of up tö 1522 g per m^2 were obtained from the intercropped soyabeans (Table 3.9). These yields were similar to those obtained by others working with maize and soyabeans grown as sole crops. (Gerlach et. al, 1971; Piggot et al. 1980; Dyson 1972; Douglas, 1975; Kerr, 1975; McCormick and Douglas, 1975). However the yield obtained from the intercropped plots was higher than the average grain yield of 675 g/m^2 of commercial crops grown in the Manawatu in the 1982/83 season (New Zealand Department of Statistits, 1984).

Although the yield obtained from each maize plant of the maize was reduced as the population increased (Table 3.10) the total grain yield obtained per m^2 was increased (Table 3.6), because the loss of yield from each plant was compensated for by the increase in plant number.

This is a typical response of maize to increase in population, and indicates that the planting of 6 and 8 plants/m^2 were below the optimum population for this cultivar. The increase in grain yield showed no sign of flattening as **plant** population was increased to 10 plants/m^2 (Equation 3.1) which suggests that the optimum population for this cultivar, Pioneer 3901, was not reached in this experiment.

The maize population had no effect on the grain yield of the components of yield of the soyabeans (Table 3.9). Neither the population or the cultivars of soyabeans had any effect on the growth and yeild of maize. This may be expected because the competition coefficients calculated for crops (3.1 maize and 0,4 soyabeans) (Table 3.12) indicated that the maize dominated the much shorter soyabean plants. The planting pattern (Figure 2.1) and orientation of the intercropped maize and soyabeans rows in a North-South direction minimised the competition for light between these two plants. Although the maize plants received a greater share of incoming light, they still allowed light to reach the top of soyabean canopy and this was not ifluenced by the population of maize in the mixture (Table 3.13). The soyabean rows were at least 50 cm away from the adjacent rows of maize and were unlikely to have any significant influence on the growth and yield of the maize in the mixture. Since nitrogen was applied to the maize close to the plants and away from the soyabeans the nitrogen requirement of the maize plants may well have been met from this applied nitrogen. The presence of nodules on soyabeans plants in the mixtures suggests that soyabeans were able to obtain their nitrogen requirement from N-fixation. Thus it seems possible that the maize and soyabeans plants grown in this mixture were not competing for light or nitrogen fertilizer.

Matara yielded 315 g/m^2, more than the 216 g/m^2 obtained from AMT (Table 3.8). This was associated with a higher yield of grain per plant and larger seeds (Table 3.10). Matara accumulated more total dry matter throughout the growth period than AMT (Figure 3.3), and this contributed to the grain yield. The Manawatu has been considered to be marginal area for soyabeans and Matara has been bred as a cool tolerant soyabean and has been recently released for growing in this area (J.A.D. Anderson, Pers. comm.). Yields of 307 g/m^2 have reported for BD-18-2-12 which was the code used for Matara in early trials (McCormick and Anderson, 1981). The earlier maturing Matara was more competitive than AMT (Table 3.12) which may also have been contributed to the higher yields obtained in this experiment. In this experiment Matara produced higher yields and matured 14 days earlier so does appear to better suited the to Manawatu.

The population of soyabeans had no effect on the LAI (Figure 3.8), accumulation of dry matter (Figure 3.3) and the yields of soyabeans in the mixture (Table 3.8) probably due to the use of relatively wide row spacings (25 cm) in this experiment. Brown et al, (1971) and Dougherty (1962) concluded that reducing the spacing to 17.5 cm between rows resulted in higher yields.

Matara had a higher leaf index throughout its growth, with a peak LAI of 5.8, compared with AMT at 4.7 (Figure 3.8), and this contributed to the higher grain yield and growth in Matara. Beets (1982) suggested that a higher LAI generally leads to more photosythesis.

Matara plants tended to lodge more than those of AMT when planted between the rows of maize and plants tended to lodge more when the population was increased. There was no lodging in monocropped soyabeans (Table 3.5). It is possible that the lodging in intercropped plots occured because a small amount of competition for light occured and tended to increase the height of soyabeans (Table 3.5). Because lodging occured late in the season when seed development was almost complete and was not very severe, it had little effect on the seed yield of the intercropped soyabeans. Recent trials have shown that a new cultivar, Maple Arrow, has produced better yields than Matara, and is likely to replace Matara in commercial sole crop production (J.A.D. Anderson, per comm.).

4.2 Evaluation of intercropping

In most tropical countries where agricultural land is limited the purpose of most intercropping is to miximise land utilisation. The LER has been frequently used to evaluate land productivity in order to standardise yields for comparison between years, dissimilar planting practices, and even species (Mead and Willey, 1980).

There are times, however, when the aim of combining crops is to attain a full yield of one crop and some additional yield of the other crop. Such a requirement may occur when one crop is a staple food and the other is cash crop. Many examples of this cropping system occur in India (Mead and Willey, 1908; Willey, 1979) in Mexico (Vandermer, 1983), and in the maize-peanut intercropping system used in Malaysia. LER values greater than one may show that intercropping is more successful than sole cropping but these values may occur without the production of a full yield of maize so that, the use of LER does not always given an indication of the value of intercropping to the farmers.

In this experiment the mixture of maize and soyabeans was examined using a replacement model. As the optimum plant population for maize cv Pioneer 3901 was not pracisely known three populations were chose to cover the range of populations found to be optimum for other cultivars (Douglas and Dyson, 1972; Edmeads, 1972). As the optimum populations of the two cultivars of soyabeans used in this experiment were also not known exactly, it was not possible to use the concept of 'plant unit' developed by Willey and Osiru (1972). Instead the replacement was based upon the area of land occupied by each crop so that two thirds of the area was occupied by maize and one third by soyabeans but the relationship between the of plants depended on the populations sown in each plot. A similar approach was used by Beets (1976) when growing a mixture of maize and soyabeans. This meant that the changes in the yield of the intercrops was largely due tothe changes in the population of the component crops in the mixture, and calculation of LER values were based on maximum yields obtained which were not necessarily the optimum yields. Further work is required to define the optimum plant population of the estimation of LER is to be improved.

As the maize and soyabeans plants in the mixture were planted over two thirds and one third of the total area (Figure 2.1) so that a comparison could be made between the yields from the intercropped plots and from the monocropped yield, combined in 2:1 ratio. The underlying assumption in this method of calculation is that when these crops are sown as sole crops the grain yield obtained per m^2 is similar to that obtained when the crops are grown as a mixture (Willey and Osiru, 1972). This may not always true because the competition occuring between crops may be different from that occuring between plants of the same species.

A total yield of 1785 g per m^2 was obtained in this experiment (Table 3.11) which was higher than the yield of 1304 g per m^2 calculated by summing the yield from two thirds of a square meter of the sole maize crop and one third of a square meter of sole crop soyabeans. These calculations were made in accordance with the procedures yield by Willey and Osiru (1972).

The LER and the ratio of the total yields of intercropped and monocropped maize (yield ratio) indicated the area of land that would be needed to produce from sole crops the same amount yields as that produced by a unit area of the mixture, but this calculation does not take into consideration a farmers requirement to produce a fixed amount of one of the component crops. Should the farmer aim to produce a full yield of maize and yet gain some yields from the supplementry crop (as in the case of the Malaysian small farmer) the advantage of intercropping is better evaluated by calculating the total yield as suggested by Mead and Willey (1980) and Chui and Shibles (1984). Under thid situation the yield obtained from the second crop in the mixture indicated yield advantage in intercropping.

The result in Table 3.11 showed that LER values were greater than one which means that larger areas of land area are needed to produce similar yields if the crops are grown separately than if they are intercropped. A LER value of 1.5 was obtained when maize was planted at 11.9 plants/m^2 (Table 3.11) and this value was also obtained when Matara was interplanted at 61 plants/m^2 (Table 3.11) which suggests that growing maize and Matara together at their highest populations made better use of land than growing them separately. Substitution in the equation (3.2) indicated that a yield of 477 g per m^2 would be obtained when the maize population was zero which is similar to the 412 g/m^2 obtained when sole cropped Matara was planted at 61 plants/m^2. This meant that reducing the number of maize plants in the association from 11.9 plants to zero would produce a similar yield of soyabeans as when the soyabeans were grown alone and confirmed that there was little competition occuring between maize and soyabean plants.

The use of a yield ratio for comparing the yields of intercropped and monocropped maize may provide a better estimate of the yield advantages of intercropping. In this experiment the use of this method resulted in a yield advantage of 1.03 when maize was grown at 11.9 plants/m^2 (Table 3.11). Substitution in the equation (3.3) showed that the ratio was less than one when the population of maize was less than 11 plants per m^2 and soyabeans in the intercrop did not supplement maize. Similar finding had been reported by Chui and Shibles (1984) in mixture of maize and soyabean.

This means that the success of an intercropped mixture can depend on the populations at which the component plants are sown. The results show that when the maize population in the soyabean-maize intercrop was reduced the competitive ability of the maize was reduced, and the competitiveness of the soyabeans increased (Table 3.12), but the competitive ratio remained less than one, which suggested that there was little competition between the maize and soyabeans plants at all populations of maize. If the primary objective of intercropping is to maintain the yield of maize then planting this cultivar of maize at lower populations could not give a yield advantage. However the small farmer may still consider intercropping advantageous if he is willing to sacrifice the small amount of yield lost from the maize fo an equivalent yield of soyabeans. If the economic value of the soyabeans is higher than that of maize the farmer may be more ready to accept these yields.

The yield advantage shown by soyabeans was not affected by increasing the population of these soyabeans (Table 3.11). The yield per plant of soyabean decreased as the population increased (Table 3.9) which suggested that the contribution of soyabeans to total yield and therefore the yield advantage of intercropping may be affected by further increases in soyabean population. However further work is required to determine the effect of soyaben population on the yield advantage.

The maize and soyabean grown in this experiment matured at different periods. Matara mature at least 14 days before AMT and attained higher LAI in the growing season (Figure 3.8) so that it received a greater share of light. This means that the earlier maturing Matara and maize mixtures had at least 14 days difference in temporal use of resources than the AMT and maize mixture. This temporal differenct enable more light to reach soyabean canopy before maize leaf had fully developed.

The grain yields obtained from AMT were lower than those obtained from Matara (Table 3.8) so that when maize was interplanted with Matara the yield advantage was larger than that obtained from interplanting of AMT (Table 3.11). The shorter maturity of Matara means that temporal difference between the maize-Matara mixtures were greater than they were for maize-AMT mixtures so that the former made better temporal use of light and other growth resources. Similar conclusions have been reported by Willey (1979a; Baker, 1974 and Baker and Yusof, 1974). The choice of the cultivar that is best suited to intercropping is there fore important. If the yield advantages is the only consideration then Matara is a better choice for intercropping with maize than AMT, but if lodgingis considered a problem, it may be better to include AMT in the intercrop, as in this experiment this cultivar lodged less.

Evaluation of methods for calculating yields from intercropping

LER value of calculations of the total combined yield of intercrops is based upon the sole crop yields from plant populations that produced the highest yields. Huxley and Maigu (1978) emphasised that all intercrop yields should be compared with the sole crop grown at its optimum population and Mead and Willey (1980) also recomended this should be done. The highest densities of maize and Matara which produced the best yields of 175 g/m^2 were used for comparision of the productivity of the intercrop. However different values can be obtained by basing these calculation on other seed yields obtained from the sole crops. Using values for sole crop yields other than those which produced maximum yields would give rise to higher values for LER or the yield ratio. In this experiment high LER values, yield ratios or high total combined yields of the intercrop could result from successful growth of plants grown in the mixture or poor growth of plants grown as sole crops so that the result could tend to be biased towards intercropping. It is indeed unfortunate that a better estimates of the sole crop yields were not obtained.

Both the LER values and the yield ratio indicate that intercropping was advantageous only when maize was grown at the highest population but the yield advantage calculated using the yield ratio method was almost half of that calculated using LER (Table 3.11). This resulted from the use of seed yield from the sole crops soyabeans as the denominator in the LER calculation (see section 2.6) and only the seed yield of one of the sole crops was used in the calculation of yield ratio. Similar findings have been reported by Trenbath (1976).

Those scientists who desire a common base for comparisons between crops, the farmers who aim to maximise yields and the farmers who wish to retain a full yield of one crop while gaining a supplementary yield of a second crop all have very different requirements of intercropping. As Mead and Riley (1981) suggest there is no single method of evaluating the yield of intercropped plots that can satisfy the diverse demands of the user. The choice of the methods for evaluation of intercrops depends upon of the farmers purpose of combining crops. The results from this experiment suggest that intercropping could be wrongly rejected when the wrong cultivars or plant population have been grown and care must be taken to avoid these mistake when intercropping is undertaken.

4.3. Conclusions

The results of this study showed that neither the population nor the cultivars of soyabeans had any effect on the growth and grain yield of the maize. Similarly the population of maize had no effect on the growth and grain yield of soyabeans. The highest yields were obtained from the intercropped plots when maize was grown at 12 plants/m^2 with Matara at 75 plants/m^2. The magnitude of the yield advantage depended on the method of calculation used.

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