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-ral production is to be increased, agriculturists must concentrate on inprovements 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 developing 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 intercropping.

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	-	Planting 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:

$$A_b = \frac{Y_a}{S_a \; X \; Sown_a} \qquad \frac{Y_b}{S_a \; X . Sown_a}$$

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.