INTERCROPPING OF MAIZE AND DRY BEANS FOR THE VULINDLELA DISTRICT OF KWAZULU-NATAL

by

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DECLARATION

I certify that the research work reported in this dissertation is the result of my own original investigation, except where acknowledged herein.

BC Liebenberg

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ABSTRACT

The use of a maize/bean intercropping system to improve land productivity was investigated after limited land availability had been identified (Liebenberg, 1993) as a major constraint to crop production in the Vulindlela area of the KwaZulu-Natal province of South Africa.

The objective of this study was to develop an intercropping system that would: a) Give an intercrop bean yield approximately equal to that of the sole crop yield. b) Give a maize yield acceptable to the farmer (needed mainly for green maize). c) Produce a land equivalent ratio (LER) greater than one.

In order to ensure high bean yields, maize dominance was reduced by lowering the normal maize population of the intercrop by 50% and by using a tramline row arrangement instead of evenly spaced rows. Two bean cultivars namely Mkuzi (carioca) and Umlazi (speckled sugar) and two maize cultivars namely Kalahari Early Pearl (KEP) (an open pollinated cultivar) and SR 52 (a hybrid) were used. Single trials were planted at four localities spread over three seasons i.e. Vulindlela and Ukulinga (1992/93), Cedara (1995/96) and Makhathini (1996). The treatments included varying bean densities, bean planting times and maize harvesting stages. These treatments were compared to maize and bean sole crop controls.

High maize yields led to low bean intercrop yields. However, there was little or no difference between sole bean yield and intercrop bean yields associated with lower maize yields. Intercrop maize yields were 50% of the sole maize yields at all the sites. The mean LER's for the Vulindlela and Ukulinga trials were 1.04 and 0.96 respectively while the mean LER's for the Cedara and Makhathini trials were 1.34 and 1.31 respectively. Only the latter two trials displayed significant improvements in land productivity. Mkuzi was more affected by intercropping than

Umlazi while KEP competed less with the beans than SR 52 and gave higher yields under less favourable growing conditions.

Yield component studies indicated that stress during the vegetative, pod formation, and pod filling stages led to yield reduction in the dry bean crops. Light and leaf nutrient level studies suggested that the yield reduction resulted from competition for nitrogen and light. There was no competition for phosphate and potassium. The study indicates that the intercropping system did meet the desired requirements under conditions that are less than ideal for maize production, such as low soil fertility, water stress and cool temperatures.

CHAPTER 1
INTRODUCTION

At the root of most modern agricultural systems lies an intercropping ancestor (Francis, 1986). If one looks at nature, the arrangement that commonly occurs among plant communities is that of a mixture of species. It can thus be argued that such an arrangement is ecologically the most stable agricultural system.

Intercropping, which has been practised from the dawn of civilization, is still a dominant cropping practice in Latin America, Africa and South East Asia (Vandermeer, 1989). The percentage of land devoted to intercropping in the tropics is reported to vary from 17% in India (Vandermeer, 1989, citing Srivastava, 1972) to 94% in Malawi (Edje, 1996, pers. comm.). Chagas, Araujo & Vieira (1984) reported that at least 70% of all beans in Brazil are grown in intercropping systems.

For many years intercropping was seen as a practice used only by resource poor and subsistence farmers. It was thought that all farmers should be encouraged to "advance" to sole cropping. This way of thinking has been challenged in recent years due to the increased emphasis on ecological sustainability (Amador & Gliessman, 1990). It is now realized that a good case exists for the continued use of intercropping. In many instances intercropping can reduce the use of ecologically damaging inputs e.g. insecticides and herbicides, and protect the soil against erosion by wind and water (Amador & Gliessman, 1990; Capinera, Weissling & Schweizer, 1985; Castro, Isard & Irwin, 1991; Midmore, 1993b).

The benefits of intercropping are normally only experienced by small scale farmers. This is mainly due to the fact that small scale farmers rely less on mechanization. Mechanization often necessitates that crops be grown in a pattern that reduces the intimacy with which they are associated. The reduced intimacy can lead to a reduction in benefit due to the fact that the system becomes similar to sole cropping (Willey, 1979 a&b; Capinera *et al.*, 1985). Benefits resulting from intercropping may not necessarily be in the form of increased yield. Reduced need for insecticides, fungicides and other inputs can be a major consideration when resource poor farmers have to decide on a cropping system (Tripathi & Singh, 1983). Improved labour distribution needs throughout the season, reduced risk of crop failure, specific dietary needs and reduced weed competition are some of the possible reasons why farmers intercrop (Rao & Singh, 1990; Willey, 1979a; Woolley and Davis, 1991).

The advantages of intercropping are not limited to small-scale and subsistence farmers. Large scale commercial farmers are also benefitting from intercropping practices (Capinera, *et al.* 1985). In Mauritius sugar cane is intercropped with food crops on a large scale, 77 percent of the country's potatoes being produced in intercropping systems (Govinden, 1990).

Increased land productivity is still one of the main factors contributing to the importance of intercropping (Ranganathan, Fafchamps & Walker, 1991; Rao & Singh 1990). Not all crops, however, are suitable for intercropping. Some crops combine well, while others are too competitive or effect each other adversely (Ranganathan, *et al.*, 1991; Rao & Singh 1990). Certain crop combinations are frequently encountered, the most common being a cereal and a legume (Trenbath, 1974; Woolley & Davis, 1991). Maize and sorghum are generally intercropped with dry beans, cowpeas or pigeonpeas.

In the tropics and subtropics dry beans are more commonly intercropped than sole cropped (Davis, Woolley & Moreno, 1986). The beans are generally dominated by the cereal crop but usually have a negligible effect on the cereal (Woolley & Davis, 1991). In most situations where intercropping with maize and beans is practised, beans are regarded as the secondary crop (Rezende & Ramalho, 1994). The extent to which maize dominates the beans is dependant on the management practices involved, e.g. relative planting time, spacing and population density. Planting beans before or simultaneously with the maize reduces competition from the maize early in the season. Planting beans after maize leads to serious competition from the maize (Barker & Francis, 1986). Reducing light interception by maize by reducing the maize population and/or the row arrangement can lead to increased bean yields (Woolley & Davis, 1991).

The intercropping experiments reported on in this thesis were initiated by a study done on the state of agriculture in the Vulindlela area of rural KwaZulu-Natal (lying approximately 20 km east of Pietermaritzburg), which indicated the following constraints (Liebenberg, 1993).

1. Small land size due to a) high population pressure,
b) uncontrolled grazing and
c) lack of land ownership.
2. Limited agricultural inputs,
3. Limited manpower due to absenteeism of migrant workers and limited labour saving devices.

The most important crops, in order of importance, were found to be potatoes, beans (*Phaseolus vulgaris* L.) and maize (*Zea mays*). In 1982 Lea & Standfort reported intercropping of maize and beans to be common practice in the area, with maize as the most important crop, followed by beans. It appears that the popularity of refined maize meal readily available in shops has reduced the need for home grown maize. The production of beans was boosted by the introduction of higher yielding, disease resistant bean cultivars, as well as an increase in the demand for beans. Traditional intercropping practices of alternate maize and beans rows produced very low bean yields. This prompted the farmers who adopted the new cultivars to switch to sole cropping of beans.

The objective of this study was to develop a new intercropping system that would give: a) high bean yields - close to that of the sole bean crop (a yield ratio of ± 1). b) an acceptable maize crop, as green maize is still important. c) increased land productivity as measured by land equivalent ratio.

The target group was the resource poor farmer who has very little land and inputs. Willey (1979a) stated that the most important fact about the advantages of intercropping is that they are achieved without costly inputs. The objectives of this study had, therefore, to be met without the use of costly inputs. Maize and beans were selected as the two crops that would receive attention, as potatoes (the other important crop) generally require the use of fungicides and large quantities of fertilizers which was not within the means of the target group.

Definitions

Definitions of intercropping terms vary from author to author, and from organisation to organisation. No consensus has been reached as to the terms that should describe specific cropping patterns (Francis, 1986). The definitions adopted in this thesis will be those given in Table 1.1, 1.2 and 1.3 as these are currently the most commonly used.

Table 1.1 Definitions of principal multiple cropping patterns

MULTIPLE CROPPING

The intensification of cropping in time and space dimensions. Growing two or more crops on the same field in a year.

SEQUENTIAL CROPPING

Growing two or more crops in sequence on the same field per year. The succeeding crop is planted after the preceding crop has been harvested. Crop intensification is only in the time dimension. There is no intercrop competition.
Farmers manage only one crop at a time on the same field.

Double Cropping Growing two crops a year in sequence.

Ratoon Cropping The cultivation of crop regrowth after harvest, although not necessarily for grain.

INTERCROPPING

Growing two or more crops simultaneously on the same field. Crop intensification is in both the time and space dimensions. There is intercrop competition during all or part of crop growth. Farmers manage more than one crop at a time in the same field.

Mixed Cropping Growing two or more crops simultaneously with no distinct row arrangement.

Row Intercropping Growing two or more crops simultaneously where one or more crops are planted in rows.

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

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

Source: Francis (1986, citing Andrews and Kassam, 1976, with modification by P A Sanchez, North Carolina State University).

Table 1.2 Related terminology used in multiple cropping systems.

Cropping index

The number of crops grown per annum on a given area of land x 100.

Cropping pattern

The yearly sequence and spatial arrangement of crops or of crops and fallow on a given area.

Cropping system

The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technology which determine their makeup.

Land equivalent ratio (LER)

The ratio of the area needed under sole cropping to one of intercropping at the same management level to give an equal amount of yield. LER is the sum of the fractions of the yields of the intercrops relative to their sole crop yields.

Income equivalent ratio (IER)

The ratio of the area needed under sole cropping to produce the same gross income as one hectare of intercropping at the same management level. IER is the conversion of LER into economic terms.

Mixed farming

Cropping systems which involve the raising of crops, animals, and/or trees.

Monoculture

The repetitive growing of the same sole crop on the same land.

Rotation

The repetitive cultivation of an ordered succession of crops (or crops and fallow) on the same land. One cycle often takes several years to complete.

Sole cropping

One crop variety grown alone in pure stand at normal density. Synonymous with solid planting; opposite of intercropping.

Source: Francis (1986, citing Andrews and Kassam, 1976) with modifications by P A Sanchez, North Carolina State University).

Table 1.3 Defining Maize and Beans

The term bean(s) will always refer to *Phaseolus vulgaris* (L), commonly called dry beans or common beans, unless otherwise stated.
The term maize will always refer to *Zea mays*.

The cropping system developed in the trials would still be defined as row intercropping. The use of tramlines do bring an element of strip intercropping but not to the extent that independent cultivation is possible.

CHAPTER 2
LITERATURE REVIEW

2.1 Historical overview

It is commonly accepted that cropping systems developed out of tending of plants growing naturally in the wild (Plucknett & Smith, 1986). It can therefore be argued that the first cropping systems must have resembled the natural conditions of multiple crops on the same piece of land at the same time. According to historical records mixed cropping was practised in many different forms in many developed countries until relatively recent times. In developing countries it is often still the dominant cropping system (Bradfield, 1986, Francis, 1986, Plucknett & Smith, 1986). Sole cropping developed in temperate areas and became the dominant cropping practice. This process was greatly accelerated by mechanization.

With the advent of the green revolution intercropping was destined for extinction and farmers were discouraged from continuing the practice (Van Rheenen, Hasselbach and Muigai, 1981). However, during the past few decades, the persistence of small-scale farmers and an increased interest in ecology has turned the tide against monocropping and stimulated interest and research into intercropping (Risch, Andow and Altieri, 1983, Francis, 1986). As a result, intercropping is returning to many cropping systems, including large scale mechanized farming. This can take various forms, for example strip cropping, alley cropping, mixed pastures and cover crops (Francis, 1986).

2.2 Resource use

When plants occupy the same space, there is always a possibility of competition for limiting resources. When all the plants are of the same species, having the same needs at the same time, competition will most likely occur during times of peak demand.

In intercropping, however, advantages occur when the component crops have differing requirements for resources. These differences can be either in time and/or space (Trenbath, 1986; Willey, 1990). In addition, the component crops can supply resources to each other, e.g. through nitrogen binding, physical support, etc. Thus, through minimizing competition and maximising complementarity between the different crops, better resource use efficiency can be realized (Midmore, 1993a). However, a factor that may be complementary at one stage of the growing cycle may become competitive at a later stage. Likewise, a competitive factor at one stage could become complementary at another. It is therefore necessary to prolong complementarity for as long as possible. This can be done by manipulating inputs, planting dates, planting methods and arrangements (Davis, Roman & Garcia, 1987; Pilbeam, Okalebro, Simmonds, & Gathua, 1994; Willey, 1979a & b).

2.2.1 Solar radiation

Solar radiation is a resource which cannot easily be stored, and must be used immediately. Neighbouring plants will therefore compete with each other through direct interception (Keating & Carberry, 1993). The crop that intercepts the radiation first shades the other, and is usually the dominant crop. Clément, Chalifour, Bharati and Gendron (1992) list radiation and nitrogen as the two major resources for which cereal and legumes compete when intercropped in the humid subtropics. Sufficient radiation for photosynthesis is essential for plant growth and production. Increased interception and/or increased solar radiation use efficiency can lead to greater productivity (Keating & Carberry, 1993). Greater efficiency can be achieved through better distribution of leaf area over time and space, increased leaf area duration and increased light interception (Trenbath, 1981). The proportion of radiation energy that reaches the ground must also be minimized (Keating & Carberry, 1993).

In a sorghum/pigeonpea intercropping trial in India, light was used more efficiently under intercropping than by sole crops (Natarajan & Willey, 1980). The sorghum matured fast, making use of the resources early in the season, while the pigeonpea experienced no competition for the remaining 91 days after the sorghum had been harvested. Climbing beans, using maize plants as structural support, can achieve an improved distribution of leaves through the canopy, thereby increasing light interception (Francis, 1978). Short season crops usually exhibit a rapid increase in leaf area per unit of thermal time (cm^2 $plant^{-1}.°C$ day^{-1}). Long season crops, on the other hand, exhibit a slow increase in leaf area per unit of thermal time. This means that, for a short season crop, radiation may be poorly utilized during the end of the season, whereas a long season crop makes poor use of radiation at the beginning of the season. Combining a short and long season crop can therefore enhance temporal capture of radiation energy (Clark & Francis, 1985; Keating & Carberry, 1993). Willey (1990) illustrated in his review that improved light conversion efficiency can be experienced by an understorey groundnut crop intercropped with millet. He attributed this to greater conversion efficiency of the C3 canopy at lower light intensities and avoidance of light saturation of upper leaves. C4 plants i.e. maize and millet, utilise high light intensities and let filtered light through to C3 canopies.

The benefit is however not always due to increased light interception. Some crops have been found to benefit greatly from shading. In a study with chickpeas and safflower, chickpea yields were increased as the safflower population increased from 4 to 6 plants m^{-2}, due to increased shading, after which yields decreased due to competition (Willey, 1981). Under agro-forestry, shading of potatoes during the first four weeks after planting and last two weeks before harvest increased tuber yield by 20% (Kuruppuarachchi, 1990). This yield advantage was realised in the shade of *Leucaena leucocephala* during the first two years after establishment. Shading was regulated by harvesting the *Leucaena* and by regrowth. Shading in the first four weeks hastened emergence and increased the number of stems, while shading during the last two weeks provided a cooling effect against increasing heat. The same results were achieved in a maize/potato intercropping system (Midmore, Roca & Berrios, 1988 and Midmore, Berrios & Roca, 1988)

By contrast, beans have been found to be sensitive to shading. Liebenberg (1989) applied three levels of shading, i.e. 25%, 50% and 75%, to sole-cropped beans at various stages of the bean's growing cycle. Shading at all stages after flower initiation, except 25% shading during the seed fill stage, reduced seed yield significantly.

In an intercropping study done with maize cultivars ranging from less-leafy to more-leafy cultivars, light interception levels ranging from 41% to 70% were recorded (Woolley & Rodríguez, 1987). The less-leafy cultivars reduced bean yield less than the more-leafy cultivars.

Changing the spatial arrangement and density of component crops also influences the shading effects of these crops. Row orientation can also have an influence on shading (Midmore 1993b), but unfortunately this is often determined by the topography of the field.

From the foregoing it can be seen that crop sensitivity to shade, amount of shading, growth cycles, cultivar choice and time of planting will have an effect on light use efficiency.

2.2.2 Nutrients

Crops require varying amounts of nutrients during their life cycle. If the component crops reach their peak demands at different times of the season, competition for nutrients can be minimized. An improved distribution and concentration of roots in the soil can also ensure more efficient uptake of nutrients (Willey, 1990).

Due to the mobility of nitrogen it is usually the most likely candidate for competition, and it's effect has therefore received the most attention. This is mainly due to dramatic growth responses caused by nitrogen (Midmore, 1993b). The effect of nitrogen fixation is also a common research topic. Significant transfer of nitrogen from legume to non-legume within a single season is very unlikely and is still to be proven (Stern, 1993). The only clear route of transfer is indirectly through the death and decomposition of the plant or plant material. This has been observed over several years in forage legume/grass mixtures, (Heichel & Henjum, 1991). It is very unlikely that a non-legume will benefit from nitrogen fixed by a legume in that same season unless the non-legume grows actively for a considerably longer time than the legume. Under laboratory conditions, however, non-legumes intercropped with legumes have been found to benefit from nitrogen recently fixed by the legumes (Fujita, Ofosu-Budu & Ogata, 1992). The effectiveness of nitrogen transfer was dependent on the legume crop, the nitrogen status of the soil and the intimacy of root association (Fujita *et al.*, 1992). Dalal (1974) reported a significant increase in mineral soil nitrogen due to pigeonpeas when intercropped with maize but this does not necessarily mean that it was available to the maize crop when needed during it's active growing season. Under South African conditions the effect of atmospheric nitrogen fixation by beans has been found to be negligible as indigenous inactive *Rhizobium* is too competitive for inoculated active *Rhizobium* (Liebenberg (1992), pers. comm.). For these reasons, nitrogen fixation will not be covered by this study.

The application of nitrogen has varying influences on the component crops. Woolley and Davis (1991) found that maize yields increased with increased nitrogen application. Bean yields initially decreased and then increased again at higher levels of nitrogen. The reduction in bean yield was due to increased competitiveness of the maize at higher fertility levels. Increased plant size vertically and horizontally increased shading of bean plants. Midmore (1993b) states that where soil nutrients are competed for, application of mineral nutrients can alter the balance in competition between the component crops which can be expressed as competition for irradiance or a change in dominance. In a study by Stern and Donald (1962) on the effect of four nitrogen levels on a grass/clover mixture, the grass became more dominant with an increase in nitrogen. At low levels of nitrogen, the clover, which can bind its own nitrogen, could compete more effectively with the grass. Some intercropping systems are only more productive than sole crops under low soil nitrogen conditions (Ofori & Stern, 1987a; Olasantan, 1991; Chang & Shibles, 1985). Chang & Shibles, (1985) showed that increased productivity over sole cropping could only be achieved when cowpeas were almost as competitive as maize in a maize/cowpea intercropping system. This was only possible under low nitrogen levels. Under higher levels maize became too competitive.

Chui (1988), applying six levels of nitrogen to a maize/bean intercrop in Kenya, found no significant response in either of the crops. This phenomenon may be explained by examining the bean yields, i.e. 2,387 t/ha and 1,277 t/ha for sole and intercropped beans respectively. These yields are so high that they suggest that no or very little fertilizer was needed in the first place. Faris, Burity, Dos Reis & Mafra (1983) reported improved maize and bean yields with increased fertilizer application. De Lima, de La Lima, de La Andrade & de Rezende (1986) reported a direct correlation between bean yield and rate of applied fertilizer. Tripathi & Singh, (1983) reported that maize yields could be sustained with less fertilizer in a maize/soyabean intercropping system over that of the sole crop. This was most likely due to the reduced number of weeds found where soyabeans were intercropped with the maize, leading to better nutrition of the maize crop. Ayeni, Akobundu & Duke (1984) reported similar results in a maize/cowpea intercrop, also due to reduced number of weeds resulting from the presence of the cowpeas.

Competition for macro-nutrients other than nitrogen is only likely to occur at very high plant densities (Woolley & Davis, 1991). Fusseder, Kraus & Beck (1988) studied root competition for phosphate in a maize/lupin intercrop and concluded that no competition occurred for phosphate. Phosphate was only depleted in the root hair zone. By studying the depletion cylinders (circles of depletion around the roots) it was found that competition between separate roots occurred in less than 1% of the soil volume that supplied phosphate to the maize plants. However, Natarajan & Willey (1980) observed that interpenetration of root systems of sorghum and pigeonpea did occur. Morris and Garrity (1993b) reported that capture and utilization of phosphate and potassium is generally higher in intercrops than in sole crops. This is mainly due to the greater soil volume explored by the roots and to the longer uptake period. In general, growth of the dominated crop, even under low nutrient status, is determined more by factors other than phosphate and potassium availability (Morris & Garrity, 1993b). Never the less Chang and Shibles (1985) reported reduced cowpea yields due to application of phosphate fertilizer in a cowpea/maize intercrop due to improved maize growth. Low phosphate levels did not affect cowpeas, which need very little phosphate, but did limit maize growth. Woolley & Davis (1991) reported a steady increase in bean yield with an increase in applied phosphate in a maize/bean intercrop trial. Wahua (1983) indicated that cowpeas experienced competition for P, K & Ca in a maize/cowpea intercrop. Uptake in mg per plant was measured, and uptake of intercropped cowpeas was compared with that of sole cropped cowpeas. However, the fact that cowpea plants are usually smaller under intercropping was not taken into account. If percentage P,K and Ca had been used instead of total uptake per plant there would most likely have been no difference between intercropped and sole cropped uptake levels.

It appears that although nutrient utilization is efficient under intercropping, fertilization can play a positive role in yield increases. It can also be argued that intercropping might deplete soil nutrients faster than sole cropping due to increased nutrient uptake.

2.2.3 Water

There are several possible ways in which intercropping can improve water use compared to sole cropping (Willey, 1990).

1. Increased water availability to plants.

The increased canopy cover that is usually experienced with intercropping protects the soil against capping, leading to improved infiltration and reduced soil erosion. This effect is potentially the greatest where a slow developing crop (that provides poor canopy cover at the beginning of the season) is intercropped with a crop that grows rapidly giving canopy cover at the beginning of the season (Willey, 1990). Lal, (1984) reports increased infiltration in a maize/cassava intercrop as compared to the sole crops. Reduction in weeds due to intercropping (Tripathi & Singh, 1993 and Ayeni Akobundu & Duke, 1984) will also increase water availability to the crops. The lowering of soil temperature due to intercropping together with a higher humidity (Midmore, Roca & Berrios, 1988 and Stoetzer & Omunyin, 1984) reduces the evaporation of water from the soil, increasing the water available to the crops.

2. Increase in the total amount of water withdrawn from the soil in the form of evapotranspiration.

With increased canopy cover, increased evapotranspiration is bound to occur. However, if water availability is limited the increased withdrawal can lead to water stress. Increased withdrawal of soil water will therefore only be advantages if transpiration relative to evaporation is improved.

3. Increased transpiration without increasing the total evapotranspiration.

Lower soil temperature due to better canopy cover is likely to reduce evaporation. Intercropping can, however, lead to an increase in evaporation later in the season after the first crop has been harvested. Natarajan and Willey, (1980) reported increased evaporation after the harvest of sorghum in a sorghum/pigeonpea intercrop.

4. Increased conversion efficiency.

Reddy and Willey, (1981) achieved a conversion efficiency ratio of 1.07 in a millet/groundnut intercrop, due to the fact that C3 plants often exhibit a higher conversion efficiency when radiation is slightly reduced. In this way transpiration is reduced without a proportional reduction in photosynthesis (Willey, 1990).

5. Increased harvest index, i.e. applying a greater proportion of the available water towards those components which determine yield. Under stress conditions plants often favour reproductive organs leading to greater harvest indices. Natarajan and Willey (1986) showed that water stress in millet/groundnut and sorghum/groundnut intercropping increased the harvest indices.

6. Increased water use efficiency.

Intercropping has been found to increase water use efficiency by more than 18% and by as much as 99% in some cases (Morris & Garrity, 1993a). Surplus water early in a crop's life cycle can be utilised by another crop. The short season crop using water early in the season should be past its peak demand period before the onset of the peak demand period of the long season crop. Short seasoned sorghum intercropped with long seasoned pigeonpea was used by Natarajan & Willey, (1980) to achieve a water use efficiency of 38% (that is: 38% more dry matter production per millimetre of water). In a study of a sunflower/mustard strip intercrop, both components outyielded the sole crops (Putnam and Allan, 1992). Soil depletion patterns showed that mustard border rows utilised water and N from the sunflower strips early in the season when sunflower requirements were low. In the latter part of the season sunflower border rows obtained water and N from the mustard strips. Hulugalle and Lal, (1986) reported a higher water use efficiency for a maize/cowpea intercrop only when water was not a limiting factor. Likewise, in the Kenyan highlands maize/bean and maize/potato intercrops were only more productive than sole crops when water availability was not limited (Fisher, 1977). A sorghum/groundnut intercrop in India produced contradictory results. Under wet conditions the yield advantage of intercropping over sole cropping was only 14%, whereas it was 88% under dry conditions (Harris, Natarajan and Willey, 1987 a&b).

Water use efficiency can be increased by means of an improved distribution of roots in time and/or space. Intercropping can also increase water use efficiency by reducing runoff during showers as a result of a more extensive root network in the soil.

From the above it can be seen that water can be used more efficiently in many intercropping systems and so reduce the risk of crop failure and/or increase total yield. The prudent choice of component crops and planting times is extremely important in order to ensure that peak water demands do not coincide.

2.3 Quantifying advantages

Intercropping is one of the dominant cropping practices in Latin America, Africa and South East Asia (Vandermeer, 1989). Percentages of land devoted to intercropping in the tropics are reported to vary from 17% in India (Vandermeer, 1989, citing Srivastava, 1972) to 94% in Malawi (Edje, 1996, pers. comm.). According to Davis *et al*. (1986), intercropping of beans in the tropics and sub-tropics is far more important than sole cropping. Chagus, Araujo and Vieira (1984) reported that at least 70% of all beans in Brazil are grown in intercropping systems. On the other hand, Woolley and Davis (1991) concluded that intercropping was a major contributor to low bean yields in countries where beans are predominantly intercropped. These seemingly contradictory factors can be explained by the fact that the criteria determining intercropping advantages differ according to predetermined needs. Willey (1979a & 1981) suggests three basic situations:

1. "Where combined intercrop yield must exceed the yield of the higher yielding sole crop."
2. "Where intercropping must give full yield of a 'main' crop plus some additional yield of a second crop."
3. Where the combined intercrop yield must exceed a combination of sole crop yields.

Situation one arises where both crops are equally acceptable. Maximum yield is desired regardless of the yield ratios of the different crops. This situation is most often found with fodder mixtures. In the second case, the full yield crop is usually an essential food crop or a very high value cash crop: any additional output is a bonus. The third situation is possibly the most common. The farmer regards both crops as important, whether it be for practical reasons, e.g. to provide a balanced diet or spread labour peaks, or for economical reasons, for example to reduce risk or to increase quality, profitability, or yield stability. It is important to note that the combined intercrop yield does not have to exceed the yield of the higher yielding sole crop.

From the above it can be seen that no one method for evaluating intercropping yield advantages is applicable to all situations. Several methods need to be considered for each location and circumstance. The most common and useful way to describe yield advantages is the Land Equivalent Ratio (LER).

LER can be described as the area of land needed under sole cropping to give the yields achieved in intercropping. It is important to note that management levels should be the same for both sole- and intercropping.

A similar term, giving identical results, is Relative Yield Total (RYT) (Vandermeer and Schultz, 1990). For a maize/bean intercrop it is written as:
LER = RYT = intercrop maize yield /sole crop maize yield + intercrop bean yield/sole crop yield.
These yields are measured form the same area.

LER does, however, have some restrictions. Problems arise when, for example, the producer is only concerned that the major crop must give at least the same yield as a sole crop (Vandermeer, 1989). This author also points out the inadequacy of LER when a particular mixture is required for dietary purposes or market conditions. Substituting monetary values into the LER formula will give the same value as LER using crop yield and cannot therefore be used as an indication of profitability. If monetary value is the sole interest, the intercrop can to be compared to the most valuable sole crop by using the Income Equivalent Ratio (IER) (Vandermeer, 1989):
IER = Relative Value Total (RVT) = (aP1 + bP2)/ aM1 (Where a and b = price of crop 1 and 2 respectively, P1 and P2 = intercrop yield of crop 1 and 2 respectively, M = sole crop yield and aM1 > bM2.)

Willey (1979a) proposes several functions indicating competitiveness, i.e. Relative Crowding Coefficient, Aggressivity & Competition Index, but they are seldom used due to their complexity.

Yield is the main underlying factor of all the above methods. Unfortunately, mathematical formulas and research trials often do not take factors such as yield stability, risk, ease of cultivation, spread of labour requirements, reduction of weeds (weeding requirements) etc. into consideration. It is difficult to put numeric values to these variables. Fukai and Midmore (1993) are of the opinion that non-numeric values can best be evaluated by means of farmer participation. Once promising systems have been identified on the research station, on farm trials need to be conducted in order to establish which system best meets the needs of farmers. In this way Dlamini, Pali-Shikhulu and Dlamini (1993) determined that alternating rows of maize and cowpeas were more acceptable for the farmers than the higher yielding two hills maize - two hills cowpeas within the row arrangement. This was due to the fact that alternating rows was easier to manage.

It can therefore be seen that although there are some useful mathematical methods by means of which superior systems can be determined, the ultimate decisions will have to be based on acceptability to farmers.

2.4 Planting date

Planting date can be a useful tool in the hands of the farmer to ensure intercrop benefits.

The factors determining planting dates of component crops are generally similar to those of sole crops i.e. temperature, photoperiod-sensitivity, soil moisture, season duration, stress conditions during life cycle and the occurrence of certain pests and diseases during the season (Barker & Francis, 1986).

An additional factor namely relative planting dates of the component crops, applies to intercropping. Ideally, competition between component crops should be minimized. However, this is not always possible due to climatic conditions, which necessitates a compromise between optimum planting time and minimum competition. Cultivar differences, e.g. short and long season, can be used to minimize such compromises. Woolley & Davis (1991) found that a switch from traditional to improved cultivars often led to a change in the planting date. It was also reported that changing the cultivar of one crop sometimes necessitates changing the cultivar of the other in order to ensure that the competitive balance between the crops is not upset.

A large number of intercropping systems include a long and short season crop. With simultaneous planting the short season crop can complete its life cycle before the long season crop reaches its peak demand period. Domination of one crop over another can often be reduced or reversed by planting the dominated component first, giving it a relative advantage. This phenomenon is illustrated by the interaction in a maize/bean intercrop. Willey 1979b, Barker and Francis, (1986) and Woolley and Davis, (1991) found that a significant bean yield advantage is achieved if beans are planted before maize as opposed to simultaneous planting or delaying planting of beans. However, maize yields tend to be adversely affected by early planting of beans. Francis, Prager and Tejada, (1982c) achieved similar results (see Table 2.3.1) as did Ntare and Williams, (1992) with a cowpea/millet intercrop. When bean planting is delayed until approximately physiological maturity of maize, i.e. relay intercropping, bean yields are also increased. Davis *et al.* (1987) demonstrated this by planting beans 150 days after maize. The advantages obtained were probably due to the shorter growing season of beans, which have a peak demand for resources between 30-80 days after planting (DAP) as compared to 60-100 DAP for maize. High levels of shading of beans after flower initiation, which causes high yield losses (Liebenberg, 1989) are also avoided by early planting. The findings of Woolley & Rodríguez (1987) appear to support this. They found that simultaneous planting of an early maturing, short stature maize cultivar, reduced the yield of bush beans more than a later maturing, leafier maize.

Table 2.1 Intercropping bean and maize yields with five relative planting dates and four bean plant types at CIAT, Colombia (Francis *et al.*, 1982c)

	Yield (t ha^{-1})							
	P788 (type 1)		P566 (type 2)		P498 (type 3)		P589 (type 4)	
Planting date	Bean	Maize	Bean	Maize	Bean	Maize	Bean	Maize
Beans 10 days before maize	1.4	3.6	1.9	2.8	1.5	3.0	1.4	1.6
Beans 5 days before maize	0.8	5.6	1.4	5.2	1.2	4.8	1.6	3.3
Beans and maize same day	0.7	6.3	1.0	5.8	0.9	5.3	1.4	4.7
Maize 5 days before beans	0.6	6.5	1.0	5.9	0.7	5.7	1.0	5.3
Maize 10 days before beans	0.5	6.8	0.8	6.2	0.5	5.9	1.1	5.7
Bean sole crop	1.5	--	1.6	--	1.3	--	3.0	--
Maize sole crop	--	6.4	--	6.4	--	6.4	--	6.4

2.5 Genotype differences

When selecting for new cultivars most plant breeders do so under sole crop conditions. It is possible that these cultivars may not perform equally well under intercropping (Davis and Woolley, 1993).

It has been argued that the performance of a crop in intercropping is not sufficiently predictable from its performance in sole cropping, particularly for the dominated crop (Davis & Woolley, 1993). Cultivar differences play an important role in both the influence of the dominating crop and the reaction of the dominated crop (Francis *et al.*, 1982c; Davis and Woolley, 1993). Significant, but varying degrees of cultivar x cropping system interactions have been reported (Francis, Prager, Laing and Flor, 1978; Woolley and Rodríguez, 1987; Francis, 1991; Smith and Zobel, 1991).

In spite of these difficulties, certain characteristics have been found to be useful pointers for use in selection, but can only give general trends. (Davis and Woolley, 1993). In beans, cultivars with prolonged leaf area establishment and longer internodes do better in intercropping (Clark & Francis, 1985). Both these characteristics are linked to growth habit. In a study where bean cultivars exhibiting all four growth habits (i.e. Type I, determinate bush bean; Type II, indeterminate small vine; Type III, indeterminate large vine; and Type IV, indeterminate climbing [CIAT, 1979]) were tested, it was found that beans with a type IV growth habit were less adversely affected by intercropping than were Type I,II & III (Davis, van Beuningen, Ortiz & Pino, 1984). These authors concluded that selection under sole cropping will tend towards bush beans and under intercropping, towards climbing beans. Within Type IV the most vigorous climbers are often most suitable. In a cowpea (*Vigna unguiclata)*/pearl millet (*Pennisetum glaucum)* intercropping trial, Ntare and Williams (1992) also found that indeterminate cultivars produced higher yields than the semi-erect cultivars. This was somewhat contradictory to the findings of Clark and Francis (1985), who reported that higher yields were achieved by climbing beans under sole cropping than by bush beans. Climbing beans also exhibited more severe yield losses under intercropping than bush beans. It therefore seems that Davis *et al.*'s (1984) conclusion is not universally applicable. Francis, Prager & Tejada (1982 a&b) reported that both bush and climbing beans are suitable for intercropping.

In a study using 145 climbing and semi-climbing bean cultivars, Davis and Garcia, (1983) showed that there was great variation in competitive ability of cultivars. Those that gave the highest yields under intercropping were not necessarily the highest yielder under sole cropping and there was a low correlation between sole and intercrop yields. On the other hand, Francis et al. (1978a) reported a significant correlation between sole and intercrop yields for non-climbing beans.

For maize it has generally been found that dwarf maize depresses bean yields less than larger cultivars due to lower vigour and competition (Davis & Garcia, 1983; Holguin, Lopez & Davis, 1985). Maize cultivars with long internodes and narrow leaves, allowing more sunlight through, are often most congenial to higher bean yields (Woolley & Rodríquez, 1987). In intercropping systems where climbing beans grow up the maize plant, maize cultivars with strong stems are needed to prevent lodging (Davis *et al.*, 1986; Woolley and Smith, 1986). The length of the cultivar growth season is also important, the length required being determined by the cropping system used. In a system where both crops are planted simultaneously, a long season maize cultivar is needed to prevent overlapping of peak resource requirements. A relay system on the other hand requires a short season maize cultivar so that the beans can achieve maturity before the end of the season (Woolley and Smith, 1986).

Breeding for intercropping is complicated by various factors. Characteristics which will minimize competition and maximize the complementary effect are important selection criteria (Smith and Francis, 1986). However, these differ within each cropping system. For instance, Woolley & Rodríquez (1987) found that there was a positive correlation between "visual shade score" of maize and bean yield for relay intercropping but a negative correlation under simultaneous intercropping. The Leaf Area Index (LAI),(which determines the amount of shading), of maize at 45 days after planting showed similar correlations. These were mostly due to increased competition with: a) weeds before bean planting in the relay, resulting in cleaner bean fields, and b) the beans in the simultaneous planting.

Due to the many factors involved in selecting for intercropping and the high cost of intercropping trials, Davis and Woolley

(1993) suggested that early generation selection could be made under sole cropping but that later generation selections should be made under intercropping over a number of seasons or locations in order to reduce variation due to seasonal differences. A bean cultivar with low competitiveness and high productivity is needed (Davis *et al.*, 1986). Davis and Woolley (1993) estimated that approximately 0.5 million hectares under cereal/legume intercropping are needed to justify a breeding program specifically for intercropping. These breeding programmes should be undertaken by international research organizations as they are expensive and should serve extended regions. Areas receiving special attention should be a) time to flowering and maturity, b) patterns of resource use, c) plant type, d) stress tolerance and e) pest and disease resistance.

2.6 Spatial arrangement and density

These are two of the agronomic factors over which the farmer initially has full control, although plant mortality may influence the final density. Selection of the optimum arrangement and density is far more complex than for sole cropping due to multiple possible combinations. A change in population density and spatial arrangement affects more than just intra- and inter-specie competition. It can also influence the microclimate which in turn has an effect on pathogen and insect incidence (Castro *et al.*, 1991).

Spatial arrangement and population density are two of the most important management factors determining intercropping advantages (Natarajan, 1990), but at the same time are sensitive to changes in other factors such as moisture, soil fertility and cultivar. Spatial arrangement and population density can not easily be separated and are often interrelated, but some separation is needed for discussion purposes.

2.6.1 Plant population

This factor can be defined as the number of plants per unit area or the unit area per plant. In intercropping it has two aspects namely: a) The total population - which is the sum of the populations of all the component crops, and b) the component populations - which is the population of each individual component crop (Natarajan, 1990). Due to the fact that the component crops cannot be compared on a plant for plant basis (e.g. one maize plant does not exert the same "pressure" on resources as one bean plant), intercropping systems have been divided into two broad classes (Willey, 1979b).

The first is "replacement" type intercrops. This is where one crop is replaced by fixed proportion of the other crop. For example, if optimum sole crop density for beans is 250 000 plants per ha and the optimum maize population density is 40 000 plants per ha, then a 50:50 mixture will have 125 000 bean plants and 20 000 maize plants per ha. A 25:75 mixture will have 62 500 bean plants and 30 000 maize plants per ha. This system is usually used where component crops are phenologically very similar i.e. they have very similar season durations and development patterns (Baker, 1981). These systems often derive their benefit from a simple response to "reduced population" caused by complementarity in space. For the crops to produce yield advantages under this arrangement the component crops need to take advantage of the lower population density. In reality this type is not often found in farmers fields due to the fact that crops are often unable to utilize the "lower" population density, or fail to meet farmers requirements (Natarajan, 1990). This system has been found to produce yield advantages in a millet/sorghum intercrop in northern Nigeria (Baker, 1981). Millet is sown early with the first rains and sorghum is inter sown later when the rains become more reliable. In this way the millet can benefit from a low population early in the season when rainfall is unreliable. The low sorghum population towards the end of the season after the millet is harvested enables the sorghum to mature on stored soil moisture.

It is usually found that the optimal combined plant density for intercropping is higher than for sole cropping. This brings us to the second type of plant density which is known as "additive" or "superimposed" density. It is often used where component crops are phenologically dissimilar (Natarajan, 1990). As the proportion of each crop required can be controlled to a greater extent, this system is far more flexible. In this system a secondary crop is often added to the main crop. In many intercropping systems the full sole crop yield of one crop (usually the cereal) is required, with some additional yield from the secondary crop. The main crop is kept at the optimum population or very close to it. This is due to the fact that the dominant crop, for example maize, often has a response curve very similar to that of the sole crop. Reduction in the population from the optimum decreases yield (Willey, 1979b; Baker, 1981; Chang & Shibles, 1985, Woolley & Davis, 1991; and Barker & Francis, 1986). Under sole cropping beans generally have been found to compensate well for variations in population density (Edje, 1981b, Liebenberg, 1993), and react in a similar manner under intercropping (Edje, 1981a, Francis *et al.*, 1982a). Bush beans are more sensitive to density variations than indeterminate types, which generally produce larger plants (Francis, Flor, Prager & Sanders, 1978b). It has commonly been found that the growth and yield of legumes in cereal/legume intercropping systems decreases markedly with an increase in cereal population (Ofori and Stern, 1987b).

Due to the fact that maize is normally the dominant crop in a maize/bean intercrop and the yield of the maize is less affected by the beans, the magnitude of the intercropping advantage is usually dependant on the bean yield (Ofori and Stern, 1987b). This can be maximized in two ways, namely by increasing the bean density, and/or by changing the spacial arrangement.

2.6.2 Spatial arrangement

Altering the spatial arrangement from that of the sole crop is usually done to benefit the dominated crop. Competition can be reduced to providing more space for the understorey crop. This is usually done by changing the spacing of the cereal crop, which allows for improved radiation penetration (Ofori & Stern, 1987b; Natarajan, 1990 and Midmore, 1993b).

There are various ways in which the spacing can be altered. The most straight forward is by increasing the inter-row spacing. Lima and Lopes, (1981) reported increased bean yields as maize inter-row spacing increased from 1 m to 1.5 m to 2 m while the maize and bean population was kept constant. Another popular method is to "pair" (tramline) cereal rows, for instance, reduce the inter-row spacing of 0.90 m used in sole maize to 0.45 m and then leave 1.35 m between pairs for beans (Ofori & Stern, 1987b; Natarajan, 1990 and Woolley and Davis, 1991). In this way, the yield of the understorey crop can be considerably improved, as the yield of cereals can be maintained over a wide range of spacial arrangements. (Natarajan, 1990). Similar results have been reported when cereal plants are clumped, i.e. several plants planted together in one spot called a hill (Edje,1981b).

This leads to the consideration of another important aspect of spatial arrangement namely the intimacy of the mixture. The association intimacy of the component crops varies considerably. A list of some examples in decreasing order of intimacy are:

1) both crops planted in the same hole. In an extreme example, Edje (1981 a&b) reports that Malawian farmers grow three maize and two to six bean plants per hill. Hills are 0.91 m apart;
2) plants of the two crops alternating in the same row;
3) plants of each crop in adjacent rows;
4) alternating double rows of each crop;
5) various row ratios including strips of each crop.

The intimacy is often dependant on factors such as 1) greater temporal differences, which allow for greater intimacy, and 2) competition for water, light and nutrients, which necessitates lower intimacy. If intimacy is reduced too much the advantages of intercropping will be lost as the system will resemble sole cropping (Putnam and Allan, 1992).

Spatial arrangement is also often influenced by practical considerations. Where planting is done by hand, it might be more practical to sow both crops in the same hole (hill) and/or to have more plants per hill and less hills per row (Edje, 1981b & Davis *et al.*, 1987). Labour-wise it might not profit a farmer to grow the crops in separate rows although this gives higher yields. Arias and Chumo (1990) report that, in order to save labour, Malawian farmers maintain their practice of planting three plants per hill every 0.90 m although it is known that higher yields can be achieved by spacing hills every 0.30 m. Davis *et al.*, (1987) found that growing climbing beans with maize on hills where the maize serves as a physical support for the beans, increased the bean harvest index significantly over that achieved by planting in rows. Bush beans which cannot benefit from structural support will, on the other hand, benefit more from reduced intimacy. Once mechanization is introduced, intimacy is often reduced in order to facilitate management. Arrangements can also be influenced by relative planting dates as this strongly effects temporal differences. Liebenberg (1989) showed that shading of beans throughout the season strongly reduced yield. Different spacial arrangements could be needed when beans are planted after, before or simultaneously with maize. The type of cultivar also greatly affects optimum spacing and density e.g.

a dwarf maize cultivar might shade beans less and therefore allow closer intimacy (Holguin *et al.*, 1985).

Several spacing designs have been developed for initial use in spacing and density investigations when little is known about specific crop combinations. The most important are: 1) a two-way systematic spacing design which entails changing the population of each crop independently by changing the intra-row spacing in a perpendicular direction to one another (at a constant row arrangement) (Mead, 1990), 2) a fan design where inter-row spacings are progressively increased, and 3) spirals and other complex designs (Willey, 1979b).

It can be concluded that this aspect of intercropping is an important tool in the hands of both agronomist and farmer. However, it requires good understanding as it is often area or farming system specific, as it is influenced by numerous factors.

2.7 Management of weeds, insects and diseases

2.7.1 Weeds

In intercropping the different crops often occupy more than one ecological niche, thus reducing resources available to weeds (Woolley & Davis, 1991). On the other hand, weeds can increase already elevated competition. Weeds can also host harmful diseases and insects and/or their predators, or encourage disease by creating a more suitable microclimate (Woolley & Davis, 1991). On the other hand they can also stabilize the soil against erosion and some weeds can act as insect repellents.

The level of weed management exercised by farmers will depend on their circumstances. The impact made by the weeds will, for instance, determine the practicality of selective weeding or whether complete elimination will be necessary. Ayeni, Duke & Akobundu, (1984) and Ayeni, Akobundu & Duke, (1984) reported yield losses of ±50% due to weeds in a maize/cowpea intercrop. Hand weeding has been reported to utilise between 30-70% of the total agricultural labour available to small-scale farmers (Ransom, 1990). It is commonly accepted that maize needs 2-3 weddings per season and that the first 4-6 weeks are the most critical (Ayeni, Duke & Akobundu, 1984; Ayeni, Akobundu & Duke, 1984; Ransom, 1990; Auerbach and Lea, 1992). Labour is often a limited resource for small-scale farmers and limited to family members. This often results in inadequate or a complete lack of weeding. Although intercropping seldom makes weeding unnecessary, weeds often encounter more competition from multiple crops. In their studies on maize/bean/squash intercropping, Amador & Gliessman (1990) obtained substantial yield advantages from weeding, but unweeded intercropped maize and weeded sole maize gave the same yield. Ramalho, Cruz & Passini (1986) reported that maize was less affected by weeds when grown with beans, than when sole cropped. On the other hand, beans were more susceptible to weeds when intercropped than when sole cropped. In a cassava/maize intercrop, Olasantan, Lucas and Ezumah (1994) found that, whereas cassava's weed suppressing ability was only slightly improved by intercropping alone, it was significantly improved by a combination of intercropping and N-fertilizer. Zuofa, Tariah and Isirimah (1992) also found little improvement in weed control due to cassava/maize intercropping but when groundnuts were added, effective weed control was achieved. They reported similar results for cowpeas and melon, although these were not as effective as groundnuts. In a maize/soyabean intercropping trial, Tripathi and Singh (1983) found that intercropping reduced weeds to such a extent that maize in the intercrop only needed half the amount of N-fertilizer as the sole crop in order to produce the same yield.

Intercropping can be a disadvantage in that it can hamper hand weeding or render cultivation between rows with a tractor or animal drawn implements impossible. This is particularly so where crops are grown in the inter-row space in a random way. Hand weeding around plants is necessary, and the lack of large unobstructed inter-row areas necessitate more careful weeding necessary (Ransom, 1990). Cultivation with implements is possible when all crops are in the same row, although this might not be the most productive arrangement. Yield loss may also be serious if timely weeding cannot be done. In such cases, each farmer must determine his own priorities. Ransom (1990) reported that the first weeding in a intercrop generally required more or the same amount of labour as the sole crop but that the second weeding required considerably less.

Application of a pre-emergence herbicide can reduce labour needs considerably, particularly early in the season. Tripathi and Singh (1990) found that a single pre-emergence application of alachlor at a rate of 2.5 kg a.i./ha in a maize/soyabean intercrop controlled weeds as effectively as three hand weddings. However, the use of herbicides is far more complicated in intercropping than in sole cropping. The choice of a suitable selective herbicide is difficult because more than one crop is involved. This becomes especially complicated where both a monocotyledon (e.g. maize) and a dicotyledon (e.g. beans) are involved (Woolley & Davis, 1991). The use of herbicides by resource poor farmers is also restricted by the lack of capital and low level of skills. With increased use of technology in intercropping, innovative techniques need to be employed in order to encourage the use of herbicides. Examples of such innovations are: addition of antidotes to the herbicide formulation, e.g. EPTC with safener (Eptam Super) which makes it suitable for use with maize, and the use of contact herbicides under controlled conditions, e.g. the use of nozzle guards (Woolley & Davis, 1991). In a maize/bean intercrop system, herbicides (mainly pre-emergence) are readily available for the control of grass weeds for example Alachlor (Lasso), EPTC (Eptam Super) and Matolachlor (Dual), but broad leaf weeds cannot be well controlled.

The influence of weeds in intercropping systems has not been comprehensively studied and needs further investigation.

2.7.2 Insects

Intercropping of maize with beans has often been found to control many bean pests and diseases (Van Rheenen, Hasselbach & Muigai, 1981). This can be expected in a vegetationally diverse system. In a natural situation where many plants grow together, insect pests seldom as serious a problem as in sole crops. Spatial isolation and low levels of resistance keep pest and host in balance (Davis *et al.*, 1986).

Reduction mechanisms for insects in intercrops can be classified into the following three basic groups:

1) The association of the different crops makes the host less favourable to the pest (Trenbath, 1993). This can be achieved in various ways, for example:

a) Changes in micro-climate. Characteristic modifications in a maize/bean association versus bean sole crop are lower temperatures and wind speed, higher humidity, and the presence of shading which are all unfavourable for some insect pests (Castro *et al.*, 1991).

b) The presence of more favourable food. The presence of wild mustard in a collard/wild mustard intercrop significantly reduced flee beetle (*Phyllotreta crucifera*) densities per collard plant as the beetles favoured the wild mustard (Altieri & Liebman, 1986).

c) Flee beetle has also been reported to be affected by background colour. Cole crops on bare soil are more attractive to flee beetle than those with a foliage background (Hasse & Litsinger, 1981 cited by Altieri & Liebman, 1986).

d) The scent of the companion crop can act as an insect repellant, for example Marigold is well known for its repelling effect on insects and nematodes and is widely intercropped in India (Mathews, 1994, pers. comm.).

2) Direct interference with the activity of the pest. This is

achieved in several ways, for example:

a) Interference with flight movements and restriction of movement between plants due to the barrier effect. Power (1987) found that beans planted between maize rows slowed the dissemination of insect transmitted diseases in maize.

b) Reduction in time spent feeding on the host plant due to disruption caused by landing on non-host plants.

c) Inability to find host plant due to visual and olfactory interference (masking) (Altieri & Liebman, 1986; Trenbath, 1993).

3) Increased activity of natural enemies of pests (Cardona, 1990; Trenbath, 1993). Predators are often polyphagous and favour a broader habitat (Altieri & Liebman, 1986). They are often sustained by a wider range of prey results in a more stable population. Milanez (1984 & 1987) reported a reduction in some pests, as well as an increase in the incidence of predators as a result of intercropping of maize and beans.

Capinera *et al.* (1985), reporting on the effect of a bean/maize intercrop on insect abundance, found that the mexican bean beetle *(Epilanchna varivestis* M.) and leafhoppers were less abundant in beans in intercropping and that the population increased when strips were wider. The same tendency was reported for pale striped flea beetles *(Systena blana* M.) and a shining flower beetle of the *Phalacrus* spp. in maize. On the other hand, these authors also found that western corn rootworms, (*Diabrotica virgifera* LeConte) and corn leaf aphids, (*Rhopalosiphum maidis* Fitch) were significantly favoured by heterogeneity. The mechanisms involved were not recorded. Several species were not affected by intercropping for example grass thrips, green-bugs, spider-mites, etc. Karel (1991) reported a lower incidence of bean flies (*Oliomyi* sp.) in a beans/maize intercrop. Once again the mechanism behind the reduction was not recorded, but was thought to be either an increase in natural enemies and/or a restriction in movement (barrier effect). In Kenya, maize was found to effectively reduce aphid movement and incidence in a maize/bean intercrop (Stoetzer & Omunyin, 1984). Fewer winged aphids occurred in the intercrop which explained the lower incidence of Bean Common Mosaic Virus. The incidence of corn stunt spiroplasma in maize was also lower in intercropping with beans due to lower movement rates and higher emigration rates of the vector, a corn leafhopper (*Dalbulus maidis*) (Power, 1987). The presence of cowpeas and lablab (*Lablab purpureus* L.) reduced the infestation of *Chilo partellus* in sorghum by up to 23.4% when intercropped. This led to yield increases of more than 1000 kg ha^{-1} (Mahadevan & Chelliah, 1986). It appeared that the lablab and cowpeas prevented oviposition by gravid females.

It is important to note that intercropping does not benefit all crops in the association to an equal extent. The insect population in maize is often less affected than in beans (Trenbath, 1993). The specific crops in the combination and the plant density also affect the incidence of insects in the system (Davis & Woolley, 1993). In general it can be said that intercropping reduces the incidence of insects in at least one of the crops in the association (Castro *et al*., 1991, Woolley & Davis, 1991 and Trenbath, 1993).

2.7.3 Disease

The effect of intercropping on disease depends on the nature of the disease, the location and climatic conditions (Boudreau & Mundt, 1992). As a result, disease incidence can be increased or decreased by intercropping (Msuku & Edje, 1982).

Castro *et al*. (1991) reported that the presence of maize in a maize/bean intercrop led to a reduction in the transpiration rate of moisture from the bean leaves and also increased the humidity between the maize rows. Differences in temperature can also be induced, for instance higher temperatures under dry conditions due to less air movement and cooler temperatures under wet conditions due to evaporation. These factors induce conditions more conducive to some diseases but less conducive to others.

Mabagala & Saettler (1992) reported an increase in severity of halo blight (*Pseudomonas syringae* pv. *phaseolicola*) (both leaf and seed infection) in intercropped beans relative to sole cropped beans, probably because the intercropped foliage took longer to dry. These findings are contradictory to those of Msuku & Edje (1982) and Vermeulen (1982 cited by Mabagala & Saettler, 1992) who reported a decrease in halo blight due to intercropping. Mabagala & Saettler interpreted this difference as being due to the fact that the maize formed a barrier, which slowed down the infection in Vermeulen's study. Msuku & Edje and Vermeulen relied on natural infection, whereas Mabagala & Saettler infected their crops artificially.

Msuku and Edje (1982) also reported lower levels of other bacterial blights, rust, anthracnose and ascochyta blight in beans whereas angular leaf spot increased in intercropping v. sole cropping. They found latter tendency puzzling as this pathogen has the same dissemination mechanism as anthracnose and ascochyta blight. However anthracnose commonly spreads through physical contact and angular leaf spot through wind and water, the higher levels of angular leaf spot is most likely due to altered micro-climate in the intercrop as angular leaf spot prefers wet conditions and cannot survive temperatures higher than 30-35 °C during infection (Liebenberg, 1998, pers. comm.). Bourdreau and Mundt (1992) found less rust on beans intercropped with maize than on sole beans.

Van Rheenen, *et al.*, (1981) also reported lower incidence of halo blight, bean common mosaic virus, scab, mildew and angular leaf spot on beans in maize/bean intercrops whereas that of white mould was higher and rust showed a variable response.

The main mechanisms involved are therefore: restriction of dispersal factors, e.g. wind and rain, by non-host crop; interception of spreading agents by non-host crop; modification of microclimate, and reduction of host density (Bourdreau and Mundt, 1992). The contradictory findings indicate that all the mechanisms involved are not fully understood (Sengooba, 1990).

CHAPTER 3

YIELD AND YIELD COMPONENTS

3.1 Introduction

As a result of a study done on the state of agriculture in the Vulindlela district of the KwaZulu-Natal province of South Africa, limited land size was identified as a major constraint on agricultural development (Liebenberg, 1993). Traditionally, maize and beans were intercropped, which improved land productivity (Lea and Standford, 1982). Intercropping is, however, no longer used due to a shift in crop importance. Maize is now less important than potatoes and beans. In the traditional intercropping system maize was the dominant crop, resulting in very low bean yields. The introduction of new disease resistant high yielding bean cultivars favoured the increased production of beans, especially as refined maize meal is preferred to home ground meal and is readily available in shops.

As maize is still grown for green maize on a small scale, the development of a suitable intercropping system, producing a near optimum bean yield with some maize, was desirable. The new system should therefore have beans as the dominant crop and maize as the secondary crop.

In the traditional intercropping system beans, were grown in the inter-row of a maize crop. This led to severe competition for light from the maize. Competition for light from maize can be reduced in two ways: firstly by reducing the maize population density, and secondly by changing the row arrangement (Woolley and Davis, 1991). As maize yield could be sacrificed, both strategies were implemented.

Two bean types are commonly grown in the Vulindlela area i.e. Carioca and Speckled Sugar beans, the latter being more popular. The most common bean cultivars of each type, and two popular maize cultivars were included in order to evaluate their ability to perform in an intercropping system.

Due to the community's preference for beans over maize the former crop was studied in far greater detail. Beans are very adaptable to stress and can compensate to some degree for stress experienced earlier in the season (Liebenberg, 1989). By studying the yield components, stress conditions can be identified and, where possible, avoided in future. Stress experienced during the vegetative phase of the bean plant will manifest as a reduced plant mass. If stress conditions are experienced during pod set, more pods will be weaned off, resulting in less pods available to be filled. Stress during pod filling leads to less seeds per pod. Seed size is reduced where stress is experienced during seed fill. Should stress conditions be relieved at any stage and sufficient resources are available, subsequent stages will compensate to some degree for potential yield loss (Liebenberg, 1989).

For the purpose of the investigation of intercropping potential, four trials in total were planted at four different sites during three seasons. This arrangement was chosen for security and practical reasons, as well as a result of the limited time available.

3.2 Materials and methods

3.2.1 Vulindlela trial

3.2.1.1 General information

The first trial was planted in the 1992/93 summer season at the KwaGubese Training Centre in the Vulindlela area of KwaZulu-Natal. The site is situated in the mist belt, at an altitude of 1100 m at 29,66° south 30,18° east, (50 km east of Pietermaritzburg), and receives an average of 929 mm rain annually. The soil type at the trial site is a Avalon form with an orthic A horizon. The B horizon is a yellow brown apedal on top of a soft plintite, the latter limiting root growth mainly to the top 600 mm. Soil analysis, land preparation and fertilization is given in Appendix 1, and rainfall data in Appendix 2.

3.2.1.2 Treatments

a) Maize cultivars: 1) Kalahari Early Pearl (KEP), a white open pollinated cultivar with a high yield potential, well adapted to adverse conditions and popular in the local community and 2) SR 52, a hybrid with high potential under favourable conditions and very popular as green maize.

b) Bean cultivars: 1) Mkuzi, a Carioca bean with an indeterminate growth habit and high yield potential, rust resistant and commonly planted in the community and 2) Umlazi, a red speckled sugar bean with a bush type growth habit, resistant to rust and very popular with the local community.

c) Bean density : The sole crop control was planted in rows 800 mm apart at a population of 250 000 plants per ha. Intra-row spacings were kept at 50 mm for both sole and intercrops. The following densities were used for beans in intercropping: Density 1 = 75% of sole crop population, resulting in three rows of beans 700 mm apart; Density 2 = 100% of the sole crop population, resulting in four rows 560 mm apart; Density 3 = 125% of sole crop population, resulting in five rows 470 mm apart. The inter-row spacings of the intercrops had to change due to the presence of the maize.

d) Maize harvesting stages: Half of each maize plot was harvested at the green maize stage. The plants were cut off at ground level and laid flat to prevent shading. The remaining half was left to form dry grain. As this treatment had no effect on bean yield or yield components, it was omitted from the final statistical analysis in order to improve accuracy.

e) Sole crop controls: Both maize and bean cultivars were grown as sole crops at the normal inter-row spacing of 800 mm and 350 mm in the row for maize and 50 mm in the row for beans. Six rows of each cultivar was planted per plot.

Beans were planted eight weeks after the maize in order to mature at the end of the rain season. For the intercropping treatments the row arrangements were adapted. The maize population was reduced to 50% of the sole crop, giving two rows per 3.2 m instead of four. These two rows were spaced 400 mm apart so that 2.8 m would be available for beans, which were grown between pairs of maize rows (Fig 3.1)

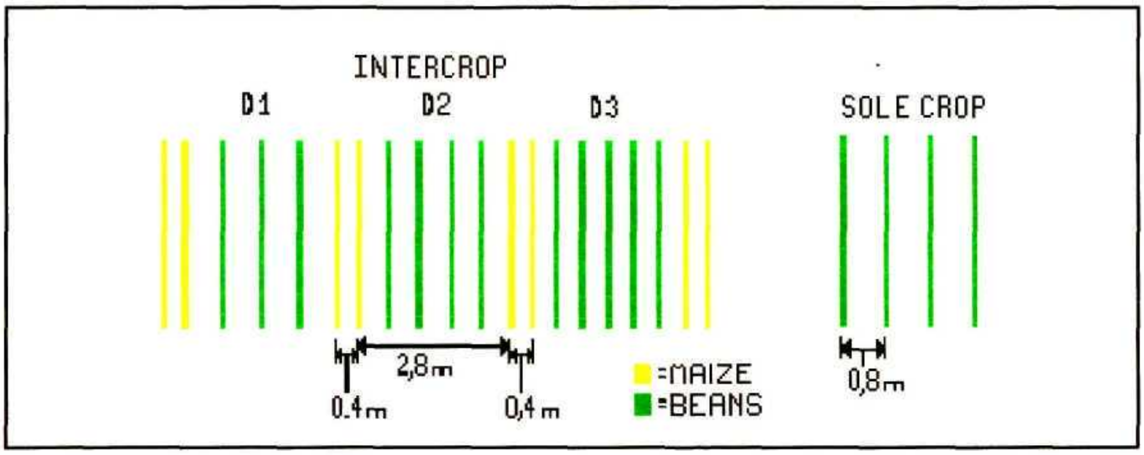

Figure 3.1 Sole and intercrop row arrangements used for the investigation of intercropping potential in KwaZulu-Natal.

The trial was arranged in a split-split block design with three replications. The main blocks were intercropped maize and bean cultivars and sub-blocks were bean densities split for maize harvest stage. Plots were 10 m long of which 5 m was used for green maize and 5 m for dry grain yield. Net plot length for each maize stage was 4 m, with 3,5 m for beans.

When the beans had reached the 50% flowering stage, four bean plants per row were randomly selected, sampled and dried at a temperature of 70 °C for 48 hours and weighed to determine plant dry mass. At harvest a sample of ten bean plants per row was taken. Number of pods per plant, seeds per pod and hundred seed mass were recorded.

Bean rows were numbered from row 1 to 5 using Roman numerals. The rows were orientated in a east-west direction along the contour, the site being on a 10% north facing slope. Numbering started up-slope with row I always occupying the most elevated position on the slope, row III in the middle and row V at the lowest position. Consequently, in Density 1 only rows I, III and V occurred; in Density 2 only rows I, II, IV and V occurred, and in Density 3 all the rows (Fig 3.2). This numbering was necessary to enable simultaneous analysis of the different densities. In order to make comparison possible, rows that had the same position relative to the maize needed to have the same number.

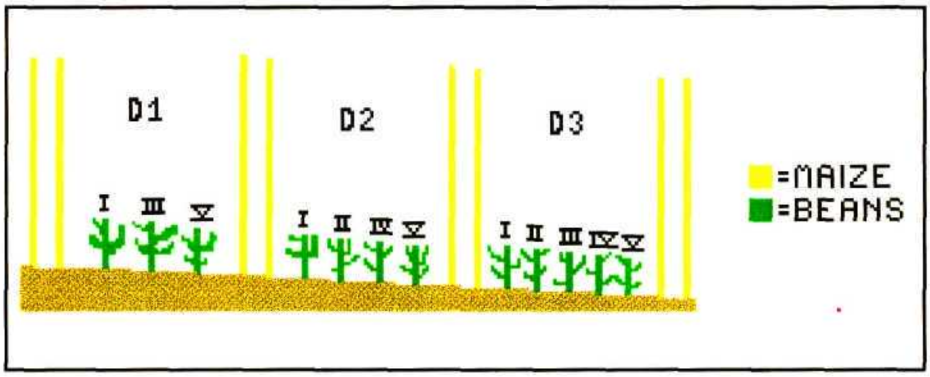

Figure 3.2 Row numbering used for the investigation of intercropping potential in KwaZulu-Natal.

The two rows on either side of the bean plots were used to supply maize data. After the green maize had been harvested, the total number of cobs per plot, as well as the number of marketable cobs (those longer than 200 mm) were determined.

The dry maize cobs were harvested and allowed to dry thoroughly for ± 35 days after which the grain was removed with a hand thresher. Grain moisture was subsequently determined with the aid of a "Dicky John" hydrometer and moisture standardized at 14%.

The statistical analyses were performed with the aid of Genstat 5.22. After consultation with the Biometry Department of the University of Natal Pietermaritzburg analysis of variance was used to identify significant differences, and mean differences between rows were compared using the t test.

3.2.2 Ukulinga trial

A similar but scaled down version of the trial described in paragraph 3.2.1 was planted during the summer of 1992/93 at the Ukulinga Research Farm of the University of Natal, situated 29,67 ° south and 30,40 ° east at an altitude of 775 m, just south of Pietermaritzburg. This region has a thorn veld bioclimate with a low yield potential due to low rainfall (500 mm/annum). The maize cultivar SR 52 was omitted from this trail as it is not adapted to these conditions. The bean cultivar Mkuzi was planted but could not be included in the analysis as it was destroyed by an unknown disease during the podfill stage.

The trial site is situated on a Bonheim soil type. Soil analysis and fertilizer recommendations are given in Appendix 3, and meteorological data in Appendix 4. Only 25% of the recommended fertilizer was applied due to the lower rainfall and consequently lower yield potential. Soyabeans had been grown on the same site during the previous year.

Statistical design and analysis was the same as that used for the Vulindlela data.

3.2.3 Cedara and Makhathini trials

Two further trials were planted, namely at Cedara Agricultural College during the summer of 1995/96 and at Makhathini Experiment Station during the winter of 1996. These two trials differed from the Vulindlela trial in the following ways:

1) Bean density was dropped because a negligible response was obtained to this factor in the first two trials.
2) Maize stage treatments were not included because the Vulindlela farmers said that green cobs would be picked randomly. All cobs not used green would be left in the field to dry on the plant, which would not be removed until the end of the season.

3) Two bean planting times were included, the first being simultaneous with maize and the second eight weeks later (at the same maize stage as in the Vulindlela trial).
4) A second maize control treatment was added. Maize was planted in tramlines with the same spacing and density as in the intercrop, but no beans were included.
5) Beans were planted at a constant density of 250 000 plants per ha, with inter-row spacing of 560 mm (i.e. the same as Density 2 used in the Vulindlela and Ukulinga trials).
6) The 16 treatments were arranged in a randomized block design with 5 replications.
These changes were made due to problems which were experienced with the analysis of the previous trials, and also to solve some questions which arose from the previous trials. Rows were numbered as in the first trial.

3.2.4 Cedara trial

The Cedara trial was planted at the Cedara Agricultural College situated 29,53° south and 30,28° east at an altitude of 1076 m (about 20 km north of the Vulindlela site). The climate is similar to that of Vulindlela. The trial site is located on a Bainsvlei soil type which consists of a orthic A horizon with a red apedal B horizon on top of a soft plintite. The soil analysis and fertilizer recommendations are given in Appendix 5 and meteorological data in Appendix 6. The maize and first bean planting took place on 13-14 November 1995 and the second on 8 January 1996.
Each plot was 5 m wide and 7.7 m long. Sole crops consisted of 6 rows of which 4 were harvested as the nett plot. Tramline plots consisted of 4 maize rows of which the centre two rows were harvested as the nett plot. Intercrop plots consisted of 4 maize rows and 6 bean rows, the 4 bean rows between the maize rows and the two maize rows bordering the beans were harvested as the nett plot (Fig 3.3).

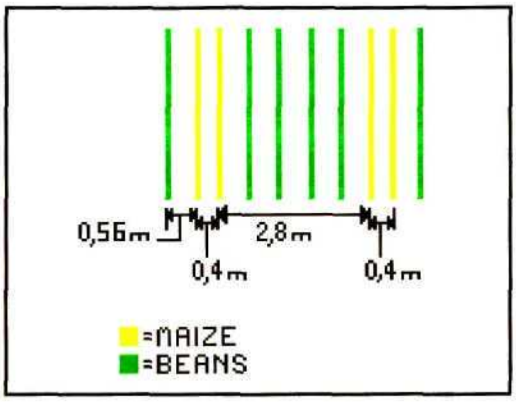

Figure 3.3 Intercrop plots used for the investigation of intercropping potential in KwaZulu-Natal.

Beans were harvested when ripe, each bean row separately. Four metres were harvested and threshed for seed yield, and one metre for recording plant number. The material from this metre was then separated into yield components i.e. plant dry mass (air dry), number of pods, number of seeds, and seed mass. From this, number of plants per metre, number of pods per plant, number of seeds per pod and hundred seed mass were calculated. Seed yield was calculated by adding the 1 m and 4 m yields to give a 5 metre nett plot for beans plots. A 1.35 m border was left on both sides of the nett plot. The nett maize plot consisted of the centre 2 rows for intercropped and tramline maize and the centre 4 rows for sole cropped maize. A 0.35 m border was left on both ends of the rows, leaving 7 metre as the nett plot.

The Statistical analyses were performed using Genstat 5.22. Analysis of variance was used to establish significant differences.

3.2.5 Makhathini trial

A trial identical to the Cedara trial was planted at the Makhathini Experiment Station in North-Eastern KwaZulu-Natal. This site is 50 km from the coast at 27,43° south and 32,18° east at an altitude of 70 m. Maize and beans are grown in winter as temperatures are too high in summer. The trial was grown under irrigation. In order to compensate for inadequate rainfall, low levels of irrigation were applied in order to simulate a sub optimal rain season. The trial site was situated on a Hutton soil (Shorrocks series) which consists of an orthic A with a red apedal B horizon that is at least 2.5 m deep. The maize- and first bean planting took place on 3 April 1996 and the second bean planting 8 weeks later on 28 May 1996. Harvesting was carried out in the same way as at Cedara. The soil analysis and fertilizer recommendations are given in appendix 7 and meteorological data in appendix 8.

The Statistical analysis was the same as the Cedara trial.

3.3 Results - Vulindlela

3.3.1 Dry beans

3.3.1.1 Seed yield

Under sole cropping Mkuzi produced a significantly (P=0.01) higher yield than Umlazi, but the cultivar differences were not significant in the intercropping treatments (Table 3.1). Intercropping did however reduce the seed yield significantly (P=0.01) by 48.3% and 42.1% for Mkuzi and Umlazi respectively. Density and maize cultivar treatments had no significant effect on seed yield, but there was a significant (P=0.05) linear tendency for higher yield with increasing density (Appendix 9).

Table 3.1 The effect of intercropping on the seed yield of the different bean cultivars at Vulindlela.

	Yield (kg ha^{-1})		
Treatment	Bean Cultivars		Mean
	Mkuzi	Umlazi	
Sole	1556 A	900 B	1228 a
Intercrop			
Density 1	708	418	661
Density 2	724	601	673
Density 3	942	544	776
Intercrop mean	805 C	521 C	663 b

Yields followed by the same letter do not differ significantly (P=0.01) (only compare values followed by a letter in the same case).

Comparing rows

The inner rows of the intercropping treatments yielded significantly (P<0.01) more seed than the outer rows. This can be expected as the outer rows are adjacent to the maize plants. Mkuzi showed a significantly (P=0.05) greater difference than Umlazi (Table 3.2). Row I also yielded significantly (P<0.01) higher than row V (Table 3.3). All other row differences were not significant.

Table 3.2 The difference in yield between rows bordering on maize (outer rows)and those surrounded by beans (inner rows) for two bean cultivars in a maize/bean intercrop at Vulindlela.

	Yield differences(g $plant^{-1}$)		
	Bean Cultivar		Mean
	Mkuzi	Umlazi	
inner v outer rows	3.24 a	1.40 b	2.47

Values followed by the same letter do not differ significantly (P=0.01).

Table 3.3 Means and t values of bean yield differences between different rows in a maize/bean intercrop at Vulindlela.

Rows	Mean*	t values	Significance
Inner -* outer	2.47	9.84	P<0.01
I - V	1.24	3.60	P<0.01
II - IV	0.39	0.69	NS
II - III	-0.41	0.71	NS
III - IV	0.49	0.65	NS

NS = not significant

* = Mean yield differences(g plant^{-1})

-* = Subtract

3.3.1.2 Number of pods per plant

The two bean cultivars showed significant differences in the number of pods produced per plant (Table 3.4). Mkuzi produced significantly (P<0.01) more pods per plant than Umlazi under both sole and intercropping. This could be expected as Mkuzi has an indeterminate growth habit, producing pods over a longer period and consequently a larger number of pods. Intercropping significantly (P=0.01) reduced the number of pods per plant by 26.5% and 43.3% for Mkuzi and Umlazi respectively.

Table 3.4 Number of pods per plant of two bean cultivars grown as a sole crop and in a maize/bean intercrop at Vulindlela.

	Number of pods per plant		
Treatment	Cultivars		Mean
	Mkuzi	Umlazi	
Sole crop	9.33 a	4.94 b	7.13 A
Intercrop	6.86 c	2.80 d	5.17 B

Values followed by the same letter do not differ significantly (P=0.01) (only compare values followed by a letter in the same case).

Difference in number of pods produced between inner and outer rows

The reduction in number of pods per plant in the outer rows was significantly (P=0.05) greater (Table 3.5) when intercropped with SR 52 than with KEP. KEP grew less vigorously and was slightly shorter (1.93 m v 2.3 m) than SR 52. This could explain the smaller difference in number of pods per plant between the inner and outer rows of beans intercropped with KEP. The difference for Mkuzi was also significantly (P<0.01) higher than that for Umlazi. Increased bean density did not lead to a significant increase in the number of pods between the inner and outer rows. However an increase in bean density led to a linear increase in the difference in number of pods between the inner and outer rows (Appendix 10).

Table 3.5 The effect of maize and bean cultivars on the difference in number of pods per bean plant between the inner and outer rows in a maize/bean intercrop at Vulindlela.

Number of pods $plant^{-1}$					
Treatment	Maize Cultivars		Bean Cultivars		Mean
	KEP	SR 52	Mkuzi	Umlazi	
Density 1	0.9	2.73	2.84	0.75	1.97
Density 2	1.89	2.48	3.12	1.01	2.24
Density 3	2.47	4.39	5.22	1.30	3.59
Mean	1.75 A	3.20 B	3.73 a	1.02 b	2.60

Yields followed by the same letter do not differ significantly (P=0.01) (only compare values followed by a letter in the same case).

Differences between rows

Row I yielded significantly (P=0.01) more than row V, while row II yielded significantly more than row IV (Table 3.6). This could probably be explained by the increased light that rows I and II would have received.

Table 3.6 Means and t values of differences in number of pods per plant between different rows in a maize/bean intercrop at Vulindlela.

Rows	Mean*	t values	Significance
Inner -* outer	2.60	9.087	P=0.001
I - V	1.51	3.277	P=0.01
II - IV	1.53	2.34	P=0.05
II - III	1.10	0.65	NS
III - IV	0.48	0.63	NS

NS = not significant

* = Mean differences (pods plant^{-1})

-* = Subtract

3.3.1.3 Number of seeds per pod

As could be expected, the two cultivars differed significantly (P<0.01) (Table 3.7) in the number of seeds produced per pod, Mkuzi producing more seeds per pod than Umlazi. Intercropping significantly (P=0.01) affected mean number of seeds per pod. KEP had a significantly greater effect on the number of seeds per pod than SR 52. KEP provided greater competition during bean seed set, as it flowered two weeks earlier than SR 52. It's peak demand period for resources was therefore reached before that of SR 52. There was a decreased number of seeds per pod with increasing density. This trend was significantly linear (P=0.02) (Appendix 11). Density 3 produced significantly less seeds per pod (P=0.05) than the sole crop, but not Density 1 and Density

2. This is most likely due to the fact that there was an increased number of pods per unit area with increasing density. This means that under stress conditions less seeds per pod are formed at the higher densities.

Table 3.7 The influence of maize and bean cultivars and bean density on the number of bean seeds per pod produced under sole cropping and in a maize/bean intercrop at Vulindlela.

	Seed pod^{-1}				
Treatment	Maize Cultivars		Bean Cultivars		Mean
	KEP	SR 52	Mkuzi	Umlazi	
Sole crop	---	---	4.288 A	2.915 B	3.601 *A*
Intercrop					
Density 1	3.361	3.781	4.208	2.763	3.606 *a*
Density 2	3.318	3.694	3.976	2.924	3.538 *a*
Density 3	2.870	3.546	3.911	2.359	3.264 *b*
Intercrop Mean	3.183 a	3.674 b	4.032 C	2.682 D	3.469 *B*

Values followed by the same letter do not differ significantly (P=0.01) (only compare values followed by a letter in the same case and font).

Number of seeds per pod, comparing rows

The inner rows of Umlazi had significantly (P=0.01) (Table 3.8) more seeds per pod than the outer rows (Table 3.9). There was no significant difference for Mkuzi. Comparing row I and V, Mkuzi produced significantly (P=0.05) more seeds per pod in row V than in row I (Table 3.9). Conditions during the pod fill of Mkuzi were most likely less ideal than for Umlazi with the result that the greater number of pods formed by Mkuzi in row I compared to row V, failed to fill (see Table 3.6). This reduction in number of seeds per pod for row I of Mkuzi is most likely the reason why it failed to produce significantly more pods in the outer rows compared to the inner rows.

Table 3.8 Table of mean number of seeds per pod and t values of row differences of beans planted in an intercrop with maize at Vulindlela.

Rows	Means*	t values	Significance
Inner -* outer	0.317	3.368	P=0.001
I - V	-0.11	1.415	NS
II - IV	-0.20	0.898	NS
II - III	-0.13	1.273	NS
III - IV	0.26	1.204	NS

NS = not significant

*Means = Mean difference (seeds pod^{-1})

-* = Subtract

Table 3.9 The effect of bean cultivar in the difference between inner and outer rows and row I and V in a maize/bean intercrop at Vulindlela.

	Mean difference (seeds pod^{-1})		
	Bean Cultivars		Mean
	Mkuzi	Umlazi	
Inner v outer	0.044 NS	0.698 P=0.01	0.317
I v V	-0.35 P=0.05	0.13 NS	-0.15

NS = not significant

3.3.1.4 Hundred seed mass

Genetic differences between the two bean cultivars led to significant differences (P<0.01) in hundred seed mass (Table 3.10). Seed mass for Mkuzi was not affected by intercropping, but intercropping did significantly (P=0.05) decrease seed mass for Umlazi. Bean seed mass was significantly (P=0.01) reduced by SR 52 but KEP had no significant influence on bean seed mass. This is possibly due to the more vigorous growth habit of SR 52 and the greater no of seeds that needed to be filled as a result of the increased number of pods per plant (Table 3.5).

Table 3.10 The effect of maize and bean cultivar on hundred seed mass of beans under sole cropping and intercropping of maize and beans at Vulindlela.

g 100 seed^{-1}					
Treatment	Maize cultivars		Bean cultivars		Mean
	KEP	SR 52	Mkuzi	Umlazi	
Sole Crop	---	---	22.9 *a*	41.2 *b*	32.05 A
Intercrop	33.02 a	25.39 b	19.41 *c*	41.39 *b*	28.57 A

Values followed by the same letter do not differ significantly (P=0.01)(only compare values followed by a letter in the same case and font).

Inter row differences

There were no significant differences in seed size of the different rows (Table 3.11).

Table 3.11 Mean row differences of bean hundred seed mass and t values in a maize/bean intercrop at Vulindlela.

Rows	Means*	t values	Significance
Inner -* outer	0.35	0.530	NS
I - V	-0.50	0.113	NS
II - IV	-0.73	1.174	NS
II - III	-0.96	0.498	NS
III - IV	-0.70	1.204	NS

NS = not significant

*Means = Mean difference g 100 seed^{-1}

-* = Subtract

3.3.1.5 Plant dry mass

Plant dry mass was significantly (P<0.01) influenced by intercropping (Table 3.12). Intercropping decreased plant mass dramatically by 41.71% on average. As was expected, Mkuzi plants had significantly (P=0.01) greater mass due to this cultivar's indeterminant growth habit and longer growingseason. Although bean density had no significant effect on plant size, there was a significant (P=0.02) linear tendency for plant mass (Mkuzi only) (Table 3.12 and Appendix 12). This was probably due to the larger plants causing greater intra-varietal competition.

Table 3.12 The influence of sole and intercropping of maize and beans on the mean plant dry mass of two bean cultivars at Vulindlela

Differences between rows (grams plant^{-1})			
Treatment	Bean cultivars		Mean
	Mkuzi	Umlazi	
Sole Crop	14.15 a	5.06 b	9.61 A
Intercrop			
Density 1	8.25	3.16	6.13
Density 2	7.10	3.53	5.61
Density 3	5.94	3.06	5.06
Intercrop mean	7.28 c	3.25 d	5.60 B

Values followed by the same letter do not differ significantly (P=0.01)(only compare values followed by a letter in the same case).

Comparing rows

When comparing plant masses of the inner rows with that of the outer rows, the inner row plants had significantly (P<0.01) higher masses than the outer row plants (Table 3.13). Mkuzi plants also showed significantly greater reduction in plant mass compared with Umlazi.

Table 3.13 The effect of bean cultivar on the difference in plant dry mass between inner and outer rows under intercropping of maize and beans at Vulindlela.

	g plant^{-1}		
	Bean cultivar		Mean
	Mkuzi	Umlazi	
Inner v outer	4.1 a	1.3 b	2.7

Values followed by the same letter do not differ significantly (P=0.01).

The differences between rows I & V and rows III & IV were also significant (P=0.01) (Table 3.14). The rows closest to the maize row on the northern side of the plot displayed lower plant masses due to increased shading.

Table 3.14 Mean row differences and t values of bean plant dry mass in a maize/bean intercrop, Vulindlela.

Rows	Means*	t values	Significance
Inner -* outer	2.88	8.69	P=0.001
I - V	1.50	3.046	P=0.01
II - IV	0.83	1.61	NS
II - III	-0.2	0.68	NS
III - IV	1.13	3.207	P=0.01

NS = not significant

*Means = Mean difference g plant^{-1}

-* = Subtract

3.3.2 Maize

3.3.2.1 Green maize yield

The number of marketable green maize cobs was significantly (P<0.01) reduced by intercropping. However, this was not as much as expected taking into consideration the 50% reduction in population density (Table 3.15 and Table 3.16). Approximately 50% of the total crop was of marketable size. It is also interesting to note that intercropped maize bore an average of 0.82 cobs per plant whereas sole cropped maize only bore an average of 0.72 cobs per plant (results not shown). However there was no significant difference in green maize yield between cultivars. The expected higher green maize yield for SR 52 was not realized due to the less favourable climatic conditions and low soil fertility.

A significant (P=0.05) interaction between maize cultivars and density was experienced for marketable green maize yield (Table 3.15); this was only for KEP at Density 3 where the number of marketable green maize cobs was significantly lower than the rest. It would appear that KEP was more sensitive to the higher bean density as it produced fewer marketable cobs.

Table 3.15 The influence on sole and intercropping of maize and beans on the number of marketable green maize at Vulindlela.

Cobs ha^{-1}			
Treatment	Maize cultivars		Mean
	KEP	SR 52	
Sole Crop	12790 A	11119 A	23982 *A*
Intercrop			
Density 1	9225 a	8369 a	8729 *a*
Density 2	9784 a	7794 a	8625 *a*
Density 3	5388 b	8825 a	7394 *b*
Intercrop Mean	8138 B	8330 B	8250 *B*

Values followed by the same letter do not differ significantly (P=0.01, P=0.05 for densities)(only compare values followed by a letter in the same case and font).

Table 3.16 The influence on sole and intercropping of maize and beans on the total number of green maize cobs at Vulindlela.

	Cobs ha^{-1}		
Treatment	Maize cultivars		Mean
	KEP	SR 52	
Sole crop	33.7 a	29.5 a	31.6 A
Intercrop mean	19.41 b	18.85 b	18.92 B

Values followed by the same letter do not differ significantly (P=0.01)(only compare values followed by a letter in the same case).

3.3.2.2 Dry grain yield

Maize grain yield under intercropping was significantly (P<0.01) lower than that under sole cropping (Table 3.17). A intercrop maize yield of approximately 50% of the sole crop yield was expected due to the intercrop population being 50% that of the sole crop. Under sole cropping SR 52 yielded significantly (P=0.05) more than KEP but the difference was not significant under intercropping. All other treatments had no significant effect on maize grain yield.

Table 3.17 The effect of sole and intercropping on dry grain yield of two maize cultivars, Vulindlela.

	Grain yield (t ha^{-1})		
Treatment	Maize Cultivars		Mean
	KEP	SR 52	
Sole Crop	5.442 a	5.912 b	5.677 A
Intercrop	2.558 c	2.991 c	2.775 B

Values followed by the same letter do not differ significantly (P=0.01, P=0.05 for sole crop)(only compare values followed by a letter in the same case).

3.3.3 Discussion

The trial failed to meet two of the objectives: a) The mean intercrop bean yield was only 663 kg ha^{-1} compared to the sole crop bean yield of 1226 kg ha^{-1} resulting in a yield ratio of only 0.54 compared to the desired ratio of 1. b) The mean maize yield ratio was only 0.49 giving a LER of only 1.03 which is not a "substantial" improvement in land productivity.

The maize severely dominated the beans, leading to low bean yields. The main mechanism of yield reduction was a reduction in number of pods per plant. Reductions in number of seeds per pod and seed mass also attributed further to yield loss. Plant dry mass was also reduced by intercropping. It can be concluded that the beans were subjected to stress conditions throughout the season (Liebenberg, 1989). This can be explained by the fact that the yield component that is being formed during a stress period is affected. If the stress condition is lifted, consequent components can compensate to some degree provided the bean plant has the necessary resources. Bean plants growing on the southern side of the maize rows also displayed greater yield reductions than those on the northern side of the maize row, which indicates that there was competition for light. The fact that the beans displayed little response to the different population densities is consistent with the findings of Edje (1981) and Liebenberg (1993) (pers. comm.) that beans compensate well for changes in population density. The reduction in maize yield can be attributed to the reduction in maize population. This is consistent with the findings of Willey (1979b); Baker (1981); Chang & Shibles (1985), Woolley & Davis (1991) and Barker & Francis (1986), who found that the dominant crop usually has the same response curve as under sole cropping. The maize yields were higher than the normal subsistence farmer yields of ± 1 to 2 t ha^{-1}. This is probably due to the higher management level required to reduce error in the trial. It could be argued that the maize in the trial was more competitive than would have been the case in a typical subsistence farmer situation, but farmer yields could be improved by improved management.

3.4 Results - Ukulinga

3.4.1 Dry beans

3.4.1.1 Seed yield

In comparison with the sole crop, intercropping significantly (P=0.01) reduced yield. None of the other intercropping treatments influenced the bean yield significantly (Table 3.18). However there was a significant (P=0.04) linear tendency (Appendix 13) for yield to increase with increasing density at maize harvesting stage 2. It would therefore appear that beans planted at higher densities benefited slightly from the removal of the maize plants.

Table 3.18 The influence on sole and intercropping of maize and beans as well as the stage of maize harvest on bean seed yield for Umlazi at Ukulinga

Treatment	Maize harvest		Mean bean yield
	Stage 1*	Stage 2*	($t\ ha^{-1}$)
Sole Crop			1.501 A
Intercrop			
Density 1	0.649	0.498	0.574
Density 2	0.762	0.748	0.754
Density 3	0.734	0.821	0.778
Intercrop Mean	0.715	0.688	0.702 B

Values followed by the same letter do not differ significantly (P=0.01).

* Stage 1 = Maize harvested at the green maize stage and plants removed.
* Stage 2 = Maize left to be harvested as dry grain.

Yield differences between rows

Yield differences between rows were significant (P<0.01), except between rows III and IV (Table 3.19). The yield from the outer rows (adjacent to the maize) was much less than that from the inner rows. Unlike the Vulindlela trial, row I yielded less than row V, row II less than row III, and row II less than row IV. It suggests that this could be due to differences in water availability. The maize rows were in an east - west orientation, row V on the southern side of the closest maize row and received more shade than row I. Moisture would therefore tend to evaporate more slowly. The maize plants, being much shorter than at Vulindlela due to lack of moisture, tended to shade the bean plants less. This could mean that competition for water was more severe than competition for sunlight.

Table 3.19 Mean row differences of bean grain yield and t values in a maize/bean intercrop, Ukulinga.

Rows	Means*	t values	Significance
Inner -* outer	139	9.87	P=0.001
I - V	-78	5.45	P=0.001
II - IV	-50.7	18.96	P=0.001
II - III	-63.3	32.96	P=0.001
III - IV	-9.6	1.04	NS

NS = not significant

*Means = Mean differences (grams)

-* = Subtract

3.4.1.2 Number of pods per plant

Intercropping significantly (P<0.01) reduced the mean number of pods in comparison with that borne by the sole crop (Table 3.20). Increase in density led to a significant (P=0.01) reduction in number of pods per plant. This tendency was significantly linear (P<0.01) (Appendix 14).

Table 3.20 The effect of sole and intercropping of maize and beans, maize harvesting stage and bean density on the mean number of pods per plant at Ukulinga.

	pods plant^{-1}		
Treatment	Maize harvest		Mean
	Stage 1	Stage 2	
Sole Crop			5.85 A
Intercrop			
Density 1	4.90	4.07	4.48 a
Density 2	3.84	3.41	3.63 a
Density 3	3.33	3.15	3.24 b
Intercrop mean	4.03 *a*	3.54 *b*	3.78 B

Values followed by the same letter do not differ significantly (P=0.01, P=0.05 for maize stage)(only compare values followed by a letter in the same case and font).

* Stage 1 = Harvesting maize at the green maize stage and removing the plants.

* Stage 2 = Leaving maize to be harvested as dry grain.

The difference between the inner and outer rows was highly significant (P<0.01) indicating competition from the maize (Table 3.21). The lack of significant differences between the other rows indicated that bean density had no effect on number of pods per plant.

Table 3.21 Mean row differences of the number of bean pods per plant and t values in a maize/bean intercrop at Ukulinga.

	Pods plant^{-1}		
Rows	Mean differences	t values	Significance
Inner -* outer	2.53	4.50	P=0.001
I - V	-0.29	1.13	NS
II - IV	-0.15	0.57	NS
II - III	0.12	0.45	NS
III - IV	-0.38	1.36	NS

NS = not significant

-* = Subtract

3.4.1.3 Number of seeds per pod

There was no significant difference in the number of seeds per pod produced under sole crop and intercropping conditions (Table 3.22). There were no significant differences in number of seeds per pod between any of the intercropping treatments.

Table 3.22 The effect of sole and intercropping of maize and beans on the number of seeds per pod at Ukulinga.

	Seeds pods^{-1}
Treatment	
Sole Crop	3.031
Intercrop	2.677
Mean	2.854

Comparing rows

At densities 2 and 3, the inner and outer rows differed significantly (Table 3.23) but not at density 1. At density 2 and 3 the outer rows would have been closer to the maize and therefore subjected to more competition, leading to less seeds per pod.

Table 3.23 The influence of bean density on differences between inner and outer rows for number of seeds per pod, Ukulinga.

Treatment	Difference*		t value	Significance
Density 1	0.039	a	0.782	NS
Density 2	0.386	b	7.644	P=0.001
Density 3	0.214	a	4.24	P=0.01
Mean	0.212		4.437	P=0.01

Values followed by the same letter do not differ significantly (P=0.05) from each other.

*Difference = differences between rows in number of seeds pod^{-1}

Rows IV and V produced significantly more seeds per pod than rows II and I respectively (Table 3.24), a tendency that was also observed in the yield data (Table 3.19). This can be attributed to the fact that rows IV and V were on the southern side of the maize. The shade from the maize would have reduced evaporation, leaving more water available to the beans.

Table 3.24 Mean row differences of number of seeds per bean pod and t values in a maize/bean intercrop, Ukulinga.

	Seeds pod^{-1}		
Rows	Mean differences	t values	Significance
Inner -* outer	0.441	4.437	P=0.01
I - V	-0.41	2.888	P=0.05
II - IV	-0.26	2.942	P=0.05
II - III	-0.25	2.327	NS
III - IV	-0.10	0.720	NS

NS = not significant

-* = Subtract

3.4.1.4 Hundred seed mass

The only significant difference (P=0.05) in bean seed mass between sole crop and intercropping treatments was at density 1 where the early removal of maize plants increased seed mass (Table 3.25). There were also significant linear (P=0.01) tendencies for hundred seed mass to: a) decrease with increasing density when maize was removed early and b) increase with increasing density when maize was left to mature (Appendix 15).

Table 3.25 The influence of sole and intercropping of maize and beans, maize stage and bean density on hundred seed mass at Ukulinga.

	Hundred seed mass (g 100 seeds^{-1})		
Treatment	Maize harvest		Mean
	Stage 1*	Stage 2*	
Sole Crop			44.82
Intercrop			
Density 1	46.03 a	36.10 b	41.07
Density 2	42.31 ab	42.67 a	42.49
Density 3	41.27 ab	45.60 a	43.44
Intercrop mean	43.20	41.46	42.33

Values followed by the same letter do not differ significantly (P=0.05) from each other.

* Stage 1 = Maize harvested at the green maize stage and plants removed

* Stage 2 = Maize left to be harvested as dry grain.

Comparing rows

Inner rows yielded significantly lighter seeds than the outer rows (P=0.01)(Table 3.26) which was probable due to the fact that the inner rows had more pods per plant and more seeds per pod (Tables 3.21 & 3.24) and the plants were inability to fill all the seed. Rows V and IV yielded significantly (P=0.05) heavier seed than rows I and III probable due to increased water availability as had been mentioned before.

Table 3.26 Mean row differences of bean hundred seed mass and t values in a maize/bean intercrop, Ukulinga.

Rows	Mean differences*	t values	Significance
Inner -* outer	-6.7	4.202	P=0.001
I - V	-4.3	2.832	P=0.05
II - IV	-3.0	2.159	NS
II - III	1.4	0.751	NS
III - IV	-4.92	7.525	P=0.05

NS = not significant * = grams
-* = Subtract

3.4.2 Maize

3.4.2.1 Green maize yield

The sole crop yield of 9897 cobs per ha was significantly higher (P=0.01) than the intercrop yield of 5773 cobs per ha (Table 3.27). Due to the hot season the cob yield was very low, but cobs tended all to be of marketable size. Other treatments did not influence cob yield significantly.

Table 3. 27 The effect of sole and intercropping of maize and beans on the number of green maize cobs per ha at Ukulinga.

	Cobs ha^{-1}
Treatment	Yield
Sole crop	9897 a
Intercrop	5773 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.4.2.2 Dry grain yield

The only significant (P=0.01) difference found was a reduction in yield due to intercropping. The yield was reduced by 51.2% from 6.198 t/ha to 3.025 t/ha, which could be expected with 50% of the sole crop population density.

Table 3. 28 The effect of sole and intercropping of maize and beans on the maize grain yield at Ukulinga.

	t ha^{-1}
Treatment	Yield
Sole Crop	6.198 a
Intercrop	3.025 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.4.3 Discussion

The results at Ukulinga were very similar to those observed at Vulindlela. There was an interesting difference in that the rows that received the most shading gave the highest yields, i.e. a larger number of seeds per pod and a higher 100 seed mass. This was probably due to the fact that shade reduced the rate of evaporation in a situation where water was more limiting than sunlight. In addition to this, the maize only grew to approximately 1,60 m, which would have resulted in less shading than at Vulindlela. However, the outer rows experienced more competition than those at Vulindlela, as can be seen in the inner - outer row differences in Tables 3.3 versus 3.19. This was probably due to competition for water from the maize which would have been far greater at Ukulinga than at Vulindlela, particularly during February and March when water demand was at it's peak for both beans and maize.

3.5 Results - Cedara

3.5.1 Dry beans

3.5.1.1 Seed yield

There was no significant difference between mean sole crop and intercropping yields (Table 3.29). There was, however, a significant (P=0.05) difference between the two bean cultivars under sole cropping. Mkuzi yielded significantly higher than Umlazi. However, there was no significant difference between the two under intercropping. The yield of Mkuzi under intercropping was significantly (P=0.05) reduced to 59% that of the sole crop yield. The yield of Umlazi increased by 9% due to intercropping, although this was not statistically significant. The large reduction in the yield of Mkuzi under intercropping was of a similar magnitude to that found at Vulindlela. This confirms the findings of Clark and Francis (1992), who found that beans with an indeterminate growth habit are influenced more by intercropping than bush types.

Table 3.29 The influence of sole and intercropping of maize and beans on the bean seed yield of two bean cultivars at Cedara.

	Bean seed yield (kg ha^{-1})		
Treatment	Bean Cultivar		Mean
	Mkuzi	Umlazi	
Sole cropping	1741 a	1093 b	1417 A
Intercropping	1027 b	1191 b	1109 A

Values followed by the same letter in the same case do not differ significantly (P=0.05) from each other.

Under intercropping row IV yielded significantly less than the sole crop but this was not the case for the other intercrop rows (Table 3.30). This can be explained by the fact that row IV was more shaded than the other rows, due to the fact that it was on the southern side of the maize row.

Table 3.30 The influence of sole and intercropping of maize and beans on bean seed yield of each row, Cedara.

	Bean seed yield (kg ha^{-1})			
Treatment	Row I	Row II	Row III	Row IV
Sole cropping	1425 a	1386 a	1466 a	1390 a
Intercropping	1120 ab	1241 ab	1101 ab	975 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

Maize cultivar had a significant (P=0.05) influence on bean seed yield under intercropping. SR 52 reduced yield whereas KEP had no effect on bean yield (Table 3.31). SR 52, being the taller and more vigorous plant, competed more with the beans than KEP.

Table 3.31 The influence of maize cultivar on bean seed yield in a maize/bean intercrop at Cedara.

	Bean seed yield (kg ha^{-1})		
Treatments		Intercropped with Maize cultivars	
	Sole crop	KEP	SR 52
Yield	1417 a	1380 a	838 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.5.1.2 Number of pods per plant

There was no significant difference between sole and intercropping means but there was a significant (P=0.01) difference between cultivars. Mkuzi gave significantly more pods than Umlazi under sole cropping but the difference was not significant for intercropping (Table 3.32). Mkuzi had significantly fewer pods per plant under intercropping compared to the sole crop. Umlazi had more pods per plant under intercropping (difference not significant).

Table 3.32 The influence of sole and intercropping of maize and beans on the number of pods per bean plant of two bean cultivars at Cedara.

	Pods $plant^{-1}$		
Treatment	Bean Cultivar		Mean
	Mkuzi	Umlazi	
Sole cropping	7.450 a	3.902 b	5.676 A
Intercropping	4.659 b	4.967 b	4.813 A

Values followed by the same letter in the same case do not differ significantly (P=0.01) from each other.

Row IV produced significantly (P=0.05) less pods per plant than the sole crop rows, but not significantly less than the other intercrop rows (Table 3.33). This reduction in number of pods is the cause of the reduction in yield for row IV (described in paragraph 3.5.1.1).

Table 3.33 The influence of sole and intercropping of maize and beans on number of pods per bean plant of each row at Cedara.

	Pods plant^{-1}			
Treatment	Row I	Row II	Row III	Row IV
Sole cropping	5.649 a	5.672 a	5.739 a	5.643 a
Intercropping	5.094 ab	5.211 ab	4.918 ab	4.030 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

SR 52 caused a significant (P=0.05) reduction in number of pods per plant when compared to the sole crop (Table 3.34), whereas KEP caused an increase in number of pods per plant (difference not significant).

Table 3.34 The influence of maize cultivar on the number of pods per bean plant in a maize/bean intercrop at Cedara.

	Pods Plant^{-1}		
Treatments	Sole Crop	Intercropped with maize cultivars	
		KEP	SR 52
Pods plant^{-1}	5.676 a	6.004 a	3.623 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.5.1.3 Number of seeds per pod

The only factor that significantly (P=0.01) affected the number of seeds per pod was maize cultivar (Table 3.35). SR 52 significantly (P=0.01) reduced the number of seeds per pod when compared to KEP, but not when compared to the sole crop.

Table 3.35 The influence of maize cultivar on number of bean seeds per pod in a maize/bean intercrop at Cedara.

	Seeds pod^{-1}		
Treatments	Sole Crop	Intercropped with maize cultivars	
		KEP	SR 52
Seeds pod^{-1}	3.843 ab	4.351 a	2.730 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.5.1.4 Hundred seed mass

Results obtained from the Cedara trial were similar to those observed at Vulindlela and Ukulinga. Only maize cultivar had a significant influence on hundred bean seed mass (Table 3.36). Beans intercropped with KEP resulted in a significantly (P=0.001) lower bean seed mass compared to beans intercropped with SR 52. SR 52 induced a significantly higher bean seed mass than the sole crop (P=0.05). This was probably the result of the fact that the bean plants were inclined to compensate for the reduction in number of pods per plant and seeds per pod caused by SR 52.

Table 3.36 The influence of maize cultivar on bean hundred seed mass in a maize/bean intercrop at Cedara.

	Grams hundred seed^{-1}		
Treatments	Sole Crop	Intercropped with maize cultivars	
		KEP	SR 52
	28.3 ab *a*	22.0 a *a*	38.6 b *b*

Values followed by the same letter do not differ significantly (P=0.001), (*Italics P=0.05*) from each other.

3.5.1.5 Plant dry mass

Under sole cropping Mkuzi produced a significantly higher plant mass than Umlazi (P=0.01). However, this difference was not significant under intercropping (Table 3.37). The plant mass of Mkuzi was significantly lower under intercropping than under sole cropping. The higher plant mass of Mkuzi under sole cropping was due to the fact that it has an indeterminant growth habit and longer growing season whereas Umlazi has a determinant growth habit and a shorter growing season.

Table 3.37 The influence of sole and intercropping of maize and beans on bean plant dry mass of two bean cultivars at Cedara.

	Grams plant^{-1}		
Treatment	Bean cultivar		Mean
	Mkuzi	Umlazi	
Sole cropping	3.360 a	1.583 b	2.472 A
Intercropping	2.309 b	2.200 b	2.254 A

Values followed by the same letter in the same font do not differ significantly (P=0.01) from each other (only compare values followed by a letter in the same case).

For beans planted at first planting time, SR 52 induced a plant mass significantly (P=0.01) lower than for beans intercropped with KEP. This was not the case for beans planted at the second planting time (Table 3.38). None of the intercrop values differed significantly from the sole crop mean. Early in the season, SR 52 reduced the vegetative growth of the beans more than KEP. This was not the case later in the season.

Table 3.38 The influence of bean planting time and maize cultivar on bean plant mass under sole and intercropping of maize and beans at Cedara.

		Bean plant mass (g $plant^{-1}$)	
Treatment		Bean planting time	
		With maize	After maize
Sole crop	2.472 ab		
Intercrop	KEP	2.787 b	2.167 ab
	SR 52	1.260 a	2.804 b

Values followed by the same letter in the same font do not differ significantly (P=0.01) from each other.

The plant mass of row IV of the intercrop was significantly (P=0.01) lower than that of rows I and II of the sole and intercrop, but was not significantly different to the mean of the sole crop (Table 3.39). It is evident that the significantly lower plant mass of row IV was caused by competition for light, as this bean row was on the southern side of the maize. This competition effect was also reflected in seed yield and number of pods per plant.

Table 3.39 The influence of sole and intercropping of maize and beans on bean plant mass of each row at Cedara.

	Bean plant mass (g $plant^{-1}$)				
Treatment	Row I	Row II	Row III	Row IV	Mean
Sole cropping	2.626 a	2.626 a	2.347 ab	2.289 ab	2.472 ab
Intercropping	2.534 a	2.458 a	2.173 ab	1.852 b	

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.5.1.6 Number of plants per metre

It was interesting to note that bean plant survival was significantly (P=0.01) influenced by maize cultivar (Table 3.40) and bean planting time (Table 3.41). When beans were intercropped with SR 52, there were significantly fewer bean plants per metre (compared to the intercrop with KEP), which confirms earlier speculation that SR 52 was more competitive than KEP. Under intercropping there were significantly more plants per metre at the first bean planting time compared to the second. There was no significant difference in the number of bean plants per metre between sole and intercropping.

Table 3.40 The influence of maize cultivar on number of bean plants per metre in a maize/bean intercrop at Cedara.

	Number of bean plants (plants m^{-1})		
Treatments	Sole crop	Intercropped with maize cultivars	
		KEP	SR 52
plants m^{-1}	18.07 ab	18.85 a	17.36 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

Table 3.41 The influence of bean planting time on number of bean plants per metre under sole and intercropping of maize and beans at Cedara.

	Number of Bean plants (plants m^{-1})		
Treatment		Bean planting time	
	Sole crop	With maize	After maize
	18.07 ab		
Intercrop		18.81 a	17.40 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.5.2 Maize

3.5.2.1 Grain yield

Maize yields were compared on a per row basis in order to see if there was any compensation for lower plant population in the intercrop and tramline treatments. However, no compensation took place (Table 3.42). The actual yield of the sole crop was double the intercrop and tramline yields (Table 3.42).

Table 3.42 The influence of sole and intercropping of maize and beans on maize grain yield at Cedara.

	Yield (kg ha^{-1})	
Treatment	Per row basis	Actual
Sole crop	2027 a	4054 A
Intercrop and tramline	2031 a	2031 B

Values followed by the same letter in the same case do not differ significantly (P=0.01) from each other.

3.5.2.2 Percentage root lodging

Intercropping significantly (P=0.05) reduced percentage root lodging compared to that of the sole crop (Table 3.43). It appears that the beans had some anchoring effect on the maize roots. Root lodging was caused by wind during wet periods.

Table 3.43 The influence of sole and intercropping of maize and beans on percentage lodging of maize at Cedara.

	Percentage lodging
Treatment	
Sole crop	1.49 a
Intercrop and tramline	0.63 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.5.2.3 Shelling percentage

The shelling percentage was significantly (P=0.05) higher in the intercrop and tramline arrangement than in the sole crop (Table 3.44).

Table 3.44 The influence of sole and intercropping of maize and beans on shelling percentage of maize at Cedara.

	Shelling percentage
Treatment	
Sole crop	83.758 a
Intercrop and tramline	84.397 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.5.2.4 Other factors

None of the treatments had any significant effect on percentage diseased cobs or number of cobs per plant (Appendix 16 & 17).

3.5.3 Discussion

The objectives of the trial were met at Cedara when Umlazi was intercropped. a) Intercropped Umlazi produced a mean yield of 1191 kg ha^{-1} compared to the sole crop yield of 1093 kg ha^{-1}, resulting in a yield ratio of 1.09. b) Land productivity was improved. A LER of 1.90 was achieved when Umlazi was intercropped with KEP. Mkuzi intercropped with KEP produced a LER of 1.20. As at Vulindlela and Ukulinga, Mkuzi again displayed a large reduction in yield due to intercropping, although this was less than at Vulindlela and Ukulinga. This study indicated that Mkuzi is less suitable for intercropping than Umlazi, but that Mkuzi performs considerably better than Umlazi under sole cropping (1741 v. 1093 kg ha^{-1}). Shaded rows once again produced lower yields than rows receiving more sunlight. SR 52 was again more competitive than KEP and caused bean yield reductions. As before, yield reductions resulted from reductions in number of pods per plant and seeds per pod. As was the case for KEP at Vulindlela, beans grown with SR 52 compensated to some extent for reduction in pods per plant and seeds per pod by increasing seed mass. Lower bean yields associated with SR 52 were also the result of a reduction in number of plants. As in the Vulindlela and Ukulinga trials, intercropped maize at Cedara yielded 50% of the sole crop due to the intercrop population being 50% of the sole crop population. The beans had no influence on the maize as there was no difference between intercropped and tramlined maize. The shelling percentage was higher in the tramline and intercropped maize compared to the sole crop but this was not sufficient to improve yield.

3.6 Results - Makhathini

3.6.1 Dry bean

3.6.1.1 Seed yield

Due to the relatively low winter temperatures (Appendix 8) the bean yields were not as high as at the other trial sites. The only factor that had a significant (P=0.01) influence on bean seed yield was maize cultivar (Table 3.45). SR 52 brought about a yield reduction of approximately 50% in the intercropped beans, as compared to the sole crop and beans grown with KEP.

Table 3.45 The influence of maize and bean cultivar on bean seed yield in a maize/bean intercrop at Makhathini.

	Yield (kg ha^{-1})		
Treatments	Sole crop	Intercropped with maize cultivars	
		KEP	SR 52
Bean Cultivars			
Mkuzi	623 a	623 a	375 b
Umlazi	631 a	727 a	294 b
Means	627 a	675 a	334 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

3.6.1.2 Number of pods per plant

SR 52 brought about a significant (P=0.01) reduction in the number of pods per plant compared to the sole crop and the intercrop with KEP (Table 3.46). This reduction in pods per plant was the main cause for the reduction in bean yield when intercropped with SR 52.

When the data was analysed separately for bean planting times, the reduction in pods per plant caused by SR 52 was only significant (P=0.05) for the first bean planting time (Table 3.47).

Table 3.46 The influence of maize cultivar on the number of pods per bean plant in a maize/bean intercrop at Makhathini.

	Pods $plant^{-1}$		
Treatments	Sole crop	Maize cultivars	
		KEP	SR 52
Pods $plant^{-1}$	4.11 a	4.34 a	2.78 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

Table 3.47 The influence of maize cultivar and bean planting time on the number of pods per bean plant in a maize/bean intercrop at Makhathini.

	Pods plant^{-1}		
Treatments	Sole crop	Maize cultivars	
Bean planting time		KEP	SR 52
	4.11 a		
With maize		4.40 a	1.61 b
After maize		4.29 a	3.95 a

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.6.1.3 Number of seeds per pod

No significant differences in number of seeds per pod were observed for any of the treatments (Table 3.48)

Table 3.48 The influence of sole and intercropping of maize and beans on the number of seeds per pod at Makhathini.

	Seeds pod^{-1}
Treatment	
Sole crop	3.55 a
Intercrop	2.81 a

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.6.1.4 Hundred seed mass

There were no significant differences in hundred seed mass between treatments (Table 3.49).

Table 3.49 The influence of sole and intercropping of maize and beans on the bean hundred seed mass at Makhathini.

	Grams hundred seed^{-1}
Treatment	
Sole crop	34.5 a
Intercrop	43.6 a

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.6.1.5 Plant dry mass

Intercropping significantly (P=0.05) reduced bean plant dry mass compared to that of the sole crop. This reduction was due mainly to the lower plant mass of row I in the intercrop (Table 3.50). The row orientation was such that row I was on the southern side of the closest maize row and therefore received less light, leading to smaller plants. The plant mass was higher than at the Cedara trial due to the fact that the bean plants did not loose all their leaves at maturity as a result of the cooler weather.

Table 3.50 The influence of sole and intercropping of maize and beans on bean plant mass of each row at Makhathini.

	Bean plant dry mass (g plant^{-1})				
Treatment	Row I	Row II	Row III	Row IV	Mean
Sole cropping	6.22 ab	6.74 b	7.86 b	7.86 b	7.12 A
Intercropping	4.35 a	6.09 b	5.84 ab	6.00 b	5.57 B

Values followed by the same letter do not differ significantly (P=0.05 from each other (only compare values followed by a letter in same case).

3.6.1.6 Number of plants per metre

The number of Mkuzi plants per metre were significantly (P=0.01) reduced as a result of intercropping. This was not the case with Umlazi (Table 3.51). Mkuzi had significantly more plants per metre than Umlazi under sole cropping but not under intercropping. The reason for these differences is unclear.

Table 3.51 The influence of bean cultivar on number of bean plants per metre in a maize/bean intercrop at Makhathini.

	Bean plants m^{-1}			
Treatments	Sole crop		Intercrop	
Bean cultivars	Mkuzi	Umlazi	Mkuzi	Umlazi
plants m^{-1}	17.40 a	14.55 b	14.74 b	15.25 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

The number of bean plants per metre was significantly (P=0.01) reduced when intercropped with SR 52, compared to those intercropped with KEP and the sole crop (Table 3.52). This again reconfirms the higher competitiveness of SR 52 in comparison with KEP. With the exception of row II, all the bean rows grown in association" with SR 52 produced significantly (P=0.05) fewer plants per metre than the bean rows grown in association with KEP.

Table 3.52 The influence of maize cultivar and row position on number of bean plants per metre in a maize/bean intercrop at Makhathini.

plants m^{-1}			
Treatments	Sole crop	Intercropped with maize cultivars	
Row Position		KEP	SR 52
Row I	16.65 a	16.73 a	13.15 bd
Row II	16.45 a	15.18 ac	14.85 ad
Row III	15.95 a	15.18 ac	14.05 bd
Row IV	14.85 ab	16.55 a	13.50 bcd
Means	15.98 A	16.10 A	13.89 B

Values followed by the same letter do not differ significantly (means P=0.01, rows P=0.01) from each other (only compare values followed by a letter in the same case).

3.6.2 Maize

3.6.2.1 Dry grain yield

The growing conditions for maize were less than ideal due to cold weather, water stress and low soil fertility. As a result yields were much lower in comparison with yields obtained at the" other trial sites.

SR 52 yielded significantly less than KEP under both sole and intercropping, (sole crop P=0.05, intercrop P=0.001) (Table 3.53 and Table 3.54). When comparing yield on a row basis, there was no significant difference between sole and intercropping. There was therefore no compensation for reduced population.

Table 3.53 The influence of maize cultivar on the dry maize grain yield in a maize/bean intercrop at Makhathini.

Maize grain yield (t ha^{-1})			
Treatments	Sole crop		Intercrop
Maize cultivars	KEP	SR 52	
Yield (per row basis)	1.263 a *a*	1.071 b *b*	1.189 ab *a*

Values followed by the same letter do not differ significantly (P=0.001, *P=0.05*) from each other.

Table 3.54 The influence of maize cultivar on the dry maize grain yield in a maize/bean intercrop at Makhathini.

Maize grain yield (t ha^{-1})			
Treatments	Sole crop	Intercropped with maize cultivars	
		KEP	SR 52
Yield (per row basis)	1.167 a	1.323 b	1.055 a

Values followed by the same letter do not differ significantly (P=0.001) from each other.

Yield on an area basis, together with the LER, is presented in Table 3.55. This table takes the fact that the sole crop had twice the number of rows as the intercrop, into account. The sole crop yield is approximately double than of the intercrop.

Table 3. 55 The influence of maize cultivar on dry maize grain yield and yield ratio (Y.R.) under sole and intercropping of maize and beans at Makhathini.

Maize grain yield (t ha^{-1}) and Y.R.			
Maize cultivar	Sole crop	Intercrop	Y.R.
KEP	2.526	1.323	0.52
SR 52	2.142	1.055	0.49

The sole cropped maize produced significantly (P=0.05) less maize grain than the tramline spaced maize, but neither of these treatments differed significantly from the intercropped maize (Table 3.56). On a row basis the maize in the tramline spacing was able to compensate for reduced population to a greater extent than the intercropped maize, which was planted at the same population density. However, there was no significant difference in yield between the tramline and intercrop maize.

Table 3.56 The influence of planting pattern on the dry maize grain yield in a maize/bean intercrop at Makhathini.

	Yield (row^{-1} basis)(t ha^{-1})		
Treatments	Sole crop	Tramlines	Intercrop
	1.103 a	1.294 b	1.189 ab

Values followed by the same letter do not differ significantly (P=0.05) from each other.

At the first bean planting time, Mkuzi significantly (P=0.05) reduced the maize grain yield (Table 3.57). This reduction in yield can be ascribed to the greater competitive ability of Mkuzi as a result of it's indeterminate growth habit. None of the other treatments reduced maize yield.

Table 3.57 The influence of bean cultivar and bean planting time on the maize grain yield in a maize/bean intercrop at Makhathini.

		Maize yield (t ha^{-1})		
Treatments		Bean planting time		
Bean cultivars	Sole crop	With maize	After maize	Mean
	1.167 b AB			
Mkuzi		0.955 a	1.257 b	1.106 A
Umlazi		1.316 b	1.226 b	1.274 B

Values followed by the same letter do not differ significantly (Bean planting time P=0.01, Bean cultivar P=0.05) from each other (only compare values followed by a letter in the same case).

3.6.2.2 Percentage lodging

Lodging of SR 52 was significantly (P=0.001) higher than that of KEP, both under sole and intercropping (Table 3.58). This can be ascribed to a cultivar characteristic rather than to cropping practice.

Table 3.58 The influence of maize cultivar on percentage lodging of maize under sole and intercropping of maize and beans at Makhathini.

	Lodging (%)	
Maize cultivar	Sole crop	Intercrop
KEP	25.0 a	29.8 a
SR 52	66.0 b	59.3 b

Values followed by the same letter do not differ significantly (P=0.001) from each other.

SR 52 lodged significantly (P=0.05) less when intercropped with beans planted at the first planting time (Table 3.59). This could be either due to an anchoring effect by the bean roots or competition for water which would encourage a better maize root system development.

Table 3.59 The influence of maize cultivar and bean planting time on percentage lodging of maize in a maize/bean intercrop at Makhathini.

	Lodging (%)		
Treatments	Sole crop	Bean planting time	
Maize cultivars		With maize	After maize
KEP	25.0 a	35.2 a	24.4 a
SR 52	66.0 c	50.4 b	68.3 c

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.6.2.3 Shelling percentage

Shelling percentage showed no significant variation. The average shelling percentage was 75.8% (Appendix 18).

3.6.2.4 Number of cobs per plant

Both the tramline spaced and intercropped maize gave more cobs per plant than the sole crop but the difference was only significant (P=0.05) for the tramline maize (Table 3.60). The same trend was observed in maize grain yield (Table 3.56). However, this compensation was insufficient to make up for the reduction in population in the intercropped and tramline spaced maize.

Table 3.60 The influence of planting pattern on the number of maize cobs per plant in a maize/bean intercrop at Makhathini.

	Cobs $plant^{-1}$		
Treatments	Sole crop	Tramlines	Intercrop
(cobs $plant^{-1}$)	0.947 a	1.070 b	1.047 ab

Values followed by the same letter do not differ significantly (P=0.05) from each other.

In the treatments where beans were planted eight weeks after the maize, the number of cobs per plant was significantly (P=0.05) higher than that for the sole crop maize and the treatments where beans was planted with the maize (Table 3.56). This was due to the low population density of the maize plants and a lack of competition from the beans during the first eight weeks.

Table 3.61 The influence of bean planting time on the number of cobs per maize plant in a maize/bean intercrop at Makhathini.

Treatments	Sole crop	Planting time	
		Beans with maize	Beans after maize
Cobs plant^{-1}	0.988 a	0.999 a	1.096 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

3.6.3 Discussion

The results obtained from the Cedara and Makhathini trials were similar in that both gave bean yield ratios greater than one and LER's significantly greater than one. Bean yield at Makhathini was only reduced due to intercropping with SR 52. This was again due to a reduction in number of pods per plant and plants per metre. Mkuzi at Makhathini was unique in its yield reducing effect on the maize when intercropped (Table 5.57). This probably indicates that maize was more sensitive to competition under low potential conditions. The lower competitive ability of the maize enabled the intercropped beans to produce yields similar to that of the sole cropped beans which led to improved land productivity. Once again the presence of beans caused a reduction in lodging for SR 52 when beans were planted at the same time as the maize. Maize yield displayed the same trends as in all the other trials.

3.7 Conclusion

As far as the objectives are concerned, intercropping gave varying responses. Bean yield ratios greater than or equal to that obtained with sole cropping, and meaningful improvement in land productivity were achieved at Cedara and Makhathini but not at Vulindlela or Ukulinga.

At Vulindlela and Cedara, Mkuzi produced higher yields under sole cropping than Umlazi but this was not the case under intercropping (Tables 3.62 & 3.64). This supports Clark and Francis' (1992) conclusion that indeterminate type beans produce higher yields under sole cropping than bush types but that comparable yields are produced under intercropping. The variability in bean yield was mainly related to the maize yield. When the maize yield and concomitant competition was high, bean yields under intercropping were low. This supports the findings of Chang and Shibles, (1985) who reported that increased productivity could only be achieved in a maize/cowpea intercrop when the competitiveness (and consequently the yield) of the maize was low. The maize and bean yields, as well as yield ratios for each of the components, are given in Tables 3.62, 3.63, 3.64 and 3.65.

Table 3.62 Bean and maize yields under sole and intercropping and Yield Ratios (Y.R.) of each component at Vulindlela.

	Yield (kg ha^{-1}) and Y.R.					
Treatments	Bean yields			Maize yields		
	Mkuzi	Umlazi	Mean	KEP	SR 52	Mean
Sole Crop	1556 a	900 b	1226 A	5442 *a*	5912 b	5677 A
Intercrop	805 bc	521 c	663 B	2558 *c*	2991 *c*	2775 *B*
Y.R.	0.52	0.58	0.54	0.47	0.51	0.49

Values followed by the same letter do not differ significantly (P=0.05) from each other (compare only values followed by a letter in the same case and font).

Table 3.63 Bean and maize yields under sole and intercropping and Yield Ratios (Y.R.) of each component at Ukulinga.

	Yield (kg ha^{-1}) and Y.R.	
Treatments	Bean yields Umlazi	Maize yields KEP
Sole crop	1501 a	5442 *d*
Intercrop	805 b	2558 *c*
Y.R.	0.52	0.47

Values followed by the same letter do not differ significantly (P=0.05) from each other (compare only values followed by a letter in the same font).

Table 3.64 Bean and maize yields under sole and intercropping and Yield Ratios (Y.R.) of each component at Cedara.

	Yield (kg ha^{-1}) and Y.R.					
Treatments		Bean yields			Bean yield mean	Maize yield mean
	Mkuzi	Umlazi	KEP	SR 52		
Sole crop	1741 a	1093 b			1417 A	4054 *A*
Intercrop	1027 b	1191 b	1380 *b*	838 *c*	1109 B	2031 *B*
Y.R.	0.59	1.09				0.50

Values followed by the same letter do not differ significantly (P=0.05) from each other (compare only values followed by a letter in the same case and font).

Table 3.65 Bean and Maize yields under sole and intercropping and Yield Ratios (Y.R.) of each component at Makhathini.

	Yield (kg ha^{-1}) and Y.R.						
Treatments	Bean yields				Maize yields		
Maize cultivars	KEP	SR 52	Mean	Sole	KEP	SR 52	Mean
Bean cultivar				crop			
Mkuzi	623 a	375 b	499 A	623 a	1220 *a*	992 *c*	1106 *B*
Y.R.	1.00	0.60	0.80		0.48	0.46	0.47
Umlazi	727 a	294 b	511 A	631 a	1425 a	1177 *c*	1271 *B*
Y.R.	1.15	0.47	0.81		0.56	0.55	0.54
Mean	675 a	334 b	505 A	627 a	1323 *a*	1055 *c*	1189 *B*
Y.R.	1.08	0.53	0.81		0.52	0.49	0.51
Sole Crop					2526 *b*	2142 *d*	2334 *A*

Values followed by the same letter do not differ significantly (P=0.05) from each other (compare only values followed by a letter in the same case and font).

Maize yields at Vulindlela and Ukulinga were considerably higher than at Cedara and Makhathini. However, the LER for beans was higher at Cedara and Makhathini than at the previous two sites. This was in spite of the fact that bean yields were similar for all the sites with the exception of Makhathini where the bean yields were low due to poor growing conditions.

At both Cedara and Makhathini KEP gave the highest LER due to its smaller size and it can be presumed to be less competitive than SR 52. The maize yields at Cedara and Makhathini were also lower than at Vulindlela and Ukulinga. Umlazi gave a higher LER than Mkuzi due to the fact that Umlazi is less sensitive to intercropping. This confirms the findings of Clark and Francis (1992). The results indicate that intercropping will generally only give bean yields close to that of the sole crop when the competitiveness of maize is reduced, that is, when conditions are less ideal for maize than they are for beans. It also seems likely that intercropping with Mkuzi will not meet the aim of a near sole crop bean yield. In a typical subsistence farmer situation, the growing conditions for both crops would probably be less ideal than in the trials due to poorer management.

When yield components are examined, it appears that intercropping caused stress on the bean plants during the vegetative, pod formation and pod fill stages. Plant dry mass (which gives an indication of the conditions during the vegetative stage) was reduced for both bean cultivars at Vulindlela and for Mkuzi at Cedara. At Vulindlela, Mkuzi was also more adversely affected than Umlazi. This was due to the fact that Mkuzi has a longer growing season (and therefore longer vegetative phase) than Umlazi, making it more prone to competition at this stage. In all cases where yield was reduced, it was due to a reduction in number of pods per plant. This indicates that competition during the pod formation stage was the most important cause of yield reduction. KEP's shorter growing season was the most likely reason why it caused a greater reduction in number of pods per bean plant at Vulindlela, while SR 52's competitiveness caused a greater reduction in number of pods per bean plant at Cedara and Makhathini. The same tendencies were observed for number of seeds per pod at Vulindlela and Cedara, which further reduced bean yield. Reduced number of pods per plant and seeds per pod were compensated for to some extent during seed fill, as reflected by hundred seed mass. At Vulindlela, the compensation for reduction in pods per plant caused by KEP was sufficient to produce an equal yield compared to that of SR 52. At Cedara compensation for reductions due to SR 52 was insufficient to negate the effect of fewer pods per plant. The influence of intercropping on the number of bean plants per running metre is difficult to explain but requires more attention as it occurred consistently at Cedara and Makhathini.

Due to more favourable growing conditions for maize at Vulindlela and Ukulinga, maize yields were considerably higher than those obtained at Cedara and Makhathini. Intercrop maize yields were half the sole crop yield due to the 50% reduction in plant population, which is consistent with the findings of Willey, (1979b), Baker, (1981), Chang & Shibles, (1985), Woolley & Davis, (1991), and Barker & Francis, (1986). These authors reported that the dominant crop in an intercropping system usually shows the same response curve to changes in population as in a sole cropping system. Only at Vulindlela did SR 52 produce a higher yield than KEP. Maize was not influenced by the presence of beans in the intercrop, except at Makhathini where the more vigorous Mkuzi caused a yield reduction when planted at the same time as the maize. Maize was unable to compensate for the reduced population. At Makhathini, the tramline sole maize was able to compensated to some extent for reduced grain yield and number of cobs per plant caused by reduced population density. When intercropped with beans, maize did not compensate in this manner which indicates that the beans did compete with the maize to some extent.The yield ratios for the maize component are tabulated in Tables 3.62 to 3.65.

Land productivity was generally increased (LER>1) by intercropping (Table 3.66). However, the desired results were only achieved with the maize cultivar KEP at Cedara and Makhathini. It would seem that this intercropping system would only achieve the goal of a near to sole crop bean yield and increased land productivity under conditions that are less than ideal for maize growth. This is consistent with the findings of Davis and Garcia, (1983) and Holguin, *et al.*, (1985) who found that lower maize vigour reduced the competitiveness of the maize which led to higher bean yields.

Table 3.66 Land Equivalent Ratios (LER) for the treatments that affected Yield significantly for the Maize/Bean intercrops at Vulindlela, Ukulinga, Cedara and Makhathini.

Land Equivalent Ratios			
Treatments		Bean Cultivars	
	Maize Cultivars	Mkuzi	Umlazi
Vulindlela	KEP	0.99	1.04
	SR 52	1.03	1.08
Ukulinga	KEP		0.96
Cedara	KEP	1.20	1.90
	SR 52	0.97	1.28
Makhathini	KEP	1.48	1.71
	SR 52	1.06	1.02

CHAPTER 4

NITROGEN, WATER AND LIGHT STUDIES

4.1 Introduction

When plants grow in close proximity with each other they compete for limited resources, especially water, solar radiation and nutrients (Trenbath, 1986). Pilbeam *et al.* (1994) reported that intercrops show complementarity for these resources which enables them to achieve yield advantages.

In order to determine whether competition or complementarity took place in the maize/bean intercrops described in Chapter 3, leaf analyses for nitrogen were done for three trials, phosphate and potassium for two trials, light interception for two trials and water depletion for one trial. These studies could not be done at all sites due to financial and logistical reasons. Lower leaf nutrient levels in the intercropped beans compared to the sole cropped beans would suggest competition for the nutrients while no difference could mean complementarity or an excess of nutrients.

4.2 Materials and methods

4.2.1 Vulindlela

For the purpose of this study the same trial as described in paragraph 3.2.1 was used, with the exception that maize harvest stage was not included as a treatment.

Leaf samples of the youngest mature bean leaves (35 leaves per row) were taken at the 10% flowering stage as described by MacKay and Leefe, (1962). The samples were dried at 50 °C, ground to a fine powder and % leaf nitrogen determined, using the Kjeldahl method.

For the water depletion study, aluminum neutron probe access tubes were sunk to a depth of 600 mm into the middle of each bean plot two weeks after bean planting. Holes fractionally smaller than the access tubes were made with a soil auger to the required depth after which the tubes were inserted, taking care not to disturb the soil density around the holes. Neutron probe readings were taken every 3 to 4 days at three levels, namely 250 mm, 400 mm and 550 mm. The neutron probe readings were calibrated at the end of the season after the crops had been harvested. Five tubes representing the whole trial were selected, and the surrounding soil, to a radius of 1 m, drenched with water to field capacity. Readings and samples were taken every second day as the soil dried. The samples were dried to determine the water content of the soil on a mass basis. After the readings had stabilised, soil bulk density was determined for each level and each hole. The neutron probe readings were than calibrated to give readings in ml cm^{-3}. For the purposes of statistical analyses, readings taken during the longest period without rain (during which both cultivars were close to peak water demand) were used. Water depletion during that period was calculated.

In order to measure the light interception of the maize, light intensity (photosynthetic photon flux density) was measured in each bean row at the top of the bean leaf canopy of both intercropped and sole cropped beans at two hour intervals from 06:00 till 18:00. For this purpose a line quantum sensor with a volt meter was used. Readings were recorded in millivolts, high light intensity giving a high reading, and shading giving a low reading. The sensor was calibrated using shade netting with known values of shading, and the percentage shading experienced by the beans was calculated. The percentage shading experienced by the sole cropped beans was taken to be zero and used as the control. Due to political unrest around Vulindlela and exceptionally cloudy conditions, only one set of meaningful readings could be taken. This was when maize leaf area was at its maximum.

The statistical analysis was performed as described in Chapter 3.

4.2.2 Cedara

Leaf samples were taken as at Vulindlela, but analyses were done for nitrogen, phosphate and potassium. The trial described in paragraph 3.2.3 was used. No light interception or water depletion readings were taken for this trial as the site was 450 km from the author"s home base.

4.2.3 Makhathini

Leaf analysis procedure was identical to that used at Cedara. Light interception data was recorded at the second bean planting time and just after maize had reached full plant size. This was done as described for the Vulindlela trial. Unfortunately, only the first set of data could be used as the line quantum sensor started to malfunction during the second recording and repairs could only be completed after the beans had reached maturity. The method of recording and processing of data was the same as described in paragraph 4.2.1 with the exception that, due to the shorter winter day length, readings could only be done from 08:00 to 16:00.

No water depletion studies were done due to lack of equipment.

4.3 Results

4.3.1 Leaf analysis - Vulindlela

4.3.1.1 Percentage leaf nitrogen

There was a significant (Mkuzi $P=0.01$, Umlazi $P=0.05$) drop in the leaf nitrogen levels of the beans due to intercropping, implying that maize competed with the beans for nitrogen (Table 4.1). There was also a significant ($P=0.05$) cultivar difference, Mkuzi having a higher leaf nitrogen content than Umlazi. When compared to the optimum leaf nitrogen level of 5.1% set by MacKay and

Leefe, (1962), nitrogen was only limiting in Umlazi. Accordingly, a yield reduction due to competition for nitrogen would only be expected for Umlazi. However, leaf yellowing (particularly later in the season) clearly indicated that competition for nitrogen did occur with both cultivars, in particular in the rows adjacent to the maize.

Table 4.1 The influence of sole and intercropping of maize and beans on the mean percentage nitrogen in the bean leaves at Vulindlela.

	Leaf Nitrogen (%)		
Treatment	Cultivars		Mean
	Mkuzi	Umlazi	
Sole Crop	8.23 a	5.76 b	7.00 A
Inter crop	5.82 c	3.84 d	4.83 B

Values followed with the same letter do not differ significantly (P=0.05)(only comparing values in the same font).

Differences between rows

The difference in leaf nitrogen content between the inner and outer rows was highly significant (P<0.01) (Table 4.2). This was expected as the outer rows were closest to the maize plants and showed symptoms of nitrogen deficiency throughout the season. SR 52 reduced bean leaf nitrogen to a significantly (P=0.05) greater extent than KEP (Table 4.2). This was due to the larger size and higher competitiveness of SR 52. The difference in leaf nitrogen between the inner and outer rows of Mkuzi was also significantly (P=0.05) greater than for Umlazi.

Table 4.2 The influence of maize and bean cultivars on differences in percentage bean leaf nitrogen between the inner and outer rows in a maize/bean intercrop at Vulindlela.

Difference in leaf nitrogen (%)				
Maize cultivars		Bean cultivars		Mean
KEP	SR 52	Mkuzi	Umlazi	
0.77 a	1.63 b	1.64 A	0.75 B	1.20

Values followed by the same letter do not differ significantly (P=0.05 for maize cultivars and P=0.001 for bean cultivars)(only compare values followed by a letter in the same case)(the t value for the mean = 5.658 which was highly significant P=0.001)

4.3.1.2 Discussion

The major reduction in leaf nitrogen due to intercropping and leaf yellowing clearly indicated that competition for nitrogen did occur between the maize and the beans. It can be expected that this competition for nitrogen would have caused bean yield reductions. The optimum leaf nitrogen values proposed by MacKay and Leefe (1962) did not appear to be valid in this situation.

4.3.2 Leaf analysis - Cedara

4.3.2.1 Percentage leaf nitrogen

Maize cultivar significantly (P=0.05) affected the percentage leaf nitrogen under intercropping at Cedara (Table 4.3), that of SR 52 being lower than that of the sole crop and the intercrop with KEP.

Table 4.3 The influence of maize cultivar on the percentage bean leaf nitrogen in a maize/bean intercrop at Cedara.

Bean leaf nitrogen (%)			
Treatments	Sole crop	Intercropped with maize cultivars	
		KEP	SR 52
Percentage	4.954 a	4.907 a	4.595 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

4.3.2.2 Percentage leaf phosphate

Bean planting time had a significant (P=0.01) influence on the percentage bean leaf phosphate under intercropping. Beans planted at the same time as the maize had a significantly lower leaf phosphate content than the sole crop and than the beans planted after the maize (Table 4.4). This was probably due to the fact that the first half of the season was cold and wet, which would cause reduced phosphorus uptake for the first bean planting time, whereas by the second bean planting time, temperatures were considerably higher.

Table 4.4 The influence of bean planting time on the percentage phosphate in bean leaves in a maize/bean intercrop at Cedara.

Leaf phosphate (%)			
Treatments	Sole crop	Bean planting time	
		With maize	After maize
Percentage	0.3885 a	0.3535 b	0.3894 a

Values followed by the same letter do not differ significantly (P=0.01) from each other.

4.3.2.3 Percentage leaf potassium

Intercropping significantly (P=0.01) reduced the percentage leaf potassium of intercropped beans in comparison with sole cropped beans (Table 4.5).

Table 4.5 The influence of cropping method on the percentage potassium in bean leaves in a maize/bean intercrop at Cedara.

	Leaf potassium (%)	
Treatments	Sole crop	Intercrop
Percentage	2.299 a	2.002 b

Values followed by the same letter do not differ significantly (P=0.01) from each other.

As far as the bean cultivars are concerned, (Table 4.6) it can be seen that only Umlazi showed a significant (P=0.01) reduction in percentage leaf potassium under intercropping. The difference between Mkuzi and Umlazi was also only significant under sole cropping.

Table 4.6 The influence of cropping method and bean cultivar on the percentage bean leaf potassium in a maize/bean intercrop at Cedara.

	Leaf potassium (%)			
Treatments	Sole crop		Intercrop	
Bean cultivar	Mkuzi	Umlazi	Mkuzi	Umlazi
Percentage	2.023 a	2.575 b	2.021 a	1.983 a

Values followed by the same letter do not differ significantly (P=0.01) from each other.

4.3.2.4 Discussion

The bean leaf nitrogen data for Cedara differed considerably from that for Vulindlela. The average nitrogen level was lower than at Vulindlela but no visual signs of nitrogen deficiency occurred. This could be partly due to the fact that beans were planted at the same time as the maize which would have reduced losses due to earlier uptake by the maize and leaching. The beans planted after the maize were given a top dressing of nitrogen which would have compensated for losses. Some additional nitrogen was also expected to be available due to the fact that lupines had been grown on the land during the previous season. Competition for nitrogen by the maize was observed for beans planted with SR 52, which again confirms its greater competitive effect when compared to KEP.

The reduction in leaf phosphate for beans planted with the maize (in comparison with sole cropped beans) was due to the lower soil temperatures prevailing during the first half of the season (see grassminimum Appendix 6) (Thibaud, 1996), (pers. comm.). It could also be expected that shading between the maize rows would keep the soil cooler.

Intercropping caused a reduction in the bean leaf potassium for Umlazi but not for Mkuzi. This is probably due to the fact that Umlazi, with it's determinant bush growth habit, shorter growing season, smaller plant size and less prolific root system, was more sensitive to competition from the maize.

4.3.3 Leaf analysis - Makhathini

4.3.3.1 Percentage leaf nitrogen

Intercropping reduced the percentage leaf nitrogen significantly (P=0.05) compared to sole cropping (Table 4.7). Under sole cropping Umlazi had significantly higher (P=0.05) leaf nitrogen levels than Mkuzi but this was not the case under intercropping (Table 4.8). The reduction in percentage leaf nitrogen due to intercropping was therefore due to that experienced by Umlazi.

Table 4.7 The influence of cropping method on the percentage nitrogen in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf nitrogen (%)	
Treatments	Sole crop	Intercrop
Percentage	4.104 a	3.795 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

Table 4.8 The influence of bean cultivar on the percentage leaf nitrogen in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf nitrogen (%)		
Treatments	Sole Crop		Intercrop
Bean cultivars	Mkuzi	Umlazi	
Percentage	3.790 a	4.417 b	3.795 a

Values followed by the same letter do not differ significantly (P=0.05) from each other.

Planting time of beans only had a significant (P=0.01) influence on percentage leaf nitrogen in the presence of SR 52, which reduced the percentage leaf nitrogen for the second bean planting time (Table 4.9). It appears that SR 52 competed for nitrogen with the beans planted after the maize.

Table 4.9 The influence of bean planting time and maize cultivar on the percentage nitrogen in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf nitrogen (%)		
Treatments	Sole crop	Bean planting time	
Maize cultivar		With maize	After maize
	4.104 b A		
KEP		3.879 ab	3.745 ab
SR 52		4.331 b	3.226 a
Mean		4.105 A	3.486 B

Values followed by the same letter do not differ significantly (P=0.01) from each other (only compare values followed by letter in the same case).

4.3.3.2 Percentage leaf Phosphate

Umlazi had significantly (P=0.01) higher leaf phosphate levels than Mkuzi under sole cropping but not under intercropping (Table 4.10). This is probably due to a dilution effect. Under sole cropping, the Mkuzi plants tended to be larger than the Umlazi plants (due to the indeterminate growth habit of the former) thus diluting the available phosphate.

Table 4.10 The influence of bean cultivar on the percentage phosphate in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf phosphate (%)		
Treatments	Sole crop		Intercrop
Bean cultivars	Mkuzi	Umlazi	
Percentage	0.3270 a	0.4343 b	0.3986 ab

Values followed by the same letter do not differ significantly (P=0.01) from each other.

Intercropping of beans with SR 52 led to significantly higher bean leaf phosphate levels than intercropping with KEP (Table 4.11). This could be due to a reduced sink as a result of the association with SR 52, which would lead to a lower demand on leaf phosphate.

Table 4.11 The influence of maize cultivar on the percentage phosphate in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf phosphate (%)		
Treatments	Sole crop	Maize cultivars	
		KEP	SR 52
Percentage	0.3807 a	0.3743 a	0.4229 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

Bean planting time had a significant (P=0.05 influence on the percentage leaf phosphate under intercropping. Beans planted at the same time as the maize had higher leaf phosphate levels than those planted later (Table 4.12). This was probably due to the fact that the first bean planting took place in autumn when temperatures were relatively high, while the second bean planting took place in winter when temperatures were lower and phosphate uptake could be expected to decrease.

Table 4.12 The influence of bean planting time on the percentage phosphate in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf phosphate (%)			
Treatments	Sole crop		Intercrop	
	Bean planting time			
	With maize	After maize	With maize	After maize
Percentage	0.4031 ab	0.3583 b	0.4282 a	0.3690 b

Values followed by the same letter do not differ significantly (P=0.05) from each other.

There was a significant (P=0.05) interaction between row position and planting time (Table 4.13). The second bean planting showed some dilution effect for row I giving higher levels of phosphorus than rows II and III.

Table 4.13 The influence of bean planting time and row position on the percentage phosphate in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf phosphate (%)		
Treatments	Sole crop	Intercrop	
		Bean planting time	
		With maize	After maize
Percentage N	0.3807 ab		
Row I		0.4500 a	0.4130 abc
Row II		0.4390 ab	0.3520 d
Row III		0.4193 abc	0.3505 d
Row IV		0.4045 abc	0.3605 cd

Values followed by the same letter do not differ significantly (P=0.05) from each other.

4.3.3.3 Percentage leaf potassium

Mkuzi displayed significantly (P=0.001) lower leaf potassium levels than Umlazi due to a dilution effect (Table 4.14).

Table 4.14 The influence of bean cultivar on the percentage potassium in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf potassium (%)		
Treatments	Sole crop		Intercrop
Bean cultivars	Mkuzi	Umlazi	Mean
Percentage	1.860 a	2.729 b	2.153 a

Values followed by the same letter do not differ significantly (P=0.001) from each other.

The second bean planting exhibited reduced levels of potassium (Table 4.15) as was observed for phosphate (Table 4.12) and probably for the same reasons. There was a significant difference between planting times when beans were intercropped with SR 52 but not with KEP. This is probably due to the reduced demand by the reproductive organs as displayed in the reduced numbers of pods per plant caused by SR 52 at the first bean planting time (Table 3.46). This would leave higher concentrations in the bean leaves.

Table 4.15 The influence of bean planting time on the percentage potassium in bean leaves in a maize/bean intercrop at Makhathini.

	Leaf potassium (%)		
Treatments	Sole crop	Intercrop	
		Bean planting time	
		With maize	After maize
	2.295 a A		
KEP		2.064 ab	1.996 ab
SR 52		2.579 b	1.973 b
Mean		2.321 A	1.984 B

Values followed by the same letter do not differ significantly (P=0.01) from each other (only compare only values followed by a letter in the same case).

4.3.3.4 Discussion

Reduced leaf nitrogen of beans intercropped with maize indicated the existence of competition for nitrogen by the maize. However it was again SR 52 that proved to be the most competitive particularly for beans planted after the maize. This confirms the greater competitive ability of SR 52 when compared to KEP. Bean leaf phosphate and potassium, however, displayed the opposite tendency, i.e. levels tended to be higher for beans intercropped with SR 52. This was due to the fact that there was a smaller demand by the sink (reproductive organs) leading to greater concentrations in the leaves. Cooler temperatures in the latter half of the season were probably responsible for reduced uptake of phosphate and potassium by the beans planted after the maize (Thibaud, 1996), (pers. comm.).

4.3.4 Water depletion - Vulindlela

4.3.4.1 Topsoil - 250 mm

When compared with the sole crop, intercropping did not significantly influence the soil water depletion in the topsoil. However, bean cultivar had a significant effect on water depletion (Table 4.16). Mkuzi, the larger of the two, used significantly (P=0.05) more water than Umlazi. Density also had a significant effect (P=0.01) on soil water depletion. The tendency was linear (P<0.01) (Appendix 19), beans planted at high density (density 3) using the most water. However, this was only the case for beans intercropped with SR 52 (Table 4.16).

Table 4.16 The influence of bean density, maize and bean cultivar on soil water depletion at a depth of 250 mm in a maize/bean intercrop at Vulindlela.

	Soil water depletion ($ml.cm^{-3}$)				
	Maize cultivars		Bean cultivars		
	KEP	SR 52	Mkuzi	Umlazi	Mean
Sole crop	---	---	0.02337 A	0.01755 B	0.02046
Intercrop					
D1*	0.02292 bc	0.01488 a	0.01922	0.01683	0.01823 *a*
D2*	0.02253 bc	0.02125 b	0.02235	0.02098	0.02178 *ab*
D3*	0.02114 b	0.02610 c	0.02670	0.02029	0.02403 *b*
Intercrop Mean	0.02219	0.02074	0.02276 A	0.01937 B	0.02135

Values followed by the same letter do not differ significantly (P=0.05) from each other.(Only compare values followed by letter in the same case and font).

*D1, D2 & D3 = Bean Densities 1, 2 and 3

4.3.4.2 Soil water depletion at a depth of 400 mm

Cropping system and maize cultivar had no significant influence on water depletion at this depth. However, bean cultivar and density influenced soil water depletion significantly (P=0.05) (Table 4.17). At densities 2 and 3 Mkuzi used significantly (P=0.01) more water than Umlazi whereas water depletion at density 1 was similar for both cultivars.

Table 4.17 The influence of bean density, maize and bean cultivar on soil water depletion at a depth of 400 mm in a maize/bean intercrop at Vulindlela.

	Soil water depletion ($ml.cm^{-3}$)				
	Maize cultivars		Bean cultivars		
	KEP	SR 52	Mkuzi	Umlazi	Mean
Sole crop	---	---	0.0646	0.0229	0.0438
Intercrop					
D1*	0.0435	0.0351	0.0337 a	0.0454 a	0.0386 *a*
D2*	0.0537	0.0619	0.0766 b	0.0331 a	0.0585 *b*
D3*	0.0541	0.0605	0.0721 b	0.0379 a	0.0579 *b*
Intercrop Mean	0.0504	0.0525	0.0608 A	0.0388 B	0.0516

Values followed by the same letter do not differ significantly (P=0.05) from each other.(Only compare values followed by letter in the same case and font).

*D1, D2 & D3 = Bean Densities 1, 2 and 3

4.3.4.3 Soil water depletion at a depth of 550 mm

There were no significant differences at this depth, the average depletion being 0.01332 ml/cm^3 (results not shown).

4.3.4.4 Discussion

Competition for water did no occur in the centre of the plot where the readings were taken but it is probable that it did occur closer to the maize. Unfortunately it is not possible to establish the precise effect on bean yield resulting from competition for water from the maize. Competition for water probably did not occur at Cedara, due to the adequate and well spaced rains. At Ukulinga and Makhathini competition for water could have taken place. However, the data available failed to assist evaluation of the intercropping system.

4.3.5 Light interception

4.3.5.1 Vulindlela

At 06:00 (6am) all bean intercrop rows were 90% shaded. From 08:00 until 12:00 row V received the most shade, which ranged from 85% at 08:00 to 48% at 12:00 (Figures 4.1, 4.2 and 4.3). From 14:00 onward, row I received the most shade. For most of the day, row II was not shaded, as was the case with Row III.

By comparing Figures 4.1, 4.2 and 4.3, it can be seen that row V received the largest total amount of shade, followed by row I. The centre rows received the least. This is due to the fact that rows I and V were closer to the maize.

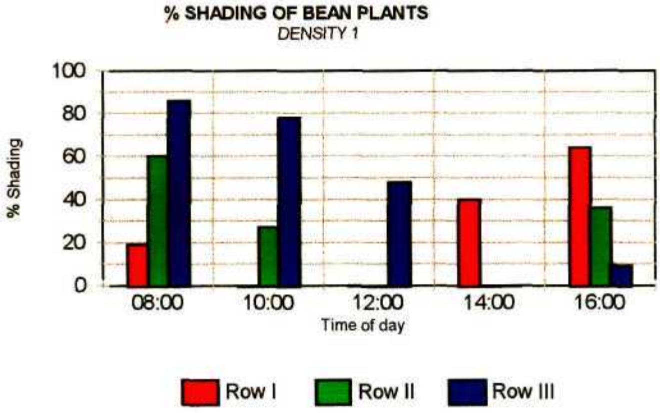

Figure 4.1 Percentage shading at different times of the day for density 1, used for the investigation of intercropping potential in KwaZulu-Natal.

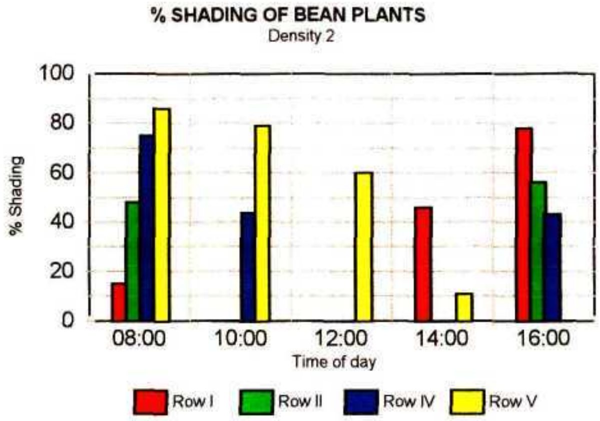

Figure 4.2 Percentage shading at different times of the day for density 2, used for the investigation of intercropping potential in KwaZulu-Natal.

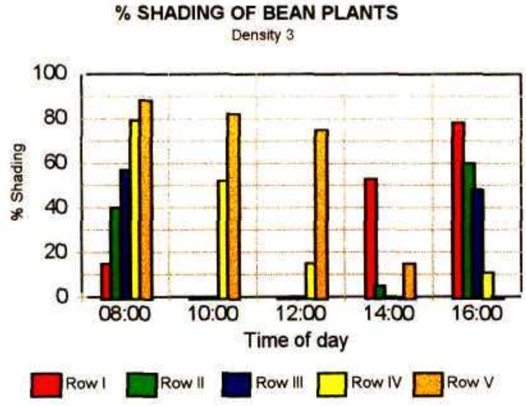

Figure 4.3 Percentage shading at different times of the day for density 3, used for the investigation of intercropping potential in KwaZulu-Natal.

4.3.5.2 Makhathini

There was a highly significant (P=0.001) difference in light interception between cropping systems at all five times at which readings were taken (Table 4.18). Sole maize intercepted the most light, whereas the maize in the intercrop intercepted far less.

Table 4.18 The effect of sole and intercropping of maize and beans on the percentage shading at 8:00, 10:00, 12:00, 14:00 and 16:00 at Makhathini.

	Shading (%)		
Time of day / Cropping method	Sole maize	Sole bean	Intercropping
08:00	90 a	0 b	64 c
10:00	80 a	0 b	40 c
12:00	67 a	0 b	22 c
14:00	71 a	0 b	45 c
16:00	50 a	0 b	22 c

Values followed by the same letter do not differ significantly (P=0.001) from each other (only compare values within the same time group).

At 8:00 there was a significant (P=0.001) difference in the amount of shading received by each bean row, rows I and II receiving the most shade, with shading decreasing as row number increased (Table 4.26). At 8:00 all the intercropped bean rows were shaded significantly more than the sole cropped beans but significantly less than the sole cropped maize. At 10:00 and 12:00 row I did not receive significantly more light than the sole maize. At 8:00 rows III and IV and at 12:00 and 14:00 row IV were not shaded significantly more than the sole cropped beans. Row I was always shaded, but the percentage shading decreased as the day progressed. Rows II and III received the least shading at 10:00 after which shading again increased. Row IV was not significantly more shaded from 10:00. At 16:00 there was no significant difference between rows. The above tendencies were possibly due to the fact that the rows were planted with an east-west orientation, which placed row I on the southern side of the closest maize row, whereas row IV was on the northern side of the closest maize row.

Table 4.19 The effect of sole and intercropping of maize and beans and row position on the percentage shading at 8:00, 10:00, 12:00 and 14:00 at Makhathini.

	Sole Maize	Shading (%) Row number I	II	III	IV	Sole Bean
08:00	90 a	72 b	72 b	64 c	45 d	0 e
10:00	80 a	73 a	47 b	14 c	3 c	0 c
12:00	67 a	71 a	53 b	22 c	0 d	0 d
14:00	71 a	62 b	53 c	38 d	17 e	0 e

Values followed by the same letter do not differ significantly (P=0.001) from each other (only compare values within the same time group).

For the first bean planting time, percentage shading decreased significantly (P=0.001) at 08:00 from rows II to IV, rows I and II receiving practically the same amount of shading, while there was no significant difference between the rows for the second bean planting time (Table 4.20). At 10:00, 12:00 and 14:00 the trend towards decreasing shading with increasing row number was significant for both planting times but percentage shading was generally higher for the second planting. This difference was significant (P=0.001) when means are compared, except at 14:00. This indicates that the maize plants were larger or more leafy when associated with the second bean planting. This is in accord with the similar trends found for yield and cobs per plant, which indicate that the beans planted at the same time as the maize competed with the maize.

Table 4.20 The effect of sole and intercropping of maize and beans and row position on the percentage shading at 8:00, 10:00, 12:00 and 14:00 at Makhathini.

	Shading (%)				
Planting	Row number				
Time (T*)	I	II	III	IV	Mean
08:00 T1	73 a	74 a	65 b	17 c	59 A
T2	71 a	69 a	72 a	66 a	69 B
10:00 T1	67 a	26 c	6 cd	0 d	31 A
T2	78 b	62 a	24 cd	6 d	49 B
12:00 T1	73 a	36 b	8 c	0 c	36 A
T2	69 a	68 a	34 b	3 c	50 B
14:00 T1	62 a	42 b	31 bc	14 c	37 A
T2	61 a	61 a	44 b	17 c	36 A

Values followed by the same letter do not differ significantly (P=0.001) from each other (only compare values within the same time group).T*: T1 = Beans planted at the same time as maize, T2 = Beans planted 8 weeks after maize.

4.3.5.3 Discussion

Liebenberg (1989) applied three levels of shading i.e. 25%, 50% and 75% to bean plants at various stages of bean development. His results showed that, with the exception of 25% shading during seed fill stage, all levels of shading applied after flower initiation reduced bean yield. These shadings were confined to one specific growth stage. However, but in the intercrop the shading was present throughout the season. The resulting yield reduction due to shading could therefore be expected to be greater. At Makhathini, light was probably not the most limiting factor as bean yields were generally low. Photosynthesis was presumably sufficient to adequately supply the sink (reproductive organs). However, the amount of shading measured was typical to what could have been expected at Cedara and Ukulinga and was of a similar order to the Vulindlela readings although there were differences due to different row orientations. Woolley & Rodríguez, (1987) recorded shading levels of 40 to 70% in their maize intercrops, which are of the same order as those recorded in the present study. These authors found that a higher degree of shading led to greater yield loss, results which are also supported by this study. The wider maize row spacing of the intercrop clearly reduced shading compared to the sole maize crop. This supports the findings of Ofori & Stern, (1987b), Natarajan, (1990) and Midmore, (1993b). In the traditional intercropping systems, beans would have received the levels of shading recorded in the maize sole crop. Planting beans the same time as the maize only reduced shading of the beans prior to the flower initiation stage. During this period yield is not affected significantly (Liebenberg, 1989).

4.4 Conclusion

MacKay and Leefe's (1962) optimum bean leaf nutrient values were of little value. These values indicated that there was no competition for nitrogen at Vulindlela although clear signs of nitrogen deficiency were visible in the bean plants. At Cedara and Makhathini the nutrient values indicated nitrogen to be sub-optimal although bean yields at Cedara were higher than at Vulindlela. MacKay and Leefe's (1962) optimum values are based on the assumption that nutrient levels in the soil are maintained throughout the season. Leaching and competition from other crops are not taken into consideration. It is therefore apparent that these values were not suitable for an intercropping situation similar to that of the study, as competition for nitrogen did occur. It was particularly noticeable in the rows adjacent to the maize at Vulindlela and the beans intercropped with SR 52 at Cedara and Makhathini. There was a significant ($P=0.05$) positive correlation ($r=0.160$) between yield and leaf nitrogen at Cedara, indicating that the reduction in bean yield due to SR 52 was partly due to competition for nitrogen. However, there was no correlation ($r=-0.110$) between leaf nitrogen and yield at Makhathini.

At Vulindlela the bean yield reduction caused by intercropping was probably due to competition for nitrogen and light from the maize. At Ukulinga, competition for light and water was apparently responsible for lower bean yields. At Cedara the reduction in the yield of Mkuzi was probably caused by competition for light, whereas at Makhathini the yield potential was so low that competition by the maize other than SR 52 did not occur. SR 52 presumably competed for nitrogen and water.

It would therefore appear that the lower competitiveness of maize at Cedara and Makhathini (as reflected in the lower maize yields) reduced competition in the intercrop so that the beans were able to produce yields similar to that of the sole crop.

Chapter 5

SUMMARY AND FINAL CONCLUSIONS

The use of a maize/bean intercropping system to improve land productivity was investigated after limited land availability had been identified as a major constraint to crop production in the Vulindlela area of the KwaZulu-Natal province of South Africa. In this area maize is the third most important crop after potatoes and beans.

The intercropping system had to meet certain requirements i.e. a) The intercrop bean yield had to be close to the sole crop yield. b) Some maize, acceptably less than the sole crop yield, needed to be produced, mainly for green maize purposes. c) The land equivalent ratio (LER) had to be greater than one.

In this area, beans (which are becoming increasingly important) are traditionally grown in the inter-row spaces of the maize crop. In this system, maize strongly dominates the beans, leading to very low bean yields. In order to ensure higher bean yields, maize dominance needs to be reduced in the intercropping system. In order to achieve this, the present study examined the effect of a 50% reduction in maize population and altered row arrangement. Maize tramline rows were planted 2.8 m apart, with beans planted between the tramlines. Two bean cultivars, representing the two types of beans cultivated in Vulindlela, were used, i.e. a speckled sugar bean variety (Umlazi) and a carioca bean variety (Mkuzi). Beans were initially planted only 6 - 8 weeks after the maize. Two maize cultivars - an open pollinated cultivar, Kalahari Early Pearl (KEP), and a hybrid, SR 52, were used. Four trials were planted at four different localities during three seasons i.e. Vulindlela and Ukulinga (1992/93), Cedara (1995/96) and Makhathini (1996). The trials at Vulindlela and Ukulinga included different bean density treatments (75%, 100% and 125% of the sole crop) and two maize harvesting stages (green and dry). Due to the ability of beans to compensate for changes in population density, the density treatment was not meaningful. The different number of bean rows in the different density treatments also limited statistical analysis and complicated interpretation. Harvesting all the maize at the green maize stage was criticised by the community as unpractical and socially unacceptable. The above mentioned two treatments were therefore replaced by two other treatments at Cedara and Makhathini. They were: a) Bean planting time: I) concurrently with the maize and ii) eight weeks later. b) Tramline sole cropping: maize planted at intercrop spacing without beans. In these two trials, all beans were grown at the same density. All four trials included controls consisting of maize and bean grown as sole crops.

Where maize yields were high, bean intercrop yields were low. At Vulindlela and Ukulinga, maize dominated the beans leading to bean yields of approximately 50% of the sole crop yield. Intercrop maize yields were 50% of the sole maize yields at all the sites. LERs for Vulindlela and Ukulinga were 1.04 and 0.96 respectively. At Cedara and Makhathini maize yields were lower than at Vulindlela and Ukulinga but intercrop bean yields were similar to the sole bean yields. LER's were 1.90 and 1.71 for the best combinations at Cedara and Makhathini respectively, indicating significant improvement in land productivity. Due to it's indeterminate growth habit and longer growing season Mkuzi was more affected by intercropping than Umlazi. KEP was less competitive than SR 52 when planted with beans and gave higher yields under sub-optimal growing conditions.

Bean yield component measurements indicated stress during the vegetative, pod formation, and pod fill stages. Light and leaf nutrient level studies suggested that the yield reductions took place due to competition for nitrogen and light. There was no competition for phosphate and potassium. It would appear that this intercropping system will fit the set requirements under conditions that are less than ideal for maize production. Additional fertilization of beans in order to increase their competitiveness could also limit yield reductions. A further reduction in maize population might also lessen its competitiveness but this might not comply with the needs of the farmers.

Although this system shows promise, it should be tested in an on-farm setting and it's performance determined under farmer management. Both land productivity and the yield ratios need be judged by the farmers themselves.

Additional research, in which the above- and below ground components of competition between beans and maize are separated, will make a useful contribution towards the understanding of the mechanisms involved. Ideally, intercropping research should be done by a group of researchers from different disciplines, each concentrating on a different aspect. This would improve the coverage of the different variables. Ample research funding and equipment is also essential.

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LIST OF APPENDICES

Appendix 1 Sundry information recorded about the trial at Vulindlela

1.1 Soil analysis

Element	Value	Element	Value
P (mg/l)	7.0	Acid Sat. (%)	34.9
K (mg/l)	0.24	pH (KCl)	4.28
Ca (mg/l)	1.61	Zn (mg/l)	2.1
Mg (mg/l)	0.39	Mn (mg/l)	2.0
Al (cmol)	1.2	Dens. (g/ml)	0.86

1.2 Cedara fertilizer recommendations

Maize		Beans	
Element	Recommendation	Element	Recommendation
N	75 kg/ha	N	40 kg/ha
P	80 kg/ha	P	33 kg/ha
K	20 kg/ha	K	75 kg/ha
Lime	0 t/ha	Lime	5 t/ha

1.3 Fertilization and land preparation

Dolomitic lime was applied at a rate of 1 ton/ha and ploughed in with land preparation. On the day of planting fertilizer mixture 2:3:4 (30%) was broadcasted at a rate of 280 kg/ha and worked in with hand hoes, this being the final seedbed preparation. This was only half the recommended rate as most farmers apply only very little fertilizer.

Appendix 2 Rainfall data recorded at Vulindlela

Year	Month	Total rainfall (mm)
1992	October	55.0
	November	68.0
	December	94.5
1993	January	87.8
	February	105.8
	March	77.5
	April	24.7
	May	0.0
	June	0.0

Appendix 3 Sundry information recorded about the trial at Ukulinga

3.1 Soil analysis

Element	Value	Element	Value
P (mg/l)	13.0	Acid Sat. (%)	0
K (mg/l)	106	pH (KCl)	4.77
Ca (mg/l)	3477	Zn (mg/l)	5.7
Mg (mg/l)	1338	Dens. (g/ml)	1.11
Al (cmol)	0		

3.2 Cedara fertilizer recommendations for Ukulinga

Maize		Beans	
Element	Recommendation	Element	Recommendation
N	75 kg/ha	N	40 kg/ha
P	55 kg/ha	P	58 kg/ha
K	15 kg/ha	K	25 kg/ha
Lime	2 t/ha	Lime	0 t/ha

Appendix 4 Selected climatic data recorded at Ukulinga

Year	Month	Total rainfall (mm)	Mean max temp (°C)	Mean min temp (°C)
1992	Oct	49.0	26.5	12.7
	Nov	48.8	27.4	14.5
	Dec	66.7	27.1	16.5
1993	Jan	75.2	28.3	17.1
	Feb	94.1	27.2	16.7
	Mar	42.0	24.3	11.6
	Apr	50.7	25.5	13.3
	May	49.5	22.5	11.2
	Jun	0.0	21.6	8.8

Appendix 5 Sundry information recorded about the trial at Cedara

5.1 Soil analysis

Element	Value	Element	Value
P (mg/l)	11.0	Acid Sat. (%)	13
K (mg/l)	203	Ph (KCl)	4.77
Ca (mg/l)	740	Zn (mg/l)	2.4
Mg (mg/l)	99		
Al (cmol)	0.77		

5.2 Cedara fertilizer recommendations for Cedara

Maize		Beans	
Element	Recommendation	Element	Recommendation
N	75 kg/ha	N	40 kg/ha
P	140 kg/ha	P	20 kg/ha

5.3 Fertilizer and herbicides applied

100 kg DAP per ha pre plant and disced in. 70 kg LAN was topdressed on maize at the second planting time and on beans at the second planting time. Eptam super was applied before planting and Dual after planting at the recommended dosages.

Appendix 6 Selected climatic data recorded at Cedara

Year	Month	Total rainfall (mm)	Mean Max temp (°C)	Mean min temp (°C)	Grass min temp (°C)
1995	Oct	95.1	22.4	11.3	8.3
	Nov	110.1	23.6	13.3	9.6
	Dec	303.6	22.7	13.0	11.4
1996	Jan	147.0	24.5	16.2	14.8
	Feb	169.8	25.1	15.4	13.6
	Mar	140.3	23.8	13.0	10.5
	Apr	17.5	21.0	10.2	4.7
	May	89.4	20.1	7.5	4.1
	Jun	5.7	19.0	3.5	0.9

Appendix 7 Sundry information recorded about the trial at Makhathini

7.1 Soil analysis

Element	Value	Element	Value
P (mg/l)	13.0	Acid Sat. (%)	1
K (mg/l)	399	Ph (Kcl)	5.62
Ca (mg/l)	709	Org carbon (%)	0.9
Mg (mg/l)	185	Dens. (g/ml)	1.18
Al (cmol)	0.01		

7.2 Cedara fertilizer recommendations for Makhathini

Maize		Beans	
Element	Recommendation	Element	Recommendation
N	75 kg/ha	N	40 kg/ha
P	20 kg/ha	P	20 kg/ha

7.3 Fertilizer and herbicides applied

100 kg DAP per ha pre plant and disced in. 70 kg LAN was topdressed on maize at the second planting time and on beans at the second planting time. Eptam super was applied before planting and Dual after planting at the recommended dosage.

Appendix 8 Selected climatic data recorded and irrigation applied at Makhathini

Year	Month	Total rainfall (mm)	Total irr (mm)	Mean max temp (°C)	Mean min temp (°C)
1996	Mar	69.8	20.4	28.8	17.5
	Apr	52.6	81.6	26.8	14.9
	May	3.1	61.2	26.3	12.6
	Jun	1.5	50.9	25.4	7.8
	Jul	6.5	71.3	24.0	9.3
	Aug	16.7	25.5	24.8	11.5

Appendix 9 Analysis of variance: effect of intercropping of Maize and Beans on the total bean yield, Vulindlela.

Source of variation	DF	MS	F
Reps stratum			
Maize var	1	223892	
Bean var	1	848628	
Reps whplots stratum			
Maize va	1	110780	0.477
Bean var	1	81743	0.522
Maize va.Bean var	1	81926	0.539
Residual	6	192858	
Reps whplots.Bean den Stratum			
Bean den	2	180422	0.082
Lin	1	284273	0.049 *
Quad	1	76571	0.281
Bean den.Maize va	2	95531	0.242
Lin maize va	1	30867	0.489
Quad.Maize va	1	160194	0.126
Bean den.Bean var	2	86528	0.274
Lin.Bean var	1	80360	0.270
Quad.Bean var	1	92697	0.238
Bean den.Maize va.Bean var	2	17075	0.761
Lin.maize va.Bean var	1	180	0.958
Quad.Maize va.Bean var	1	33969	0.469
Residual	16	61603	
Total	35		

Appendix 10 Analysis of variance: effect of intercropping of Maize and Beans on the difference in the number of productive pods between the inner and outer rows, Vulindlela.

Source of variation	DF	MS	F
Reps stratum			
Maize var	1	114.9	
Bean var	1	0.2	
Reps whplots stratum			
Maize va	1	1722.4	0.014
Bean var	1	5248.1	0.001
Maize va.Bean var	1	276.6	0.222
Residual	6	148.9	
Reps whplots.Bean den Stratum			
Bean den	2	903.4	0.075
Lin	1	1571.9	0.035
Quad	1	235.0	0.385
Bean den.Maize va	2	162.0	0.588
Lin maize va	1	1.2	0.949
Quad.Maize va	1	322.7	0.311
Bean den.Bean var	2	290.2	0.395
Lin.Bean var	1	439.9	0.240
Quad.Bean var	1	140.5	0.500
Bean den.Maize va.Bean var	2	243.6	0.455
Lin.maize va.Bean var	1	75.4	0.620
Quad.Maize va.Bean var	1	411.9	0.254
Residual	16	294.7	
Total	35		

Appendix 11 Analysis of variance: effect of intercropping of Maize and Beans on the mean number of seeds per pod, Vulindlela.

Source of variation	DF	MS	F
Reps stratum			
Maize var	1	0.03399	
bean var	1	1.45469	
Reps whplots stratum			
Maize va	1	1.98618	0.010
Bean var	1	13.03605	<.001
Maize va.Bean var	1	0.00031	0.965
Residual	6	0.14233	
Reps whplots.Bean den Stratum			
Bean den	2	0.39201	0.036
Lin	1	0.69987	0.015
Quad	1	0.08415	0.361
Bean den.Maize va	2	0.07637	0.465
Lin maize va	1	0.09518	0.332
Quad.Maize va	1	0.05757	0.448
Bean den.Bean var	2	0.18198	0.180
Lin.Bean var	1	0.01492	0.697
Quad.Bean var	1	0.34904	0.073
Bean den.Maize va.Bean var	2	0.16844	0.202
Lin.maize va.Bean var	1	0.00902	0.762
Quad.Maize va.Bean var	1	0.32787	0.082
Residual	16	0.09502	
Total	35		

Appendix 12 Analysis of variance: effect of intercropping of Maize and Beans on the mean plant dry mass, Vulindlela.

Source of variation	DF	MS	F
Reps stratum			
Maize var	1	34.41	
Bean var	1	74.29	
Reps whplots stratum			
Maize va	1	6.77	0.702
Bean var	1	1856.71	<.001
Maize va.Bean var	1	70.18	0.243
Residual	6	41.91	
Reps whplots.Bean den Stratum			
Bean den	2	55.22	0.061
Lin	1	110.38	0.020
Quad	1	0.05	0.957
Bean den.Maize.va	2	1.42	0.918
Lin maize va	1	0.07	0.949
Quad.Maize va	1	2.77	0.688
Bean den.Bean var	2	35.59	0.148
Lin.Bean var	1	57.61	0.080
Quad.Bean var	1	13.57	0.378
Bean den.Maize va.Bean var	2	0.50	0.970
Lin.maize va.Bean var	1	0.37	0.883
Quad.Maize va.Bean var	1	0.64	0.847
Residual	16	16.51	
Total	35		

Appendix 13 Analysis of variance: effect of intercropping of Maize and Beans and harvest stage on the total bean yield, Ukulinga.

Source of variation	DF	MS	F
Reps stratum	2	0.420525	
Reps.Bean den stratum			
Bean den	2	0.074612	0.407
Lin	1	0.124670	0.240
Quad	1	0.024555	0.574
Residual	4	0.065689	
Reps.Bean den. M stage stratum			
M stage	1	0.003321	0.493
Bean den.M stage	2	0.021209	0.103
Lin.M stage	1	0.042181	0.041
Quad.M stage	1	0.000237	0.852
Residual	6	0.006243	
Total	17		

Appendix 14 Analysis of variance: effect of intercropping of Maize and Beans and harvest stage on the mean number of productive pods, Ukulinga.

Source of variation	DF	MS	F
Reps stratum	2	577.43	
Reps.Bean den stratum			
Bean den	2	242.00	0.002
Lin	1	461.28	0.001
Quad	1	22.72	0.130
Residual	4	6.26	
Reps.Bean den. M stage stratum			
M stage	1	104.64	0.044
Bean den.M stage	2	16.28	0.421
Lin.M stage	1	32.01	0.210
Quad.M stage	1	0.54	0.862
Residual	6	16.25	
Total	17		

Appendix 15 Analysis of variance: effect of intercropping of Maize and Beans and harvest stage on the mean hundred seed mass of beans, Ukulinga.

Source of variation	DF	MS	F
Reps stratum	2	19.28	
Reps.Bean den stratum			
Bean den	2	8.54	0.742
Lin	1	16.85	0.470
Quad	1	0.22	0.931
Residual	4	26.48	
Reps.Bean den. M stage stratum			
M stage	1	13.77	0.292
Bean den.M stage	2	81.25	0.021
Lin.M stage	1	152.51	0.008
Quad.M stage	1	10.00	0.363
Residual	6	10.31	
Total	17		

Appendix 16 Analysis of variance: effect of intercropping of Maize and Beans on the percentage diseased cobs, Cedara.

Source of variation	DF	MS	F
Reps stratum	4	163.52	
Reps.Treat stratum			
Control	1	15.56	0.707
Control.B1	1	13.85	0.723
Control.T1	1	291.66	0.109
Control.M2	1	0.72	0.936
Control.B2	1	6.27	0.811
Control.T2	1	21.39	0.660
Control.B1.T1	1	170.02	0.218
Control.M2.B2	1	23.45	0.645
Control.M2.T2	1	331.88	0.088
Control.B2.T2	1	39.86	0.548
Control.M2.B2.T2	1	4.05	0.848
Residual	44	108.82	
Reps.Treat.rows stratum	80	55.36	
Total	139		

Appendix 17 Analysis of variance: effect of intercropping of Maize and Beans on the number of cobs per plant, Cedara.

Source of variation	DF	MS	F
Reps stratum	4	0.00571	
Reps.Treat stratum			
Control	1	0.01361	0.579
Control.B1	1	0.07824	0.187
Control.T1	1	0.00299	0.795
Control.M2	1	0.00058	0.908
Control.B2	1	0.01949	0.507
Control.T2	1	0.00062	0.906
Control.B1.T1	1	0.00270	0.805
Control.M2.B2	1	0.01760	0.528
Control.M2.T2	1	0.00080	0.893
Control.B2.T2	1	0.11925	0.105
Control.M2.B2.T2	1	0.00199	0.832
Residual	44	0.04353	
Reps.Treat.rows stratum	80	0.01379	
Total	139		

Appendix 18 Analysis of variance: effect of intercropping of Maize and Beans on the shelling percentage of maize, Makhathini.

Source of variation	DF	MS	F
Reps stratum	4	3319.8	
Reps.Treat stratum			
Control	1	610.1	0.112
Control.B1	1	180.0	0.382
Control.T1	1	15.9	0.794
Control.M2	1	22.3	0.757
Control.B2	1	184.5	0.377
Control.T2	1	13.3	0.812
Control.B1.T1	1	590.9	0.117
Control.M2.B2	1	1.8	0.931
Control.M2.T2	1	111.1	0.492
Control.B2.T2	1	136.6	0.446
Control.M2.B2.T2	1	179.8	0.383
Residual	44	231.3	
reps.Treat.rows stratum	80	106.7	
Total	139		

Appendix 19 Analysis of variance: effect of intercropping of Maize and Beans on the difference in soil water depletion in ml/cm^3 at a soil depth of 250 mm, Vulindlela.

Source of variation	DF	MS	F
Reps stratum			
Maize var	1	0.0000297	0.355
Residual	1	0.0000116	
Reps whplots stratum			
Maize va	1	0.0000174	0.276
Bean var	1	0.0000878	0.036
Maize va.Bean var	1	0.0000437	0.106
Residual	6	0.0000121	
Reps whplots.Bean den Stratum			
Bean den	2	0.0001027	0.002
Lin	1	0.0002021	<.001
Quad	1	0.0000034	0.586
Bean den.Maize va	2	0.0001234	<.001
Lin maize va	1	0.0002468	<.001
Quad.Maize va	1	0.0000001	0.915
Bean den.Bean var	2	0.0000187	0.212
Lin.Bean var	1	0.0000213	0.182
Quad.Bean var	1	0.0000161	0.242
Bean den.Maize va.Bean var	2	0.0000075	0.516
Lin.maize va.Bean var	1	0.0000008	0.795
Quad.Maize va.Bean var	1	0.0000143	0.269
Residual	16	0.0000109	
Total	35		