TITLE: BIOLOGICAL PRODUCTIVITY, SOIL RESOURCE USE AND STALK BORER INFESTATION IN MAIZE LABLAB PLANTING DATE AND DENSITY INTERCROPPING SYSTEMS

A DISSERTATION SUBMITTED TO THE SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES, DEPARTMENT OF PLANT PRODUCTION, UNIVERSITY OF THE NORTH

BY

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MASTERS OF SCIENCE IN AGRICULTURE (CROP SCIENCE)

JULY 2004

DECLARATION

I hereby declare that the work herein submitted as dissertation for the degree Masters of Science in Agriculture (Crop science), is the result of my own investigation, and that it has neither wholly nor partially been presented as dissertation for the degree in this University or elsewhere. Work by other authors, which served as sources of information have duly been acknowledged by reference to authors.

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ACKNOWLEDGEMENTS

First and always, I would like to thank God the Almighty for the opportunity he gave me to finish my studies. I am extremely grateful to my supervisor Prof. K.K Ayisi, for his active support, supervision in times of need during my research study. Thank you for sharing your knowledge and talent. I owe my special thanks to Dr P.E Olorunju for her support and motherly guidance. It was a blessing for me to have co-supervisor like you. I will also like to express my sincerely thanks to Dr Abe Addo-Bediako for his assistant and support always. I am thankful to Mr Lutting, and Mr Mojapelo for letting me use their land for field trials.

I also extend my gratitude to Canon Collins Educational Trust of Southern Africa (CCETSA), and National Research Foundation (NRF) for generous financial support. To my parents and grandmother Mercy Ndhambi thank you for your patience, love, support and mostly for praying for me during time of a need.

I record my special thanks to my husband, Ntsako Doctor Ngobeni for his encouraging words when I was stressed he will say ' Keep on praying everything will be fine one day,' for that honey you deserved to be called love of my life.

Last but not least I will like to express my special thanks to my brothers and Sisters especially Sam and Basani, my friends Rhandzu, Amukelani, Grace, Prudence and Shalort for their unmeasured support. Hi, guys keep it up. Thanks to the rest of the plant production team for technical assisting with data collection.

DEDICATION

To my parents, husband and son, who had a role to play, this is the harvest of what you have sown all those years. I hope you will love it.

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DISSERTATION ABSTRACT

Hanyeleni Mary Maluleke

374 words

Incorporation of leguminous species into the predominantly smallholder maize monoculture systems in the Limpopo Province of South Africa is required for a variety of human and animal nutritional, and soil fertility reasons. Lepidopterous stem borers seriously affect production of maize in sub-Saharan Africa. Intercropping maize with legumes is one of the effective systems that can improve maize productivity and control stem borers. Field experiments were set up over two seasons at two locations in the province to test the effect of two relative planting date of lablab, simultaneously with maize and at 28 days later, as well as lablab planting densities, namely two, four, six, eight and ten plants per meter on grain yield, agronomic characteristics, biomass accumulation, legume symbiotic activity, soil moisture content, maize leaf chlorophyll content, leaf senescence, and incidence and severity of stem borers with particular reference to *Chilo partellus* (Lepidoptera: Pyralidae). Grain yield of maize, simultaneously planted with lablab was on average, reduced by 26 and 57%, compared to those intercropped with later planted lablab in the 2001/02 growing season at Dalmada and Syferkuil respectively. Intercropped maize at two and four plants per meter maintained desirable agronomic characteristics and produced yield equal or higher than

sole maize, when lablab was planted 28 days later at both growing seasons. At both seasons maize dry matter accumulations were reduced at lablab densities beyond 4 plants per meter whereas, lablab dry matter accumulation increased with increasing densities when simultaneously planted with maize.

Lablab biomass accumulation at later planted lablab was consistently reduced in the intercropping system with maize compared to those simultaneously planted with maize at both locations and in the two growing seasons. High rate of lower leaf senescence occurs at 103 DAP under both planting dates at all locations. Maize simultaneously intercropped at 2 and 4 lablab per meter seems to use water more efficiently than sole maize and other intercrops, whereas at 28 days after planting maize intercropped at high densities used soil moisture content efficiently. Stem borer infestation was found to be more severe in sole maize than in maize-lablab intercrop. When lablab is planted 28 days later appears to offer better productivity of the cereal than when the two are planted simultaneously.

CHAPTER 1

BIOLOGICAL PRODUCTIVITY, SOIL RESOURCE USE AND STALK BORER INFESTATION IN MAIZE LABLAB PLANTING DATE AND DENSITY INTERCROPPING SYSTEMS

GENERAL INTRODUCTION AND LITERATURE REWIEW

Maize is a dominant crop worldwide and a staple food in many rural communities of the Limpopo Province of South Africa. The crop originated in central Mexico although it is currently produced on every continent except Antarctica. Considering the growing problems of human population explosion and the poor nutrition of food exhibited among rural communities of developing countries (Francis, 1986), the growing of maize mixtures with legumes offers good quality and quantity grain source. Maize monoculture dominates the cropping practice of smallholder farmers in the Limpopo Province. This has led to rapid decline in soil fertility, particularly nitrogen and phosphorus. Identification of a suitable legume that can be successfully incorporated into the system, either as intercrops or in rotation is essential in enhancing crop production among the farmers. Intercropping is currently being practice by farmers, but usually the proportion of legumes in the mixture is too scanty to make significant impacts. Lablab is a species that has exhibited good potential as an intercrop legume in the province. The most important thing about maize is that labour demand for its production and processing are relatively lower compared to other crops (Leach, 1995).

Intercropping system has successfully been practiced in many parts of the world (Shivashakar and Kularni, 1989), but their benefits have varied over factor, such as habitats, relative planting dates, plant densities, crop species and crop varieties. It is therefore critical to evaluate performance of maize intercropped with lablab in Limpopo province if productivity is to be maintained or enhanced.

Intercropping is an age-old, widespread practice in the warmer climates of the world especially the tropics (Agboola and Fayemi, 1972, and Willey, 1979). Total grain and plant N-yields can often be increased by intercropping legumes with non-legumes (Singh et al., 1986).

Intercropping is the growing of two or more crops simultaneously on the same area of land, and this is a very common practice among smallholder farmers in the Limpopo Province. Intercropping legumes with maize is widely practiced to maximize productivity of land, which often increases the total crop yield above that of sole crops (Clark and Myers, 1994). Worldwide, intercropping has received a lot of research attention and the published information is voluminous, but very little has been published in South Africa.

Maize is produced predominately as intercrop with legumes by smallholder farmers in the Limpopo Province. Common intercrops include a combination of maize with cowpea (*Vigna unguiculata*), bambara groundnut (*Vigna subtarerrnean*), groundnut (*Arachis hypogaea L.*) or non-legumes such as pumpkin (*Cucurbita purpo*) and even grain sorghum (*Sorghum bicolar*) in some drier parts of the province.

In a situation where maize is intercropped with non-legumes, the main objective of the farmers is to minimize complete crop failure due to drought, thereby increasing food security and diversity for a large part of the year (Liphadzi, 1998).

In the Limpopo Province of South Africa, maize problems constraints are mainly drought, low fertility, pest and continuous maize production (monoculture) in smallholder farming (Mpangane, 2001). In an intercropping situation, the use of leguminous species can help minimize N fertilizer requirements of maize, while reducing runoff and conserving moisture through complete crop cover (Francis, 1986).

Pest problem in maize production, especially stalk borer occurs in the Province. According to Mphosi (2001), intercropping reduces stalk borer infestation in cereals, due to the presence of the non-host crop among the host, which disturbs the movement of the pest. Magwira and Hague (1993) reported that lablab had high tannin and phenolic content and the residues had better nutritive value, which need to be considered when assessing the value of the crop for forage quality improvement.

Continuous maize production in Limpopo Province, where grazing of crop residues in winter follows summer rainfall season is also a problem that can be solved by intercropping maize with legumes to sustain the productivity of the soil. When maize is grown with Legumes, the grain yield of maize can be improved, through symbiotic nitrogen fixation by legume either in the current season or later seasons. Fixed N returns to the soil usually through nodule decay, leaf fall and exudation of organic nitrogenous component in the soil rhizosphere, the overall fertility of the soil can be improved which has also been found to improves soil water use efficiency in the system (Wiley and Osiru, 1972). The possibility of better control of weeds, pests or diseases was suggested as another possible advantage.

Even though intercropping has numerous advantages, some disadvantages may also occur. These include; competitive pressure through shading of the less competitive component crop in the system, and competition for soil resources mainly nutrient and water.

Various factors that affect shading of legume in intercrop include choice of genotype, time of planting, time of harvest of taller crop, density and spacing arrangement of the intercrop (Huxley and Mungu, 1978).

Light availability during critical stages of legume development could theoretically be controlled by manipulation of the relative time of planting of component crops. A number of authors have also reported other detrimental effects in intercropping systems that include allelopathy (Wiley, 1979; Reynolds *et al.*, 1994; Rezende and Ramahlo, 1994). When increasing efficiency of an intercrop system, it is important that different systems are critically assessed over two or more cropping habitats and seasons to identify compatible crop combinations.

Some of the speculated advantages of intercropping maize with legumes are soil fertility improvement, moisture conservation; reduce soil erosion and pest control. Soil fertility improvements occur when legumes fix substantial amounts of nitrogen through symbiotic fixation for its use and also for an associated maize plants, and again when legume residues are left in the soil for decomposition as organic matter. Intercropping conserves soil moisture content because the under-storey growing legume completely covers the soil thereby minimizing evaporation, reduce runoff and enhance infiltration (Francis, 1986).

Lablab

Lablab (*Lablab purpureus*) is a relatively new legume species in the Limpopo province and is produced on a limited scale by smallholder farmers. The growth habit and vigour of Lablab renders it a potentially suitable crop for intercropping system, but this has not yet been explored.

The crop has a long growing duration, ranging from 70-300 days and when intercropped with maize, significant green vegetative matter could still be maintained even after the maize is harvested, which is essential for livestock production (Francis, 1986). The combinations of maize stover and lablab will not only offer excellent fodder for livestock which depends on crop residue during winter months in the province, but will also provide a good cover, against soil erosion in summer the late season rains and may contribute significantly to soil nitrogen pool through symbiotic fixation.

Preliminary studies on lablab in the province indicated that the crop is very aggressive and competitive and may out-compete maize in an intercropping system when well established, thereby reducing maize yield. However, staggering planting date and density of the legume at compatible level can minimize the competitiveness of lablab and enhance overall system productivity (Misbaimunir *et al.*, 1989).

Evidence suggests that N_2 fixed by a legume component may be available to the associated cereal in the current growing season (Brophy and Helenel, 1989; Eaglesham *et al.*, 1981, Ta *et al.*, 1989) or as residual both current and residual N for a subsequent cereal crop (Searle *et al.*, 1981; Singh, 1983). Cereals and other nonlegumes usually require heavy applications of fertilizer nitrogen for good yield. Intercropping of legumes with cereal can help in improving and increasing agricultural yields worldwide to accommodate population growth without compromising in food production levels (Ladha and Peoples, 1995).

Studies indicated that farmers themselves are aware of soil fertility problem (Diagne 1997; Kamanga, 1999). The net result of diminishing in soil fertility and monoculture is the reduction in food security of subsistence farmers. The main task is to determine how to combine farmer's knowledge of legumes with technical expertise to make legume technologies not only sustainable but also economically viable and environmentally sound (Reeves, 2000). Soils in Limpopo province are dominated by low activity clays, inherently poor in fertility, fragile and degrade rapidly under present continuous intensive cropping and livestock production systems.

Lablab improves soil fertility and provides animal feed and production. Its green material also can be made into silage. The variety Rongai has been used successfully as cover crops to suppress weed growth, retard soil erosion and as green manure. Lablab retains some green growth during droughts. In some of the parts of the world such as Sudan, lablab has been interplanted with sorghum and maize (Misbaimunir *et al*., 1989). The contribution of cover crops to the sustainability of agriculture is becoming increasingly evident in many region of the world

Most soils in Limpopo Province of South Africa are inherently low in organic matter, and alternative sources to commercial nitrogen (N) fertilizers are particularly important in rainfed arable production. Nitrogen is an essential plant nutrient; it is the nutrient that is most commonly deficient, contributing to reduced agricultural yields throughout the world. The need to reduce production costs has promoted a renewed interest in using legumes as a source of N for non-leguminous summer crops.

Growing interest in intercropping in developed countries (Ofori and Stern, 1986) stems from increasing awareness of environmental degradation arising from high chemical inputs (Nielson, 1975) and give rise to a search for ways to reduce modern agriculture's over dependence on fertilizers, manufactured mainly with the use of fossil energy.

Soil moisture content

Water is a medium for proper nutrition and healthy growth in plant and it is an important constituent of living cells. It comprises approximately 90% of the plant tissue. Water is required for cellular activities and maintenance of turgor pressure within cells, water in plants cell keeps the stem upright and maintains expanded leaves to receive sunlight for photosynthesis. The quantity of moisture in the soil determines dry matter accumulation and grain yields in crop production.

Water use efficiency is defined as the amount of dry matter per unit evapotranspiration, which is expressed as grams of dry matter per kilogram of water used by the plant (Helweg, 1991). This is expressed as the ratio of dry matter per evaporation or net photosynthesis or transpiration. An intercropping system involving two species is often reported to use water more efficiently than a monocrops of either species can use it (Willey, 1979). Morris *et al.* (1990) discovered that intercrops of species competing for water at partially different times (i.e., growth and development not fully concurrent) or from partially different zones (i.e, different soil water extraction patterns) use water more efficiently than do sole crops of the species. The performance of component crops in intercropping is determined by competitive ability for the use of limiting environmental resources. Low harvest index (HI) may result from the reduction in the supply of assimilates, when competition for water occurs during the yield production stage. Therefore, understanding the water use (WU) in intercropping would provide suggestions for improved technologies for sustainable crop production. The actual WU and microclimatic quantification of intercropping systems have received appreciably less attention than their agronomic manipulations.

According to Morris *et al.* (1990) water use did not increase under the intercrops composed of annual legumes and course grains but water use efficiency (WUE) by the Intercrop was greater. Interspecific comparison gives an intercropping advantage as compared to sole cultures. Improved biological efficiency has been well established and explained for legume-non-legume combinations (Hiebsch and Mc Collum, 1987; Ofori and Stern, 1987).

Leaf nitrogen accumulation through chlorophyll content

According to Scott and Hector (1997), chlorophyll meters are used as a quick, inexpensive method of estimating leaf N concentration in both experiments and production fields. Infact, it was discovered that leaf N concentrations greatly influence both the development of maize canopies and their photosynthesis (Muchow, 1985; Muchow and Davis, 1998; Greef, 1994). It is often recommended that a mechanistic understanding of the influence of N supply on crop yield requires accurate monitoring of these levels (Kroff *et al.*, 1993; Sinclair and Muchow, 1995), as N applied at planting may bear little relationship to N uptake and yield of the crop (Cassman *et al.*, 1993; Muchow and Sinclair, 1995). Leaf N concentration is the common method of expressing the N status of crops, whereas specific leaf N is often used in explanatory models of crop response to N as it is well correlated with Co_2 assimilation per unit leaf area in maize (Wong *et al.*, 1985; Van Keulen and Seligman, 1987). Evidence also reported that the use of chlorophyll meter is increasing.

The use of chlorophyll content is usually to predict the need for additional N for cereals, leaf chlorosis, and it can also be used to determine rate of leaf senescence and benefit of nitrogen fixation in an intercropping systems. Fox *et al.*, (1994) found that the chlorophyll meter reading was more accurate in determining cereals N status than was plant N concentration.

Mechanisms of intercrop advantage

Willey and Osiru (1972) proposed the concept of land equivalent ratio (LER) as an index of combined yield for evaluating the effectiveness of all forms of intercropping. LER is defined as the total land area required under sole cropping to give the yields obtained in the intercropping mixture. The LER is the most frequently used index to determine the effectiveness of intercropping relative to growing crops separately (Willey, 1985). The LER is determined by several factors including density and competitive abilities of component crops in the mixture, crop morphology and duration, and management variables that effect individual crop species (Enyil, 1973; Natarajan and Willey, 1980; Fawusi *et al.*, 1982).

Two theoretical principles for understanding mechanism for yield advantages in intercrops have been proposed (Vandemeer, 1992; Fukai, 1993; Fukai and Trenbath, 1993), namely competitive production principle and facilitative production principle. The competitive production principle states that an intercrop may be successful if the resource requirements of the two species are sufficiently distinct. Competition for the resources of light, water or nutrients might be high in sole crops as compared to intercrop, which may lead to intercrop yield advantages. Either time or space may explain differention, which occurs in an intercrop and sole. When time or space are to be explained in terms of competition, during simultaneously planting or in an intercrop there is different types of crops, differed in rooting depth, leaves structure and physiological. The efficiency of soil water uptake by the root system is therefore a key factor in determining the rate of transpiration and tolerance to drought.

The facilitative production principle on the other hand states that one species benefit directly from modification of the growth environment by other species in an intercrop. According to Ofori and Stern (1987), Siame *et al.*, (1998), the transfer of N from legumes to non-legumes within a growing season is a well-known example of facilitative production principle.

This process of facilitation mentioned above is distinct from the competitive production principle wherein legumes and non legumes may be compatible because they do not compete for the same resources namely soil N (Francis *et al*, 1982). Shading is another important factor in an intercrop; it may either be beneficial in hot environment or detrimental for photosynthesis. N_2 fixation is said to be energy depended as results there is a reduction in the photosynthesis supply to the nodules is detrimental, it is often speculated that if the non legume is taller than the legume, shading occurs and results in reduced photosynthesis and N_2.fixation (Wahua and Miller, 1978). A more-efficient use of resources is a major reason advanced for the advantage of intercropping over alternative cropping systems.

Plant density is one of the three important management decisions to consider when deciding to practice intercropping. Others are cultivars selection and row arrangement. Planting date and density should be known before intercropping lablab with maize. Conducting a study to assess the response of maize dry matter accumulation and yield is therefore crucial to determine the correct planting date and density.

Time of sowing of component crops is an important management variable that is manipulated in cereal-legume intercrop but has not been extensively studied. Andrews (1972), Willey (1979), Francis *et al.* (1976) pointed out that differential sowing improves productivity and minimizes competition for growth-limiting factors in intercropping. The difference is that with simultaneous planting, competition can only be reduced if cultivars are selected which are markedly different in their vegetative growth cycle. Density and spatial arrangement can affect the extent of competition between component crops. According to Woolley and Davis (1991), poor management of plant population can clearly be detrimental to the intercrop. Differences in plant and root architecture affect the competition between species, and their ability in combination to exploit the environment more efficiently.

Length of crop growth cycles and water availability in the soil determine relative time of planting. Lablab is a climbing bean, which can pull over the stem of the associated maize if the density is too high, resulting in lodging of the whole crop. If the bean density is not excessive, climbing beans have a beneficial effect by anchoring the maize plant and reducing lodging (Davis and Garcia, 1987). Root competition between component crops is mostly for nutrients like nitrogen, and for water, because their extraction extends far away from the roots. Competition from an intercropped cereal for N may stimulate N_2 fixation in the legume, and cultivars may respond differently to this. On the other hand, too much applied N may suppress N_2 fixation in the legumes. According to Weil and Mc-Fadden (1991), a large part of the benefit of intercropping may be lost with high levels of N fertilization. For example in maize/ soybean intercrop Stern (1993), Woolley and Davis (1991) reported that low rates of applied N might not be prejudicial to fixation.

Grain legumes could be used either as sequential, relay or full intercrops. Intercrop technologies could be particularly valuable where main crop yields are increased as a result of reduced competition or facilitation, despite the presence of the grain legume (Vandermeer, 1989). Additionally, it is thought that some fixed N may be transferred directly to the crop at least in full intercropping. Leaf litter may also provide N for the main crop. When assessing maize-legume intercropping is important that issues relating to main crop competition between the legume intercrop and the main crop are determined. Depending on the nature of the plants selected, the main crop may either reduce the growth of the legume intercrop, or the legume intercrop may reduce the growth of the main crop.

Main goal of the study is to improve the overall productivity of maize in the small farming system of the Limpopo province through an intercropping system with lablab bean. The specific objectives are as follows:

a) To assess the influence of lablab planting date and density on dry matter accumulations, agronomic characters and grain yield of maize and lablab in an intercropping system.

b) To asses nitrogen uptake patterns, chlorophyll production and soil moisture use maize and lablab in the system and.

c) To evaluate stalk borer infestation in the cropping system.

CHAPTER 2

MAIZE GRAIN YIELD AND YIELD COMPONENTS RESPONSE TO LABLAB PLANTING DATE AND DENSITY IN ROW INTERCROPPING SYSTEM

INTRODUCTION

Maize is the major staple food in the Limpopo province of South Africa and hence, dominates the smallholder farming system of the province. The preference for maize has led to continuous culture of the crop, which together with low external input, has resulted in severe soil degradation in many smallholder-farming systems in the province. Identification of cropping systems, capable of maintaining soil fertility is required to enhance crop productivity on farmers' fields. Intercropping maize and leguminous species, mainly cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogeae*) and bambara groundnut (Vigna subterranean) is common among farmers but usually the legume component is minimal. Lablab bean (*Lablab* purp*ereus*) is a leguminous species with prolific growth rates and biomass accumulation and hence has the potential to be incorporated into the predominantly maize monoculture system in the Limpopo Province. Preliminary studies conducted on lablab indicated that the crop has prolific growth characteristics and if not well managed in an intercropping system, could severely suppress maize growth and yields. Planting date and density of lablab are two important management tools that could be explored to minimize competitive pressure created by lablab. Ofori and Stern (1986) reported that the magnitude of intercropping advantage or efficiency in a legume-non-legume system seems to be determined by legume components. Most researchers have reported significant reductions in legume yields with only slight changes in yields of the cereal grown in association with them (Willey and

Osiru, 1972; Dalal, 1974; Fisher, 1977; Wahua and Miller, 1978; Wahua *et al*., 1981). However, relative yields of crops in most importantly on the relative size of the component populations (Francis *et al*., 1978;Trenbath, 1976; Willey, 1979). Growth and yield of legume component is reduced markedly when intercropped at high densities of the cereal component. Many studies have been conducted on the effects of component and total populations in cereal-legume intercrops, on mixture productivity and yield components (Kassam, 1972; Willey and Osiru, 1972; Wahua and Miller, 1978; Willey, 1979). Delaying the legume planting up to four weeks resulted in more yield of maize and no yield of legumes (Guridno and Sugito, 1990). Planting date of the legume is said to determine the productivity of the two crops in intercropping system. Ofori and Stern (1987) however reported that differences in planting dates of component crops have no advantage over simultaneous sowing. Relative time of planting was also reported to produce small effect on the performance of component crops in cassava/soybean intercropping (Thung and Cock, 1979). Thus, clarity on the importance of legume planting date relative to the cereal needs to be sorted out. Researchers in cereal-legume intercropping have discovered that when intercropping maize and legume, the maize often depresses the yield of the legume crop especially when the legume is planted later. However, combinations in which legume yield was increased by maize had been reported and these include maize-soybean (Yunusa, 1989), sorghum-bean intercrop (Willey and Osiru, 1972) and in a maize/cowpea intercrops (Fawusi *et al*., 1982).

Other researchers have reported yield depression of maize with legume (Shumba *et al.*, 1990; Siame *et al.*, 1998). Fujita and Ofusu-budu (1992) observed that in maize-bean intercrop, yield was reduced by 30% at high bean density. Once a component crop develop better access to a limiting resource, it tends to become progressively more dominant while the growth of the other may be suppressed almost completely (Stern, 1993). Thus, identifying lablab density that can maintain satisfactory growth and yield when simultaneously planted with maize will be important in sustaining the productivity of maize-lablab intercropping systems where production resources is limiting.

Maize is the most important food crop in rural communities of many developing countries, and in the Limpopo Province and therefore, when intercropping maize with any legume, the farmer's yield objective tend to follow a similar theme. According to Liphadzi (1998) and Mpangane (2001), maize is the crucial component of the system on the farmer's field and therefore its yield has to be enhanced or maintained. Legumes are important as a high protein crops, a source of forage for animals and sometimes a high cash crop, so provided there is no significant sacrifice of cereal yield, a secondary objective will be to produce good legume yield. The objectives of the study were

(i) to assess yield performance of maize in sole and intercropping systems with various densities of lablab and planting date, and (ii) to identify lablab density and which can maintain desirable agronomic characteristics and yield when intercropped with maize.

MATERIALS AND METHOD

Field experiments were carried out at two locations in the Limpopo Province of South Africa namely; the University of the North experimental farm at Syferkuil and a smallholder farmer's field at Dalmada near Polokwane during 2001/02 and 2002/03 growing seasons. The pre-sowing soil fertility status at the two locations is presented in Table 2.1. Temperature at both locations in all growing season is presented in Table 2.3, whereas rainfall is in Fig 2.1-2.2.

Experimental fields were ploughed two to three days before planting and 30 kg P ha^{-1} was applied in the form of superphosphates at Dalmada, 2001/02, followed by disking to incorporate the fertiliser. Nitrogen fertiliser was applied as urea, at planting to maize at 30kg N ha^{-1} at Dalmada. The lablab seeds were inoculated with a commercial *Bradyrhizobium* strain just before planting.

The experiments were planted on the 12th December at Dalmada and on the 13th December at Syferkuil during the 2001/02 growing season, and in the 2002/03 growing season, they were planted on the 6th and 12th December 2002 at Dalmada and Syferkuil respectively. The experiment was established as a randomized completely block design in factorial arrangement with three replications at each location. The factors studied were planting date and planting density of lablab as follows: five different density of lablab, namely: 0 plant per meter length (sole maize); 2 plant per meter length; 4 plant per meter length; 6 plants plant per meter length; 8 plants per meter length in the 2001/02 and an additional 10 plants per meter length in 2002/03. These treatments were either planted simultaneously with maize or 28 days later.

The lablab was planted between 90-cm inter row spacing of maize and thus creating a distance of 45cm between the maize and the lablab. Five rows were planted at both locations in the 2001/02 growing season and 8 rows in the 2002/03 growing season. Three rows were harvested in the 2001/02 growing season at both locations and 5 rows in 2002/03 growing season. Row length was 4 m in the 2001/02 growing season at both locations, whereas in the 2002/03 the length was 4.5m. Spacing between lablab and maize was 0.45m. The maize cultivar used was SNK 2147 and that of lablab was Rongai, a long duration type. Weeds were controlled by hand on two occasions during the growing season. Days to flowering in both crops were recorded when 50% of the plants in a plot had flowered. Physiological maturity of maize was scored when 90% of the plants in a plot revealed cobs with no milk line (Stoskopf, 1981).

Yield and yield components

Maize grain yield was harvested from 9.45m^2 and 22.5 m^2 during 2001/02 and 2002/03 growing season respectively for yield and yield components determination. Cobs were namely: 0 plant per meter length (sole maize); 2 plant per meter length; 4 plant per meter length; 6 plants plant per meter length; 8 plants per meter length in the 2001/02 and an additional 10 plants per meter length in 2002/03. These treatments were either planted simultaneously with maize or 28 days later.

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Maize grain yield was harvested from 9.45m^2 and 22.5 m^2 during 2001/02 and 2002/03 growing season respectively for yield and yield components determination. Cobs were oven dried at $65^{0}C$ to reduce grain moisture percent to 12%. Seed yield samples of maize were taken from the middle rows of each plot, leaving one row on each side as a border row. Yield components of both crops were recorded when the seed yield data was collected. Maize yield components were recorded as cob number and weight, rows cob^{-1}, kernels cob^{-1}, cob weight and weight of 100 seed.

Maize mortality

Maize mortality was determined by first, combining the number of plant within a defined harvest area on each experimental unit at seedling establishment.

Maize mortality or number of maize plants killed was then calculated as total number plants in harvested area at seedling establishment minus harvested number of plants within harvested area at physiological maturity.

Maize harvest index (HI) rate

$$HI = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Two maize plants were harvested at 82 DAP, 96 DAP, 110 DAP and at harvest at 154 DAP. Cobs from the two plants were oven dried, shelled and the grain weighed. The total dry matter vegetative and reproduction from the two plants was oven dried at 65 ^{0}C to constant weight.

Data analysis

Data were subjected to analysis of variance (ANOVA) using the program, Statistical Analysis System (SAS,1989). Differences between treatment means were separated using the least significant difference (LSD) procedure (Gomez and Gomez, 1984). Data was pooled across planting date when no interaction effect between planting date and density was significant.

RESULTS AND DISCUSSION

Grain yield

Maize

Maize grain yield was influenced by both lablab planting date and density at both locations and seasons (Tables 2. 4 and 2. 5). The interaction effect of planting date and density was also significant at all locations and seasons except at Dalmada in the 2002/03 growing season. Grain yield of maize, simultaneously planted with lablab was on average, reduced by 26 and 57%, compared to those intercropped with later planted lablab in 2001/02 at Dalmada and Syferkuil respectively (Fig 2.3). In 2002/03, the yield reduction was 20 and 41% respectively. A general trend of decreasing maize grain yield with increase in lablab density under the simultaneous planting system was observed in both seasons at the two locations. Grain yield of maize, in a mixture with simultaneously planted lablab was reduced compared to the sole crop yield at the two locations in 2001/02 with greater yield reduction occurring at density of six plants per hectare and above (Table 2.5). However, in the 2002/03, planting density of two and four plants per meter at Dalmada and two plants per meter at Syferkuil resulted in similar yields as the sole crop.

In maize-legume intercrop, most researchers have reported yield depression of the legume by maize (Clement *et al.*, 1992; Ezumah *et al.*, 1987 and Ofori and Stern, 1987). The yield reduction in maize observed in this study could be attributed to increased competition created by the high-density lablab. Maize grain yield reduction has been reported in maize-cowpea intercrops (Shumba *et al.*, 1990; Siame *et al.*, 1998) and in maize-bean system (Siame *et al.*, 1998).

When lablab was planted 28 days after maize, grain yield of maize at planting densities of two and four were similar to the sole in the 2001/02 at Dalmada, whereas at Syferkuil, an average of 59 higher maize yield, was obtained at lablab densities of two and four compared to the sole maize yield during the same season. In the 2002/03 season, yields of maize intercropped with later planted lablab at densities of 2 and 4 plant per meter were similar to the sole crop at Dalmada, but were higher than the sole by about 46% and 38% respectively at Syferkuil. The greater yield boost under the later planted lablab intercropping system could primarily be attributed to the better suppression of lablab vigor by the earlier planted maize. Yield advantage in intercrop could arise when component crops have different growth pattern and make major demands on resources at different times (Harris *et al.*, 1987; Putnam and Allan, 1992). In an intercropping system, a component crop can positively modify the growing environment for the benefit of the other crop, which can lead to overall yield advantage relative to the sole crop (Vandemeer, 1992). In this study, the later planted lablab, though less competitive with maize was observed to completely cover the soil, later in the season and thus, suppressing weeds effectively in the intercrop plots, creating cooler soil conditions and possibly minimizing moisture loss compared to the sole crops. This could have contributed to the enhanced yield of the intercropped maize compared to the sole crops.

In both growing seasons, decreasing yield tendency was observed when lablab-planting densities per meter length were increased. The lower maize grain yield at higher lablab densities at Dalmada may be due to competition for soil resources such as soil nutrients and soil moisture.

The tendency of decreasing yield with increasing lablab density strengthened the fact that the magnitude of intercropping advantage or efficiency seems to be determined by the legume component (Ofori and Stern, 1986). The generally reduced maize grain yields at relatively higher lablab density could be attributed to the aggressive nature of intercropped legume. The presence of the vigorously growing lablab reduced the exposure of the main crop to sunlight and also competed for the other growth resources. Lablab was observed to climb the maize at higher densities and interfering with the cereal's maintenance of upright position to intercept solar radiation. Francis *et al.*, (1982) and Hart (1975) reported reduced maize grain yield when intercropping with climbing bean. Below-ground competition at higher lablab density could have also contributed to the observed yield reduction in maize (Davis and Garcia, 1987; Woolley and Davis, 1991)

The increased of maize yield when intercropped with 2 and 4 plants of lablab at a later planting date are in disagreement with the findings by Ofori and Stern (1987) stating that variation in time of sowing on intercrop yields has no advantage over simultaneous sowing. Our findings however clearly support evidence by Woolley and Davis (1991).

Lablab

In both growing seasons at Dalmada and Syferkuil lablab did not produced yield, only border rows of few plots flowered and yielded when simultaneously planted with maize. Second planted lablab (28 DAP) did not flower at both locations in the 2001/02 and 2002/03 growing season. The lack of flowering could due to the limited solar radiation exposure and interception by the under-storey lablab bean. According to Gardiner and Cracker (1981) bean-maize intercrop plantings increase light interception and decrease light reflection as compared with bean monocrops plantings. However, the quantity of light available to the bean canopy is decreased as the maize population is increased. Lablab is a bean such as *Phaseolus vulgaris L* is very sensitive to shading by the component crops in the intercrop (Dalal, 1974; Graham and Rosas, 1978 b).

Maize yields components

Weight per cob

At both locations, maize weight per cob was influenced by lablab planting date, density and interactions at $p \leq 0,05$ in all growing seasons (Tables 2.6 - 2.9). Weight per cob responded similar under both planting dates at both locations in the 2001/02. Maize weight per cob was reduced on averaged by 26% at Dalmada and Syferkuil during 2001/02 growing season, when simultaneously planted with maize relative to later planting of lablab (Fig 2.4). Sole maize weight per cob was lower, when compared to maize at 2 and 4 plants lablab m^{-1} (Tables 2.6 and 2.7) at both locations during 2001/02 growing season. During 2002/03 growing season, planting date, density and interaction affect of planting date and density had a significant effect on maize weight per cob at Dalmada and Syferkuil (Tables 2.8 and 2.9). At both locations, maize weight per cob was high at maize intercropped at 2 and 4 plants of lablab, followed by the sole maize when maize was simultaneously planted with lablab (Tables 2.8 and 2.9). However, when lablab was planted 28 days later, sole maize weight per cob was similar to maize intercropped at 2 and 4 plants of lablab at both locations during 2002/03 growing season.

Number cobs per plants

Lablab planting date had a significant effect on number of cobs per plants at both locations during 2001/02 growing season (Tables 2.6 and 2.7). The interaction effect of planting date and density was significant at both locations in the 2001/02. When maize was planted simultaneously with lablab bean, differences among intercrops or lablab planting densities were detected, whereas at later planting no differences were observed at both locations in the 2001/02 growing season (Tables 2.6 and 2.7). Maize intercropped at 2 and 4 plants of lablab produced high number of cobs, than sole maize and other intercrops (Tables 2.6 and 2.7) at both locations during 2001/02 growing season.

Significant effect was detected from planting dates and interaction on number of cobs, in 2002/03 growing season at both locations (Tables 2.8 and 2.9). Number of cobs were similar statistically for sole maize, and maize intercropped at 2 and 4 plants of lablab, when planted simultaneously at both locations in 2002/03 growing season. However, later planting of lablab produced similar number of cobs across all planting densities at both locations during 2002/03 (Tables 2.8 and 2.9).

Number of rows per cob

The number of rows per cob was significantly effected by lablab planting date and the interaction at Dalmada in the 2001/02 (Table 2.6). At Syferkuil maize number of rows per cob was influenced by lablab planting date, whereas the effect of lablab planting density and interaction was not significant during 2001/02 (Table 2.7). Under simultaneous planting, sole maize and maize intercropped at 2 and 4 plants of lablab produce similar number of rows at both locations during 2001/02 (Tables 2.6 and 2.7).

The number of rows was increased by 6% on averaged when lablab was planted simultaneously with maize at Dalmada, however, was reduced by 4% at Syferkuil in 2001/02 (Fig 2.4). Similar results were obtained in the 2002/03 at both locations, where the number of rows per cob was increased when maize was simultaneously planted with lablab at Dalmada but decreased at Syferkuil (Fig 2.5).

The interaction effect of planting date and density was significant at all locations during 2002/03 growing season (Tables 2.8 and 2.9). When lablab was planted with maize simultaneously, the maize number of rows was increased under maize intercropped at 2 plants of lablab, followed by 4 at both locations. Under 28 DAP, maize intercropped at 2 and 4 plants of lablab resulted in a similar number of rows per cob at both locations during 2002/03 (Tables 2.8 and 2.9)

Reduction in row number per cob increases as number of lablab plants m^{-1} was observed at both locations when lablab was simultaneously planted with maize in the 2001/02 and 2002/03 growing seasons.

Number of kernels per cob

The number of kernels per cob was influenced by lablab planting date and interaction at Dalmada during 2001/02 growing season (Table 2.6). At Syferkuil the number of kernels per cob was effected by lablab planting date and density, whereas the interaction effect was not significant during 2001/02 growing season (Table 2.7). At Dalmada, maize kernels number was reduced by 16% on average (Fig 2.4) in the 2001/02 when maize was simultaneously planted with lablab, whereas at Syferkuil there was increase of 9%. Similar to 2001/02 results kernels number per cob was also increased at Syferkuil in the 2002/03 growing season (Fig 2.5). At Dalmada sole maize, and maize intercropped at 2 and 4 plants resulted in similar number of kernels per cob when lablab was planted 28 days later, number of kernels were the same across all planting densities during 2001/02 in the later lablab planted system (Table 2.6).

In the 2002/03, lablab planting date, density, and the interaction influenced number of maize kernel per cob at both locations (Tables 2.8 and 2.9). At Dalmada, maize intercropped with 2 plants of lablab resulted in high number of kernels per cob, followed by maize with 4 plants of lablab under both planting dates in the 2002/03 seasons.

Sole maize, at Dalmada produced few numbers of kernels per cobs, compared to maize intercropped with 2 and 4 plants of lablab in the 2002/03 growing season. In the 2002/03, number of kernels per cob was similar for maize intercropped with 2 and 4 plants of lablab under simultaneous planting at Syferkuil during 2002/03. Sole maize and other intercrops produced similar number of kernels but were all lower than those plants under 2 and 4 lablab density.

Maize seed mass

Maize seed mass was influenced by lablab planting date, density and interaction effect of planting date and density at both locations in both seasons, except at Dalmada when lablab was planted later in the 2002/03 (Tables 2.6-2.9). When maize was simultaneously planted with lablab, maize seed mass was increased on average by 20 and 9% at Dalmada and Syferkuil respectively during 2002/03 season (Fig 2.4). On average maize seed mass was increased at both locations when maize and lablab was planted simultaneously (Fig 2.5). At Dalmada, maize intercropped with 2 plants of lablab produced higher maize seed mass, compared to sole maize and other intercrops under simultaneously planting during 2001/02 (Table 2.6). At Syferkuil when maize was simultaneously planted with lablab, maize intercropped with 2 and 4 plants of lablab produced similar seed mass, followed by the sole maize at Syferkuil during 2001/02 growing season (Table 2.7). However, under later planting of lablab, seed mass was the same for sole maize and maize with 2, 4, 6 and 8 plants of lablab (Tables 2.6 and 2.7).

Maize seed mass at Dalmada was higher when maize was intercropped with 2 plants of lablab planted simultaneously, whereas at later planting of lablab, seed mass was similar across all planting dates (Table 2.8) during 2002/03 growing season. At Syferkuil, maize intercropped at 2 and 4 plants of lablab produced high seed mass than sole and other intercrops during 2002/03 growing season (Table 2.9). However, when lablab was planted later, sole maize and maize intercropped at 2 and 4 plants resulted in the same maize seed mass in the 2002/03 at Syferkuil (Table 2.9).

Relationship between maize grain yields and yield components

Similar pattern was observed on maize grain yield and yield components at both locations and growing season. Simultaneously planting of lablab and maize at high density significantly reduces maize grain yield and yield components. Maize intercropped at 2 and 4 plants of lablab per meter produce equal or higher maize grain yield and yield components than sole maize and other intercrops when planted simultaneously. When lablab was intercropped with maize at later stage, maize yield was increased as compared to simultaneously planted

Flowering and physiological maturity

Days to flowering of maize ranged from 62-75 across locations and seasons. Maize plants intercropped with higher density of lablab tended to flower later than those planted with lower density and also the sole maize (Tables 2.10 and 2.11). The flowering date of maize, simultaneously planted with lablab generally did not differ from those intercropped with later planted lablab. In the 2001/02 growing season, sole maize crop and those simultaneously intercropped with lablab at 2 and 4 lablab plants m^{-1} matured almost at the same time at both Dalmada and Syferkuil (2.11).

Similar to days to flowering, physiological maturity was delayed when maize was intercropped with 8 and 10 lablab plants m^{-1}.

During 2002/03 growing season, a similar maturity pattern was observed where maize plants, intercropped at higher densities had delayed maturity (Table 2.11). Maize plants intercropped with later planted lablab did not show consistent response to planting density with regard to maturity.

Maize plant height

Lablab planting densities and interaction influenced maize plant height at both locations during 2001/02 growing season (Table 2.12). The effect of planting date was detected at Dalmada, whereas at Syferkuil was not in the 2001/02 growing season (Table 2.12). In the 2001/02 growing season maize plant height ranged from 1.37-1.90m and 1.04-2.77m at Dalmada and Syferkuil respectively (Table 2.12). Maize height was reduced on average, when lablab and maize were planted simultaneously at both locations in all growing seasons (Fig 2.6). Sole maize resulted in taller maize plants, compared to all other intercrops at Dalmada in the 2001/02 growing season. However, at Syferkuil in the same season, maize plant height for sole maize, and maize intercropped with 2 and 4 plants of lablab were similar when maize and lablab were planted simultaneously. At Dalmada maize plants height was tall under sole, and short when maize was intercropped with lablab at later planting of lablab (Table 2.12), whereas at Syferkuil maize plant height were similar in the 2001/02 (Table 2.12). Maize plant height was reduced when maize was simultaneously intercropped with 10 plants of lablab by 83% and 67% at Dalmada and Syferkuil respectively during 2001/02 (Table 2.12).

In the 2002/03 growing season, planting date had a significant effect on maize height (Table 2.13). Maize-lablab intercrop at 2 and 4 plants of lablab m^{-1} resulted in tall maize plants, followed by sole maize, when maize and lablab were planted simultaneously at

Dalmada during 2002/03. The other densities resulted in shorter when maize was planted simultaneously with lablab at Dalmada in the 2002/03 growing season (Table 2.13). This demonstrates the suppression of maize growth by high density of lablab (Table 2.13). The above-mentioned supports results by other researchers that lablab at high-density uses maize for support.

Maize Mortality

Maize mortality is number of plants killed by physiological maturity. Planting date, density and interaction influenced mortality at Dalmada and Syferkuil in both growing seasons at $P \leq 0.05$ level of significance (Tables 2.14 and 2.15). At maize simultaneously intercropped with lablab, maize mortality was increased on average by 37% at Dalmada during 2001/02 growing season, whereas at Syferkuil mortality was increased by 57% compared to 28 days planting of lablab (Fig 2.7). Averaged across lablab planting density, maize mortality was reduced at both locations and seasons when lablab was planted 28 days after planting maize (Fig 2.7). Similar pattern was observed at both locations, where increasing lablab density m^{-1} resulted in high maize mortality in both growing seasons. Mortality of maize was low when lablab was planted 28 days after maize, compared to the simultaneously planted (Tables 2.14 and 2.15). Maize mortality was similar across all lablab planting densities at both locations and growing seasons, when lablab was planted 28 days after planting maize. Treatments with higher mortality had a decrease maize grain yield, which may be explained by the fact that lablab is a climber, which, at high density suppress and cause death through whole plant lodging of maize crop (Gardiner and Craker, 1981; Francis *et al*., 1982; Agboola and Fayemi, 1971 and Enyil, 1975).

Harvest Index of maize

Harvest index (HI) is a ratio of grain yield to biological yield of a crop and it reflects how plant partition dry matter into reproductive organs relative to vegetative parts (Ayisi *et al.*, 2000). Harvest index provides an estimate of the conversion efficiency of dry matter yield (Gebeyehou *et al.*, 1982). Pooled across planting date, HI of maize intercropped with two and four lablab plants m^{-1} length, were similar, compared to sole maize (Figs. 2.8 and 2.9). The harvest index rate ranged from 4-32 % at Dalmada, whereas at Syferkuil the range was 4 -55 % across all sampling date during 2001/02 growing season. The above results show greater dry matter partitioning into reproductive organs at Syferkuil, which resulted in higher maize grain yield at Syferkuil as compared to Dalmada. In the 2002/03 growing season at 110 and 154 DAP, of maize intercropped at 2, 4 plants of lablab m^{-1} had higher HI and appeared to partition more of its photosynthates to grain yield than sole maize and other densities intercropped with maize at both locations (Figs 2.8 and 2.9).

The harvest index rate was increased as the number of date after planting increases. Intercropping of 2 and 4 plants of lablab plants resulted on the same harvest index as sole maize across all sampling date at Syferkuil during 2002/03 growing season. As number of plants m^{-1} increased, harvest index showed tendency of decrease, following a pattern similar to maize biomass accumulation and yield (Figs 2.6 and 2.7). The above results show the efficiency of maize intercrops under 2 and 4 plants of lablab m^{-1} in partitioning photosynthates into grain formation.

CONCLUSIONS

Grain yield of maize, simultaneously planted with lablab was generally reduced compared to the sole crop. However, at intercropped lablab density of two and four at Dalmada and density two at Syferkuil in the 2002/03, maize produced similar yield as the sole crop. There was a general trend of decreasing maize grain yields as lablab density increase under the simultaneous planting. When lablab was planted 28 days after maize, grain yields of the associated maize crop were similar to or higher than the sole crop yield. Maize yield components followed the similar patterns as maize grain yield. Maize mortality rate was high at maize intercropped with 6, 8 and 10 plants as compared to sole maize and maize, intercropped at 2 and 4 lablab plants m^{-1}. Higher maize grain yield at lower lablab density could also partially be attributed by increased harvest index at these densities.

The flowering date of maize intercropped with high-density of lablab tended to be longer compared to those with lower lablab densities as well as the sole maize crop. The planting date of lablab did not influence flowering in maize. Similar to flowering, physiological maturity of maize was also delayed with increasing lablab densities. Lablab could thus be incorporated in the predominantly maize monoculture of the Limpopo Province without reducing yield of the cereal when it planted about a month later. When planted simultaneously with maize, a density of 4 lablab plants m^{-1} should not be exceeded.

STUDY TABLES AND FIGURES

Table 2.1. Initial top and subsoil nutrient status at Syferkuil and Dalmada during the 2001/02 and 2002/03 growing seasons.

Location	Season	[a]pH		[b]Mineral N		[c]P		[d]K	
				(Mg/g)		(Mg/g)		(Cmol (+)/kg)	
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Syferkuil	2001/02	6.6	7.0	20	12	23	14	0.38	0.49
	2002/03	7.8	7.5	11	9	33	27	0.29	0.30
Dalmada	2001/02	7.6	7.9	3.2	2.8	9	7	1.41	0.82
	2002/03	6.9	7.1	3	2	43	27	1.02	0.95

[a] 1:5 soil: water

[b]NH4 +NO_3 1:5 etractant 0.1N K_2SO_4

[c] 1:7.5 extractant Bray 2

[d] 1: 10 extract Ammonium Acetate 1N, pH7

Table 2.2 Bio-physical data at Dalmada and Syferkuil

	Location	
	Dalmada	Syferkuil
Bio- physical data		
Ave. max. temperature	25.3°C	25.3°C
Ave. max. temp	13.4°C	13.4°C
Longitude/Latitude	23°C85'S.29°C 66 E	23°C85'S.29°C 66 E
Elevation	1250m	1250m

Table 2.3. Average maximum and minimum temperatures for each location during 2001/02 and 2002/03 growing seasons.

Month	2001/02 Dalmada		2002/03 Syferkuil	
	Max	Min	Max	Min
December	26.2	13.6	28.2	17.2
January	25.3	15.8	28.8	16.6
February	26.5	16.3	30.1	17.3
March	28.5	16.0	28.7	14.6
April	27.7	15.6	25.1	12.4
May	28.4	13.7	25.2	6.5
June	27.4	11.4	20.3	4.4
Average	28.5	5.0	23	12.7

Table 2.4 Response of maize grain yield to lablab planting date and density at Dalmada and Syferkuil during 2001/02 growing season.

Density (Plants m^{-1})	Dalmada		Syferkuil	
	Simultaneous	28 DAP	Simultaneous	28 DAP
	....	kg ha^{-1}	....	
0	1076 a	1076 a	863 a	863 c
2	802 b	999 a	528 b	1615 a
4	721 b	971 a	436 c	1126 b
6	321 c	539 b	189 d	803 c
8	90 d	464 b	122 d	583 d
10	-	-	-	-
LSD ($P \leq 0.05$)	106	106	81	81
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; 28 DAP= Lablab planted 28 days after the maize.

Table 2.5 Response of maize grain yield to lablab planting date and density at Dalmada and Syferkuil during 2002/03 growing season.

Density (plant m^{-1})	Dalmada Simultaneous	Dalmada 28 DAP	Syferkuil Simultaneous	Syferkuil 28 DAP
	kg ha^{-1}			
0	1674 a	1674 a	5181 a	5181 b
2	1438 a	1908 a	4729 a	7550 a
4	121 a	1654 a	3055 b	7141 a
6	733 b	971 b	2567 bc	5797 b
8	819 ab	961 b	2041 bc	3985 c
10	572 b	884 b	1583 c	2875 c
LSD ($P \leq 0.05$)	459	459	1184	1184
Date	**	**	**	**
Density	**	**	**	**
Interaction	Ns	ns	*	**

LSD = Least significant difference. Means followed by the same latter within columns are similar statistically; **= $p<0.01$; *= $p<0.05$; ns =not statistically significant. Lablab planted 28 days after the maize.

Table 2.6 Maize yield components as influenced by lablab planting date and density at Dalmada during 2001/02 growing season.

Density (plants m^{-1})	Weight per cobs (g)		# cobs/P		# Rows per cob		# Kernels per cob		Seed mass (g)	
	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
					kg ha^{-1}					
0	64 b	64 b	0.7 b	0.7 a	13 a	13 a	429 a	429 a	21 c	21 ab
2	122 a	126 a	0.9 a	0.9 a	16.6 a	13.6 a	451 a	408 a	45 a	25 a
4	109 a	125 a	1.1 a	0.8 a	15.3 a	13.6 a	434 a	401 a	38 b	23 ab
6	50 b	98 b	0.3 c	0.9 a	6.5 b	13.4 a	163 b	366 a	18 c	21 ab
8	34 b	94 b	0.2 c	0.7 a	5.9 b	12.2 a	163 b	357 a	15 d	19 b
10	-	-	-	-	-	-	-	-	- -	-
LSD (P≤ 0.05)	26	26	0.24	0.24	2.49	2.49	105.4	105.4	4.70	4.70
Date	**	**	**	**	**	**	**	**	**	**
Density	**	**	**	ns	**	ns	**	ns	**	**
Interaction	**	**	**	**	**	**	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 2.7 Maize yield components as influenced by lablab planting date and density at Syferkuil during 2001/02 growing season.

	Weight of cobs (g)		#Cobs/p		#Rows per cob		#Kernels per cob		Seed mass (g)	
Density (plants m^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	………	………	………	………	………	kg ha^{-1}	………	………	………	………
0	36 b	36 b	0.5 b	0.5 a	11.2a	11.2 a	386 a	386 a	23 b	23 ab
2	48 a	79 a	0.6 ab	0.7 a	9 .2 a	11.3 a	268 b	385 a	46 a	27 a
4	42 a	73 a	0.9 a	0.6 a	8.2 a	11.3 a	252 b	350 a	42 a	25 a
6	31 b	38 b	0.1 c	0.6 a	4.3 b	11.1 a	136 c	272 b	12 c	23 ab
8	35 b	34 b	0.0 c	0.5 a	4.3 b	9.9 a	242 c	225 b	6 d	20 b
10	-	-	-	-	-	-	-	-	-	-
LSD ($P \leq 0.05$)	17.1	17.1	0.24	0.24	3.9	3.9	56	56	4.1	4.1
Date	**	**	*	*	*	*	*	*	**	**
Density	**	**	**	ns	*	n.s	*	*	**	**
Interaction	**	**	*	*	n.s	n.s	n.s	n.s	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *=$p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 2.8 Maize yield components as influenced by lablab planting date and density at Dalmada during 2002/03 growing season.

	Weight per cob (g)		# cobs/p		# Rows per cob		# Kernels per cob		Seed mass (g)	
Density (plants m^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	…………	…………	…………	…………	…………	kg ha^{-1} …………	…………	…………	…………	…………
0	89 b	89 a	1.4 a	1.1 a	14 c	14 b	187 c	187 c	26 c	26 a
2	121 a	99 a	2.7 a	1.8 a	17.7 a	19 a	403 a	561 a	62 a	29 a
4	140 a	90 a	3.3 a	1.6 a	15.6 b	18 a	317 b	452 b	46 c	27 a
6	70.3 c	68.2 b	0.6 b	1.8 a	9.0 d	9 c	164 c	172 cd	23 c	21 a
8	70.5 c	66.6 b	0.4 b	1.4 a	6.5 e	10 c	153 c	152 c	21 c	19 a
10	47.7 d	61.9 b	0.5 b	1.2 a	5.5 e	7 c	153 c	128 d	20 c	18 a
LSD ($P \leq 0.05$)	20.7	20.7	2.7	2.7	1.4	1.4	46	46	11	11
Date	**	**	**	**	**	**	**	**	**	**
Density	**	**	**	n.s	**	**	**	**	**	n.s
Interaction	**	**	**	**	*	*	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM = Simultaneous planting; 28 DAP =Lablab planted 28 days after the maize.

Table 2.9 Maize yield components as influenced by lablab planting date and density at Syferkuil during 2002/03 growing season.

Density (plants m^{-1})	Weight per cob (g)		# cops/p		#Rows per cob		#Kernels per cob		Seed mass (g)	
	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	kg ha^{-1}									
0	102a	102 b	1.0 b	1.0 b	19 c	19 b	288 b	288 c	33 b	33 a
2	78 b	140 a	2.2 a	3.5 a	23 a	25 a	504 a	661 a	51 a	33 a
4	64 b	140 a	2.0 a	3.7 a	21 b	24 a	417 a	552 b	53 a	32 a
6	60 c	79 c	1.0 b	1.2 b	15 d	15 c	265 b	273 c	27 c	25 b
8	55 c	51 d	1.2 b	1.4 b	13 e	16 c	254 b	253 c	25 c	22 c
10	55 c	38 d	0.6 b	1.0 b	12 e	13 d	254 b	253 c	24 c	21 c
LSD ($P \leq 0.05$)	13.9	13.9	2.7	2.7	1.4	1.4	86	86	2.89	2.89
Date	**	**	**	**	**	**	**	**	**	**
Density	**	**	**	**	**	**	**	**	**	**
Interaction	**	**	**	**	*	*	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP =Lablab planted 28 days after the maize.

Table 2.10. Flowering and maturity of maize at Dalmada and Syferkuil during 2001/02 growing season.

Density (Plants m^{-1})	Dalmada				Syferkuil			
	Flowering		Maturity		Flowering		Maturity	
	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	……………………………………………………# days				………………………………………………………………			
0	64	64	110	109	73	73	115	115
2	65	64	111	110	70	72	118	112
4	68	64	111	109	71	71	120	115
6	70	64	108	109	66	69	120	112
8	68	64	110	110	62	70	118	114
	-	-	-	-	-	-	-	-

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting, 28 DAP =Lablab planted 28 days after the maize.

Table 2.11 Flowering and maturity of maize at Dalmada and Syferkuil during the 2002/03 growing season.

Density (Plants m^{-1})	Dalmada				Syferkuil			
	Flowering		Maturity		Flowering		Maturity	
	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	# days							
0	66	66	118	118	65	65	110	110
2	66	69	113	125	65	61	111	116
4	62	70	109	122	67	65	121	108
6	75	71	122	124	65	71	120	112
8	74	71	124	117	67	75	120	108
10	75	70	126	124	75	75	128	109

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting, 28 DAP =Lablab planted 28 days after the maize.

Table 2. 12 Maize plant height (m) at Dalmada and Syferkuil during 2001/02 as influenced by planting date and density of lablab.

	Height (m)			
Density (Plants m^{-1})	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
	....	.... m.	....	....
0	1.90 a	1.90 a	2.74 a	2.74 a
2	1.71 b	1.77 b	2.73 a	2.73 a
4	1.72 b	1.65 c	2.77 a	2.65 a
6	1.59 c	1.80 d	1.34 b	2.56 a
8	1.37 d	1.69 e	1.04 b	2.66 a
10	-	-	-	-
LSD ($P \leq 0.05$)	0.082	0.082	0.36	0.36
Date	**	**	n.s	n.s
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP =Lablab planted 28 days after the maize.

Table 2.13. Maize plant height (m) at Dalmada and Syferkuil during 2002/03 as influenced by planting date and density of Lablab.

Density (Plants m^{-1})	Height (m)			
	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
	........................m	....	....	....
0	1.17 b	1.17 a	2.49 a	2.49 a
2	2.27 a	1.15 a	2.32 a	2.65 a
4	2.07 a	1.08 a	2.06 a	2.53 a
6	0.62 c	1.14 a	1.11 b	2.59 a
8	0.48 c	1.18 a	0.91 b	1.82 a
10	0.38 c	1.12 a	0.81 b	2.24 a
LSD ($P \leq 0.05$)	0.45	0.45	0.66	0.66
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; * $p < 0.05$; ns = not statistically significant SIM= Simultaneous planting. 28 DAP =Lablab planted 28 days after the maize.

Table 2.14 The impact of lablab planting date and density on maize mortality at Dalmada and Syferkuil during 2001/02 growing season.

Density (Plants m^{-1})	Mortality			
	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
	# maize plants killed			
0	2.83 d	2.83 a	3.0 c	3.0 a
2	9.33 c	5.67 a	11.3 b	7.00 a
4	13.00 c	8.33 a	15.0 b	8.33 a
6	28.00 a	8.67 a	30.5 a	8.00 a
8	21.67 b	5.67 a	35.0 a	4.57 a
10	-	-	-	-
LSD ($P \leq 0.05$)	5.49	5.49	4.47	4.47
Density	**	**	**	**
Date	**	Ns	**	n.s
Interaction	*	*	*	*

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP =Lablab planted 28 days after the maize.

Table 2. 15 The impact of lablab planting date and density on maize mortality at Dalmada and Syferkuil during 2002/03 growing season.

Density (Plants m^{-1})	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
	# maize plants killed			
0	7.9 b	7.9 a	4.0 c	4.0 a
2	5.3 b	5.0 a	6.0 c	6.0 a
4	8.3 b	7.0 a	7.0 c	8.0 a
6	10.0 b	10 a	20 b	6.0 a
8	21.3 a	9.5 a	22 b	8.0 a
10	25.5 a	7.0 a	35 a	8.2 a
LSD (P≤ 0.05)	7.37	7.37	3.6	3.6
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	*	*

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM= Simultaneous planting, 28 DAP =Lablab planted 28 days after the maize.

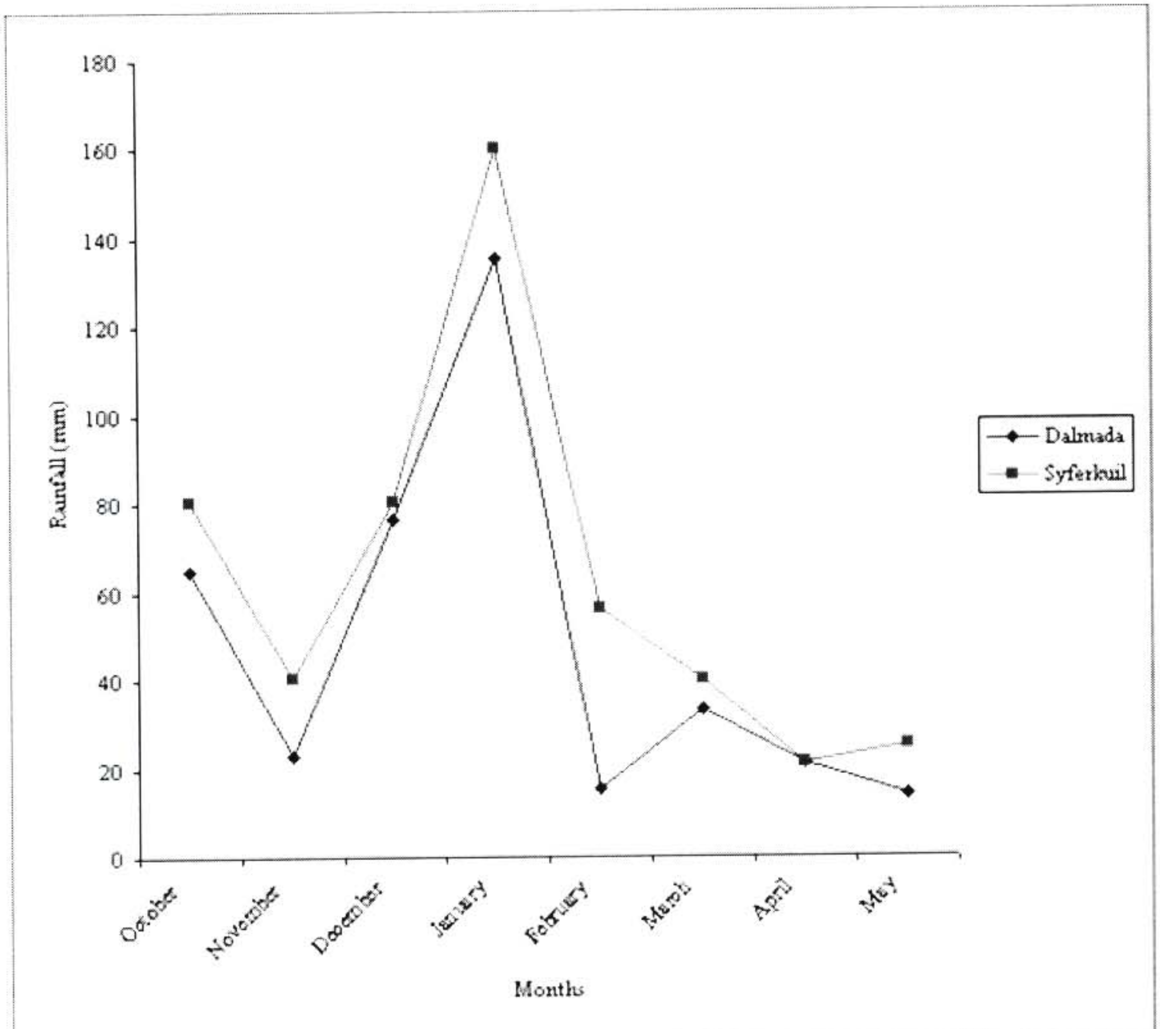

Fig 2.1 Total rainfall at Dalmada and Syferkuil during 2001/02 growing season

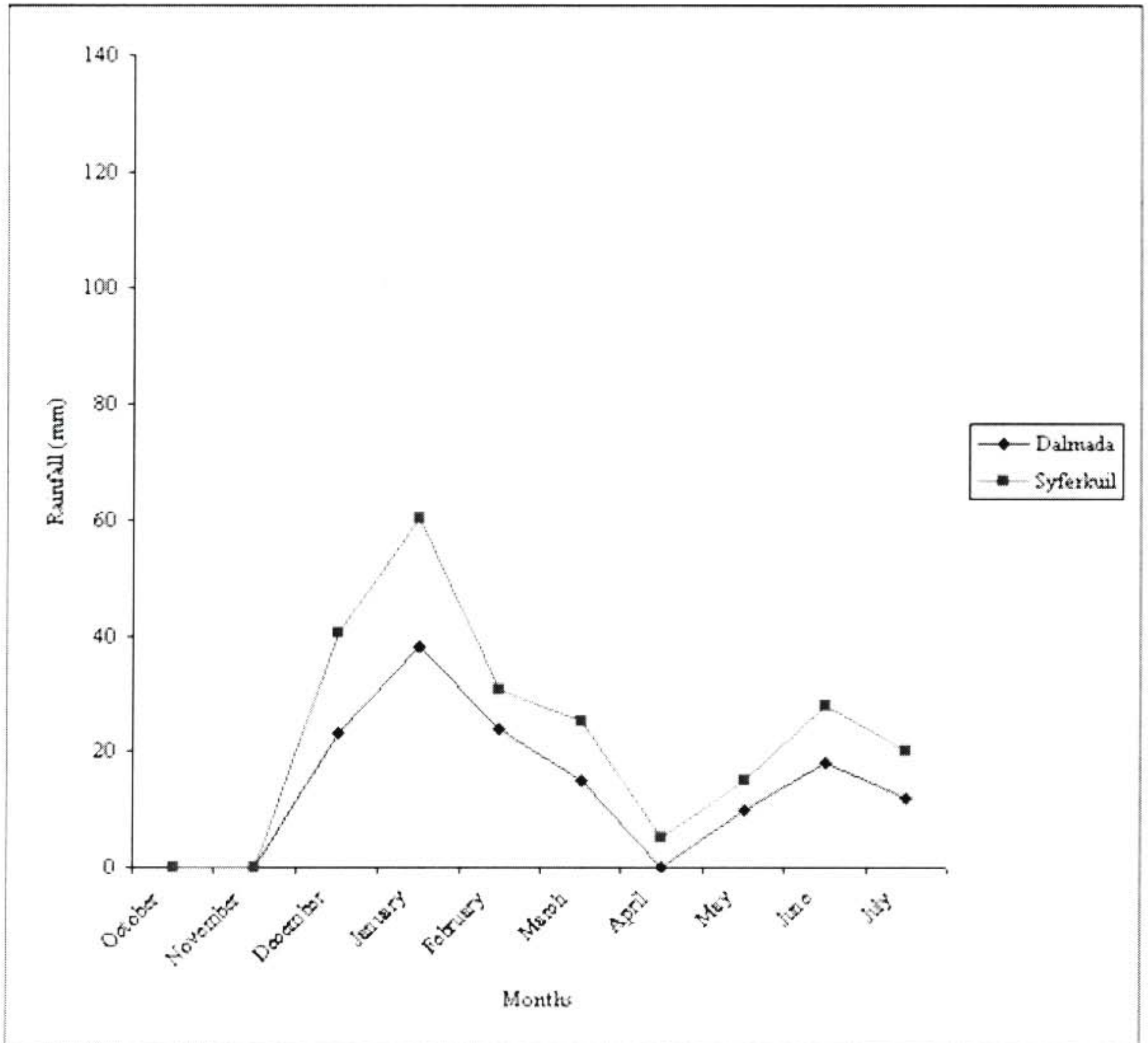

Fig 2.2 Total rainfall at Dalmada and Syferkuil during 2002/03 growing season

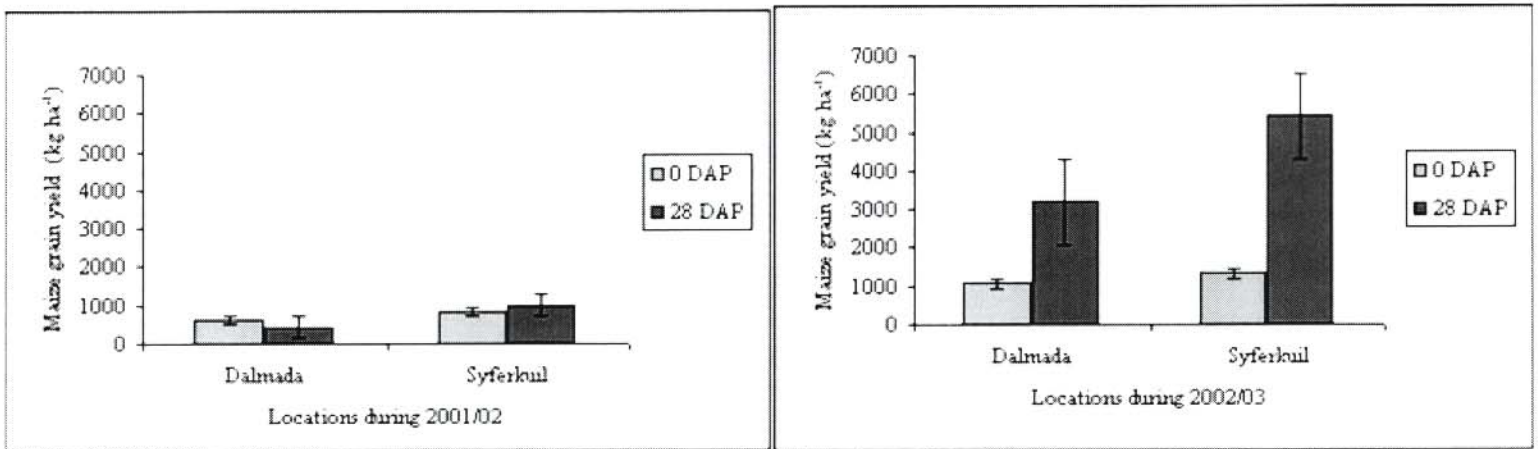

Fig 2.3 Maize grain yield as influenced by planting date at Dalmada and Syferkuil during 2001/02 and 2002/03 growing season

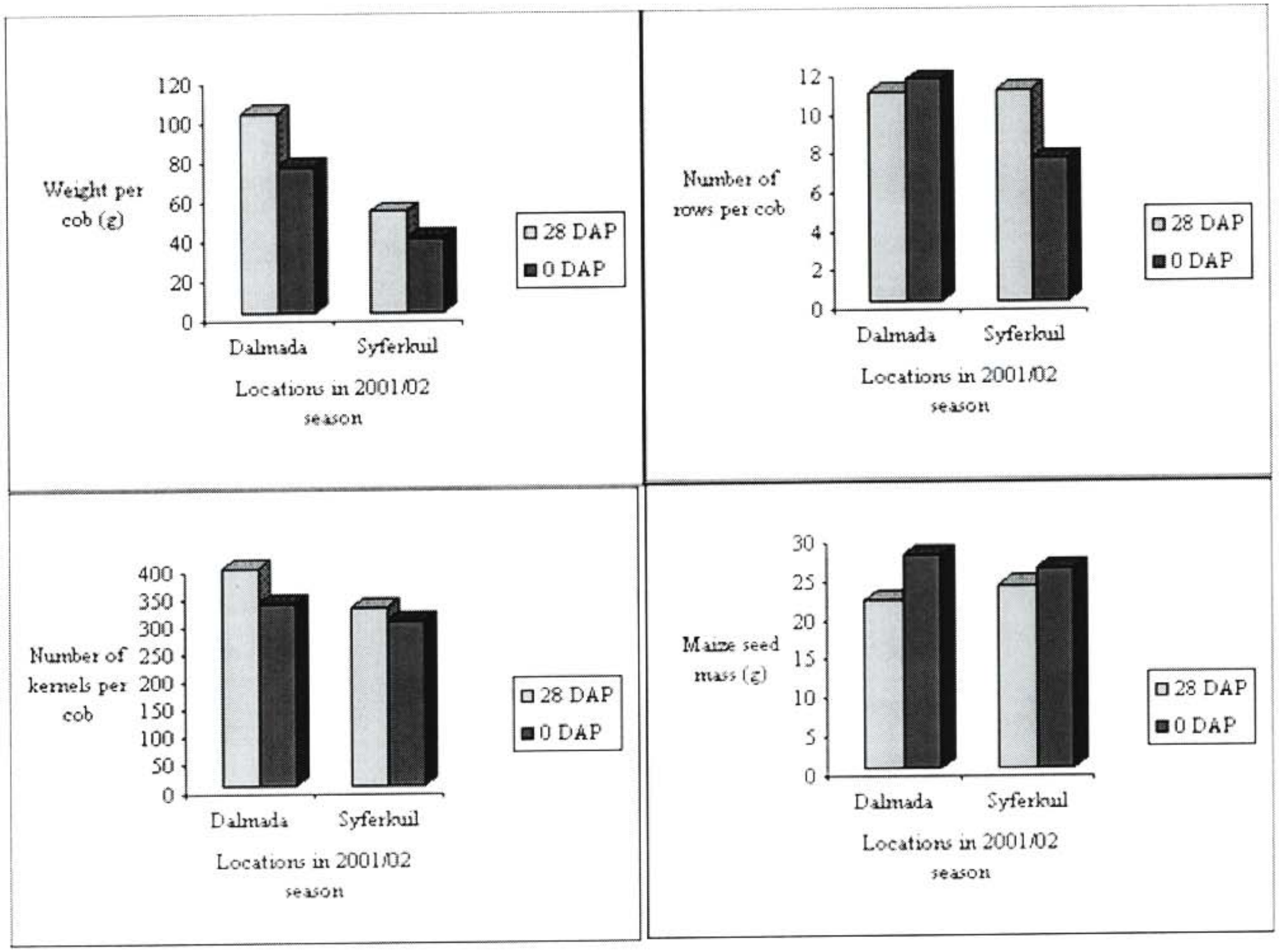

Fig 2.4 Maize yield components at Dalmada and Syferkuil as influenced by lablab planting date during 2001/02 growing season

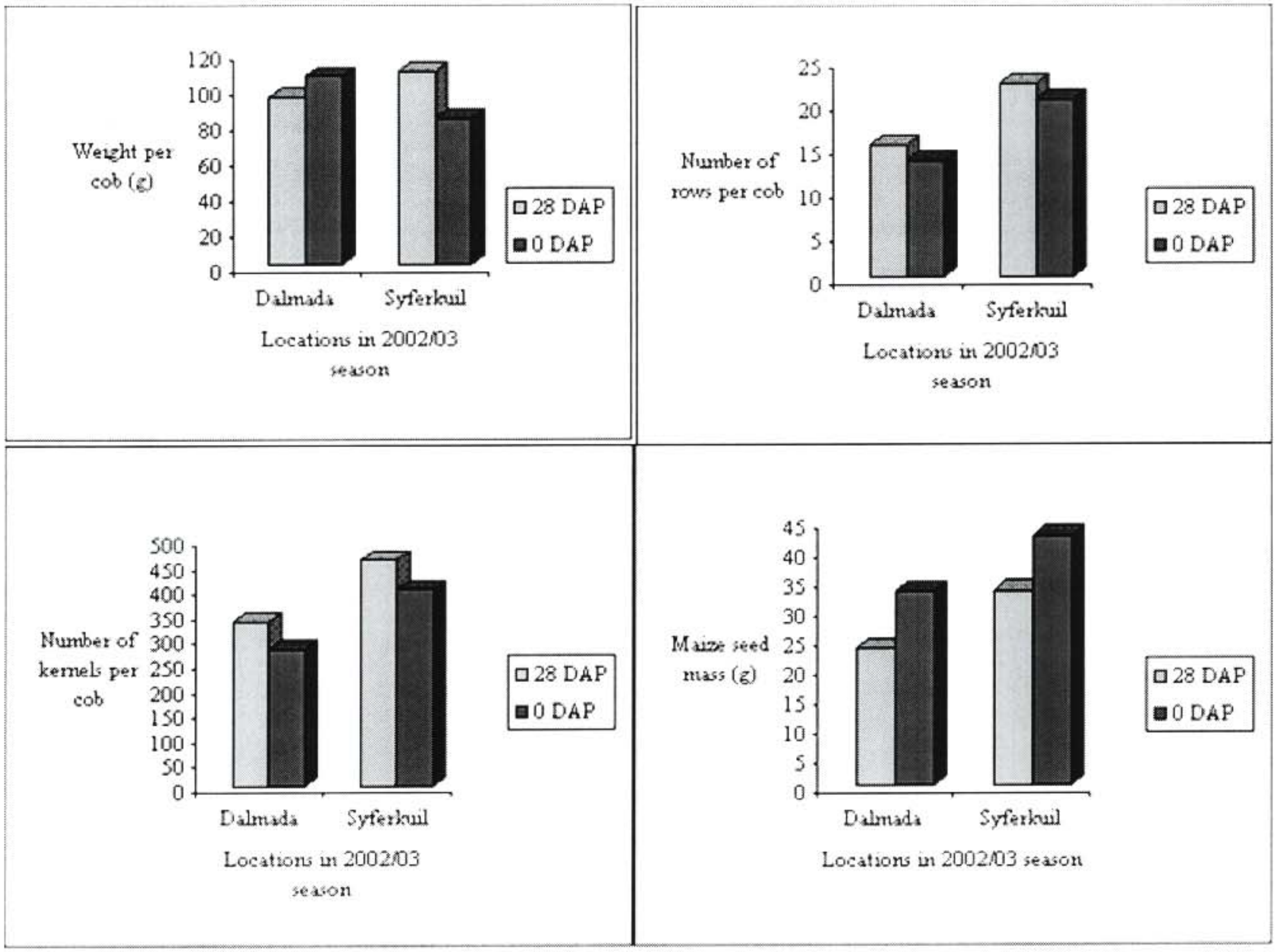

Fig 2.5 Maize yield components at Dalmada and Syferkuil as influenced by lablab planting date During 2002/03 growing season.

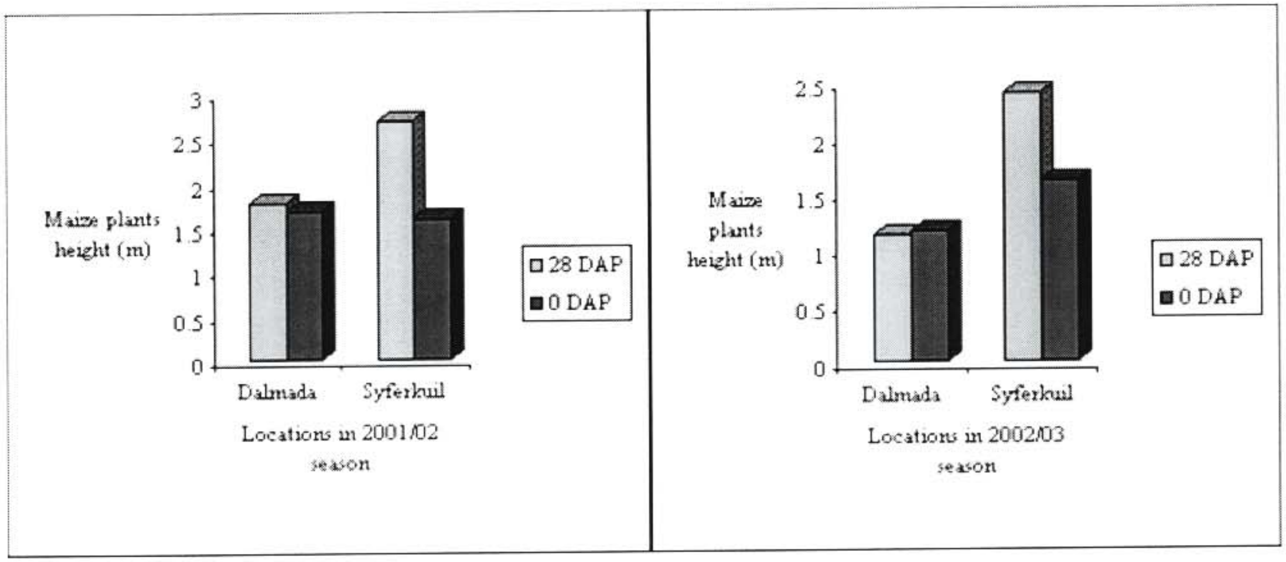

Fig 2.6 Lablab planting date effect on maize plant height (m) at Dalmada and Syferkuil at 2001/02 and 2002/03 growing seasons.

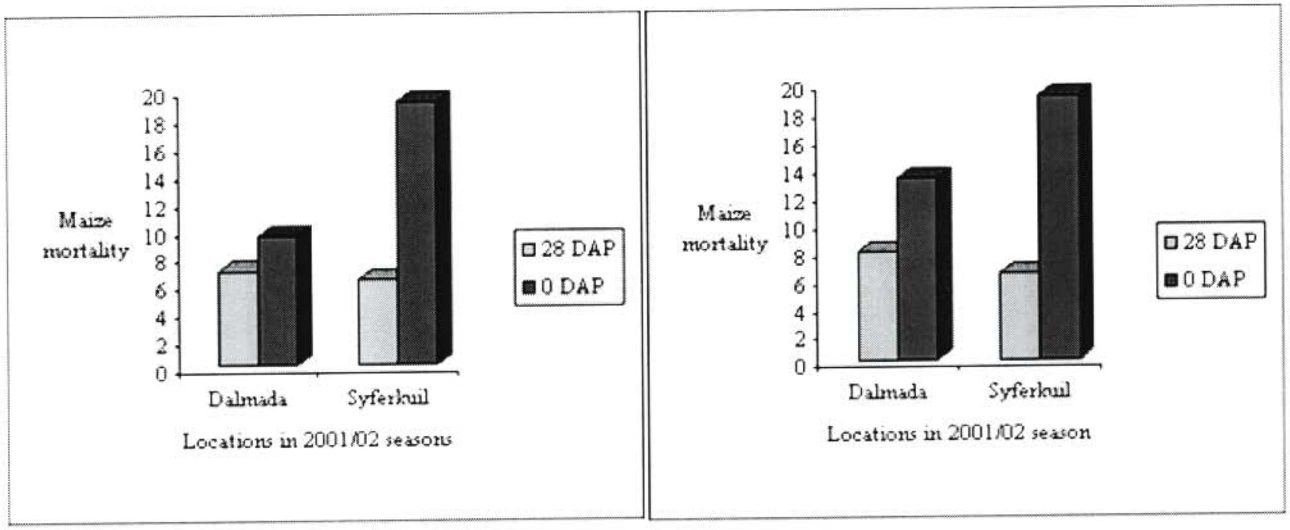

Fig 2.7 Maize mortality at Dalmada and Syferkuil as effected by planting date during 2001/02 and 2002/02 growing seasons.

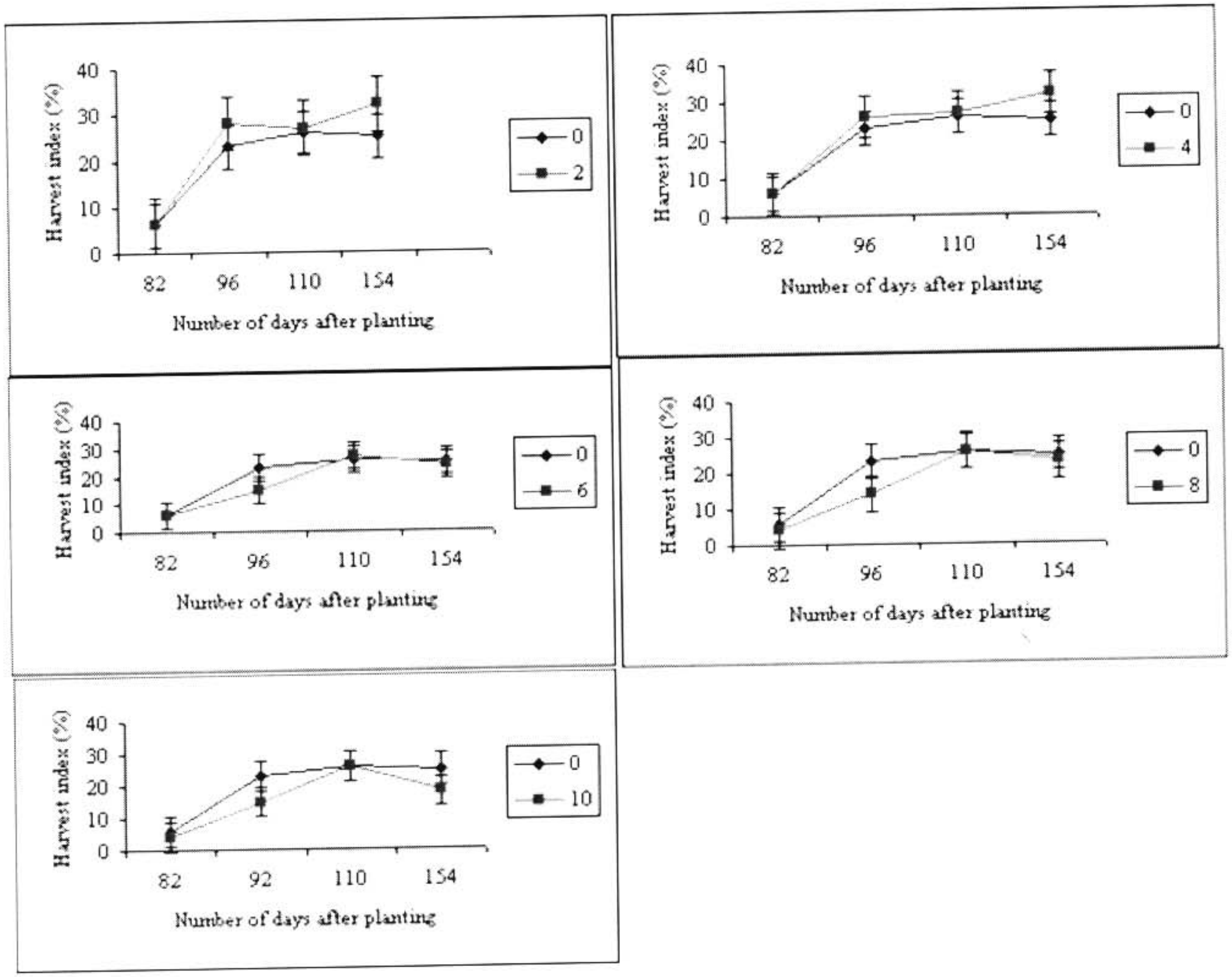

Fig 2.8 Lablab planting density effect on rate of maize harvest index at Dalmada in 2002/03

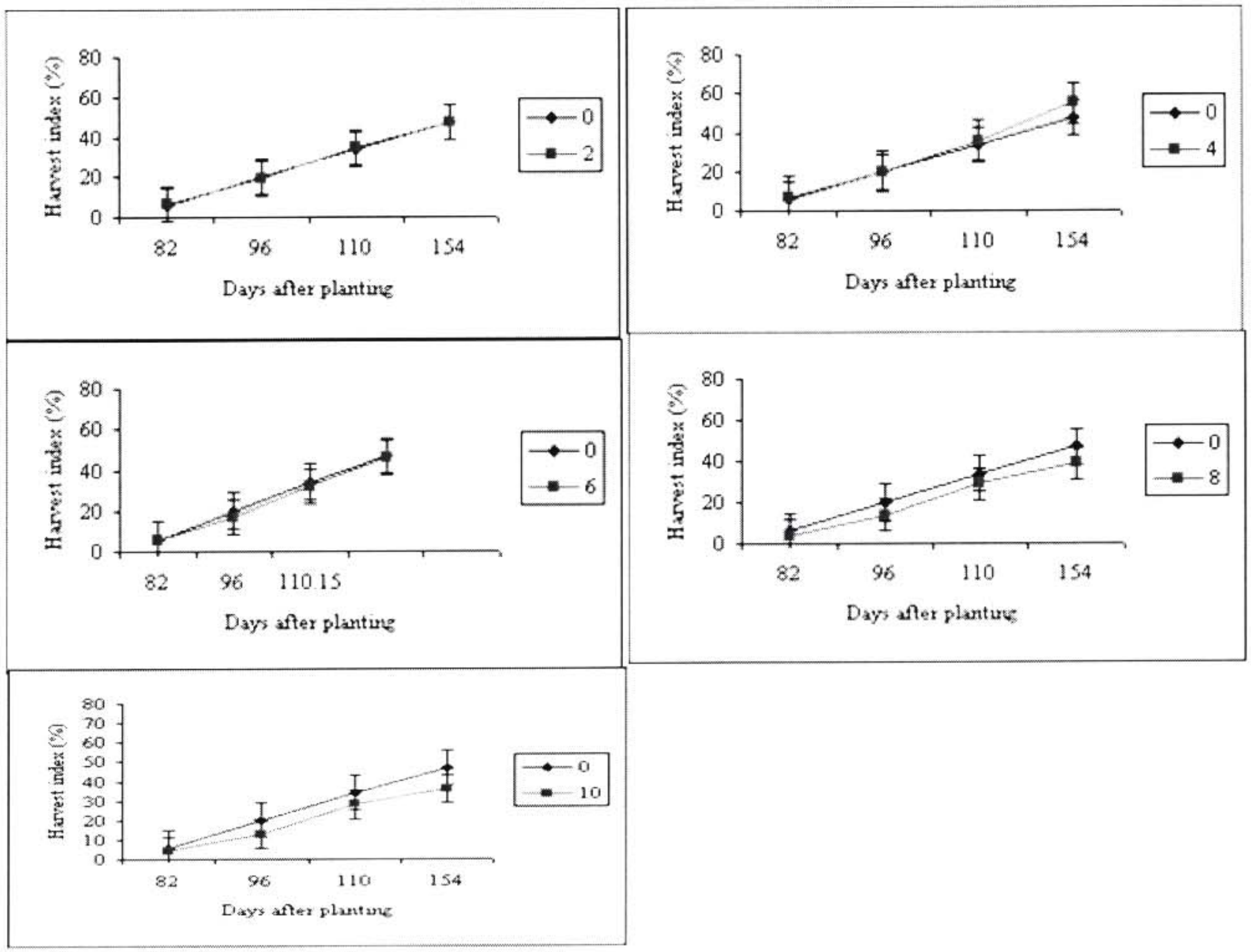

Fig 2.9 Lablab densities effect on rate of maize harvest index at Syferkuil during 2002/03

CHAPTER 3

MAIZE-LABLAB INTERCROP SYSTEM: THE INFLUENCE OF LABLAB PLANTING DATE AND DENSITY ON DRY MATTER ACCUMULATION AND SOIL RESOURCES DYNAMICS

INTRODUCTION

Plant growth is determined by dry matter production in crops. Higher biomass accumulation results from high rate of photosynthesis. The ability of crops to efficiently intercept photosynthetically active radiation (PAR) will determine rate of dry matter production in crops (Biscoe and Gallegher, 1977; Monteith, 1992). It is often claimed that in cereal-legume intercropping system, cereal shades the legume at high densities and causes reduced growth and yield of the companion legume. While there is increasing evidence that this can be so, it must be appreciated that intercropping is an infinitely variable and often complex system in which the adverse effects can occur.

Over many years researchers in cereal-legume believed that cereal-legume intercropping increases dry matter production and grain yield more than their respective monocultures. Several factors including the population of component crops, soil nitrogen (N) status, and genotype of component cereal is important to ensure greater efficiency of intercrops (Fujita and Ofosu-Budu, 1992). However, no benefits of intercropping have been reported in some cases (Cenpukdee and Fukai, 1992). Greater amount of intercropped biomass, compared to their respective sole has been reported by (Rerkasem and Rerkasem, 1998; Van Kessel and Roskoski, 1988; Fujita *et al.*, 1990). Higher biomass production is frequently due to the enhanced growth of the component non-legume.

Major limiting factors affecting the relative competitiveness of component crops in cereal-legume intercropping have been conjected to be light (Wahua and Miller, 1978) or soil resources (Willey and Osiru, 1972). It is always postulated that taller cereals shade the legume and causes reduction in growth and yield of the legume at high densities.

Higher production of intercrop systems compared to the sole cropping may be attributed to better light utilization by a crop canopy composed of plants with different foliage distributions (Willey and Rao, 1981; Willey, 1979). Overall mixture densities and the relative proportions of component crops are important in determining yields and production efficiency of cereal-legume intercrop systems (Willey and Osiru, 1972; Lakhani, 1976). Productivity and efficiency appear to be determined by the more aggressive crop, usually the cereal.

Andrews (1972) pointed out that differential sowing improves productivity and minimizes competition for growth limiting factors in intercropping. Willey (1979) suggested that sowing component crops at different times ensures full utilization of growth factors because crops occupy the land throughout the growing season. Francis *et al*., (1982) did not find any advantage of later planting over simultaneous sowing of maize and cowpea.

It is often believed that the amount of N-fixed by the legume component in legume-cereal intercropping system depends on several factors such as species, plant morphology, density of component crops, type of management and competitive abilities of the component crops (Ofori and Stern, 1987).

Fujita and Ofusu-Budu (1992) postulated that there is variation in BNF activity among legumes with both mono and intercrop system. It was observed that BNF in climbing bean was unaffected by intercropping with maize (Graham and Rosas, 1978a; Francis, 1986).

Plant density has also been reported to influence N_2- fixation, but total N_2 –fixation activity on an area basis appeared less variable. Some findings by Van Kessel and Roskoski (1988) indicated that plant density has little effect on quantity of N derived from dinitrogen fixation. Generally higher nitrogen benefit of an intercropping system relative to the sole culture is major contributor to the advantage of the former.

The objectives of this study were to

(i) determine the affect of intercropping maize with different lablab planting density and date on biomass accumulation.

(ii) assess the effect of intercropping on nodulation and nitrogen uptake by component crops.

(iii) measure the rate of leaf chlorophyll production and senescence of sole and intercropped maize in the system.

MATERIALS AND METHOD

The experimental set up was similar to what is reported in chapter 2. Dry matter samples of the crops were taken periodically from a $1.8m^2$ area of each experimental unit throughout the growing season. Maize plants were cut at ground level to determine the aboveground dry matter. In lablab, whole plant samples were taken during dry matter determination. The plants were dug carefully to maintain their root system and then immersed in water to remove bound soil. The samples were carefully washed under a tap on a sieve to recover all loose roots. Both maize and lablab plant materials were oven-dried at 60 ^{0}C to constant weight.

Chlorophyll content

Chlorophyll content of maize was periodically determined from the upper youngest fully expanded leaf of five individual plants in an experimental units using Minolta chlorophyll meter SPAD- 502 in 2001/02 growing season. In 2002/03, the readings were taken from upper younger fully expanded leaves and the lower leaves as well.

Nodulation

Prior to planting the lablab seed were inoculated with Bradyrhizobium inoculant suitable for lablab. Nodule number and mass from sampled number of plants from each experimental unit were recorded after each dry matter sampling.

Nitrogen yield

Nitrogen accumulation by plants was measured through tissue analysis of ground dry matter samples using the semi-micro Kjeldhal procedure. Dry matter samples of stover at maize maturity were harvested and analyzed for crude protein.

Soil moisture content

Soil water dynamics during a growing season was assessed gravimetrically at specific intervals through the growing season. Soil samples were collected from 0-15cm, and 15-30cm.

$$\text{Gravimetric soil moisture} = \frac{\text{Weight of wet soil- dry weight of the soil}}{\text{Dry weight of the soil}} \quad \text{(Scott, 2000)}$$

Soil samples were collected within 14 days interval, if it did not rain. Wet weight was measured immediately after sampling. The samples were oven dried at 110^0C until constant weight for the dry weight determination.

Data analysis

Data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS). Differences between treatment means were separated using the least significant difference (LSD) procedure (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Shoot biomass accumulation

Maize

Planting dates of lablab significantly ($P \leq 0.05$) influenced maize shoot dry matter accumulation at all sampling dates at both Dalmada and Syferkuil during the two seasons of experimentation. Lablab planting density also influenced maize shoot dry matter accumulation at all sampling dates and seasons at the two locations except at 45 and 59 DAP at Syferkuil in 2001/02 (Tables 3.1 and 3.2). The interaction effect between planting density and dates was not significant at the two locations and seasons. Pooled across planting date, shoots accumulation showed a decreased pattern as the number of lablab bean per meter increased at both locations. The decreased shoot biomass accumulation with increasing density could have resulted in the observed lower grain yields at higher densities. However, maize shoot dry matter accumulation was generally not affected by intercropping compared to sole crop when maize was planted together with lablab at 2 and 4 plants m^{-1} length in the 2001/02 at Dalmada (Table 3.2). At Syferkuil, this effect was observed only at 45 DAP, beyond which the shoot dry matter was reduced significantly compared to the sole crops. In 2002/03, yield of maize, intercropped at 2 and 4 plants m^{-1} were similar to the sole crop at all sampling dates at the two locations, except at 54 DAP at Dalmada, where shoot dry matter accumulation intercropped with 4 plants m^{-1} lablab was reduced by 31% compared to the sole maize (Table 3.5). On average, maize shoot dry matter was reduced at all sampling dates when planted simultaneous with lablab, especially at the later stage of growth (Tables 3.1 and 3.2).

Lablab

In the 2001/02 growing season, statistical differences in seasonal lablab shoot accumulation resulting from planting date, density and interaction (Tables 3.3 and 3.4) were observed at all location, except at Syferkuil at 88 DAP were interaction was not significant. Lablab shoot dry matter accumulation was significantly influence by planting dates, density and the interaction effect of in 2002/03 at Dalmada (Table 3.5). At Syferkuil in the 2002/03, lablab shoot dry matter accumulation was influenced by planting date and interaction throughout the growing stages, except at 88 DAP (Table 3.6). Shoot dry matter accumulation of later planted lablab was consistently reduced in the intercropping system with maize compared to those simultaneously planted with maize at both locations in the two growing seasons (Figs 3.1-3.4).

The reduction in shoot biomass accumulation may be attributed to reduced light, and soil resources. Competition also seems to be higher at higher densities of lablab, causing reduction in shoot accumulation as explained by (Willey and Osiru, 1972; Lakhani, 1976). When lablab was planted later than maize, lablab shoot accumulation was reduced compared to simultaneously planted lablab.

Reduction in lablab shoot accumulation in late plantings might be due to the fact, that by the time lablab was planted maize had already establish excessive root system to mine water and nutrients, resulting in maize being a better competitor (Vandemeer 1992; Davis and Garcia, 1987). When lablab was simultaneously planted with maize, a general increase in shoot biomass accumulation of the legume was observed at all locations and seasons as compared to later planted. The increased in lablab shoot biomass accumulation can be attributed to the simultaneous use of soil resources and better utilization by a crop canopy composed of plants with different foliage distributions (Willey and Rao, 1981; Willey, 1979).

The increased lablab shoot biomass accumulation over density is contrary to the dry matter accumulation pattern of maize, where increase in lablab density resulted in decrease maize shoot biomass accumulation. The above-mentioned results however agree with evident by (Fujita and Ofusu-Budu, 1992) that planting density influences efficiency of maize-cereal intercropping.

Maize stem and leaf fractions

At 54 DAP maize leaf contributed more to total above-ground dry matter accumulation than stem, whereas at 68 and 82 DAP maize stem contributed more at Dalmada and Syferkuil in the 2002/03 growing season (Figs 3.5 and 3.6). Increase in plant population increased main stem length and growth, and decreased all other plant components.

Maize leaf dry matter fraction was similar to maize intercropped at 2, and 4 plants of lablab at both locations under simultaneously planting. At Dalmada maize stem fraction of maize intercropped at 2 plants of lablab m^{-1} was similar to sole maize when pooled over planting date, except at 82 DAP where it was higher (Fig 3.5)

Maize stem fraction at Syferkuil was similar for sole maize and maize intercropped with at 2 or 4 lablab plants m^{-1} except at 82 DAP (Fig 3.6). Maize intercropped stem and leaf biomass at 2 and 4 plants m^{-1} was higher as compare to maize at 6, 8, and 10 plants of lablab. Similar to total maize dry matter accumulation, stem fraction decreased at maize simultaneously intercropped with 6 to 10 plants of lablab m^{-1}. The above finding support findings by Andrews (1972), Willey (1979), and Francis and Ofori (1992),

Stover yield

Lablab planting date, density, and interaction had a significant effect on maize stover yield at Dalmada and Syferkuil in the 2001/02 and 2002/03, except at Syferkuil where interaction was not significant (Tables 3.7 and 3.8).

When maize and lablab were planted simultaneously, maize intercropped at 2 and 4 plants m^{-1} had same stover yield as the sole maize at Dalmada and Syferkuil, except at Dalmada in 2001/02, where yield at density 4 was 29 % lower than that of the sole crops (Tables 3.7 and 3.8). However in 2002/03 the stover yields of simultaneously intercropped maize was lower than the sole crop at both locations. In the 2002/03, maize intercropped with 2 and 4 lablab plants m^{-1}, produced low stover yield than sole maize at both locations (Tables 3.7 and 3.8).

When lablab was intercropped 28 DAP, stover yield of intercropped maize at 2 and 4 plants m^{-1} were similar to the sole crop yield at both locations and in the 2 seasons. Maize intercropped with 6, 8 and 10 plants of lablab m^{-1} on the other produced lower maize stover yield than sole maize. Comparing the effect of planting date, maize stover yield was reduced by 4% and 15% when planted simultaneously with maize in 2001/02 and 2002/03 respectively (Figs. 3.7 and 3.8).

On average maize stover yield increased by 3.3 and 0.95 % yield when lablab was planted 28 days later compared to the simultaneously planted at Dalmada and Syferkuil respectively in 2001/02 (Figs. 3.7 and 3.8). In 2002/03 maize stover yield at both locations was on average increased when lablab was planted later (Figs 3.7 and 3.8).

Nodulation

There were inconsistence nodulation in the 2001/02 and 2002/03 growing seasons at both locations. This might be due to low amount of rainfall received for growing seasons, poor soil nutrients and high temperatures (Figs. 2.1, and 2.2,).

Soil at Syferkuil is characterized by high soil N, which is said to be detrimental to biological nitrogen fixation (Table 2.1). Differently from Syferkuil soil at Dalmada got high Mg content, which prohibits the release of other nutrients (Table 2.1). Poor nodulation in both growing seasons may also be attributed to low levels of Bradyrhizobium in the soil and several other factors including high roots competition.

Nitrogen yield

At Dalmada, nitrogen yield was similar for sole maize, and maize intercropped at 2 and 4 plants of lablab m^{-1}, whereas maize intercropped with lablab from 6 to 10 plants of lablab were lower than the sole (Fig. 3.9). Nitrogen yield was higher at Syferkuil as compared to Dalmada in the 2002/03 growing season (Fig 3.9). The lack of significantly higher N yield in the intercrop relative to the sole crop is an indication that no nitrogen benefit to the intercropped maize was obtained during the growing season (Ofori and Stern, 1987). Nitrogen benefit of legume to cereals is reported to occur in the following season and not in the current season (Patra *et al*., 1986; Stern, 1993: Weil and Mc-Fadden, 1991; Woolley and Davis, 1991; Brophy *et al.*, 1989; Eaglesham *et al*., 1981; Ta *et al*., 1989, Scarie *et al*., 1981, Singh, 1983). The lack of nitrogen benefit could also be the result of poor legume nodulation, which could lead to increased competition of soil nitrogen by the component crops.

Chlorophyll content

Chlorophyll content of the youngest fully expanded leaf showed a consistent decline under both sole crop and intercropped systems and also in the simultaneous and the later planted intercrops from 68 DAP at Dalmada and Syferkuil in 2001 (Figs 3.10 to 3.13). 68 DAP corresponded to the onset of the reproductive stage, suggesting an increased mobilization of nitrogen from the leaves, presumably to reproductive structures. Comparing the leaf chlorophyll of sole (0 plants m^{-1}) and the different intercropped densities, there was also consistently higher chlorophyll in the sole crop than the simultaneously planted intercrops during the early reproductive stages but the reverse occurred later on in the season at both locations during the same season (Figs 3.10 and 3.11). However, in the later planted intercrops, the difference was very minimal throughout the season (Figs. 3.12 and 3.13).

During the 2002/03 growing season, chlorophyll content of the youngest fully expanded leaf generally increased from 54 DAP in the sole and the intercrops until 96 DAP and declined afterwards in the simultaneously planted intercrop at Dalmada (Fig. 3.14). The chlorophyll content at Syferkuil, however remained relatively unchanged between 54 and 103 DAP for both the sole crops and the intercrops (Fig. 3.15). In the later-planted intercrops, the pattern of chlorophyll production was similar to the simultaneously planted system at both locations; where chlorophyll content generally peaked at 96 DAP at Dalmada and at Syferkuil, remained unchanged over the period. The lack of decline in chlorophyll reading at Syferkuil is an indication that, nitrogen was not a limiting factor at this location. The initial soil content indicated relatively higher nitrogen levels at Syferkuil compared to Dalmada in both growing seasons (Table 2.1).

Rate of leaf senescence

Chlorophyll content of the lower leaf of maize over a period was measured only in the 2002/03 growing season and this was used to assess rate of leaf senescence in the sole and intercrops systems. There was a general decrease in chlorophyll readings from 54 DAP to 103 DAP in the sole and all the intercrops at both locations (Figs. 3.17-3.21). The readings were between 45 and 55 at 54 DAP, but by 103 DAP they were between 0 and 15. Reduced chlorophyll reading is an indication of breakdown of chlorophyll, which is usually the result of age or shading. In this study, chlorophyll readings of the intercrops, which could lead to lower interception of photosynthetically active radiation by maize, did not differ from the sole crops. Chlorophyll breakdown of maize older leaf could therefore be attributed to age, rather than shading.

Gravimetric soil moisture content

Gravimetric soil moisture content of top and sub soils, recorded during the reproductive stage of intercropped maize in the 2001/02, were generally higher when lablab was planted 28 days after maize than the simultaneously planted system at Dalmada and Syferkuil (Figs. 3.22 and 3.23). The difference increased at densities beyond 4 plants per meter at 84 DAP, but by 98 DAP, this observation was not evident. There was also a general higher soil moisture content in the later planted intercropping systems than in the sole crops (0 plants m^{-1}) at both locations during the same season.

During the 2002/03 growing season, gravimetric soil moisture appeared inconsistence at Dalmada though, the later planted intercropping system showed a tendency of higher moisture content at either density 4 or 6 compared to the simultaneous plantings (Fig 3.24). However, at Syferkuil, the intercropping involving late planting of lablab consistently showed higher soil moisture content relative to the simultaneously planted system, with the difference increasing as density increases (Fig 3.25). Comparing moisture content of the intercrops and the sole crops, gravimetric moisture content of the intercrop beyond four plants per meter were generally higher than that of the sole crops in the later-planted intercrop, whereas in the simultaneously-planted system, the moisture content was either similar or reduced in the intercrops. The higher soil moisture content in the later planted intercropping system is an indication of good cover of the soil by the legume, coupled with low competition and better moisture conservation when the legume is planted late. Maize growth and grain yield in the later planted intercrop were superior to that of the simultaneous planting and this observation could be partly explained by the observed increased moisture in the former. Thus, the facilitative production principle proposed by Vandermeer (1992) could be operative in this intercropping system. The principle indicates that higher growth or yield could be obtained in an intercropping system compared to the sole crop if a component crop, positively modify the growing environment for the benefit of the other crop.

CONCLUSIONS

Maize dry matter accumulation at intercrops densities of two and four were generally similar to the sole crop, beyond this density, a general decrease in dry matter was observed. Dry matter accumulation of lablab on the other hand increased with increasing density of the legume. Even though nodulation was not consistence in growing seasons at all locations, nitrogen yield at 68 DAP produced similar N for sole maize and maize intercropped at 2 and 4 plants per meter length at Dalmada and Syferkuil in 2002/03. Maize leaf chlorophyll content was high when lablab was planted 28 days after planting maize than the simultaneously planting. A general increase of maize leaf N was also observed in maize intercropped at 2 and 4 plants per meter as compared to the soil maize. Senescence of lower leaves occurred at 103 and 117 DAP for first and second leaves respectively. Soil moisture content increases with planting density at both locations and in all growing seasons at 98 and 112 DAP. The soil moisture content was also higher when lablab was planted 28 days after planting maize as compared to simultaneous planting of lablab and maize. Therefore, lablab 2 and 4 plants m^{-1} can be incorporated in predominantly maize culture in the Limpopo province.

STUDY TABLES AND FIGURES

Table 3. 1 Total maize dry matter accumulation at different growth stages as influenced by lablab planting density at Dalmada and Syferkuil during 2001/02 growing season.

	Dalmada				Syferkuil			
Density	41 DAP	55 DAP	88 DAP	102 DAP	45 DAP	59 DAP	83 DAP	102 DAP
Plants m^{-1}	....	....	....	$kgha^{-1}$	....	....	....	
0	858 a	2712 a	5752 a	8488 c	623 a	892 a	4784 a	7878 a
2	788 a	2958 a	5508 a	9780 a	562 ab	782 b	3626 b	6091 b
4	710 ab	2655 a	4037 b	9314 b	633 a	774 bc	3560 bc	5688 b
6	579 bc	1672 b	3347 bc	4590 d	456 bc	737 c	2890 cd	4026 c
8	534 c	1619 b	2737 c	3292 e	425 c	683 c	2447 d	3563 c
Date	**	**	**	**	n.s	n.s	**	*
Density	**	**	**	**	**	**	**	**
Interaction	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= p< 0.01;*=P< 0.05; ns = not statistically significant.
DAP= Days after planting.

Table 3.2 Total maize dry matter accumulation at different growth stages as influenced by lablab planting density at Dalmada and Syferkuil during 2002/03 growing season.

	Dalmada			Syferkuil		
Density (Plants m^{-1})	54 DAP	68 DAP	82 DAP	54 DAP	68 DAP	82 DAP
	....kg ha^{-1}	....	....	....	....	....
0	1001 a	2616 a	3911 a	2630 a	3956 a	9673 a
2	954 a	2512 a	3896 a	2587 a	3999 a	9077 a
4	690 b	2537 a	3853 a	2475 a	3839 a	9188 a
6	615 bc	1734 b	2703 b	1187 b	2546 b	7205 b
8	596 bc	1584 bc	2686 b	1173 b	2431 b	7058 bc
10	581 c	1336 c	2296 b	1028 b	2307 b	6482 c
Date	**	**	**	**	**	**
Density	*s	*	*	**	**	**
Interaction	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$;*=$P< 0.05$; ns = not statistically significant.
DAP= Days after planting.

Table 3.3 Total dry matter accumulation of lablab at Dalmada as effected by lablab planting date and density during 2001/02 growing season.

	41 DAP		55 DAP		88 DAP		102 DAP	
Density	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
Plants m^{-1}	....	....	....	.kg ha^{-1}.	....	....	....	....
2	150.0 b	29.2 a	358 d	42.5 a	667 c	45 a	671 c	34 a
4	170.8 b	29.7 a	441 c	59.0 a	511 c	63 a	562 c	53 a
6	225.0 a	29.7 a	608 b	44.4 a	1020 b	48 a	1196 b	34 a
8	212.5 a	37.5 a	754 a	44.0 a	1375 a	48 a	1546 a	24 a
10	-	-	-	-	-	-	-	-
Date	**	**	**	**	**	**	**	**
Density	**	**	**	**	**	**	**	**
Interaction	**	**	**	**	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 3.4 Total dry matter accumulation of lablab at Syferkuil as effected by lablab planting date and density during 2001/02 growing season.

	41 DAP		55 DAP		88 DAP		102 DAP	
Density	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
Plants m^{-1}	....	....	....	kg ha^{-1}	....	....	....	....
2	182 b	48 a	621 c	60 a	3480 d	170 a	5589 c	239 a
4	117 c	50 a	575 c	68 a	4018 c	204 a	6093 b	308 a
6	200 b	69 a	746 b	85 a	4411 b	256 a	6514 b	331 a
8	256 a	78 a	921 a	92 a	4784 a	296 a	7421 a	357 a
10	-	-	-	-	-	-	-	-
LSD (≤0.05)	29	29	102	102	238	238	475	475
Date	**	**	**	**	**	**	**	**
Density	**	**	**	**	**	**	**	**
Interaction	**	**	**	**	Ns	ns	*	*

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 3. 5 Total dry matter accumulation of lablab at Dalmada as affected by planting date and density during 2002/03 growing season.

	54 DAP		68 DAP		82 DAP	
Density (Plants m^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	....kg ha^{-1}..					
2	177 c	25 c	709 b	62 b	798 d	94 b
4	208 c	35 bc	744 b	59 b	922 c	90 b
6	259 b	52 bc	770 b	90 a	916 c	115 b
8	263 b	60 b	852 a	108 a	998 b	140 b
10	298 a	101a	925 a	125 a	1392 a	190 a
Date	**	**	**	**	**	**
Density	**	**	**	**	**	**
Interaction	**	**	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 3.6 Total dry matter accumulation of lablab at Syferkuil as effected by planting density and date during 2002/03 growing season.

	54 DAP		68 DAP		82 DAP	
Density (Plants m^{-1})	SIM	28 DAP	SIM	28 DAP	28 DAP	SIM DAP
	....	....	kgha^{-1}	....	....	....
2	213 c	60 c	539 c	84 a	893 d	189 b
4	244 c	70 c	635 c	96 a	1016 c	185 b
6	294 b	87 b	845 b	142 a	1011 c	210 b
8	299 a	96 b	873 a	152 a	1093 b	236 b
10	333 a	137 a	1001a	172 a	1485 a	286 a
Date	**	**	**	**	**	**
Density	**	**	**	**	**	**
Interaction	**	**	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table 3.7 Maize stover yield as influenced by lablab planting date and density at Dalmada and Syferkuil during 2002/03 growing season.

Density (Plants m^{-1})	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
	....	....	kg ha^{-1}	
0	9061 a	9061 a	9939 a	9939 a
2	8533 a	8638 a	9081 a	9408 a
4	7279 b	8447 a	8844 a	8848 a
6	6879 b	6887 b	6776 b	6901 b
8	6806 b	6809 b	6276 b	6210 b
10	-	-	-	-
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; ns = not statistically significant. SIM= Simultaneous planting.
28 DAP= Lablab planted 28 days after the maize

Table 3.8 Maize stover yield as influenced by lablab planting date and density at Dalmada and Syferkuil during 2002/03 growing season.

Density	Dalmada		Syferkuil	
	SIM	28 DAP	SIM	28 DAP
Plants m^{-1}	....	....	....kg ha^{-1}....	....
0	8856 a	8856 a	6238 a	6238 a
2	7011 b	8478 a	4023 b	6338 a
4	6308 b	7701 a	3898 b	7177 a
6	5012 c	5994 b	2949 c	5100 b
8	5457 c	5731 b	2605 c	4246 b
10	4729 c	5606 b	2119 c	4521 b
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting.
28 DAP= Lablab planted 28 days after the maize.

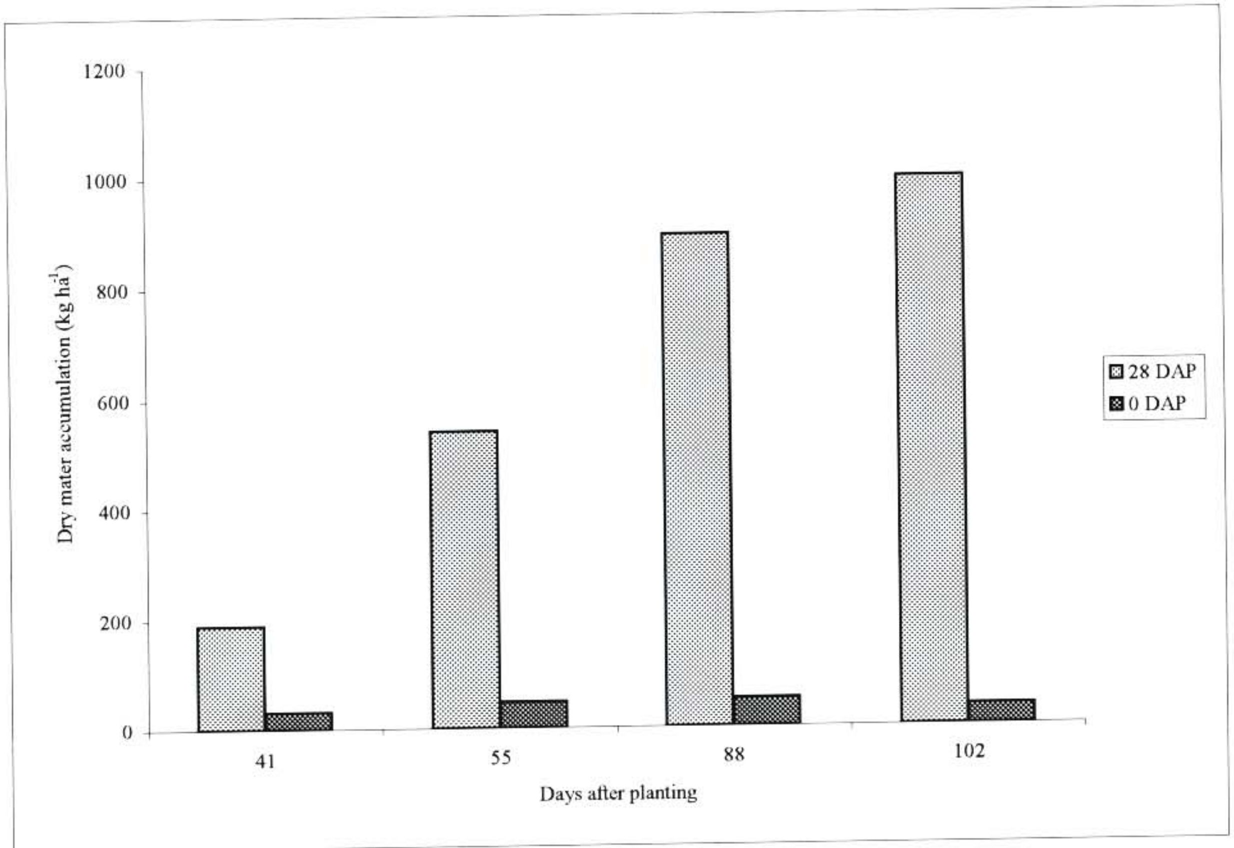

Fig 3.1 Lablab dry matter accumulation at Dalmada during 2001/02 season

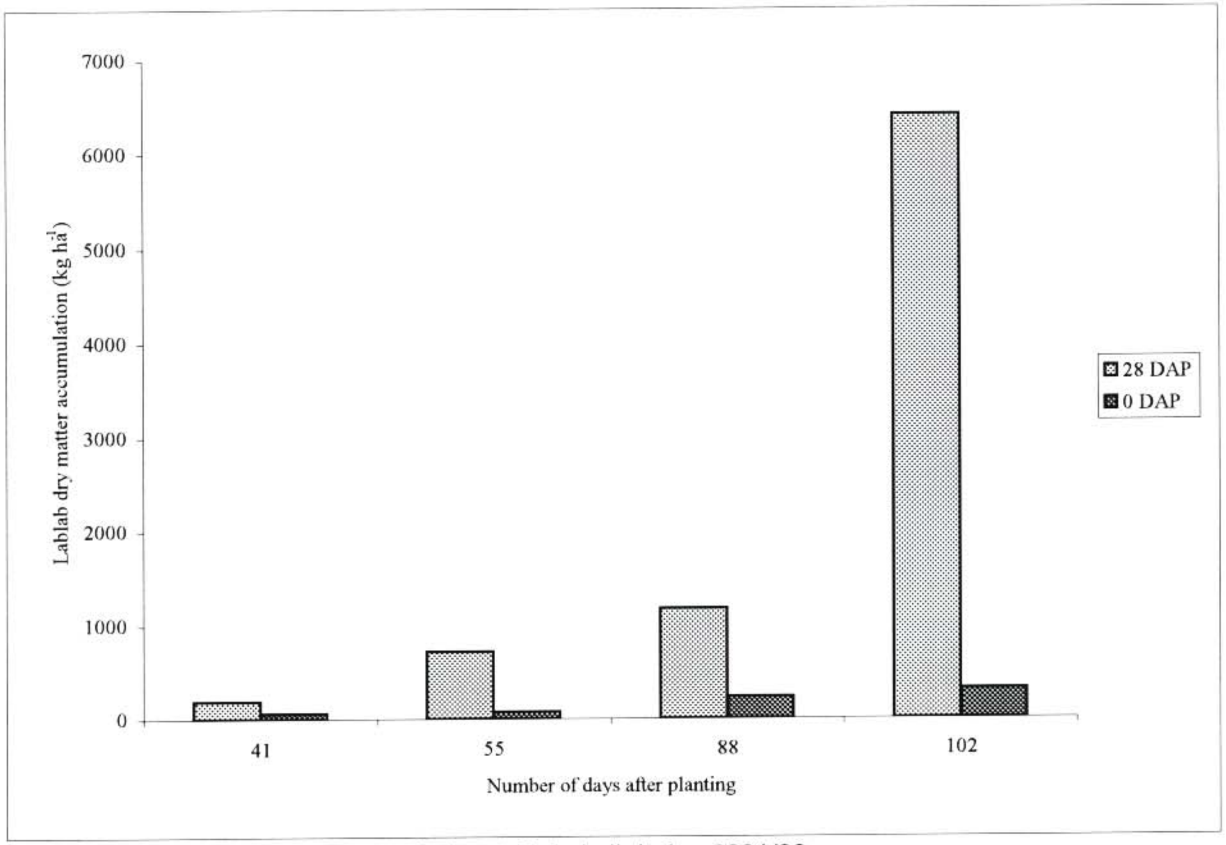

Fig 3.2 Lablab dry matter accumulation at Syferkuil during 2001/02 season

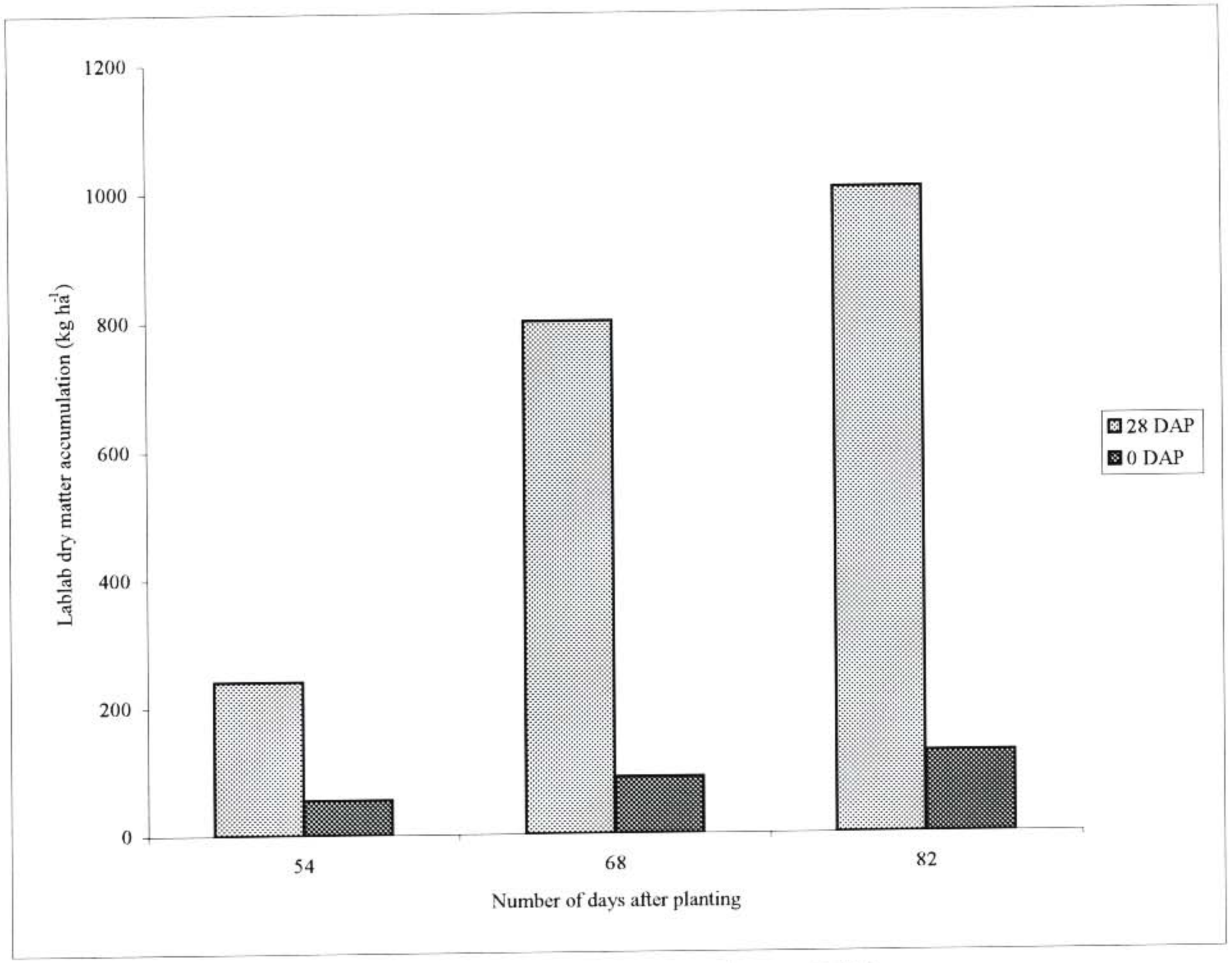

Fig 3.3 Lablab dry matter accumulation at Dalmada during 2002/03 season

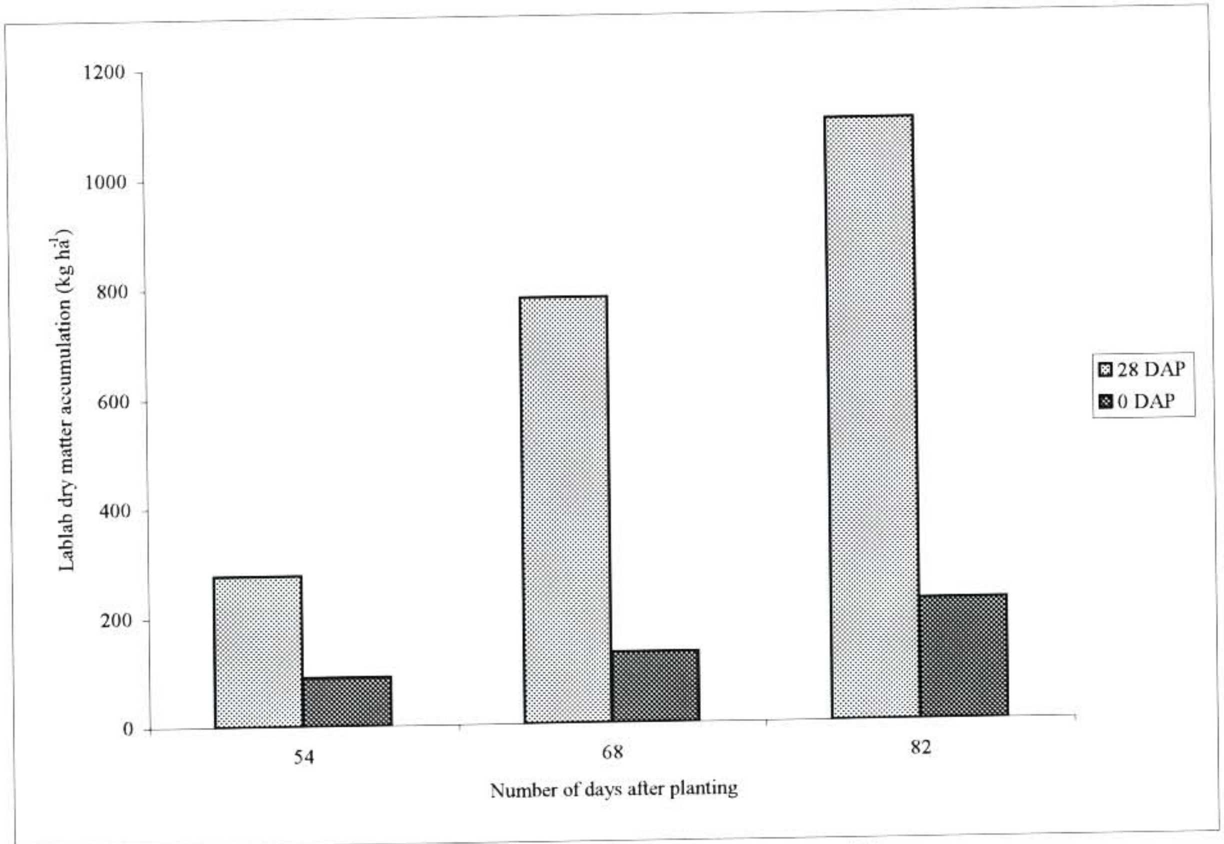

Fig 3.4 Lablab dry matter accumulation at Syferkuil during 2002/03 season

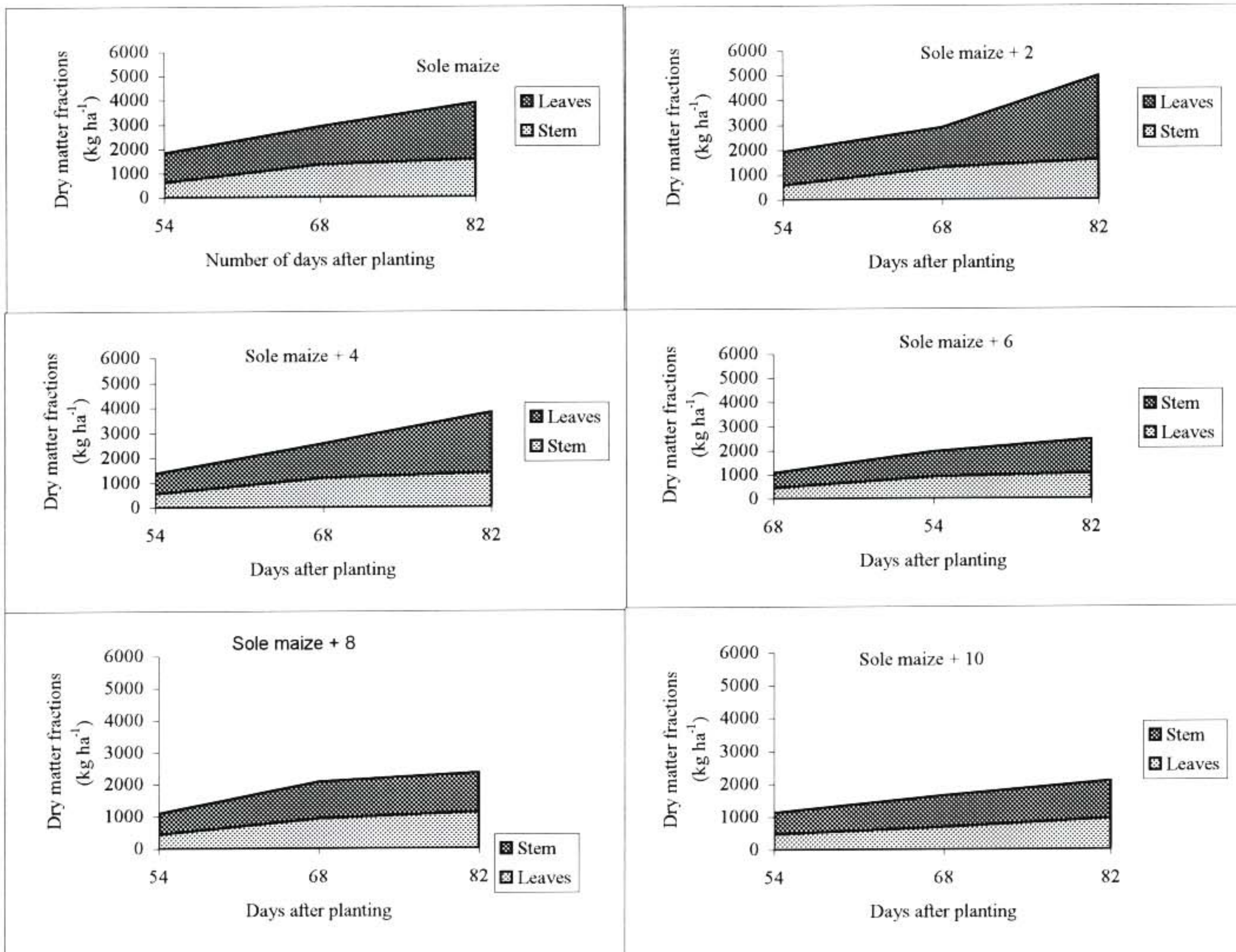

Fig 3.5 Maize stem and leaves fractions of dry matter accumulation at Dalmada during 2002/03

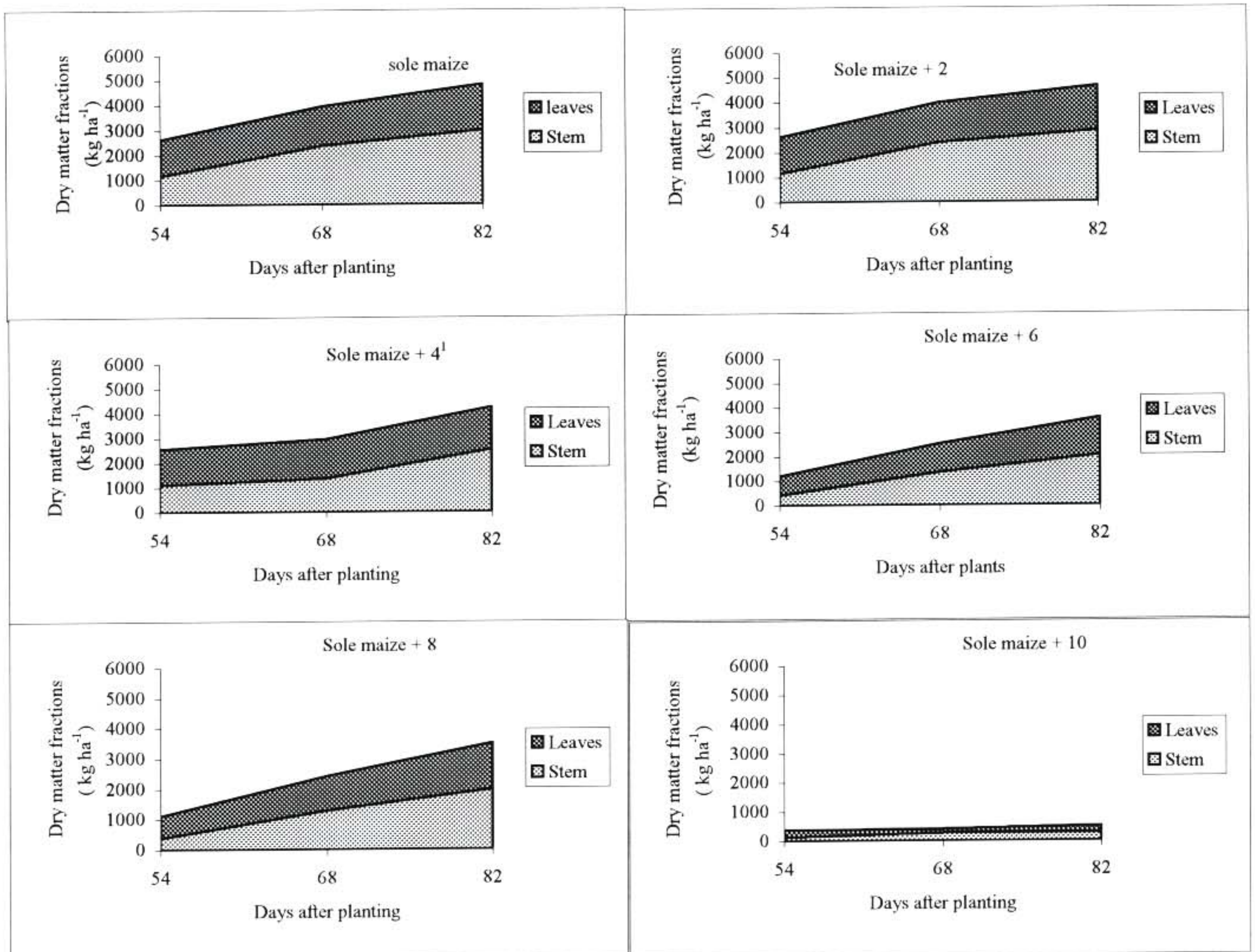

Fig 3.6 Maize stem and leaves fractions of dry matter accumulation at Syferkuil during 2001/02

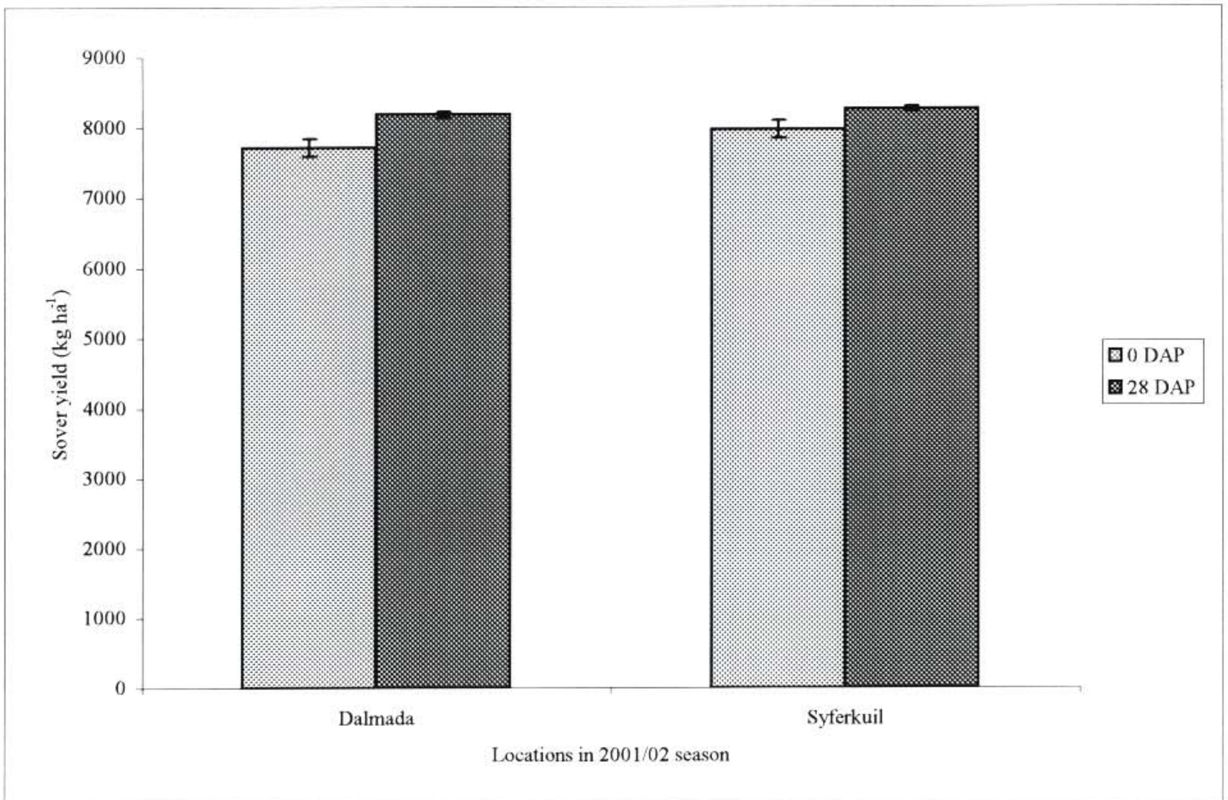

Fig 3.7 Maize Stover yield as influenced by lablab planting date at Dalmada and Syferkuil during 2001/02

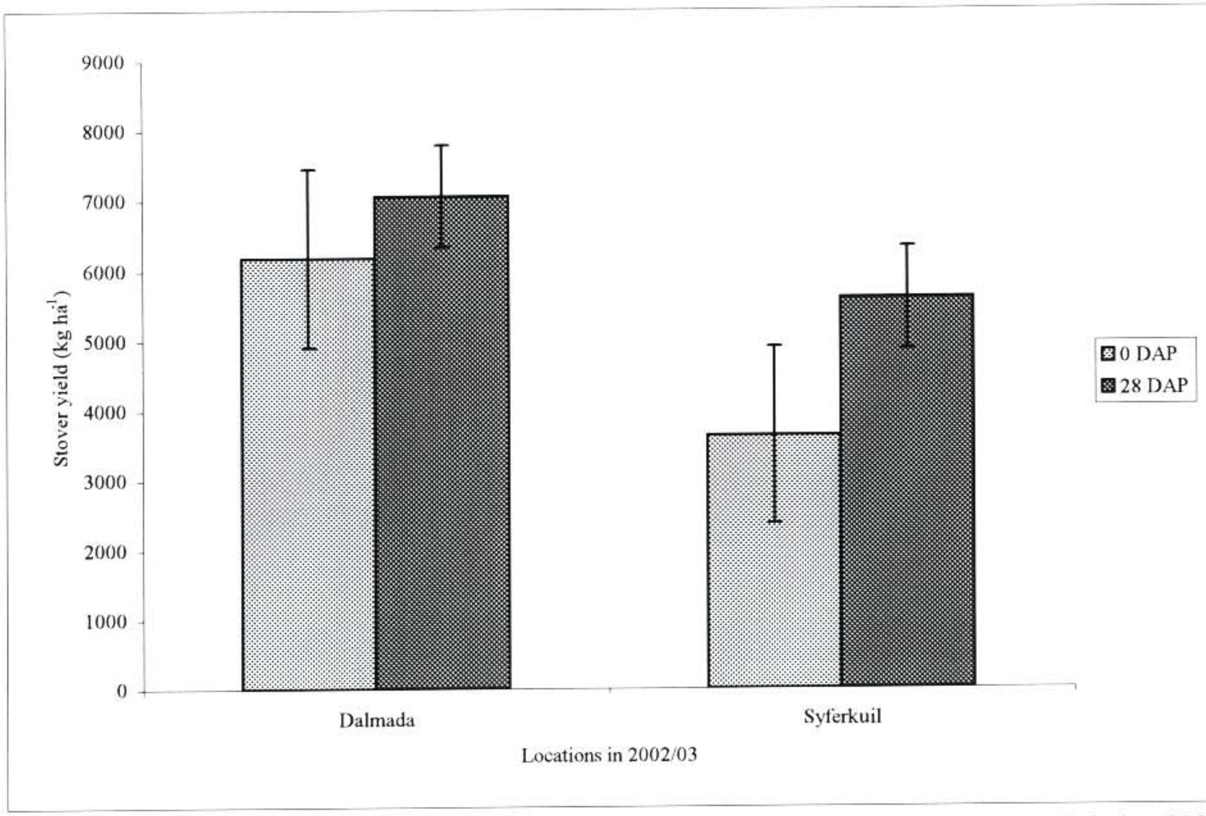

Fig 3.8 Maize stover yield as influenced by lablab planting date at Dalmada and Syferkuil during 2002/03

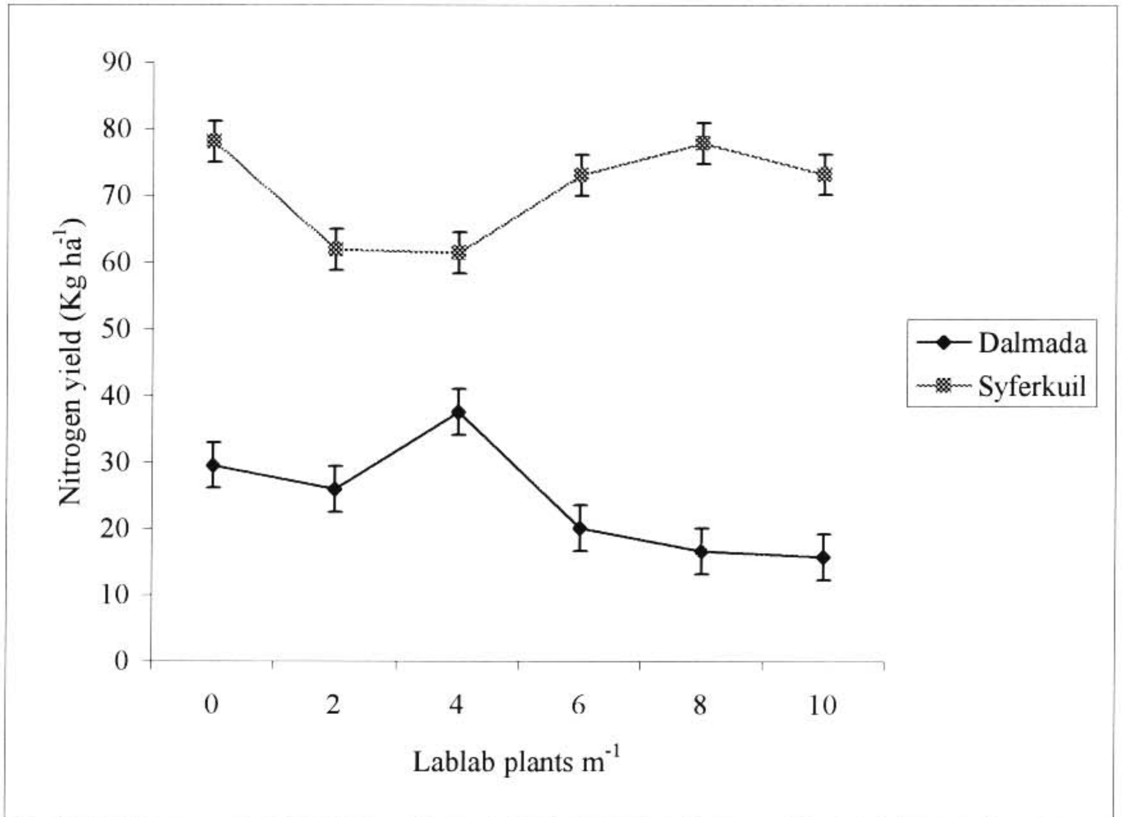

Fig 3.9 Nitrogen yield at Dalmada and Syferkuil as influenced by lablab planting den:
during 2002/03 growing season

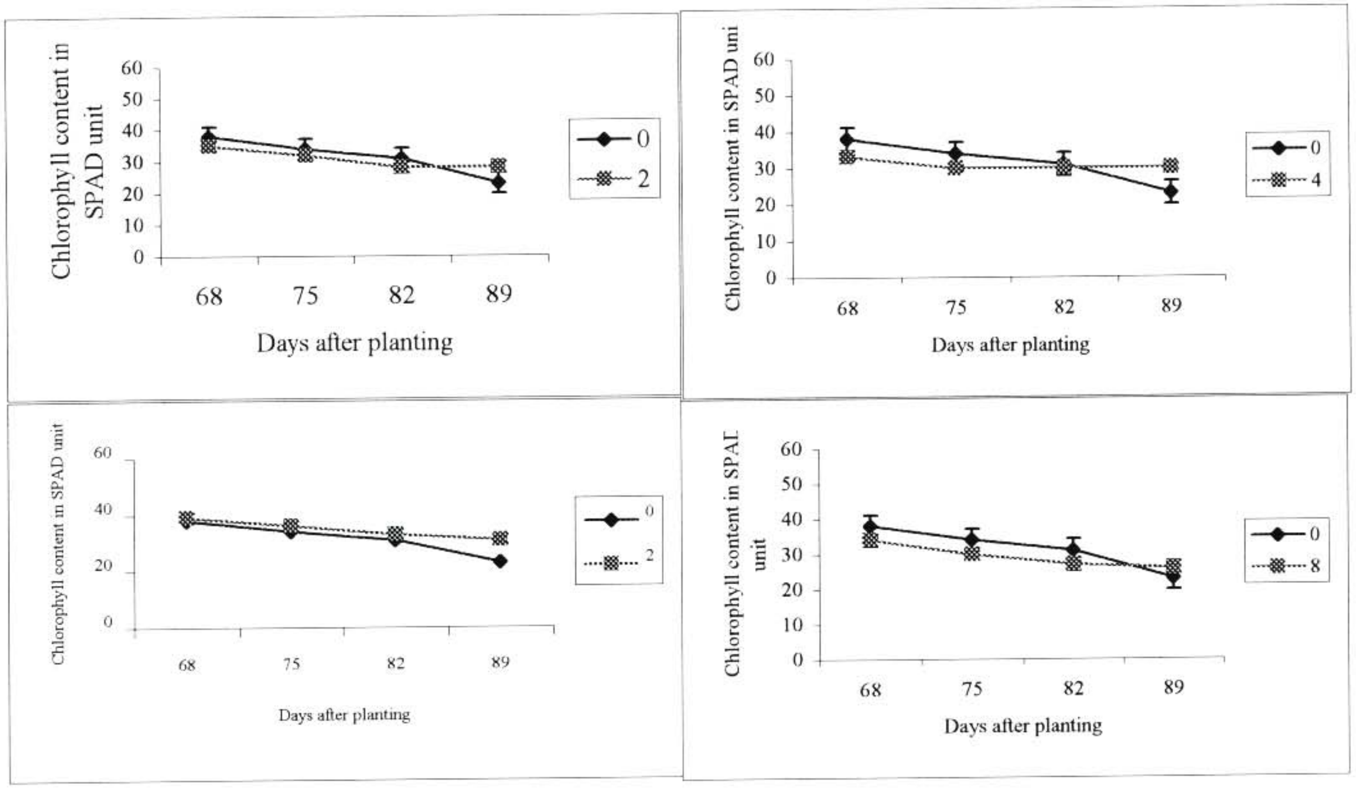

Figure 3.10 Maize upper leaf chlorophyll content at Dalmada during 2001/2002 growing season when maize was simultaneously planted with lablab.

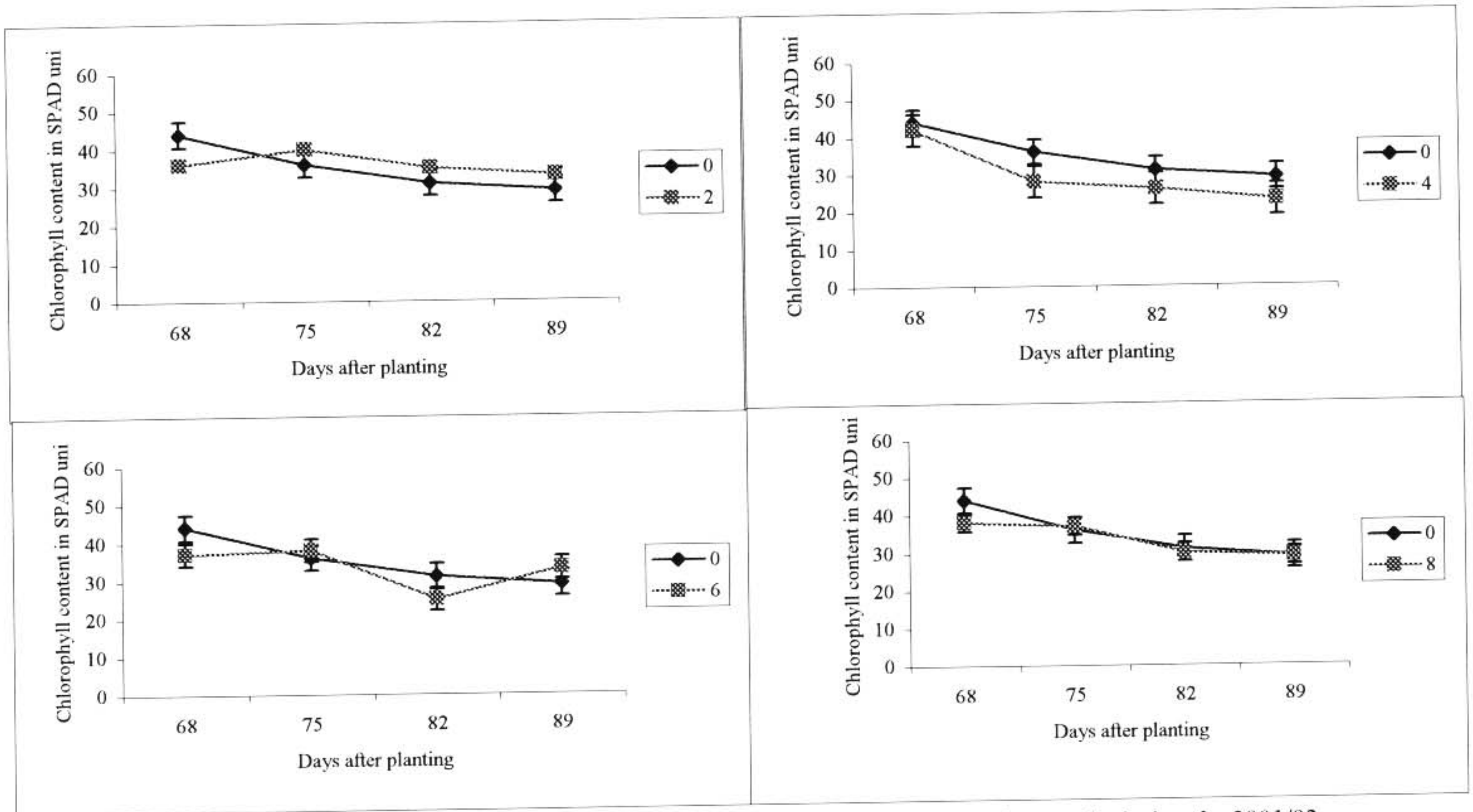

Figure 3.11 Maize upper leaf chlorophyll content at Syferkuil when lablab was planted simultaneously during the 2001/02

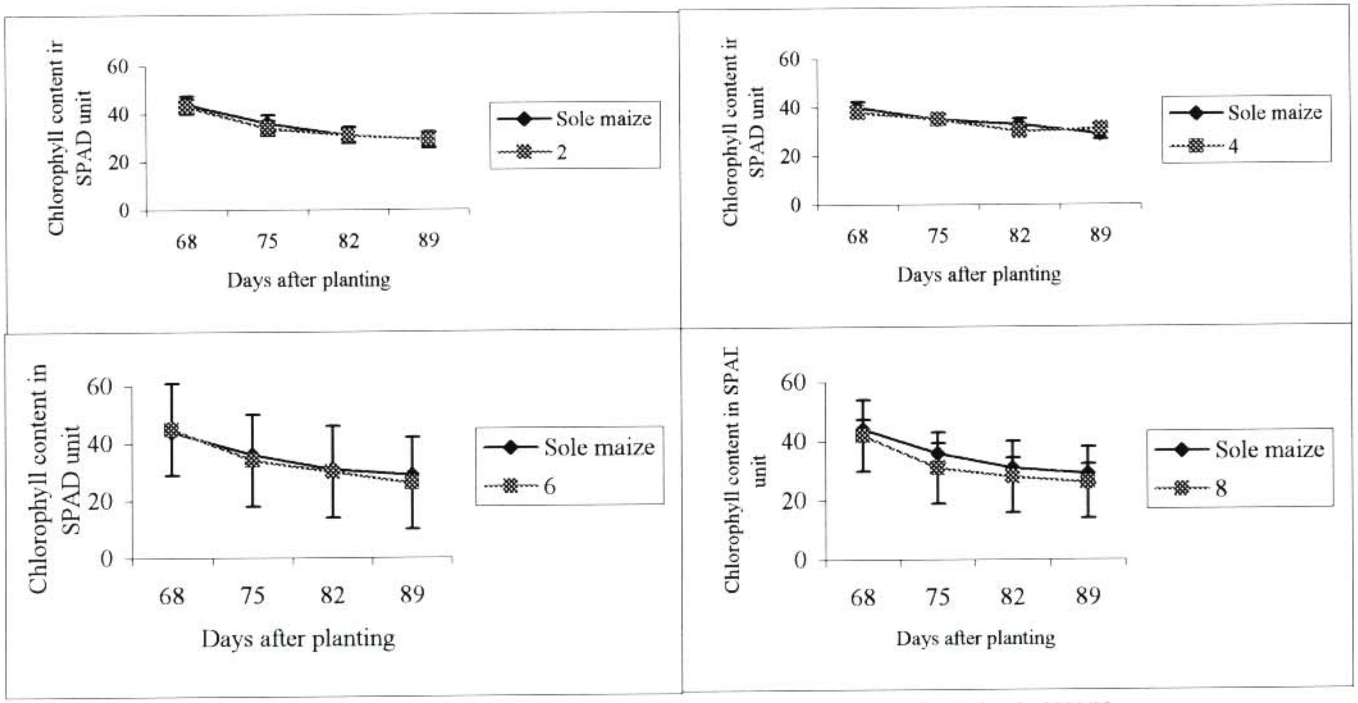

Fig 3.12 Maize upper leaf chlorophyll content at Dalmada when lablab was planted 28 days after planting maize during the 2001/02 season

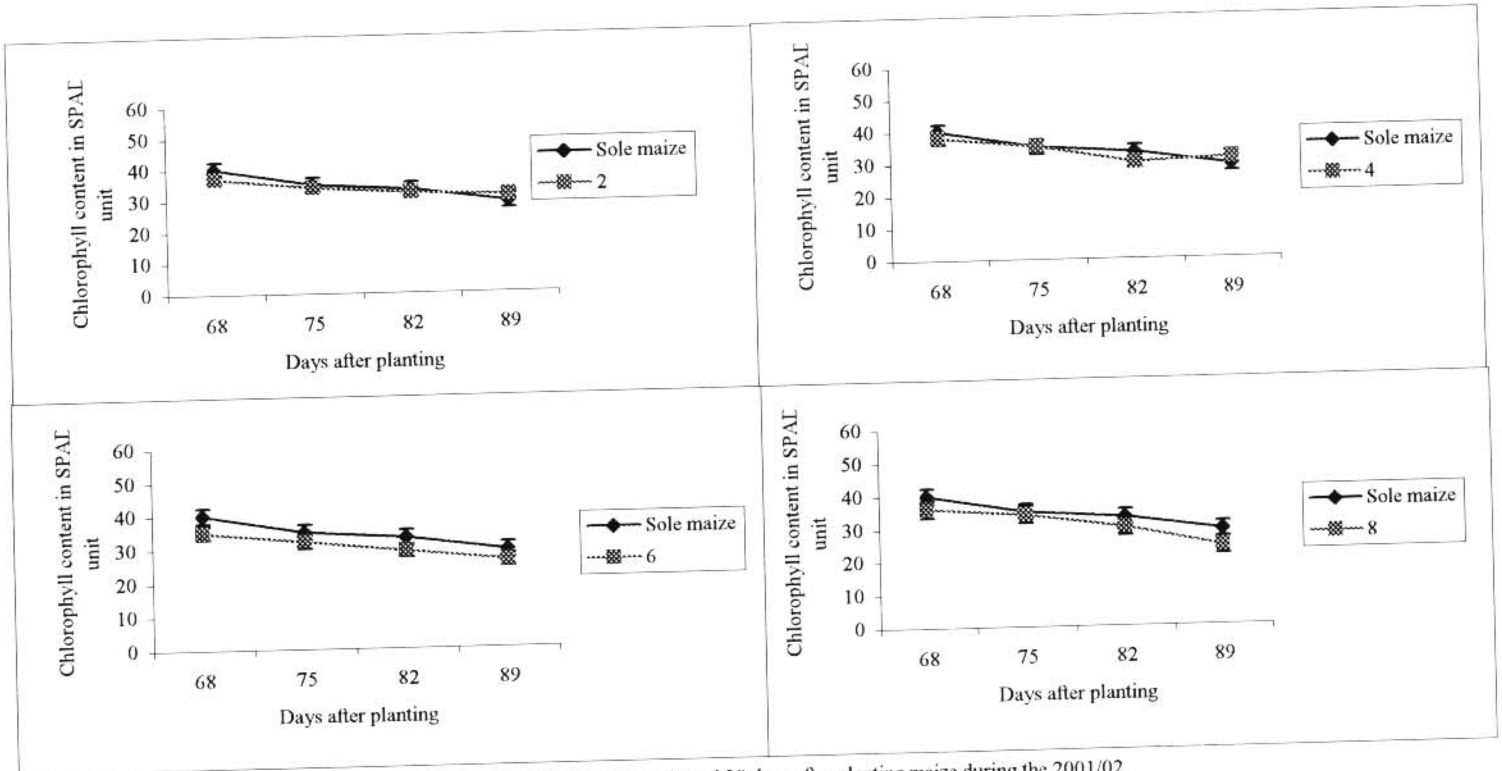

Fig 3.13 Maize upper leaf chlorophyll content at Syferkuil when lablab was planted 28 days after planting maize during the 2001/02

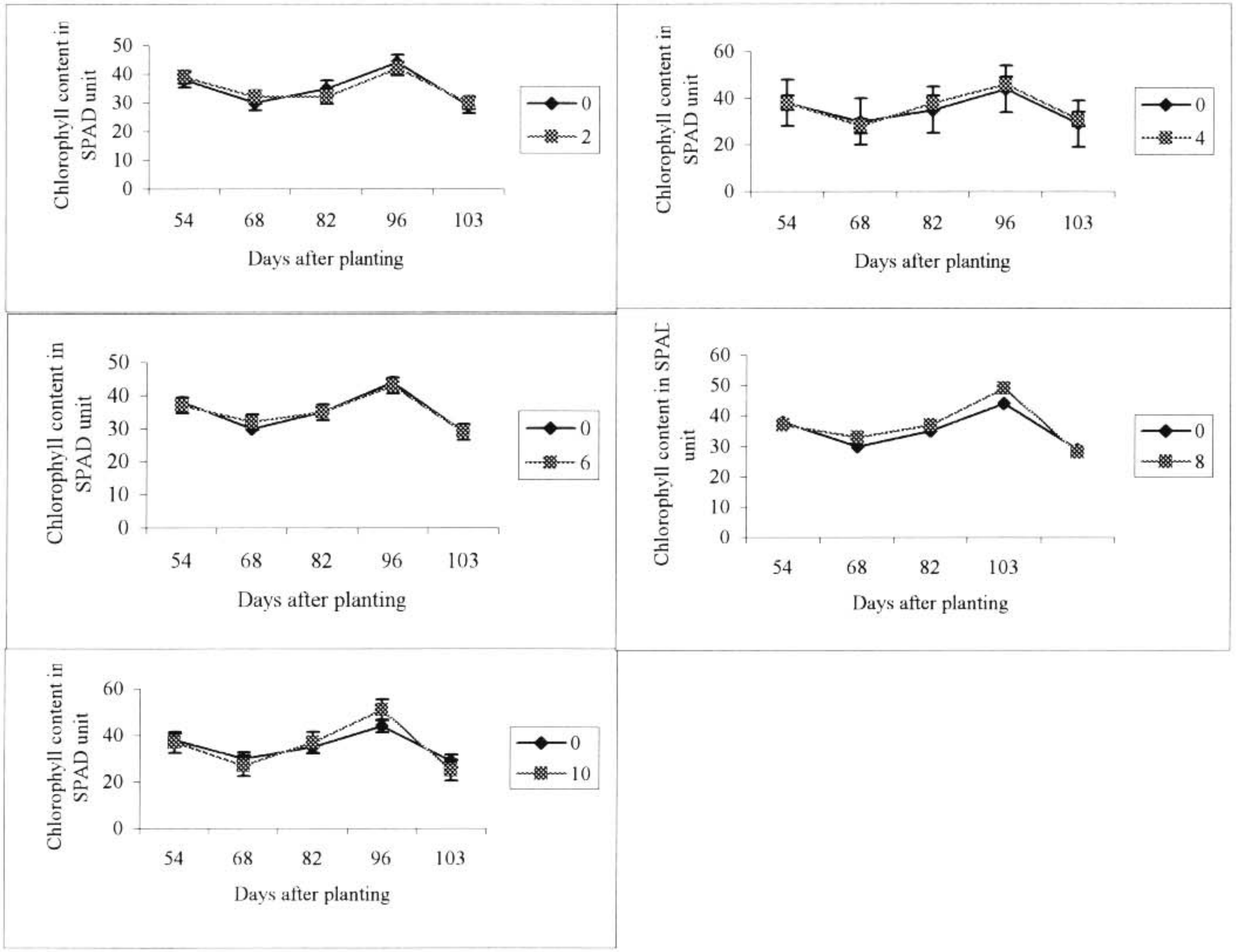

Fig 3.14 Maize upper leaves chlorophyll content at Dalmada during 2002/03 when maize was simultaneously planted with lablab

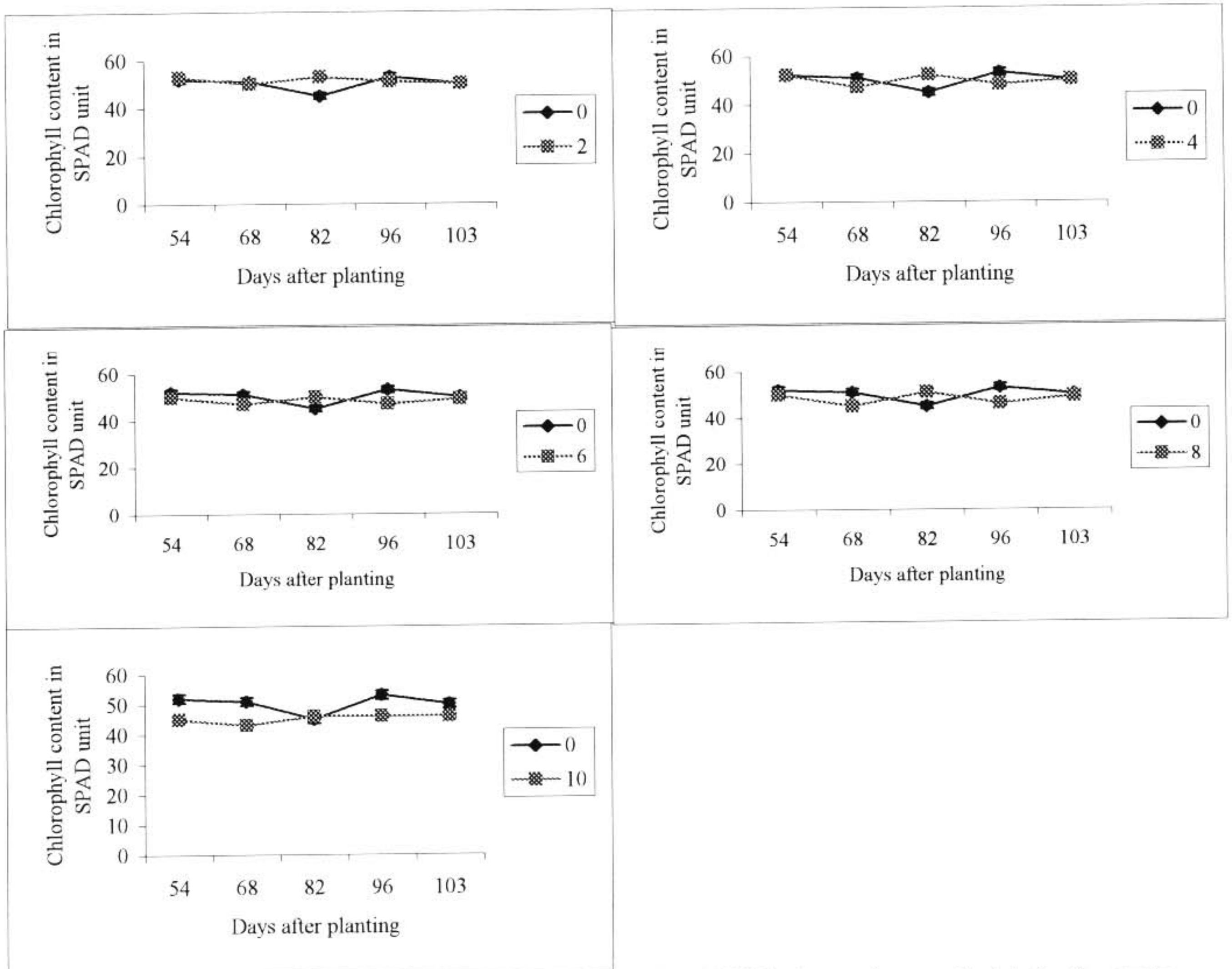

Fig 3.15 Maize upper leaves chlorophyll content at Syferkuil during 2002/03 when maize was planted simultaneously with lablab.

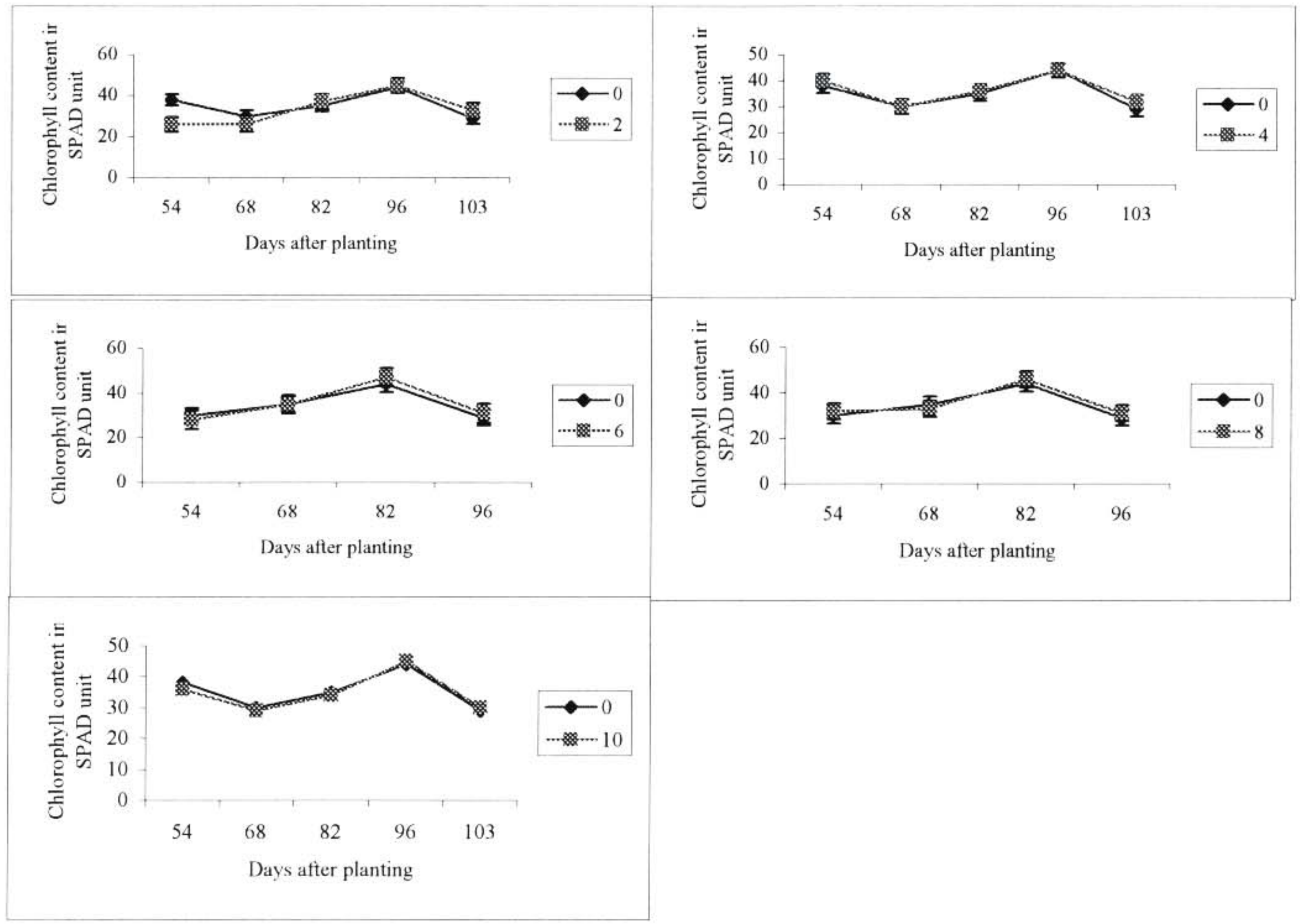

Fig 3.16 Maize upper leaves chlorophyll content at Dalmada during 2002/03 when lablab was planted 28 days later

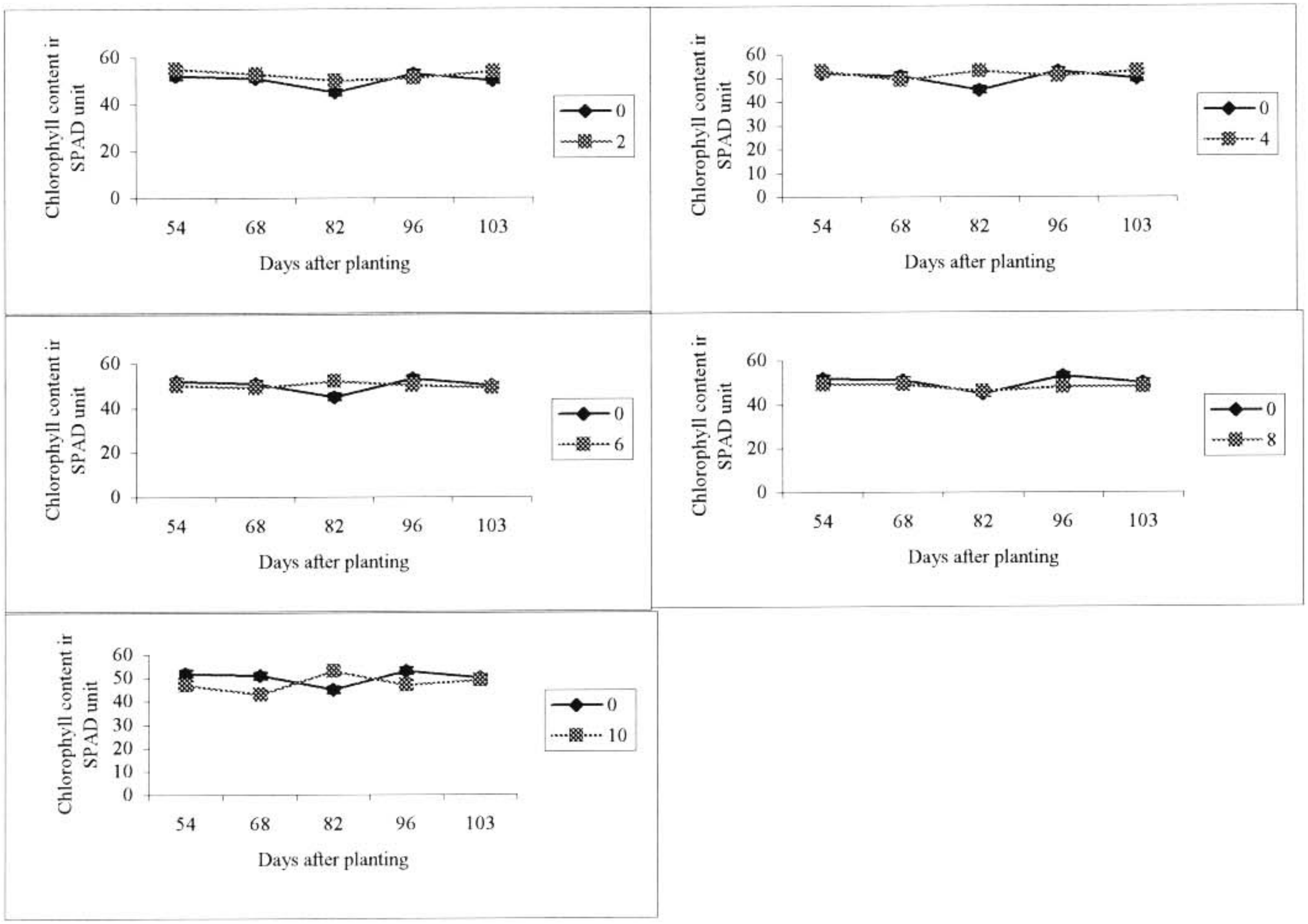

Fig 3.17 Maize upper leaves chlorophyll content at Syferkuil during 2002/03 when lablab was planted 28 days later

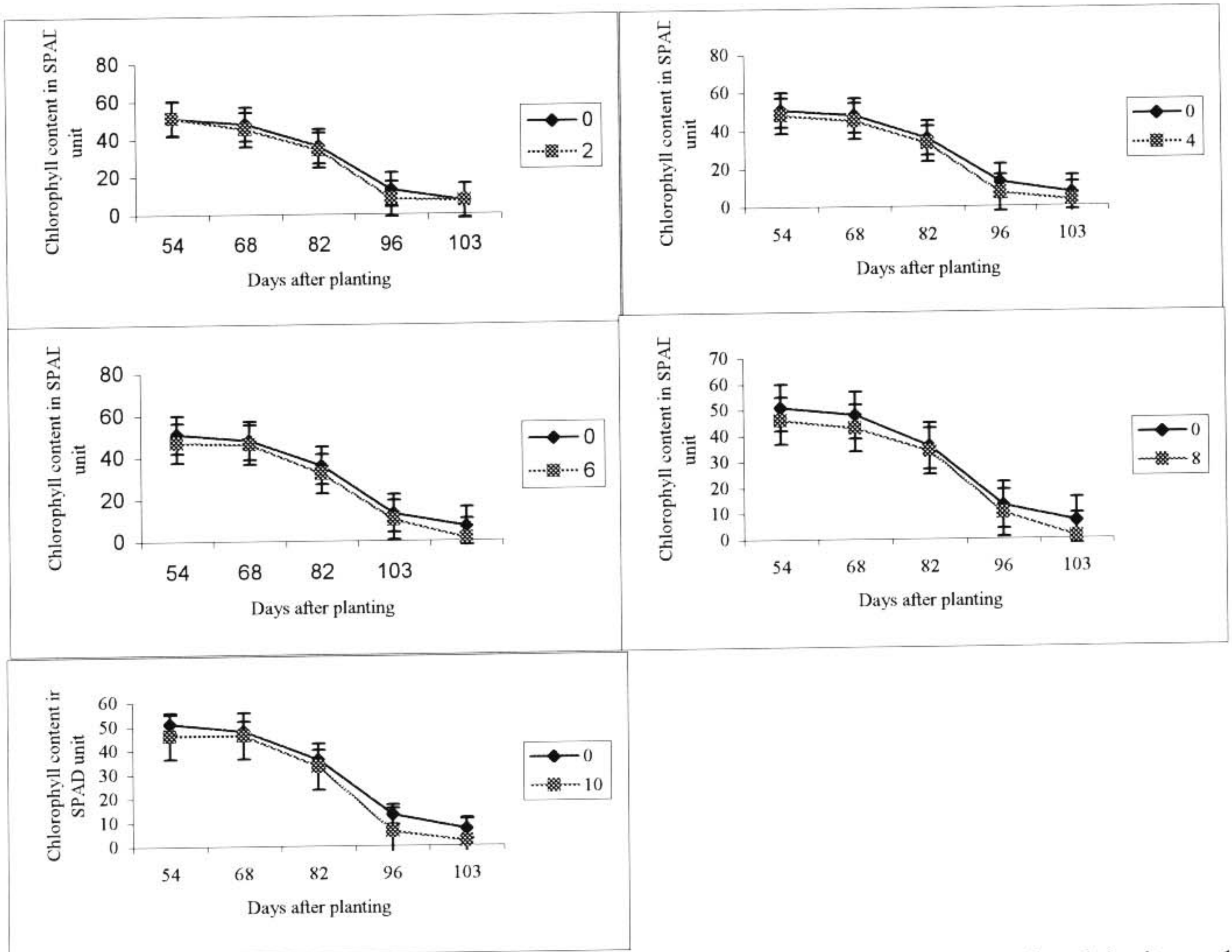

Fig 3.18 Lower leaf chlorophyll content at Dalmada during 2002/03 growing season when maize was planted simultaneously with lablab.

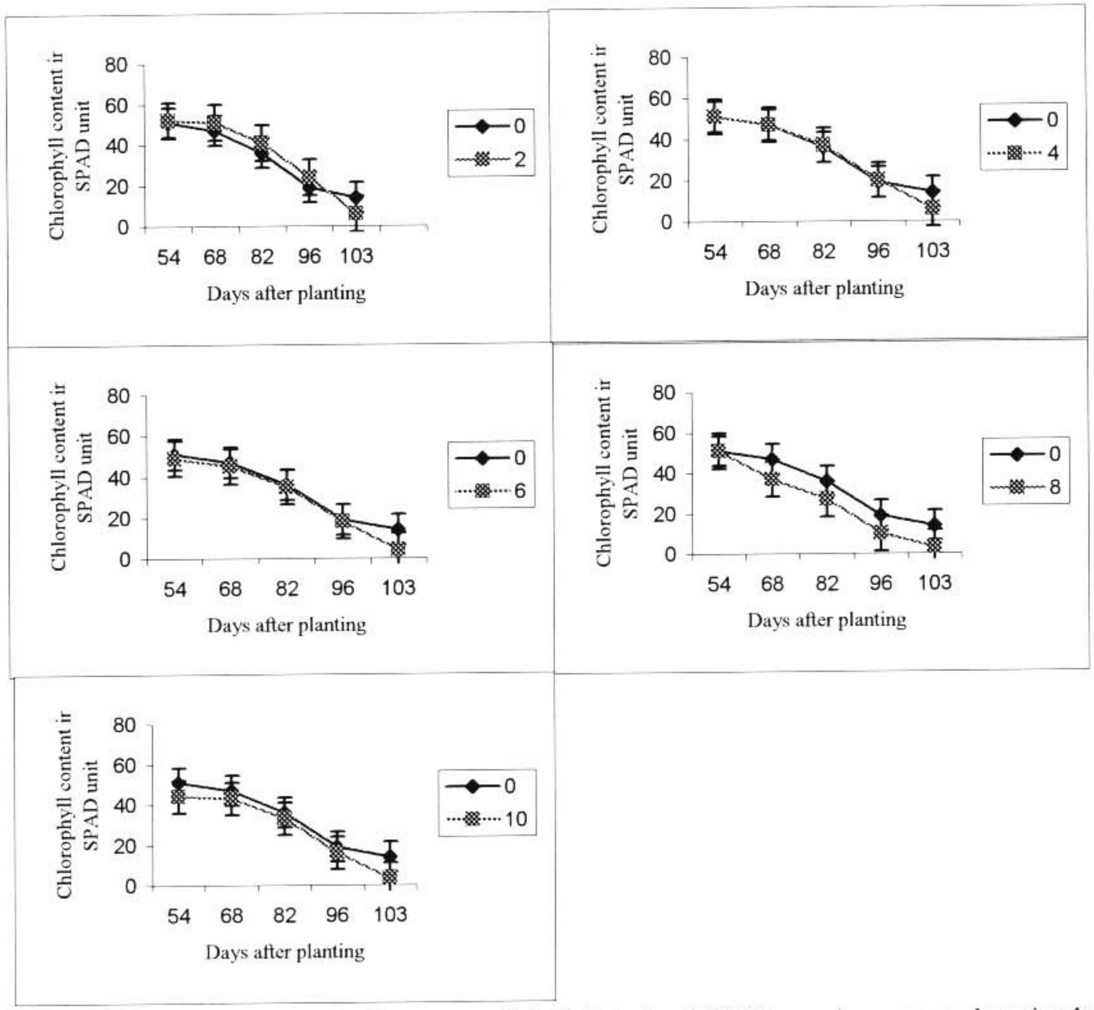

Fig 3.19 Lower leaf chlorophyll content at Syferkuil during 2002/03 growing season when simultaneously planted with maize.

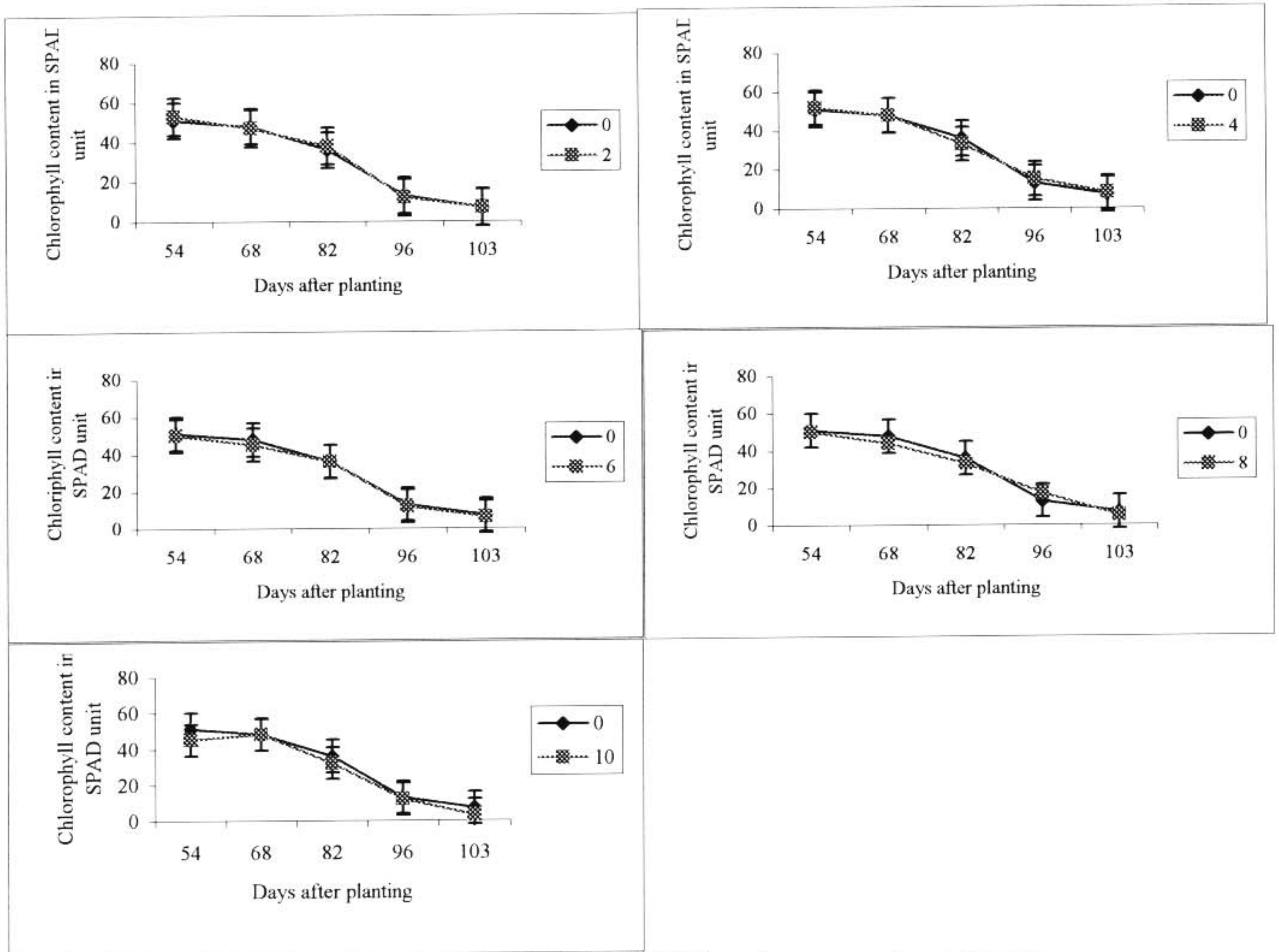

Fig 3.20 Lower leaf chlorophyll content at Dalmada during 2002/03 growing season when maize was planted 28 days after maize

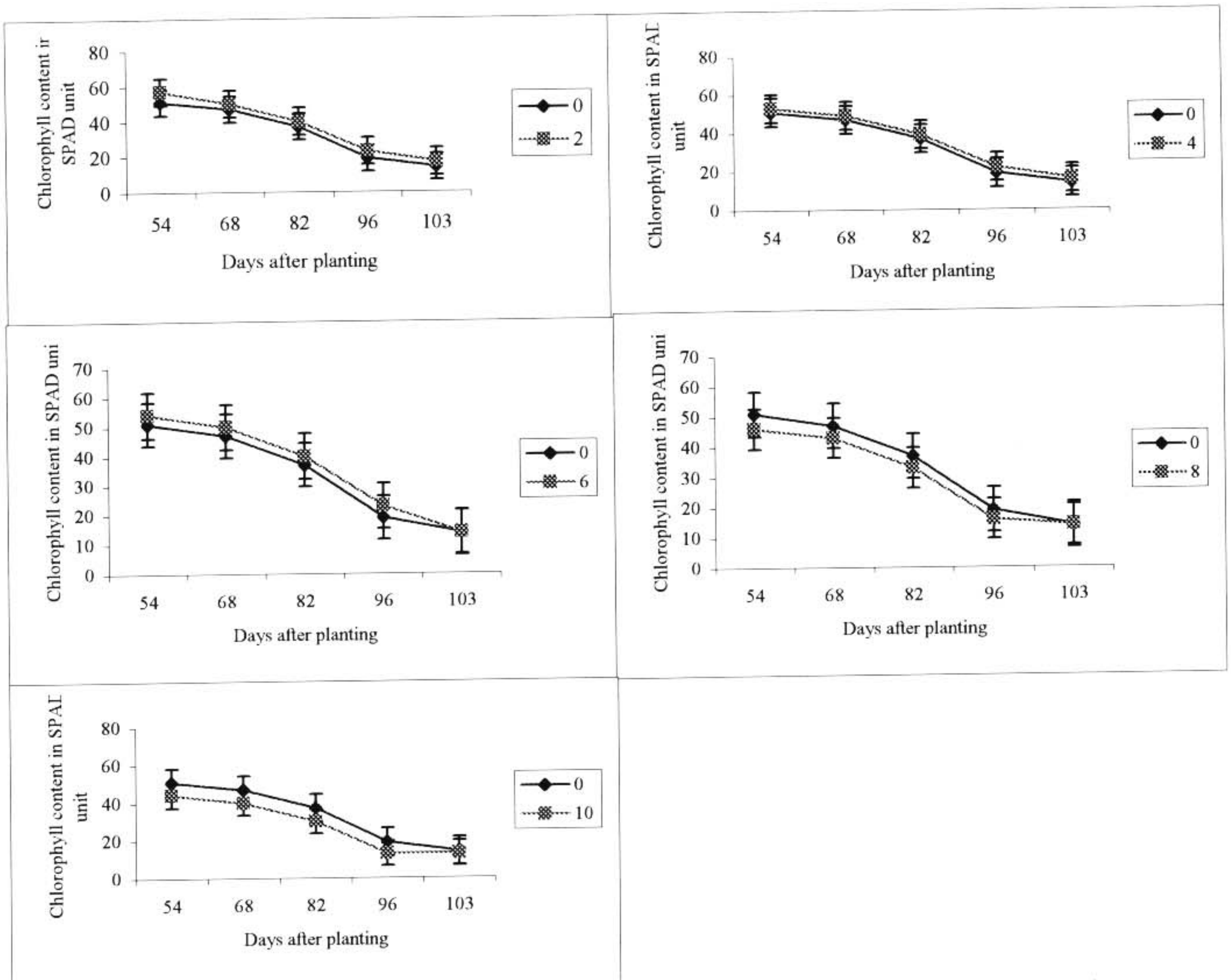

Fig 3.21 Lower leaf chlorophyll content at Syferkuil in 2002/03 growing season when lablab was planted 28 days after maize.

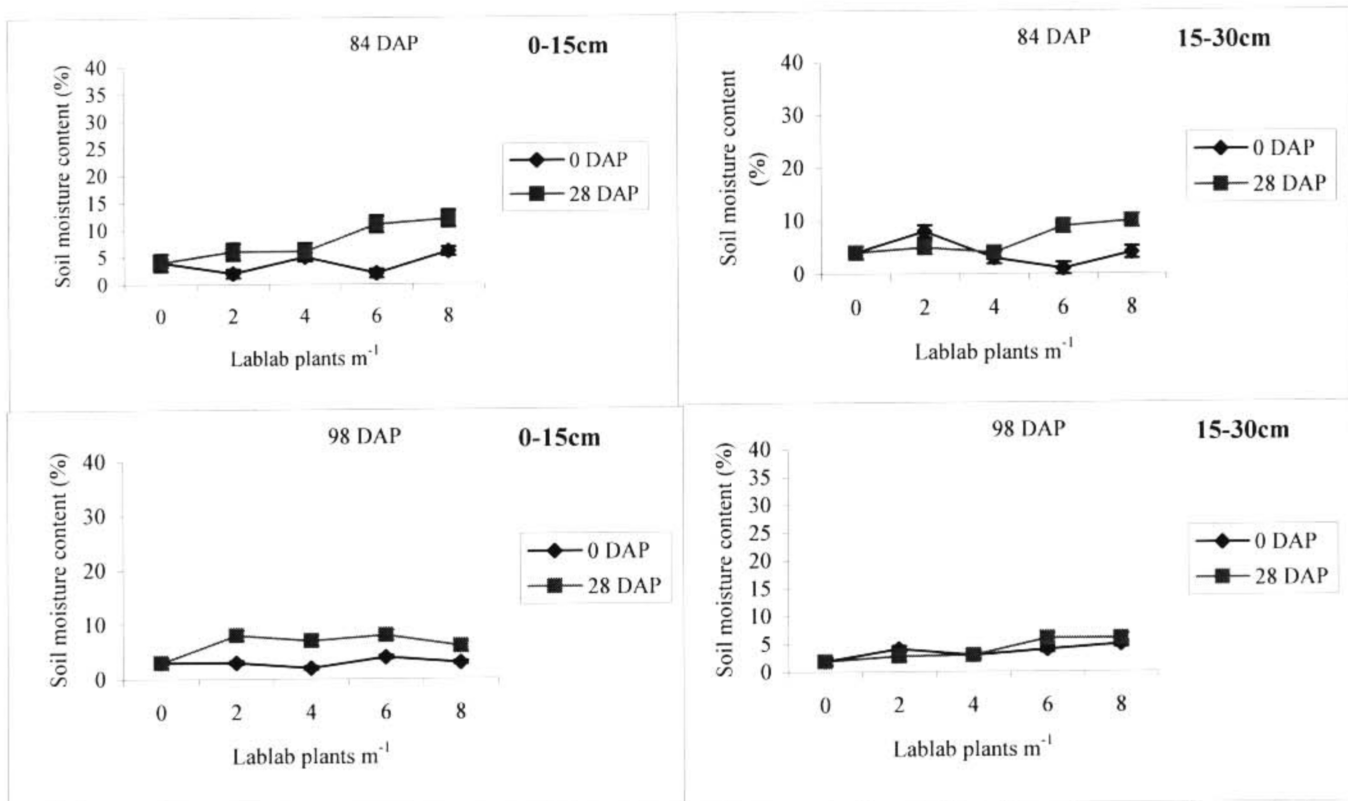

Fig 3.22 The influence of lablab planting date and density on gravimentric soil moisture at Dalmada duri
2001/02

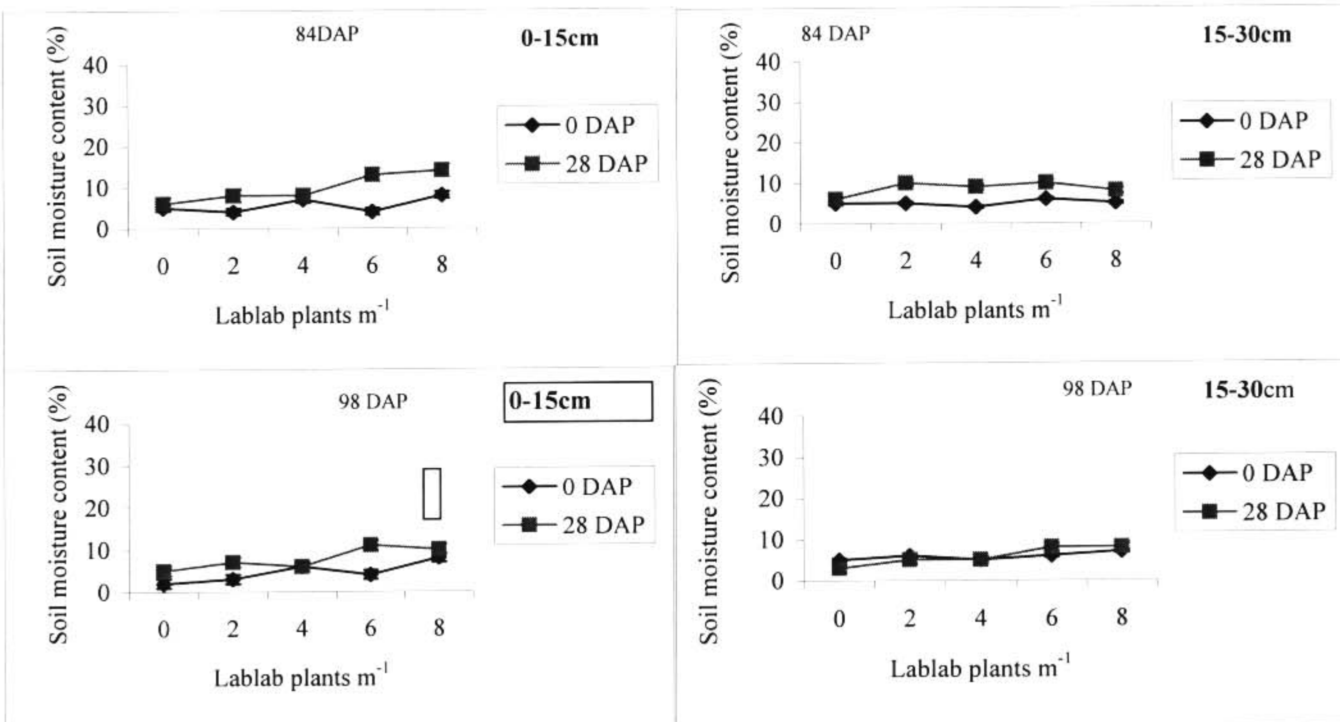

Fig 3. 23 The influence of lablab planting date and density on gravimetric soil moisture at Syferkuil during 2001/02 season

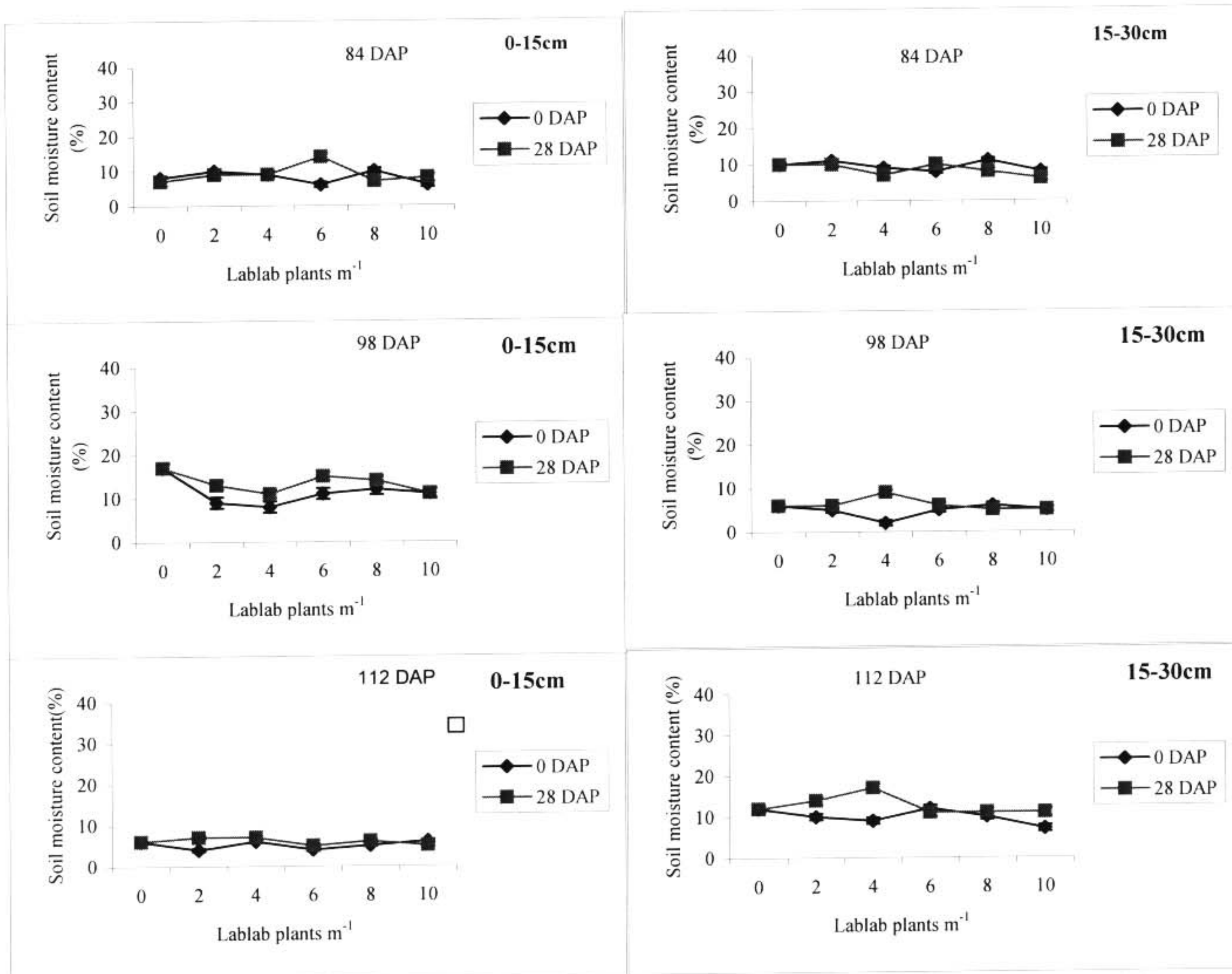

Fig 3.24 The influence of lablab planting date and density on gravimentric soil moisture at Dalmada during 2002/03

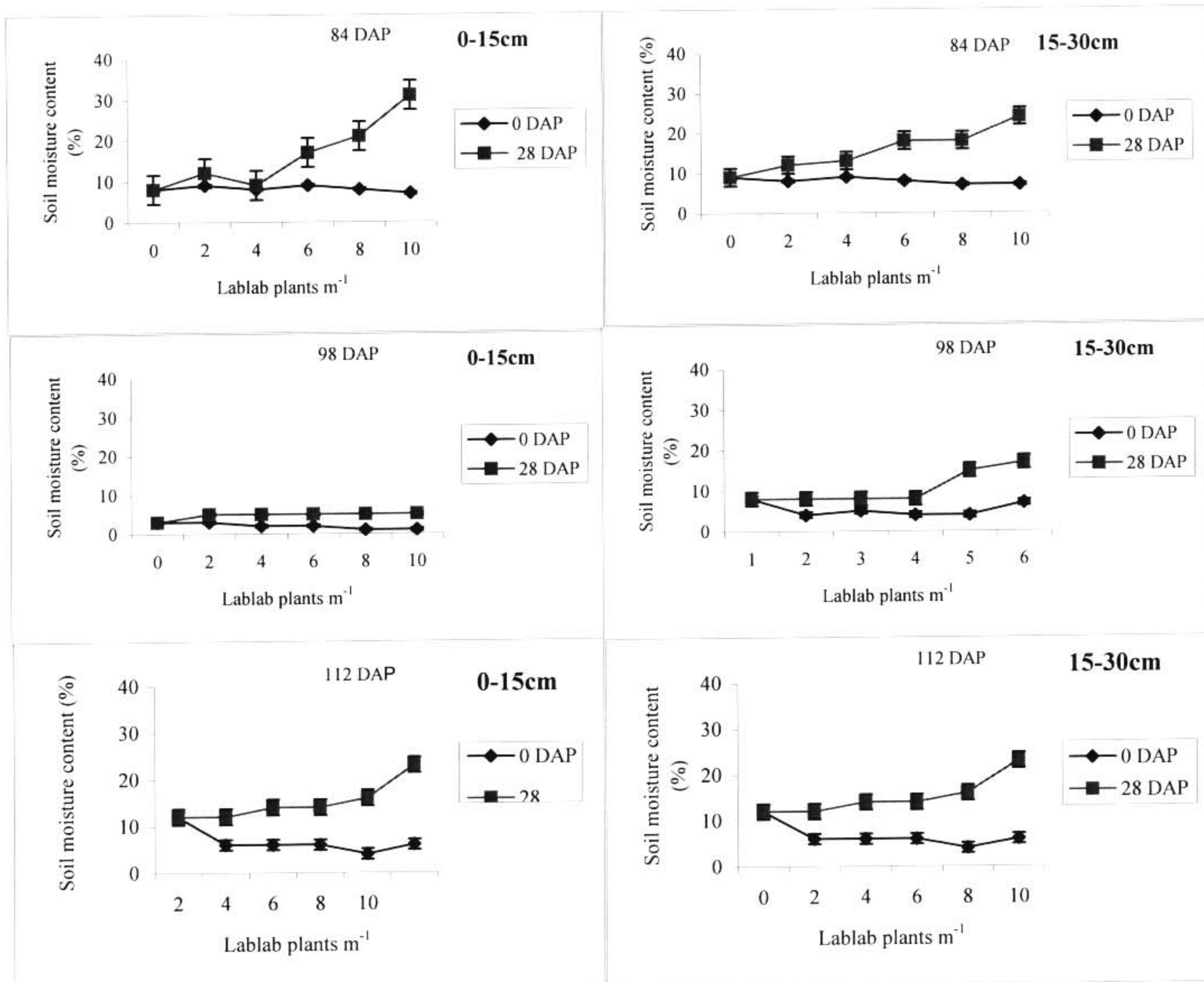

Fig 3.25 The influence of lablab planting date and density on gravimetric soil moisture content at Syferkuil during 2002/03

CHAPTER 4

INFLUENCE OF MAIZE/LABLAB INTERCROPPING ON LEPIDOPTEROUS STEM BORER INFESTATION ON MAIZE.

INTRODUCTION

The effects of lepidopterous stem borers on cereal crops are well studied. They inflict damages to the crops and as a result reduce the total crop yield. The spotted stem borer, *Chilo partellus* has become a key pest of many agronomic crops such as sorghum and maize in several countries in the sub- Saharan Africa (Swaine, 1957; Smithers, 1960; Usua, 1968; Walker and Hodson 1976; Van Rensburg *et al*., 1987).

Management practices have relied mainly on chemical control of agricultural pests, based on the economic threshold. However, the use of chemical insecticides as the main source of controlling pests has been criticized due to their adverse effects on the environment. Integrated pest management (IPM) programs are currently being used widely to control agricultural pests in an effort to reduce over dependence on chemicals. IPM programs use various cultural, biological, and chemical methods for managing insect pests.

In certain areas, cereals such as maize and sorghum are traditionally intercropped with other crops, some of them are non hosts, which may minimize the chances for the pest to develop in the field (Dissemond and Hindorf, 1990; Skovgard and Paets, 1996). Reduction in pest number through intercropping is due to disruption of certain pests' ability to find and exploit host plants (Vandermeer, 1989; Trenbath, 1993). Intercropping system does not only reduce the pest density but also increase the fertility of the soil when legumes are used as component crops in the system.

Lablab, *Lablab purpurens* is produced on a limited scale in the Limpopo Province of South Africa. It is grown for both its foliage and seed and has nitrogen-fixing properties. Like many forage legumes, it has the ability to reduce soil erosion and control weeds through its perennial characteristics. Preliminary studies on lablab in the province indicated that the crop is very aggressive and competitive and may out-compete maize in an intercropping system when well established, thereby reducing maize yield. However, staggering its planting date and density, the competitiveness of lablab can be minimized and enhance overall productivity of the intercropping system.

This study was established to determine whether intercropping maize with lablab would reduce the densities of stem borer on maize when compared with maize grown in sole culture and to assess the impact of different lablab densities on stem borer infestation and grain yield of maize.

MATERIALS AND METHOD

Field experiments were conducted at the University of the North experimental farm at Syferkuil and farmers' field at Dalmada in the Limpopo province of South Africa during the 2001/02 and 2002/03 growing seasons. The experiment was set up as a randomized complete block design in factorial arrangement with two factors, namely planting date and planting density of lablab. Planting date consisted of two treatments, simultaneous planting with maize and planting at 28 days after maize. The second factor, lablab planting density consisted of the following; (i) zero lablab (sole maize); maize-lablab intercrop at (ii) two (iii) four; (iv) six and (v) eight lablab plants per meter. In 2002/03, an additional density of ten lablab plants per meter was evaluated at both locations. In the intercrop treatment, the lablab was planted between two maize rows, spaced 90 cm apart, thus creating an inter row spacing of 45 cm between a maize and lablab row. During 2001/02 season the crops were planted on 12 and 13 December, 2001 at Dalmada and Syferkuil respectively, and on 6 and 12 December, 2002 respectively at the two locations during 2002/03 season. Fertilizers were applied at planting at a rate of 20kg P ha^{-1} as Superphosphate, 30 kg N ha^{-1} as urea, and 30kg of K ha^{-1} as potassium chloride. Weeding was done with a hand hoe two-three times during the growing seasons.

Maize plant samples were collected at 84 and 112 days after planting (DAP) for assessment of stem borer infestation. At each sampling, 5 plants were randomly selected from a defined area in each experimental unit, cut at ground surface and dissected to determine the number of stem borer larvae per plant.

For grain yield determination, cobs of plants from 3.2 m^2 and 4.5 m^2 area of the central portions of each plot were harvested after physiological maturity in 2001/02 and 2002/03 respectively. Cobs were oven dried at 65^0C to constant weight, weighed and then shelled. Shelled grains were then dried to 14% moisture and weighed to determine grain yield per unit area.

Data were subjected to statistical analysis to assess differences in lablab density; date and interaction effects on stem borer infestation and grain yield using the statistical analysis system (SAS 1999). The least significance difference method was used to assess differences in treatment means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The predominant stem borer species encountered was *Chilo partellus*. During 2001/02 season, relatively less number of stem borers were encountered at Syferkuil compared to Dalmada. In comparison, greater numbers of stem borers were generally found on sole maize than intercropped maize at both locations. Within the intercrops system at Dalmada, stem borer density generally decreased with increasing lablab density with maize crops intercropped at lablab density of 6 and 8 resulting in much reduced borer numbers compared to the sole crops (Table 4.1). At Syferkuil, a similar trend was observed, where borer density decreased with increasing lablab density. However, no significant difference in stem borer density was observed within the intercropped maize under simultaneous planting during 112 days sampling period. There was also no significant difference in borer density between lablab density of 6 and 8 at both sampling periods at each planting dates with the exception of the later planting during 84 days sampling period (Table 4.1). Significant differences were observed between the planting dates. At both locations, maize plants from simultaneous planting recorded significantly lower stem borer densities as compared to those intercropped with later lablab (28 DAP) at all lablab densities except lablab density of 8 at 84 DAP at both locations (Table 4.3).

During the 2002/03 season, there was a dramatic increase in the number of stem borers relative to 2001/02, at locations, sampling periods and treatments. Similar to 2001/02 season, Dalmada recorded a higher borer density than Syferkuil with more than twice the number of borers at certain stages (Tables 4.4 and 4.5).

The borer density was also higher on sole maize than intercropped maize at both locations. At Dalmada, among the intercrops, stem borer density generally decreased with increasing lablab density but there were no significant differences at high lablab densities (8 and 10) for simultaneous planting at both sampling periods (Table 4.4). At Syferkuil, similar trend was observed, sole maize recorded higher incidence of borer infestation than the intercropped maize. In the intercrops, borer density also decreased with increasing lablab density. There were significant differences in borer density between the planting dates. Maize plants from simultaneous planting recorded significantly lower stem borer densities than those intercropped with later lablab (28 DAP) at all densities, both sampling periods and locations (Table 4.6).

During 2001/02 season, the total grain yield was higher at Syferkuil than Dalmada. At Dalmada, the highest maize grain yield under the simultaneous planting was recorded in sole maize followed by intercropped maize of lablab density at two and then four. The lowest grain yield was recorded in maize intercropped with the highest lablab density (Table 4.7). The pattern of grain yield of maize intercropped with later-planted lablab at this location was similar to that of simultaneous planting where sole maize was superior to the intercrops. Grain yields of maize intercropped at lablab densities of 2 and 4 were similar. At Syferkuil, the grain yields of sole maize were lower than that from intercropped maize at density 2 under both planting dates, and also at density 4 of the later planting date. The highest grain yield was recorded in intercrop maize with lablab density of two at 28 DAP followed by density of four at the same planting date (Table 4.7). The grain yield decreased with increasing density of lablab.

There was improvement in grain yield in 2002/03 as compared to the previous season. At Dalmada, there was no significant difference between grain yield of sole and intercropped maize at lablab density of two. Maize grain yield decreased with increasing lablab density (Table 4.8). Date of planting lablab and the density of lablab influenced the grain yield but there was no significant interaction between the two. At Syferkuil, intercropped maize with lablab density of two at 28 DAP had the highest grain yield, followed by lablab density of four at 28 DAP (Table 4.8). Yield also decreased with increasing lablab density with the lowest yield recorded in plots with lablab density of 10. Lablab density, date of planting and their interaction had significant effect on the yield.

The numbers of stem borer larvae were reduced in the maize intercropping system as compared to the sole maize. Increasing lablab density caused a corresponding decrease in the number of larvae. This study supports the finding of Ndemah *et al*., (2003), who reported reduction in numbers of both *Chilo* and *Sesamia* species in maize/cowpea intercropping. The decline in numbers of larvae in the intercrop was probably due to either fewer females attracted to the intercrop or because the larvae were less likely to encounter a host plant when the nonhost plant (lablab) density was high.

The negative relationship between the lablab density and numbers of larvae could also be due to difficulties encountered by the female moth in finding a suitable host for oviposition. It is possible that a lot of energy and time were utilized assessing unsuitable hosts that could have affected the rate of reproduction. Furthermore, expenditure of energy might have increased mortality among the population, thus reducing the numbers of adults that reached intercropped host plants compared with crops grown in sole cultures. This study agrees with Skovgard and Paets (1996), who found that maize/cowpea intercropping reduced larva and pupa numbers of *Chilo spp*, and *Sesemia calamistis*. Similar results were found in *Busseola fusca* where the number decreased with increasing density of the nonhost cassava in a maize/cassava intercropping system (Ndemah *et al*., 2003).

In terms of planting dates, incidence of infestation was higher at simultaneous planting than late lablab planting and this could have been caused by the differences in size of lablab plants. Lablab at simultaneous planting has greater chance of developing relatively larger biomass than those planted later and consequently making the former more difficult for the pests to locate maize plants.

During 2002/03 season, the population of stem borers increased dramatically over the previous year at both locations. This increased in numbers could have resulted from multiple and possible interacting factors that might include the presence of residues of the 2001/02 maize crop. The maize residues from the previous season at the locations could have provided an ideal environment for diapausing larvae and therefore could have enhanced the development and growth of the borers (Harris 1962). Similar results have been found in European corn borer, *Ostrinia nubilalis* (Umeozor *et al.*, 1985).

There was a decline in the incidence of infestation at 112 days sampling period compared to 84 days sampling period at Dalmada in 2001/2002. The low numbers of larvae encountered during the second sampling period might have been caused by high immature mortality and migration. Furthermore, the lower number of borers encountered in 2001/02 could be attributed to high immature mortality caused by the severe drought, experienced in that season. At Syferkuil, there were occasional irrigation that could have improved the survival rate of maize crops and hence the larvae. The lower infestation at Syferkuil as compared to Dalmada could also be due to high rate of dispersal to nearby maize fields at the former location.

The reason for lower grain yield in the intercrop as compared to sole maize could be associated with competition for nutrients, moisture and solar radiation. Lablab is prolific in growth and tends to grow vertically through to the top of maize canopy and partially impeding light intercepted by the maize plant. In addition, the lablab could have impeded weeding and fertilization of maize plants during anthesis and silking and therefore affecting the growth and development of the maize plants. Nonetheless, high grain yields were obtained not only in sole maize but also intercropped maize with lablab density of 2 and 4 (Tables 4.7 and 4.8). It contrast to expectation, the high incidence of borer infestation had little effect on the grain yield, an indication that the threshold level of the pest was not reached. This observation also indicates that other factors such as competition for growth resources could be important factor causing yield reduction in the intercrop maize relative to the sole maize. The low rainfall recorded in that season could have caused the lower yield in 2001/2002 season. However, the occasional irrigation at Syferkuil during that season could have contributed to a better grain yield than that of Dalmada.

CONCLUSION

In conclusion, the findings of this study show that maize/lablab intercrops reduce stem borer populations compared with sole cultures. However, while intercropping may have beneficial effects on maize production associated with a reduction in borer populations, it may also have adverse effects on plant growth and grain yield production as a result of competition. In order to maximize the beneficial effects of maize/lablab intercropping we recommend that lablab density should not exceed the density of four and lablab should not be planted simultaneously with maize in order to reduce competition and easy management of the field.

STUDY TABLES

Table 4.1 Lablab planting date and density in maize/lablab intercropping effects on stem borer density at different growth stages at Dalmada during 2001/02 season.

Density (Plants m^{-1})	84 days		112 days	
	Simultaneous	28DAP	Simultaneous	28DAP
	………………………# of borers m^{-1}		…………………	
0	6.45 a	6.45 a	3.09 a	3.48 a
2	3.87 b	4.74 b	2.03 b	2.51 a
4	4.64 c	5.41 b	2.22 b	2.70 a
6	2.12 d	4.83 b	1.16 c	2.42 b
8	2.12 d	1.55 c	1.06 c	0.77 c
LSD (P≤ 0.05)	0.69	0.69	0.28	0.28
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; 28 DAP= Lablab planted 28 days after the maize.

Table 4.2. Lablab planting date and density in maize/lablab intercropping effects on stem borer density at different growth stages at Syferkuil during 2001/02 season

	84 days		112 days	
Density (Plants m^{-1})	Simultaneous	28DAP	Simultaneous	28DAP
	...............................# of borers m^{-1}.................			
0	4.83 a	4.83 a	3.58 a	3.58 a
2	1.45 b	5.22 a	0.87 b	3.19 a
4	1.55 b	3.57 b	0.97 b	2.19 b
6	1.25 c	1.64 c	0.97 b	0.58 c
8	0.68 c	1.16 d	0.58 b	0.77 c
LSD ($P \leq 0.05$)	0.764	0.764	0.65	0.65
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; 28 DAP= Lablab planted 28 days after the maize.

Table 4.3 Effects of planting date on stem borer density at Dalmada and Syferkuil during 2001/02 season.

Site	Sampling date	Planting date	Lablab density			
			2	4	6	8
			...........No of borers per plant................			
Dalmada	84 days	Simultaneous	3.87b	4.64b	2.12b	2.12a
		28DAP	4.74a	5.41a	14.83a	1.55a
		Lsd	**	**	**	n.s
	112 days	Simultaneous	2.03b	2.22b	1.16b	1.06a
		28DAP	2.51a	2.70a	2.42a	0.77b
		Lsd	**	**	**	**
Syferkuil	84 days	Simultaneous	1.45b	1.55b	1.25a	0.68a
		28DAP	5.22a	3.57a	1.64a	1.16a
		Lsd	**	**	n.s	n.s
	112 days	Simultaneous	0.87b	0.97b	0.97a	0.58a
		28DAP	3.19a	2.19a	0.58a	0.77a
		Lsd	**	**	n.s	n.s

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; 28 DAP= Lablab planted 28 days after the maize.

Table 4.4. Lablab planting date and density in maize/lablab intercropping effects on stem borer density at different growth stages at Dalmada during 2002/03 season.

Density	84 days		112 days	
	Simultaneous	28DAP	Simultaneous	28DAP
	....# of borers m^{-1}	....		
0	18.90 a	18.90 a	6.09 a	6.09 a
2	11.02 b	15.53 b	3.55 b	5.00 b
4	9.90 c	14.63 c	3.19 c	4.71 c
6	7.88 d	13.73 d	2.54 d	4.42 c
8	7.20 e	11.70 e	2.32 d	3.77 d
10	6.53 e	10.35 f	2.10 d	3.33 e
LSD (P≤0.05)	0.47	0.47	0.152	0.152
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; 28 DAP= Lablab planted 28 days after the maize.

Table 4.5 Lablab planting date and density in maize/lablab intercropping effects on stem borer density in different growth stages at Syferkuil during 2002/03 season.

	84 days		112 days	
Density plants m^{-1}	Simultaneous	28DAP	Simultaneous	28DAP
	……………………………# of borers m^{-1}	……………………………		
0	5.86 a	5.86 a	5.22 a	5.22 a
2	3.26 b	4.71 b	2.69 b	4.13 b
4	2.90 b	4.42 c	2.33 c	3.85 c
6	2.24 d	4.13 d	1.67 d	3.56 d
8	2.03 c	3.48 d	1.45 e	2.93 e
10	1.81 c	3.05 d	1.23 f	2.47 f
LSD (P≤ 0.05)	0.152	0.152	0.154	0.154
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; 28 DAP= Lablab planted 28 days after the maize.

Table 4.6 Effects of planting date on stem borer density at Dalmada and Syferkuil during 2002/03 season.

Site	Sampling date	Planting date	Lablab density				
			2	4	6	8	10
			...........No of borers per plant...............				
Dalmada	84 days	Simultaneous	11.02b	9.90b	7.88b	7.20b	6.53b
		28DAP	15.53a	14.63a	13.73a	11.70a	10.35a
		Lsd	**	**	**	**	**
	112 days	Simultaneous	3.55b	3.19b	2.54b	2.32b	2.10b
		28DAP	5.00a	4.71a	4.42a	3.77a	3.33a
		Lsd	**	**	**	**	**
Syferkuil	84 days	Simultaneous	3.26b	2.90b	2.24b	2.03b	1.81b
		28DAP	4.71a	4.42a	4.13a	3.48a	3.05a
		Lsd	**	**	**	**	**
	112 days	Simultaneous	2.69b	2.33b	1.67b	1.45b	1.23b
		28DAP	4.13a	3.85a	3.56a	2.93a	2.47a
		Lsd	**	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; 28 DAP= Lablab planted 28 days after the maize.

Table 4.7 Grain yield of sole and intercropped maize at Dalmada and Syferkuil under different lablab planting date and density during 2001/02 growing season.

	Dalmada		Syferkuil	
Density plants m^{-1}	Simultaneous	28 DAP	Simultaneous	28 DAP
	……………..…………………kg ha^{-1}	………………………………………		
0	1076 a	1076 a	863 a	863 c
2	802 b	999 b	528 b	1615 a
4	721 c	971 b	436 c	1126 b
6	321 d	539 c	189 d	803 c
8	90 e	464 d	122 d	583 d
LSD ($P \leq 0.05$)	106	106	81	81
Date	**	**	**	**
Density	**	**	**	**
Interaction	**	**	**	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; 28 DAP= Lablab planted 28 days after the maize.

Table 4.8 Grain yield of sole and intercropped maize at Dalmada and Syferkuil under different lablab planting date and density during 2002/03 growing season.

	Dalmada		Syferkuil	
Density plants m^{-1}	Simultaneous	28 DAP	Simultaneous	28 DAP
	……………kg ha^{-1}……………			
0	1674 a	1674 a	5181 a	5181 b
2	1438 a	1908 a	4729 a	7550 a
4	1211 a	1654 a	3055 b	7141 a
6	733 b	971 b	2567 b	5797 b
8	819 ab	961 b	2041 b	3985 c
10	572 b	884 b	1583 b	2875 c
LSD ($P \leq 0.05$)	459	459	1184	1184
Date	**	**	**	**
Density	**	**	**	**
Interaction	ns	Ns	*	**

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; 28 DAP= Lablab planted 28 days after the maize.

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Intercropping is the growing of two or more crops simultaneously on the same area of land, and this is a very common practice among smallholder farmers in the Limpopo Province. Intercropping is an alternative cropping strategy with potential for fostering agricultural sustainability. However, the compatibility of many crops for management systems is very important. Legumes and cereal such as maize has shown compatibility when grow together. Intercropping maize with legumes is one of the effective systems to control stem borers.

Increased used of legume offers the potential for a significant decrease in the need for inorganic fertilizer (N), and therefore is a key component of sustainable agricultural systems. Sustainability is the ability to produce with greater efficiency of resources use, and a balance with the environment. Maintaining soil fertility in Limpopo province of South Africa requires approaches that encourage the efficient use of all available nutrients sources in smallholder soil management.

The preference for maize has led to continuous culture of the crop, which together with low external input, has resulted in severe soil degradation in many smallholder-farming systems in the province. Identification of cropping systems, capable of maintaining soil fertility is required to enhance crop productivity on farmers' fields. Lablab bean (*Lablab* *purpureus*) has been found to be well adapted to the dry environment of the Limpopo Province and has the potential to be intercropped with maize. Its prolific growth characteristic requires that the species be well managed when intercropped with maize in order to be maintained or enhance yield of the cereal.

Overall study objective

The overall study objective is to improve the productivity of maize in the smallholder farming system of the Limpopo province through an intercropping system with lablab bean.

Specific objectives

a) To assess the influence of lablab planting date and density on dry matter accumulations, agronomic characters and grain yield of maize and lablab in an intercropping system.
b) To asses nitrogen uptake patterns, chlorophyll production and soil moisture use in maize - lablab system and.
c) To evaluate stalk borer infestation in the cropping system.

Experimental field studies were set up over two seasons at two locations in the province to test the effect of two relative planting date of lablab, simultaneously with maize and at 28 days later, as well as lablab planting densities, namely two, four, six, eight and ten plants per meter on grain yield, agronomic characteristics, maize biomass accumulation, legume symbiotic activity, soil moisture content, leaf chlorophyll content and leaf senescence, and incidence and severity of stem borers with particular reference to *Chilo partellus* (Lepidoptera: Pyralidae). Maize grain yield was harvested from 9.45m^2 and 22.5 m^2 during 2001/02 and 2002/03 growing season respectively for yield and yield components determination.

MAJOR STUDY FINDINGS

Similar pattern was observed on maize grain yield and yield components at both locations and growing seasons. Simultaneously planting of lablab and maize at high density significantly reduces maize grain yield and yield components. Maize intercropped at 2 and 4 plants of lablab per meter produce equal or higher maize grain yield and yield component than sole maize and other intercrops when planted simultaneously. When lablab was intercropped with maize at later stage, maize yield was increased as compared to simultaneously planting. Days to flowering of maize ranged from 62-75 across locations and seasons.

At Dalmada maize plants height was tall under sole, and short when maize was intercropped with lablab at later planting of lablab, whereas at Syferkuil maize plant height were similar in the 2001/02. Maize plant height was reduced when maize was simultaneously intercropped with 10 plants of lablab by 83% and 67% at Dalmada and Syferkuil respectively during 2001/02. In the 2002/03 growing season at 110 and 154 DAP of maize intercropped at 2, 4 plants of lablab plants per meter had higher HI and appeared to partition more of its photosynthates to grain yield than sole maize and other densities intercropped with maize at both locations. Pooled across planting date, shoots dry mater accumulation showed a decreased pattern as the number of lablab bean per meter increased at both locations. During 2001/02 season, relatively less number of stem borers were encountered at Syferkuil compared to Dalmada. In comparison, greater numbers of stem bores were generally found on sole maize than intercropped maize at both locations. Significant differences were observed between the planting dates. At both locations, maize plants from simultaneously planting recorded significantly lower stem borer densities as compared to those intercropped with later lablab (28 DAP) at all lablab densities except lablab density of 8 at 84 DAP at both locations.

CONCLUSIONS

Based on the study the following conclusions were drawn

- ❖ Lablab can be predominantly incorporated with maize by small-scale farmers in the Limpopo province at density of two or four per meter length when planted simultaneously with maize.
- ❖ Intercropping maize and lablab, when lablab is planted 28 days later appears to offer better productivity of the cereal than when planted simultaneously, especially at high planting density of lablab.
- ❖ Maize-lablab intercrops reduce stem borer populations compared with sole cultures

RECOMMENDATIONS

- ❖ Further study is recommended on evaluation of effective inoculants at various rates, which can enhance biological nitrogen fixation especially at compatible densities when lablab bean is intercropped with maize.

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Dissertation appendix

Table.1. Lablab planting date and density effect on maize harvest index at Dalmada during 2002/03 growing season

Density (Plant m^{-1})	Harvest index rate (%)			
	82 DAP	96DAP	110 DAP	154 DAP
	………………	………………	%………	………………
0	6 a	23 a	26 b	25 b
2	6 a	28 a	26 a	32 a
4	6 a	26 a	27 a	32 a
6	6 a	15 b	27 a	24 b
8	4 b	14 b	26 b	23bc
10	4 b	15 b	26 b	18 b
LSD ($P \leq 0.05$)	0.43	5.79	0.28	1.77
Date	**	**	**	n.s
Density	**	**	**	**
Interaction	n..s	n.s	n.s	n.s

LSD= Least Significant Difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; $p < 0.05$; ns= not statistically significant statistically. DAP= 28 days after planting

Table. 2. Lablab planting date and density effect on maize harvest index at Syferkuil during 2002/03 growing season

	Harvest index rate (%)			
Density (Plants m^{-1})	82 DAP	96 DAP	110 DAP	154 DAP
	....	%	....	
0	6 b	20 a	34 a	47 a
2	7 a	19 a	35 a	47 a
4	7 a	20 a	36 a	55 b
6	6 b	17 b	32 ab	46 c
8	4 c	14 c	29 b	39 d
10	4 c	13 c	28 b	36 d
LSD ($P \leq 0.05$)	0.93	2.87	4.09	6.51
Date	n.s	n.s	n.s	**
Density	**	**	**	**
Interaction	n.s	n.s	n.s	n.s

LSD= Least Significant Difference. Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; $p < 0.05$; ns= not statistically significant statistically. DAP= 28 days after planting

Table. 3. Nitrogen yield as effected by lablab planting density at Dalmada and Syferkuil during 2002/03 growing season.

Density (Plants m^{-1})	Dalmada	Syferkuil
	……………………………Kg/ha…	…………………………
0	29.56	78.08
2	25.99	61.91
4	37.60	61.42
6	20.1	73.07
8	16.63	77.92
10	15.76	73.22

Table. 4. Maize leaf fractions dry matter accumulation at different growth stages as influenced by lablab planting density at Dalmada and Syferkuil during 2002/03 growing season.

	Dalmada				Syferkuil		
Density (Plants m^{-1})	54 DAP	68 DAP	82 DAP		54 DAP	68 DAP	82 DAP
	....	....	....	kg ha^{-1}	....	....	....
0	625 a	1356 a	1575 a		1475 a	1595 a	1857 a
2	594 a	1297 a	1610 a		1449 a	1610 a	1799 a
4	557 a	1191 a	1407 a		1448 a	1603 a	1696 ab
6	460 b	913 b	1060 b		787 b	1166 b	1535 b
8	463 b	952 b	1144 b		744 b	1132 b	1526 b
10	482 b	697 c	960 b		649 b	1089 b	1492 b
LSD (P≤0.05)	93	165	203		239.4	137.52	244.76
Date	**	**	**	**	**	n.s	n.s
Density	n.s	n.s	n.s	**	**	**	**
Interaction	n.s	n.s	n.s	n.s	*	n.s	n.s

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. DAP= Days after planting.

Table.5. Maize stem fraction dry matter accumulation at different growth stages as influenced by lablab planting density at Dalmada and Syferkuil during 2002/03 growing season.

	Dalmada			Syferkuil		
Density (Plants m^{-1})	54 DAP	68 DAP	82 DAP	54 DAP	68 DAP	82 DAP
	....	....	............kg ha^{-1}	....	....	
0	1215 a	1575 a	2336 b	1155 a	2361 a	2979 a
2	1347 a	1610 a	3396 a	1173 a	2405 a	2863 a
4	821 b	1407 a	2418 b	1123 a	1380 a	2559 b
6	625 c	1060 b	1425 c	444 b	1380 b	2067 c
8	652 c	1144 b	1230 c	386 b	1299 b	2002 cd
10	652 c	960 c	1136 d	380 b	1218 b	1749 d
LSD ($P \leq 0.05$)	133	167	200	135.65	287.68	283.97
Date	**	**	**			
Density	n.s	n.s	n.s	**	**	**
Interaction	n.s	n.s	n.s	n.s	n.s	n.s

LSD = Least significant difference. Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. DAP= Days after planting.

Table. 6. Response of upper leaf chlorophyll content to lablab planting date and density at Dalmada during 2001/02 growing season.

	68 DAP		75 DAP		82 DAP		89 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	........Chlorophyll content in SPAD units........							
0	40	40	35	35	33	33	29	29
2	35	37	32	34	28	32	28	31
4	33	38	30	35	30	30	30	31
6	39	35	36	32	33	29	31	26
8	34	36	30	34	27	30	26	24
10	-	-	-	-	-	-	-	-
Date	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Density	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table. 7. Response of upper leaf chlorophyll content to lablab planting date and density at Syferkuil during 2001/02 growing season.

	68 DAP		75 DAP		82 DAP		89 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	……………………………Chlorophyll content in SPAD units……………………………………							
0	44	44	36	36	31	31	29	29
2	36	43	40	34	35	31	33	29
4	42	45	28	37	26	32	23	31
6	37	45	38	34	35	30	33	26
8	38	42	37	31	30	28	29	26
10	-	-	-	-	-	-	-	-
Date	n.s	n.s	*	*	n.s	n.s	n.s	n.s
Density	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. DAP= Lablab planted 28 days after the maize.

Table. 8. Response of upper leaf chlorophyll content to lablab planting date and density at Dalmada during 2002/03 growing season.

Density	54 DAP		68 DAP		82 DAP		96 DAP		103 DAP	
(Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	........Chlorophyll content in SPAD units........									
0	38	38	30	30	35	35	44	44	29	29
2	39	26	32	26	32	37	42	45	30	33
4	38	40	28	30	38	36	46	44	31	32
6	37	40	32	28	35	35	43	47	29	31
8	37	40	33	32	37	33	49	46	28	31
10	37	36	27	29	37	34	51	45	25	30
Date	n.s	n.s	n.s	n.s	*	*	n.s	n.s	n.s	n.s
Density	ns	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table .9. Response of upper leaf chlorophyll content to lablab planting date and density at Syferkuil during2002/03 growing season.

	54 DAP		68 DAP		82 DAP		96 DAP		103 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	………Chlorophyll content in SPAD units………									
0	52	52	51	51	45	45	53	53	50	50
2	53	55	50	53	53	50	51	51	50	54
4	52	53	47	49	52	53	48	51	50	53
6	50	50	47	49	50	52	47	50	49	49
8	50	49	45	49	47	46	46	48	47	48
10	45	47	43	43	46	46	46	47	46	47
Date	**	**	**	**	**	**	**	**	**	**
Density	**	**	**	**	**	**	**	**	**	**
Interaction	**	**	**	**	**	**	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.10. Lower leaf chlorophyll content as influenced by lablab planting date and density at Dalmada during 2002/03 growing season.

Density (Plants m^{-1})	54 DAP		68 DAP		82 DAP		96 DAP		103 DAP	
	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	..................Chlorophyll content in SPAD units..................									
0	51	51	48	47	35	36	13	13	7	7
2	51	53	45	47	34	38	8	12	7	9
4	48	52	45	48	33	33	7	15	3	8
6	47	50	46	45	32	36	10	12	1	6
8	46	50	43	44	34	33	10	17	0.9	5
10	46	45	46	48	33	32	6	12	2	3
Date	n.s	n.s	n.s	n.s	*	*	n.s	n.s	n.s	n.s
Density	ns	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.11. Lower leaf chlorophyll content as influenced by lablab planting date and density at Syferkuil during 2002/03 growing season.

Density	54 DAP		68 DAP		82 DAP		96 DAP		103 DAP	
(Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	……Chlorophyll content in SPAD units……									
0	51	51	47	47	36	37	19	19	14	14
2	52	57	51	50	41	40	24	23	6	17
4	51	53	47	49	37	39	20	22	6	16
6	49	54	45	50	35	40	18	23	4	14
8	51	46	37	43	27	33	10	16	3	14
10	44	44	43	40	33	30	16	13	3	13
Date	**	**	**	**	**	**	**	**	**	**
Density	**	**	**	**	**	**	**	**	**	**
Interaction	**	**	**	**	**	**	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant.
SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.12. Gravimetric soil moisture content at Dalmada as effected by lablab planting date and density during 2001/02 growing season at 0-15cm depth.

	0-15cm			
	84 DAP		98 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP
	..........%			
0	4± 1.9	4± 1.9	3± 2.0	3±2.0
2	2± 1.3	6± 1.2	3± 1.8	8± 7.7
4	5± 1.5	6± 2.5	2± 0.11	7± 6.6
6	2± 1.0	11± 9.3	4± 1.54	8±5.5
8	6± 4.5	12± 4.3	3± 2.3	6± 0.9
10	-	-	-	-
Date	*	*	*	*
Density	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.13. Gravimetric soil moisture content at Dalmada as effected by lablab planting date and density during 2001/02 growing season at 15-30cm depth.

	15-30cm			
	84 DAP		98 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP
	……………………………%…………………………………………			
0	4± 1.3	4 ± 1.31	1.9± 0.9	1.9± 0.9
2	8± 0.7	5 ± 1.2	4.1± 1.0	2.8± 1.7
4	3± 1.32	4 ± 3.6	3 ± 1.5	3 ± 1.5
6	1±0.9	9 ± 7.2	4 ± 0.6	6 ± 0.4
8	4±3.3	10 ± 2.8	5 ± 1.8	6 ± 3.4
10	-	-	-	-
Date	**	**	**	**
Density	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.14. Response of gravimetric soil moisture content to lablab planting date and density at Dalmada during 2002/03 growing season at 0-15cm depth.

	0-15 CM					
	84 DAP		98 DAP		112 DAP	
Density (Plantsm^{-1})	SM	28 DAP	SM	28 DAP	SM	28 DAP
	%					
0	8 ± 2	8 ±2	17 ± 6	17 ± 6	6 ± 2	6 ± 2
2	10 ± 2	9 ±1	9 ± 5	13 ± 1	4 ± 0.6	7 ± 9
4	9 ± 1	9 ± 0.4	8 ± 2	11 ± 1	6 ± 1	7 ± 1
6	6 ± 2	14± 8	11 ± 3	15 ± 7	4 ± 1	5 ± 2
8	10 ± 0.9	7 ± 2	12 ± 2	14 ± 3	5 ± 1	6 ± 0.9
10	6 ± 1	8 ± 0.6	11 ± 3	11 ± 3	6 ± 0.8	5 ± 1
Date	n.s	n.s	n.s	n.s	n.s	n.s
Density	n.s	n.s	*	*	n.s	n.s
Interaction	**	**	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p < 0.01$; *= $p < 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.15. Response of gravimetric soil moisture content to lablab planting date and density at Dalmada during 2002/03 at 15-30cm depth.

	15-30CM					
	84 DAP		98 DAP		112 DAP	
Density (Plantsm^{-1})	SM	28 DAP	SM	28 DAP	SM	28 DAP
	……………………………………%……………………………………					
0	10 ± 4.0	10 ± 4.0	6 ± 2.0	6 ± 2.0	12 ± 7.0	12 ± 7.0
2	11 ± 0.9	10 ± 3.8	5 ± 0.6	6 ± 0.7	10 ± 3.3	14 ± 6.3
4	9 ± 0.4	7 ± 1.8	2 ± 0.9	9 ± 1.2	9 ± 5.5	17 ± 9.6
6	11 ± 2.9	10 ± 1.5	5 ± 0.9	6 ± 2.0	12 ± 2.7	11 ± 1.1
8	8 ± 0.8	8 ± 0.3	6 ± 1.3	5 ± 0.9	10 ± 2.3	11 ± 2.3
10	8 ± 0.6	6 ± 2.2	5 ± 0.8	5 ± 1.3	7 ± 4.9	11 ± 1.0
Date	*	*	n.s	n.s	n.s	n.s
Density	n.s	n.s	**	**	n.s	n.s
Interaction	*	*	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= p< 0.01; *= p< 0.05; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.16. The influence of lablab planting date and density on gravimetric soil moisture content at Syferkuil during 2001/02 growing season at 0-15cm depth.

	0-15CM			
	84 DAP		98 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP
	%			
0	5 ± 2.4	6± 2.4	5± 2.3	6± 2.3
2	4 ± 1.2	8± 1.2	5± 1.8	10± 7.7
4	7± 1.6	8± 1.2	4± 0.1	9± 6.6
6	4± 1.0	13±2.5	6± 1.5	10± 5.5
8	8± 4.5	14±9.3	5± 2.3	8± 0.9
10	-	-	-	-
Date	n.s	n.s	*	*
Density	n.s	n.s	n.s	n.s
Interaction	n.s	n.s	n.s	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.17. The influence of lablab planting date and density on gravimetric soil moisture content at Syferkuil during 2001/02 growing season at 15-30cm depth.

	15-30cm			
	84 DAP		98 DAP	
Density (Plantsm^{-1})	SIM	28 DAP	SIM	28 DAP
	……………………%……………………			
0	2± 1.7	5± 1.7	5± 3.7	3± 3.7
2	3± 0.7	7± 1.2	6± 1.0	6± 1.8
4	6± 1.3	6± 3.6	5± 1.5	5± 1.5
6	4± 0.9	11± 7.2	6± 0.6	6± 0.4
8	8± 3.3	10± 2.8	7± 1.8	7± 3.9
10	-	-	-	-
Date	*	**	n.s	n.s
Density	**	**	**	**
Interaction	n.s	n.s	ns	n.s

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.18. Response of gravimetric soil moisture content to lablab planting date and density at Syferkuil during 2002/03 growing season at 0-15cm depth.

Density (Plantsm^{-1})	0-15 cm					
	84 DAP		98 DAP		112 DAP	
	SM	28 DAP	SM	28 DAP	SM	28 DAP
	……………………………………………… % ………………………………………………					
0	8 ± 1	8 ± 0	3 ± 0	3 ± 0	12 ± 0	12 ± 0
2	9 ± 0	12 ± 0	3 ± 3	5 ± 0	6 ± 0.04	12 ± 0.9
4	8 ± 0	9 ± 0.4	2 ± 0	5 ± 0	6 ± 0	14 ± 0
6	9 ± 0	17 ± 6	2 ± 0	5 ± 0	6 ± 0.9	14± 3
8	8 ± 0	21 ± 0	1 ± 0	5 ± 0	4 ± 0	16± 4
10	7 ± 0	31 ± 0	1 ± 0	5 ± 0	6 ± 4	23± 0.7
Date	**	**	**	**	**	**
Density	**	**	n.s	n.s	**	**
Interaction	**	**	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.

Table.19. Response of gravimetric soil moisture content to lablab planting date and density at Syferkuil during 2002/03 growing season at 15-30 cm depth.

	15-30 cm					
	84 DAP		98 DAP		112 DAP	
Density ($Plants m^{-1}$)	SIM	28 DAP	SIM	28 DAP	SIM	28 DAP
	………………	………………	………………	%………………	………………	………………
0	9 ± 4	9 ± 4	8 ± 0	8 ± 0	10 ± 0.2	10 ± 0
2	8 ± 4	12 ± 5	4 ± 2	8 ± 0	10 ± 0	12 ± 0.9
4	9 ± 4	10 ± 8	5 ± 0	8 ± 0	8 ± 0	14 ± 0
6	8 ± 0	18 ± 0	4 ± 0	8 ± 0	7 ± 0	14± 0
8	7 ± 4	18 ± 8	4 ± 0	15 ± 0	4 ± 0.1	21± 0
10	7 ± 4	24 ± 2	7 ± 0	17 ± 0	5 ± 0	25± 0.1
Date	n.s	n.s	**	**	**	**
Density	**	**	n.s	n.s	**	**
Interaction	n.s	n.s	**	**	**	**

Means followed by the same letter within columns are similar statistically; **= $p< 0.01$; *= $p< 0.05$; ns = not statistically significant. SIM= Simultaneous planting. 28 DAP= Lablab planted 28 days after the maize.