GRAIN YIELD, GRAVIMETRIC MOISTURE CONTENT, DRY MATTER ACCUMULATION AND CHLOROPHYLL PRODUCTION IN MAIZE-LEGUME INTERCROP UNDER MINIMUM AND CONVENTIONAL TILLAGE SYSTEMS

MOKGADI MIZEN RAMOROKA

DISSERTATION SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE MASTER OF AGRICULTURAL MANAGEMENT (AGRONOMY)

DEPARTMENT OF PLANT PRODUCTION, FACULTY OF SCIENCE AND AGRICULTURE,
AT THE **UNIVERSITY** OF LIMPOPO, SOUTH AFRICA

AUGUST 2008

SUPERVISOR: PROF. K. K. AYISI

Table of contents

LIST OF TABLES

LIST OF FIGURES

DISSERTATION ABSTRACT

379 words

Maize is a dominant crop in smallholder farming systems in the Limpopo province of South Africa, generally cultivated as intercrop with grain legumes. The major constraint in this cropping system is inadequate soil moisture during the growing season, which also limits nutrient availability to the component crops. The minimum tillage system has been reported to improve soil moisture availability on farmers' fields but this has not yet been verified in an intercropping system in the province. The objective of this study was to quantify grain yield and chlorophyll production of intercropped maize, and to assess seasonal moisture availability under minimum tillage (MT) and conventional tillage (CT) systems. Dryland field experiments were conducted at two locations in the province namely, farmer's field at Dalmada in 2002/2003 and 2003/2004 growing seasons and at the University of Limpopo Experimental farm at Syferkuil during the 2003/2004. The experimental design was a randomized complete block in split plot arrangement at all locations and seasons. Tillage systems consisting of conventional tillage and minimum tillage were the main plot treatments, whereas five different cropping systems namely, sole maize, and maize intercrop with cowpea (variety, Bechuana White), cowpea (variety, Agripers), Lablab bean (variety, Rongai) and Velvet bean were assigned as sub-plot treatments. Maize grain yield in 2002/2003 at Dalmada was significantly lower (357 kg/ha) under CT relative to 755kg/ha under MT. In 2003/2004 at Dalmada, grain yields under the two systems were similar, where as at Syferkuil, 15% higher grain yield results was obtained under MT. Minimum tillage systems resulted in higher number of maize cobs per plant at Dalmada in both growing seasons and weight per cob was

higher under MT at both locations and seasons. At Dalmada, significantly higher soil moisture was recorded under the MT relative to the CT depending on depth and sampling dates. Chlorophyll content of the youngest fully expanded leaves of maize was generally higher under MT than CT, but this was observed only at the later stages of plant growth. The results also showed that the rate of senescence (reduced chlorophyll content in older leaves) was higher in maize plants grown under CT relative to those under MT. The minimum tillage system has shown the potential of being a superior system for dryland maize production, but further research involving additional locations is required to ascertain this fact.

CHAPTER I

GRAIN YIELD, GRAVIMETRIC MOISTURE CONTENT, DRY MATTER ACCUMULATION AND CHLOROPHYLL PRODUCTION IN MAIZE-LEGUME INTERCROP UNDER MINIMUM AND CONVENTIONAL TILLAGE SYSTEMS.

GENERAL INTRODUCTION AND LITERATURE REVIEW

Maize is the major field crop produced by smallholder and commercial farmers in the Limpopo province. Worldwide, maize is considered a staple food crop for mankind through direct consumption and indirectly through animal feed (Evans, 1993). The crop originated from Mexico but its production spread quickly around the world. In the Limpopo province, maize is generally cultivated as intercrop with grain legumes such as cowpea, groundnut and bambara nuts. Grain legumes are major sources of protein for humans. Intercropping is reported to be one of the most common cropping systems in Africa (Vandemeer, 1992). Some of the advantages of including grain legumes in cropping systems are, reduced insect and disease problems, improved soil N availability through biological nitrogen fixation by the legumes, and increased yield per unit area (Van Rensburg, 1998).

Water is an important constituent of all living cells, comprising approximately 90% of the plant tissue and it is a medium for proper nutrition and healthy growth in higher plants. It is also required for cellular activities and maintenance of turgor pressure within cells. The water in plant cells keeps the stem upright and maintains expanded leaves so as to receive sunlight for photosynthesis. Hence, any water stress during the course of growth constitutes a major limitation to crop growth and development and final yield (Modiba, 2002).

In South Africa and Limpopo Province in particular, water is the most limiting production resource among smallholder farmers engaged in field crop production. A dry and cold winter and hot summer with few raining days characterize the Limpopo province. Moisture evaporates very quickly because of the prolonged hot days.

Water sources are generally scarce, and agriculture's share of these resources is competing with the domestic and industrial sectors.

Agriculture in the Limpopo province is an active sector but unless moisture availability during crop growth is maintained on farmer's fields, productivity of crops will remain marginal. Irrigation is currently the most effective means of minimizing the constraint of moisture in the cultivation of crops but this facility is available to only a small proportion of the entire farming population in the province. In the production of a crop such as maize, moisture stress especially during the reproductive stage can lead to drastic yield reduction in grain mass. The initial effects of water stress could occur during the process of germination and emergence. Germination of maize seed, like that of many field crops, is very sensitive to water shortage and therefore, reduced soil moisture potential during the germination process can limit moisture movement through the seed coat. Water deficits can drastically reduce the yield from its genetic potential to zero. In the Limpopo province, losses in crop yields from water deficits probably exceed the losses from all other yield-reducing causes combined.

Low soil nitrogen and phosphorus content are the next limiting production factors in the Limpopo province and South Africa as a whole. Nitrogen stress in field crops generally decreases leaf area index, leaf area duration and crop photosynthesis rate, all of which leads to lower radiation interception, decreased crop growth rate, and hence lower grain yield (Barbieri *et al*., 2000). Olaoye, (2002) found that an increased surface residue under minimum tillage and the resulting increase in organic matter had a positive effect on corn yield in some but not in all soil types. Authors further indicated that the increase in surface residue which results in a long term increase of organic matter can improve soil and its water management, especially in soils which are naturally low in organic matter. Improvement in soil fertility can be achieved by retaining or incorporating crop residues on the field and supplementing the residues with mineral fertilizers and also through the extensive use of leguminous species in rotational or intercropping systems. Retaining crop residues maintains soil fertility through the slow build up of soil organic matter, thereby improving aggregation and water-holding capacity of soils (Belay *et al*., 1998).

Plants obtain the bulk of their nitrogen requirements primarily as nitrate and ammonium from the soil. It is well documented that the mineral nutrition of plants is related, in many ways directly or indirectly, to soil moisture since the root hairs absorb dissolved plant nutrients from the soil solution. Dry soils will obviously result in lower nutrient uptake since the lack of water reduces nutrient flow and diffusion. Nitrate is very water-soluble and its movement through the soil via the process of mass flow to plant roots is reduced when soil moisture is low (Modiba, 2002).

An important cropping system that has been reported to improve soil moisture availability on farmers' fields in recent years is the No-till or reduced tillage system. No-till system is a production practice, where the soil is left undisturbed from harvest to planting, except in a narrow seedbed and for nutrient application (Unger, 1991). No-till system has been defined as one in which the crop is planted either without tillage or with just sufficient tillage to allow placement and coverage of the seed with soil to allow it to germinate and emerge (Torbert *et al*., 2001). It has been further defined as the use of herbicides or other method of killing all live plants on the surface of the soil, followed by as little disturbance of the soil as possible to provide good seed placement. No-till system leaves crop residues on the soil surface that reduces the risk of water and wind erosion. It also reduces soil temperature, minimizes soil water evaporation and hence increases water availability in the soil for crops to grow. The system can also reduce the requirements for labour and the general cost of production, which create the potential for higher profitability (Rozas *et al*., 1999).

Currently, the main soil preparation method in the Limpopo province is by the conventional tillage system, which involves ploughing followed by disking. Conventional tillage system is designed to prepare a seedbed by eliminating almost all the residue that is left on the soil surface. The major goals of using conventional tillage system by farmers are to control weeds prior to planting and also to prepare a fine seedbed for placement. Ploughed surface may also improve water infiltration for a short period of time after an initial tillage operation. However, the long-term effects of it are generally, a steady decline in soil structure, which reduces soil porosity, increases erosion and hence reduced soil fertility and productivity. The adoption of the no-till system thus has the potential of improving soil moisture and nutrient availability during crop growth. However, since the system is relatively new in the Limpopo province, thorough information needs to be generated before recommendations are made to farmers.

Water resources are generally scarce, not only in South Africa but in many other parts of the continent. In South Africa, field crop production is mainly carried out summer rain conditions. Rainfed crop production under this climate thus depends strongly on both the amount and distribution of rain. The amount of rainfall is however low and generally poorly distributed and as a result, crop yield and water use efficiency are low and variable (Oweis *et al*., 2000).

Although water is the most abundant compound on earth, severe to occasional deficits can occur during a growing season, which can have devastating effects on crop productivity. The water used per day by maize generally increases rapidly from about 30 days before silking, peaks during fertilization and early grain fill and declines thereafter (Sprague and Dudley, 1988). Smith (1995) also, reported that moisture deficit is most damaging during the silking to early grain fill period, causing up to 8 percent yield reduction per day of stress. It is therefore important for maize farmers to time the planting date so that the peak water demand of the crop coincides with periods of rainfall abundance.

Moisture stress interrupts photosynthesis and growth until turgor is restored by removal of the stress. Sprague and Dudley (1988) pointed out that, a deficit of water is the single most important factor limiting crop yield on the worldwide scale. Water use varies with the stage of development of the maize crop. Early in the growing season the loss is primarily evaporation from soil. As the crop cover increases, transpiration becomes an increasingly dominant factor.

No-till increases the water availability for the crop. By using the no-till system, surface residue can be managed to better conserve soil water for greater use efficiency by the plant. Water loss is different under no-till system, compared with a conventional tillage system (Daniel *et al*., 1999). Soil water storage is greater where there is no-till compared to stubble mulching or where disk tillage was used (Unger, 1991). Daniel *et al*., (1999) reported that surface residue potentially increases infiltration of water into the soil by 25 to 50% under no-till as compared to conventional tillage system. With conventional tillage, the soil surface is unprotected against moisture evaporation from the beginning of the growing season until the end. Moisture evaporation can also be minimized by using cover crops or cereal-legume intercrops.

Maize is one of the most suitable crops for cultivation under no-tillage (Rozas *et al.*, 1999). No-till has the effect of increasing water infiltration and storage due to the soil cover and the undisturbed soil structure as compared to conventional tillage. Soil cover reduces water evaporation, keeps moisture in the soil, it does not disturb the biological activities of the soil and makes water available to the root system. No-till system can be effective not only in increasing soil and water conservation, but also by reducing labor requirement and time (Kladivko, 2001;Yusuf *et al*., 1999; Rozas, 1999).

Cereal-legume intercrops are common throughout Africa and also in the Limpopo Province of South Africa. There are many advantages of the system compared to sole cultures. Two main reported advantages in intercrop system are transfer of nitrogen fixed by legumes to the companion grass species (Brophy and Heichel, 1989; Eaglesham *et al*., 1981) and the control of spread of diseases and pests (Ayisi and Mposi, 2001 and Maluleke, 2004). These advantages vary over factors such as plant species, planting dates, soil moisture and soil fertility. Cereals can be intercropped with legumes, such as cowpea (*Vigna unguiculata*), lablab (*Lablab purpureus*) and velvet bean (*Mucuna pruriens*) and other legumes.

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 practised to maximize productivity of land, which often increases the total crop yield above that of the 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.

In Africa, up to 90% of legumes are produced as intercrop with maize, millet or sorghum, although sole crops of legumes are important in some parts of West Africa (Vandemeer, 1992). Cowpea is one of the legumes that is widely intercropped. In maize/cowpea intercropping system, the two components grow vigorously at about the same time and therefore competition for available resources such as solar radiation, moisture and nutrients is high. Solar radiation is a major resource determining growth and yield of component crops in intercropping, especially when other resources (e.g. water and N) are not severely limiting crop growth. As maize plants become increasingly taller than cowpea plants, radiation becomes less available to the cowpea. Some cowpea cultivars may mature before the adverse effect of associated maize crop becomes severe and often early-maturing cowpea cultivars are advantageous in intercropping (Watiki *et al*., 1993).

Maize can also be intercropped with legume cover crops such as velvet bean (*Mucuna pruriens*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*). These cover crops are widely promoted as means of reversing or slowing down the negative effects of landuse. Legume cover crops are used as improved fallows and intercropped in major cereal cropping systems (Hartkap *et al*., 2002). Suggested benefits include reduced soil erosion and weed competition, as well as improved soil fertility and structure.

Velvet bean is one of the widely used Legume cover crops in maize production systems in Meso America, West and South Africa. It is a vigorous, large seeded, twining annual climbing legume with a growth cycle of 120-180 days, depending on cultivar, planting date and environment (Hartkap *et al*., 2002). It has been proven in Zimbabwe that velvet bean is a good nutritious crop as animal feed, both on dairy and beef cattle (Murungweni *et al*., 2002). It has high level of protein and accumulates large quantity of dry matter. Hartkap *et al.*, (2002) reported that velvet bean can be introduced into maize production systems in several arrangements including rotation, relay cropping and intercropping. The benefits of velvet bean-maize systems may vary with the arrangement of the crop relative to the maize crop, as well as the climate and soil environment where it is grown.

Lablab bean (*Lablab purpureus*) is a leguminous species that has the potential to be intercropped with maize because of its drought tolerance characteristics and ability to produce large biomass quickly. Lablab originated in Asia but it is now grown for food throughout the world. The crop is capable of contributing to the soil N pool through symbiotic fixation and its biomass production can be used as cover cropping and mulching. Preliminary studies conducted on lablab in the province indicated that the crops could be very aggressive and competitive and if not well managed, could severely suppress maize yields in an intercropping system.

One of the benefits of leaving plant residue on the soil surface is to reduce soil moisture evaporation, improve the soil structure and increase the status of soil organic matter. Any tillage method that leaves at least 20% of the surface soil covered with crop residue is considered a conservative tillage (Olaoye, 2002; Kladivko, 2001). Olaoye, (2002) indicated that residue placement preceding and during the growing season, especially the amount remaining on the soil surface, affect accumulation of soil organic matter, soil erodibility, soil temperature and soil moisture. They may also affect crop growth, maturity and yield.

According to Yusuf *et al.*, (1999), production results under no-till system changes soil physical properties and can also increase soil organic matter content. These changes influence the plant growth. The change can be detrimental, neutral or beneficial for crop growth and yield depending on soil structure and texture, climatic factors such as rainfall and weed control. Generally, no-till system have greater yield when used in soils characterized by low organic matter and poor structure, rather than in well-structured soils with high organic matter content.

The objective of this study is to determine the growth, moisture and nitrogen dynamics in maize-legume intercropping as influenced by tillage systems.

CHAPTER 2

YIELD AND YIELD COMPONENTS OF MAIZE-LEGUME INTERCROP SYSTEM UNDER MINIMUM AND CONVENTIONAL TILLAGE.

INTRODUCTION

Reduced tillage is an important soil conservation system in crop production. To increase and maintain sustainability of crop yields in the Limpopo province, available water should be efficiently utilized. Water is identified as the most widely limiting factor for crop production in the province. As maize is the most important food crop in most areas of the province, its yield needs to be maintained or enhanced to ensure food security.

Increased water use efficiency (WUE) is of greatest interest to farmers when yields are maximized for the available water supply in each growing season. High water use efficiency is of less interest if it is not associated with high yields. Economic benefits from increased water use efficiency under water-limiting conditions are usually achieved only if yield is maximized for the available water (Sinclair and Muchow, 2001). WUE, the ratio of grain yield to crop water use, provide a simple means of assessing whether yield is limited by water supply or other factors (Angus and van Herwaarden, 2001). Water availability plays a major role in the regulation of seed development and maturity.

Sinclair and Muchow (2001) reported that crops that establish deeper root systems clearly increase crop yields while earlier maturity and osmotic adjustment had little or no benefit. According to the authors, increasing soil volume occupied by roots was the most effective adaptive mechanism for increasing growth during succession drying cycle. Crops will be able to resist drought and even lodging caused by strong wind.

Increased water storage within the soil profile is necessary to increasing plant available soil water. Tillage roughens the soil surface and breaks apart any soil crust. This leads to increased water storage by increasing infiltration into soil as well as decreasing soil water losses by evaporation compared to residue-covered surface or an undisturbed surface. If surface residue is buried, the soil surface can become smooth and infiltration rates can decrease for subsequent rain events (Hatfield et al., 2001). Many authors reported that the grain yield of most cereals (maize, sorghum wheat, etc) is higher with reduced tillage, than with conventional tillage. More water is conserved during the fallow periods and there is deeper wetting of the soil profile in reduced tillage plots.

Reduced tillage systems increase the amount of plant residues left on soil surface. The presence of residue on the surface reduced soil water evaporation by 34-50% (Hatfield et al., 2001). Availability of crop residue does not only increase soil water availability but also increases nitrogen availability to plants and soil organic matter. Nitrogen is a complex part of the soil system and its availability is affected by soil type, tillage, N resources (e.g. fertilizer and manure) and crop rotation. Nitrogen is a major nutrient required by maize crop for higher grain yields and quality kernels, and it is a key resource in influencing grain productivity of maize (Bratia and Mitra, 1990). Nitrogen is also a dominant factor affecting plant chlorophyll content, which is generally related to yield (Reeves et al., 1993). Inorganic nitrogen fertilizers are usually applied to maize as available nitrogen is limited in most soils (Sallah, 1991). Nitrogen deficiency in maize may be detrimental to yield and quality, hence must be avoided.

The specific objectives of this study are:

1. To determine the effect of tillage systems on grain yield of maize and legumes in an intercropping system.
2. To evaluate yield components as affected by the tillage system.
3. To determine the response of agronomic characteristics of component crops (flowering, silking, tasselling and physiological maturity) to the tillage systems.

MATERIALS AND METHODS

Field experiments were conducted at two locations in the Limpopo province namely, University of the North Experimental farm at Syferkuil and at Dalmada on a farmer's field. At Dalmada, the experiment was conducted during the 2002/2003 and 2003/2004 growing seasons, whereas at Syferkuil it was conducted in 2003/2004. The landtypes present at the experimental site at Dalmada is Ia132 and that of Syferkuil is Bc56. The dominant soil form at Dalmada is Dundee followed by Valsrivier, whereas at Syferkuil, the dominant forms are Hutton and Bainsvlei. The characteristic of the soil forms and their suitability for crop production is presented in table 2.1 (Soil classification working group, 1991)

Table 2.1. Soil form characteristics and their level of suitability for crop production.

Soil form	**Land types characteristics**	**Suitability for agriculture**
Hutton	This soil type is defined as a succession of red-coloured sandy material that exhibits little or no structure and is deemed freely draining. The topsoil horizon is Orthic A, which do not show organic, humic, vertic or melanic character. This material is generally easy to excavate by hand or light mechanical tillage implements. *Clay content ranges from 10 -25 % and* exhibits moderately low to low permeability.	Suitable
Dundee	Soil depth exceeds 1200 mm and a clay content of 15 - 20 %. It is characterised by seasonal perched water table which may subject it waterlogging conditions.	Moderately suitable
Bainsvlei	This soil type is defined as a succession of red-coloured sandy material underlain by soft ferricrete, and is indicative of the seasonal occurrence of perched water tables at relatively shallow depth. Although the upper sandy horizons are generally easy to excavate by hand or light mechanical excavator, the soft ferricrete occurring at depth may prove difficult to remove, especially during the drier months. The sandy upper soil layers may exhibit a potentially compressible and/or collapsible character. *Bainsvlei* soil also exhibits moderately low to low permeability, and the possibility of lateral movement of liquids within the sandy topsoil layers is there.	Moderate suitability
Valsriveir	Soil depth exceeds 1200 mm and a clay content of 15 - 20 %. It is characterised by strongly structured clays which may be difficult to excavate by hand. The soil is potentially expansive which may interfere with proper root development.	Moderately suitable

The soil type at Dalmada is sandy-clay loam and at Syferkuil, loamy sand.

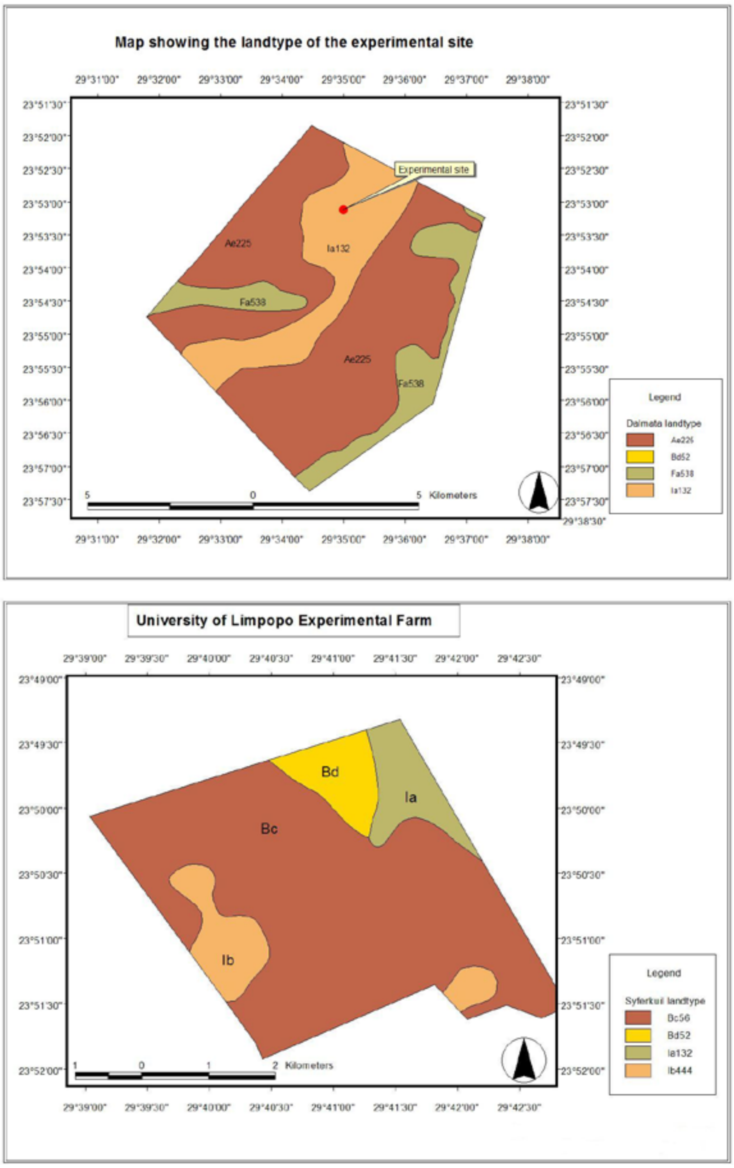


Fig.2.1: Land type maps at Dalmada and at the University of Limpopo Experimental farm at Syferkuil.

Prior to land preparation, representative soil samples were taken from the two project locations and analyzed for nutrient concentration and textural classes. Two spots from the demarcated experimental site were sampled during 2003/2004 at both locations and one sampling spot during 2002/2003 at the depth of 0-300 mm for topsoil and 300-600 for subsoil (table 2.2).

Temperatures at both locations during the two growing seasons are presented in figure 2.2, whereas rainfall and evaporation are presented in fig 2.3. Land preparation was done three to two days before planting at both locations in the two growing seasons, using tractor, ripper planter, disk and hoes. The experiment was conducted under dryland but irrigation was applied at a critical stage of maize when the rainfall was not received for an extended period.

Experimental Design

Randomized Complete block in Split plot arrangement was used as an experimental design with five replications during 2002/2003 growing season and four replications in 2003/2004. Tillage systems consisting of conventional tillage and minimum tillage were the main plot treatments whereas five different cropping systems were assigned as the sub-plot treatments. The sub-plot treatments were, sole maize and maize intercrop with Bechuana White, Agripers, Lablab bean and Velvet bean. The conventional tillage system consisted of ploughing, disking and planting of maize using a conventional planter, whereas under the minimum tillage system, maize was planted using the ripper planter without ploughing or disking. Under both tillage systems, an inter row spacing of 0.9m was maintained for maize at a density of 25000 ha^{-1}. The legumes were planted by hand between the maize at a density of 55000 plants ha^{-1} for the Cowpea varieties, Lablab and Velvet bean. Maize was planted on 11^{th} December at both locations and years whereas the legumes were planted approximately a month later on the 07^{th} and 09^{th} January 2004 at Syferkuil and Dalmada respectively. Weeding was done by hand, twice at both locations and seasons during the growing season.

Agronomic characteristics

Days to flowering, anthesis and silking of maize were scored when 50% of the plants on an experimental unit had displayed these traits. Physiological maturity was scored when 90% of the maize plants do not show kernels with milk line. Flowering and pod stage of legumes was also scored at 50 %, while the physiological maturity was scored when 90% pods had turned brown and when seeds rattled pods were shaken.

Yield and Yield components

Grains of both maize and legumes were harvested manually after physiological maturity to determine grain yields. The harvested area was 12.6 m^2 and 18.0 m^2 at Syferkuil and Dalmada respectively from the middle rows of each experimental unit. The maize cobs were oven dried at 65^0C in the laboratory to reduce grain moisture to approximately 14%. Maize yield components were determined after drying as weight per cob, cob number per plot, cob number per plant, rows per cob, number of kernels per row, number of kernels per cob, 100 seed mass (table 2.3). Yield components of legumes were also determined after drying the pods as pods number and weight per plant, number of seeds per pod, pods length and 30 seeds weight.

Data Analysis

Data were subjected to analysis of variance (ANOVA) as outlined by Statistical Analysis System (SAS Institute, 1990) to detect statistical significance of treatments. Differences between treatment means were separated using the least significant difference (LSD) procedure (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Site characteristics

Initial soil condition

The topography at both experimental locations was relatively flat with a slope of approximately 1 – 2 %. Nutrient runoff is thus, expected to be minimal at the two sites.

The soil pH at the experimental sites ranged from 7.6 - 7.8 during the 2002/2003 growing season at Dalmada. In 2003/2004, the pH ranged from 6.8 - 7.7 and 6.6 - 8.1 at Syferkuil and Dalmada respectively. The pH at the experimental sites is close to neutral and this should enhance the efficient nutrient ion release for crop growth and development.

The available nitrogen levels in the top and sub soils ranged from 8 - 13 $mg\ kg^{-1}\ N$ at Syferkuil and 1-3 $mg\ kg^{-1}\ N$ at Dalmada in both growing seasons. These N concentrations correspond approximately to 32 - 52 kg N ha^{-1} at Syferkuil and 4 - 12 kg N ha^{-1} at Dalmada. The soil nitrogen concentration is relatively low with the severe deficiency occurring at Dalmada. Supplementary nitrogen as Urea was applied as topdress at a rate of 30 kg N ha^{-1}, three weeks after planting at both locations to improve growth of maize.

Phosphorus concentration at Syferkuil was 18 – 32 $mg\ P\ kg^{-1}$ compared to 1 - 24 $mg\ P\ kg^{-1}$at Dalmada. P concentration of 20 $mg\ P\ kg^{-1}$ is usually the recommended minimum satisfactory growth of grain crops. Super phosphate was applied at planting at both locations at a rate of 30 kg P ha^{-1} at Dalmada and 15 kg P ha^{-1} at Syferkuil to improve available phosphorous concentration in the soil.

Potassium concentration ranged from 30 - 117 *mg K* kg^{-1} At Syferkuil, and from 110 - 305 *mg K* kg^{-1} and 99 - 515 *mg K* kg^{-1} at Dalmada in 2002/2003 and 2003/2004 respectively. The soil potassium concentration was generally adequate at the two locations and hence no supplementary fertilizer was applied. The concentrations of Ca, Mg, Na, Cl and Zn were adequate at both locations.

Weather

The seasonal temperature (max and min) was recorded at both locations and the readings are presented in figure 2.2. Syferkuil experienced a relatively hotter summer temperature with the maximum temperature of 30.2 ^{o}C. The minimum temperature at Syferkuil was 1.5 ^{o}C during winter. At Dalmada the recorded temperatures for two growing seasons were 29.9 ^{o}C maximum and 9.6 ^{o}C minimum in 2002/2003 and 29.2 ^{o}C maximum and 3.1 minimum in 2003/2004. The data suggests the possibility of frost during winter months at both locations.

According to the recorded seasonal rainfall on both locations, Syferkuil received relatively high rainfall (132.5 mm) during December month when the experiment was established. The total rainfall of 481.4 mm was received at Syferkuil for the entire growing season. 22 mm and 48.7 mm rainfall received in Dalmada during 2002/2003 and 2003/2004 respectively during December month. An average of 124.3 mm evaporation occurred at Syferkuil, 132.5 mm and 133.4 mm at Dalmada 2002/2003 and 2003/2004 respectively. Due to high amount of moisture evaporation at both locations supplementary irrigation was in place and applied during the critical stages of drought.

Grain yield

Maize

Maize grain yield was influenced by the tillage systems at both locations (Fig. 2.4). At Dalmada in 2002/2003, maize yielded higher under minimum tillage (MT) compared to conventional tillage (CT). Maize yields of 357 kg/ha and 755kg/ha were obtained from CT and MT respectively during 2002/2003 growing season. During 2003/2004 growing season, maize yielded equally between CT and MT (Fig. 2.4). Significant differences were observed at Syferkuil during 2003/2004. Maize grain yield was 15.3% higher under MT tillage at Syferkuil compare to CT (Fig. 2.4). Mehdi *et al*., (1999) also found that maize yield is often higher under minimum tillage, because MT crops are more efficient at utilizing soil N than conventionally tilled crops. Moisture content under the MT was reserved for longer period due to the undisturbed soil. Root penetration was also observed to be deeper compared to CT. These factors might have contributed to higher maize yield recorded under MT in the present study. According to Vandermeer (1992), in an intercropping system, component crop can positively modify the growing environment for the benefit of the other crop which can lead to overall yield advantage in the intercropping system relative to the sole crop. In this study, later planting of legumes, though low growing rate was observed, suppressed weeds to some extent in the intercrop plots, creating cooler soil conditions which could have benefited the maize crop (Maluleke, 2004)

Legumes

The legumes did not produce any yield at both locations except for only few border rows that flowered. The legumes were planted a month after maize which may be one of the reasons for lack of reproductive growth. Lower rainfall was received at both locations and in both growing season. At Dalmada a heavy hail storm was experienced during the middle of the growing season when legumes were only a month old causing significant damage to the crops.

A legume such as lablab bean has a long growing duration, ranging from 70-300 days which may lead to failure or delay of flowering during the dry seasons (Maluleke, 2004). According to Gardiner and Cracker (1981), bean-maize intercrop plantings increase light interception and decrease light reflection as compared with bean solecrop plantings. However, the quantity of light available to the bean canopy is decreased as the maize population is increased.

Maize yield components

Number of rows per cob

At Dalmada in 2002/2003 the number of rows per cob was highly influenced by tillage systems. Maize under MT produced cobs with 14 rows compared to 12 under CT (Table 2.3). Legumes under MT grew taller as compared to CT, therefore the increase on row per cob might be associated with the favourable growing environment created by from the legumes. During 2003/2004 growing season, the measured parameter was non significant at both locations (Tables 2.3 and 2.4). The lack of significant effect is an indication that these parameters are generally not environmentally dependent but rather genetically controlled (Modiba, 2002)

Number of kernels per cob

Kernel number per cob was highly significant at Dalmada in 2002/2003 with maize under MT producing 31% more kernels per cob than under CT (Table 2.3). A similar trend was observed at Syferkuil during 2003/2004 growing season where MT produced significantly higher results than CT. Kernels per cob was 14% higher in the MT system than in the CT system (Table 2.5).

The number of kernels per cob at Dalmada in 2003/2004 growing season did not show any significant results (Table 2.3). The best on number of kernels per row was recorded under minimum tillage compared to the conventional tillage system except at Dalmada in 2003/2004. This implies that the moisture stress was not high as on the CT. Kernel number is one of the parameters that determine the grain yield and it depends on the rate of grain-filling, duration and stress during the reproduction stage (Wang *et al*., 1999).

Number of kernels per row

Significantly higher number of kernels per row on maize cob was recorded under MT compared to CT at the two locations. The effect was not significant at Dalmada in 2003/2004 (Table 2.4). MT was 21% and 8.6 higher than CT respectively at During 2002/2003 growing season (Table 2.3). The number of kernels set is more critical for maize yield and it is more affected by environment (Andrade *et al*., 2000).

Unfavourable environmental conditions at the period of flowering and silking can cause the reduction in number of kernels per row.

Number of cobs per plant

Minimum tillage systems resulted in higher number of maize cobs per plant at Dalmada during both growing seasons (Table 2.3 and 2.4). Number of cobs per plant was non significant at Syferkuil (Table 2.5).

Weight per cob

The effect of tillage systems was significant at all locations in both seasons. Weight per cob recorded under MT was higher at both locations and growing seasons (Table 2.3-2.5). Weight per cob is associated with the grain-filling stage. Cobs produced under MT were bigger and well filled compared to CT production. Similar results of lighter cob weight under CT were observed by Ghaffarzadeh *et al*., (1997).

Hundred Seed mass

Hundred seed mass was not affected by tillage system at both locations and in all growing seasons (Table 2.3-2.5).

Agronomic Characteristics

Tasseling and Silking

Days to tasseling was influenced by the tillage system only at Dalmada during 2002/2003 growing period (Table 2.7). During 2003/2004 growing season, there was no significant difference at both locations (Table 2.7). Tasseling is an important phonological stage of crop development because it signals change of growth of annual crops from vegetative to generative phase, essential for yield of most crops (Modiba, 2002). Days to silk emergence were significant highly affected by tillage at Syferkuil and not at Dalmada in both seasons (Table 2.7).

Maturity

There were no significant differences for days to physiological maturity between CT and MT systems for 2002/2003 and 2003/2004 growing seasons at Dalmada. Significant differences between tillage systems were observed at Syferkuil during 2003/2004 growing season. CT system, maize matured a day earlier than maize planted in the MT system (Table 2.7). Days to physiological maturity did not appear to have contributed significantly to grain yield differences observed at Syferkuil.

Maize plant height

Maize plant height significantly responded to tillage system at Dalmada (2002/2003) and Syferkuil (2003/2004). The tallest plants were produced under MT system across locations in the two growing seasons (Table 2.8). Differences in plant height was non significant at Dalmada during 2003/2004, but tillage and cropping system interaction was significant. The height of maize might have partly contributed to the higher grain yield observed under minimum tillage system.

CONCLUSIONS

The evaporation rate was much higher than the rainfall received and However supplementary irrigation was in place at both locations to minimise excessive moisture stress on the plants. Maize grain yield was generally higher under the minimum tillage system compared to the conventional tillage system at the two locations in both growing seasons. Significantly higher yield components were observed under the minimum tillage system in most of the parameters studied relative to the conventional system. The number of cobs per plant and weight per cob in maize were the main yield components accounting for grain yield increment under the minimum tillage system. Number of rows per cob was not significant at both locations and this is not surprising as this plant component is usually genetically determined and not environmental based. Hundred seed mass was not affected by tillage system at both locations and in all growing seasons. Days to physiological maturity did not differ between the two tillage systems at Dalmada during both growing seasons, but at Syferkuil, differences were observed. The number of days to tasseling in maize was influenced by tillage system only at Syferkuil and not at Dalmada. No grain yield was produced in the grain legumes primarily due to severe competition from the maize for moisture and sunlight. The minimum tillage system has shown the potential to be a superior system for dryland maize production but further research involving additional locations is required.

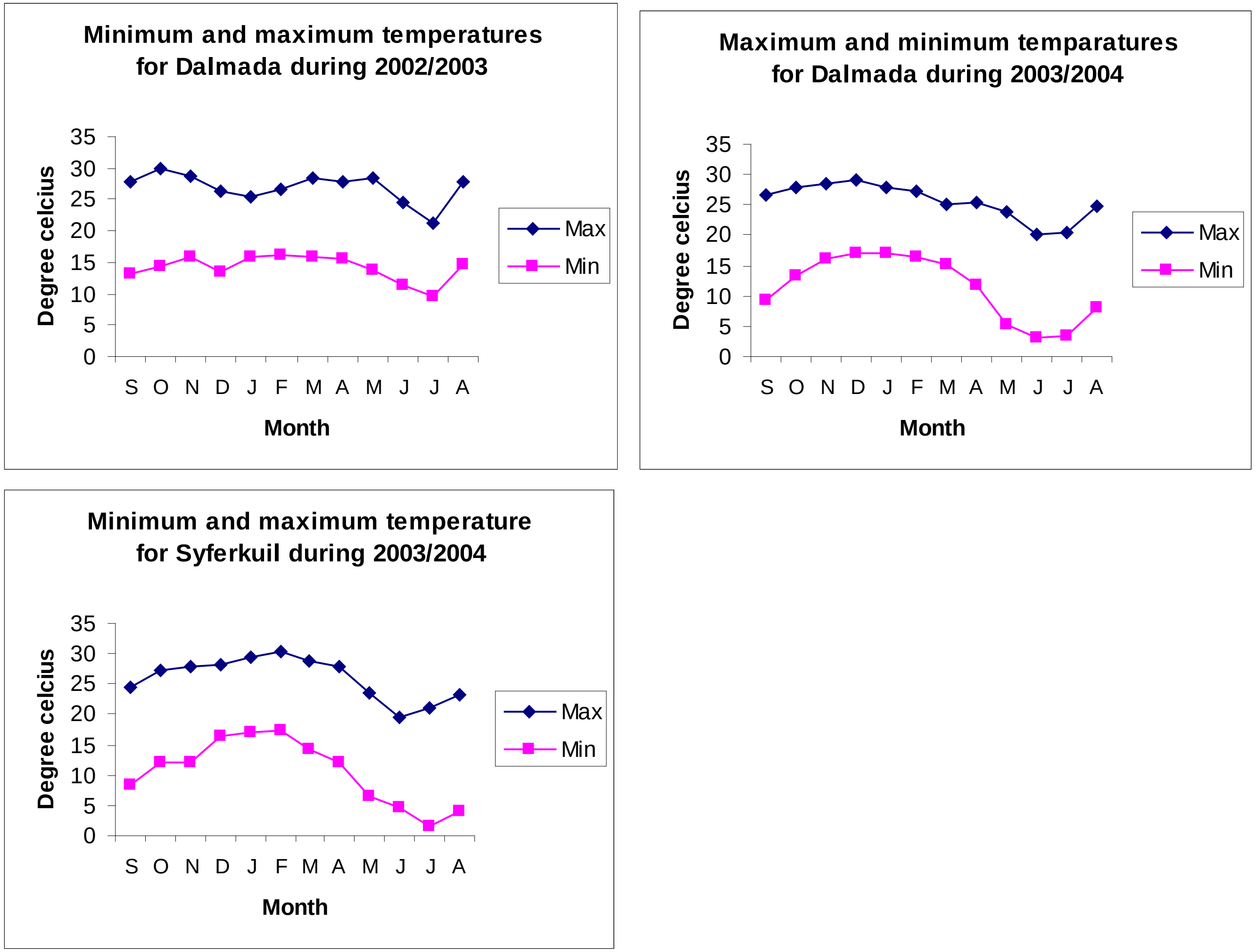


Fig. 2.2: Minimum and maximum temperature for Syferkuil during 2003/2004 growing season and for Dalmada during 2003/2004 and 2002/2003 growing season.

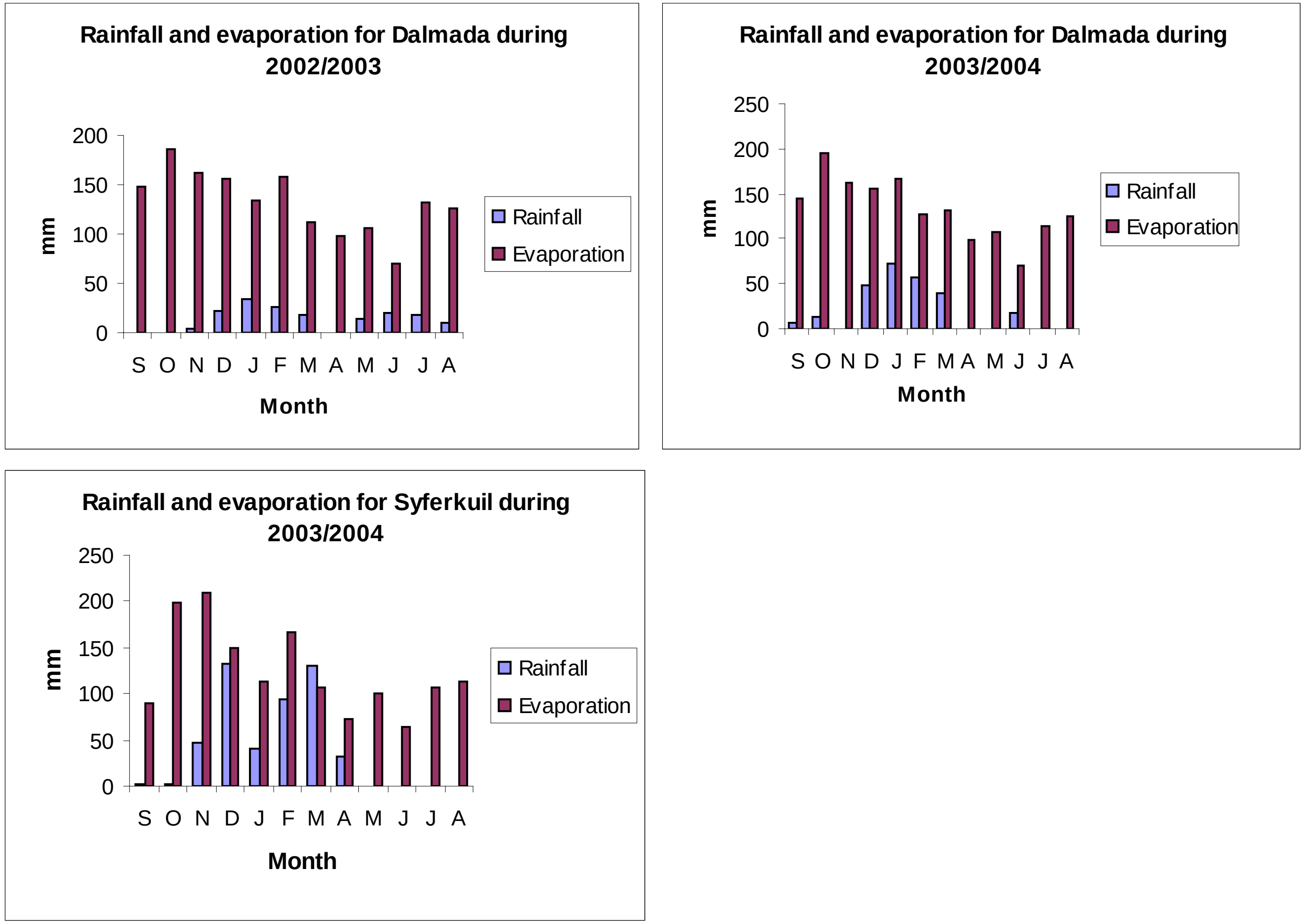


Fig. 2.3: Rainfall and evaporation measurements for Syferkuil during 2003/2004 growing season and Dalmada during 2002/2003 and 2003/2004 growing season.

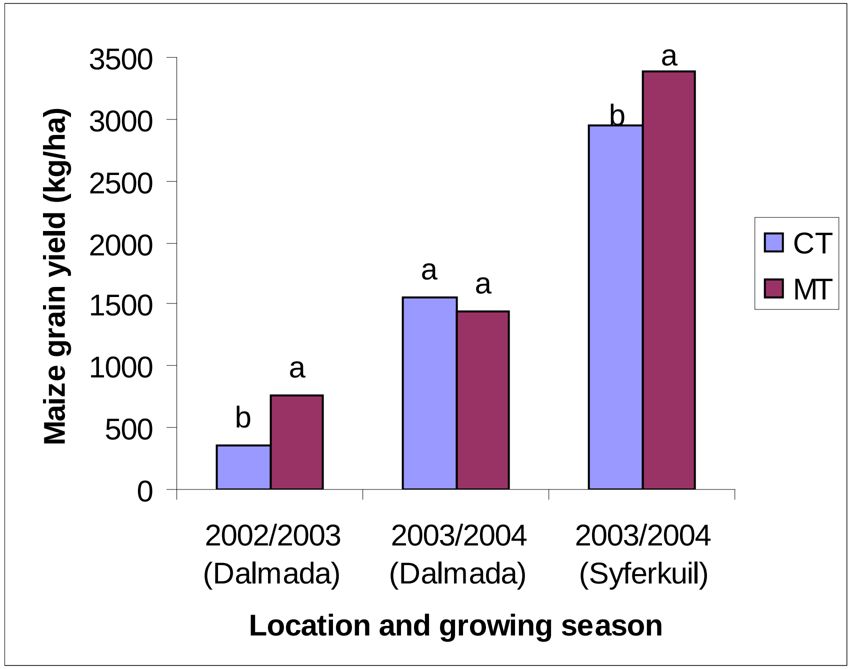


Fig. 2.4: Maize grain yield at Dalmada and Syferkuil as influenced by tillage systems during 2002/2003 and 2003/2004 growing season.

Table 2.2. Initial top and subsoil nutrient status at Dalmada and Syferkuil during the 2002/2003 and 2003/2004 growing season.

	Dalmada						Syferkuil			
	…….2002/2003…...		……………….………………………2003/2004………………………………………							
			Sampling point 1		Sampling point 2		Sampling point 1		Sampling point 2	
			Depth (mm)				Depth (mm)			
Minerals mg kg^{-1}	0-300	300-600	0-300	300-600	0-300	300-600	0-300	300-600	0-300	300-600
N	3.4	1.5	3	1	1	1	13	8	12	11
P	9	1	24	1	9	1	32	27	28	18
K	110	305	99	320	515	290	30	38	117	60
Ca	957	1215	1020	1190	895	1240	523	518	430	448
Mg	676	895	720	830	633	960	313	320	283	235
Na	47	139	50	78	45	200	58	125	78	88
Cl	2	22	1	21	2	23	2	16	6	23
Zn	1.82	0.42	1.84	0.48	1.8	0.36	1.8	0.84	1.04	1.4
pH	7.6	7.8	6.6	7.6	7.8	8.1	7.6	6.9	7.7	6.8
% Clay	15	20	15	32	19	23	20	17	13	11

Table 2.3. Maize yield components as influenced by tillage systems at Dalmada during 2002/2003 growing season.

Tillage	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass
	..count..	….g….	….........count…………			…..g…..
CT	0.5b	52b	12b	28b	356b	23a
MT	1.0a	151a	14a	34a	468a	24a
Lsd	0.12	32.01	0.879	2.7	42.09	ns
Tillage	**	**	**	**	**	ns
Cropping system	ns	Ns	ns	ns	Ns	ns
Tillage*Cropping	**	Ns	ns	**	**	*

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 2.4. Maize yield components as influenced by tillage systems at Dalmada during 2003/2004 growing season.

Tillage	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass
	..count..	….g….	….........count…………			…..g…..
CT	0.75b	92.9b	13a	40a	539a	42.5a
MT	1.30a	193.1a	13a	41a	540a	50.2a
Lsd	0.25	43.21	ns	ns	Ns	ns
Tillage	**	**	ns	ns	Ns	ns
Cropping system	ns	Ns	ns	ns	Ns	ns
Tillage*Cropping	ns	Ns	**	*	*	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage.

Table 2.5. Maize yield components as influenced by tillage systems at Syferkuil during 2003/2004 growing season.

Tillage	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass
	..count..	….g….	…..........count…………			…..g…..
CT	1.1a	179b	13a	35b	459b	58a
MT	1.3a	238a	14a	38a	524a	59a
Lsd	ns	41.03	ns	1.89	36	ns
Tillage	ns	**	ns	**	**	ns
Cropping system	ns	Ns	ns	ns	Ns	ns
Tillage*Cropping	ns	Ns	ns	ns	Ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 2.6. Summary of maize yield components as influenced by tillage systems at Dalamada during 2002/2003 and 2003/2004 and at Syferkuil during 2003/2004 growing season.

Tillage	Dalmada												Syferkuil					
	2002/2003						2003/2004											
	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass	# Cob/ plant	Weight/ cob	# Rows/ cob	# Kernel/ row	# Kernel/ cob	100 seed mass
	..count..	….g….	…........count…………			....g...	..count..	….g….	…........count…………			..g….	..count..	….g ….	…........count…………			..g…
CT	0.5b	52b	12b	28b	356b	23a	0.75 b	92.9b	13a	40a	539a	42.5a	1.1a	179b	13a	35b	459 b	58a
MT	1.0a	151a	14a	34a	468a	24a	1.30 a	193.1a	13a	41a	540a	50.2a	1.3a	238a	14a	38a	524 a	59a
Lsd	0.12	32.01	0.879	2.7	42.09	ns	0.25	43.21	ns	ns	Ns	ns	ns	41.03	ns	1.89	36	ns
Tillage	**	**	**	**	**	ns	**	**	ns	ns	Ns	ns	ns	**	ns	**	**	ns
Cropping system	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns	Ns	ns	ns	Ns	ns	ns	ns	ns
Tillage* Cropping	**	ns	ns	**	**	*	ns	Ns	**	*	*	ns	ns	Ns	ns	ns	ns	ns

Table 2.7. Tasseling, silking and maturity at Dalmada and Syferkuil for both growing seasons.

Tillage	Dalmada					Syferkuil		
	2002/2003		2003/2004			2003/2004		
	Tasseling	Maturity	Tasseling	Silking	Maturity	Tasseling	Silking	Maturity
	………………………………………No. days……………………………………………..							
CT	64a	120	75	81	144	64	72a	133b
MT	62b	119	76	81	144	63	71b	134a
Lsd	1.4	ns	ns	ns	ns	ns	0.50	0.55
Tillage	ns	ns	ns	ns	ns	ns	**	**
Cropping system	ns	ns	ns	ns	ns	ns	Ns	Ns
Tillage*Cropping	ns	ns	ns	ns	ns	ns	Ns	Ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 2.8. Maize plant height (m) at Dalmada (2002/2003 and 2003/2004) and Syferkuil (2003/2004) as influenced by tillage systems.

Tillage	Dalmada 2002/2003	Dalmada 2003/2004	Syferkuil 2003/2004
	……………………….m…………………….		
CT	1.10b	1.85	1.6b
MT	1.33a	1.86	1.8a
Lsd	0.09	ns	0.07
Tillage	**	ns	**
Cropping system	ns	ns	Ns
Tillage*Cropping	ns	*	Ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage.

CHAPTER 3

THE RESPONSE OF GRAVIMETRIC SOIL MOISTURE, CHLOROPHYLL CONTENT, NITROGEN UPTAKE AND DRY MATTER ACCUMULATION IN MAIZE TO TILLAGE SYSTEMS

INTRODUCTION

Soil moisture is one of the most limiting factors to economical crop production in many part of South Africa including the Limpopo Province. Most smallholder farmers in the Limpopo Province have no access to irrigation facilities and hence, crop yields are marginal and unreliable even though the soil is good enough for production. Crops such as maize cannot tolerate drought longer than one month especially during the reproductive stage because this is the stage where large amount of water is needed (Tabassum, 2004). Management practices that enhance rain water infiltration and conservation are therefore required to improve farmer's productivity and ensure food security in the province.

Tillage practices may influence soil moisture availability throughout the growing season. Moisture evaporation from the soil can also be minimized through cropping systems such as intercropping. Although not all the crops being intercropped will reduce the evaporation, cereal-legume or cereal-cover crop combination is reported to reduce evaporation and further prevent soil and nutrients erosion (Rozas *et al*., 1999). Morris *et al*., 1990 indicated that water captured by intercrop differ from water captured by the sole crops and further reported that water-utilization efficiency by intercrop is greater than water-utilization efficiency by sole crops, often by more than 18%.

Conventional tillage practices are not an efficient soil moisture conservation technique. Cultivating methods such as minimum tillage can improve the storage of soil water better because the soil is left undisturbed thereby minimizing evaporation losses. Water runoffs is also slowed by roughness of the soil surface, the presence of plant residue which allows more time for infiltration and also prevent soil crusting which in turn increase infiltration (Olaoye., 2002).

Nitrogen is considered to be the most important plant nutrient due to its demand in greatest quantities by plants. In Limpopo Province, it is the major limiting nutrient in the smallholder farming systems. Nitrogen is a complex part of the soil system and its availability is affected by soil type, tillage, N sources (eg. Fertilizers and Manure), crop rotation and precipitation (Hatfield *et al*., 2001).

The role of legumes is very important in the improvement of soil nutrient status in both the natural and the agro-ecosystems. Environmental factors such as temperature, soil pH, aeration and nitrate concentration in the soil influence the effectiveness of biological nitrogen fixation by legumes. At temperatures suitable for plant growth, nitrogen fixation usually proceeds at an optimum rate. At temperature above 30 ^{0}C, N_2 fixation is reduced and nodules are generally sloughed off. Maximum rates of fixation occur in pH ranges of 6 to 8 similar to those that are optimum for plants (Rauschkolb and Hornsby, 1994).

Smartt (1990) indicated that in most parts of Africa where legumes are not planted, agricultural productivity is limiting because of poor soil nutrients or high inputs of chemicals to supplement nitrogen. The author further indicated that there are three main areas in the improvement of agricultural productivity namely; soil nutrient status, soil physical structure and biotic competition. Legumes have a role to play in agricultural systems, as they can maintain nitrogen status of the soil during the cropping phase and restore soil nitrogen status. Legumes can be intercropped with cereals so that the cereals may effectively use the nitrogen fixed, either currently or in subsequent years.

Intercropping of N_2 fixing legumes with non-legumes is often used to increase dry matter production and protein content of the harvested crop while minimizing the need for nitrogen fertilizer inputs. Ideally the legumes will fix most of their required nitrogen and also supply a significant portion of that required by the non-legumes.

Legumes offer several advantages over soil degradation. They do not only add substantial amount of organic matter and improve structure but when properly inoculated, legumes can fix considerable quantities of atmospheric N_2 and make it available to the succeeding crops as the residues decompose. Nitrogen requirement can be assessed or measured from the plant using techniques such as the Kjeldah analysis and chlorophyll meter SPAD-502. Scott and Hector, (1997) indicated that the amount of chlorophyll per unit leaf area in maize is a good indicator to the overall conditions of the plant. Healthy plants, capable of maximum growth, generally can be expected to have larger amount of chlorophyll than unhealthy plants. Determination of the chlorophyll content of a leaf can be used to detect and study plant stress and nutritional status. The Minolta chlorophyll meter SPAD-502 can be used to rapidly determine chlorophyll concentrations in plant leaves without damage of the leaf (Scott and Hector, 1997).

The objectives of the study were to:

i) Determine the impact of tillage system on chlorophyll content and dry matter accumulation of maize.

ii) To determine soil moisture content as influenced by the legumes and tillage systems.

MATERIALS AND METHODS

The study area and experimental details are the same as reported in Chapter 2.

Gravimetric moisture

Soil samples were collected every other week for gravimetric moisture determination of the soil from two different portions of a plot using an augar and zip log plastic bags to conserve moisture. The samples were collected from 0-150 mm depth and 150-300 mm depth within the profile. Determination of the fresh weight of the samples was done quickly at arrival in the laboratory from the field and dry weight was measured after oven drying for two days at 100^0C. Gravimetric moisture content was determined using the formula:

Gravimetric water = *[(Wet weight – Dry weight)/ Dry weight] x 100* (Scott, 2000)

Dry matter

Above ground maize and legume samples were taken every other week during 2002/2003 growing season to determine plant growth characteristics. Samples were taken at 63 DAP, 77 DAP and 97 DAP at Dalmada (2002/2003) and at 70 DAP, 87 DAP at Syferkuil and Dalmada (2003/2004) respectively. Plants were collected from a 0.5 m length at both end of the middle row where two plants were left out as borders. During 2003/2004 growing season the plant samples were collected once at maize tasseling due to poor stand establishment. Samples were dried at 65^0C for several days in the oven to constant weight. The maize samples were separated into leaves, shoot and cob fractions and for the legumes into leaves, shoots, roots and nodules. Each fraction was weighed separately.

Chlorophyll readings

Chlorophyll readings on maize were determined from the fully expanded younger leaf and the lowest leaf, which is the oldest leaf. Five individual plants were selected randomly for the readings on each plot using Minolta Chlorophyll meter SPAD-502. During 2003/2004 the chlorophyll readings were determined from the youngest leave and the middle leaves because of the severe hail damage of maize at 26 DAP at Dalmada.

RESULTS AND DISCUSSIONS

Gravimetric moisture

During the two growing seasons, gravimetric soil moisture under the minimum tillage system was generally higher than the conventional tillage, but in some instances, they were similar depending on the depth of sampling. There were no instances where soil moisture under the conventional tillage system was recorded as higher than that of the minimum tillage system. At Dalmalda in 2002/2003, higher soil moisture under minimum tillage (MT) occurred at 0 - 150 mm depth at 81 DAP and at the 150 - 300 mm depth at 63 DAP (Fig. 3.1), representing 22.9 % and 55.4 % increase respectively. In 2003/2004, the difference occurred at 0 - 150 mm depth at 74 DAP (Fig. 3.2), which is equivalent to 32.6 % increase. At Syferkuil, 27.5 % higher soil moisture occurred at both 0 - 150 mm and 32.9 % at 150 - 300 mm depths at 126 DAP (Fig. 3.3). The moisture difference between the two systems were similar at 84 DAP.

The observed differences in gravimetric soil moisture were strongly influenced by the amount and timing of rainfall during a season and the location of study. Higher rainfall was received at the later stage of the growing season at Dalmada 2003/2004, which could have resulted in the non-significant difference in soil moisture under the two tillage systems. There was no late season rain at Syferkuil which may explain the observed differences in soil moisture under the two tillage systems.

Increased soil moisture under no-till system relative to the conventional tillage system had been reported by other authors. Daniel et al., (1999) reported that surface residue potentially increases infiltration of water into the soil by 25 to 50% under no-till as compared to conventional tillage system. Unger, (1991) reported that soil water storage is greater where there is no-till compared to stubble mulching or where disk tillage was used. The increased maize yield under the minimum tillage system observed at Dalmada and Syferkuil could partly be attributed to increased soil moisture during periods of drought.

Chlorophyll Production

Younger maize leaf

Chlorophyll production in the youngest fully expanded leaf of maize at Dalmada and Syferkuil was significantly influenced by tillage system, especially during the later stages of growth (figure 3.10 and 3.11). At Dalmada, higher chlorophyll content was recorded under minimum tillage system at 78 DAP in 2002/2003, indicating an increase of 23.2 %. In 2003/2004 15.5 % higher chlorophyll was recorded under minimum tillage system at 103 DAP. There was a trend of decreasing chlorophyll concentration during the growing seasons in both seasons.

Similar to Dalmada, higher chlorophyll content in the younger leaves was recorded under minimum tillage system relative to the conventional system in Syferkuil (Fig. 3.12). A

17.7% and 29.8 % increase was at 54 DAP and 76 DAP respectively under minimum tillage. A trend of decreasing chlorophyll content over the season was also observed.

Scott and Hector, (1997) indicated that the amount of chlorophyll per unit leaf area in maize is a good indicator to the overall conditions of the plant. Healthy plants, capable of maximum growth, generally can be expected to have larger amount of chlorophyll than unhealthy plants. The observed higher grain yield in maize under the minimum tillage system could be an indication of healthy growth as inferred by higher dry matter accumulation (table 3.1).

Older maize leaf

Significant differences were observed at the early and the latest sampling dates at Dalmada during 2002/2003 with regard to the chlorophyll content of the older maize leaf. Plants grown under MT generally recorded higher chlorophyll concentration compared to those grown under CT except at 78 DAP (fig. 3.10). Similar trend was recorded during 2003/2004, where plants under minimum tillage predominantly produced higher leaf chlorophyll except at 51 DAP and 89 DAP. Reduced chlorophyll concentration in the lower leaves generally signifies the onset of senescence. The results showed that the rate of senescence was higher in maize plants grown under CT relative to those under MT.

At Syferkuil leaf senescence were measured equally for both tillage systems at 44 DAP and 76 DAP (Fig. 3.12) which might be the results of aging rather shading. A 27.6% increase was recoded at 54 DAP under MT.

Chlorophyll on legumes

Legumes showed a quadratic response irrespective of legume cultivar in both younger and older leaves. The coefficient of determination (R^2) across the legumes intercrop ranged from 0.8391 – 0.9638 and 0.58 – 0.9997 during 2002/2003 and 2003/2004 respectively. The results indicated a strong relationship between chlorophyll production of maize and legume intercropping (fig. 3.13 – 3.18).

Dry matter production

Maize

At Dalmada, during 2002/2003 higher dry matter production was recorded only at 97 DAP. The amount of dry matter accumulated was 4379.5 kg/ha under MT at 97 DAP compared to 347.2 kg/ha under CT (Table 3.1). In 2003/2004 there was no significant difference at Dalmada, but at Syferkuil maize grown under minimum tillage produced dry matter, 4215 kg/ha compared to 3220 kg/ha under conventional tillage at 70 DAP.

Maize dry matter as influenced by the intercropping was significant at an early stage of 63 DAP at Dalmada in 2002/2003 growing season only (Table 3.2). Sole maize accumulated 3305.80 kg/ha which was higher than the yield of the intercropped maize. The lack of benefit of maize in a maize-legume intercropping system has also been reported by Cenpukdee and Fukai, (1991).

Legumes

During the 2002/2003 growing season, legume dry matter accumulated was not affected by any of the tillage systems but in 2003/2004 significant results were recorded at both locations. Legume dry matter production was higher under minimum tillage (table 3.3). Legume intercropping was significant at both locations and growing seasons except at Syferkuil during 2003/2004 at 44 DAP. Higher dry matter production was recorded in the cowpea varieties compared to lablab and velvet bean (table 3.4). Cowpea is indigenous to the experimental location whereas velvet bean and lablab bean are introduced species. This might contributed to the superior production in cowpea.

CONCLUSION

Gravimetric soil moisture under the minimum tillage system was generally higher than under the conventional tillage, but in some instance, they were similar depending on the depth of sampling during the two growing seasons. There were no instances where soil moisture under the conventional tillage system was higher than that of the minimum tillage system. The observed differences in gravimetric soil moisture was strongly influenced by the amount and timing of rainfall during a season and the location of study. Higher rainfall was received at the later stage of the growing season at Dalmada 2003/2004, which could have resulted in the non-significant difference in soil moisture under the two tillage systems. Increased soil moisture under no-till system relative to the conventional tillage system had been reported by other authors.

Chlorophyll production in the youngest fully expanded leaf of maize at Dalmada and Syferkuil was significantly influenced by tillage systems. At Dalmada, higher chlorophyll content was recorded under minimum tillage system at 78 DAP in 2002/2003, indicating an increase of 23.2 %. In 2003/2004 15.5 % higher chlorophyll was recorded under minimum tillage system at 103 DAP. There was a trend of decreasing chlorophyll concentration in the younger leaves during the growing seasons in both seasons.

In the older maize leaves significant results were observed at the early and the latest sampling dates at Dalmada during 2002/2003 with regard to the chlorophyll content. Plants grown under MT generally recorded higher chlorophyll concentration compared to those grown under CT except at 78 DAP (fig. 3.10). Reduced chlorophyll concentration in the lower leaves generally signifies the onset of senescence. The results showed that the rate of senescence was higher in maize plants grown under CT relative to those under MT. Similar trend was recorded during 2003/2004. At Syferkuil leaf senescence measured the same for both tillage systems at 44 DAP and 76 DAP.

In 2003/2004 there was no significant difference of dry matter production at Dalmada, but at Syferkuil maize grown under minimum tillage produced higher dry matter compared maize grown under conventional tillage. During 2002/2003 growing season legume dry matter accumulated was not affected by any of the tillage systems, but in 2003/2004 significant results were recorded at both locations.

Legume intercropping was significant at both locations and growing seasons except at Syferkuil during 2003/2004 at 44 DAP. Legume dry matter production was higher under minimum tillage. Comparing dry matter production amongst the legumes, significantly higher production was recorded in the cowpea varieties compared to lablab and velvet bean.

From the above study, both maize and legume plants grown under minimum tillage system generally produced higher dry matter and chlorophyll and also conserved significantly higher soil moisture compared to those under conventional tillage irrespective of the location.

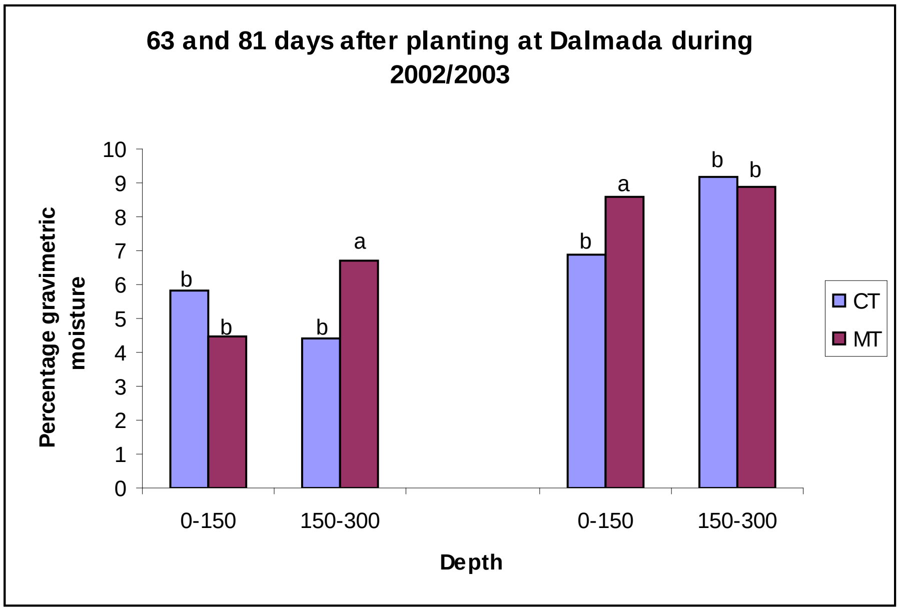


Figure 3.1: Moisture response to tillage system at Dalmada during 2002/2003 growing season.

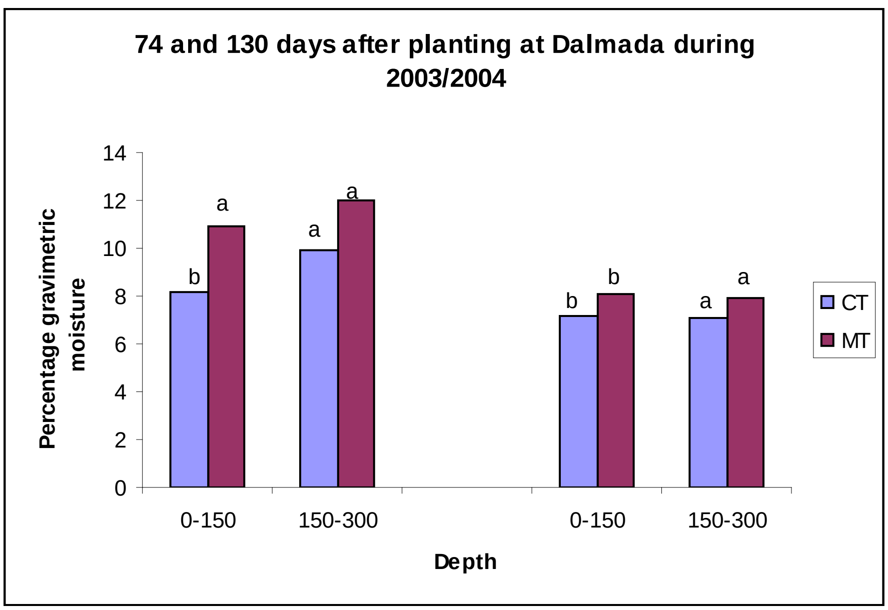


Figure 3.2: Moisture response to tillage system at Dalmada during 2003/2004 growing season.

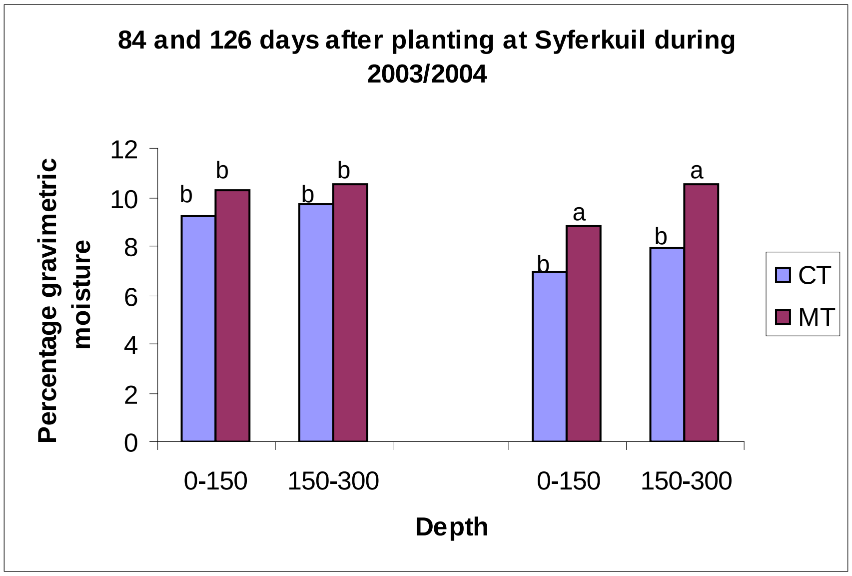


Figure 3.3: Moisture responses to tillage system at Syferkuil during 2003/2004 growing season.

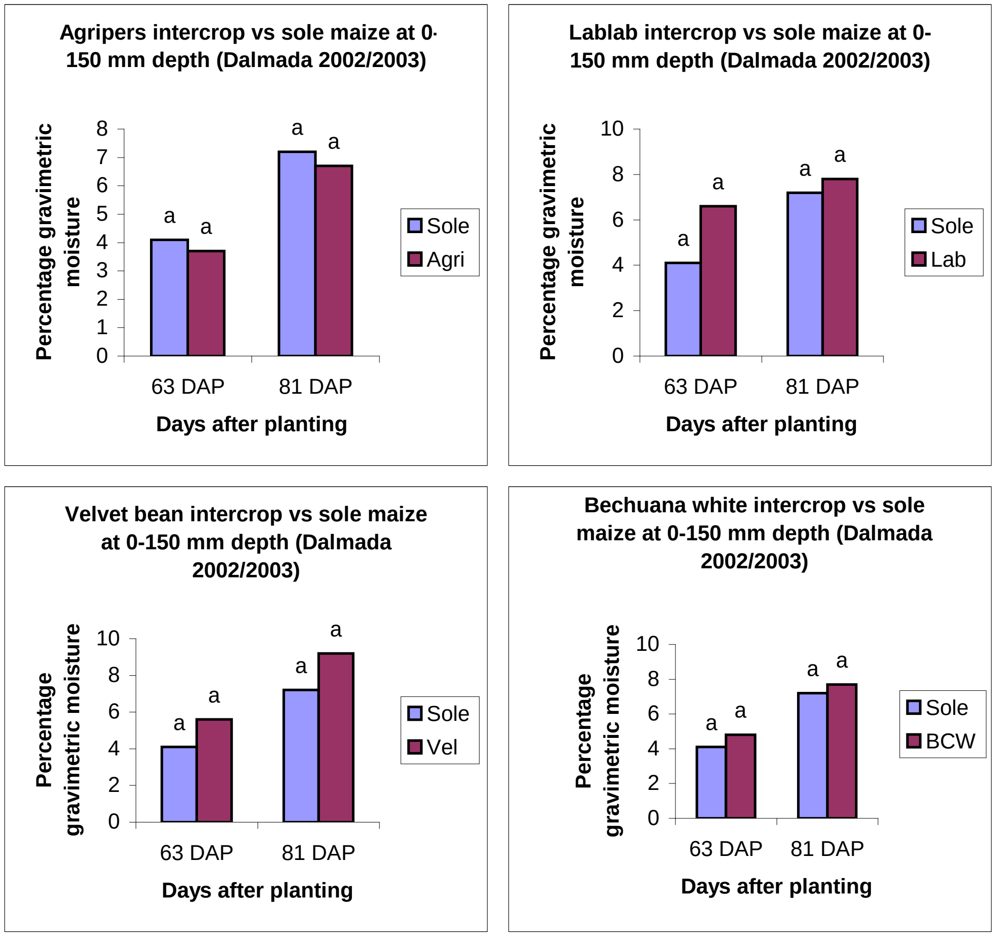


Figure 3.4: Moisture response to cropping system at 0-150 mm depth at Dalmada during 2002/2003 growing season.

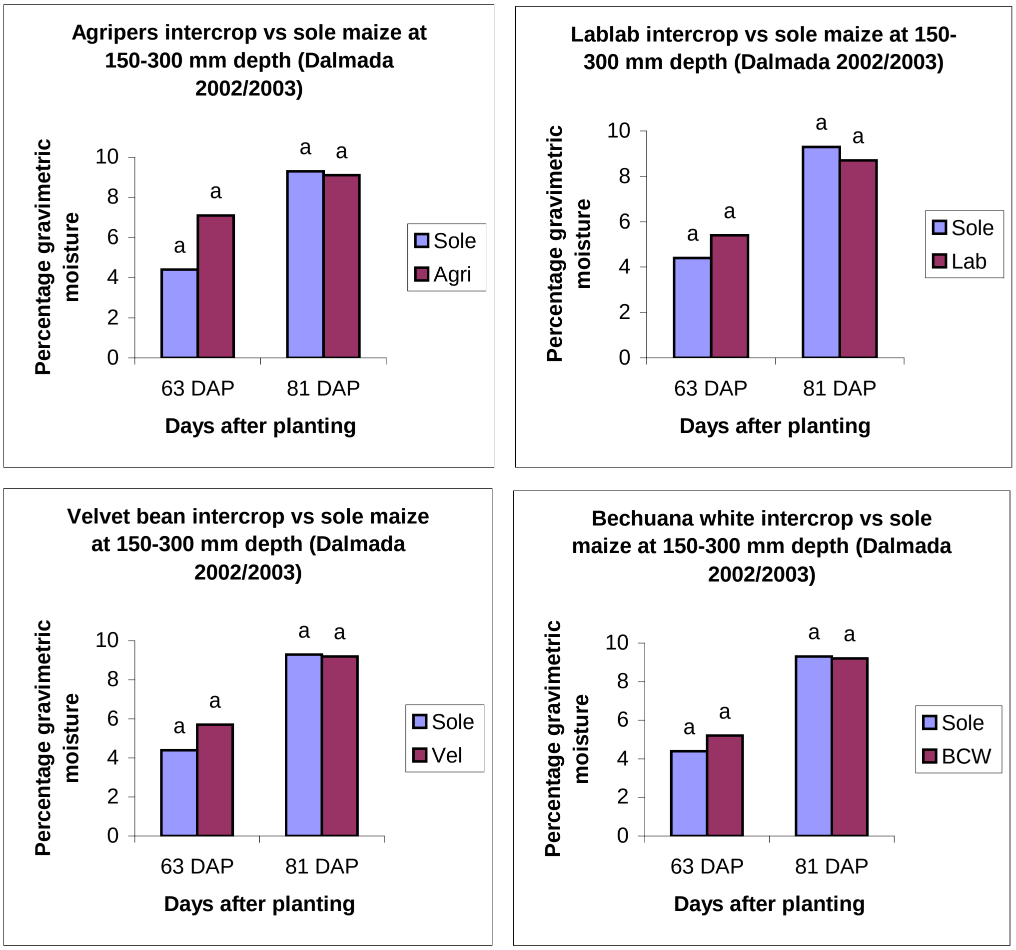


Figure 3.5: Moisture response to cropping system at 150-300 mm depth at Dalmada during 2002/2003 growing season.

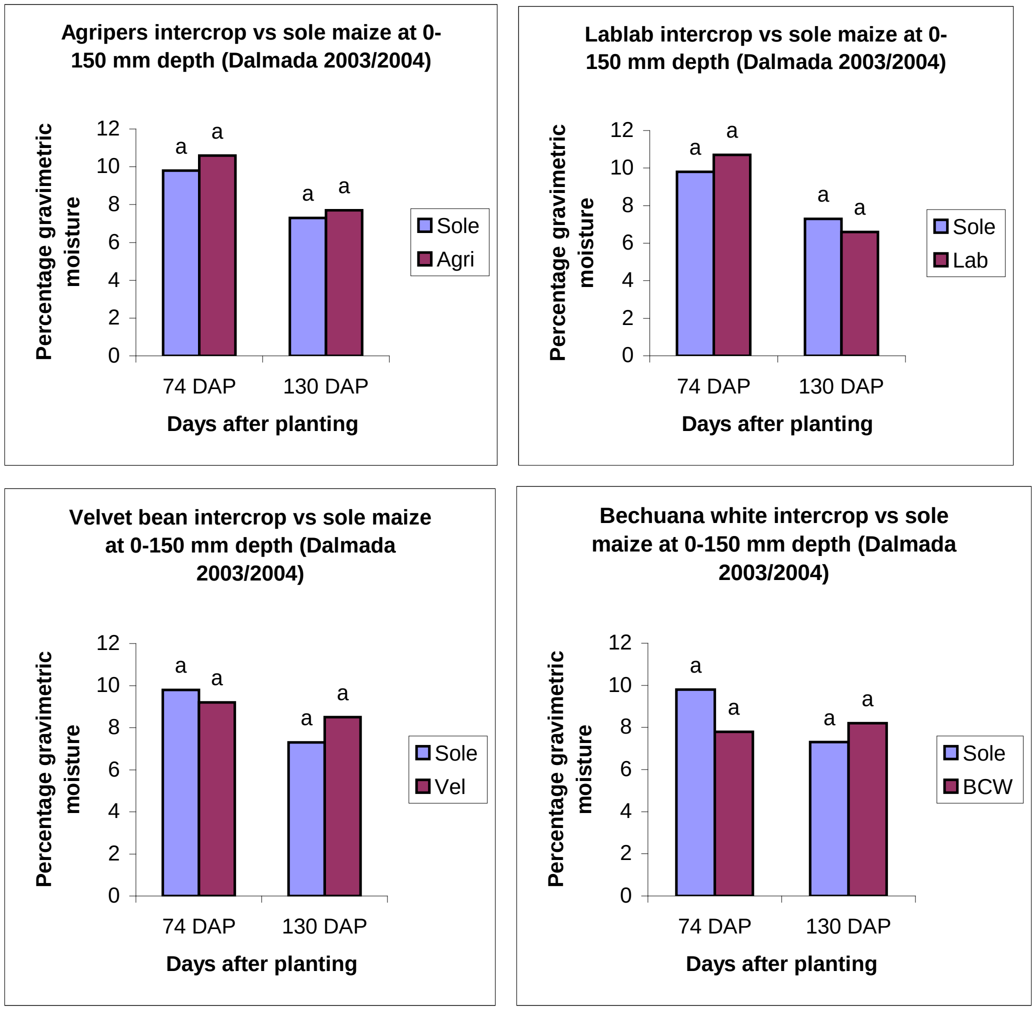


Figure 3.6: Moisture response to cropping system at 0-150 mm depth at Dalmada during 2003/2004 growing season.

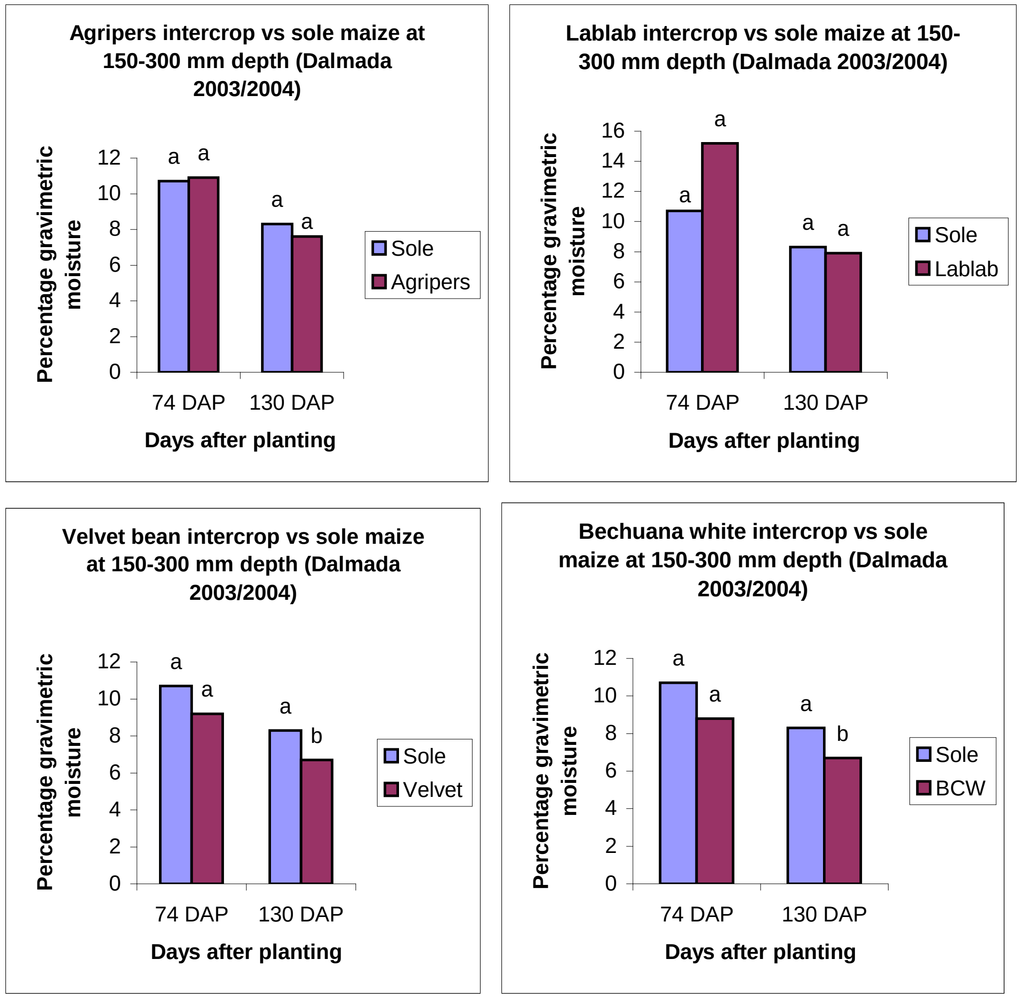


Figure 3.7: Moisture response to cropping system at 150-300 mm depth at Dalmada during 2003/2004 growing season.

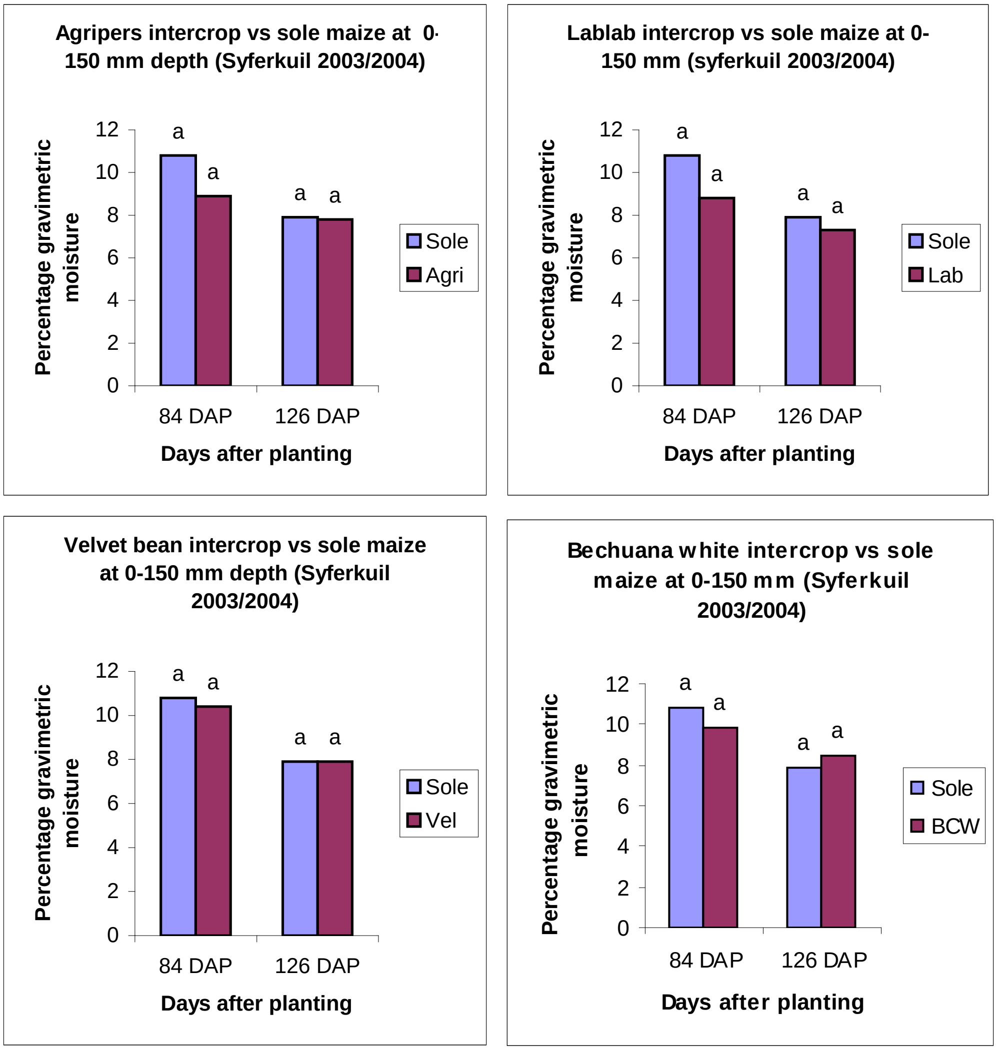


Figure 3.8: Moisture response to cropping system at 0-150 mm depth at Syferkuil during 2003/2004 growing season.

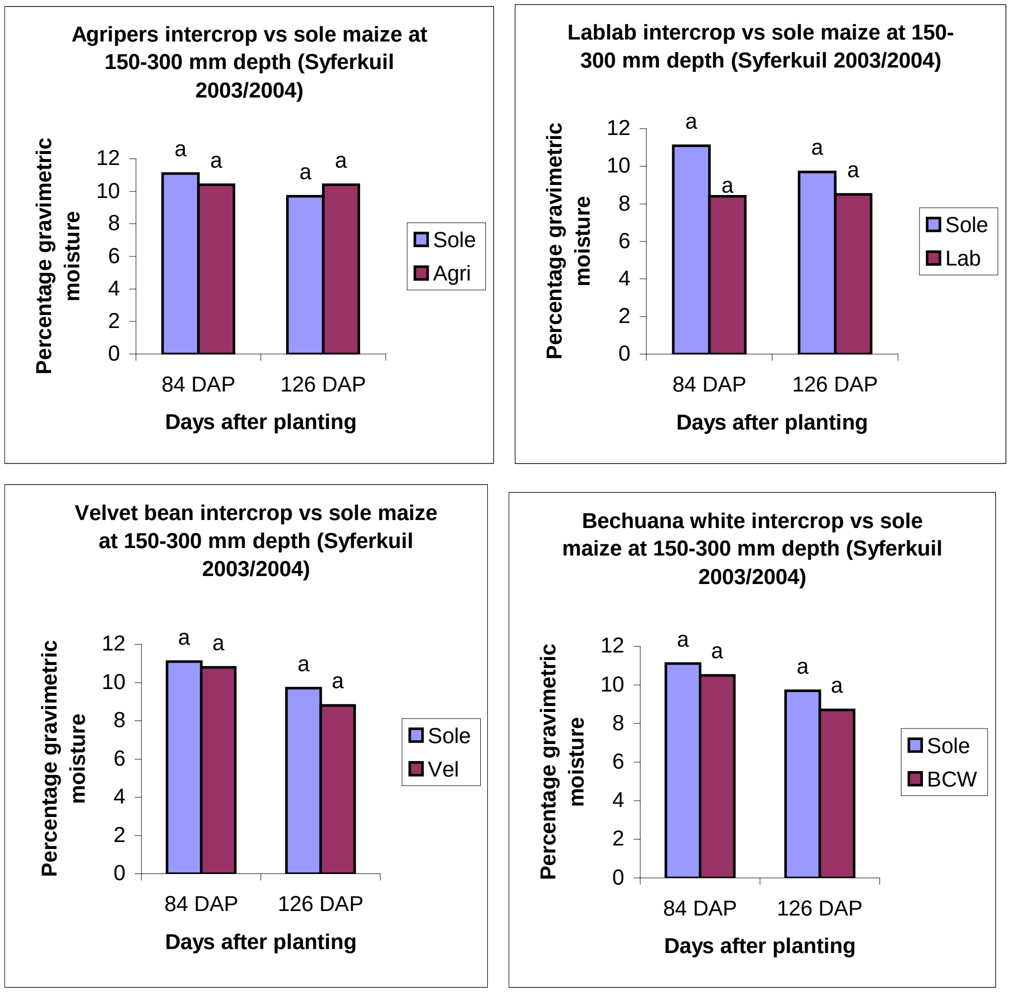


Figure 3.9: Moisture response to cropping system at 150-300 mm depth at Syferkuil during 2003/2004 growing season.

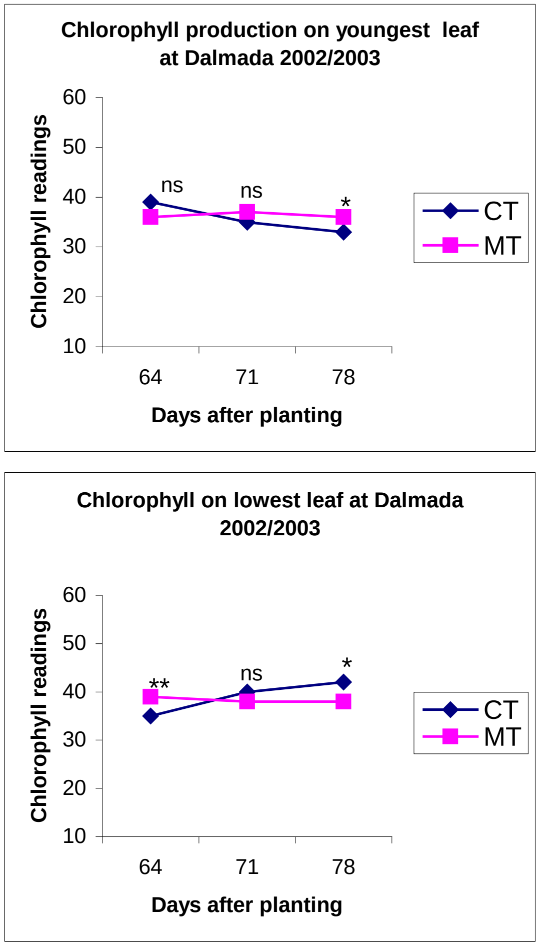
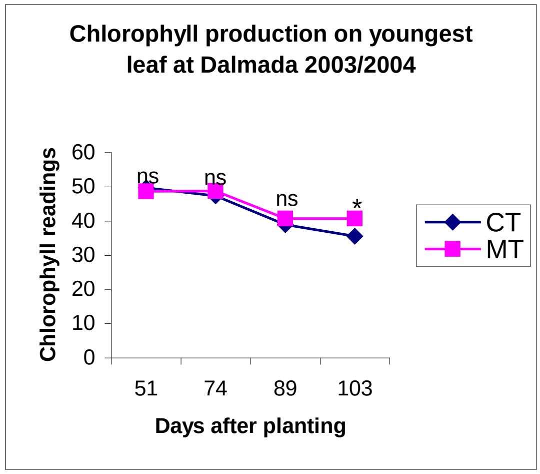


Figure 3.10: Effect of tillage system on chlorophyll production in youngest leaf and senescence in oldest under CT and MT.**= $p<0.01$; *= $p<0.05$; ns = not statistically significant.



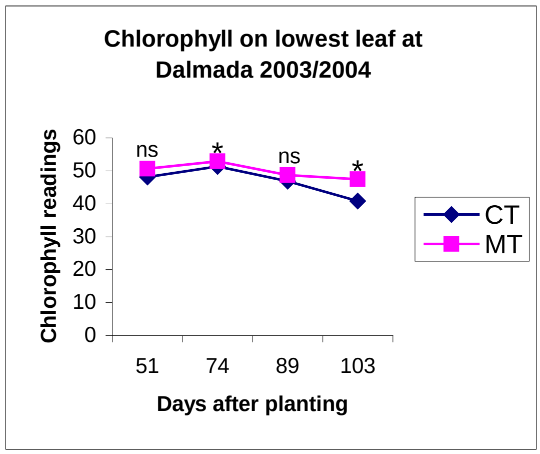
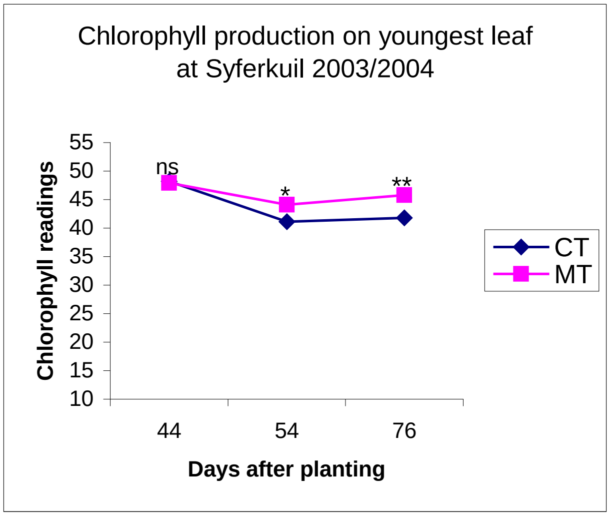


Figure 3.11: Effect of tillage system on chlorophyll production in youngest leaf and senescence in oldest under CT and MT.**= p<0.01; *= p<0.05; ns = not statistically significant.



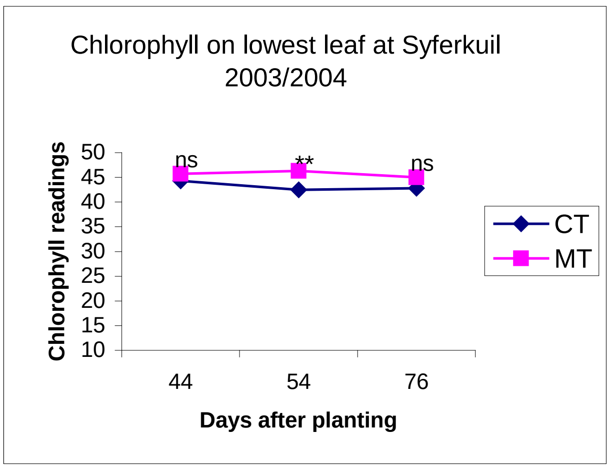


Figure 3.12: Effect of tillage system on chlorophyll production in youngest leaf and senescence in oldest under CT and MT.**= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

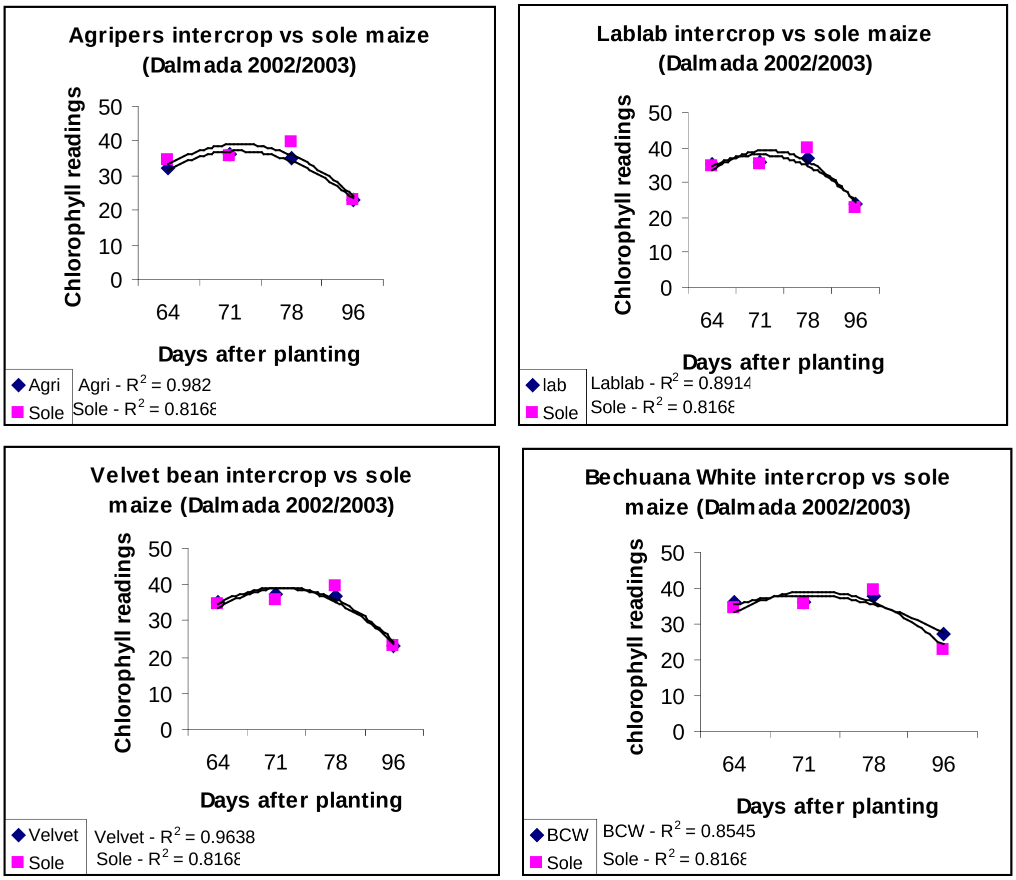


Figure 3.13: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the youngest fully expanded leaf at Dalmada during 2002/2003 growing season. **= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

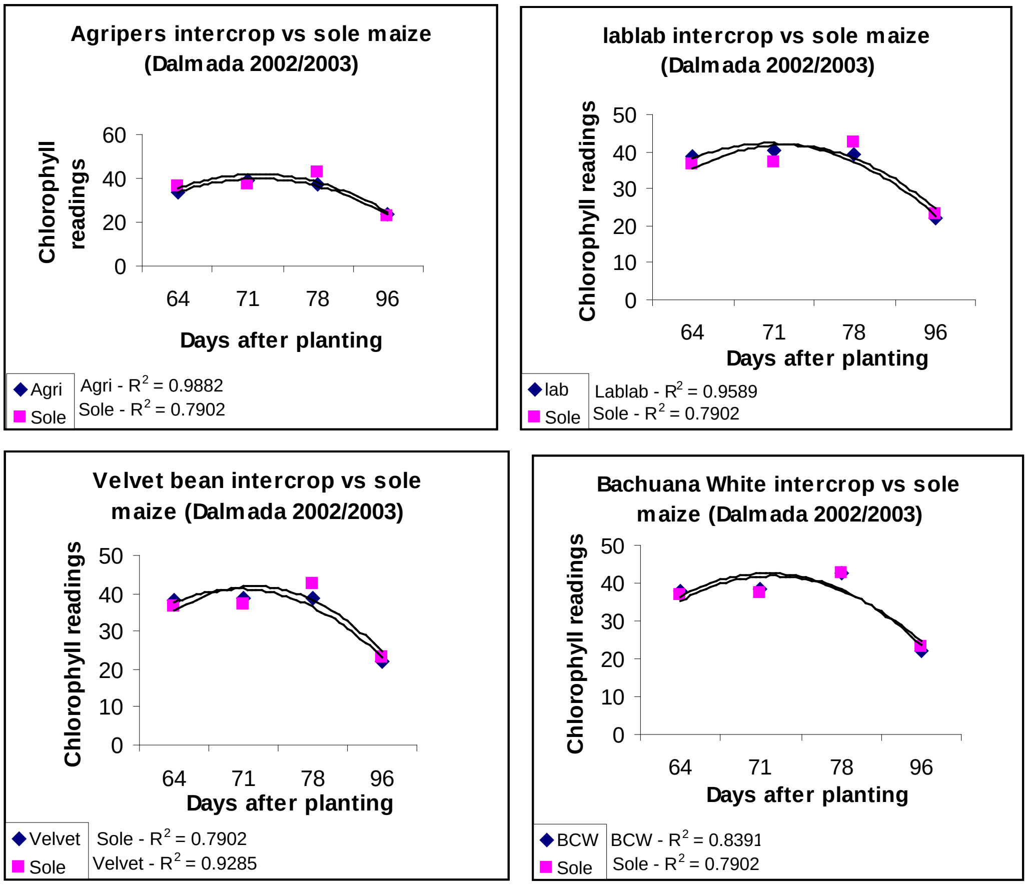


Figure 3.14: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the lowest leaves at Dalmada during 2002/2003 growing season. **= p<0.01; *= p<0.05; ns = not statistically significant.

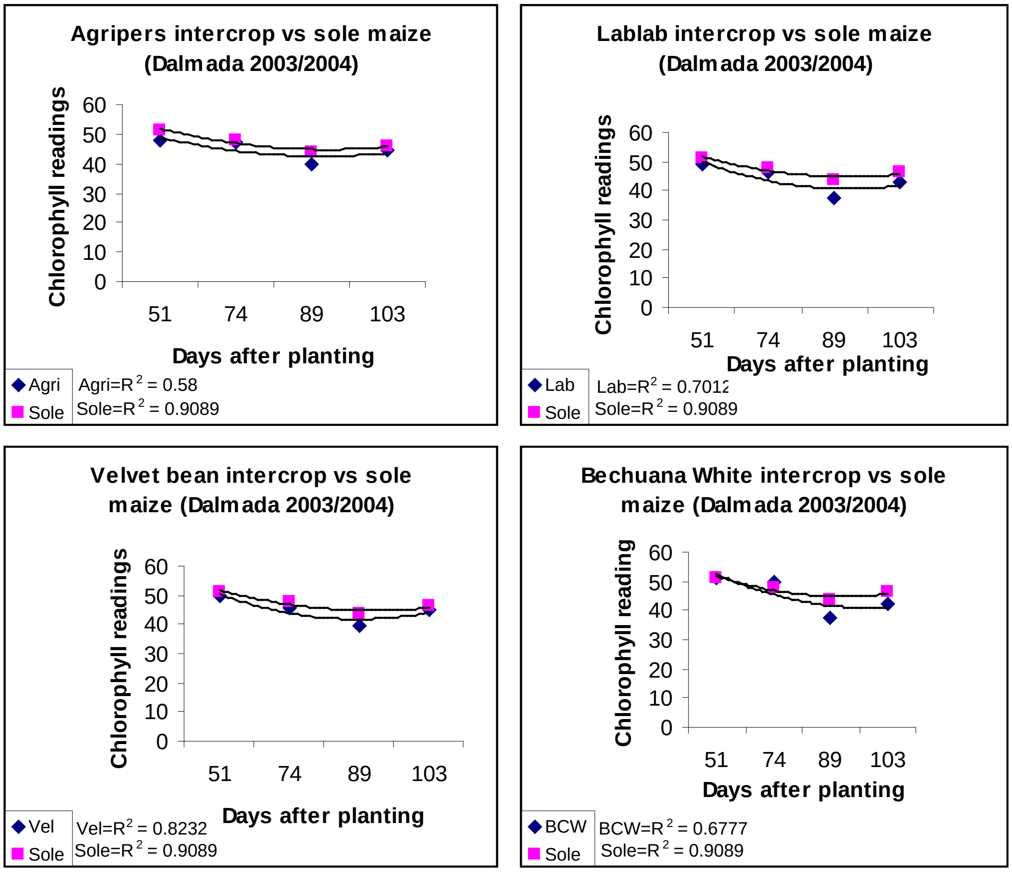


Figure 3.15: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the youngest fully expanded leaf at Dalmada during 2003/2004 growing season. **= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

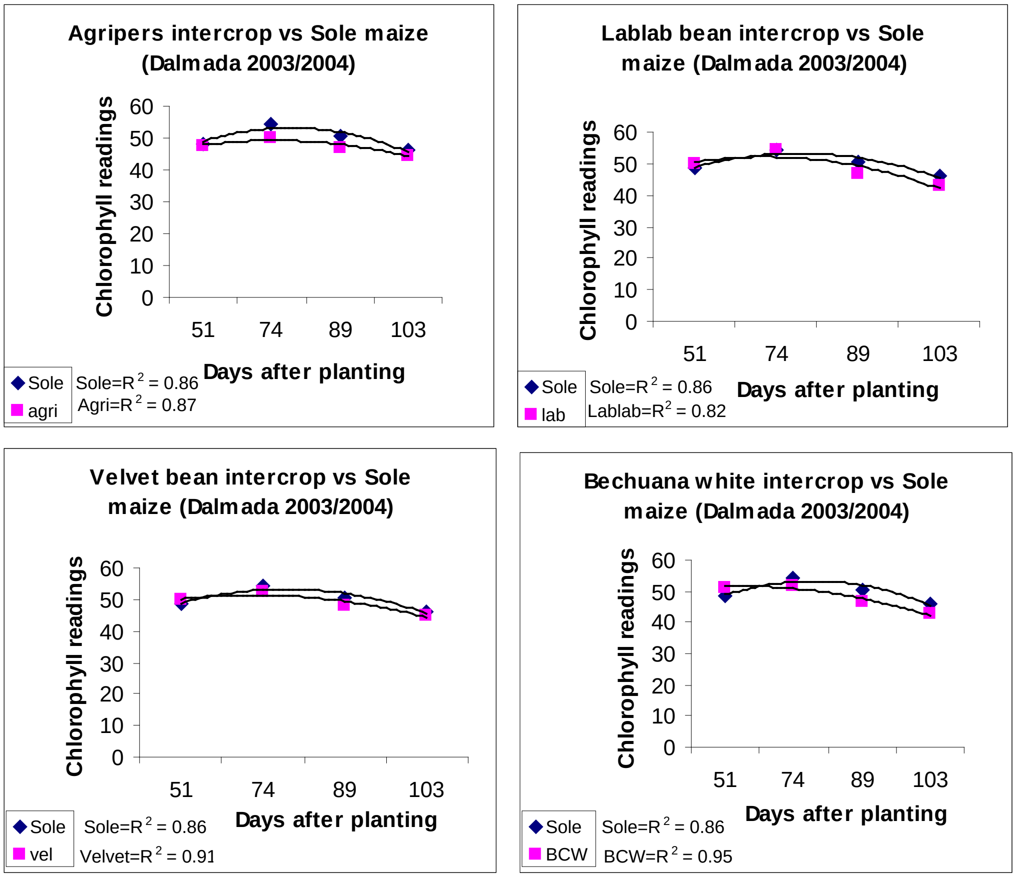


Figure 3.16: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the lowest leaves at Dalmada during 2003/2004 growing season. **= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

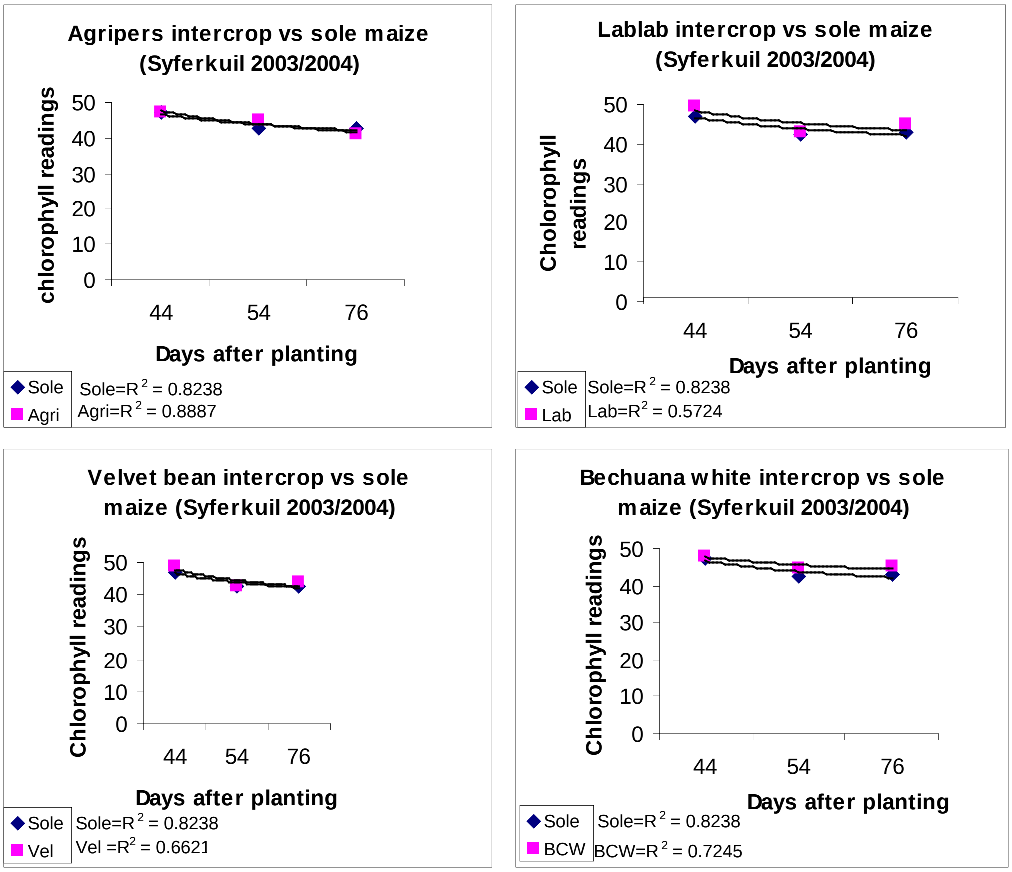


Figure 3.17: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the youngest fully expanded leaf at Syferkuil during 2003/2004 growing season. **= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

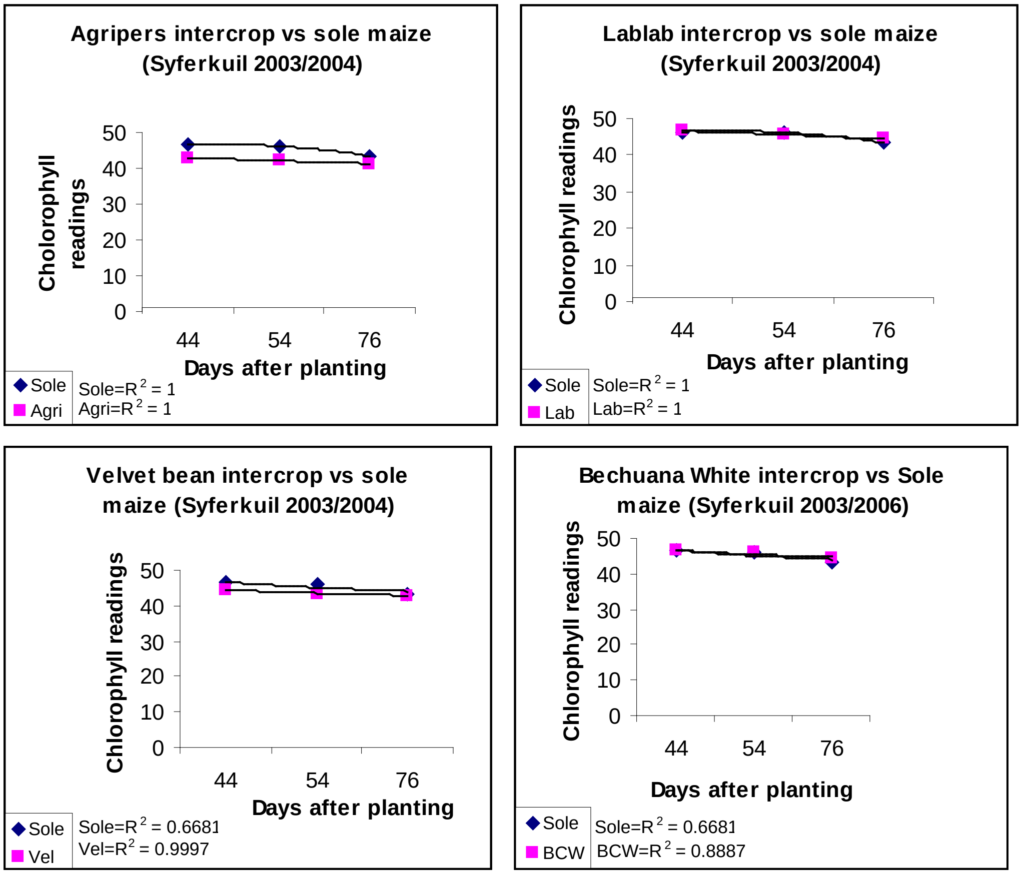


Figure 3.18: Effect of cropping system on chlorophyll content of maize intercropped with the different legumes in the lowest leaves at Syferkuil during 2003/2004 growing season. **= $p<0.01$; *= $p<0.05$; ns = not statistically significant.

Table 3.1: Maize total Dry matter accumulation response to tillage system at Dalmada and Syferkuil during 2002/2003 and 2003/2004 growing seasons.

	Dalmada			Dalmada	Syferkuil
	2002/2003			2003/2004	
Tillage	63 DAP	77 DAP	97 DAP	87 DAP	70 DAP
	……………………………………Kg/ha……………………………				
CT	2358.0	2930.0	3469.2b	3924.1	3220.0b
MT	2089.9	3317.9	4379.5a	4266.0	4215.6a
Lsd	Ns	Ns	434.51	Ns	498.53
Tillage	Ns	Ns	**	Ns	**
Cropping system	*	Ns	ns	Ns	ns
Tillage*Cropping system	Ns	Ns	ns	Ns	ns

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.
CT = Conventional tillage. MT = Minimum tillage. DAP = Days after planting.

Table 3.2: Maize total Dry matter accumulation response to cropping system at Dalmada and Syferkuil during 2002/2003 and 2003/2004 growing seasons.

	Dalmada			Dalmada	Syferkuil
	2002/2003			2003/2004	
Crop System	63 DAP	77 DAP	97 DAP	87 DAP	70 DAP
	……………………………………..Kg/ha………………………………….				
Sole	3305.8a	3244.1	1206.8	3759.8	4133.3
M+Agri	1745.6b	3019.6	697.8	4027.0	3505.6
M+Lab	2195.5b	3102.0	1395.3	4307.6	3427.8
M+Vel	2188.8b	3442.7	1435.4	3759.8	3972.2
M+BCW	1684.3b	2811.5	918.1	4587.2	3550.0
Lsd	984.62	Ns	ns	Ns	788.25
Tillage	Ns	Ns	**	Ns	**
Cropping system	*	Ns	ns	Ns	ns
Tillage*Cropping system	Ns	Ns	ns	Ns	ns

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.
CT = Conventional tillage. MT = Minimum tillage. DAP = Days after planting.

Table 3.3: Legume Dry matter accumulation to tillage systems at Dalmada and Syferkuil during 2002/2003 and 2003/2004 growing seasons.

	Dalmada		Dalmada		Syferkuil	
	2002/2003		2003/2004		2003/2004	
Tillage	41 DAP	67 DAP	58 DAP	74 DAP	44 DAP	71 DAP
	……………………..……………..kg/ha………………………………					
CT	25.8	65.1	309.5b	608.8b	90.7b	312.1b
MT	25.4	88.6	870.8a	1255.8a	161.9a	986.6a
Lsd	8.19	35.37	414.42	215.64	35.13	269.8
Tillage	Ns	Ns	*	**	**	**
Cropping system	**	**	**	**	ns	**
Tillage*Cropping system	**	Ns	ns	*	ns	*

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. CT = Conventional tillage. MT = Minimum tillage. DAP = Days after planting.

Table 3.4: Legume dry matter accumulation response to cropping system at Dalmada and Syferkuil in all growing seasons.

	Dalmada		Dalmada		Syferkuil	
	2002/2003		2003/2004		2003/2004	
Tillage	41 DAP	67 DAP	58 DAP	74 DAP	44 DAP	71 DAP
	……………………..……………..kg/ha……………………………………..					
M + Agrinawa	32.4ab	95.7ab	1321.7a	1717.4a	180.7a	1152.5a
M + Lablab	25.4b	67.6b	551.9bc	1065.7b	133.9a	909.7ab
M + Velvet bean	44.9a	95.0ab	408.2bc	710.9c	134.1a	640.7b
M + Bechuana White	25.2b	126.8a	669.2ab	1167.4b	182.9a	544.0b
Lsd	12.9	55.9	655.3	340.9	55.5	426.6
Tillage	ns	ns	*	**	**	**
Cropping system	**	**	**	**	ns	**
Tillage*Cropping system	**	Ns	ns	*	ns	*

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. CT = Conventional tillage. MT = Minimum tillage. DAP = Days after planting.

CONCLUSION AND RECOMMENDATIONS

Major study finding

Based on the study, minimum tillage system proved to be generally more superior in the parameters measured throughout the experimentation at both locations. Maize yield during 2002/2003 and 2003/2004 (Syferkuil) growing season was significantly higher under minimum tillage. Agronomic characteristics and yield components were a good reflection of the grain yield. According to the finding of this study, grain yield of the two tillage systems was strongly determined by the number of cobs per plant and weight of cob. Weight of kernels did not show any significant role on grain yield.

Generally at both locations, significantly higher soil moisture was recorded under the minimum tillage system compared to conventional system. A decreasing trend of chlorophyll production was observed throughout the experimental period at both locations. Although dry matter accumulation for both maize and legumes were similar at several sampling dates, there were some instances where crops grown under minimum tillage were superior to those under conventional system.

The following additional conclusions could be drawn from the studies:

- ❖ The implementation of minimum tillage especially on dryland farming and in drought prone areas such as the Limpopo province can be beneficial to farmers as grain yield and major yield components increase compared to conventional tillage system.

- Due to minimal disturbance of the soil, more soil moisture was conserved under the minimum tillage system compared to conventional system as inferred by higher gravimetric soil moisture.
- Legumes in both seasons and locations played a minimal and non significant role as the growth and development was very poor due to late planting and poor solar radiation interception.

Recommendations

Production of good yield in low rainfall and water scarce areas need good cultural practices and suitable tillage systems. Further study is recommended on the evaluation of tillage systems on different crops in order to ascertain the optimal system for each crop and suitable planting time for legumes.

REFERENCES

Andrade, F. H., M. E. Otegui and Vega C. 2000. Intercepted Radiation at flowering and kernel number in maize. Agron. J. 92: 92-97.

Ayisi, K.K., M.S. Mposi, and J. van den Berg. 2001. Grain yield response and *C. partellus* infestation in diverse sorghum: cowpea intercrop arrangements. S. Afr. J. of Plant and Soils. 18 (1).

Barbieri, P. A., H. R. Rozas, F. H. Andrade and H. E. Echeverria. 2000. Row spacing Effect at Different levels of Nitrogen Availability in Maize. Agron.J.92:283-288.

Belay, A., H. Gebrekidan and Y. Uloro. 1998. Effect of tied ridges on grain yield response of Maize (*Zea mays L.*) to application of crop residual N and P on two soil types at Alemaya, Ethiopia. South African J. Plant and Soil 15:123-129.

Bratia, C. R. and R. Mitra. 1990. Bioenergetic of grain protein. In Nitrogen in higher plants. Y.P Abrol. P.427.New York

Brophy, L. S. and G. H. Heichel. 1989. Nitrogen release from root of alfalfa and soybean growth in sand culture. Plant and Soil 116:77-84

Cenpukdee, U. and S. Fukai., 1991. Effects of nitrogen supply on Cassava/pigeon pea intercropping with three contrasting cassava cultivars. Field Crops Res., 29: 275-280.

Clark, K. M. and R. L. Myers. 1994. Intercrop performance of pearl millet, amaranth, cowpea and soybean in response to planting pattern and nitrogen. Agron. J. 86:1097-1102.

Daniel, J. B., A. O. Abaye, M. M. Alley, C. W. Adcock and J. C. Maitland. 1999. Winter Annual Cover Crops in a Virginia No-till Cotton Production System: II. Cover and Tillage Effects on Soil Moisture, Cotton Yield, and Cotton Quality. The Journal of Cotton Sci. 3:84-91.

Eaglesham, A. R. J., A. Ayanaba., V. Ranga Rao and D. L. Eckew. 1981. Improving the nitrogen nutrition of maize by intercropping with cowpea. Soil Biol. Biochem. 13:169-171.

Evans, L. T. 1993. Crop Evaluation, Adaptation and Yield. Cambridge Press, Australia

Ghaffarzadeh, M., F. G. Prechac, and R. M. Cruse. 1997. Toillage effect on soil water content and corn yield in a strip intercropping system. Agronomic journal. 89: 893-899

Gardiner, T. R., and L. E. Cracker., 1981. Bean growth and light interception in a bean-maize intercrop. Field Crops Res. 4: 313-320

Gomez, K. A., and A. A. Gomez. 1984. Statistical procedure for agricultural research. 2nd ed. John Wiley and sons, Inc. New York.

Hartkap, A. D., G. Hoogenboon, R. A. Gilbert, T. Benson, S. A. Tarawali, A. J. Gijsman, W. Bown and J. W. White. 2002. Adaptation of the CROPCRO growth model to velvet bean (*Mucuna prupriens*). II. Cultivar evaluation and model testing. Field Crop Res. 78:27-40.

Hartkap, A. D., G. Hoogenboon and J. W. White. 2002. Adaptation of the CROPCRO growth model to velvet bean (*Mucuna prupriens*). I Model development. Field Crop Res. 78:9-25.

Hatfield, J. L., T. J. Sauer and J. H. Prueger. 2001 Managing soils to achieve greater water use efficiently: A review. Agron. J. 93:271-280.

Kladivko, E. J. 2001. Tillage systems and Soil ecology. Soil and Tillage Res. 61:61-76.

Maluleke, H. M. 2004. Biological productivity, soil resource use and stalk borer infestation in maize lablab planting date and density intercropping system. Masters thesis. University of the North.

Mehdi, B. B., C. A. Madramootoo and G. R. Mehuys. 1999. Yield and Nitrogen Content of corn under different tillage practices. Agron. J. 91:631-636.

Modiba, M. D. 2002. Growth and grain yield response of maize (Zea mays) water and Nitrogen in smallholder irrigation schemes in the Limpopo province. Master thesis. University of the North, Syferkuil.

Morris, R. A., Villegas, A. N., Polthane, A. and Centeno, H. S., 1990. Water use by mono-cropped and intercropped cowpea and sorghum grown after rice. Agronomy Journal., 82: 884-668.

Murungweni, C., S. Chibi, L. Svisva, C. Nyama, G. Manyawu, N. Mukombe and N. Mutema. 2002. Velvet bean Hay (*Mucuna pruriens*), Dolichos lablab Hay (*Lablab purpureurs*) and Paprika Calyx (*Capsicum anuum L*) as Substitutes for Conventional Protein Sources used in Dairy and Fattenning Diets by Smallholder Farmers of Zimbabwe. AS2/96/149 Annual workshop, Makgobaskloof. 7-10 October 2002. Pp. 144-122.

Olaoye, O. J. 2002. Influence of tillage on crop residue cover, soil properties and yield components of cowpea in derived Savannah Ectones of Nigeria. Soil and Tillage Res. 64:179-187.

Oweis, T., H. Zhang and M. Pala. 2000. Water use Efficiency of Rainfed and Irrigated Bread Wheat in a Mediterranean Environment. Agron. J. 92:231- 238.

Rauschkolb, R. S. and A. G. Hornsby. 1994. Nitrogen management in irrigated agriculture. Oxford, University Press, 251pp.

Rozas, H. S., H. E. Echeverria., G. A. Studdent and F. H. Andrade. 1999. No-till maize Nitrogen uptake and yield: Effect of Urease inhibitor and application time. Agron. J. 91:950-955.

Sallar, R. Y. K. 1991. Effect of six cycle of recurrent selection on the nitrogen response of a Lowland Tropical maize production. Proceedings of the SAFGRAD Inter Network Conference held at 'Palais des Congres'.p 195-197. Menyonga J. M, yayouk J. Y., Niamey, Niger.

SAS Institute. 1990. SAS/statistics user's guide. Version 6, 4th Ed. SAS Inst. Cary, NC.

Scott, H. D., 2000. Soil physics. Agricultural and Environmental applications. Published at Iowa State University Press. USA

Scott, C. C and J. B. Hector., 1997. Using a chlorophyll meter to estimate specific leaf nitrogen of tropical maize during vegetative growth. Agronomy Journ. 89: 557-562.

Sinclair, T. R and R. C. Muchow. 2001. System Analysis of Plant Traits to Increase Grain Yield and Limited Water Supplies. Agron. J. 93:263-270.

Smartt, J. 1990. Pulses of the classical world, p. 190-198. In: R.J. Summerfield and E.H. Ellis (eds.). Grain legumes: evaluation and genetic resources. Cambridge Univ. Press, Cambridge.

Smith, C. W. 1995. Crop production. Wiley, Canada.

Soil classification working group. 1991. Soil classification, A Taxonomic System for South Africa. Soil and Irrigation Research Institute, Department of Agricultural Development. Pretoria.

Sprague, G. F and J. W. Dudley. 1988. Corn and Corn Improvement. Madison, Wisconsin: USA.

Tabassum, M. I. 2004. Development of maize under water stress areas. DAWN-Business.14November2004.

Torbert, H. A., K. N Potter, and J. E Morrison. 2001. Tillage system, fertilizer Nitrogen rate and timing effect on corn yields in the Texas Blank land Prairie. Agron. J.93:1119-1124.

Unger, P. W. 1991. Ontogeny and water use of No-tillage Sorghum Cultivars on D Dryland. Agron. J. 83:961-968.

Van Rensburg, J. 1998. Farming Systems Research. Maize-cowpea intercropping research at Impendhile. Agri-update, Kwazulu Natal.

Vandemeer, J.1992. The Ecology of Intercropping. Cambridge Press. New York.

Wang, G., M. S. Kang and O Morero. 1999. Genetic analyses of grain-filling rate and duration in maize. Field Crops Res. 61:211-222.

Watiki, J. M., S. Fuka, J. A. Banda and B. A. Keating. 1993. Radiation interception and growth of maize/cowpea intercrop as affected by maize plant density and cowpea cultivar. Field Crop Res. 35:123-133.

Yusuf, R. I., J. C. Siemens and D. G. Bullock. 1999. Growth analysis of soybean under No-tillage and conventional tillage systems.

DISSERTATION APPENDIX

Table 1. Response of maize grain yield to tillage systems at Dalmada (2002/2003 and 2003/2004) and Syferkuil (2003/2004).

	Dalmada		Syferkuil
Tillage	2002/2003	2003/2004	2003/2004
	………………………………Kg/ha…………………		
CT	357b	1557a	2943b
MT	755a	1436a	3393a
Lsd	145.07	ns	355.26
Tillage	**	ns	*
Cropping system	ns	ns	ns
Tillage*Cropping	*	*	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 2: Moisture response to tillage system at Syferkuil during 2003/2004 growing season.

Tillage	0-150mm	150-300mm	0-150mm	150-300mm
	84 DAP		126 DAP	
CT	9.24a	9.72a	6.9b	7.9b
MT	10.29a	10.53a	8.8a	10.5a
Lsd	ns	ns	0.95	1.5
Tillage	ns	ns	**	**
Cropping system	ns	ns	Ns	ns
Tillage*Cropping system	ns	ns	Ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table3: Moisture response to cropping system at Syferkuil during 2003/2004 growing season.

Cropping system	0-150mm	150-300mm	0-150mm	150-300mm
	84 DAP		126 DAP	
Sole	10.76a	11.05a	7.9a	9.7a
M+Agri	8.98a	10.36a	7.8a	10.4a
M+Lab	8.83a	8.39a	7.3a	8.5a
M+Vel	10.40a	10.79a	7.9a	8.8a
M+BCW	9.87a	10.03a	8.5a	8.7a
Lsd	Ns	ns	ns	ns
Tillage	Ns	ns	**	**
Cropping system	Ns	ns	ns	ns
Tillage*Cropping system	Ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 4: Moisture response to tillage system at Dalmada during 2003/2004 growing season.

Tillage	0-150mm	150-300mm	0-150mm	150-300mm
	74 DAP		130 DAP	
CT	8.2b	9.9a	7.2a	7.1a
MT	10.9a	12.0a	8.1a	7.9a
Lsd	2.4	ns	Ns	ns
Tillage	*	ns	Ns	ns
Cropping system	ns	ns	Ns	*
Tillage*Cropping system	ns	ns	Ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 5: Moisture response to cropping system at Dalmada during 2003/2004 growing season.

Cropping system	0-150mm	150-300mm	0-150mm	150-300mm
	74 DAP		130 DAP	
Sole	9.79a	10.67a	7.3a	8.3a
M+Agri	10.6a	10.9a	7.7a	7.6ab
M+Lab	10.7a	15.2a	6.6a	7.9ab
M+Vel	9.2a	9.2a	8.5a	6.7b
M+BCW	7.8a	8.8a	8.2a	6.7b
Lsd	Ns	ns	ns	1.28
Tillage	*	ns	ns	ns
Cropping system	Ns	ns	ns	*
Tillage*Cropping system	Ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 6: Moisture response to tillage system (Dalmada 2002/2003).

Tillage	0-150mm	150-300mm	0-150mm	150-300mm
	63 DAP		81 DAP	
CT	5.58a	4.35b	6.99b	9.16a
MT	4.37a	6.76a	8.59a	8.96a
Lsd	ns	2.13	1.52	ns
Tillage	ns	*	*	ns
Cropping system	ns	ns	Ns	ns
Tillage*Cropping system	ns	ns	Ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 7: Moisture response to cropping system (Dalmada 2002/2003).

Cropping system	0-150mm	150-300mm	0-150mm	150-300mm
	63 DAP		81 DAP	
Sole	4.11a	4.40a	7.08a	9.27a
M+Agri	3.69a	7.11a	6.66a	9.06a
M+Lab	6.61a	5.41a	7.78a	8.66a
M+Vel	5.65a	5.68a	9.17a	9.24a
M+BCW	4.81a	5.18a	9.07a	
Lsd	ns	ns	ns	ns
Tillage	ns	*	ns	ns
Cropping system	ns	ns	ns	ns
Tillage*Cropping system	ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 8: Effect of tillage system on chlorophyll content in the youngest fully expanded leaf at Dalmada during 2002/2003 growing season.

Tillage	64 DAP	71 DAP	78 DAP	96 DAP
CT	33a	35a	39a	23a
MT	36a	37a	36b	23a
Lsd	ns	ns	2.6	ns
Tillage	ns	ns	*	ns
Cropping system	ns	ns	ns	ns
Tillage*Cropping system	ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 9: Effect of tillage system on chlorophyll content in the lower leaves at Dalmada during 2002/2003 growing season.

Tillage	64 DAP	71 DAP	78 DAP	96 DAP
CT	35b	40a	42a	23a
MT	39a	38a	38b	21a
Lsd	3.75	ns	3.58	ns
Tillage	**	ns	*	ns
Cropping system	ns	ns	ns	ns
Tillage*Cropping system	ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= p<0.01; *= p<0.05; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 10: Effect of cropping system on chlorophyll content in the lower leaves at Dalmada during 2002/2003 growing season.

Cropping system	64 DAP	71 DAP	78 DAP	96 DAP
Sole	36.82a	37.32a	42.64a	23.0a
M+Agri	34.00a	38.91a	37.32a	23.3a
M+Lab	38.68a	40.20a	39.16a	22.1a
M+Vel	38.34a	38.59a	38.98a	22.1a
M+BCW	37.87a	38.35a	42.41a	22.2a
Lsd	ns	ns	Ns	ns
Tillage	**	ns	*	ns
Cropping system	ns	ns	Ns	ns
Tillage*Cropping system	ns	ns	Ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

Table 11: Effect of Crop system on chlorophyll content in the youngest fully expanded leaf at Dalmada during 2003/2004 growing season.

Cropping system	64 DAP	71 DAP	78 DAP	96 DAP
Sole	34.45a	35.49a	39.46a	23a
M+Agri	32.24a	36.05a	35.13a	23a
M+Lab	35.50a	35.57a	36.94a	24a
M+Vel	35.18a	37.56a	36.85a	23a
M+BCW	36.02a	35.94a	37.59a	27a
Lsd	ns	ns	ns	ns
Tillage	**	ns	*	ns
Cropping system	ns	ns	ns	ns
Tillage*Cropping system	ns	ns	ns	ns

LSD = Least significant difference. Means followed by the same letter within a column are similar statistically; **= $p<0.01$; *= $p<0.05$; ns = not statistically significant. CT = Conventional tillage. MT = Minimum tillage

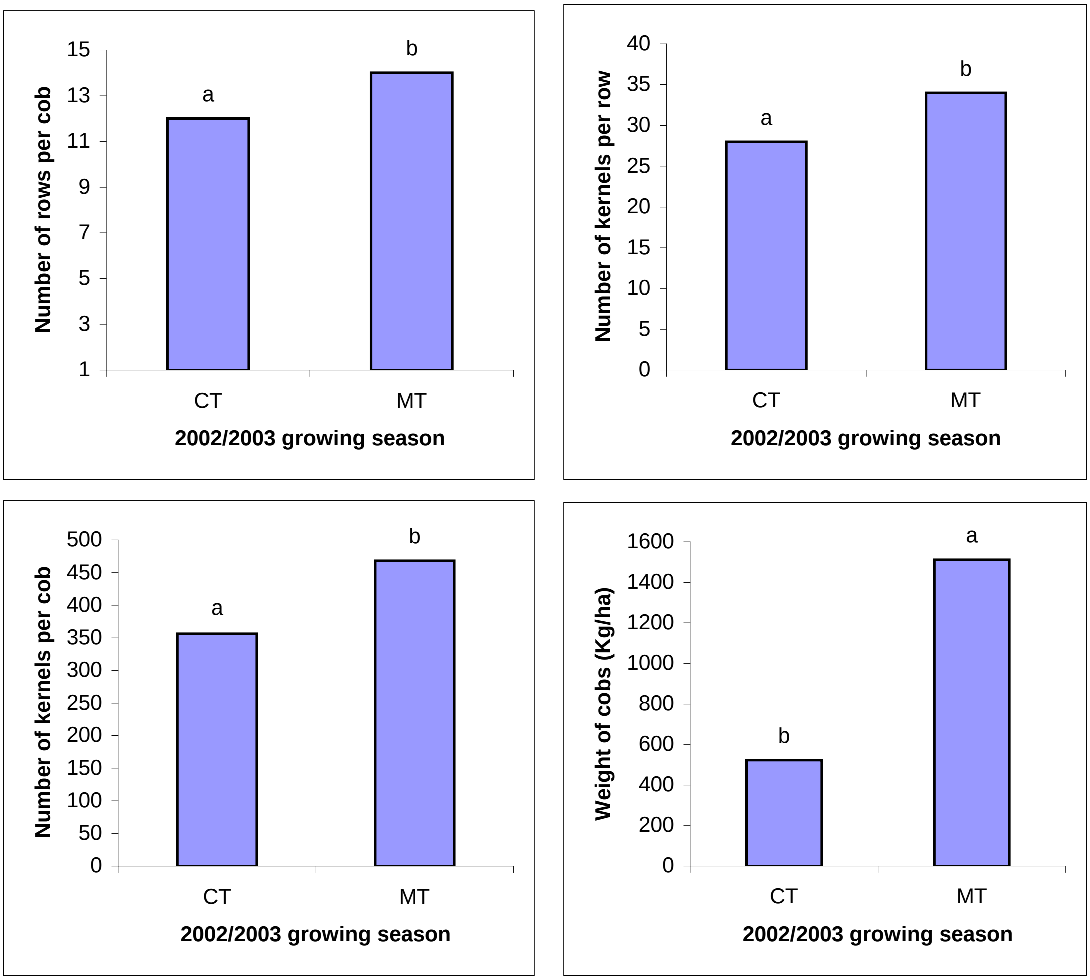


Fig 1. Maize yield components as influenced by tillage systems at Dalmada during 2002/2003 growing season.

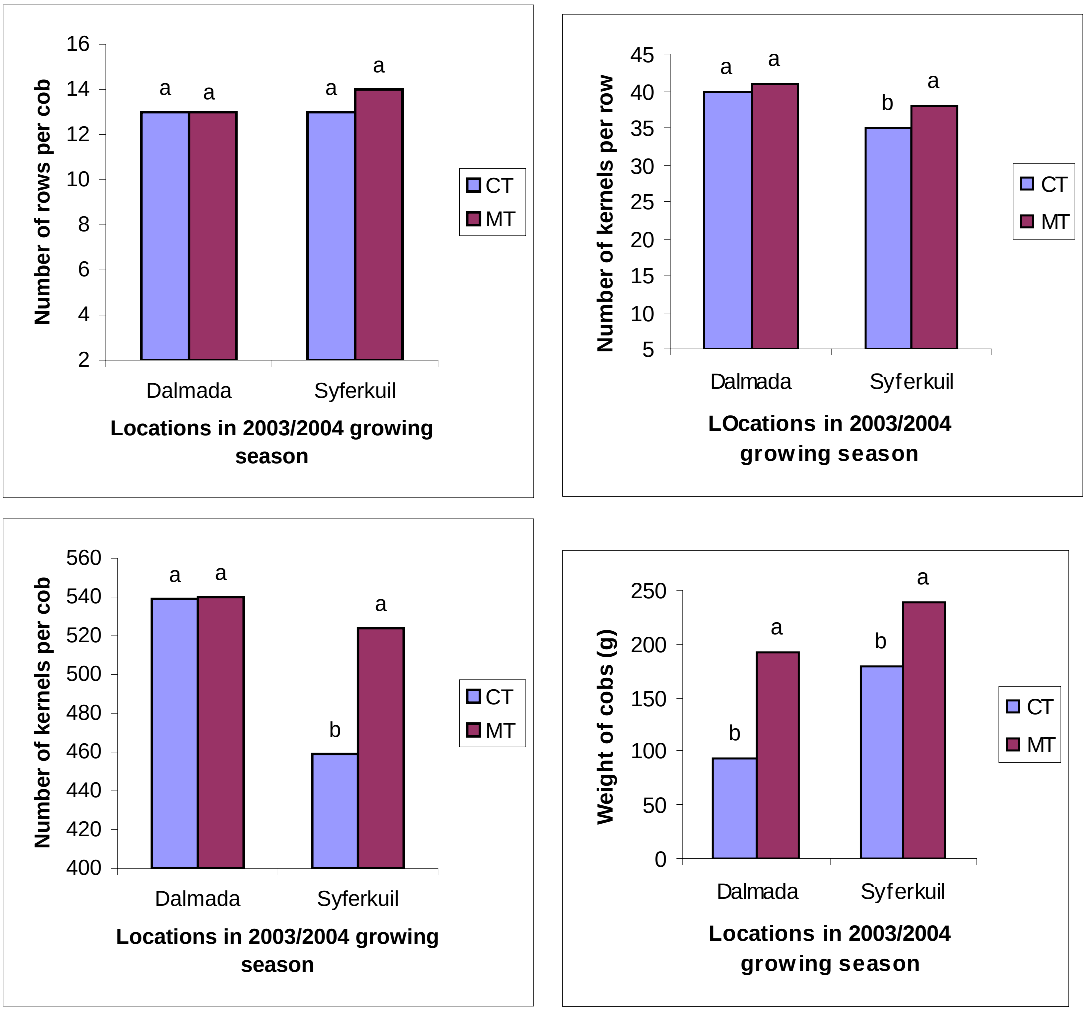


Fig. 2. Maize yield components as influenced by tillage systems at Dalmada and Syferkuil during 2003/2004 growing season.