Soybean (*Glycine max* L. Merr) productivity in varying agro-ecological zones

by

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DECLARATION

I, Abraham P. Dlamini declare that the dissertation, which I hereby submit for the degree MSc (Agric) Agronomy at the University of Pretoria is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution. I also certify that no plagiarism was committed in writing this dissertation.

Signature............................

Date....................................

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ABSTRACT

Soybean (*Glycine Max* L. Merr) is one of the most important food crops in the daily diets of humans and animals, as it provides essential proteins and other nutrients. The crop is not only a source of food, but is also beneficial to the soil, as the crop has a symbiotic relationship with *Rhizobium* bacteria, which is capable of fixing atmospheric nitrogen in the soil, resulting in no need to apply nitrogen to the crop. Although soybean is a crop grown world-wide, individual cultivars often demonstrate a limited adaptation to specific agro-ecological conditions, since the growing season must be long enough and soybeans are also photoperiod sensitive. During the growing season, daylength is therefore one of the most important factors to take into consideration for cultivar choice. The aim of this study was to determine the growth, development and yield response of soybean cultivars of different maturity groups when planted in varying agro-ecological zones.

Field experiments were conducted at Pretoria, South Africa, and at two locations in Swaziland, Malkerns and Nhlangano. Six soybean cultivars of different maturity groups and different growth habits (determinate and indeterminate) were planted at these sites. Plant growth analyses were carried out every two weeks, from plant establishment until physiological maturity. Thermal time requirements to reach different growth stages were calculated and final grain yield was determined at harvest and also during growth analysis.

The growing degree day requirement from planting to crop emergence ranged from 45 to 62 d°C for all six cultivars. Thermal time requirement for completion of the vegetative stage ranged from 530 to 900 d°C, with the early maturing cultivar LS 6162 having the lowest requirement of 530 d°C, while the late maturing cultivars PAN 737 and LS 6164 required 890 and 900 d°C. The different cultivars also showed distinct differences in growth during the season. Grain yields obtained from the different cultivars from the three locations ranged from 0.9 t ha^{-1} (LS 6162) to 3.4 t ha^{-1} (PAN 737).

The indeterminate cultivar (LS 6150) gave significantly higher yields compared to the other cultivars at Malkerns (1.3 t ha^{-1}) and Nhlangano (1.9 t ha^{-1}). Cultivar PAN 737 gave higher yields than all the cultivars at Pretoria (3.4 t ha^{-1})

The six soybean cultivars that were evaluated in these experiments have demonstrated substantial differences in growth, development and yield potential. Cultivar specific model growth parameters were calculated. The Soil Water Balance model was then calibrated and used to simulate growth and yields of each cultivar. The simulations were acceptable for all the cultivars, which will in future enable us to forecast how cultivars of different maturity groups will perform in different environments.

Keywords: soybean cultivars, determinate, indeterminate, day degree requirement, soybean grain yield, response to environment, growth modelling.

CHAPTER 1

1.1 INTRODUCTION

Soybean (*Glycine max* L. Merr,) is one of the most important food crops in our daily diets as it provides our bodies with proteins and iron (Oluyemisi, 1991). They are used to feed both humans and animals. Soybeans are not only good for consumption, but are also good for the soil as they are nitrogen self-sufficient, and they also produce leaf biomass which gives a soil fertility benefit to subsequent crops (Mpepereki *et al*., 2000). They can be planted in rotation with other crops like wheat to ensure two crops per annum. This results in increased yields for both crops and simplifies weed and pest control (Erasmus & Fourie, 2010).

Although the soybean crop is grown world-wide, individual varieties demonstrate a limited adaptation to specific geographical areas, meaning that they are area specific with regard to optimal adaptation (Heinemann *et al*., 2006). The duration from planting to maturity is approximately 120 to 130 days for well-adapted cultivars. Where cultivars are planted at higher altitudes the growth period will be lengthened. A selection can be made for varieties with high yield and optimum yield reliability under comparable environmental conditions as well as production practices (Erasmus & Fourie, 2010).

The length of the growing season of soybean is the most important characteristic to take into consideration in selecting a suitable cultivar. Unlike most other commonly cultivated crops, soybeans are sensitive to day length (photoperiod) and a given cultivar will mature later, giving a longer growing season, when planted further south in Southern Africa. Planting dates also influence the length of the growing season and a given variety will flower at the same time irrespective of the planting date.

Prevailing temperatures also have an effect, with soybean growing much slower in the cooler highveld as compared to the warmer lowveld (Erasmus & Fourie, 2010).

Experienced soybean producers can utilize the photoperiod sensitivity of the crop along with the genetic variation for relative length of the growing season with great success. For example for hay production, a long growing variety can be used. Varieties of different maturity dates should also be planted at different dates for scheduling of harvest. Short growing season varieties are recommended for drought avoidance or emergency planting.

Producers with little or no experience in soybean production, risk losing the crop when the wrong cultivar choice is made. The same may happen when the crop is ready for harvest while rain and high temperatures hamper harvesting and adversely affect quality of the crop (Erasmus & Fourie, 2010).

Temperature is one of the most important factors in plant growth and development. Plants and animals depend on temperature for their survival. Under optimal temperatures, plants and animals exhibit their full potential in growth and development if water and nutrients are not limiting. Crops grown under low temperatures may exhibit a loss of vigour, reduced growth rate and yield (Janas *et al*., 2002).

Heinemann *et al*., (2006) reported that due to an increase in carbon dioxide level of the atmosphere, it is expected that the maximum and minimum mean global temperatures will also change by 3 to 4°C. The intergovernmental panel on climate change (IPCC) expects a global surface temperature increase ranging from 1 to 3.5°C by 2100 based on the predictions of general circulation models, such as GISS, UKMO, OSU; and GFDL-R30. The interactive effects of global warming and increasing carbon dioxide levels could especially impact agriculture, affecting both growth and development of crops and ultimately impacting yield and food production (Southwort *et al*., 2006). Climate change is expected to affect solar radiation, temperature and precipitation, which will lead to changes in crop growth, development, yields, cropping systems and crop production practices.

Since environmental conditions, especially temperatures affect crop growth and yields; there is currently a need to forecast how different types of soybean varieties will adapt to new conditions or localities, for example locations in Swaziland where little or no soybean has been planted to date. A model can be a handy tool to help establish how well a cultivar will adapt and perform in such environments if weather data is available. Furthermore, calibrated crop models can be used to assess how climate change and rising temperatures will affect future adaptation of crops and yield. However, model growth parameters are required for growth, development and yield modelling, and these parameters may differ from cultivar to cultivar, depending on the different maturity groups and growth habits. Growth analysis needs to be carried out to be able to calculate such model parameters. Calibrated models can then be used to simulate yields of different cultivars in different geographical regions, for example, in Swaziland.

The Soil Water Balance model (Jovanovic *et al*., 2000) is an example of such a crop growth model and was used in this study. This model is a mechanistic, real-time, generic crop, soil water balance, irrigation scheduling model. It gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop databases. However, since SWB is a generic crop model, parameters for each crop have to be determined.

1.1.1 Problem statement

Although soybean is a crop grown world-wide, individual cultivars often demonstrate limited adaptation to specific agro-ecological conditions and low yields are obtained. The growing season must be long enough to enable the crop to reach its full potential growth so as to obtain maximum yields. Soybean is photoperiod sensitive which means that some growth stages of the crop could be delayed if the conditions required by the crop to perform a certain activity are not met (e.g. flowering may be delayed if conditions for flowering are not met). During the growing season, day length is therefore one of the most important factors to take into consideration for cultivar choice.

1.1.2 Specific Objectives

The objectives of this study were:

i. To determine how growth, development and yield of six soybean cultivars of different maturity groups will be affected by varying agro-ecological zones.

ii. To calibrate a crop model that can be used to simulate yields of different cultivars in different environments.

CHAPTER 2: LITERATURE REVIEW

2.1 Reproductive development of soybean as affected by photoperiod

Soybean varieties are classified into thirteen maturity groups (MGs) 000,00,0 and I-X in accordance to photoperiodic response and geographical region of cultivation. Photoperiod (day length) is responsible for many processes that are required in soybean development. It is primarily responsible for the time of flowering in soybean and some later stages in the development of the soybean crop. Reports suggest that in photoperiod responsive varieties, successive reproductive stages seem to require progressively shorter days. The photoperiodic response is modified to some extent by temperature and the age of the plant. Photoperiod can also modify a number of physiological processes during soybean reproductive growth, such as nitrogen and dry-matter partitioning (Morandi *et al*., 1998).

Photoperiod also modifies the temperature response in soybean, a quantitative short day plant, in which longer day length slows the development rate by delaying the reproductive growth stage. The maturity group classification for soybean varieties is based on the soybean development response to photoperiod. Considering the well-known photoperiod flower induction response in soybean, the use of photoperiod function in soybean phenology modelling can be applied (Setiyono *et al*., 2007).

According Miladinovic *et al*., (2006) soybean development can be divided into two stages, vegetative and reproductive. Since soybean is photo-periodically sensitive, it means that the transition from the vegetative stage to the reproductive stage depends directly on day length. When grown late in locations with low temperatures soybean will flower irrespective of the planting time, have a smaller vegetative mass and mature earlier, resulting in lower yield. Photoperiod requirements, therefore limit the geographical distribution of a variety to a narrow belt of latitudes to which a variety has been adapted. Therefore, for every soybean growing region there is an optimum maturity group.

Varieties that are one maturity group earlier than the optimum are too early for the area concerned and vice versa, those that are one group later are too late (Miladinovic *et al*., 2006).

Soybean has been selected to adapt even in low-latitude areas through the discovery and incorporation of long-juvenile genes that delay flowering. Without these genes soybean grown in these low-latitude areas would flower very soon after crop emergence, resulting in very short plants that produce low yields (Sinclair *et al*., 2005).

According to Kantolic *et al*., (2005) the number of pods per plant is an important yield component that is responsible for differences in soybean yields between varieties and environments. These components are mainly determined during a period that begins sometime around flowering and extends through pod set, including the beginning of the seed-filling period. During this period limitations in assimilate supply reduce flower production and increase flower abortion and pod abscission.

A direct relationship between seed number per unit area and crop growth rate during the critical period of pod and seed formation has been found, independent of changes in growth during the rest of the cycle (Kantolic & Slafer, 2005). Furthermore a direct relationship between the duration of the critical period of pod formation and the seed number produced per area has been found (Egli & Bruening, 2000). These findings suggest that soybean yields can be improved by optimising growing conditions during the critical period of pod and seed formation which will ensure increased crop growth rate and duration. It had been reported that the duration of the reproductive period may be modified by manipulating plant responses to the environmental factors controlling development, mainly temperature and photoperiod (Setiyono *et al*., 2007).

There is genetic variability in plant sensitivity to photoperiod during post-flowering stages, but it is not clear whether the sensitivity to photoperiod during the period for seed number determination is directly related to crop ability to set pods or grains (Kantolic & Slafer, 2005).

In some field studies conducted with four indeterminate varieties, exposing the plants after R3 (beginning of pod stage) to photoperiods two hours longer than the natural day length resulted in a longer period of pod and seed formation and increased seed number. These increments were evident in early sowing dates but were not very noticeable when the sowing was delayed, suggesting that the range of natural photoperiods explored by plants during the reproductive phases conditioned their response to treatments (Kantolic & Slafer, 2001).

Although photoperiod has been proven to be the major factor controlling post-flowering development of soybean, little is known about how photoperiod controls the growth of vegetative organs and functional duration of leaves, especially its effects at reproductive phases (Han *et al*., 2006). Photoperiod sensitivity can apparently be manipulated in soybean. Han *et al*., (2006) reported that photoperiod-sensitive soybean varieties were shown to revert to vegetative growth following flower and pod abortion, and sprout new branches when exposed to long days after flowering. Although abscission of flowers and pods happened after the transfer from short days to long day conditions, it was not confirmed that long days and not flower and pod abortion was the triggering factor of vegetative growth resumption during the process of ‘whole plant reversion’. It has been found that most leaves of late-maturing soybean varieties were induced by short days before flowering and there were few new leaves produced after beginning of bloom at the initial stage of post-flowering long day treatment (Han *et al*., 2006).

Photoperiodic responses of soybean were shown to be persistent throughout its life cycle, however, there is not enough evidence to prove that photoperiod is the major factor affecting the duration of podding, seed filling and maturation phases (Han *et al*., 2006).

Studies showed that post-flowering photoperiod treatments started on the onset of blossoming, and the stages of the initial pod growth and beginning of seed filling were later in long day treatments than those in the short day control, when the lowering outdoor temperature might have been the dominant factor delaying the reproductive development in long day treatment (Han *et al*., 2006).

Photoperiod-induced flowering in soybean has been found to be a red/far-red (R/FR) light reversible reaction, indicating that this reaction was mediated by phytochromes (Han *et al*., 2006). Experiments also proved that the post flowering reproductive development of soybean was delayed by night-break with mixed light (Han *et al.*, 2006), indicating that the post flowering photoperiod responses of soybean shared a common mechanism with that of flowering responses. It is however, not clear if the post-flowering vegetative growth and reproductive development are also red/far-red reversible reactions (Han *et al*., 2006).

2.2 Soybean adaptability to different temperature regimes

Temperature is one of the most important factors that influence crop development. Soybean is also one of those crops that require suitable temperatures for its development. The possibility of precisely predicting plant developmental stages is of great practical importance in the sense that it makes it easier to make decisions on when to apply a certain practice, which should be paired with a specific stage of plant development for maximum efficacy. The assessment of phenological development as a function of specific environment variables is a basic piece of information necessary for any attempt at modelling plant growth, adaptation and productivity as a dynamic process. Soybean phenology, however, is hard to predict because it depends on a combination of factors such as photoperiod, temperature and the amount of water available to the plant. However, other factors, like soil fertility, resistance to specific diseases and insect pests, or resistance to lodging under rainy conditions are also important (Miladinovic *et al*., 2006).

Since temperature plays an important role in crop development, it is the reason why temperate varieties belong to the early maturity groups (MG 000-III) and are cultivated in regions with short summer periods and long summer days such as Sweden, Southern Canada and Northern USA. Soybean varieties belonging to the late maturity groups (MGs) e.g. MG VII and VIII are generally cultivated in tropical and sub-tropical regions. When grown under an 11 hour photoperiod and 30°C/20°C day/night temperatures, early maturity varieties flower 26-27 days after crop emergence, whereas late maturity varieties generally flower only after 42 days. This large difference in flowering response between tropical soybean varieties may be a confounding factor when trying to distinguish between intrinsic dark chilling tolerance and avoidance (escape) of chilling damage (Van Heerden *et al*., 2004).

A longer growing season result in higher potential production, defined by the suitable temperatures for plant growth and no water limitations. Therefore, a longer crop period means greater biomass yield, which is an important determinant of seed yield. Miladinovic *et al*., (2006) provided evidence that, in the absence of water stress, lower levels of insulation during the reproductive growth stage were a major contributor to yield loss, with temperature only becoming important for very late maturing varieties. However, investigations in dry conditions showed that in dry years early varieties may have yields that are the same as or even higher than those of the late ones.

Temperature influences crop productivity, and it is generally accepted that the highest soybean yields are obtained from varieties that have a total growth cycle that uses most of the available growing season. This is attributed to the fact that there are adapted cultivars differing by 20 to 30 days in the length of their total growth cycle that produce similar yields. Yield differences among varieties with differences in the length of their total growth cycle could occur because critical growth stages may fall in more or less favourable environments. Egli (1993) reported that if environmental effects are not a factor, yields would respond to changes in the length of the total growing cycle only if there were differences in canopy photosynthesis, partitioning or the duration of seed fill.

Wang et *al.*, (1997), proved that soybean grown in controlled environmental conditions at a range of day/night temperatures, namely 23/18°C, 28/23°C, and 33/28°C and exposed to cold temperature of 8°C for 24 hours at the different development stages of growth, showed different growth patterns. The low temperature of 8°C was selected because soybean frequently experiences this temperature during the early growing season and chilling injury does occur at this temperature. The V5 and R1 (the appearance of first open flower) stages were selected because V5 represents the late vegetative stage and R1 represents a reproductive stage that is very sensitive to low temperature (Table 2.1). The cold temperature delayed R1 stage for plants grown at 28 /23°C and delayed R2 stage (the appearance of flowers at the node immediately below the upper most nodes) for plants grown at all three temperatures by up to 7 days, and prolonged the time period between R1 and R2 stages. The delay in the reproductive stages to some extent resulted from decreased rates of leaf photosynthesis, reduced concentration of leaf soluble carbohydrates, and the preferential partitioning of plant biomass into shoots, which resulted in the stem height of the cold-treated plants being greater than the stems of the control plants, and in particular into preferential partitioning to leaves rather than reproductive organs. This was because exposure of the soybean plants to 8°C for 24 hours at V5 and R1 stages altered vegetative growth. Visible leaf wilting of plants occurred during the period of cold treatment and plants gained turgor shortly after the treatment was terminated (Wang *et al*., 1997).

Table 2. 1: Development stages and growth of soybean

Stage	Description of stage
VE	Emergence, cotyledons are above the ground
V1	Unifoliate leaf completely unrolled
V2	Leaf above Unifoliate leaf completely unrolled
V3	Three nodes on main stem have fully developed leaves
VN	Nth node has leaves fully unrolled
R1	One flower on any node of the main stem
R2	Open flower at one of the two uppermost nodes of the main stem with fully developed leaf
R3	Pods about 0.5 cm long at one of the four upper most nodes with completely unrolled leaf
R4	Pods about 2.0 cm long at one of the four upper most nodes with completely unrolled leaf
R5	Seeds about 3 mm long in one of the four upper most nodes with completely unrolled leaf
R6	Pods have full-size, green beans at one of the four upper most nodes with completely unrolled leaf
R7	One of the pods on the main stem has its mature pod colour
R8	Physiological maturity; about 95% of the pods are mature

Improved soybean varieties are needed for adaptation to environments of South Africa, where the maximum temperatures are similar to those in regions in North America, where soybean is grown, but where early morning temperatures (daily minimum temperature) are much lower due to altitude and the more arid climate. The differential influence of night versus day temperature on soybean development rate to flowering has been noted in growth chamber studies by many researchers (Piper *et al*., 1996).

Reports suggest that certain soybean yields were accepted and thought to be the maximum yields that could be obtained in specific production regions. With time yields obtained became higher than the yields which were initially thought to be the maximum yields. This led to research being carried out for several years to ascertain the high yields being obtained. It was noted that higher yields were associated with higher temperatures, which resulted in early flowering of the soybean when planted during high temperature periods (Cooper, 2003). It had been suggested that the effect of day and night temperature rate to flowering is mediated by both a weighed mean temperature and the diurnal temperature difference. Researchers then observed that night temperature had a greater effect on time of flowering than day temperature. Relating temperature to time from sowing to flowering in 'thermal units' as the accumulation of the difference between the daily mean temperature and a base temperature has since been widely used by researchers (Piper *et al*., 1996).

2.3 Effects of low temperature stress at different development stages

Low temperature stress (chilling) is one of the most important environmental constraints in agriculture. Soybean is regarded as a chilling sensitive crop species. As such chilling stress represents a major limitation on the cultivation of soybean for nutritional purposes. In South Africa, it is especially the low temperature nights (dark chilling) in high altitude regions that limit the cultivation of soybean. A single night of dark chilling, with minimum temperatures of less than 8 ^{o}C, is sufficient to inhibit pod formation in soybean (Van Heerden *et al*., 2004).

In order to increase soybean production in South Africa, breeding strategies must seek to develop varieties less sensitive to dark chilling. One strategy that may be employed to increase the dark chilling tolerance of soybean varieties is the inclusion of temperate varieties of known dark chilling tolerance as parental material in breeding programmes. It is generally assumed that soybean varieties adapted for grown in temperate areas should contain chilling tolerance trends not found in subtropical or tropical varieties (Van Heerden *et al*., 2004).

Low temperature has been reported to cause numerous symptoms in soybeans, including non-opening of flowers, numerous small seedless pods developing predominantly at the top of the plant and the presence of multi-carpelate and deformed pods along the stem, abscission of the reproductive structures which could result in single poorly yielding or barren nodes (Gass *et al*., 1996).

2.4 Role of temperature in respiration and photosynthesis

Tambussi *et al*., (2004) reported that low temperatures severely limit growth of plants of tropical and subtropical origin. It was reported that the photosynthetic capacity declines in chilling-susceptible plants that are exposed to low temperatures, and this decline is related to the decrease in the quantum efficiency of photo system II (PSII) and the activities of photosystem 1, the ATP synthase and the stromal enzymes of the C3 carbon reduction cycle.

According to Vu *et al.,* (2001) temperature is one of the most important factors affecting photosynthesis of soybeans, with optimum day/night temperatures of 32/22°C. High temperatures of e.g. 40/30°C lead to a decline in photosynthesis, as the activity of the protein Rubisco, which is responsible for photosynthesis, declines during high temperatures, resulting in low photosynthesis, hence slow plant development, maturity and reduced yield.

Metabolic comparisons of soybean cultivars from different maturity groups at different temperatures may help guide future selection of new soybean genotypes for growth in a given climate (Hemming *et al*., 2000).

2.5 Quality of the soybean product as affected by temperature

Quality of a product is one of the most important aspects in crop marketing. Soybean is one of the crops whose quality deteriorates if harvested or stored at temperatures that are not suitable. Chlorophyll degradation has been a problem in de-greening (removal of the green colour) crops. Soybean is one of the crops whose quality is greatly affected by this phenomenon. The presence of greenish pigments in soybean grain can not only imparts an undesirable dark colour and promotes oxidation in the presence of light, it also poisons the catalysts during the hydrogenation process of oils (Sinnecker *et al*., 2005).

The presence of green grains can sometimes be observed as a consequence of hot weather during the maturation period, which causes water stress (excessive water loss) or high rainfall which forces farmers to prematurely harvesting the crop in order to avoid losses. Prematurely harvested seeds require post-harvest drying in order to reduce the moisture content to a maximum of 13%, which is the upper limit considered for safe storage. Chlorophyll break down is currently described as a multi-step mechanism. The first group of reactions produces greenish derivatives, while the more advanced steps produce colourless compounds; the whole process is as complex as chlorophyll biosynthesis (Sinnecker *et al*., 2005).

The main changes occurring in the first group of reactions correspond to the release of magnesium by displacement with two hydrogen molecules under acidic conditions and/or by the action of magnesium dechelalatase and the cleavage of the phytol chain by the enzyme chlorophyllase, which produces greenish intermediates, such as pheophtins, chlorophyll lidespheophorbides, all of them showing an intact tetrapyr-role ring.

The second group of reactions is responsible for de-greening by the rapid formation of colourless and polar derivatives due to the opening of the tetrpyr-role ring by the action of pheophorbide and monooxygenase (Sinnecker *et al*., 2005).

Temperature, degree of maturation and harvest time influence the chlorophyll level of soybean seed. Fast drying of soybean at high temperatures produce seeds with high levels of green pigments and block the break down. In order to avoid retention of chlorophyll and to guarantee high marketing quality, soybean should be harvested at the R8 (physiological maturity) stage, which should be followed by either fast or slow drying. If crops are harvested before full maturity, drying should be performed at temperatures below 40°C, otherwise high amounts of chlorophyll will be retained, which may not meet the grading standards, resulting in poor product quality (Sinnecker *et al*., 2005).

2.6 Role of temperature in soybean nodulation

Suitable root zone temperatures are an essential requirement for optimal soybean growth and development. A temperature range of 25 – 30°C is reported to be optimal for symbiotic activities. Low temperature restricts the growth of N_2-fixing soybean plants more than that of plants utilizing combined nitrogen where a legume crop was previously grown. The poor adaptability of soybean to cool soils may be the primary yield limiting factor in short-season areas (Legros & Smith, 1994). A decrease in root zone temperature from 25 to 15°C results in decreased nodule growth and total N_2 fixation per plant. This is attributed to inhibition of infection and nodule initiation by the nitrogen fixing bacteria (*Bradyrhizobium japonicum)* (Zhang *et al*., 2003).

CHAPTER 3: MATERIALS AND METHODS

3.1 Location and treatments

Field experiments were conducted at Pretoria, South Africa (latitude 25° 45′ S, longitude 28°15′ E and altitude of 1364 m.a.s.l.) and two locations in Swaziland, Malkerns Research Station (latitude 26° 34′ S, longitude 31° 10′ E with an altitude of 684 m.a.s.l.) and Nhlangano Experimental Farm (latitude 27° 07′ S, longitude 31° 11′ E with an altitude of 1050 m.a.s.l.). Six soybean cultivars of different maturity groups and different growth habits (determinate and indeterminate) were planted at these sites (Table 3.1).

Determinate cultivars are cultivars that cease initiating new leaves after the beginning of flowering, hence need a fairly short transition period. Indeterminate cultivars are cultivars that keep on producing new leaves after the onset of flowering; that is both flowers and leaves can be produced during the flowering stage.

Table 3.1: Six soybean cultivars of different maturity groups that were planted at the three sites.

Cultivar	Maturity group	Growth habit
1. LS 6162	IV	DETERMINATE
2. PAN 535	V	DETERMINATE
3. PAN 1664	VI	DETERMINATE
4. LS 6164	VI	INDETERMINATE
5. LS 6150	VI	INDETERMINATE
6. PAN 737	VII	DETERMINATE

3.2 Soils

The experiments were planted on sandy loam soils at all three locations. Soil analysis was carried out for all the locations (Appendix A, page 79). Phosphorus was applied at a rate of 200 Kg ha^{-1} and Potassium at a rate of 250 Kg ha^{-1} at Nhlangano. Potassium was applied at 400 Kg ha^{-1} at Malkerns and Dolomitic lime at 1 t ha^{-1}. No soil amendment was applied at Pretoria as the soil analysis results showed that the soils were conducive for soybean production. The seed was inoculated with bradyrhizobium bacteria before planting to enhance nitrogen fixation, hence no nitrogen fertilizer was applied.

3.3 Planting and cultivation

The experiments were planted on the 18th November 2010 in Pretoria, 29th December 2010 at Nhlangano Experimental Farm and 30th December 2010 at Malkerns Research Station. The plot size was 4 rows wide and 5 m long. Inter-row spacing was 0.45 m and intra-row spacing was 0.05 m for all the six soybean cultivars. Harvesting of the experiments at all sites started in March 2011 and ended in April 2011 as the different cultivars matured at different times.

3.4 Experimental Design

A Randomised Complete Block Design (RCDB) was used for the experiments and the trial was replicated three times in Pretoria, and four times each at Malkerns Research Station and Nhlangano Experimental Farm.

3.5 Data collected

Plant growth analysis was carried out every two weeks from plant establishment until physiological maturity. Destructive sampling was carried out to assess the effects of environment on growth and development of the different cultivars. Furthermore the data was used to determine cultivar specific model parameters. Three plants per cultivar per plot in all replications were sampled at every monitoring time point. The following measurements were made:

3.5.1 Leaf, stem and pod dry mass

Dry leaf, stem and pod mass were determined from the sampled plants. This was done through the separation of plants into leaves, stems and pods. Wet mass of the leaves, stems and pods were first determined and the samples were then oven dried at 60°C for 96 hours, and dry mass determined.

3.5.2 Number of plants at harvest

The number of plants was counted at harvest to determine the final plant stand. The final plant stand is one of the factors that influence yield of a crop.

3.5.3 Pod height

Pod height was measured from the soil to the lowest pod in the plant at harvesting to determine suitability for mechanical harvesting. The suitable pod height for mechanical harvesting is 12.5 cm from the soil surface to the lowest pod in the plant.

3.5.4 Number of nodes

Numbers of nodes were counted at harvest to help in the interpretation of the final grain yield. The nodes are the points where the pods will be formed. It is anticipated that plants with a high number of nodes will give more pods, and hence increased grain yield.

3.5.5 Number of pods

Numbers of pods were counted at harvest to help explain the final grain yield.

3.5.6 100-seed mass

100-seed mass was taken as it plays a role in determining grain yield. The higher the100-seed mass, the bigger the seeds. Therefore, it is a contributing factor to higher grain yield.

3.5.7 Seed moisture content

The moisture content of seeds was taken at harvest to adjust the final grain yield to 12% moisture content.

3.5.8 Leaf area

Leaf area was determined for every destructive sampling in Pretoria, using an LI 3100 belt driven leaf area meter. However, this was not done for the Swaziland localities due to a lack of equipment.

3.5.9 Plant height

Plant height was determined every two weeks using a ruler and recorded in centimetres. Plant height is one of the agronomic characters that help a soybean grower to select a cultivar that best suits his/her production area. This is an important characteristic in areas which are prone to high winds.

3.5.10 Fractional interception

Canopy interception of photosynthetically active radiation (PAR) was measured in Pretoria, using a ceptometer (Accupar model LP-80, Decagon Devices). This was, however, not possible for the Swaziland localities due to a lack of equipment. The PAR was measured at two heights, above the canopy (reference reading) and below the canopy on the soil surface; thereafter fractional interception of PAR was calculated as follows:

$$\mathrm{FI} = 1 - \frac{PAR\ below}{PAR\ above} \qquad \text{[Equation 3.1]}$$

3.5.11 Leaf area index

The leaf area index is a dimensionless quantity that characterizes plant canopy size and was calculated using the measured leaf area and corresponding ground area:

$$\mathrm{LAI} = \frac{Leaf\ area}{Ground\ area} \qquad \text{[Equation 3.2]}$$

3.5.12 Total dry matter yield

Total dry matter yield (t ha^{-1}) was determined by adding the dry leaf, stem and pod yields together.

3.5.13 Seed yield

Seed yield (t ha^{-1}) was determined by separation of seeds from the pod shells.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Weather data

The monthly rainfall and air temperatures recorded for the three locations where the experiment was conducted are presented in Figures 4.1 and 4.2. Rainfall distribution during the growing season was erratic at all three locations. The month of December had an almost similar rainfall at all the locations. March was very unique for Pretoria when compared to the other locations, as it had the highest rainfall of 247 mm, while Malkerns and Nhlangano had only 51 and 34 mm respectively. During the growing season of the crop, Pretoria received the highest total rainfall of 883 mm. This was followed by Malkerns with a rainfall of 580 mm, and Nhlangano with the lowest rainfall of 540 mm. Pretoria had the highest mean maximum temperature of about 31°C in October 2010 and Nhlangano had the lowest mean maximum temperature of 20°C in August 2010 and May 2011. Malkerns had the highest mean minimum temperature of about 19.3°C in January 2011 and Pretoria had the lowest mean minimum temperature of 6°C in August 2010.

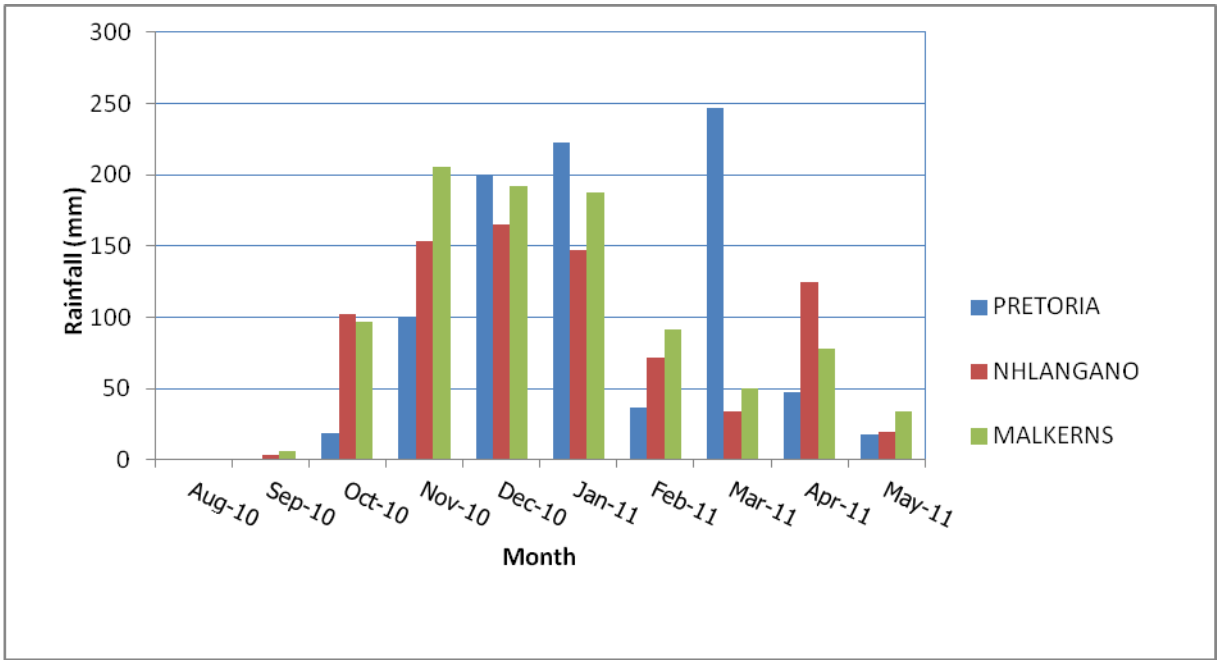


Figure 4.1: Monthly rainfall for the three locations where the experiment was carried out during the 2010/2011 growing season.

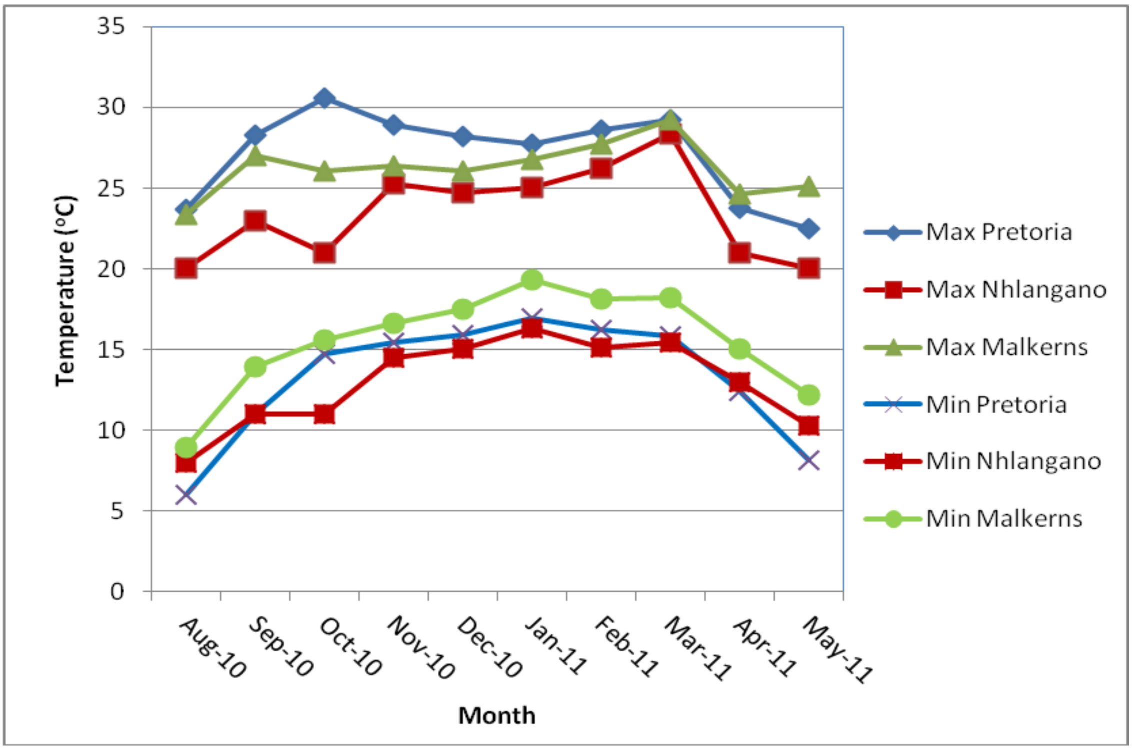


Figure 4.2: Mean monthly maximum and minimum temperatures recorded at the locations where the experiment was carried out during the 2010/2011 growing season.

PRETORIA TRIAL

4.2 Plant growth analysis results

4.2.1 Leaf dry matter yield

Plant growth analysis results for leaf mass are presented in Figure 4.3. At 33 days after planting leaf dry matter (LDM) yields ranged from 11.1g m^{-2} to 20.9 g m^{-2}. At this stage of plant growth there were no significant differences in the leaf dry matter yield between the different growth habit and maturity groups of cultivars as they all gave almost similar leaf dry matter yields. This is attributed to the fact that this is an early development stage and most assimilates are channelled to the leaves and stems as they are the main sink for the plant.

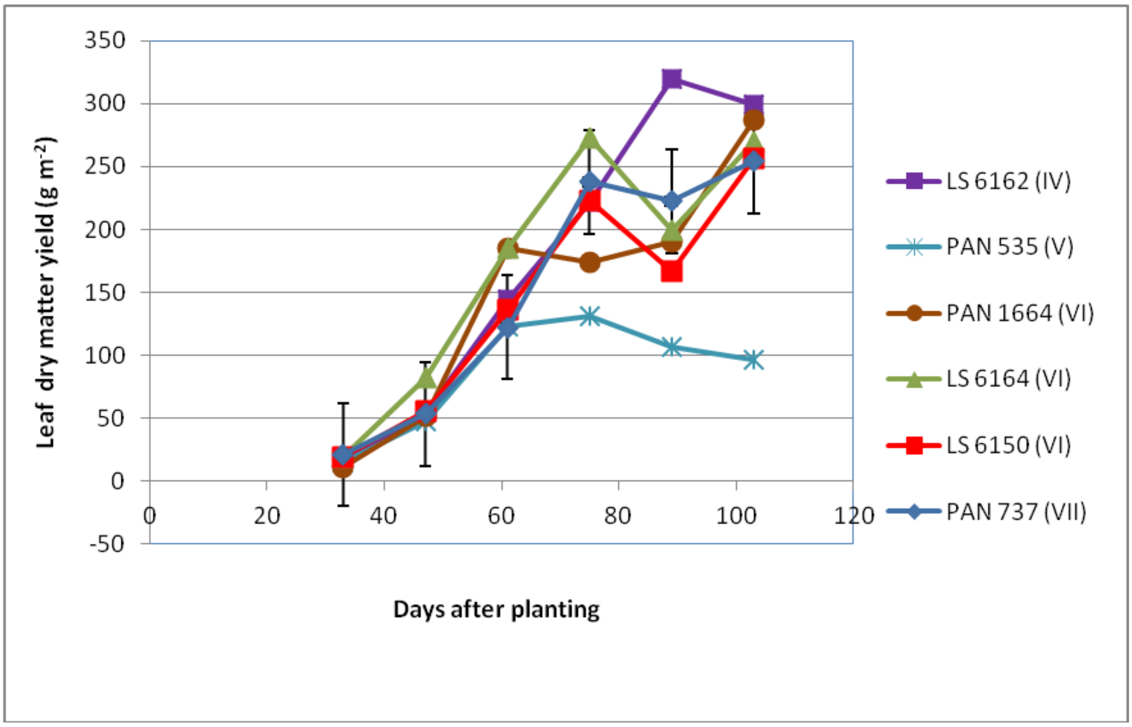


Figure 4.3: Plant growth analysis for Pretoria: leaf dry matter yield (g m^{-2}), for six soybean cultivars at different days after planting.

At 47 days after planting, the leaf dry matter yield ranged from 48.1 g m^{-2} to 82.0 g m^{-2}. Cultivar LS 6164 had the highest leaf dry mass yield of 82.0 g m^{-2} (Figure 4.3), which was significantly different ($P < 0.05$) from all the other cultivars. Cultivar PAN 535 had the lowest leaf dry mass yield of 48.1 g m^{-2}. At this stage of plant growth the later maturing cultivars showed a higher leaf dry mass yield. This indicates that longer maturing cultivars (e.g. PAN 737) are able to produce higher quantities of assimilates than shorter maturing cultivars, even though some cultivars of both the long and short maturing group were still not different from each other. These results agree with the statement by (Miladinovic *et al.*, 2006), that longer growing cultivars tend to result in higher potential crop production than shorter growing cultivars.

Cultivar PAN 1664 had the highest leaf dry mass yield of 185.5 g m^{-2} (Figure 4.3) at 61 days after planting. It was significantly higher than the other cultivars, except for cultivars LS 6164, LS 6162, and LS 6150 which had leaf dry mass yields ranging from 136.0 g m^{-2}, to 185.0 g m^{-2}.

The day length and temperatures were optimal for plant growth and development for maturity group VI cultivars (PAN 1664, LS 6164 and LS 6150) during this period of plant growth.

Day length plays an important role in soybean development, as when days become shorter the crop will proceed to the reproductive stage even if it had not reached its full growth period. This usually happens with late maturing cultivars as they take a longer time to reach reproductive stage.

The highest leaf dry mass yield obtained at 75 days after planting was 273.1 g m^{-2} for cultivar LS 6164 (Figure 4.3). It was at the same level as cultivars PAN 737, LS 6150, and LS 6162, which had leaf dry masses ranging from 221.5 g m^{-2} to 237.9 g m^{-2} respectively. At this growth stage it was clear that different maturity groups and growth habits play a significant role in plant development. While the longer maturity group cultivars (LS 6164, PAN 737, and LS 6150) were still developing steadily, the shorter maturity group (LS 6162) was rapidly sending most assimilates to the leaves in preparation for assimilate partitioning to other parts of the plant (pods).

At 89 days after planting cultivar LS 6162, which is determinate and early maturing, had the highest leaf dry mass yield of 319.9 g m^{-2} (Figure 4.3). There was a sharp decline in leaf dry matter yield of the indeterminate cultivars LS 6164 and LS 6150. This can probably be attributed to the low rainfall of only about 46 mm recorded in February, which was less than rainfall received in the other months at a time when the crop needed more water, namely the stage of pod development.

Cultivar LS 6162 still had the highest (299.5 g m^{-2}) leaf dry matter yield at 103 days after planting (Figure 4.3). The indeterminate cultivars that had a sharp decline in leaf dry mass yield at 89 days after planting, showed an increase in leaf dry matter yield. This resulted from the increase in the amount of rainfall that was received from mid-February and a temperature increase at the same time, which created more favourable growing conditions for regrowth of the indeterminate cultivars. Cultivar PAN 535, which is determinate, had the lowest final leaf dry matter yield of

96.8 g m^{-2}. From 75 days after planting it started showing a decline in leaf dry mass yield, suggesting that it may have started sending most assimilates to other parts of the plant (stems, flowers and pods) at that time.

4.2.2 Stem dry matter yield

Stem dry matter yield at 33 days after planting ranged from 5.9 g m^{-2} to 9.8 g m^{-2} (Figure 4.4). Cultivar LS 6162 had the highest stem dry matter yield (9.7 g m^{-2}). Since LS 6162 is a short maturity cultivar, its genetic makeup gives it the ability to accumulate and partition assimilates to other plant parts early, while other cultivars were still supplying most assimilates to the leaves. Cultivar LS 6164 had the lowest stem dry matter yield (5.9 g m^{-2}). However, the results showed that there were no significant differences among the cultivars at 33 days after planting.

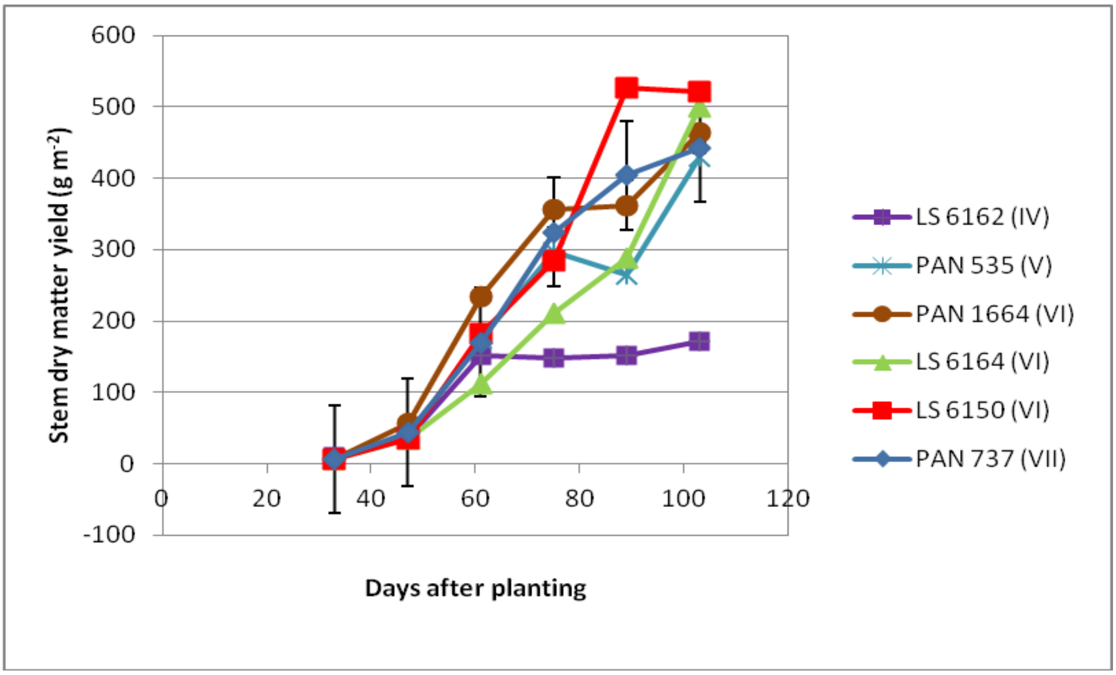


Figure 4.4: Plant growth analysis results for Pretoria: stem dry matter yield (g m^{-2}) for six soybean cultivars at different days after planting.

Cultivar PAN 1664 had the highest stem dry matter yield of 57.5 g m^{-2} at 47 days after planting. It was, however, not significantly different from cultivars PAN 737 and PAN 535, which had stem dry matter yields of 43.7 g m^{-2} and 39.6 g m^{-2} (Figure 4.4) respectively.

These results proved that as the season progressed, late maturing cultivars accumulated more assimilate than early maturing cultivars. In the earlier stages cultivar LS 6162 (which is an early maturing cultivar) had the highest stem dry matter yield, but this trend did not continue.

At 61days after planting cultivar PAN 1664 still had the highest stem dry matter yield of 234.5 g m^{-2} (Figure 4.4). It was, however, not significantly different from cultivars LS 6150, PAN 535, PAN 737, and LS 6162, which had stem dry matter yields of 182.00 g m^{-2}, 174.9 g m^{-2}, 170.3 g m^{-2} and 151.5 g m^{-2} respectively. These results followed the same trend as at 47 days after planting. In this period there was a steady supply of assimilates to the stems by all the cultivars, hence the results did not change. Cultivar LS 6164 still had the lowest stem dry matter yield of 112.4 g m^{-2}. It was however not significantly different from cultivars LS 6162, PAN 737, PAN 535 and LS 6150, which had stem dry matter yields ranging from 151.5 g m^{-2} to 182.0 g m^{-2}.

At 75 days after planting cultivar PAN 1664 still had the highest stem dry matter yield of 356.9 g m^{-2}. It was however, not significantly different from cultivars PAN 737, PAN 535 and LS 6150 which had stem dry matter yields ranging from 284.4 g m^{-2} to 324.7 g m^{-2} respectively (Figure 4.4). At this time the trend shifted slightly and cultivar LS 6162 now had the lowest stem dry matter yield of 147.3 g m^{-2}. These results indicate that cultivar LS 6162 had supplied enough assimilates to the stem and started partitioning assimilates to other parts of the plant, while other cultivars were still supplying assimilates to the stem. However, cultivar LS 6164 was also not significantly different from cultivars LS 6150, PAN 535 and PAN 737. Also Cultivar LS 6164 had increased its supply of assimilates to the stems, as it was at par with the other cultivars, except cultivar PAN 1664.

Cultivar LS 6150 had the highest stem dry matter yield of 526.5 g m^{-2} at 89 days after planting (Figure 4.4). As the season progressed, larger differences started to develop between cultivars. At this stage of plant development cultivar LS 6150, which is a late maturing and indeterminate cultivar was accumulating dry matter faster than the other cultivars. It was significantly different ($p < 0.05$) from cultivars LS 6164, PAN 535 and LS 6162, which had stem dry matter yields of 287.9 g m^{-2}, 264.0 g m^{-2} and 150.9 g m^{-2} respectively. These results clearly indicated that different cultivars accumulated assimilates at different rates in each development stage.

At 103 days after planting the highest stem dry matter yield was 520.5 g m^{-2} and the lowest was 171.6 g m^{-2} (Figure 4.4). Again LS 6150 had the highest stem dry matter yield. It was not significantly different from cultivars LS 6164, PAN 1664, PAN 737 and PAN 535, which had stem dry matter yields ranging from 499.3 to 429.9 g m^{-2}. As the growing period continued the cultivars which were initially producing less assimilates started to produce more, and hence they caught up with cultivars that initially had highest stem masses. For example cultivar LS 6164, which , initially partitioned less dry matter to the stem, partitioned more dry matter to stems at 103 days after planting. This is a further indication that the cultivars responded differently to the environmental conditions. Cultivar LS 6162 had the lowest final stem dry matter yield of 171.6 g m^{-2} and was significantly different from all the other cultivars. This cultivar was therefore partitioning more dry matter to other parts of the plant (leaves and pods) later in the growing season.

4.2.3 Pod dry matter yield

Cultivar LS 6162 had the highest pod dry matter yield of 355.5 g m^{-2} at 89 days after planting (Table 4.1). It was significantly different from all the other cultivars which had pod dry matter yields ranging from 109.5 to 198.3 g m^{-2}. Cultivar PAN 737 had the lowest (109.5 g m^{-2}) pod dry matter yield, but it was not significantly different from all the other cultivars, except cultivar LS 6162. This trend clearly explains why cultivar LS 6162 had lower stem dry matter yield (Table 4.1) at the later stages of plant growth and development. This cultivar started partitioning most of its dry matter to pod development, while other cultivars were still partitioning dry matter to the stems and leaves.

At 103 days after planting cultivar LS 6162 still had the highest pod dry matter yield of 524.7 g m^{-2}. It was however not significantly different from the other cultivars, except PAN 737, which had pod dry matter yield of 310.8 g m^{-2} (Table 4.1). At this stage of crop growth and development most of the other cultivars were at par with the pod yield of cultivar LS 6162.

Cultivar PAN 737 still had the lowest pod dry matter yield of 310.8 g m^{-2}, but was not significantly different from cultivars LS 6164, PAN 535 and PAN 1664, which had pod dry matter yields ranging from of 410.3 to 505.5 g m^{-2}. This indicates that late maturing cultivars take a longer period to partition assimilates to the pods, resulting in more assimilates being partitioned to pods by the end of the growing season compared to early maturing cultivars. According to Kantolic and Slafer (2005) longer day length and optimum temperature play an important role in soybean development. In this location the day length was long and temperatures were favourable for plant growth and development, hence the increased pod dry matter yield.

Table 4.1: Pod dry matter yield (g m^{-2}) recorded at 89 and 103 days after planting at Pretoria

Cultivar	**Days after planting**	
	89	**103**
LS 6162 (IV)	355.5a	524.7a
PAN 535 (V)	136.4b	480.7ab
PAN 1664 (VI)	194.4b	505.5ab
LS 6164 (VI)	129.5b	410.3ab
LS 6150 (VI)	198.3b	523.1a
PAN 737 (VII)	109.5b	310.8b
LSD (p<0.05)	108.8	212.3
CV (%)	31.9	25.4

4.3. Plant parameters at harvest

4.3.1. Number of plants at harvest

The results showed that Cultivar LS 6162 had the highest number of plants at harvest at this location. It had an average of 122.3 plants per plot while cultivar LS 6150 had the lowest number of 86.3 plants per plot (Table 4.2). These showed that some cultivars are more vigorous than others, as the same numbers of seeds were planted for all the cultivars, but by the time of harvesting some cultivars had fewer plants remaining than others.

Table 4.2: Number of plants, pod height (cm), number of nodes, number of pods, plant height (cm), 100-seed mass (g), and seed yield (t ha^{-1}) at harvest of six soybean cultivars at Pretoria.

Cultivar	**Plants at harvest**	**Pod height (cm)**	**Number of nodes/plant**	**Number of pods / plant**	**Plant height (cm)**	**100 Seed mass (g)**	**Seed yield (t ha^{-1})**
LS 6162 (IV)	122.3a	12.3c	10.3c	42.9b	63.3c	15.4b	2.6bc
PAN 535 (V)	121.0ab	15.0bc	13.0b	93.3a	65.7bc	15.1b	2.9ab
PAN 1664 (VI)	96.7bc	19.3ab	13.3b	61.6ab	67.0bc	13.4c	3.4a
LS 6164 (VI)	98.0abc	19.3ab	16.3a	81.7a	78.0ab	13.5c	2.0c
LS 6150 (VI)	86.3c	17.3b	17.0a	96.0a	83.7a	13.4c	3.0ab
PAN 737 (VII)	100.0abc	22.3a	13.7b	67.8ab	76.7abc	17.4a	3.4a
Mean	104.1	17.5	13.9	73.9	72.4	14.7	2.9
LSD $_{0.05}$	24.5	4.7	2.0	37.6	13.6	0.2	0.8
Significance	*	*	*	*	*	*	*
CV (%)	13.0	14.7	7.8	28.0	10.4	0.9	16.1

*Significant at ($p < 0.05$).

4.3.2 Pod height

Pod height ranged from 12.3 to 22.3 cm. Cultivar PAN 737 had the highest pod height of 22.3 cm. It was significantly different from cultivars LS 6150, Pan 535 and LS 6162, which had a pod heights ranging from 12.3to 17.3 cm (Table 4.2). It was not significantly different from cultivars LS 6164 and PAN 1664, which both had pod heights of 19.3 cm. These results showed that the late maturing cultivars had the highest pod height. This is an important trait, as higher pod height makes it easier to use mechanised equipment during harvesting.

4.3.3 Number of nodes

The results showed that cultivar LS 6150 had the highest (17.0) number of nodes (Table 4.2). It was not significantly different from cultivar LS 6164, which had 16.3 nodes. These cultivars were significantly different ($P < 0.05$) from all the other cultivars. Cultivar LS 6162 had the lowest (10.3) number of nodes. It was significantly different from all the cultivars. Cultivars PAN 737, PAN 1664 and PAN 535 had 13.7, 13.3, and 13.0 nodes. Cultivars with the highest number of nodes are expected to produce more pods per plant. These results showed that cultivar LS 6150, which is a longer maturing cultivar and is indeterminate, had the highest number of nodes while cultivar LS 6162, which is an earlier maturing cultivar and is determinate had the lowest number of nodes. This indicates that maturity group and plant growth habit play an important role in determining the number of nodes per plant. It is expected that cultivars with the highest number of nodes and pods would give high grain yields, but it was not the case with these cultivars. Cultivar PAN 737 which had fewer nodes and pods that were less than those of cultivars LS 6150 and LS 6164 gave the highest grain yield. These results concur with the findings of Egli (2013) that there is no relationship between number of nodes and pods.

4.3.4 Number of pods

Cultivar LS 6150 had the highest number of pods (96.0). However, it was not significantly different from cultivars PAN 535, LS 6164, PAN 737 and PAN 1664, which had pod numbers ranging from 61.2 to 93.3 pods/plant (Table 4.2). Cultivar LS 6162 had the lowest (42.9) number of pods but not significantly different from cultivars PAN 737 and PAN 1664 which had 61.2 and 42.9 pods. The results proved to be true that the cultivar with the highest number of nodes will have the highest number of pods, as cultivar LS 6150, which had the highest number of nodes also had the highest number of pods, but not the highest seed yield. Similarly, cultivar LS 6162, which had the lowest number of nodes, also had the lowest number of pods. The daylength was longer and the temperatures were optimal and soil moisture was adequate which enabled the different cultivars to fully express their growth which resulted in better pod formation, hence increased seed production. This is in agreement with the study conducted by Kantolic and Slafer (2005) who found that optimum daylength, temperatures and soil water availability enhance better crop development.

4.3.5 Plant height

Plant height ranged from 63.3 to 83.7 cm. Cultivar LS 6150 had the tallest plants (83.7 cm). It was not significantly different from cultivars LS 6164 and PAN 737, which had plant heights of 78.0 and 76.7 cm (Table 4.2). It was significantly different from cultivars PAN 1664, PAN 535 and LS 6162, which had plant heights of 67.0, 65.7 and 63.3 cm. PAN 737 was not significantly different from the rest of the cultivars. Again the results showed that the indeterminate and late maturing cultivars had the tallest plants. This is due to the ability of the indeterminate cultivars to continue vegetative growth while they have reached their reproductive stage, while the determinate cultivars ceased partitioning assimilates to vegetative parts once it reached the reproductive stage.

4.3.6 100-seed mass

Cultivar PAN 737 had the highest (17.4 g) 100-seed mass. It was significantly different ($P < 0.05$) from all the other cultivars. Cultivars LS 6162 and PAN 535 had 100-seed masses of 15.4 and 15.1 g respectively. They were not significantly different from each other, however, they were significantly different from cultivars LS 6164, LS 6150 and PAN 1664, with 100-seed masses ranging from 13.4 to 13.5 g, (Table 4.2). The determinate cultivars had the highest 100-seed mass. This shows that while the indeterminate and late maturing cultivars were still partitioning assimilates to the various vegetative parts of the plant, partitioning in the determinate cultivars was concentrated towards to the seed.

4.3.7 Seed yield

The results showed that seed yield ranged from 2.0 t ha^{-1} to 3.4 t ha^{-1} (Table 4.2). Cultivar PAN 737 had the highest seed yield of 3.4 t ha^{-1}, but it did not differ significantly from cultivars PAN 1664, LS 6150 and PAN 535, which had seed yields of 3.4 t ha^{-1}, 3.0 t ha^{-1} and 2.9 t ha^{-1}. Cultivar LS 6164 had the lowest seed yield (2.0 t ha^{-1}). It was however not significantly different from cultivar LS 6162, which had a seed yield of 2.6 t ha^{-1}.These results showed that the late maturing cultivars gave better yields than the early maturing cultivars under the environmental conditions of Pretoria and when they are planted at the optimal time. This environment (rainfall, temperatures and day length) was conducive to enable different maturity cultivar groups to fully express their growth and development. This concurs with Egli (1992) who stated that high soybean yields are obtained from cultivars that have a total growth cycle that uses most of the available growing season. Harvest parameters like100-seed mass, number of nodes per plant and number of pods per plant had an influence on seed yield as the cultivars that gave the highest seed yields also had the highest 100-seed mass (PAN 737) and / or highest number of nodes and pods (LS 6150).

MALKERNS TRIAL

4.4 Plant growth analysis results

4.4.1 Leaf dry matter yield

At this location the results showed that cultivar PAN 1664 had the highest leaf dry matter yield of 63.7 g m^{-2} at 42 days after planting. It was not significantly different from cultivars LS 6162, LS 6150, PAN 737 and PAN 535, which had a leaf dry matter yields ranging from 49.7 to 59.3 g m^{-2} (Figure 4.5). Cultivar LS 6164 had the lowest leaf dry matter yield of 2.8 g m^{-2}. It was however not significantly different from cultivars PAN 535 and PAN 737, which had leaf dry matter yields of 49.7 g m^{-2} and 52.0 g m^{-2} respectively. At this early stage plant growth followed a similar pattern as in Pretoria, where there was no clear differentiation between the growth habit and maturity groups of the cultivars as they all gave similar leaf dry matter yields. This is attributed to the fact that this is an early growing stage when all the cultivars channelled most assimilates to the leaves.

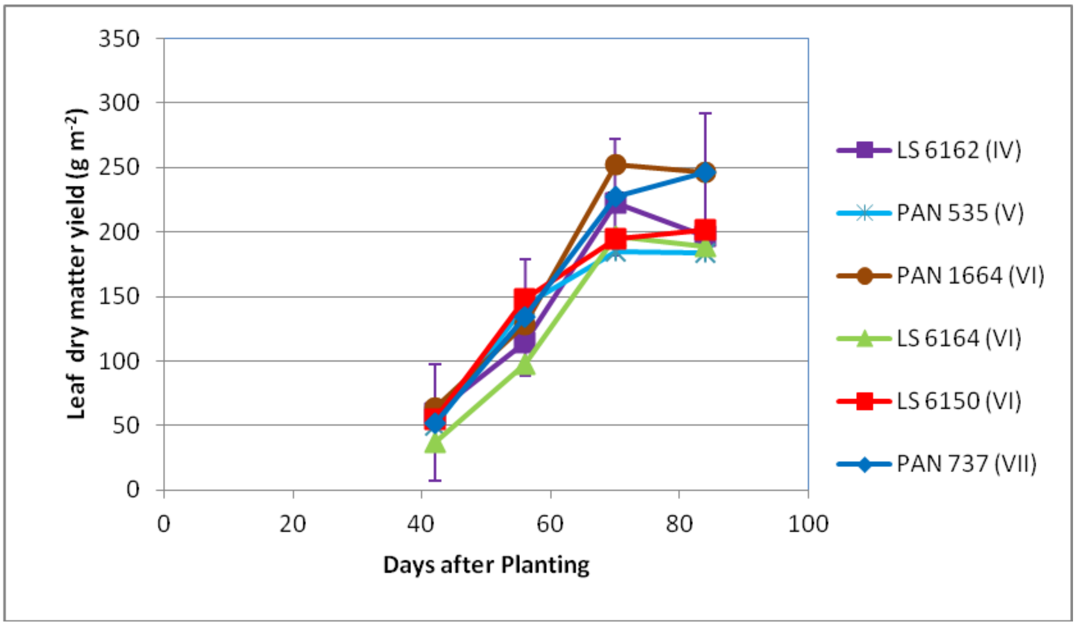


Figure 4.5: Plant growth analysis results for Malkerns: leaf dry matter yield (g m^{-2}) for six soybean cultivars at different days after planting.

At 56 days after planting cultivar LS 6150 had the highest leaf dry matter yield of 148.4 g m^{-2}. It was however not significantly different from cultivars PAN 535, PAN 737, PAN 1664 and LS 6162, which had leaf dry matter yields ranging from 114.0 to 143.3 g m^{-2}. Cultivar LS 6164 had the lowest leaf dry matter yield of 7.3 g m^{-2} (Figure 4.5). The late maturing cultivars were rapidly partitioning assimilates to the leaves as the days were getting shorter for these cultivars to complete their growth cycle.

Cultivar PAN 1664 had the highest leaf dry matter yield at 70 days after planting, but it was not significantly different from all the other cultivars. The leaf dry mass ranged from 184.7 to 227.3 g m^{-2} (Figure 4.5). Again since the days were being shortened the cultivars were producing assimilates rapidly in order be able to reproduce before the end of its growing period.

Cultivar PAN 737 had the highest leaf dry matter yield of 246.7 g m^{-2} at 84 days after planting. However it was not significantly different from cultivars PAN 1664, PAN 6150, LS 6164 and PAN 535, which had leaf dry matter yields ranging from 183.7 to 246.0 g m^{-2} (Figure 4.5). Cultivar PAN 535 had the lowest leaf dry matter yield of 183.7 g m^{-2}. It was however not significantly different from cultivars LS 6162, LS 6164 and LS 6150, which had leaf dry matter yields ranging from 189.1 to 201.3 g m^{-2}. The late maturing cultivars, for example PAN 737, were still partitioning most assimilates to the leaves while early cultivars (e.g. LS 6162) were already partitioning most assimilates to the stems. The leaf dry matter yield of this location was higher than Nhlangano, but lower than Pretoria, This is due to fact that the experiment in Pretoria was planted almost six weeks earlier than the experiment at Malkerns and Nhlangano. The better yield obtained at Malkerns than at Nhlangano was due to the fact the Malkerns had higher temperatures and rainfall which favoured plant development.

4.4.2 Stem dry matter yield

The results showed that at 42 days after planting there were no significant differences among the cultivars. Cultivar PAN 737 had the highest stem dry matter yield of 43.1 g m^{-2} (Figure 4.6), but it was not significantly different from cultivars PAN 1664, LS 6150, LS 6162, PAN 535 and LS 6164, which had stem dry matter yields ranging from 32.7 to 42.4 g m^{-2}. These results clearly showed that environmental factors play a crucial role in plant development. As the season progressed and daylength became shorter, the cultivars were hastened to complete their life cycles, and more dry matter was partitioned to stems and leaves so as to satisfy the developing sinks.

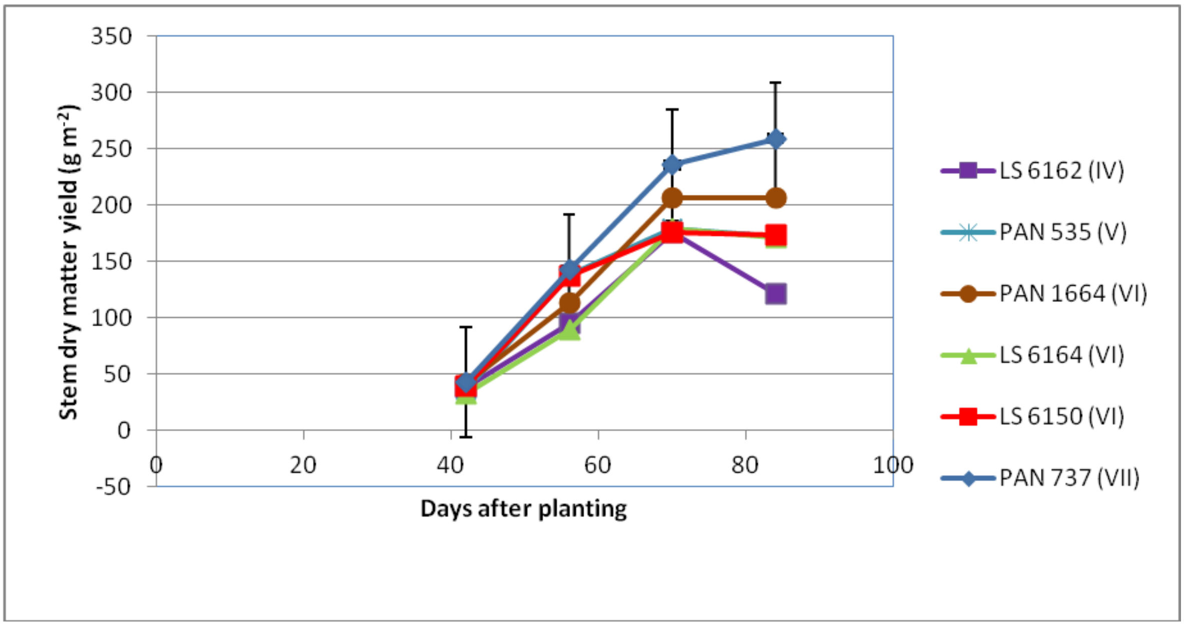


Figure 4.6: Plant growth analysis results for Malkerns: stem dry matter yield (g m^{-2}) for six soybean cultivars at different days after planting.

Cultivar PAN 737 still had the highest stem dry matter yield of 142.4 g m^{-2} at 56 days after planting. However it did not differ significantly from cultivars PAN 535, LS 6150, PAN 1664, and LS 6162, which had stem dry matter yields ranging from 95.1 to 137.7 g m^{-2} (Figure 4.6). Cultivar LS 6164 had the lowest stem dry mass of 89.3 g m^{-2}. It was however not significantly different from LS 6162, PAN 1664, LS 6150 and PAN 535, which had stem dry matter yields ranging from 95.1 to 137.7 g m^{-2}. The same trend as at 42 days after planting was followed, as the late maturity cultivars were still partitioning more assimilates to the stem, while the early maturing cultivars had started partitioning assimilates to the pods.

The stem dry matter yield reached a maximum of 235.3 g m^{-2} and the minimum was 175.3 g m^{-2} at 70 days at planting. Again Cultivar PAN 737 had the highest stem dry matter yield of 235.3 g m^{-2}. However, it was not significantly higher than cultivars PAN 1664, LS 6164, PAN 737, LS 6162 and LS 6150, which had stem dry matter yields ranging from 175.7 to 206.0 g m^{-2} (Figure 4.6). The late maturity cultivars were still partitioning more assimilates to the stems, while the early maturing cultivars were already partitioning assimilates to the pods, as they had already completed portioning to the stems.

The results showed that cultivar PAN 737 still had the highest stem dry matter yield of 259.1 g m^{-2} at 84 days after planting. It was not significantly different from cultivars PAN 1664, LS 6150, PAN 535 and LS 6164 which had stem dry matter yields ranging from 171.7 to 206.4 g m^{-2} (Figure 4.6). Cultivar LS 6162 had the lowest stem dry matter yield of 121.1 g m^{-2}, however, it was not significantly different from cultivars LS 6164, PAN 535, LS 6150 and PAN 1664, which had stem dry matter yields ranging from 171.7 to 206.4 g m^{-2}. Again the same trend as at 70 days after planting was followed as the plant growth stage was coming to an end. Cultivar PAN 737 was still sending more assimilates to the stem, while other cultivars were channelling more assimilates to the pods. The cultivars gave different stem dry mass in the different locations. Pretoria gave the highest stem mass among the location and Malkerns gave the lowest. Some of the cultivars especially the indeterminate cultivars gave about a third of the mass that was obtained from Pretoria. Nhlangano was giving half of the mass of Pretoria. This variation may have been due to the fact that the cultivars were planted later when the days were becoming shorter in these locations, hence they did not express their full potential.

4.4.3 Pod dry matter yield

Cultivar LS 6162 had the highest pod dry matter yield of 328.7 g m^{-2} at 70 days after planting, but it was not significantly different from cultivars PAN 1664, LS 6164, LS 6150 and PAN 535, which had pod dry matter yields ranging from 147.33 to 246.7 g m^{-2} (Table 4.3). PAN 737, a late maturity cultivar, had the lowest pod dry matter yield of 98.7 g m^{-2}. The results showed that plant growth and development occurred at different rates for different cultivars. While some cultivars were still channelling assimilates to stems, others have already completed that stage and moved on to the reproductive stage. The indeterminate and late maturity cultivars usually took longer before they started to supply assimilates to the reproductive parts of the plant.

At 84 days after planting the results showed that cultivar PAN 1664 had the highest pod dry matter yield of 650.7 g m^{-2}. However, it was not significantly different from cultivars LS 6150, LS 6164, LS 6162 and PAN 535, which had pod dry matter yields ranging from 408.7 to 490.7 g m^{-2}. Cultivar PAN 737 had the lowest pod dry matter yield of 300.0 g m^{-2}, but it was however not significantly different from cultivars PAN 535, LS 6162, LS 6164, and LS6150 which had pod dry matter yields ranging from 408.7 to 490.7 g m^{-2} (Table 4.3). The same trend as at 70 after planting was followed. More assimilates were channelled to pods as maturity of the plant was approaching. Again the experiment planted at Pretoria had higher pod dry matter yield than the other locations, and Nhlangano still had the lowest pod dry matter yield. This might be due to the fact that the temperatures at Nhlangano were lower than the other locations which resulted in slow plant growth and development. The results showed that the experiment planted at Malkerns had pod dry matter yield that was similar to Pretoria, but had a final grain yield that was much lower than the yield obtained at Pretoria. The difference might be due to the fact that more pods had seeds that were not fully matured at Malkerns.

Table 4.3: Pod dry matter yield (g m^{-2}) at 70 and 84 days after planting at Malkerns.

Cultivar	**Days after planting**	
	70	**84**
LS 6162 (IV)	328.7a	432.7b
PAN 535 (V)	147.3ab	408.7b
PAN 1664 (VI)	246.7ab	650.7a
LS 6164 (VI)	168.0ab	479.3ab
LS 6150 (VI)	154.0ab	490.7ab
PAN 737 (VII)	98.7b	300.0b
LSD (p<0.05)	210.7	311.2
CV (%)	43.0	26.3

4.5 Plant parameters at harvest

4.5.1 Number of plants at harvest

The results showed that cultivar PAN 1664 had the highest number of plants (69.3) at harvest. It was however, not significantly different from the rest of the cultivars except cultivar LS 6162 which had a plant stand of only 46.5 plants at harvest (Table 4.4). Cultivar LS 6162 was not significantly different from cultivars LS 6164, LS 6150 and PAN 737 which had plant stands ranging from 54.8 to 65.3, plants per plot at harvest. The final plant stand showed that some cultivars are more vigorous than other cultivars.

Table 4.4: Number of plants , pod height (cm), number of nodes, number of pods, plant height (cm), 100-seed mass (g), and seed yield (t ha^{-1}) at harvest of six soybean cultivars at Malkerns Research Station.

Cultivar	**Plants at harvest**	**Pod height (cm)**	**Number of nodes/ plant**	**Number of pods / plant**	**Plant height (cm)**	**100 Seed mass (g)**	**Seed yield (t ha^{-1})**
LS 6162 (IV)	46.5b	9.5c	13.0a	34.9a	43.3b	15.7a	0.9bc
PAN 535 (V)	68.8a	8.5c	10.8c	32.3a	34.0c	15.3ab	1.0b
PAN 1664 (VI)	69.3a	11.3ab	9.3d	29.0a	39.3bc	14.4bc	0.9bc
LS 6164 (VI)	65.3ab	9.5c	12.0abc	33.0a	41.3bc	12.9d	1.0b
LS 6150 (VI)	59.5ab	9.8bc	12.3ab	33.7a	52.0a	13.8cd	1.3a
PAN 737 (VII)	54.8ab	12.0a	11.0bc	42.3a	40.5bc	15.1ab	0.8c
Mean	60.7	10.1	11.4	34.2	41.7	14.5	1.0
LSD $_{0.05}$	20.4	1.7	1.3	18.8	8.3	1.2	0.1
Significance	*	*	*	Ns	*	*	*
CV (%)	22.3	11.4	7.7	36.4	13.3	5.3	9.8

4.5.2 Pod height

Cultivar PAN 737 had the highest pod height (12.0 cm). It was significantly different from the other cultivars, but was not different from cultivar PAN 1664 which had a pod height of 11.3 cm. Cultivar LS 6159, LS 6164, LS 6162 and PAN 535 were not significantly different from each other. They had a pod height ranging from 8.5 to 9.5 cm (Table 4.4). The pod height indicates that the indeterminate and late maturity cultivars had a pod height which was higher than the determinate and early maturity cultivars. This proves that while determinate cultivars have ceased plant growth and development the indeterminate and late maturing cultivars were still growing and developing. These results were in agreement with the findings for Pretoria. The pod height at both Malkerns and Nhlangano were generally lower than for Pretoria. This might have been due to the fact that the cultivars at Pretoria reached their full potential of growth and development while the other locations did not reach their full potential as the numbers of growing days were less and shorter as planting was late in these locations.

4.5.3 Number of nodes

The number of nodes ranged from 9.3 to 13.0. Cultivar LS 6162 had the highest (13.0) number of nodes. Cultivar PAN 1664 had the lowest number (9.3) of nodes. Cultivar LS 6162 was not significantly different from cultivars LS 6150, and LS 6164, which had 12.3 and 12.0 nodes respectively (Table 4.4). However, cultivar LS 6164 was not significantly different from cultivar PAN 737 and PAN 535, which had 11.0 and 10.8 nodes. Cultivar PAN 1664 which had the lowest number of nodes was significantly different from all the cultivars. The results showed that at this locality growth habit of the cultivars did not have an influence in the number of nodes. The number of nodes was lower than those in Pretoria. This was due to the fact that the experiment planted in Pretoria had more and longer growing days than the other locations, hence more assimilates were accumulated for plant growth and development in Pretoria than the other locations.

4.5.4 Number of pods

The results showed that the number of pods ranged from 29.0 to 42.3. Cultivar Pan 737 had the highest (42.3) number of pods and cultivar PAN 1664 had the lowest number of pods (29.0). The results showed that there were no significant differences amongst the cultivars regardless of growth habit of the cultivars (Table 4.4). Since the number of pods was the same, as such the number of pods did not have an influence on the cultivar that had the highest yield as the results show that even though cultivar PAN 737 had the highest number of pods, it was the lowest yielding cultivar at this location. It would have been expected that it would give the highest yield as there would be more seeds but was not the case as most of the pods did not bear any seeds.

Both Malkerns and Nhlangano had fewer pods than Pretoria which was due to late planting of the experiments in this location.

4.5.5 Plant height

Cultivar LS 6150 had the tallest (52.0 cm) plants, as was the case for Pretoria. Cultivar PAN 535 had the shortest (34.0 cm) plants (Table 4.4). Cultivar LS 6150 was significantly different from all the other cultivars. Cultivars LS 6162, LS 6164, PAN 737 and PAN 1664 were not significantly different from each other and had a plant heights ranging from 39.3 to 43.3 cm. Cultivar PAN 535 was significantly shorter than all the other cultivars. The results showed that growth habit was not directly correlated to plant height of the cultivars. Even though indeterminate cultivars had the tallest plants, it was followed by a determinate cultivar. The plant height was lower than Pretoria at both Malkerns and Nhlangano. The late planting was the contributing factor as the cultivars did not grow to their full potential due to fewer and shorter growing days as plantings were late in these locations.

4.5.6 100-seed mass

The results showed that cultivar LS 6162 had the highest (15. 7 g) 100-seed mass, while LS 6164 had the lowest (12.9 g) 100-seed mass. This trend was similar to what was observed for Pretoria. Cultivar LS 6162 was however, not significantly different from cultivars PAN 535 and PAN 737, which had 100-seed masses of 15.3 and 15.1 g respectively (Table 4.4). Cultivars PAN 1664 and LS 6150 were also not significantly different from each other, as they had a 100-seed mass of 14.4 and 13.8 g respectively. Cultivar LS 6164, which had the lowest 100-seed mass, was also significantly different from all the other cultivars. Again the results showed that the growth habit of the cultivars had an effect on the 100-seed mass as the determinate and early maturing cultivars LS 6162 and PAN 535 had the highest 100-seed mass while the late maturing and indeterminate cultivars LS 6150 and LS 6164 had the lowest 100-seed mass.

4.5.7 Seed yield

The seed yield ranged from 0.8 t ha^{-1} to 1.3 t ha^{-1}. Cultivar LS 6150 had the highest seed yield of 1.3 t ha^{-1}, while cultivar PAN 737 had the lowest seed yield of 0.8 t ha^{-1}. Cultivar LS 6150 was significantly different from all the cultivars, while cultivar PAN 737 was not significantly different from cultivars LS 6162 and PAN 1664, both having seed yields of 0.9 t ha^{-1} respectively (Table 4.4).

The results showed that the indeterminate cultivars had the highest seed yield at this locality. The late time of planting had a negative effect on final seed yield. The late maturity cultivar (PAN 737) gave the lowest yield because the growing season was too short for this determinate and late maturing cultivar to complete its growth cycle in the available growing season. The short growing season suited the early maturing cultivars better, although they did not have the highest yields. At this location the growth habit of cultivars had a great effect on the seed yield. Cultivar LS 6150, which is indeterminate, had the highest seed yield. It had an advantage over the other cultivars as it had the ability to flower and at the same time produce more leaves which are the sources for flower and pod development. The grain yields obtained from both Malkerns and Nhlangano were lower than those of Pretoria. This was due to the fact that the experiments were planted late at Malkerns and Nhlangano and the cultivars did not reach their full growth and development as the numbers of growing days were shorter in these locations than in Pretoria.

NHLANGANO TRIAL

4.6 Plant growth analysis results

4.6.1 Leaf dry matter yield

The results of leaf dry matter yields over the growing season are presented in Figure 4.7 and showed that at 44 days after planting yields ranged from 54.4 g m^{-2} to 65.3 g m^{-2}.

Cultivar LS 6162 had the highest leaf dry matter yield of 65.3 g m^{-2}. It was however, not significantly different from any of the other cultivars, which had leaf dry matter yields ranging from 54.4 to 62.4 g m^{-2}.

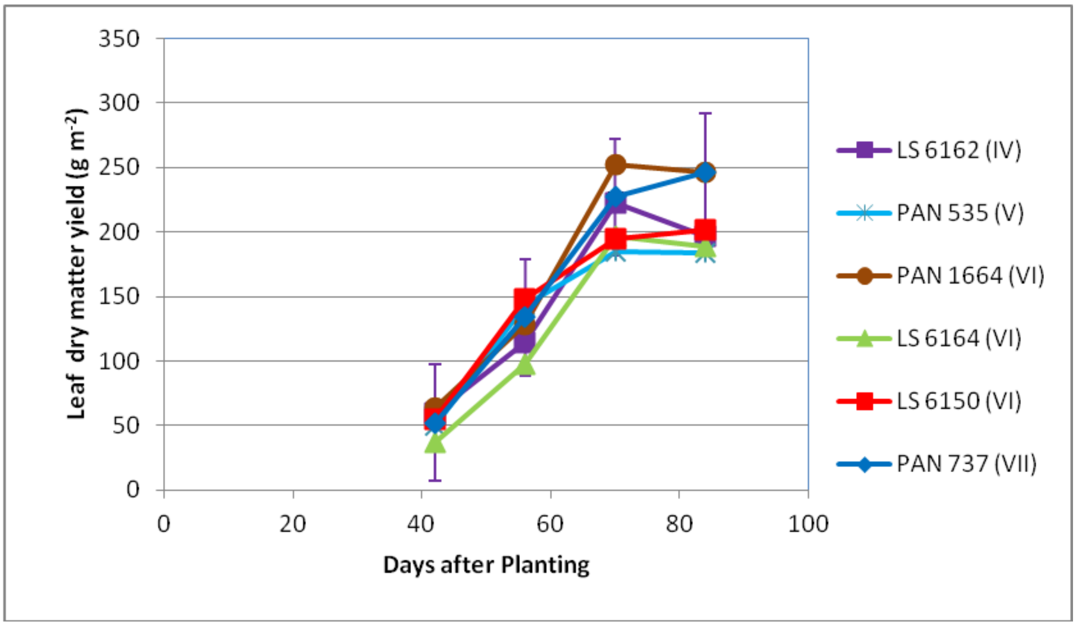


Figure 4.7: Plant growth analysis results for Nhlangano: leaf dry matter yield (g m^{-2}) for six soybean cultivars at different days after planting.

The cultivars showed no significant differences at 58 days after planting. The leaf dry matter yield ranged from 153.1 g m^{-2} to 196.7 g m^{-2} (Figure 4.7). Even though there were no significant differences cultivar, LS 6150 had the highest leaf dry matter yield of 196.7 g m^{-2}.

Cultivar PAN 737 had the highest leaf dry matter yield of 247.7 g m^{-2} at 72 days after planting. It was not significantly different from cultivars LS 6150 and LS 6162, which had leaf dry matter yields of 242.4 g m^{-2} and 229.1 g m^{-2}, but was significantly different from cultivars PAN 1664, PAN 535 and LS 6164 which had leaf dry matter yields ranging from 193.7 to 201.1 g m^{-2} (Figure 4.7). Cultivar LS 6164 gave the lowest leaf dry matter yield of 193.7 g m^{-2}, however, it was not significantly different from cultivars PAN 1664, PAN 535, and LS 6162, which had leaf dry matter yields ranging from 201.1 to 229.1 g m^{-2}.

Again at 86 days after planting the cultivars showed significant differences in leaf dry matter yield. Cultivar LS 6150 gave the highest leaf dry matter yield of 219.3 g m^{-2}, while the other cultivars had leaf dry matter yields ranging from 141.1 to 210.0 g m^{-2} (Figure 4.7). The results showed that the late maturing cultivars were consistent in their growth as they gave higher leaf dry matter yields at all locations. This showed that these cultivars are able to produce more assimilates than the early maturing cultivars. They also showed that given adequate growing periods they can fully express their growth and development and yield potential.

When comparing the three localities where the experiments were conducted Pretoria had the highest leaf dry matter yield of 299.7 g m^{-2} when compared with the other locations which had 219 and 246 g m^{-2}respectively. The reason for that was that the trial was planted earlier in Pretoria than the other locations, which gave the cultivars maximum growth and development.

4.6.2 Stem dry matter yield

The results showed that at 44 days after planting there were no significant differences among the cultivars in stem dry matter yield. Even though there were no significant differences cultivar LS 6162 gave the highest stem dry matter yield of 44.7 g m^{-2} (Figure 4.8). The remaining cultivars had stem dry matter yields ranging from 36.0 to 43.1 g m^{-2}.

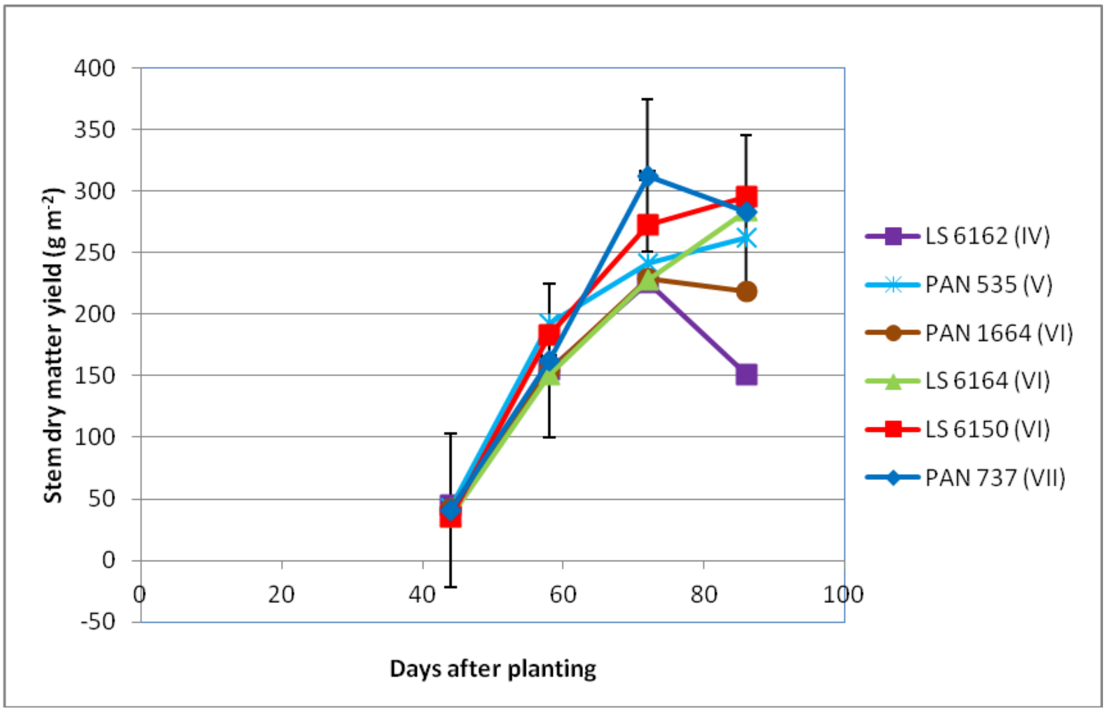


Figure 4.8: Plant growth analysis results for Nhlangano, stem dry matter yield (g m^{-2}), for six soybean cultivars at different days after planting

Also at 58 days after planting there were no significant differences among the cultivars in stem dry matter yield. Despite the fact that there were no significant differences, cultivar PAN 535 gave the highest stem dry matter yields of 192.7 g m^{-2}. The remaining cultivars had stem dry matter yields ranging from 150.7 to 183.3 g m^{-2}(Figure 4.8).

The results showed some significant differences in stem dry matter yield at 72 days after planting. Cultivar PAN 737 gave the highest stem dry matter yield of 31.7 g m^{-2}. It was not significantly different from cultivar LS 6150 which gave a stem dry matter yield of 272.7 g m^{-2} (Figure 4.8). Cultivar LS 6162 gave the lowest stem dry matter yield of 226.0 g m^{-2}. However, it was not significantly different from cultivars LS 6164, PAN 1664, PAN 535, and LS 6150 which gave stem dry matter yields ranging from 228.0 to 272.7 g m^{-2}.

The results showed that cultivar LS 6150 had the highest stem dry matter yield of 295.1 g m^{-2} at 86 days after planting. It was however, not significantly different from cultivars LS 6164, PAN 737 and PAN 535, which had stem dry matter yields ranging from 262.7 to 284.4 g m^{-2}. Cultivar

LS 6162 had the lowest stem dry matter yield of 151.3 g m^{-2} (Figure 4.8), but it was not significantly different from cultivars PAN 1664 and PAN 535, which had stem dry matter yields of 219.1 g m^{-2} and 262.7 g m^{-2} respectively**.** Again the indeterminate and late maturing cultivars showed superior stem dry matter yields compared to than the determinate and early maturing cultivars. This is due to the fact that they have an advantage over the determinate and early maturing cultivars which is largely due to their genetic makeup**.**

4.6.3 Pod dry matter yield

The pod yield results are presented in Table 4.5 and showed that cultivar LS 6162 had the highest pod dry matter yield of 282.3 g m^{-2}at 72 days after planting. It was significantly different ($p < 0.05$) from all the other cultivars. Cultivar PAN 737 had the lowest pod dry matter yield of 4.2 g m^{-2}. It was however, not significantly different from cultivars LS 6164, PAN 535, LS 6150 and PAN 1664 which had pod dry matter yields ranging from 83.33 to 107.3 g m^{-2}.

At 86 days after planting cultivar LS 6162 still had the highest pod dry matter yield of 468.7 g m^{-2}. It was again significantly different from all the other cultivars. Cultivar PAN 737 had the lowest pod dry matter yield of 206.7 g m^{-2}. It was not significantly different from cultivar LS 6164, which had a pod dry matter yield of 262.7 g m^{-2} (Table 4.5). The weather conditions favoured the determinate and early maturing cultivars, as cultivar LS 6162 gave better pod dry matter yield as compared to the other cultivars. The rainfall and temperatures were lower at this location than the other two locations, which resulted in slower growth and therefore too short growing season for the late maturing cultivars.

Table 4.5: Pod dry matter yield (g m^{-2}) at 72 and 86 days after planting at Nhlangano

Cultivar	**Days after planting**	
	72	**86**
LS 6162 (IV)	283.3a	468.7a
PAN 535 (V)	94.0b	303.3bc
PAN 1664 (VI)	107.3b	367.3bc
LS 6164 (VI)	83.3b	262.7cd
LS 6150 (VI)	99.3b	334.0bc
PAN 737 (VII)	56.0b	206.7d
LSD (p<0.05)	68.1	95.6
CV (%)	22.0	11.5

4.7 Plant parameters at harvest

4.7.1 Number of plants at harvest

The results showed that cultivar PAN 1664 had the highest (122.0) number of plants at harvest, however it was not significantly different from cultivars PAN 535 and PAN 737 which had a plant stand of 101.3 and 99.3 plants respectively (Table 4.6). Cultivar LS 6162 had the lowest number of plants at harvest (58.0). It was significantly different from all the cultivars. Cultivars LS 6164 and LS 6150 were significantly different from the other cultivars, but did not differ significantly from each other. They had a final plant stand of 91.5 and 89.8 plants respectively. The number of plants at harvest at Malkerns was lower than the other 2 locations. This was due to the fact that there was low soil moisture content when planting the experiment at Malkerns which resulted in poor crop emergence.

Table 4.6: Number of plants at harvest, pod height (cm), number of nodes, number of pods, plant height (cm), 100 seed mass (g), and seed yield (t ha^{-1}) at harvest of six soybean cultivars at Nhlangano.

Cultivar	**Plants at harvest**	**Pod height (cm)**	**Number of nodes/plant**	**Number Pods/ plant**	**Plant height (cm)**	**100 Seed mass (g)**	**Seed yield (t ha^{-1})**
LS 6162 (IV)	58.0c	8.5c	10.5a	30.8b	44.0c	15.4ab	1.4b
PAN 535 (V)	101.3ab	11.3b	10.8a	61.5a	42.0c	12.7d	1.7ab
PAN 1664 (VI)	122.0a	13.0ab	9.3b	37.6b	54.8b	13.3cd	1.7ab
LS 6164 (VI)	91.5b	12.3ab	11.3a	48.8ab	53.3b	14.7bc	1.7ab
LS 6150 (VI)	89.8b	13.5a	11.5a	37.3b	66.3a	13.2cd	1.9a
PAN 737 (VII)	99.3ab	13.8a	11.0a	43.4ab	52.0b	16.2a	1.5b
Mean	93.6	12.0	10.7	43.2	52.0	14.2	1.7
LSD $_{0.05}$	25.1	2.2	1.2	21.7	7.2	1.5	0.3
Significance	*	*	*	*	*	*	*
CV (%)	17.8	11.9	7.7	33.3	9.2	6.9	12.7

4.7.2 Pod height

Pod height from the soil surface ranged from 8.5 cm to 13.8 cm. Cultivar PAN 737 had the highest (13.8 cm) pod height. However it was not significantly different from cultivars LS 6150, PAN 1664, and LS 6164 which had a pod height ranging from 12.3 to 13.5 cm (Table 4.6). Cultivar LS 6162 had the lowest pod height of 8.5 cm. It was significantly different from all the other cultivars. Cultivars PAN 1664, LS 6164 and PAN 535 were not significantly different from each other. The results showed that the indeterminate cultivars had a higher pod height as compared to the determinate cultivars. This showed that the plant growth habit had an effect on pod height and that indeterminate cultivars should in general be better suited to mechanical harvesting. The experiment planted in Pretoria had the highest pod height when compared to the other locations.

The late maturing cultivar PAN 737 had the highest pod height in all the locations and the early maturing cultivars had the lowest pod height. This again showed that late maturing cultivars have the ability to grow and develop better than early maturing cultivars.

4.7.3 Number of nodes

Cultivar LS 6150 had the highest number (11.5) of nodes. It was not significantly different from cultivars LS 6164, PAN 737, PAN 535 and LS 6162 which had pod heights ranging from 10.5 to 11.3 nodes, but it was significantly different from cultivar PAN 1664 which had 9.3 nodes (Table 4.6). The growth habit of the cultivars did not have any effects on the number of nodes. The number of nodes was similar for all the cultivars planted at Nhlangano, the only differences were observed on the number of pods, which is why the number of pods did not have any correlation with the number of nodes. Pretoria had the highest number of nodes when compared with Malkerns and Nhlangano. PAN 1664 had the lowest number of nodes in all locations. This cultivar showed that genetically it does not have a lot of nodes.

4.7.4 Number of Pods

Cultivar PAN 535 had the highest (61.5) number of pods, while LS 6162 had the lowest pod number (30.8 pods). There were significant differences ($P < 0.05$) among the cultivars. Cultivar PAN 535 was not significantly different from LS 6164 and PAN 737 (Table 4.6), which had an average of 48.8 and 43.4 pods respectively. Cultivar LS 6164 was not significantly different from cultivars PAN 737, PAN 1664, LS 6150 and LS 6162. The results showed that the growth habit of the cultivars did not have an effect on the number of pods.

4.7.5 Plant height

Cultivar LS 6150 had the highest (66.3 cm) plant height. It was significantly different ($P< 0.05$) from all the cultivars. Cultivar PAN 535 had the shortest (42.0) plants, however it was not significantly different from LS 6162 which had a plant height of 44.0 cm.

Cultivars PAN 1664, LS 6164, and PAN 737 were not significantly different from each other. They had plant heights ranging from 52.0 cm to 54.8 cm respectively (Table 4.6). The results showed that plant growth habit and maturity had an effect on the plant height as the indeterminate and late maturing cultivars generally had higher plant heights than the determinate cultivars at all the locations.

4.7.6 100-seed mass

The results showed that cultivar PAN 737 had the highest 100-seed mass of 16.2 g. Cultivar PAN 535 had the lowest 100-seed mass of 12.7 g. Cultivar PAN 737 was not significantly different from cultivar LS 6162 which had a 100 seed mass of 15.4 g. Cultivar LS 6164, which had a 100 seed mass of 14.7 was not significantly different from cultivars LS 6162, PAN 1664 and LS 6150. They had 100-seed masses ranging from 13.2 to 15.4 g. Cultivar PAN 535, which had the lowest 100-seed mass, did not differ significantly from cultivars PAN 1664 and LS 6150 (Table 4.6). The results showed that plant growth habit did not have an effect on 100-seed mass as both the determinate and indeterminate cultivars did not differ significantly.

4.7.7 Seed yield

Cultivar LS 6150 had the highest seed yield of 1.9 t ha^{-1} and LS 6162 had the lowest seed yield of 1.4 t ha^{-1}. Cultivar LS 6150 was not significantly different from cultivars PAN 1664, PAN 535, and LS 6164, which all had seed yields of 1.7 t ha^{-1} (Table 4.6). LS 6162 which gave the lowest seed yield was not significantly different from cultivars PAN 1664, PAN 535, LS 6164 and PAN 737, which gave seed yields ranging from 1.5 t ha^{-1} to 1.7 t ha^{-1}. The results showed that plant growth habit and maturity group did not have an effect on the seed yield as early maturing cultivars gave similar yields to late maturing cultivars. The late planting date at this locality had a great influence on the late maturity cultivars, as they did not fully express themselves due to the short growing cycle. The yields obtained at this location were in the range of 1.4 to 1.9 t ha^{-1}, which were slightly lower than the yields that were obtained in Pretoria, South Africa which ranged from 2.0 to 3.4 t ha^{-1}, but higher than the yields recorded at Malkerns which ranged from 0.8 to 1.3 t ha^{-1}.

4.8 GENERAL DISCUSSION OF THE RESULTS

Final seed yields obtained from the results for the different locations indicated that the environments were completely different from each other. In Pretoria where the experiment was planted earlier, better crop growth was obtained for all the measured parameters. The mean number of plants that were harvested on this site was 104 plants per plot as compared to 93 and 66 plants per plot obtained from Nhlangano and Malkerns. The reason for the low number of plants at Nhlangano and Malkerns was that the moisture in the soil was not sufficient to promote proper seed emergence. Even though good rains (100 mm to 220 mm) were received between November and December during the planting of the experiments at all the locations, the distribution was very erratic, as a lot of rain was often received in one day, followed by a period of no rains for the next two weeks. At Pretoria good rains were received after planting, hence the good seed emergence and better plant growth in all plant growth aspects as compared to the other locations. This was also due to the fact that the experiment planted in Pretoria had a longer growing season as it was planted six weeks earlier than the other locations, hence it had an advantage over the experiments planted in the other locations, which consequently had a shorter growth cycle than in Pretoria. This location also experienced the highest maximum temperatures, which resulted in higher fractional interception of PAR, which resulted in faster growth of plants. This is in agreement with Miladinovic *et al.*, (2006) who stated that temperature is one of the most important factors that influence crop growth and development. This resulted in Pretoria having the highest mean seed yield of 2.9 t ha^{-1}. This scenario agrees with the report by Egli (1993), who stated that the highest soybean yields are obtained from cultivars that have a total growth cycle that uses most of the available growing season.

The difference in the planting dates between locations also clearly indicated the importance of plant growth habit and maturity group of the different individual cultivars. Cultivar PAN 737, which is late maturing and determinate, gave the highest seed yield of 3.4 t ha^{-1} in Pretoria and gave the lowest seed yield of 0.8 t ha^{-1} at Malkerns. This was due to the fact that Malkerns had the lowest maximum temperatures when compared to the other locations, which resulted in a slow growth of cultivar PAN 737, which could not complete its normal growth cycle, because of the late planting at this site. This is in agreement with reports by Miladinovic *et al*., (2006), who stated that later maturing cultivars with higher genetic potentials for yield need favourable growing conditions in order for that potential to be realized. The early maturing cultivars (LS 6162 and PAN 535) showed stable yields at all the locations as they gave seed yields which were very close to and sometimes higher than that of the late maturing cultivars. This showed that the early maturing cultivars have a higher adaptability potential than late maturing cultivars. This is the reason why it is very important to know the environmental conditions of each locality so that cultivars that will best suit the growing season can be selected.

Photoperiod also had a great effect on the performance of cultivars at the different locations. As a result of the declining photoperiod, late maturing soybean cultivars at Malkerns and Nhlangano had a shortened growing cycle, resulting in reduced growth and lower seed yield. According to Morandi *et al*., (1998) photoperiod is responsible for the timing of flowering in soybean, which has a great effect on soybean seed yield. Short photoperiods had a negative impact at locations where the soybean cultivars were planted late. The crop did not grow vegetatively to its full growth potential due to late planting, resulting in the crop flowering earlier as the day length was becoming shorter due to the change in season. Since photoperiod regulates the duration of most phases of soybean development (Kantolic *et al*., 2005), the late and indeterminate cultivars (e.g.

PAN 737) did not have enough time to complete the reproductive phase, leading to low yields. The field experiment planted at Pretoria gave better seed yields than the other locations. This was due to the fact that it had a better chance to grow and fully develop a large canopy before the onset of the reproductive stage as it was planted about a month earlier than the other locations.

Cultivar LS 6150 gave better seed yield when compared to the performance of the cultivars at all the locations. This cultivar had the advantage of being indeterminate and late maturing. Plant growth habit and maturity class are therefore key factors that have to be taken into consideration when selecting a soybean cultivar for each location.

CHAPTER 5: CROP MODELLING

5.1 Introduction

The accessibility of personal computers to crop producers has generated interest in computer models in agriculture (Jovanovic *et al*., 2000). A model can be a handy tool to help establish how well a cultivar will adapt and perform under varying agro-ecological conditions. Furthermore, calibrated crop models can be used to assess how climate change and rising temperatures will affect future adaptation of crops and how yield will be affected. However, model growth parameters are required for growth, development and yield modelling, and these parameters may differ from cultivar to cultivar, depending on the different maturity groups and growth habits. Growth analysis needs to be carried out to be able to calculate such model parameters. Calibrated models can then be used to simulate yields of different crop cultivars in varying agro-ecological zones.

A number of crop growth models have been developed with different levels of complexity, depending on the specific requirements of that particular model. Most of these models, like the Soil Water Balance (SWB) model (Jovanovic *et al*., 2000), could facilitate simulation of several crop growth components for different locations, taking into consideration specific crop parameters, soil and weather data.

Since the SWB model can simulate crop growth components, it was anticipated that modelling will be useful to estimate the potential seed yield of soybean cultivars of different maturity groups and growth habits when produced in varying agro-ecological zones, hence this study was conducted.

5.2 Soil Water Balance model

The Soil Water Balance model is a user friendly, mechanistic, real time, generic crop, irrigation scheduling model. It is based on the improved generic crop version of the NEW Soil Water Balance model (Jovanovic and Annandale, 2000). SWB gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop management data. There are several crop specific growth parameters, such as the canopy extinction coefficient for solar radiation, dry matter/water ratio, radiation use efficiency, crop height and thermal time requirements for the completion of several phenological stages.

5.3 Methodology

Crop growth parameters for each of the six soybean cultivars used in this study were calculated from the growth analysis data collected at Pretoria from the trial reported in Chapters 3 and 4 and some parameters were taken from the existing Soil Water Balance database. The SWB model was then calibrated and used to simulate leaf area index and top and harvestable dry matter of each cultivar. The crop growth parameters that were obtained from the SWB database or literature included: base temperature (°C), optimum light limited temperature (°C) and the cut off temperature (°C), maximum root depth (m), stem to grain translocation parameter, canopy storage (mm), minimum leaf water potential (kPa), maximum transpiration (mm d^{-1}), leaf stem partitioning (m^2 kg^{-1}), total dry matter mass at emergence (kg m^{-2}), root fraction, root growth rate and stress index (Jovanovic and Annandale, 2000). Maximum crop height (m), transition period (d °C), and leaf senescence (d °C) was measured in the field and the following parameters were calculated from growth analysis data:

$$\mathrm{FI} = 1 - \exp(-K\ LAI) \qquad \text{(Equation 5.1)}$$

$$\mathrm{DWR} = \frac{DM \times VPD}{ET} \qquad \text{(Equation 5.2)}$$

$$\text{Growing day degrees} = (T_{ave} - T_b)\ \Delta t \qquad \text{(Equation 5.3)}$$

Where: LAI is leaf area index

K is the canopy extinction coefficient

DM is dry matter yield

ET is crop evapotranspiration

DWR is vapour pressure corrected dry matter/water ratio

FI is fractional interception of photosynthetically active radiation

VPD is vapour pressure deficit

T_{ave} is average temperature

T_b is base temperature

Δt is change in temperature

Weather variables were obtained from an automatic weather station at the Pretoria site. The weather data recorded included daily maximum and minimum temperatures (°C), maximum and minimum relative humidity (%), reference evapotranspiration (mm d^{-1}), precipitation (mm), average wind speed (m s^{-1}) and solar radiation (W m^{-2}).

5.4 Results

Plant growth analysis data was collected fortnightly until the crop reached physiological maturity. The data was used to calculate some model parameters. These parameters were then added into the SWB crop data base. The model was run and calibrated to assess predictive ability.

The crop parameters for the different cultivars are given in Tables 5.1 to 5.6. The growing degree day requirement from planting to crop emergence ranged from 45d °C to 62d °C. Thermal time requirement for completion of the vegetative stage ranged from 590 to 900d °C, with the determinate and early maturing cultivar LS 6162 having the lowest requirement of 590d °C, while the late maturing cultivars PAN 737 and LS 6164 required 890 and 900d °C. Thermal time requirement for maturity ranged from 1220d °C to 1550d °C. Cultivar LS 6162 had the lowest thermal time required and cultivar PAN 737 needed the highest thermal time to maturity.

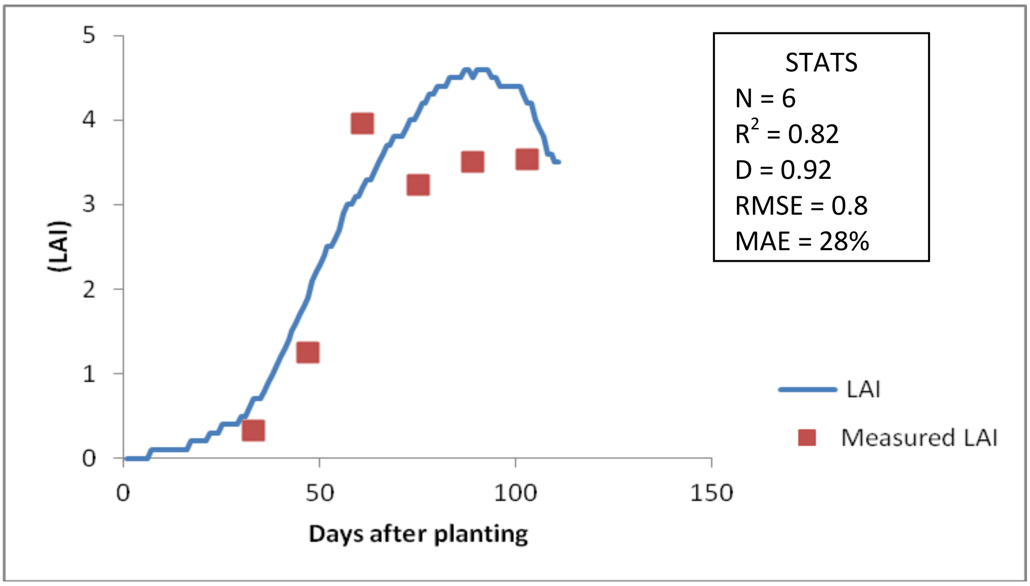
The model simulation results for the calibration data sets of the different cultivars are presented in figure 5.1 to 5.6. The model was able to successfully simulate the leaf area index and top and harvestable dry matter yields of all the cultivars. It showed that cultivars with higher leaf area index and longer maturity day degrees gave better yields than cultivars with lower leaf area indices and shorter thermal time requirements to maturity. Thus indeterminate and late maturity cultivars generally gave a better grain yield than the determinate and shorter maturity cultivars.

The simulations results showed that maturity group and growth habit had a great effect on seed yield of the different soybean cultivars. The calibration of the model was quite successful, as the simulated values generally correlated well with the actual measured values.

For example, r^2 for leaf area index ranged from 82% to 97%, and for top and harvestable dry matter yields r^2 ranged from 96% to 99%. This shows that the Soil Water Balance model was successfully calibrated for these six cultivars in Pretoria and should be useful to predict yields of soybean in varying agro-ecological environments. It is, however, important to first validate the calibrated model on independent data sets before it can be trusted for scenario modelling. Future research should therefore include model validation to ensure that model forecasts can be trusted before it could be used for scenario modelling of soybeans. The other two locations where the experiments were carried out were not validated. This was due to the protocol of the meteorological services which do not allow their daily weather data records to be issued to any individuals either for academic or work purposes.

Table 5.1: SWB model crop growth parameters for soybean cultivar LS 6162 (determinate early maturing cultivar)

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.5
Dry matter to water ratio, DWR (Pa)	5.5
Radiation Use efficiency (kg MJ^{-1})	0.00130
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	50
Flowering day degrees (d °C)	530
Maturity day degrees (d °C)	1120
Transition period (d °C)	590
Leaf senescence (d °C)	750
Maximum crop height H_{max} (m)	0.63
Maximum root depth RD_{max} (m)	0.6
Stem to grain translocation	0.200
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	18
Leaf-stem partition (m^2 kg^{-1})	1.520
Total Dry Matter at emergence (kg m^{-2})	0.0030
Root fraction	0.010
Root growth rate	5
Stress index	0.95



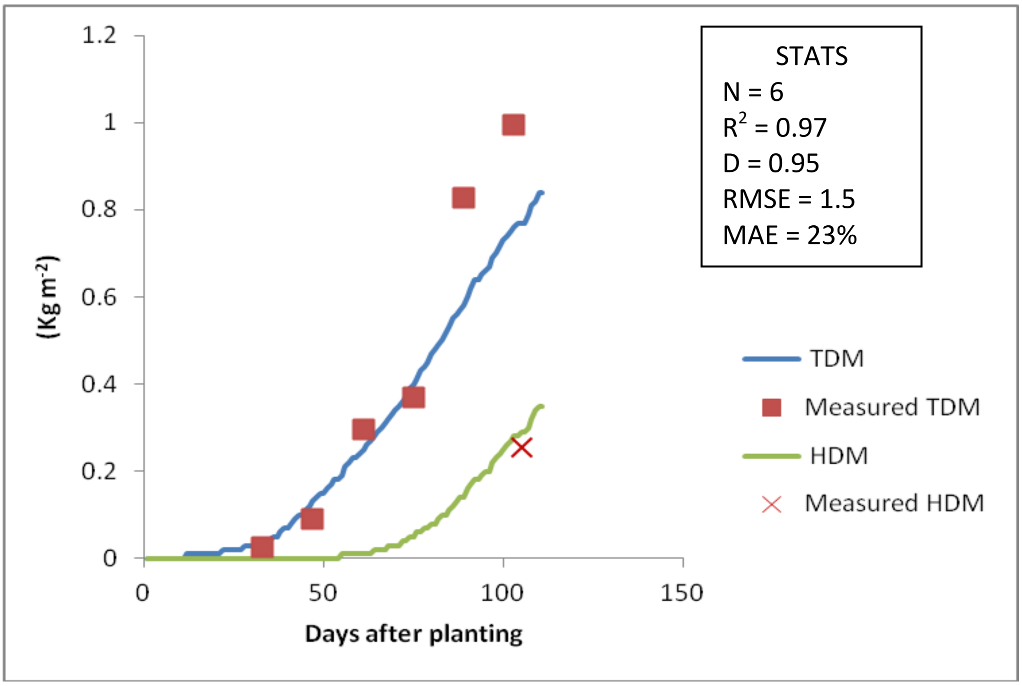


Figure 5.1: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar LS 6162 at Pretoria (calibration data set)

Table 5.2: SWB model crop parameters for soybean cultivar PAN 535 (determinate early to medium maturing cultivar)

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.65
Dry matter to water ratio, DWR (Pa)	5
Radiation Use efficiency (kg MJ^{-1})	0.00120
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	62
Flowering day degrees (d °C)	600
Maturity day degrees (d °C)	1155
Transition period (d °C)	550
Leaf senescence (d °C)	1012
Maximum crop height H_{max} (m)	0.66
Maximum root depth RD_{max} (m)	0.6
Stem to grain translocation	0.200
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	18
Leaf stem partition (m^2 kg^{-1})	1.500
Total Dry Matter at emergence (kg m^{-2})	0.0030
Root fraction	0.010
Root growth rate	5
Stress index	0.95

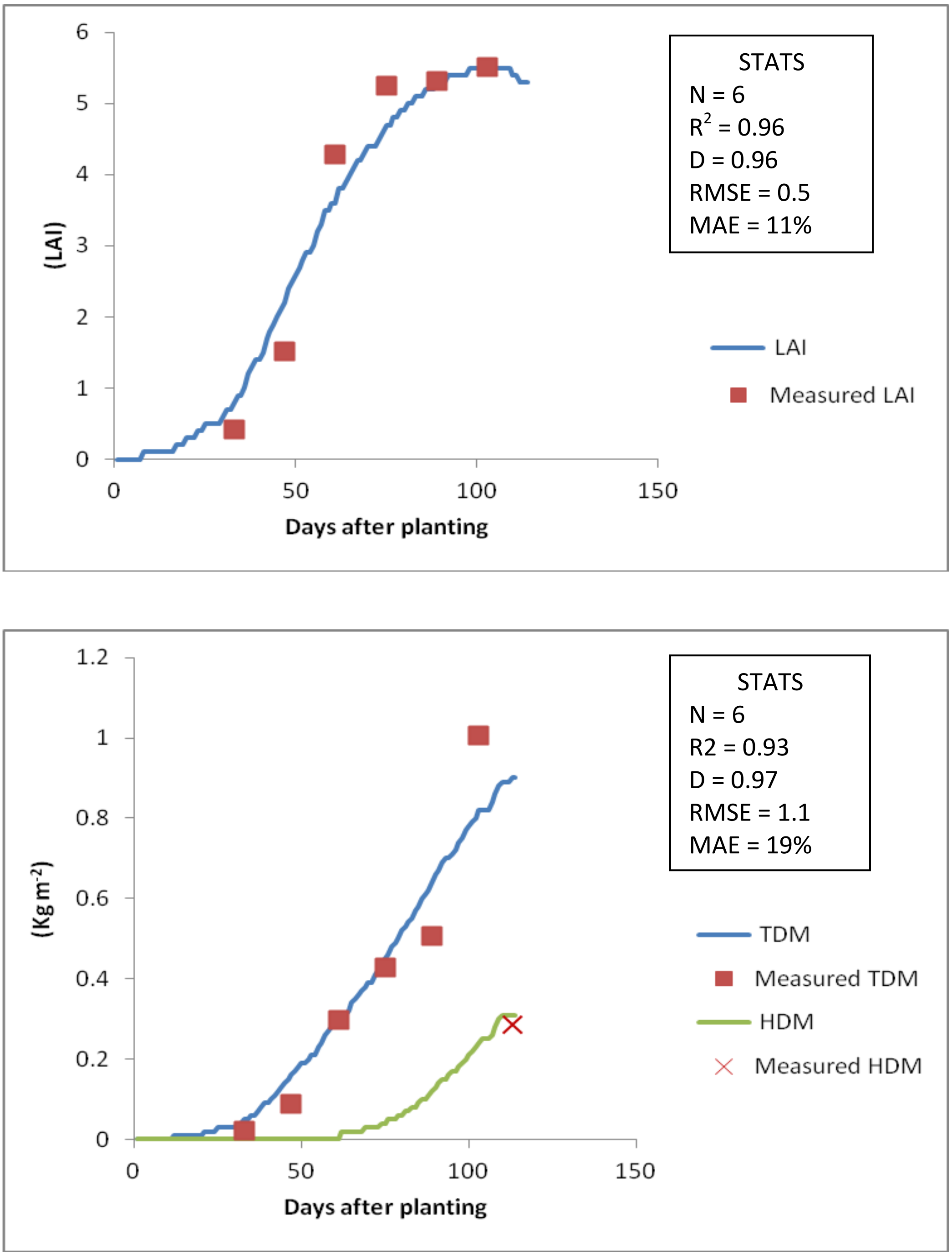
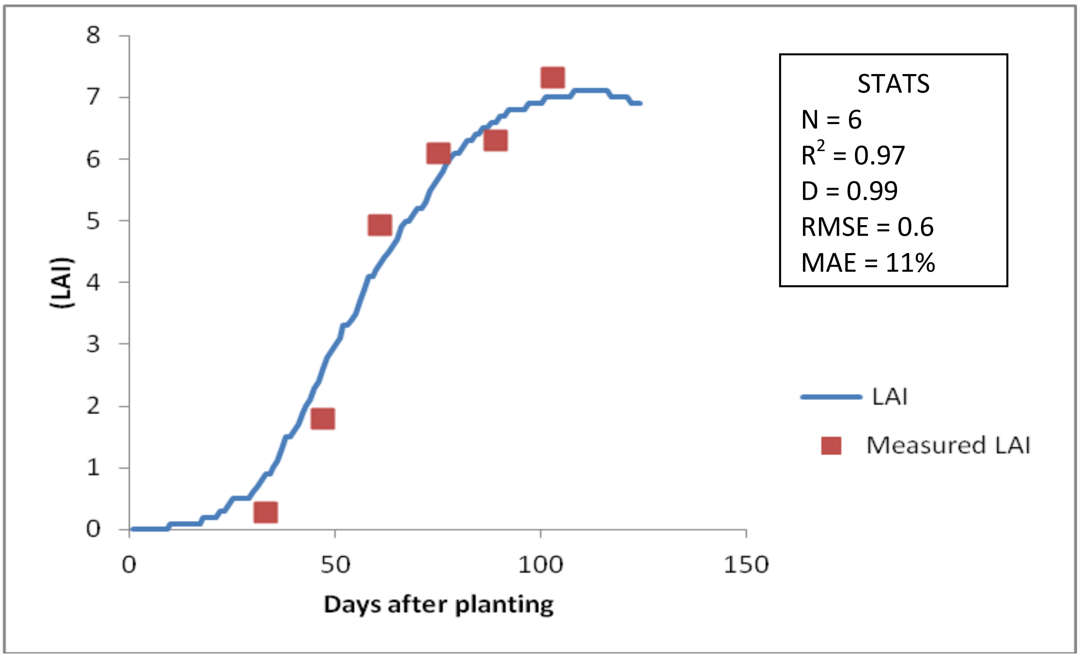


Figure 5.2: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar PAN 535 at Pretoria (calibration data set)

Table 5.3: SWB model crop parameters for soybean cultivar PAN 1664 (determinate and late maturing cultivar)

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.60
Dry matter to water ratio, DWR (Pa)	5.5
Radiation Use efficiency (kg MJ^{-1})	0.00120
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	62
Flowering day degrees (d °C)	720
Maturity day degrees (d °C)	1266
Transition period (d °C)	546
Leaf senescence (d °C)	1150
Maximum crop height H_{max} (m)	0.67
Maximum root depth RD_{max} (m)	0.5
Stem to grain translocation	0.200
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	21
Leaf stem partition (m^2 kg^{-1})	1.500
Total Dry Matter at emergence (kg m^{-2})	0.0019
Root fraction	0.010
Root growth rate	4
Stress index	0.95



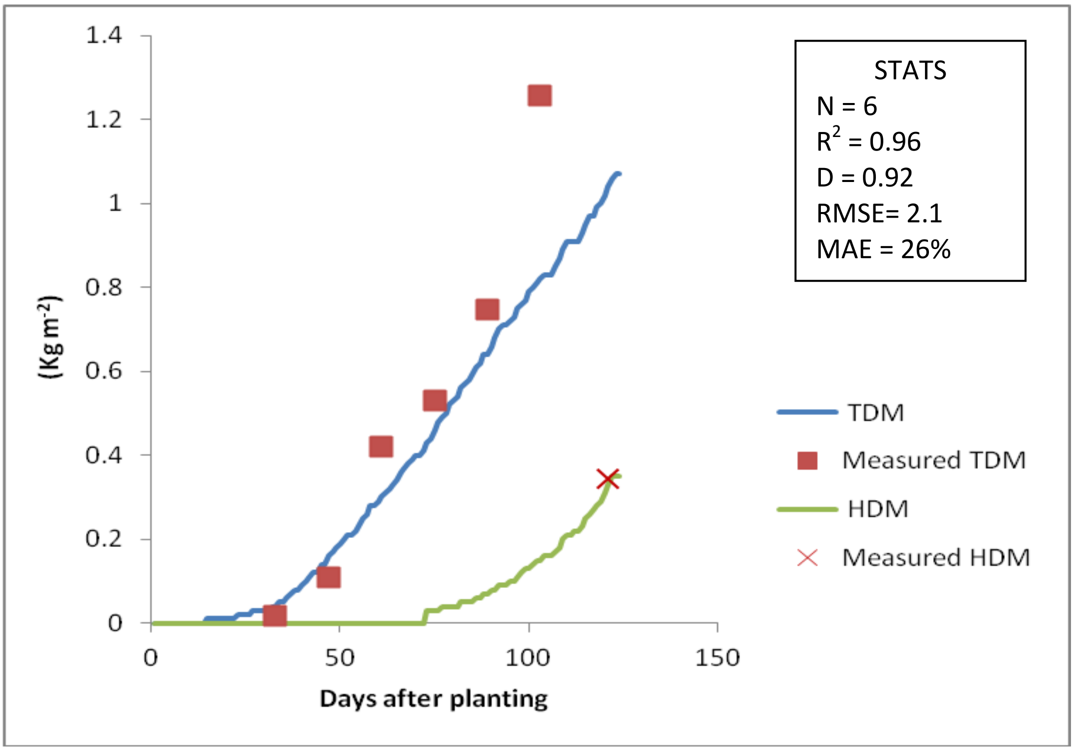
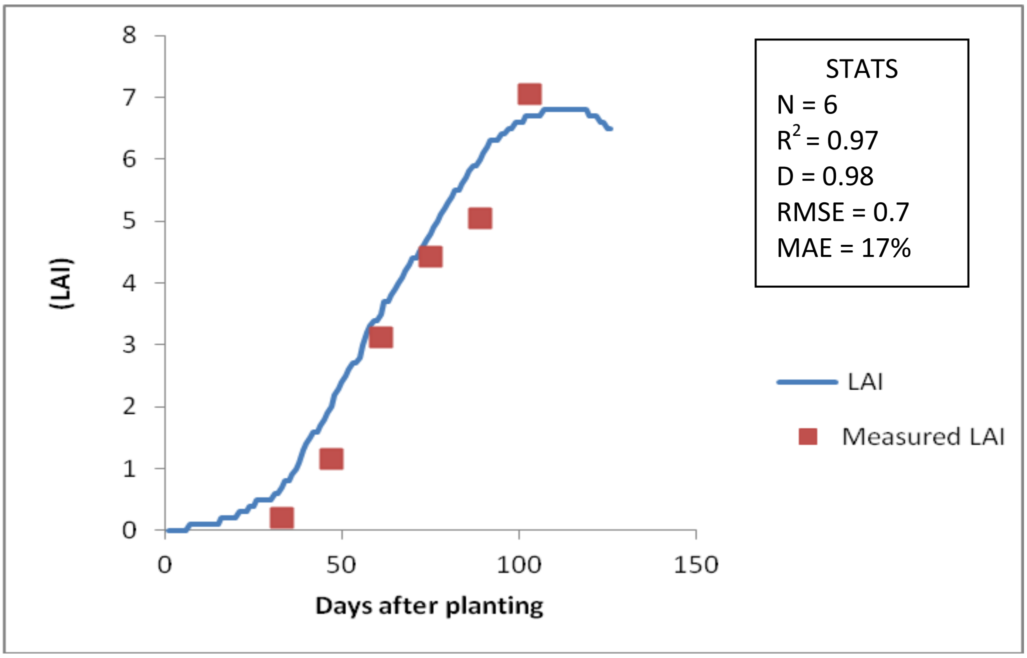


Figure 5.3: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar PAN 1664 at Pretoria (calibration data set)

Table 5.4: SWB model crop parameters for soybean cultivar LS 6164 (indeterminate and late maturing cultivar)

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.45
Dry matter to water ratio, DWR (Pa)	6
Radiation Use efficiency (kg MJ^{-1})	0.00140
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	45
Flowering day degrees (d °C)	900
Maturity day degrees (d °C)	1280
Transition period (d °C)	380
Leaf senescence (d °C)	1080
Maximum crop height H_{max} (m)	0.78
Maximum root depth RD_{max} (m)	0.6
Stem to grain translocation	0.210
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	19
Leaf stem partition (m^2 kg^{-1})	1.600
Total Dry Matter at emergence (kg m^{-2})	0.0030
Root fraction	0.012
Root growth rate	5
Stress index	0.95



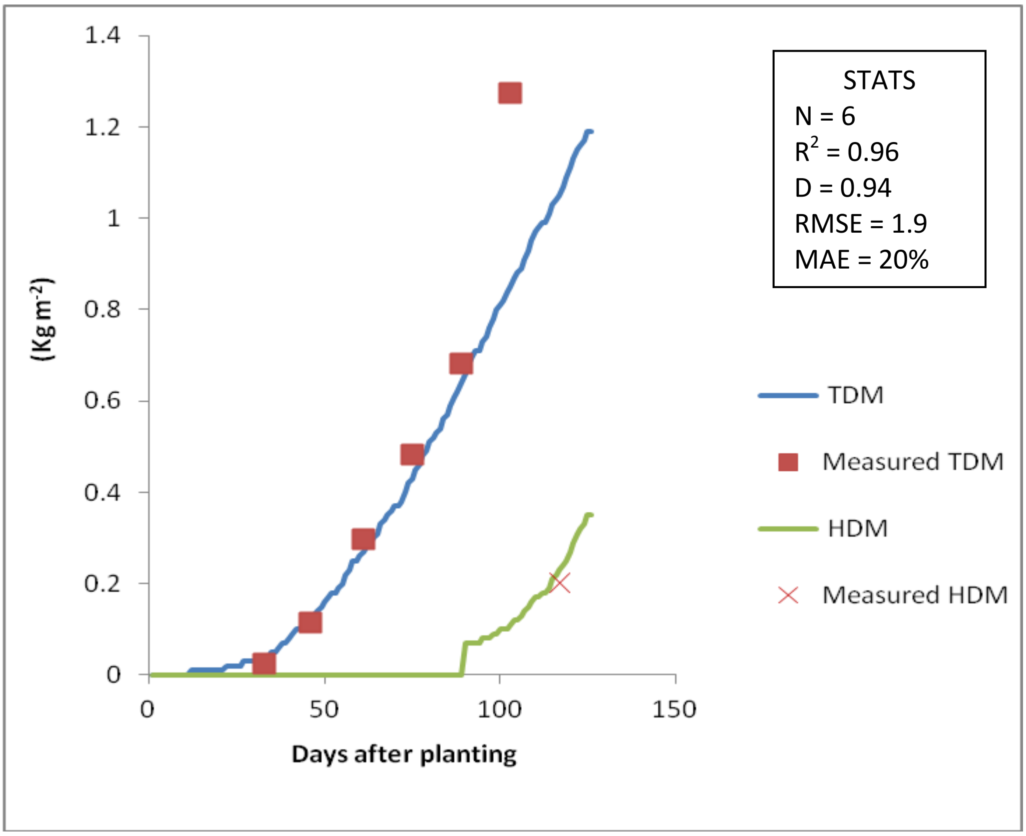
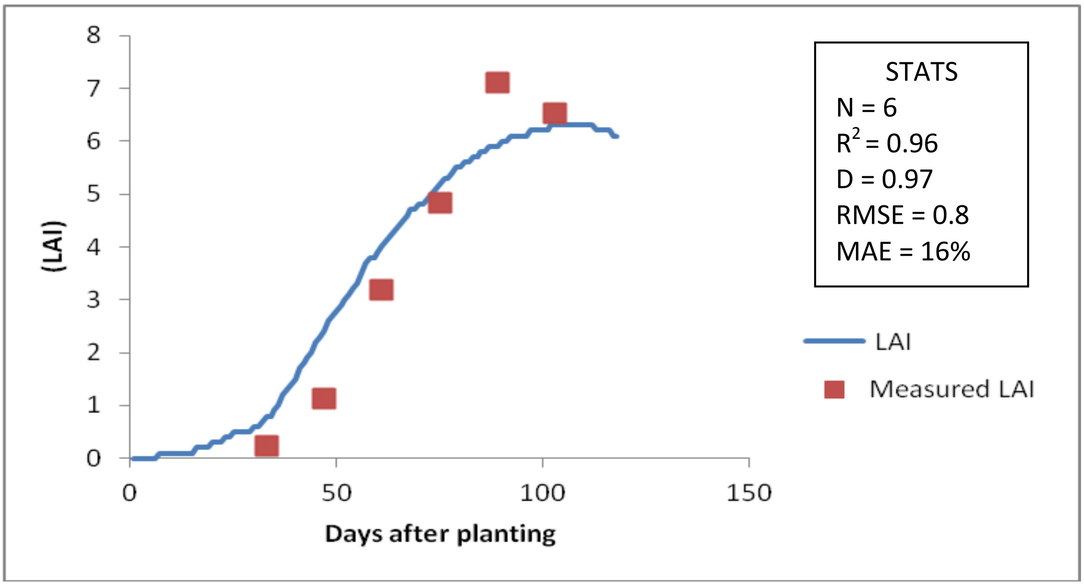


Figure 5.4: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar LS 6164 at Pretoria (calibration data set)

Table 5.5: SWB model crop parameters for soybean cultivar LS 6150 (indeterminate and late maturing cultivar**)**

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.50
Dry matter to water ratio, DWR (Pa)	6
Radiation Use efficiency (kg MJ^{-1})	0.00150
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	45
Flowering day degrees (d °C)	650
Maturity day degrees (d °C)	1200
Transition period (d °C)	550
Leaf senescence (d °C)	1050
Maximum crop height H_{max} (m)	0.87
Maximum root depth RD_{max} (m)	0.7
Stem to grain translocation	0.220
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	18
Leaf stem partition (m^2 kg^{-1})	1.500
Total Dry Matter at emergence (kg m^{-2})	0.0030
Root fraction	0.011
Root growth rate	6
Stress index	0.95



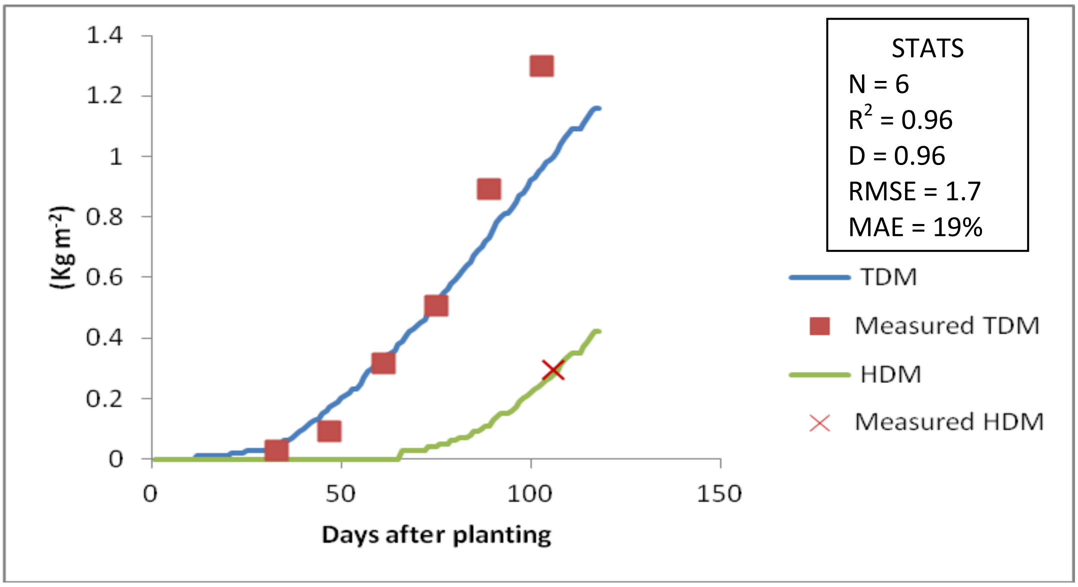
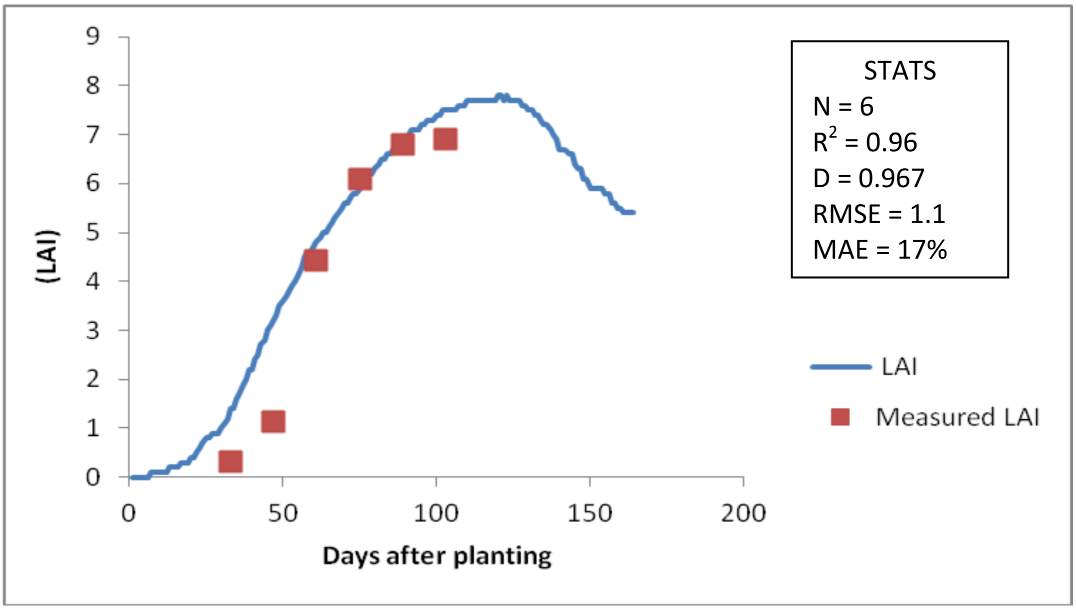


Figure 5.5: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar LS 6150 at Pretoria (calibration data set)

Table 5.6: SWB model crop parameters for soybean cultivar PAN 737 (determinate and late maturing)

Crop parameters	**Value**
Canopy radiation extinction coefficient for solar radiation	0.70
Dry matter to water ratio, DWR (Pa)	4
Radiation Use efficiency (kg MJ^{-1})	0.00130
Base temperature (°C)	12
Optimum temperature (°C)	25
Cut off temperature (°C)	32
Emergence day degrees (d °C)	62
Flowering day degrees (d °C)	890
Maturity day degrees (d °C)	1550
Transition period (d °C)	660
Leaf senescence (d °C)	1150
Maximum crop height H_{max} (m)	0.77
Maximum root depth RD_{max} (m)	0.7
Stem to grain translocation	0.230
Canopy storage (mm)	1.0
Minimum leaf water potential (kPa)	-1500
Maximum transpiration (mm d^{-1})	9
Specific leaf area (m^2 kg^{-1})	22
Leaf stem partition (m^2 kg^{-1})	1.700
Total Dry Matter at emergence (kg m^{-2})	0.0030
Root fraction	0.011
Root growth rate	5.5
Stress index	0.95



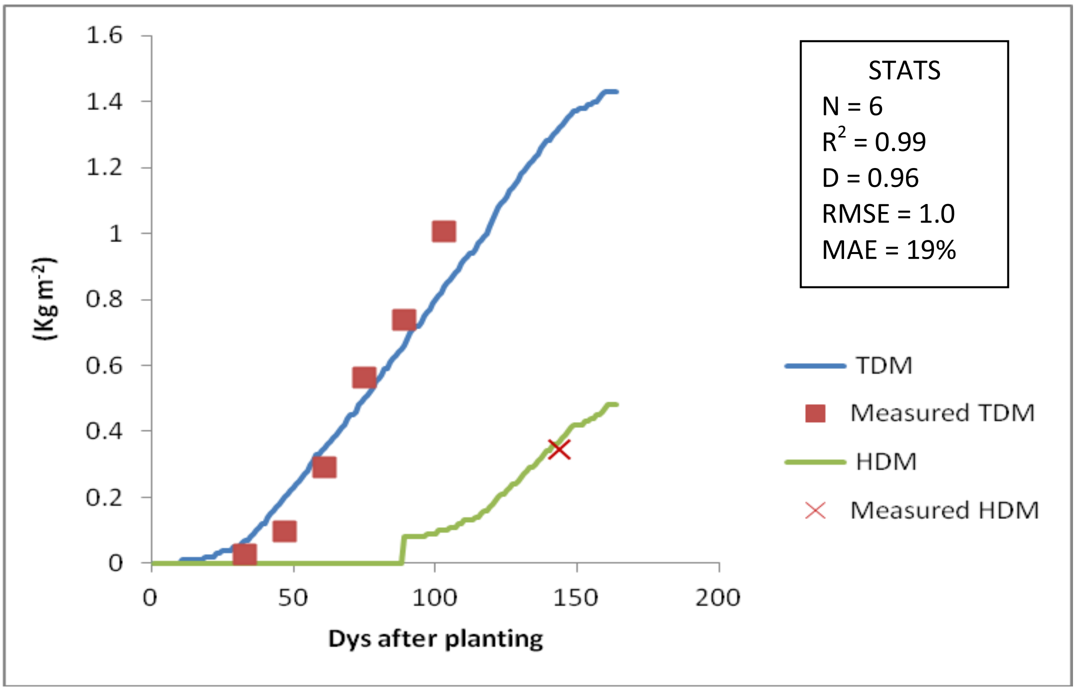


Figure 5.6: Measured and simulated leaf area index, aboveground dry matter and harvestable dry matter production for cultivar PAN 737 at Pretoria (calibration data set).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The results of this study have shown that soybean can be successfully grown in varying agro-ecological zones. The time of planting, cultivar growth habit and maturity group are important considerations in the selection of cultivars for each locality. Cultivars that are late maturing should be planted early and in agro-ecological zones that have a long growing season. This will enable the cultivar to fully express its potential, as compared to when it is planted late and the growing season is restricted. Cultivar PAN 737 showed its full potential at Pretoria, because planting was earlier than at the other sites and rainfall was better distributed, resulting in better average yields as compared to the other sites (Malkerns and Nhlangano). Daylength did not have an effect on the soybean cultivars planted at Pretoria as all the cultivars reached their full plant development. If the daylength was not adequate, late maturing cultivars (e.g. PAN 737) would have resorted to reproductive stage before developing a full canopy. Cultivar LS 6150 gave the highest soybean seed yields when compared with the other cultivars at all the sites. This cultivar is indeterminate and falls within the medium to late maturity group. This is proof that indeterminate and late maturing cultivars under good management and suitable growing conditions result in higher yields. This concurs with the findings of Miladinovic *et al.*, (2006), who stated that longer growing seasons result in higher potential crop production. Early maturing cultivars have shown that they are stable, as they performed similarly at all the locations. These cultivars suit locations with either long or and short growing seasons. It is therefore recommended that areas with a short growing season should be planted to early maturing cultivars, while areas with a long available growing season could be planted to late maturing cultivars. In the absence of late maturing cultivars in areas with a long growing season, early maturing cultivars can be planted, but late maturing cultivars should not be planted in areas with a short growing season. These experiments have proved that localities with short growing season should be planted to determinate and early maturing soybean cultivars, as they have the ability to grow fast and complete its growth and development cycle within a short period, while indeterminate and late maturing cultivars should be planted to localities with long growing season. These cultivars take long to complete their growth and development cycle, hence accumulate a lot of assimilates which give better seed yield than the determinate and early maturing cultivars. This is why the late maturing cultivars generally gave higher seed yields than the early maturing cultivars. The experiment planted in Pretoria gave higher seed yields than the other localities. This was due to the fact that planting of the experiment was done six weeks earlier at Pretoria than the other sites. This gave sufficient growth and development before flowering, resulting to higher assimilate production and hence higher yields.

Crop growth parameters were successfully determined for the six studied soybean cultivars, using growth analysis data that was collected at Pretoria. Thereafter, the Soil Water Balance model was calibrated for these cultivars with the aim of using the calibrated model to predict growth, development and yields of soybean in varying agro-ecological zones. The calibrated model should now be useful to forecast growth and yield responses of different soybean cultivars at other locations.

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Appendix A: Soil analysis results in soybean grown in field experiments at Pretoria, Malkerns and Nhlangano

Area	**pH water**	**P Bray 1 mg kg^{-1}**	**Ca mg kg^{-1}**	**K mg kg^{-1}**	**Mg mg kg^{-1}**	**Na mg kg^{-1}**
Pretoria	6.1	32.4	801	74	225	170
Malkerns	5.0	27.1	324	28	79	83
Nhlangano	5.8	27.7	422	69	155	71

Appendix B: Statistical procedure for Pretoria

LEAF DRY MATTER YIELD DATA FOR PRETORIA;

```
Input Rep   Cultivar    Cultivar Name     Dry Leaves 33 DAP Dry Leaves 47 DAP
      Dry Leaves 61 DAP Dry Leaves 75 DAP Dry Leaves 89     Dry Leaves 103;

cards;

1     1     LS6150      1.13  3.77  10.87 18.08 29.39 17.79

2     1     LS6150      1.19  4.57  12.81 16.88 27.79 19.21

3     1     LS6150      1.32  3.88  8.9   14.88 14.79 30.39

1     2     LS6162      1.42  3.84  12.88 10.69 11.3  11.39

2     2     LS6162      0.84  4.63  9.24  10.14 6.42  4.35

3     2     LS6162      1.02  2.35  5.48  8.61  6.37  6.05

1     3     LS6164      1.04  3.91  17.09 19.63 11.3  16.07

2     3     LS6164      0.94  4.27  15.37 6.36  21.59 21.16

3     3     LS6164      0.52  3.38  9.28  13.24 9.87  27.46

1     4     PAN1664     1.23  5.08  17.09 18.73 12.84 21.23

2     4     PAN1664     1.3   8     15.37 20.22 12.68 21.45

3     4     PAN1664     1.68  5.37  9.28  22.48 19.38 18

1     5     PAN535      1.62  3.6   7.58  12.78 18.15 20.19

2     5     PAN535      1.09  3.82  11.26 20.54 6.86  18.2

3     5     PAN535      1.66  5.15  11.76 16.92 12.62 19.43

1     6     PAN737      1.3   4.54  10.14 18.4  17.7  14.68

2     6     PAN737      1.4   3.7   8.53  15.38 13.58 24.34

3     6     PAN737      2.02  3.79  8.86  19.75 18.8  18.16
```

Analysis of variance leaf dry matter yield for Pretoria

```
Dependent Variable: Dry Leaves 33 DAP

                                                     Sum of
      Source                      DF         Squares      Mean Square    F Value    Pr > F

      Model                        7      1.29268889       0.18466984       2.35    0.1071

      Error                       10      0.78682222       0.07868222

      Corrected Total             17      2.07951111


                    R-Square     Coeff Var      Root MSE    Dry Leaves 33 DAP Mean

                    0.621631      22.22299      0.280504              1.262222


      Source                      DF       Type I SS      Mean Square    F Value    Pr > F

      Rep                          2      0.18457778       0.09228889       1.17    0.3487
      Cultivar                     5      1.10811111       0.22162222       2.82    0.0768
```

```
Dependent Variable: Dry Leaves 47 DAP

                                                     Sum of
      Source                      DF         Squares      Mean Square    F Value    Pr > F

      Model                        7     15.21630556       2.17375794       2.72    0.0739

      Error                       10      7.99672222       0.79967222

      Corrected Total             17     23.21302778


                    R-Square     Coeff Var      Root MSE    Dry Leaves 47 DAP Mean

                    0.655507      20.72942      0.894244              4.313889


      Source                      DF       Type I SS      Mean Square    F Value    Pr > F

      Rep                          2      2.46887778       1.23443889       1.54    0.2605
      Cultivar                     5     12.74742778       2.54948556       3.19    0.0560
```

```
Dependent Variable: Dry Leaves 61 DAP

                                                              Sum of
     Source                      DF          Squares     Mean Square    F Value    Pr > F

     Model                        7      119.5302389      17.0757484       2.57    0.0858

     Error                       10       66.5256556       6.6525656

     Corrected Total             17      186.0558944

                   R-Square     Coeff Var      Root MSE    Dry Leaves 61 DAP Mean

                   0.642443      23.00739      2.579257           11.21056

     Source                      DF        Type I SS     Mean Square    F Value    Pr > F

     Rep                          2      47.73074444     23.86537222       3.59    0.0669
     Cultivar                     5      71.79949444     14.35989889       2.16    0.1407


Dependent Variable: Dry Leaves 75 DAP

                                                              Sum of
     Source                      DF          Squares     Mean Square    F Value    Pr > F

     Model                        7      219.4237500      31.3462500       2.30    0.1120

     Error                       10      136.0659000      13.6065900

     Corrected Total             17      355.4896500

                   R-Square     Coeff Var      Root MSE    Dry Leaves 75 DAP Mean

                   0.617244      23.40305      3.688711           15.76167

     Source                      DF        Type I SS     Mean Square    F Value    Pr > F

     Rep                          2        6.8677000       3.4338500       0.25    0.7818
     Cultivar                     5      212.5560500      42.5112100       3.12    0.0590

Dependent Variable: Dry Leaves 89 DAP

                                              Sum of
     Source                      DF          Squares     Mean Square    F Value    Pr > F

     Model                        7      446.6890389      63.8127198       2.10    0.1388

     Error                       10      303.9412556      30.3941256

     Corrected Total             17      750.6302944

                   R-Square     Coeff Var      Root MSE    Dry Leaves 89 DAP Mean

                   0.595085      36.56028      5.513087           15.07944

     Source                      DF        Type I SS     Mean Square    F Value    Pr > F

     Rep                          2       30.2160111      15.1080056       0.50    0.6226
     Cultivar                     5      416.4730278      83.2946056       2.74    0.0821
```

```
Dependent Variable: Dry Leaves 103 DAP

                                                  Sum of
 Source                      DF          Squares   Mean Square    F Value    Pr > F

Model                         7      492.8284500    70.4040643       3.25    0.0453

Error                        10      216.9598000    21.6959800

Corrected Total              17      709.7882500

               R-Square     Coeff Var      Root MSE    Dry Leaves 103 DAP Mean

               0.694332      25.44139      4.657894             18.30833

Source                       DF        Type I SS    Mean Square    F Value    Pr > F

Rep                           2       27.7465333     13.8732667       0.64    0.5479
Cultivar                      5      465.0819167     93.0163833       4.29    0.0241
```

Least significant differences for leaf dry matter yield for Pretoria

```
Tests (LSD) for Dry Leaves 33 DAP

  NOTE: This test controls the Type I comparison wise error rate, not
  the experiment wise error


                              Alpha                            0.05
                              Error Degrees of Freedom           10
                              Error Mean Square            0.078682
                              Critical Value of t           2.22814
                              Least Significant Difference   0.5103


                  Means with the same letter are not significantly
                  different.


                              Grouping       Mean       N    Cultivar

                                A          1.5733       3    6

                                A          1.4567       3    5

                                A          1.4033       3    4

                             B  A          1.2133       3    1

                             B  A          1.0933       3    2

                             B             0.8333       3    3
```

```
Tests (LSD) for Dry Leaves 47 DAP

NOTE: This test controls the Type I comparison wise error rate, not the
experiment wise error


                          Alpha                               0.05
                          Error Degrees of Freedom              10
                          Error Mean Square               0.799672
                          Critical Value of t              2.22814
                          Least Significant Difference      1.6269


                 Means with the same letter are not significantly
                 different.


                     Grouping             Mean      N    Cultivar

                            A           6.1500      3    4

                            B           4.1900      3    5

                            B           4.0733      3    1

                            B           4.0100      3    6

                            B           3.8533      3    3

                            B           3.6067      3    2
```

```
Tests (LSD) for Dry Leaves 61 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                               Alpha                              0.05
                               Error Degrees of Freedom             10
                               Error Mean Square              6.652566
                               Critical Value of t             2.22814
                               Least Significant Difference     4.6924


                      Means with the same letter are not significantly
                      different.


                            Grouping          Mean        N    Cultivar

                                   A        13.913        3    3

                                   A        13.913        3    4

                              B    A        10.860        3    1

                              B    A        10.200        3    5

                              B              9.200        3    2

                              B              9.177        3    6
```

```
Tests (LSD) for Dry Leaves 75 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                             Alpha                            0.05
                             Error Degrees of Freedom           10
                             Error Mean Square            13.60659
                             Critical Value of t           2.22814
                             Least Significant Difference   6.7108


                  Means with the same letter are not significantly
                  different.


                         Grouping          Mean       N    Cultivar

                                 A        20.477      3    4

                            B    A        17.843      3    6

                            B    A        16.747      3    5

                            B    A        16.613      3    1

                            B    C        13.077      3    3

                                 C         9.813      3    2
```

```
Tests (LSD) for Dry Leaves 89 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                              0.05
                            Error Degrees of Freedom             10
                            Error Mean Square              30.39413
                            Critical Value of t             2.22814
                            Least Significant Difference      10.03


                    Means with the same letter are not significantly
                    different.


                         Grouping          Mean       N    Cultivar

                                A        23.990       3    1

                           B    A        16.693       3    6

                           B    A        14.967       3    4

                           B    A        14.253       3    3

                           B             12.543       3    5

                           B              8.030       3    2
```

```
Tests (LSD) for Dry Leaves 103 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                             0.05
                              Error Degrees of Freedom            10
                              Error Mean Square             21.69598
                              Critical Value of t            2.22814
                              Least Significant Difference     8.474


                   Means with the same letter are not significantly
                   different.


                       Grouping             Mean      N    Cultivar

                              A           22.463      3    1

                              A           21.563      3    3

                              A           20.227      3    4

                              A           19.273      3    5

                              A           19.060      3    6

                              B            7.263      3    2
```

```
STEM DRY MATTER YIELD DATA FOR PRETORIA;

input CULTIVAR Name     Cultivar    REP   Dry Stems 33 DAP  Dry Stems 47 DAP
      Dry Stems 61 DAP  Dry Stems 75DAP   Dry Stems 89 DAP  Dry Stems 103DAP;

cards;

LS6162_1    1     1     1.03  3.19  16.09 12.30 14.76 17.34

LS6162_1    1     2     0.58  3.04  11.69 11.44 10.49 10.31

LS6162_1    1     3     0.59  1.92  6.29  9.41  8.71  10.97

PAN535_2    2     1     0.37  2.45  9.51  15.25 24.66 35.03

PAN535_2    2     2     0.74  2.76  15.19 28.08 13.13 33.37

PAN535_2    2     3     0.49  3.70  14.62 23.38 21.61 28.34

PAN1664_3   3     1     0.52  3.54  22.40 23.92 25.88 37.28

PAN1664_3   3     2     0.30  6.18  19.07 26.07 21.65 34.85

PAN1664_3   3     3     0.62  3.22  11.31 30.31 33.95 32.23

LS6164_4    4     1     0.45  2.50  13.43 24.41 18.48 30.68

LS6164_4    4     2     0.58  3.28  7.06  7.16  32.12 34.68

LS6164_4    4     3     0.30  1.92  4.80  15.87 14.16 47.01

LS6150_5    5     1     0.38  1.97  12.83 23.32 50.97 35.64

LS6150_5    5     2     0.61  3.26  17.19 22.45 45.56 32.64

LS6150_5    5     3     0.56  2.60  10.94 18.21 21.94 48.85

PAN737_6    6     1     0.50  3.56  14.28 26.91 33.03 24.29

PAN737_6    6     2     0.46  2.86  11.68 19.49 24.98 40.75

PAN737_6    6     3     0.43  3.42  12.33 26.66 32.89 34.48
```

Analysis of variance for stem dry matter yield for Pretoria

```
Dependent Variable: Dry Stems 33 DAP

                                          Sum of
Source                      DF           Squares     Mean Square    F Value    Pr > F

Model                        7        0.17605000      0.02515000       0.79    0.6142

Error                       10        0.31980000      0.03198000

Corrected Total             17        0.49585000

               R-Square     Coeff Var      Root MSE    Dry Stems 33 DAP Mean

               0.355047      33.84786      0.178830             0.528333

Source                      DF         Type I SS     Mean Square    F Value    Pr > F

Cultivar                     5        0.16791667      0.03358333       1.05    0.4409
REP                          2        0.00813333      0.00406667       0.13    0.8820
```

```
Dependent Variable: Dry Stems 47 DAP

                                          Sum of
Source                      DF           Squares     Mean Square    F Value    Pr > F

Model                        7        8.72050556      1.24578651       1.79    0.1955

Error                       10        6.97472222      0.69747222

Corrected Total             17       15.69522778

               R-Square     Coeff Var      Root MSE    Dry Stems 47 DAP Mean

               0.555615      27.14948      0.835148             3.076111

Source                      DF         Type I SS     Mean Square    F Value    Pr > F

Cultivar                     5        6.56862778      1.31372556       1.88    0.1844
REP                          2        2.15187778      1.07593889       1.54    0.2607
```

```
Dependent Variable: Dry Stems 61DAP

                                                        Sum of
 Source                      DF           Squares     Mean Square    F Value    Pr > F

Model                        7       207.6308389      29.6615484       2.39    0.1024

Error                       10       124.0845222      12.4084522

Corrected Total             17       331.7153611

               R-Square     Coeff Var      Root MSE    Dry Stems 61 DAP Mean

               0.625931      27.48305      3.522563             12.81722

Source                      DF         Type I SS     Mean Square    F Value    Pr > F

Cultivar                     5       134.9338278      26.9867656       2.17    0.1385
REP                          2        72.6970111      36.3485056       2.93    0.0997
```

```
Dependent Variable: Dry Stems 75 DAP

                                                      Sum of
      Source                      DF         Squares   Mean Square    F Value    Pr > F

     Model                         7     518.3848556    74.0549794       2.49    0.0922

     Error                        10     296.8748556    29.6874856

     Corrected Total              17     815.2597111

                    R-Square     Coeff Var      Root MSE    Dry Stems 75DAP Mean

                    0.635852      26.89645      5.448622           20.25778

     Source                       DF       Type I SS    Mean Square    F Value    Pr > F

     Cultivar                      5     506.2019778    101.2403956       3.41    0.0467
     REP                           2      12.1828778      6.0914389       0.21    0.8178
```

```
Dependent Variable: Dry Stems 89 DAP

                                                      Sum of
      Source                      DF         Squares   Mean Square    F Value    Pr > F

     Model                         7     1505.635772    215.090825       2.82    0.0672

     Error                        10      763.632989     76.363299

     Corrected Total              17     2269.268761

                    R-Square     Coeff Var      Root MSE    Dry Stems 89 DAP Mean

                    0.663489      35.03463      8.738610           24.94278

     Source                       DF       Type I SS    Mean Square    F Value    Pr > F

     Cultivar                      5     1405.587894     281.117579       3.68    0.0377
     REP                           2      100.047878      50.023939       0.66    0.5403
```

```
Dependent Variable: Dry Stems 103 DAP

                                                      Sum of
      Source                      DF         Squares   Mean Square    F Value    Pr > F

     Model                         7     1401.492533    200.213219       4.37    0.0180

     Error                        10      457.682667     45.768267

     Corrected Total              17     1859.175200

                    R-Square     Coeff Var      Root MSE    Dry Stems 103 DAP Mean

                    0.753825      21.41120      6.765225           31.59667

     Source                       DF       Type I SS    Mean Square    F Value    Pr > F

     Cultivar                      5     1360.320400     272.064080       5.94    0.0083
     REP                           2       41.172133      20.586067       0.45    0.6501
```

```
Tests (LSD) for Dry Stems 33 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                              0.05
                            Error Degrees of Freedom             10
                            Error Mean Square               0.03198
                            Critical Value of t             2.22814
                            Least Significant Difference     0.3253


                  Means with the same letter are not significantly
                  different.


                     Grouping          Mean        N    Cultivar

                            A        0.7333        3    1

                            A        0.5333        3    2

                            A        0.5167        3    5

                            A        0.4800        3    3

                            A        0.4633        3    6

                            A        0.4433        3    4
```

```
Tests (LSD) for Dry Stems 47DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                           Alpha                             0.05
                           Error Degrees of Freedom            10
                           Error Mean Square             0.697472
                           Critical Value of t            2.22814
                           Least Significant Difference    1.5194


                 Means with the same letter are not significantly
                 different.


                      Grouping          Mean        N    Cultivar

                              A       4.3133        3    3

                         B    A       3.2800        3    6

                         B    A       2.9700        3    2

                         B            2.7167        3    1

                         B            2.6100        3    5

                         B            2.5667        3    4
```

```
Tests (LSD) for Dry Stems 61DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                             Alpha                            0.05
                             Error Degrees of Freedom           10
                             Error Mean Square            12.40845
                             Critical Value of t           2.22814
                             Least Significant Difference   6.4085


                  Means with the same letter are not significantly
                  different.


                         Grouping          Mean      N    Cultivar

                                 A       17.593      3    3

                            B    A       13.653      3    5

                            B    A       13.107      3    2

                            B    A       12.763      3    6

                            B    A       11.357      3    1

                            B             8.430      3    4
```

```
Tests (LSD) for Dry Stems 75 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                            0.05
                            Error Degrees of Freedom           10
                            Error Mean Square            29.68749
                            Critical Value of t           2.22814
                            Least Significant Difference   9.9125


                 Means with the same letter are not significantly
                 different.


                        Grouping          Mean       N    Cultivar

                                A       26.767       3    3

                           B    A       24.353       3    6

                           B    A       22.237       3    2

                           B    A       21.327       3    5

                           B    C       15.813       3    4

                                C       11.050       3    1
```

```
Tests (LSD) for Dry Stems 89 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                          Alpha                              0.05
                          Error Degrees of Freedom             10
                          Error Mean Square               76.3633
                          Critical Value of t             2.22814
                          Least Significant Difference     15.898


                 Means with the same letter are not significantly
                 different.


                     Grouping             Mean        N    Cultivar

                          A             39.490        3     5

                     B    A             30.300        3     6

                     B    A    C        27.160        3     3

                     B         C        21.587        3     4

                     B         C        19.800        3     2

                               C        11.320        3     1
```

```
Tests (LSD) for Dry Stems 103 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                             0.05
                              Error Degrees of Freedom            10
                              Error Mean Square             45.76827
                              Critical Value of t            2.22814
                              Least Significant Difference    12.308


                      Means with the same letter are not significantly
                      different.


                         Grouping          Mean      N    Cultivar

                                A        39.043      3    5

                                A        37.457      3    4

                                A        34.787      3    3

                                A        33.173      3    6

                                A        32.247      3    2

                                B        12.873      3    1
```

```
POD DRY MATTER YIELD DATA FOR PRETORIA;

Input CULTIVAR Name     Cultivar     REP    Dry Pod 89 DAP     Dry Pod 103 DAP;

cards;

LS6162_1     1     1     3.21   7.18   33.07  52.7
LS6162_1     1     2     2.67   7.86   26.59  35.53
LS6162_1     1     3     1.01   7.21   20.31  29.82
PAN535_2     2     1     .      .      12.01  35.52
PAN535_2     2     2     .      .      6.66   33.27
PAN535_2     2     3     .      .      12.03  39.35
PAN1664_3    3     1     .      .      12.13  41.44
PAN1664_3    3     2     .      .      13.15  39.13
PAN1664_3    3     3     .      .      18.47  33.15
LS6164_4     4     1     .      .      8.5    25.39
LS6164_4     4     2     .      .      14.04  29.62
LS6164_4     4     3     .      .      6.6    37.31
LS6150_5     5     1     .      .      21.44  36.49
LS6150_5     5     2     .      .      13.64  27.2
LS6150_5     5     3     .      .      9.54   53.99
PAN737_6     6     1     .      .      9.39   17.86
PAN737_6     6     2     .      .      5.31   26.96
PAN737_6     6     3     .      .      9.92   25.1
```

Analysis of pod dry matter yield for Pretoria

```
Dependent Variable: Dry Pod 89DAP

                                                    Sum of
   Source                  DF          Squares     Mean Square    F Value     Pr > F

  Model                     7      720.4129222     102.9161317       5.11     0.0106

  Error                    10      201.2585222      20.1258522

  Corrected Total          17      921.6714444


                 R-Square     Coeff Var      Root MSE     Dry Pod 89 DAP Mean

                 0.781637      31.94277      4.486185          14.04444


  Source                   DF       Type I SS     Mean Square    F Value    Pr > F

  Cultivar                  5     682.2250444     136.4450089       6.78    0.0053
  REP                       2      38.1878778      19.0939389       0.95    0.4195
```

```
Dependent Variable: Dry Pod 103 DAP

                                                    Sum of
   Source                  DF          Squares     Mean Square    F Value     Pr > F

  Model                     7       659.785550       94.255079       1.23     0.3698

  Error                    10       765.754500       76.575450

  Corrected Total          17      1425.540050


                 R-Square     Coeff Var      Root MSE     Dry Pod 103 DAP Mean

                 0.462832      25.41234      8.750740          34.43500


  Source                   DF       Type I SS     Mean Square    F Value    Pr > F

  Cultivar                  5     597.0445167     119.4089033       1.56    0.2568
  REP                       2      62.7410333      31.3705167       0.41    0.6745
```

```
Tests (LSD) for Dry Pod 89 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                           Alpha                             0.05
                           Error Degrees of Freedom            10
                           Error Mean Square             20.12585
                           Critical Value of t            2.22814
                           Least Significant Difference    8.1616


                  Means with the same letter are not significantly
                  different.


                      Grouping          Mean       N    Cultivar

                             A        26.657       3    1

                             B        14.873       3    5

                             B        14.583       3    3

                             B        10.233       3    2

                             B         9.713       3    4

                             B         8.207       3    6
```

```
Tests (LSD) for Dry Pod 103

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                           Alpha                             0.05
                           Error Degrees of Freedom            10
                           Error Mean Square             76.57545
                           Critical Value of t            2.22814
                           Least Significant Difference     15.92


                   Means with the same letter are not significantly
                   different.


                        Grouping          Mean       N    Cultivar

                                A       39.350       3    1

                                A       39.227       3    5

                           B    A       37.907       3    3

                           B    A       36.047       3    2

                           B    A       30.773       3    4

                           B            23.307       3    6
```

Yield Parameters for Pretoria

Obs	cultivars	Rep	plants_ Harvest	Seed_ Yied	Moist	Sd_Mas_ 100	Plant_ Height	Pod_ Height	No_Nodes	No_pods
1	LS6162_1	1	118	3.02594	8.7	15.4	56	10	11	55.333
2	LS6162_1	2	120	2.36541	8.8	15.4	65	17	11	37.333
3	LS6162_1	3	129	2.30134	8.7	15.3	69	10	9	36.000
4	PAN535_5	1	116	2.55920	8.6	15.0	60	14	12	82.667
5	PAN535_5	2	121	2.89841	8.7	15.3	75	16	14	111.000
6	PAN535_5	3	126	3.15983	8.6	15.1	62	15	13	86.333
7	PAN1664_	1	93	3.71459	8.8	13.4	62	20	14	38.333
8	PAN1664_	2	87	3.02842	8.8	13.6	70	18	12	61.667
9	PAN1664_	3	110	3.55435	8.9	13.2	69	18	14	83.667
10	LS6164_1	1	103	2.47898	9.2	13.6	81	20	16	74.667
11	LS6164_1	2	73	2.01356	9.0	13.4	87	23	17	76.000
12	LS6164_1	3	118	1.55829	9.1	13.6	66	15	16	95.000
13	LS6150_1	1	75	4.15381	8.5	13.4	88	16	16	93.333
14	LS6150_1	2	108	2.55329	8.5	13.4	86	20	19	133.667
15	LS6150_1	3	76	2.17804	8.4	13.5	77	16	16	61.000
16	PAN737_2	1	95	3.82557	8.5	17.4	84	25	13	64.667
17	PAN737_2	2	101	3.03710	8.8	17.3	70	20	14	63.000
18	PAN737_2	3	104	3.44331	8.7	17.4	76	22	14	75.667

ANALYSIS OF VARIENCE FOR YIELD PARAMETERS FOR PRETORIA

```
Dependent Variable: plants_Harv


                                            Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        7     3511.055556      501.579365       2.76    0.0711

      Error                       10     1817.888889      181.788889

      Corrected Total             17     5328.944444


                    R-Square     Coeff Var      Root MSE    plants_Harv Mean

                    0.658865      12.95742      13.48291            104.0556


      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      cultivars                    5     3128.944444      625.788889       3.44    0.0455
      Rep                          2      382.111111      191.055556       1.05    0.3852
```

```
Dependent Variable: Seed_Yied

                                        Sum of
       Source                DF        Squares    Mean Square    F Value    Pr > F

       Model                  7     5.93351225     0.84764461       3.93    0.0255

       Error                 10     2.15895409     0.21589541

       Corrected Total       17     8.09246633


                    R-Square     Coeff Var      Root MSE    Seed_Yied Mean

                    0.733214      16.13058      0.464645          2.880525


       Source                DF      Type I SS    Mean Square    F Value    Pr > F

       Cultivars              5     4.39471888     0.87894378       4.07    0.0282
       Rep                    2     1.53879336     0.76939668       3.56    0.0678
```

```
Dependent Variable: Moist

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        7      0.69722222      0.09960317      11.64    0.0004

      Error                       10      0.08555556      0.00855556

      Corrected Total             17      0.78277778


                     R-Square     Coeff Var      Root MSE    Moist Mean

                     0.890703      1.058444      0.092496      8.738889


      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      cultivars                    5      0.68944444      0.13788889      16.12    0.0002
      Rep                          2      0.00777778      0.00388889       0.45    0.6472
```

```
Dependent Variable: Sd_Mas_100

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        7     37.20388889      5.31484127     321.03    <.0001

      Error                       10      0.16555556      0.01655556

      Corrected Total             17     37.36944444


                    R-Square     Coeff Var      Root MSE    Sd_Mas_100 Mean

                    0.995570      0.874965      0.128668           14.70556


      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      cultivars                    5     37.19611111      7.43922222     449.35    <.0001
      Rep                          2      0.00777778      0.00388889       0.23    0.7949
```

```
Dependent Variable: Plant_Height

                                             Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        7     1098.722222      156.960317       2.80    0.0686

       Error                       10      561.555556       56.155556

       Corrected Total             17     1660.277778


                    R-Square     Coeff Var      Root MSE    Plant_Height Mean

                    0.661770      10.35200      7.493701             72.38889


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5     999.6111111     199.9222222       3.56    0.0415
       Rep                          2      99.1111111      49.5555556       0.88    0.4437
```

```
Dependent Variable: Pod_Height


                                            Sum of
       Source                      DF          Squares     Mean Square    F Value    Pr > F


       Model                        7      210.1666667      30.0238095       4.53    0.0161


       Error                       10       66.3333333       6.6333333


       Corrected Total             17      276.5000000



                     R-Square     Coeff Var      Root MSE    Pod_Height Mean


                     0.760096      14.71729      2.575526           17.50000



       Source                      DF        Type I SS     Mean Square    F Value    Pr > F


       Cultivars                    5      183.1666667      36.6333333       5.52    0.0107

       Rep                          2       27.0000000      13.5000000       2.04    0.1813
```

```
Dependent Variable: No_Nodes

                                               Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        7      91.0555556      13.0079365      10.94    0.0006

       Error                       10      11.8888889       1.1888889

       Corrected Total             17     102.9444444


                      R-Square     Coeff Var      Root MSE    No_Nodes Mean

                      0.884512      7.819328      1.090362         13.94444


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5     88.27777778     17.65555556      14.85    0.0002
       Rep                          2      2.77777778      1.38888889       1.17    0.3500
```

```
Dependent Variable: No_pods

                                        Sum of
       Source                      DF          Squares     Mean Square    F Value    Pr > F

       Model                        7       6728.95062       961.27866       2.25    0.1190

       Error                       10       4280.65432       428.06543

       Corrected Total             17      11009.60494


                       R-Square     Coeff Var      Root MSE    No_pods Mean

                       0.611189      28.01520      20.68974        73.85185


       Source                      DF        Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5      6269.308644     1253.861729       2.93    0.0697
       Rep                          2       459.641976      229.820988       0.54    0.6005
```

Least significant difference for yield parameters for Pretoria

```
Tests (LSD) for plants_Harv

  NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error



                             Alpha                             0.05

                             Error Degrees of Freedom            10

                             Error Mean Square             181.7889

                             Critical Value of t            2.22814

                             Least Significant Difference    24.529



                Means with the same letter are not significantly different.



                          Grouping           Mean       N    cultivars


                              A            122.33       3     LS6162_1


                         B    A            121.00       3     PAN535_5


                         B    A    C       100.00       3     PAN737_2


                         B    A    C        98.00       3     LS6164_1


                         B         C        96.67       3     PAN1664_


                                   C        86.33       3     LS6150_1
```

```
Tests (LSD) for Seed_Yied


 NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error   rate.



                              Alpha                           0.05

                              Error Degrees of Freedom          10

                              Error Mean Square           0.215895

                              Critical Value of t          2.22814

                              Least Significant Difference   0.8453



                    Means with the same letter are not significantly different.



                         t Grouping          Mean      N    cultivars


                                  A        3.4353      3    PAN737_2


                                  A        3.4325      3    PAN1664_


                             B    A        2.9617      3    LS6150_1


                             B    A        2.8725      3    PAN535_5


                             B    C        2.5642      3    LS6162_1


                                  C        2.0169      3    LS6164_1
```

```
Tests (LSD) for Moist


  NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error



                              Alpha                              0.05

                              Error Degrees of Freedom             10

                              Error Mean Square              0.008556

                              Critical Value of t             2.22814

                              Least Significant Difference     0.1683



                    Means with the same letter are not significantly different.



                          Grouping          Mean      N    cultivars


                                 A       9.10000      3    LS6164_1


                                 B       8.83333      3    PAN1664_


                            C    B       8.73333      3    LS6162_1


                            C    B       8.66667      3    PAN737_2


                            C    D       8.63333      3    PAN535_5


                                 D       8.46667      3    LS6150_1
```

```
Tests (LSD) for Sd_Mas_100


  NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error



                              Alpha                              0.05

                              Error Degrees of Freedom             10

                              Error Mean Square              0.016556

                              Critical Value of t             2.22814

                              Least Significant Difference   0.2341



                   Means with the same letter are not significantly different.



                       Grouping          Mean      N    cultivars


                               A       17.3667      3    PAN737_2


                               B       15.3667      3    LS6162_1


                               B       15.1333      3    PAN535_5


                               C       13.5333      3    LS6164_1


                               C       13.4333      3    LS6150_1


                               C       13.4000      3    PAN1664_
```

```
Tests (LSD) for Plant_Height


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                            0.05

                              Error Degrees of Freedom           10

                              Error Mean Square            56.15556

                              Critical Value of t           2.22814

                              Least Significant Difference   13.633



                   Means with the same letter are not significantly different.



                           Grouping          Mean      N    cultivars


                               A           83.667      3     LS6150_1


                          B    A           78.000      3     LS6164_1


                          B    A    C      76.667      3     PAN737_2


                          B         C      67.000      3     PAN1664_


                          B         C      65.667      3     PAN535_5


                                    C      63.333      3     LS6162_1
```

```
Tests (LSD) for Pod_Height


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                             0.05

                              Error Degrees of Freedom            10

                              Error Mean Square             6.633333

                              Critical Value of t            2.22814

                              Least Significant Difference    4.6856



                    Means with the same letter are not significantly different.


                          Grouping          Mean      N    cultivars


                                  A       22.333      3     PAN737_2


                             B    A       19.333      3     LS6164_1


                             B    A       18.667      3     PAN1664_


                             B            17.333      3     LS6150_1


                             B    C       15.000      3     PAN535_5


                                  C       12.333      3     LS6162_1
```

```
Tests (LSD) for No_Nodes


NOTE: This test controls the Type I comparison wise error rate, not the experiment twise error rate.


                              Alpha                              0.05

                              Error Degrees of Freedom             10

                              Error Mean Square              1.188889

                              Critical Value of t             2.22814

                              Least Significant Difference     1.9837


                   Means with the same letter are not significantly different.


                       Grouping          Mean      N    cultivars

                               A       17.0000      3    LS6150_1

                               A       16.3333      3    LS6164_1

                               B       13.6667      3    PAN737_2

                               B       13.3333      3    PAN1664_

                               B       13.0000      3    PAN535_5

                               C       10.3333      3    LS6162_1
```

```
Tests (LSD) for No_pods


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                           0.05

                              Error Degrees of Freedom          10

                              Error Mean Square           428.0654

                              Critical Value of t          2.22814

                              Least Significant Difference    37.64



                    Means with the same letter are not significantly different.



                          Grouping          Mean       N    cultivars


                                  A        96.00       3     LS6150_1


                                  A        93.33       3     PAN535_5


                                  A        81.89       3     LS6164_1


                             B    A        67.78       3     PAN737_2


                             B    A        61.22       3     PAN1664_


                             B             42.89       3     LS6162_1
```

Appendix C: Statistical procedure for Malkerns

LEAF DRY MATTER YIELD DATA

```
Input CULTIVAR Name      Cultivar    REP    Dry Leaves 42 DAP Dry Leaves 56 DAP
      Dry Leaves 70 DAP Dry Leaves 84 DAP;

cards;

LS6162       1     1     5.3    9.6    22.2   13.5

LS6162       1     2     5.6    7.9    15.6   10.5

LS6162       1     3     3.8    8.2    19     11.5

LS6162       1     4     3.1    8.5    10     7.5

PAN535       2     1     4.8    12.6   15     14.6

PAN535       2     2     4.2    14.6   14.3   20.8

PAN535       2     3     2.7    8.5    15     10.5

PAN535       2     4     3.2    7.3    11.1   9.2

PAN1664      3     1     5.1    6.8    29.6   33.4

PAN1664      3     2     4      7.2    13.7   10

PAN1664      3     3     5.2    10.5   14.3   13.2

PAN1664      3     4     4.8    13.9   18.2   17.2

LS6164       4     1     2.5    7.6    18.3   21.9

LS6164       4     2     3.6    7.3    10.7   10.8

LS6164       4     3     2.5    9.6    16.5   15.1

LS6164       4     4     2.6    4.8    13.5   8.9

LS6150       5     1     4.7    12.7   12.7   19.3

LS6150       5     2     4.5    10.8   17.3   13.1

LS6150       5     3     4.5    11.6   16.5   13.6

LS6150       5     4     2.7    9.4    11.9   14.4

PAN737       6     1     6      11.8   18     26.4

PAN737       6     2     3.9    9.8    16.8   14.6

PAN737       6     3     3.4    9.9    15.2   19.5

PAN737       6     4     2.3    8.6    18.2   13.5
```

Analysis of variance for Malkerns

```
Dependent Variable: Dry Leaves 42 DAP

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8     18.32166667      2.29020833       3.58    0.0160

      Error                       15      9.59666667      0.63977778

      Corrected Total             23     27.91833333

                    R-Square     Coeff Var      Root MSE    Dry Leaves 42 DAP Mean

                    0.656259      20.20702      0.799861              3.958333

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      REP                          3      9.00833333      3.00277778       4.69    0.0167
      Cultivar                     5      9.31333333      1.86266667       2.91    0.0495


Dependent Variable: Dry Leaves 56 DAP

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8      46.8183333       5.8522917       1.02    0.4617

      Error                       15      85.9979167       5.7331944

      Corrected Total             23     132.8162500

                    R-Square     Coeff Var      Root MSE    Dry Leaves 56 DAP Mean

                    0.352505      25.03957      2.394409              9.562500

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      REP                          3      6.42458333      2.14152778       0.37    0.7733
      Cultivar                     5     40.39375000      8.07875000       1.41    0.2768


Dependent Variable: Dry Leaves 70 DAP

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8     177.3566667      22.1695833       1.56    0.2171

      Error                       15     212.7566667      14.1837778

      Corrected Total             23     390.1133333

                    R-Square     Coeff Var      Root MSE    Dry Leaves 70 DAP Mean

                    0.454629      23.56289      3.766136              15.98333

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F
```

```
REP                          3     103.6033333      34.5344444       2.43    0.1051
Cultivar                     5      73.7533333      14.7506667       1.04    0.4302



Dependent Variable: Dry Leaves 84 DAP

                                        Sum of
Source                      DF         Squares     Mean Square    F Value    Pr > F

Model                        8     518.3583333      64.7947917       3.12    0.0274

Error                       15     311.1066667      20.7404444

Corrected Total             23     829.4650000


              R-Square     Coeff Var      Root MSE     Dry Leaves 84 DAP Mean

              0.624931      30.11020      4.554168                   15.12500


Source                      DF       Type I SS     Mean Square    F Value    Pr > F

REP                          3     341.1083333     113.7027778       5.48    0.0096
Cultivar                     5     177.2500000      35.4500000       1.71    0.1932
```

Least significant difference for leaf dry matter yield for Malkerns

```
Tests (LSD) for Dry Leaves 42 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                              0.05
                              Error Degrees of Freedom             15
                              Error Mean Square              0.639778
                              Critical Value of t             2.13145
                              Least Significant Difference     1.2055


                     Means with the same letter are not significantly
                    different.


                         Grouping           Mean        N     Cultivar

                                  A       4.7750        4     3

                                  A       4.4500        4     1

                                  A       4.1000        4     5

                            B     A       3.9000        4     6

                            B     A       3.7250        4     2

                            B             2.8000        4     4
```

```
Tests (LSD) for Dry Leaves 56 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                             Alpha                              0.05
                             Error Degrees of Freedom             15
                             Error Mean Square              5.733194
                             Critical Value of t             2.13145
                             Least Significant Difference     3.6088


                   Means with the same letter are not significantly
                   different.


                        Grouping          Mean      N    Cultivar

                               A        11.125      4    5

                          B    A        10.750      4    2

                          B    A        10.025      4    6

                          B    A         9.600      4    3

                          B    A         8.550      4    1

                          B              7.325      4    4
```

```
Tests (LSD) for Dry Leaves 70 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                             Alpha                                0.05
                             Error Degrees of Freedom               15
                             Error Mean Square                14.18378
                             Critical Value of t               2.13145
                             Least Significant Difference       5.6762


                  Means with the same letter are not significantly
                  different.


                     Grouping           Mean        N    Cultivar

                            A         18.950        4    3

                            A         17.050        4    6

                            A         16.700        4    1

                            A         14.750        4    4

                            A         14.600        4    5

                            A         13.850        4    2
```

```
Tests (LSD) for Dry Leaves 84 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                              0.05
                            Error Degrees of Freedom             15
                            Error Mean Square              20.74044
                            Critical Value of t             2.13145
                            Least Significant Difference     6.8639


                 Means with the same letter are not significantly
                 different.


                        Grouping          Mean       N    Cultivar

                                A       18.500       4    6

                                A       18.450       4    3

                           B    A       15.100       4    5

                           B    A       14.175       4    4

                           B    A       13.775       4    2

                           B            10.750       4    1
```

STEM DRY MATTER YIELD DATA FOR MALKERNS;

```
Input CULTIVAR Name     Cultivar    REP    Dry Stems 42 DAP   Dry Stems 56 DAP
      Dry Stems 70 DAP  Dry Stems 84 DAP;

cards;

LS6162      1     1     3.3    7.7    19.9   11.4

LS6162      1     2     3.8    6.4    14     9.4

LS6162      1     3     2.5    7.4    11     9.3

LS6162      1     4     1.9    7      7.8    6.2

PAN535      2     1     3.1    13.5   14.7   12.9

PAN535      2     2     3.2    13.9   15.6   18.7

PAN535      2     3     1.8    7.1    13.7   10.4

PAN535      2     4     2.6    6.8    9.7    9.7

PAN1664     3     1     3.2    7.2    23.4   33.6

PAN1664     3     2     2.6    5.5    10.9   8.2

PAN1664     3     3     3.6    9      11.8   10

PAN1664     3     4     3.3    12.3   15.7   10.1

LS6164      4     1     4      7.5    18.2   21

LS6164      4     2     2.6    6      9.1    8.8

LS6164      4     3     1.6    9.3    15.9   14.1

LS6164      4     4     1.6    4      10.6   7.6

LS6150      5     1     3.4    12.3   12.7   16.7

LS6150      5     2     3.2    11.2   16     12

LS6150      5     3     3.4    10.7   15.1   11.3

LS6150      5     4     1.7    7      8.3    11.9

PAN737      6     1     5.4    13.9   21.9   27.5

PAN737      6     2     3.1    10.7   19.1   14.6

PAN737      6     3     2.8    9.8    13.9   20.4

PAN737      6     4     1.6    8.3    15.7   15.2
```

ANALYSIS OF VARIENCE FOR STEM DRY MATTER YIELD FOR MALKERNS

```
Dependent Variable: Dry Stems 42 DAP

                                                 Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8     10.26666667      1.28333333       2.18    0.0916

      Error                       15      8.81958333      0.58797222

      Corrected Total             23     19.08625000

                     R-Square     Coeff Var      Root MSE    Dry Stems 42 DAP Mean

                     0.537909      26.55562      0.766793             2.887500

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5      1.73875000      0.34775000       0.59    0.7069
      REP                          3      8.52791667      2.84263889       4.83    0.0151
```

```
Dependent Variable: Dry Stems 56 DAP

                                                 Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8      84.3983333      10.5497917       1.64    0.1952

      Error                       15      96.5979167       6.4398611

      Corrected Total             23     180.9962500

                     R-Square     Coeff Var      Root MSE    Dry Stems 56 DAP Mean

                     0.466299      28.39371      2.537688             8.937500

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5     61.13375000     12.22675000       1.90    0.1543
      REP                          3     23.26458333      7.75486111       1.20    0.3421
```

```
Dependent Variable: Dry Stems 70 DAP

                                                 Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8     229.1050000      28.6381250       2.61    0.0523

      Error                       15     164.8512500      10.9900833

      Corrected Total             23     393.9562500

                     R-Square     Coeff Var      Root MSE    Dry Stems 70 DAP Mean

                     0.581549      23.08184      3.315129             14.36250

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5      67.6037500      13.5207500       1.23    0.3431
      REP                          3     161.5012500      53.8337500       4.90    0.0144
```

```
Dependent Variable: Dry Stems 84 DAP

                                             Sum of
Source                      DF          Squares     Mean Square    F Value    Pr > F

Model                        8      617.7916667      77.2239583       3.21    0.0246

Error                       15      360.7866667      24.0524444

Corrected Total             23      978.5783333

               R-Square     Coeff Var      Root MSE    Dry Stems 84 DAP Mean

               0.631315      35.56009      4.904329             13.79167

Source                      DF        Type I SS     Mean Square    F Value    Pr > F

Cultivar                     5      236.2933333      47.2586667       1.96    0.1428
REP                          3      381.4983333     127.1661111       5.29    0.0109
```

Least significant difference for stem dry matter yield for Malkerns

```
Tests (LSD) for Dry Stems 42 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                           Alpha                            0.05
                           Error Degrees of Freedom           15
                           Error Mean Square            0.587972
                           Critical Value of t           2.13145
                           Least Significant Difference   1.1557


                  Means with the same letter are not significantly
                  different.


                     Grouping          Mean       N    Cultivar

                            A        3.2250       4    6

                            A        3.1750       4    3

                            A        2.9250       4    5

                            A        2.8750       4    1

                            A        2.6750       4    2

                            A        2.4500       4    4
```

```
Tests (LSD) for Dry Stems 56 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                             Alpha                              0.05
                             Error Degrees of Freedom             15
                             Error Mean Square              6.439861
                             Critical Value of t             2.13145
                             Least Significant Difference     3.8247


                     Means with the same letter are not significantly
                    different.


                         Grouping          Mean       N     Cultivar

                                A        10.675       4     6

                           B    A        10.325       4     2

                           B    A        10.300       4     5

                           B    A         8.500       4     3

                           B    A         7.125       4     1

                           B              6.700       4     4
```

```
Tests (LSD) for Dry Stems 70 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                            0.05
                              Error Degrees of Freedom           15
                              Error Mean Square            10.99008
                              Critical Value of t           2.13145
                              Least Significant Difference   4.9964


                     Means with the same letter are not significantly
                     different.


                        Grouping           Mean        N    Cultivar

                               A         17.650        4    6

                               A         15.450        4    3

                               A         13.450        4    4

                               A         13.425        4    2

                               A         13.175        4    1

                               A         13.025        4    5
```

```
Tests (LSD) for Dry Stems 84 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                           Alpha                              0.05
                           Error Degrees of Freedom             15
                           Error Mean Square              24.05244
                           Critical Value of t             2.13145
                           Least Significant Difference     7.3916


                  Means with the same letter are not significantly
                  different.


                       Grouping            Mean         N    Cultivar

                               A         19.425         4    6

                            B  A         15.475         4    3

                            B  A         12.975         4    5

                            B  A         12.925         4    2

                            B  A         12.875         4    4

                            B             9.075         4    1
```

POD DRY MATTER YIELD DATA FOR MALKERNS

```
Input CULTIVAR Name     Cultivar    REP   Dry Pod 70 DAP    Dry Pod 80 DAP;

cards;

LS6162      1     1           2.1   34.6  40.9

LS6162      1     2           2.3   20.7  31

LS6162      1     3           2.6   14.7  24

LS6162      1     4           1.6   10.7  30.2

PAN535      2     1           0     11.3  31.5

PAN535      2     2           0.6   12.6  43.8

PAN535      2     3           0.6   10.8  13.5

PAN535      2     4           0.3   8.9   21

PAN1664     3     1           1.3   21    66.6

PAN1664     3     2           0.6   10.9  21.8

PAN1664     3     3           0.8   16    31

PAN1664     3     4           1     6.8   22.4

LS6164      4     1           0     11.8  41

LS6164      4     2           0     6     15.6

LS6164      4     3           0     13.4  30.9

LS6164      4     4           0     7.1   18.5

LS6150      5     1           0     9.1   34.8

LS6150      5     2           0     15.6  23.9

LS6150      5     3           1.2   14    38.8

LS6150      5     4           0     4.3   20

PAN737      6     1           0     8.6   39.2

PAN737      6     2           0     8.2   21.5

PAN737      6     3           0     6.2   22.1

PAN737      6     4           0     6.8   14.2
```

ANALYSIS OF VARIENCE FOR POD DRY MATTER YIELD FOR MALKERNS

```
Dependent Variable: Dry Pod 70 DAP

                                                  Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        6     424.5816667      70.7636111       1.87    0.2540

      Error                        5     188.9875000      37.7975000

      Corrected Total             11     613.5691667

                      R-Square     Coeff Var      Root MSE    Dry Pod DAP Mean

                      0.691987      43.01785      6.147967          14.29167

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5     386.7741667      77.3548333       2.05    0.2253
      REP                          1      37.8075000      37.8075000       1.00    0.3632

Dependent Variable: Dry Pod 84 DAP

                                                  Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        6     1481.448333      246.908056       3.00    0.1245

      Error                        5      412.054167       82.410833

      Corrected Total             11     1893.502500

                      R-Square     Coeff Var      Root MSE    Dry Pod 84 DAP Mean

                      0.782385      26.29411      9.078041          34.52500

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5     749.8075000     149.9615000       1.82    0.2635
      REP                          1     731.6408333     731.6408333       8.88    0.0308
```

Least significant difference for pod dry matter yield for Malkerns

```
Tests (LSD) for Dry Pod 70 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                                0.05
                              Error Degrees of Freedom                5
                              Error Mean Square                 37.7975
                              Critical Value of t               2.57058
                              Least Significant Difference       15.804


                  Means with the same letter are not significantly
                  different.


                         Grouping            Mean          N     Cultivar

                                A          24.650          2     1

                           B    A          18.500          2     3

                           B    A          12.600          2     4

                           B    A          11.550          2     5

                           B    A          11.050          2     2

                           B                7.400          2     6
```

```
Tests (LSD) for Dry Pod 84 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                              0.05
                            Error Degrees of Freedom              5
                            Error Mean Square              82.41083
                            Critical Value of t             2.57058
                            Least Significant Difference     23.336


                  Means with the same letter are not significantly
                  different.

                        Grouping          Mean        N    Cultivar

                                A       48.800        2    3

                           B    A       36.800        2    5

                           B    A       35.950        2    4

                           B    A       32.450        2    1

                           B    A       30.650        2    6

                           B            22.500        2    2
```

Yield Parameters for Malkerns

Obs	cultivars	Rep	No_plants_ Harv	Plant_ Height	Pod_ Height	No_Nodes	Seed_ Yied	Moisture	Seed_ Mas_100	No_pods
1	LS6162_1	1	31	50	12	14	0.85699	8.8	15.7	42.333
2	LS6162_1	2	63	43	8	13	0.78953	8.9	14.7	42.333
3	LS6162_1	3	55	42	10	13	0.84356	9.0	14.8	40.667
4	LS6162_1	4	37	38	8	12	1.02202	8.8	17.5	14.333
5	PAN535_2	1	52	31	10	10	1.08622	9.0	14.5	32.667
6	PAN535_2	2	62	42	8	12	0.93785	9.1	15.1	46.000
7	PAN535_2	3	74	31	7	10	0.93124	8.9	15.3	29.000
8	PAN535_2	4	87	32	9	11	1.00644	8.9	16.4	21.667
9	PAN1664_	1	68	42	14	9	0.95124	9.2	13.9	30.667
10	PAN1664_	2	73	31	10	8	0.86956	9.0	13.7	19.000
11	PAN1664_	3	69	39	9	11	0.89654	8.9	15.4	26.667
12	PAN1664_	4	67	45	12	9	0.93867	9.3	14.6	39.667
13	LS6164_4	1	50	38	10	12	1.01556	8.6	13.2	33.667
14	LS6164_4	2	56	43	9	12	0.97151	8.1	12.9	21.667
15	LS6164_4	3	80	45	9	12	1.01333	8.8	12.6	41.667
16	LS6164_4	4	75	39	10	12	0.99194	8.1	12.9	35.000
17	LS6150_5	1	65	55	10	12	1.21067	9.2	13.4	27.667
18	LS6150_5	2	71	60	10	12	1.32305	9.4	13.6	26.333
19	LS6150_5	3	50	51	10	12	1.54267	9.0	13.1	58.000
20	LS6150_5	4	52	42	9	13	1.16550	8.9	15.2	22.667
21	PAN737_6	1	46	45	12	10	0.80978	8.9	15.4	45.667
22	PAN737_6	2	54	43	12	11	0.78171	8.8	15.4	45.333
23	PAN737_6	3	37	34	11	12	0.69410	8.9	15.2	26.667
24	PAN737_6	4	82	40	13	11	0.81845	8.9	14.4	51.333

ANALYSIS OF VARIENCE FOR YIELD PARAMETERS FOR MALKERNS

```
Dependent Variable: No_plants_Harv


                                             Sum of
       Source                      DF       Squares     Mean Square    F Value    Pr > F

       Model                        8   2292.666667      286.583333       1.56    0.2175

       Error                       15   2752.666667      183.511111

       Corrected Total             23   5045.333333


                   R-Square     Coeff Var      Root MSE    No_plants_Harv Mean

                   0.454413      22.32961      13.54663               60.66667


       Source                      DF     Type I SS     Mean Square    F Value    Pr > F

       cultivars                    5   1588.333333      317.666667       1.73    0.1882
       Rep                          3    704.333333      234.777778       1.28    0.3174
```

```
Dependent Variable: Plant_Height

                                           Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8      789.166667       98.645833       3.23    0.0240

       Error                       15      457.791667       30.519444

       Corrected Total             23     1246.958333


                    R-Square     Coeff Var      Root MSE    Plant_Height Mean

                    0.632873      13.24541      5.524441             41.70833


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5     701.7083333     140.3416667       4.60    0.0096
       Rep                          3      87.4583333      29.1527778       0.96    0.4392
```

```
Dependent Variable: Pod_Height


                                          Sum of
       Source                      DF        Squares     Mean Square    F Value    Pr > F


       Model                        8    48.16666667      6.02083333       4.59    0.0054


       Error                       15    19.66666667      1.31111111


       Corrected Total             23    67.83333333



                     R-Square     Coeff Var      Root MSE    Pod_Height Mean


                     0.710074      11.35574      1.145038           10.08333



       Source                      DF      Type I SS     Mean Square    F Value    Pr > F


       Cultivars                    5    33.33333333      6.66666667       5.08    0.0063

       Rep                          3    14.83333333      4.94444444       3.77    0.0337
```

```
Dependent Variable: No_Nodes

                                            Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8     36.16666667      4.52083333       5.92    0.0016

       Error                       15     11.45833333      0.76388889

       Corrected Total             23     47.62500000


                      R-Square     Coeff Var      Root MSE    No_Nodes Mean

                      0.759405      7.683581      0.874007         11.37500


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5     35.37500000      7.07500000       9.26    0.0004
       Rep                          3      0.79166667      0.26388889       0.35    0.7929
```

```
Dependent Variable: Seed_Yied

                                          Sum of
       Source                      DF        Squares     Mean Square    F Value    Pr > F

       Model                        8    24.08831658      3.01103957       1.02    0.4628

       Error                       15    44.32395343      2.95493023

       Corrected Total             23    68.41227001


                      R-Square     Coeff Var      Root MSE    Seed_Yied Mean

                      0.352105      129.2926      1.718991          1.329535


       Source                      DF      Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5    15.71952215      3.14390443       1.06    0.4182
       Rep                          3     8.36879443      2.78959814       0.94    0.4441
```

```
Dependent Variable: Moisture

                                           Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8      1.44666667      0.18083333       4.29    0.0074

       Error                       15      0.63166667      0.04211111

       Corrected Total             23      2.07833333


                      R-Square     Coeff Var      Root MSE    Moisture Mean

                      0.696071      2.307890      0.205210         8.891667


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5      1.38833333      0.27766667       6.59    0.0020
       Rep                          3      0.05833333      0.01944444       0.46    0.7131
```

```
Dependent Variable: Seed_Mas_100


                                         Sum of
        Source                DF        Squares    Mean Square    F Value    Pr > F

        Model                  8    25.00833333     3.12604167       5.23    0.0029

        Error                 15     8.96791667     0.59786111

        Corrected Total       23    33.97625000


                     R-Square     Coeff Var      Root MSE    Seed_Mas_100 Mean

                     0.736053      5.318760      0.773215             14.53750


        Source                DF      Type I SS    Mean Square    F Value    Pr > F

        Cultivars              5    21.75375000     4.35075000       7.28    0.0012
        Rep                    3     3.25458333     1.08486111       1.81    0.1878
```

```
Dependent Variable: No_pods

                                         Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8      2972.98148       371.62268       0.76    0.6399

       Error                       15      7310.77777       487.38518

       Corrected Total             23     10283.75925


                       R-Square     Coeff Var      Root MSE    No_pods Mean

                       0.289095      58.82790      22.07680        37.52778


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       Cultivars                    5     1839.148147      367.829629       0.75    0.5957
       Rep                          3     1133.833333      377.944444       0.78    0.5257
```

Least significant difference for yield parameters for Malkerns

```
Tests (LSD) for No_plants_Harv


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             183.5111

                              Critical Value of t            2.13145

                              Least Significant Difference   20.417



                    Means with the same letter are not significantly different.



                          Grouping          Mean       N     cultivars


                                  A        69.250       4     PAN1664_


                                  A        68.750       4     PAN535_2


                             B    A        65.250       4     LS6164_4


                             B    A        59.500       4     LS6150_5


                             B    A        54.750       4     PAN737_6


                             B             46.500       4     LS6162_1
```

```
Tests (LSD) for Plant_Height


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             30.51944

                              Critical Value of t            2.13145

                              Least Significant Difference   8.3262



                    Means with the same letter are not significantly different.



                          Grouping          Mean      N    cultivars


                                  A       52.000      4    LS6150_5


                                  B       43.250      4    LS6162_1


                             C    B       41.250      4    LS6164_4


                             C    B       40.500      4    PAN737_6


                             C    B       39.250      4    PAN1664_


                             C            34.000      4    PAN535_2
```

```
Tests (LSD) for Pod_Height


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                            0.05

                              Error Degrees of Freedom           15

                              Error Mean Square            1.311111

                              Critical Value of t           2.13145

                              Least Significant Difference   1.7258



                    Means with the same letter are not significantly different.


                          Grouping          Mean      N    cultivars


                                  A       12.0000      4    PAN737_6


                             B    A       11.2500      4    PAN1664_


                             B    C        9.7500      4    LS6150_5


                                  C        9.5000      4    LS6164_4


                                  C        9.5000      4    LS6162_1


                                  C        8.5000      4    PAN535_2
```

```
Tests (LSD) for No_Nodes


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             0.763889

                              Critical Value of t            2.13145

                              Least Significant Difference    1.3173



                   Means with the same letter are not significantly different.



                           Grouping             Mean       N     cultivars


                               A             13.0000       4      LS6162_1


                          B    A             12.2500       4      LS6150_5


                          B    A    C        12.0000       4      LS6164_4


                          B         C        11.0000       4      PAN737_6


                                    C        10.7500       4      PAN535_2


                               D              9.2500       4      PAN1664_
```

```
Tests (LSD) for Seed Yield

 NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


              Alpha                     0.05
              Error Degrees of Freedom        15
              Error Mean Square          0.009187
              Critical Value of t        2.13145
              Least Significant Difference   0.1445


          Means with the same letter are not significantly different.


             Grouping        Mean      N    cultivar

                 A       1.31047     4    5

                 B       0.99809     4    4

                 B       0.99044     4    2

               C   B       0.91400     4    3

               C   B       0.87803     4    1

               C         0.77601     4    6
```

```
Tests (LSD) for Moisture


NOTE: This test controls the Type I comparison wise error rate, not the experiment twise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             0.042111

                              Critical Value of t            2.13145

                              Least Significant Difference   0.3093



                   Means with the same letter are not significantly different.



                       Grouping          Mean      N    cultivars


                               A        9.1250      4     LS6150_5


                               A        9.1000      4     PAN1664_


                               A        8.9750      4     PAN535_2


                               A        8.8750      4     LS6162_1


                               A        8.8750      4     PAN737_6


                               B        8.4000      4     LS6164_4
```

```
Tests (LSD) for Seed_Mas_100


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             0.597861

                              Critical Value of t            2.13145

                              Least Significant Difference   1.1654



                    Means with the same letter are not significantly different.



                          Grouping          Mean      N    cultivars


                                  A       15.6750      4    LS6162_1


                             B    A       15.3250      4    PAN535_2


                             B    A       15.1000      4    PAN737_6


                             B    C       14.4000      4    PAN1664_


                             D    C       13.8250      4    LS6150_5


                             D            12.9000      4    LS6164_4
```

```
Tests (LSD) for No_pods


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                            0.05

                              Error Degrees of Freedom           15

                              Error Mean Square            487.3852

                              Critical Value of t           2.13145

                              Least Significant Difference   33.273



                   Means with the same letter are not significantly different.



                       Grouping          Mean      N    cultivars


                               A        54.92      4     LS6162_1


                               A        42.25      4     PAN737_6


                               A        33.67      4     LS6150_5


                               A        33.00      4     LS6164_4


                               A        32.33      4     PAN535_2


                               A        29.00      4     PAN1664_
```

Appendix D: Statistical procedure for Nhlangano

LEAF DRY MATTER YIELD DATA FOR NHLANGANO

```
Input CULTIVAR Name Cultivar  REP   Dry Leaves 44 DAP Dry Leaves 58 DAP Dry
Leaves 72 DAP     Dry Leaves 86 DAP;

cards;

LS6162      1     1     2.7   12.5  19.8  11.6

LS6162      1     2     5.9   15.7  17.7  11

LS6162      1     3     4.9   14.2  17.5  10.2

LS6162      1     4     6.1   13.9  13.7  9.5

PAN535      2     1     4.9   15.7  16.6  18.8

PAN535      2     2     4     8.3   14.3  12.7

PAN535      2     3     4     16.5  13.2  13.3

PAN535      2     4     5.2   14.2  17.8  15.7

PAN1664     3     1     4.3   8.4   16.2  12.5

PAN1664     3     2     5.6   15.1  16.9  10.6

PAN1664     3     3     5.1   11.9  15.5  11.6

PAN1664     3     4     3.7   11.3  14.6  13.2

LS6164      4     1     3.6   11.4  15.2  16.5

LS6164      4     2     4.9   9.1   14.3  13.9

LS6164      4     3     3.2   12    14.2  16.4

LS6164      4     4     5.1   13.5  14.4  16.2

LS6150      5     1     5.5   14.5  19.3  18.1

LS6150      5     2     4.5   14.6  17.1  18.7

LS6150      5     3     3.7   13.2  18.4  16.4

LS6150      5     4     3.6   16.7  17.9  12.6

PAN737      6     1     2.8   8.4   15.8  16.3

PAN737      6     2     4.2   11.2  19.9  18

PAN737      6     3     4.6   12.9  20.4  12.4

PAN737           64     4.7   13.4  18.2  15.1
```

Analysis of variance leaf dry matter yield for Nhlangano

```
Dependent Variable: Dry Leaves 44 DAP

                                          Sum of
      Source                      DF     Squares     Mean Square    F Value    Pr > F

      Model                        8   4.99333333     0.62416667       0.63    0.7380

      Error                       15  14.76666667     0.98444444

      Corrected Total             23  19.76000000


                    R-Square     Coeff Var      Root MSE    Dry Leaves 44 DAP Mean

                    0.252699      22.29644      0.992192           4.450000


      Source                      DF     Type I SS   Mean Square    F Value    Pr > F

      REP                          3   3.08333333     1.02777778       1.04    0.4017
      Cultivar                     5   1.91000000     0.38200000       0.39    0.8493



Dependent Variable: Dry Leaves 58 DAP

                                          Sum of
      Source                      DF     Squares     Mean Square    F Value    Pr > F

      Model                        8   59.5066667      7.4383333       1.32    0.3069

      Error                       15   84.6716667      5.6447778

      Corrected Total             23  144.1783333


                    R-Square     Coeff Var      Root MSE    Dry Leaves 58 DAP Mean

                    0.412730      18.47731      2.375874           12.85833


      Source                      DF     Type I SS   Mean Square    F Value    Pr > F

      REP                          3  15.96833333     5.32277778       0.94    0.4446
      Cultivar                     5  43.53833333     8.70766667       1.54    0.2358



Dependent Variable: Dry Leaves 72 DAP

                                          Sum of
      Source                      DF     Squares     Mean Square    F Value    Pr > F

      Model                        8   55.0733333      6.8841667       2.14    0.0967

      Error                       15   48.1862500      3.2124167

      Corrected Total             23  103.2595833


                    R-Square     Coeff Var      Root MSE    Dry Leaves 72 DAP Mean

                    0.533348      10.78358      1.792322           16.62083


      Source                      DF     Type I SS   Mean Square    F Value    Pr > F

      REP                          3   3.39125000     1.13041667       0.35    0.7884
      Cultivar                     5  51.68208333    10.33641667       3.22    0.0359
```

```
Dependent Variable: Dry Leaves 86 DAP

                                            Sum of
       Source                      DF      Squares     Mean Square    F Value    Pr > F

       Model                        8  129.6216667      16.2027083       4.38    0.0067

       Error                       15   55.5179167       3.7011944

       Corrected Total             23  185.1395833


                     R-Square     Coeff Var      Root MSE    Dry Leaves DAP Mean

                     0.700129      13.52838      1.923849             14.22083


       Source                      DF    Type I SS     Mean Square    F Value    Pr > F

       REP                          3   17.7345833       5.9115278       1.60    0.2318
       Cultivar                     5  111.8870833      22.3774167       6.05    0.0029
```

Least significant difference for leaf dry matter yield for Nhlangano

```
Tests (LSD) for Dry Leaves 44 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                              Alpha                            0.05
                              Error Degrees of Freedom           15
                              Error Mean Square            0.984444
                              Critical Value of t           2.13145
                              Least Significant Difference   1.4954


                     Means with the same letter are not significantly
                     different.


                         Grouping          Mean        N     Cultivar

                                A        4.9000        4     1

                                A        4.6750        4     3

                                A        4.5250        4     2

                                A        4.3250        4     5

                                A        4.2000        4     4

                                A        4.0750        4     6
```

```
Tests (LSD) for Dry Leaves 58 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                            Alpha                               0.05
                            Error Degrees of Freedom              15
                            Error Mean Square               5.644778
                            Critical Value of t              2.13145
                            Least Significant Difference      3.5808


                   Means with the same letter are not significantly
                   different.


                      Grouping            Mean        N     Cultivar

                             A          14.750        4     5

                             A          14.075        4     1

                             A          13.675        4     2

                             A          11.675        4     3

                             A          11.500        4     4

                             A          11.475        4     6
```

```
Tests (LSD) for Dry Leaves 72 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                         Alpha                               0.05
                         Error Degrees of Freedom              15
                         Error Mean Square               3.212417
                         Critical Value of t              2.13145
                         Least Significant Difference      2.7013


               Means with the same letter are not significantly
               different.


                    Grouping            Mean       N    Cultivar

                           A          18.575       4    6

                      B    A          18.175       4    5

                      B    A    C     17.175       4    1

                      B         C     15.800       4    3

                      B         C     15.475       4    2

                                C     14.525       4    4
```

```
Tests (LSD) for Dry Leaves 86 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                             Alpha                             0.05
                             Error Degrees of Freedom            15
                             Error Mean Square             3.701194
                             Critical Value of t            2.13145
                             Least Significant Difference    2.8996


                   Means with the same letter are not significantly
                   different.


                      Grouping           Mean       N    Cultivar

                             A         16.450       4    5

                             A         15.750       4    4

                             A         15.450       4    6

                             A         15.125       4    2

                             B         11.975       4    3

                             B         10.575       4    1
```

STEM DRY MATTER YIELD DATA FOR NHLANGANO

```
Input CULTIVAR Name      Cultivar     REP    Dry Stems 44 DAP  Dry Stems 58 DAP
      Dry Stems 72 DAP  Dry Stems 86 DAP;

cards;

LS6162       1      1      1.6    7.1    17.1   11.3

LS6162       1      2      3.9    14     18.1   10.9

LS6162       1      3      3.1    12.8   18.5   12.2

LS6162       1      4      4.8    12.6   14.1   11

PAN535       2      1      3.2    16.7   21.4   23.8

PAN535       2      2      2.7    9.7    15.4   16.8

PAN535       2      3      3      16.5   14.8   17.2

PAN535       2      4      4      14.9   20.8   21

PAN1664      3      1      2.8    7.8    16.1   16.5

PAN1664      3      2      3.7    15     18.8   15.7

PAN1664      3      3      3.4    11.8   18.1   15.9

PAN1664      3      4      2.5    11.6   15.6   17.6

LS6164       4      1      2.2    9.9    16.2   21.4

LS6164       4      2      3.3    9.4    19.9   21.9

LS6164       4      3      2.2    11.8   15.8   20.3

LS6164       4      4      3.1    14.1   16.5   21.7

LS6150       5      1      3.3    14.1   21.7   25.6

LS6150       5      2      3      13.9   19.5   26.3

LS6150       5      3      2.2    11.3   20.6   19.6

LS6150       5      4      2.3    15.7   20     17

PAN737       6      1      1.9    7.8    17.1   20.3

PAN737       6      2      3.2    11.7   25.2   25.8

PAN737       6      3      3.6    14.3   27.7   17.2

PAN737            6 4      3.4    15     23.8   21.6 ;
```

ANALYSIS OF VARIENCE FOR STEM DRY MATTER YIELD FOR NHLANGANO

```
Dependent Variable: Dry Stems 44 DAP

                                                   Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8      4.25833333      0.53229167       0.97    0.4910

      Error                       15      8.19500000      0.54633333

      Corrected Total             23     12.45333333

                     R-Square     Coeff Var      Root MSE    Dry Stems 44 DAP Mean

                     0.341943      24.50200      0.739144             3.016667

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5      1.44833333      0.28966667       0.53    0.7502
      REP                          3      2.81000000      0.93666667       1.71    0.2068
```

```
Dependent Variable: Dry Stems 58 DAP

                                          Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8      72.1833333       9.0229167       1.30    0.3142

      Error                       15     104.0362500       6.9357500

      Corrected Total             23     176.2195833

                     R-Square     Coeff Var      Root MSE    Dry Stems 58 DAP Mean

                     0.409622      21.10382      2.633581             12.47917

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5     34.24208333      6.84841667       0.99    0.4575
      REP                          3     37.94125000     12.64708333       1.82    0.1862
```

```
Dependent Variable: Dry Stems 72 DAP

                                          Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                        8     141.6566667      17.7070833       2.14    0.0969

      Error                       15     124.0366667       8.2691111

      Corrected Total             23     265.6933333

                     R-Square     Coeff Var      Root MSE    Dry Stems 72DAP Mean

                     0.533159      15.24173      2.875606             18.86667

      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5     135.3733333      27.0746667       3.27    0.0339
      REP                          3       6.2833333       2.0944444       0.25    0.8578
```

```
Dependent Variable: Dry Stems 86 DAP

                                            Sum of
      Source                      DF       Squares     Mean Square    F Value    Pr > F

      Model                        8   369.6533333      46.2066667       6.34    0.0011

      Error                       15   109.3250000       7.2883333

      Corrected Total             23   478.9783333

                     R-Square     Coeff Var      Root MSE    Dry Stems 86 DAP Mean

                     0.771754      14.44329      2.699691             18.69167

      Source                      DF     Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5   340.7783333      68.1556667       9.35    0.0003
      REP                          3    28.8750000       9.6250000       1.32    0.3046
```

Least significant difference for stem dry matter yield for Nhlangano

```
Tests (LSD) for Dry Stems 44 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                           Alpha                               0.05
                           Error Degrees of Freedom              15
                           Error Mean Square               0.546333
                           Critical Value of t              2.13145
                           Least Significant Difference       1.114


                 Means with the same letter are not significantly
                 different.


                    Grouping          Mean        N     Cultivar

                           A        3.3500        4     1

                           A        3.2250        4     2

                           A        3.1000        4     3

                           A        3.0250        4     6

                           A        2.7000        4     5

                           A        2.7000        4     4
```

```
Tests (LSD) for Dry Stems 58 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                                  Alpha                            0.05
                                  Error Degrees of Freedom           15
                                  Error Mean Square             6.93575
                                  Critical Value of t           2.13145
                                  Least Significant Difference   3.9692


                         Means with the same letter are not significantly
                         different.


                             Grouping          Mean       N    Cultivar

                                    A        14.450       4    2

                                    A        13.750       4    5

                                    A        12.200       4    6

                                    A        11.625       4    1

                                    A        11.550       4    3

                                    A        11.300       4    4
```

```
Tests (LSD) for Dry Stems 72 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error


                              Alpha                              0.05
                              Error Degrees of Freedom             15
                              Error Mean Square              8.269111
                              Critical Value of t             2.13145
                              Least Significant Difference      4.334


                   Means with the same letter are not significantly
                  different.


                          Grouping          Mean        N     Cultivar

                                 A        23.450         4     6

                             B   A        20.450         4     5

                             B            18.100         4     2

                             B            17.150         4     3

                             B            17.100         4     4

                             B            16.950         4     1
```

```
Tests (LSD) for Dry Stems 86 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                           Alpha                                0.05
                           Error Degrees of Freedom               15
                           Error Mean Square                7.288333
                           Critical Value of t               2.13145
                           Least Significant Difference       4.0689


                 Means with the same letter are not significantly
                 different.


                        Grouping          Mean       N    Cultivar

                                A       22.125       4    5

                                A       21.325       4    4

                                A       21.225       4    6

                           B    A       19.700       4    2

                           B            16.425       4    3

                                C       11.350       4    1
```

POD DRY MATTER YIELD DATA FOR NHLANGANO

```
Input CULTIVAR Name     Cultivar    REP    Dry Pod 72 DAP     Dry Pod 86 DAP;

cards;

LS6162      1     1           2.2    23.7   38.7

LS6162      1     2           4.6    27.1   43.9

LS6162      1     3           3.4    18.8   31.6

LS6162      1     4           3.3    17     37.2

PAN535      2     1           .      6.6    30.4

PAN535      2     2           .      8.8    23.8

PAN535      2     3           .      7.5    24.7

PAN535      2     4           .      8.1    24

PAN1664     3     1           .      7.7    21.8

PAN1664     3     2           .      9.7    21.3

PAN1664     3     3           .      8.4    17.6

PAN1664     3     4           .      5.9    16.8

LS6164      4     1           .      5.3    21.2

LS6164      4     2           .      8.6    25.9

LS6164      4     3           .      7.2    24.3

LS6164      4     4           .      4.9    17.3

LS6150      5     1           .      7.8    24.6

LS6150      5     2           .      8.6    31.3

LS6150      5     3           .      7.1    25.5

LS6150      5     4           .      5.9    17.5

PAN737      6     1           .      2.6    16.4

PAN737      6     2           .      4.5    18.7

PAN737      6     3           .      5.8    14.6

PAN737      6     4           .      3.2    12.4
```

ANALYSIS OF VARIENCE FOR POD DRY MATTER YIELD FOR NHLANGANO

```
Dependent Variable: Dry Pod 72 DAP

                                                        Sum of
      Source                      DF          Squares     Mean Square    F Value    Pr > F

      Model                        6      375.6250000      62.6041667      15.87    0.0041

      Error                        5       19.7241667       3.9448333

      Corrected Total             11      395.3491667

                      R-Square     Coeff Var      Root MSE    Dry Pod 72 DAP  Mean

                      0.950110      21.96675      1.986160        9.041667

      Source                      DF        Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5      375.5241667      75.1048333      19.04    0.0029
      REP                          1        0.1008333       0.1008333       0.03    0.8792


Dependent Variable: Dry Pod 86 DAP

                                              Sum of
      Source                      DF          Squares     Mean Square    F Value    Pr > F

      Model                        6      477.9500000      79.6583333      10.25    0.0109

      Error                        5       38.8466667       7.7693333

      Corrected Total             11      516.7966667

                      R-Square     Coeff Var      Root MSE    Dry Pod 86 DAP Mean

                      0.924832      11.47846      2.787352        24.28333

      Source                      DF        Type I SS     Mean Square    F Value    Pr > F

      Cultivar                     5      459.6966667      91.9393333      11.83    0.0085
      REP                          1       18.2533333      18.2533333       2.35    0.1859
```

Least significant difference for pod dry matter yield for Nhlangano

```
Tests (LSD) for Dry Pod 72 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate



                               Alpha                              0.05
                               Error Degrees of Freedom              5
                               Error Mean Square              3.944833
                               Critical Value of t             2.57058
                               Least Significant Difference     5.1056


                    Means with the same letter are not significantly
                    different.


                        Grouping           Mean      N    Cultivar

                                A        21.250      2     1

                                B         8.050      2     3

                                B         7.450      2     5

                                B         7.050      2     2

                                B         6.250      2     4

                                B         4.200      2     6
```

```
Tests (LSD) for Dry Pod 86 DAP

  NOTE: This test controls the Type I comparison wise error rate, not the
  experiment wise error rate


                             Alpha                          0.05
                             Error Degrees of Freedom          5
                             Error Mean Square          7.769333
                             Critical Value of t         2.57058
                             Least Significant Difference   7.1651


                   Means with the same letter are not significantly
                   different.

                        Grouping          Mean       N     Cultivar

                               A        35.150       2     1

                               B        27.550       2     2

                          C    B        25.050       2     5

                          C    B        22.750       2     4

                          C    D        19.700       2     3

                               D        15.500       2     6
```

Yield Parameters for Nhlangano

Obs	cultivars	Rep	No_plants_ Harv	Plant_ Height	Pod_ Height	No_Nodes	Seed_ Yied	Moisture	Seed_ Mas_100	No_pods
1	LS6162_1	1	46	32	9	10	1.33181	8.8	15.2	16.6667
2	LS6162_1	2	46	49	9	12	1.51667	9.0	15.9	47.6667
3	LS6162_1	3	64	45	6	10	1.45729	9.1	13.6	34.3333
4	LS6162_1	4	76	50	10	10	1.46789	8.8	16.7	24.3333
5	PAN535_2	1	75	42	14	12	1.89014	9.1	13.6	84.6667
6	PAN535_2	2	106	44	9	11	2.02771	9.4	13.6	24.6667
7	PAN535_2	3	137	34	12	9	1.38938	9.2	12.2	81.3333
8	PAN535_2	4	87	48	10	11	1.36206	9.1	11.4	55.3333
9	PAN1664_	1	105	53	14	9	1.82510	8.6	14.1	36.3333
10	PAN1664_	2	108	60	12	10	1.98759	8.6	12.6	46.0000
11	PAN1664_	3	126	46	12	10	1.83848	8.8	12.8	41.0000
12	PAN1664_	4	149	60	14	8	1.30143	8.9	13.7	27.0000
13	LS6164_4	1	99	47	13	12	1.72088	9.2	15.7	53.0000
14	LS6164_4	2	83	56	12	12	1.44286	9.1	12.8	53.3333
15	LS6164_4	3	104	50	12	11	1.86572	8.6	14.9	65.6667
16	LS6164_4	4	80	60	12	10	1.60686	8.8	15.2	23.3333
17	LS6150_5	1	98	72	16	12	1.79780	9.1	13.9	41.3333
18	LS6150_5	2	82	64	11	12	2.02643	9.2	11.7	40.6667
19	LS6150_5	3	93	58	13	12	1.95718	8.8	13.2	37.0000
20	LS6150_5	4	86	71	14	10	1.86952	9.4	14.0	30.0000
21	PAN737_6	1	87	46	14	11	1.28118	8.9	15.9	44.6667
22	PAN737_6	2	119	55	14	11	1.56750	8.9	15.7	41.6667
23	PAN737_6	3	94	53	15	11	1.54097	9.1	16.5	48.3333
24	PAN737_6	4	97	54	12	11	1.58077	9.3	16.5	39.0000

ANALYSIS OF VARIENCE FOR YIELD PARAMETERS FOR NHLANGANO

```
Dependent Variable: No_plants_Harv


                                        Sum of
       Source                  DF      Squares     Mean Square    F Value    Pr > F


       Model                    8    9789.83333     1223.72917       4.41    0.0065


       Error                   15    4157.79167      277.18611


       Corrected Total         23   13947.62500



                   R-Square     Coeff Var      Root MSE    No_plants_Harv Mean


                   0.701900      17.78254      16.64891               93.62500



       Source                  DF     Type I SS    Mean Square    F Value    Pr > F


       cultivars                5   8734.375000    1746.875000       6.30    0.0024

       Rep                      3   1055.458333     351.819444       1.27    0.3206
```

```
Dependent Variable: Plant_Height

                                          Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8     1886.833333      235.854167      10.28    <.0001

       Error                       15      344.125000       22.941667

       Corrected Total             23     2230.958333


                    R-Square     Coeff Var      Root MSE    Plant_Height Mean

                    0.845750      9.203675      4.789746             52.04167


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       cultivars                    5     1504.708333      300.941667      13.12    <.0001
       Rep                          3      382.125000      127.375000       5.55    0.0091
```

```
Dependent Variable: Pod_Height


                                        Sum of
       Source                DF        Squares     Mean Square    F Value    Pr > F

       Model                  8     92.1666667      11.5208333       5.61    0.0021

       Error                 15     30.7916667       2.0527778

       Corrected Total       23    122.9583333


                    R-Square     Coeff Var      Root MSE    Pod_Height Mean

                    0.749576      11.89829      1.432752           12.04167


       Source                DF       Type I SS     Mean Square    F Value    Pr > F

       cultivars              5     76.70833333     15.34166667       7.47    0.0011
       Rep                    3     15.45833333      5.15277778       2.51    0.0982
```

```
Dependent Variable: No_Nodes


                                           Sum of
        Source                      DF         Squares     Mean Square    F Value    Pr > F

        Model                        8     18.83333333      2.35416667       3.49    0.0178

        Error                       15     10.12500000      0.67500000

        Corrected Total             23     28.95833333


                       R-Square     Coeff Var      Root MSE    No_Nodes Mean

                       0.650360      7.672378      0.821584         10.70833


        Source                      DF       Type I SS     Mean Square    F Value    Pr > F

        cultivars                    5     12.70833333      2.54166667       3.77    0.0208
        Rep                          3      6.12500000      2.04166667       3.02    0.0624
```

```
Dependent Variable: Seed_Yied

                                            Sum of
       Source                      DF         Squares     Mean Square    F Value    Pr > F

       Model                        8      0.74136831      0.09267104       2.10    0.1029

       Error                       15      0.66259101      0.04417273

       Corrected Total             23      1.40395932


                      R-Square     Coeff Var      Root MSE    Seed_Yied Mean

                      0.528055      12.72067      0.210173          1.652217


       Source                      DF       Type I SS     Mean Square    F Value    Pr > F

       cultivars                    5      0.57841142      0.11568228       2.62    0.0679
       Rep                          3      0.16295689      0.05431896       1.23    0.3335
```

```
Dependent Variable: Moisture


                                                Sum of
      Source                      DF           Squares      Mean Square     F Value     Pr > F

      Model                        8        0.64000000       0.08000000        1.82     0.1506

      Error                       15        0.65833333       0.04388889

      Corrected Total             23        1.29833333


                     R-Square      Coeff Var       Root MSE     Moisture Mean

                     0.492940       2.329899       0.209497          8.991667


      Source                      DF         Type I SS      Mean Square     F Value     Pr > F

      cultivars                    5        0.57833333       0.11566667        2.64     0.0667
      Rep                          3        0.06166667       0.02055556        0.47     0.7087
```

```
Dependent Variable: Seed_Mas_100

                                        Sum of
        Source                      DF         Squares     Mean Square    F Value    Pr > F

        Model                        8     42.17666667      5.27208333       5.47    0.0023

        Error                       15     14.44833333      0.96322222

        Corrected Total             23     56.62500000


                     R-Square     Coeff Var      Root MSE    Seed_Mas_100 Mean

                     0.744842      6.899394      0.981439             14.22500


        Source                      DF       Type I SS     Mean Square    F Value    Pr > F

        cultivars                    5     37.53500000      7.50700000       7.79    0.0009
        Rep                          3      4.64166667      1.54722222       1.61    0.2298
```

```
Dependent Variable: No_pods

                                        Sum of
Source                      DF         Squares     Mean Square    F Value    Pr > F

Model                        8     3405.333333      425.666667       2.05    0.1093

Error                       15     3109.037037      207.269136

Corrected Total             23     6514.370370


                R-Square     Coeff Var      Root MSE    No_pods Mean

                0.522742      33.30890      14.39684        43.22222


Source                      DF       Type I SS     Mean Square    F Value    Pr > F

cultivars                    5     2354.481481      470.896296       2.27    0.1001
Rep                          3     1050.851852      350.283951       1.69    0.2118
```

ANALYSIS OF VARIENCE FOR YIELD PARAMETERS FOR NHLANGANO

```
Tests (LSD) for No_plants_Harv


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             277.1861

                              Critical Value of t            2.13145

                              Least Significant Difference    25.093



                    Means with the same letter are not significantly different.



                          Grouping          Mean       N     cultivars


                                  A       122.00       4     PAN1664_


                             B    A       101.25       4     PAN535_2


                             B    A        99.25       4     PAN737_6


                             B             91.50       4     LS6164_4


                             B             89.75       4     LS6150_5


                                  C        58.00       4     LS6162_1
```

```
Tests (LSD) for Plant_Height

NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.

                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             22.94167

                              Critical Value of t            2.13145

                              Least Significant Difference    7.2189

                   Means with the same letter are not significantly different.

                       Grouping          Mean      N    cultivars

                               A        66.250      4     LS6150_5

                               B        54.750      4     PAN1664_

                               B        53.250      4     LS6164_4

                               B        52.000      4     PAN737_6

                               C        44.000      4     LS6162_1

                               C        42.000      4     PAN535_2
```

```
Tests (LSD) for Pod_Height


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             2.052778

                              Critical Value of t            2.13145

                              Least Significant Difference   2.1594



                    Means with the same letter are not significantly different.



                        Grouping          Mean      N    cultivars


                                A       13.750      4     PAN737_6


                                A       13.500      4     LS6150_5


                           B    A       13.000      4     PAN1664_


                           B    A       12.250      4     LS6164_4


                           B            11.250      4     PAN535_2


                                C        8.500      4     LS6162_1
```

```
Tests (LSD) for No_Nodes


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square                0.675

                              Critical Value of t            2.13145

                              Least Significant Difference    1.2383



                   Means with the same letter are not significantly different.



                       Grouping          Mean       N    cultivars

                               A        11.5000      4     LS6150_5

                               A        11.2500      4     LS6164_4

                               A        11.0000      4     PAN737_6

                               A        10.7500      4     PAN535_2

                               A        10.5000      4     LS6162_1

                               B         9.2500      4     PAN1664_
```

```
Tests (LSD) for Seed_Yied

NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.

                              Alpha                            0.05

                              Error Degrees of Freedom           15

                              Error Mean Square            0.044173

                              Critical Value of t           2.13145

                              Least Significant Difference   0.3168

                    Means with the same letter are not significantly different.

                          Grouping          Mean      N    cultivars

                                  A        1.9127      4    LS6150_5

                             B    A        1.7381      4    PAN1664_

                             B    A        1.6673      4    PAN535_2

                             B    A        1.6591      4    LS6164_4

                             B             1.4926      4    PAN737_6

                             B             1.4434      4    LS6162_1
```

```
Tests (LSD) for Moisture


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.



                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             0.043889

                              Critical Value of t            2.13145

                              Least Significant Difference    0.3157



                    Means with the same letter are not significantly different.



                          Grouping          Mean      N    cultivars


                                 A        9.2000      4    PAN535_2


                                 A        9.1250      4    LS6150_5


                                 A        9.0500      4    PAN737_6


                            B    A        8.9250      4    LS6162_1


                            B    A        8.9250      4    LS6164_4


                            B             8.7250      4    PAN1664_
```

```
Tests (LSD) for Seed_Mas_100


NOTE: This test controls the Type I comparison wise error rate, not the experiment twise error rate.


                              Alpha                            0.05

                              Error Degrees of Freedom           15

                              Error Mean Square            0.963222

                              Critical Value of t           2.13145

                              Least Significant Difference   1.4792



                    Means with the same letter are not significantly different.


                          Grouping          Mean      N    cultivars


                                  A       16.1500      4    PAN737_6


                             B    A       15.3500      4    LS6162_1


                             B    C       14.6500      4    LS6164_4


                             D    C       13.3000      4    PAN1664_


                             D    C       13.2000      4    LS6150_5


                             D            12.7000      4    PAN535_2
```

```
Tests (LSD) for No_pods


NOTE: This test controls the Type I comparison wise error rate, not the experiment wise error rate.


                              Alpha                             0.05

                              Error Degrees of Freedom            15

                              Error Mean Square             207.2691

                              Critical Value of t            2.13145

                              Least Significant Difference    21.698


                    Means with the same letter are not significantly different.


                          Grouping          Mean       N     cultivars

                                  A         61.50       4     PAN535_2

                             B    A         48.83       4     LS6164_4

                             B    A         43.42       4     PAN737_6

                             B              37.58       4     PAN1664_

                             B              37.25       4     LS6150_5

                             B              30.75       4     LS6162_1
```