EVALUATION OF DIFFERENT SOUTH AFRICAN WHEAT CULTIVARS UNDER IRRIGATION FOR QUALITY AND YIELD PARAMETERS IN LIMPOPO PROVINCE, SOUTH AFRICA

by

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (Agronomy) has not previously been submitted by me for degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

Makgoba, S.S (Mr) **05/09/2013**

DEDICATION

I dedicate this mini-dissertation for the M.Sc. degree in Agriculture (Agronomy) firstly, to my beloved family and secondly to my beloved Son Matome Joy Makgoba.

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I am grateful to God, who gave me the opportunity to complete this study. My Co-supervisor Dr M.E Morojele and his colleagues from the Small Grain Institute for giving me this opportunity. I am very grateful to Professor I.K. Mariga for his supervision and his encouragement throughout my study.

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ABSTRACT

In South Africa, wheat ranks first among the winter cereal crops produced and plays an important role in the country's economy. The study was conducted to evaluate different South African wheat cultivars under irrigation for quality and yield parameters in Limpopo province. A field experiment was conducted during 2011 winter growing season under irrigation at the University of Limpopo experimental farm (Syferkuil). Eight wheat cultivars namely: Olifants, CNR 826, SST 347, Baviaans, Duzi, Steenbrass, SST 356 and Krokodil were laid out in a randomized complete block design with four replications for evaluation of yield and quality. The results showed that the highest grain yield obtained was 2372 kg/ha by CNR 826, and the lowest 311 kg/ha by SST 347. Flour yield, break flour yield, flour protein and mixogram development time and water absorption were not significantly different among cultivars. The highest hectolitre mass was 75.13 kghl^{-1}for CNR 826 and the lowest 72.20 kghl^{-1} for Olifants. The highest falling number obtained was 187.00 sec for SST 347 and the lowest was 81.50 sec for Steenbrass. Cultivars CNR 826, SST 347, Steenbrass and SST 356 showed a good potential on protein content but Krokodil, Olifants and Baviaans had poor protein contents at 9.63%, 9.73% and 10.24% respectively. These results showed that wheat cultivars evaluated were within the requirements of the grading systems of South Africa as regards hectolitre mass and protein content. All these cultivars did not reach the required grade of 220 seconds in falling numbers with Olifants (97.50 sec), CNR 826 (103.50 sec), SST 347 (187.00 sec), Baviaans (146.75 sec), Krokodil (139.50 sec), Steenbrass (81.50 sec) and Duzi (50.25 sec), but only SST 356 met the requirement for utility grade with164.50 seconds. Olifants, CNR 826, Krokodil and Steenbrass yielded above 1500 kgha^{-1}thus showing good potential under Limpopo conditions. These cultivars could be included in future performance evaluations in Limpopo.

Key words: Bread making quality, evaluation, flour yield, grain yield, wheat

CHAPTER 1

1. GENERAL INTRODUCTION

1.1 Background

Wheat (*Triticum aestivum, L)* is the most important cereal crop produced, consumed and traded in the world today. It serves as an important staple food for many countries (Delorit and Ahlgren, 1967). In South Africa, it ranks first among the winter cereal crops produced and plays an important role in the country's economy. A decrease in wheat production would severely affect the economy and negatively influence the well-being of the inhabitants of South Africa. Wheat is cultivated in various regions of South Africa, with up to 36% of the total annual wheat harvest produced in the summer rainfall area under irrigated conditions (Wheat Board, 1996; Fletcher, 2004).

The final wheat production of 2 million tonnes for the 2011/2012 season, was 40% higher than the previous season's 1,43 million tonnes. This is 5.5% higher than the 10 year average of 1,899 million tonnes (2002/2003 to 2011/2012 seasons). A total area of 604 700 hectares was utilized for wheat production. The average yield increased from 2.56 t/ha in the 2010/2011 season to 3.32 t/ha in the 2011/2012 season. The whole wheat protein average was 11.8% compared to the 12.1% of the 2010/2011 season and 10 year average of 12.0%. The average hectolitre mass was 80.7 kg/hl and was thus slightly higher than the 80.3 kg/hl of the 2010/2011 season. The average mixogram peak time of 3.0 minutes in the 2010/11 season was similar to the previous two seasons (SAGL, 2010).

The grain protein concentration is an important component of the quality of wheat grain (Slafer and Satorre, 1999), and is therefore the most commonly used trait to measure grain quality. This is because it is considered to be of great importance for both human nutrition and bread quality (Slafer and Satorre, 1999). The environmental and genetic variation in grain protein is described by Kramer (1979), and the implications to overcome the negative correlation between grain yield and grain protein concentration were reviewed by Feil (1997). Demands for nutrition take into account high grain protein concentrations, economic and ecological demands for reducing N input without decreasing yield. Farmers everywhere are under increasing pressure to produce wheat grain that meets specific market and nutritional requirements while efficiently utilizing inputs to ensure that economic and environmental standards are met.

Grain yield and grain protein content are important in the production and marketing of wheat. Recent changes in the balance of supply and demand as a result of the new global economy mean that growers must produce grain that matches demand more closely and reliably (Van Lill and Purchase, 1994). In South Africa, wheat is grown under irrigation and rainfed conditions, varying soil fertility status and a wide range of climatic conditions. Breeding programmes are aimed at developing high yielding cultivars with appropriate quality characteristics and adapted to the different areas of production (Purchase, *et al*., 1992; Van Lill and Purchase, 1994).

Yield levels and grain quality play an important part in the successful and economic production and marketing of wheat (SAGIS, 2007). Traditionally, yield was economically the most important factor to the producer. However, as the end user became more demanding with regards to quality of the end product, linked to the possibility of exporting surplus production combined with higher quality standards required, the quality of produced grain became more important. The current grading system for wheat in South Africa includes hectolitre mass and grain protein percentage as part of the quality parameters to determine the marketability of wheat grain. Protein quantity and quality directly affect the flour protein and dough characteristics. Therefore, low protein grain fetches a lower price per tonne, leading to significant economic losses for the wheat producer.

1.2 Problem statement

South Africa is a net importer of wheat and since 2003/04, production has been decreasing while there has been a steady increase in consumption throughout. This has widened the gap that needs to be filled by importing wheat. In the six seasons from 2002/03 to 2007/08 South Africa could only produce about 60% - 70% of the country’s requirement (National Department of Agriculture, 2007). Continuous evaluation of different South African wheat cultivars for yield and quality parameters is imperative to identify cultivars of both high yield and quality that are adapted to the different conditions across the country.

1.3 Motivation of the study

Wheat is a very important cereal crop produced, consumed and traded in South Africa. It is mainly used for human consumption as bread, and the remainder is used as animal feed. There are other non-food uses such as production of ethanol, absorbing agents for disposable diapers, adhesives and industrial uses as starch on coatings.

The evaluation of different South African wheat cultivars will help farmers in South Africa to know which cultivars are best suited for production in their areas, achieving high yield and quality required by millers and bakers alike.

1.4 Aim and objectives of the study

1.4.1 Aim: The aim of this experiment was to evaluate different South African wheat cultivars for quality and yield parameters under irrigation in Limpopo province.

1.4.2 Specific objectives of the study were to:

i) To determine the yield and quality parameters of South African wheat cultivars.

ii) To identify South African wheat cultivars adaptable to Limpopo conditions.

1.5 Hypotheses of the study

i) There are no differences among South African wheat cultivars in grain yield and quality.

ii) Most of the South African wheat cultivars are not adapted to Limpopo conditions.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

Wheat is the second most important grain crop produced in South Africa. It contributed approximately 3% to the gross value of agricultural production during 2004/05 (Agricultural Statistics, 2006). Most dominant wheat produced in South Africa is bread wheat, with small quantities of durum wheat being produced in certain areas, and it is used to produce pasta. In South Africa, wheat is mainly used for human consumption and the remainder is used as seed and animal feed (Agricultural Statistics, 2002). Wheat is cultivated in various regions of South Africa, with up to 36% of the total annual wheat harvest produced in the summer rainfall area under irrigated conditions (Wheat Board, 1996; Fletcher, 2004)

2.2 Extent of wheat production and consumption

Wheat is one of the world's most important grain crops. It is cultivated on all the continents of the world, is easily stored and transported, and is an important nutritional source for humans (Slafer and Satorre, 1999). World production of wheat in 2002 amounted to 572.879 million tonnes (Mt), and together with rice (576.280 Mt) and maize (602.589 Mt), they are the most important grain crops in the world. In South Africa, between 1.27 Mt (1992/93) and 3.49 Mt (1988/89) of wheat is produced annually with an estimated total domestic consumption of 2.781 Mt for the 2005/2006 period (SAGIS, 2007). Total domestic wheat demand was estimated for the 2004/2005 season at 2.879 Mt (Fletcher, 2004). Demand is determined mainly by the need for bread, other processed products and private consumption of flour (FAO, 2002). It is estimated that 1 498000 ha was planted to irrigated crops in South Africa, with 941 000 ha planted to wheat in 2002 (FAO, 2002). The National Crop Estimates Committee listed the proposed area in South Africa to be planted to irrigated wheat in 2006/2007 at around 22% of the total of 885500 ha of cropped land (SAGIS, 2007).

2.3 Production areas in South Africa

Wheat is planted between mid-April and mid-June in the winter rainfall and between mid-May and end of July in the summer rainfall areas. It is produced throughout South Africa with the Western Cape (36%), Free State (30%) and Northern Cape (15%) being the largest producers accounting for 81% of the national production. The other provinces produce less wheat: Limpopo accounts for (3%), Mpumalanga (5%), Gauteng (1%), North West (7%), Eastern Cape (1%), and Kwazulu-Natal (2%) Their contribution is only 19% of the total production. Approximately 20% of the total area planted to wheat is cultivated under irrigation and 80% is under dryland conditions. Wheat in South Africa is produced mainly for human consumption, although small quantities of poorer quality grains are marketed as livestock feed. Approximately, 60% of the total quantity of flour and meal is used for the production of bread (Agricultural Statistics, 2006).

The total annual requirement for wheat in South Africa is 2.7 million tonnes, which is higher than the total production. In order to meet its requirements, wheat is imported from Argentina, United States of America, Germany, Canada, Ukraine and the United Kingdom (ARC, 2009).

2.4 Milling characteristics

2.4.1 Hectolitre mass

According to Nel, *et al*. (1999), wheat quality is positively related to both protein content and quality, and hectoliter mass (HLM),which gives an indication of kernel mass yield, is also of great importance. In South Africa, a minimum HLM value of 77 kg hl^{-1} for wheat is required for bread making purposes. Nel, *et al*. (1998) reported that adequate rainfall and favourable conditions during the grain filling period influence high HLM and that HLM is more affected by growing conditions than cultivar genotype.

Hectoliter mass is the weight of a standard volume of wheat and is a function of the density of wheat (Donelson *et al*., 2002). It is one of the oldest specifications used in wheat grading and serves as a guide to a combination of characteristics, including wheat flour yield (Posner and Hibbs, 2005). Many researchers investigated the effectiveness of HLM as a guide to flour yield (Mangels and Sanderson, 1925; Shuey, 1960; Barmore and Bequette, 1965; Pushman and Bingham, 1975; Dexter *et al*., 1987).

Hectolitre mass, as a density parameter, gives a direct indication of the potential flour extraction of the grain sample. Flour extraction is a critical parameter to the miller as it largely influences profitability. Hectolitre mass is therefore part of the grading regulations that determine the grade of the grain delivered. Although this characteristic is genetically associated with a particular cultivar, it is affected by environmental conditions during the grain filling period (ARC, 2009). In regions where extreme soil water and heat stresses occur during this critical period, when continuous rain events happen during harvest, and when diseases like rust and ear blight infect the crop, losses can be suffered due to downgrading of the grain because of low HLM values. The large price differentials between the B-grades and utility grade can therefore influence cultivar choice if these conditions occur regularly in a specific region. Optimum soil water and temperature conditions during grain filling favour the development of high HLM values (ARC, 2009).

2.4.2 Falling number

Pre-harvest sprouting has little impact on milling characteristics, but it is detrimental to bread quality, because the germination process leads to a high level of α-amylase activity resulting in unacceptable bread due to sticky crumb-texture, which causes a build-up on slicer blades and therefore bread cannot be cut effectively with mechanical slicers. Sprouting damage also causes a more open coarse crumb structure. Loaf volume is sometimes not affected by sprouting damage, but higher loaf volumes could be obtained due to more rapid gas production during the fermentation process (Edwards *et al*., 1989).

Falling number is an indirect measurement of α-amylase activity in samples to determine if pre-harvest sprouting has occurred or not (Hagberg, 1960; Kaldy and Rubenthaler, 1987; Posner and Hibbs, 1997). Falling number is the time, in seconds (s), it takes a viscometer stirrer to fall through a hot aqueous flour gel after it was stirred for 60 seconds (Kaldy and Rubenthaler, 1987; Posner and Hibbs, 1997). High concentrations of α-amylase break starch down and result in excessive sugars, which in turn result in bread with sticky crumbs and poor texture. The sticky crumb also causes problems during mechanical cutting of the bread that is unwanted by the industry (Chamberlain *et al*., 1981; Posner and Hibbs, 1997). Dowell *et al*. (2008) reported that flours exhibiting low falling numbers also show a decrease in their water-absorbing capacity, which might have an effect on loaf volume.

An acceptable falling number for bread production is between 220s and 350s. Falling numbers below 150 s result in sticky bread and falling numbers above 350 s result in bread with a dry crumb and diminished loaf volumes (Perten, 1964) and in classification of potential new cultivars in South Africa, falling numbers should be higher than 220 s and it should not be more than 15% lower when compared to the biological standard (SAGL, 2010).

2.4.3 Flour yield

Flour yield (flour extraction rate) is the percentage of flour obtained from a given amount of wheat. Flour yield is important because genotypes yielding higher volumes of flour are more profitable to millers (Bass, 1988). Conditioning of wheat prior to milling is necessary in order to limit bran contamination of flour and to ensure easier separation of endosperm and bran (Marais and D'Appolonia, 1981). Steve *et al*. (1995) reported flour yield as a complex trait affected by factors influencing the ease of endosperm-bran separation. Such factors include kernel hardness, endosperm-bran adherence, kernel plumpness and the endosperm-bran ratio. Pumphrey and Rubenthaler (1983) reported that poor growing conditions result in shrivelled kernels that lead to lower endosperm-bran ratios and therefore lower flour yields. Ohm *et al*. (1999) observed positive correlations among flour yield, kernel hardness, HLM and kernel density. Labuschagne *et al*. (1997) reported that softer wheat delivers lower flour yields.

Souza *et al*. (1993) observed a correlation between flour yield and flour protein content. Van Lill and Smith (1997) found that genotype as well as environment had an effect on flour yield while Bergman *et al*. (1998) found that genotype has a significant effect on flour yield. During the classification of a new cultivar in South Africa, flour yield of a potential breeding line should not be more than 1.5% lower compared to the biological standard (SAGL, 2010).

Flour extraction yield (%) refers to the process whereby the endosperm is separated from the bran. Flour extraction yield (FY) provides a useful measure of milling efficiency and the variation in flour extraction yield results from inherent cultivar differences in the amount of the endosperm and the interaction between aleurone cells and the innermost cell of the endosperm. On average flour yield that ranges between 70 and 76% for hard and soft wheat cultivars is acceptable for South African milling purposes (Nel, *et al*., 1999).

2.4.4 Flour quality

Wheat flour quality is determined by subjecting the flour to different quality tests. Most important are those tests performed with rheological devices, e.g. Mixograph, Farinograph, Alveograph and Extensiograph to measure the rheological characteristics of the dough. Dough rheology is based upon the unique property of wheat dough,namely its viscoelasticity (Mailhot and Patton, 1988). Flour obtains its property from gluten that consists of the two proteins, namely; glutenin and gliadin. Glutenin is responsible for strength and cohesiveness of gluten whilst gliadin contributes towards the extensibility trait.

Rheological methods characterize gluten by measuring characteristics such as extensibility and resistance to extension of the dough, hydration time, mixogram development time and tolerance to breakdown at a predetermined consistency during mechanical mixing (Mailhot and Patton, 1988).The Chopin Alveograph or Extensiograph are used to measure the resistance to extension and the extensibility of the fully developed dough (Mailhot and Patton, 1988). The Brabender Farinograph and Mixograph measure properties such as optimum mixing time and stability of the dough during the mixing process.

Quantitative quality analysis on Flour include protein quantification using the protein combustion method or near infrared (NIR) spectroscopy, moisture analysis using the oven method or NIR spectroscopy, starch damage, α-amylase activity with the Hagberg falling number method and colour determination with the Satake Colour Grader (SAGL, 2001).These methods are commonly used in the South African cereal industry.

2.4.5 Flour milling

According to Bass (1988), wheat is delivered to the mill by road or railway transportation. Once at the mill, it is graded according to the regulations, cleaned and stored in silos according to grade under controlled conditions. It is further conveyed to intermediate storage bins from which it can be blended with other grades to obtain desired blend or grist. A grist or blend of wheat is usually made up of different grades of wheat in order to obtain a required quality in the flour. Blending in most cases is based on flour protein and different levels of different grades of wheat are blended to obtain the required protein content required for the end product.

Ohm *et al*. (1999) reported that cleaned wheat from storage bins is conditioned to 15.5-16% moisture content with the appropriate amount of water for 8-24 hours to prepare the wheat for milling. The wheat is then conveyed to the mill to undergo the grinding process, which is basically performed with three sets of rolls, break rolls, sizing rolls and reduction rolls (Bass, 1988). During this process the kernels are broken, the endosperm scraped off from the bran and the endosperm reduced or ground to flour. After each grinding process, the material is sifted to remove the flour. At the end of the milling process, the original wheat kernels are separated into three types of material, namely; pure endosperm, composites of endosperm plus bran and relatively pure bran (Bass, 1988). It is essential to recover as much endosperm as possible from the kernel in order to conduct an efficient milling process.

2.4.6 Grading and quality

Currently, according to the law on agricultural products, there is only one bread wheat class with four grades which are determined according to the protein content of the grain, the HLM and falling number. These are B1(Minimum protein 12% moisture basis, Minimum HLM 76 kg/hl and Minimum falling Number of 220 (seconds);B2 Minimum protein 11% moisture basis, Minimum HLM 77 kg/hl and Minimum falling Number of 220 (seconds); B3 (Minimum protein 10% moisture basis, Minimum HLM 74 kg/hl and Minimum falling Number of 220 (seconds); and B4 (Minimum protein 9% moisture basis, Minimum HLM 72 kg/hl and Minimum falling Number of 200 (seconds). Hectolitre mass and protein content are largely determined by the area conditions which include management practices. Hectolitre mass, as a density parameter, gives a direct indication of the potential flour extraction of the grain sample. The flour extraction is a critical parameter for the miller since it has an influence on the profitability. A high protein content as well as protein quality is necessary to ensure that the baker can successfully bake bread that meets consumer requirements (Anonymous, 2006).

In order to grade wheat, certain characteristics have to be evaluated. The analysis is done by a professional wheat grader who evaluates characteristics such as HLM, protein content, moisture content and α-amylase activity, as determined according to Hagberg Falling number procedure (Bass, 1988 and AACC, 2004). Other evaluations include visual determination of damage from heat and insects, as well as the presence of immature and sprouted kernels, foreign materials, other grains and live insects (Anonymous, 1998). Wheat kernels are also inspected for the presence of possible fungal growth. Fungi can grow on the wheat kernel during growth in the field or during storage due to improper storage conditions. The wheat grader must also inspect a 10kg sample of wheat for noxious seeds, i.e *Convolvulus spp* and *Ipomoea purpurea* which are harmful to humans when consumed (Anonymous, 1998).The grading characteristics as evaluated for each consignment of wheat, must comply with specified criteria in order to be allocated a certain grade, the higher the grade, the better the quality of the wheat and the higher the remuneration.

2.4.7 Grain protein content and quality

Grain protein content has been found to increase with the amount of applied nitrogen whether or not a yield increase resulted (Metho *et al*, 1997). Grain protein content affects the flour yield and bread making quality of wheat. Grain protein content is genetically and environmentally controlled, and may vary with cultivars, soil fertility, location and climate. Genotype and environment interaction plays a major role in determining grain protein content level. The interface between actual field nutrient status, cultivar productivity and product quality is important for South Africa where the price of wheat grain is determined on the basis of grain protein content and bread making quality. Wheat grain contains carbohydrates (69%), protein (14%), calcium (43%), niacin (4.6%), fat (2.2%), thiamin (0.57%) and riboflavin (0.12%).

Wheat yield and grain protein content have been increased through breeding and selection as independent traits (Jenner *et al.,* 1991).

2.5 Yield components

Grain yields vary as a result of combined effects of ears per unit area, grains per ear and kernel mass. These yield components vary widely with cultivars, moisture supply, soil fertility level and other growth limiting factors. Increases in the various yield components as a result of breeding, increased availability of nitrogen, or improved soil fertility status, have been reported by many researchers (Donald, 1968; Nass, 1973, Darwinkel, 1978; Nerson, 1980 and Briggs, 1991).

The relative contribution of main stems and tillers as well as the relative contribution of first, second and third kernels in the spikelet, to grain yield and grain protein content, are seldom quantified. This may be important to South Africa where late maturing tillers are reportedly affecting grain yield and wheat quality (Wheat Board Technical Report, 1990/95).

2.6 Genotypic difference in Wheat cultivars

The high yielding dwarf and semi-dwarf wheat genotypes released during and after the Green Revolution were selected to respond to high N inputs. Dhugga and Waines (1989) found differences among wheat genotypes for biomass, N accumulation before and after anthesis at the highest soil N level. At this level, some genotypes either stopped accumulating or showed a net loss of biomass N between anthesis and maturity, which appeared to be associated with superior pre-anthesis N accumulation capacity and reduced grain N yield of such genotypes.

Van Sanford and MacKown (1987), working with soft red winter wheat detected significant cultivar differences in N remobilization from the flag leaf, peduncle, and lower culm to the developing grain. The proportion of N accumulated by the ear ranged among cultivars from 51 to 91%. They also found 83% of the total above ground N at maturity to be already present in the plant at anthesis. An analysis of cultivar differences indicated that all the cultivar variation in final ear N could be associated with variation in total N uptake. Higher post-anthesis N uptake was associated with lower N utilization efficiency, higher grain N concentration, and lower grain yields (Van Sanford and Mackown, 1987).

Higher yielding wheat cultivars are generally shorter, earlier maturing and often have more tillers and ears than earlier released cultivars (Slafer and Satorre, 1999). The increased yields with modern cultivars are largely attributed to greater distribution of above ground biomass to the grain, i.e. a higher Harvest Index (HI). Harvest index is correlated positively with grain yield and negatively with biological yield. The HI and grain growth rate are also higher and a value of 50-60 has been estimated (Simmons, 1987). It has been shown that the increases in wheat grain yield from previous breeding efforts were almost exclusively associated with parallel increases in HI (Slafer and Satorre, 1999). The yield improvement was associated with a decline in height caused by the introduction of the *Rht* semi-dwarf genes into wheat germplasm (Simmons, 1987).

2.7 Wheat performance across agro-ecozones

The three main wheat producing provinces are Western Cape (winter rainfall), Free State (summer rainfall) and the Northern Cape (irrigation). Other provinces are Limpopo (irrigation) and North-West (mainly irrigation). The local production is not sufficient for domestic requirements and South Africa has to import wheat to meet its domestic consumption. The Western Cape Province produced 675 750 tonnes and the Free State province followed with 551 250 tonnes. These two provinces were responsible for 64% of the total wheat produced in 2011/2012 season. The Northern Cape produced 281 400 tonnes, Limpopo 170 500 tonnes and North West 125 400 tonnes (SAGL, 2010).

The yield in the main production areas ranged from 6.7 tonnes per hectare (t/ha) in the Northern Cape (irrigation area) to 2.6 t/ha in the Western Cape and 2.5 t/ha in the Free State. In the Western Cape and Free State, yields increased from the 2.1 t/ha and 1.9 t/ha averaged during the previous season (2009/2010). Gauteng gave a yield of 6.4 t/ha, followed by North West and Mpumalanga both with 5.7 t/ha. Limpopo averaged a yield of 5.5 t/ha, KwaZulu-Natal 5.1 t/ha and the Eastern Cape 4.1 t/ha.

The highest percentage of samples analysed at Pretoria by South African Grain Laboratory (32.1%) had protein contents ranging from12.0-12.9%. The second highest percentage of 29.6% was for protein contents 11.0 - 11.9% and thirdly 17.3% for 10.0-10.9% protein content. The other Summer rainfall and Irrigation areas (Mpumalanga, Gauteng and Limpopo regions) had the highest average protein content of 12.1% closely followed by the Summer rainfall area (Free State) with 12.0%. The winter rainfall area and Irrigation areas both averaged protein contents of 11.6%. The average HLM values for the Irrigation areas (81.5 kg/hl) and other Summer rainfall and Irrigation areas (81.7 kg/hl) compared well. The winter rainfall area had an average HLM of 80.9 kg/hl, with the Free State (summer rainfall area) averaging the lowest of 79.8 kg/hl, which will still grade as Grade 1 wheat. (SAGL, 2010)

The weighted average falling number was 387 seconds. Eleven samples gave falling number values of less than 250 seconds and of these, seven had falling number values lower than 220 seconds. These samples were all from the Free State. The weighted mixogram peak time on flour from the Quadromat mill averaged 3.0 minutes, similar to the ten year average (2.9 minutes) and equal to the weighted mixogram peak time of the flour from the Buhler mill. The weighted average Buhler extraction was 74.1%, with a weighted average Kent Jones colour of -2.8 KJ. The farinogram had weighted average water absorption of 61.3% in 2011/2012 production season and 63.2% the previous season (2010/2011) and a weighted average development time of 4.1 minutes and 5.5 minutes in the previous season (2010/2011). The weighted average alveogram strength was 35.0 cm^2 and the weighted average P/L value 0.89 2011/2012 production season and 36.2 cm^2 and 1.29 the previous season, respectively (SAGL, 2010).

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Study site

The experiment was conducted during 2011 winter season at University of Limpopo experimental farm (Syferkuil) in Limpopo province situated at the latitude of 23° 51' 0S, longitude of 29° 41' 60 E and altitude of 1324 m above sea level. The soil type is sandy loam texture, the area usually receives mean annual rainfall of 500 mm and daily temperature ranges from 18 to 35°C from October to March and 25ºC or lower from April to September (Mpangane *et al*., 2004).

Table 3.1.1: Monthly minimum and maximum temperature (°C) and rainfall (mm).

Months	Temperature (°C)		Rainfall (mm)
	Min	Max	
May	7.11	24.7	6.86
June	1.16	22.17	2.29
July	0.56	20.7	0
August	3.47	22.82	18.54
September	7.71	27.67	0
October	12.56	28.18	60.46

3.2 Research design and treatments

Eight treatments consist of eight wheat cultivars, namely; Olifants, CNR 826, SST 347, Baviaans, Duzi, Steenbrass, SST 356 and Krokodil were laid out in a randomized complete block design (RCBD) with four replications. The dimensions of experimental plot was 12 m × 48 m with intra and inter-row spacings of 5cm and 17cm, respectively. Each plot had 12rows. Two outer rows constituted guard rows. The harvest area was 5 m × 2.72 m. A compound fertilizer 3:1:0 (28) was applied as basal dressing at a rate of 200 kg/ha. Irrigation was done twice a week using sprinkler system for three hours and was stopped after maturity stage and weeding was done 3 weeks after emergence. The date of planting was 20 May 2011 and planting was done using a winterstieger planter. Harvesting was done using a winterstieger harvester (A-4910 Ried/ Australia, Fabr nr 150/494. Type Nm, Baujahr 1985).

3.3 Data collection

The following parameters were measured.

3.3.1 Phenological data

(a) Date of planting

(b) Date of emergence

(c) Number of days to flowering

(d) Number of days to physiological maturity

3.3.2 Yield components

(a) Number of reproductive tillers/m^2

(b) Tiller height

(c) Grain yield/plot

The number of tillers were counted from an area measured with a measuring tape in each plot.

3.4 Laboratory methods for quality analysis.

Treatment samples were assessed for grain quality at the Agricultural Research Council-Small Grain Institute, Bethlehem Quality laboratory.

3.4.1 Hectolitre mass (AACC method 55-10)

Hectolitre mass was performed using a two-level funnel. Hectolitre mass was calculated by dividing the obtained mass by five and was expressed in kg hl^{-1}(AACC, 2000).

3.4.2 Falling number (AACC method 56-81B)

Falling number is the measurement of alpha-amylase activity by means of the time it takes a metallic stirrer to fall through a flour-water suspension while the suspension is being heated in a boiling water-bath. The altitude-corrected values were used (AACC, 2000).

3.4.3 Protein content (AACC method 46-30)

Crude protein content was determined on whole meal as well as white flour with a LECO FP-2000 (the Dumas combustion method). Total nitrogen (N) was measured by thermal conductivity detection (combustion at high temperature in pure oxygen set N free). Total N was multiplied by factor 5.7 to express protein content of the whole flour as well as white flour on an “as is” basis. To express protein content (whole flour as well as white flour) on a 14% moisture base, moisture content was determined by following AACC procedure 44–15A, using a Brabender moisture oven. Ten grams of flour of each sample was weighed into a moisture dish and dried at 130°C for 1 h in the Brabender moisture oven. After 1 h, the moisture content was obtained directly from the graduated scale connected to the weighing arm of the Brabender moisture oven by weighing the samples, The following formula was applied to express protein content on a 14% Moisture basis:

= (Protein, as is x 86)/ (100 – moisture content)

3.4.4 Vitreous kernels

Vitreous kernels were determined by using a special cutter, a farinator, to cut 50 kernels longitudinally. Kernels were visually scored to determine the percentage vitreous kernels. Translucent kernels scored two, floury kernels scored zero, and kernels that appeared half-translucent half-floury, scored one.

3.4.5 Flour colour (AACC method 14-30)

Flour colour was measured on a Martin series III colour grader. The influence of the branny material present in the flour sample was measured at a wavelength of 540nm. The higher the expressed value, the darker the flour colour, whereas negative values indicated whiter (brighter) flour. Flour colour expressed on a 76% flour yield basis is determined as follows:

For each 1% flour yield under 76%, 0.4 Kent Jones (KJ) units are added to the measured FCL, therefore flour colour worsens (getting darker), and for each 1% flour yield above 76%, 0.4KJ units are subtracted from the measured FCL, therefore colour improves (less dark). This is done in order not to discriminate against higher flour-yielding cultivars that will result in darker flour colour (AACC, 2000).

3.4.6 Farinograph analyses (AACC method 54-21)

The procedure for constant flour weight was applied. Due to small sample sizes, only farinogram water-absorption (ABS) was determined on 300g of white flour. Water-absorption is the volume of water required for dough to reach a definite consistency, namely 500 Brabender units. The volume of water added is expressed as a percentage of the flour mass and it is reported on a 14% moisture basis (AACC, 2000).

3.4.7 Break flour yield (AACC method 26-21A)

Wheat samples were conditioned for 18 h prior to milling, according to AACC procedure 26-95 (2000), namely experimental milling: temper table. Wheat samples were milled on a laboratory, pneumatic mill, Bühler model MLU-202. The percentage of break flour yield was determined for each sample by using the following formula (Bass, 1988).

$$\% \text{ BFLY} = \left(\frac{\text{Total break flour obtained}}{\text{Total (flour + bran)}} * 100 \right)$$

3.4.8 Alveograph analyses (AACC method 54-30A)

Chopin alveograph analyses were performed on 250g of white flour, where a 2.5% NaCl solution was added according to a sample's moisture content. Moisture content of the white flour was determined by following AACC procedure 44 – 15A, using a Brabender moisture oven.

Parameters computed by an Alveolink and used for this study, were dough strength (W-value), P-value, L-value and P/L-value. P-value is obtained by multiplying the maximum curve height with a constant factor of 1.1. According to AACC, official methods handbook, the P-value is an indication of the resistance of the dough to extension. The L-value is the curve length, measured along the base line and it indicates dough extensibility. The P/L-value is the ratio between stability and extensibility (distensibility).

3.4.9 SDS-sedimentation volume

SDS-sedimentation volumes were determined with the AACC 56-70 (AACC, 2000) method, with slight modifications. Results were reported in millilitre on flour sample sizes of 5 g. Gluten proteins are known to expand in the presence of lactic acid and SDS and the obtained sedimentation volumes gave information about both protein quantity and quality (AACC, 2000).

3.4.10 Wet gluten content (AACC method 38-12A)

Wet gluten content was measured using a Glutomatic system where 10 g of flour was washed with 2% NaCl solution and centrifuged. Wet gluten content was determined as follows:

$$\text{Wet gluten content, \% (14\% moisture basis)} = \frac{\text{Total wet gluten (g) X 86}}{\text{100 - \% sample moisture}}$$

3.4.11 Data analysis

Data obtained were subjected to analysis of variance (ANOVA) using STATISTIX 9.0 for windows (Analytical Software, Tallahassee, Florida, USA 2008) while the mean separation of treatments was determined using Tukey at 5% significance level.

CHAPTER 4

4. RESULTS

Results for the trial of 2011 season were collected during the growing season at University of Limpopo experimental farm (Syferkuil). The treatment samples were assessed for grain quality at ARC-SGI Bethlehem Quality laboratory.

The wheat cultivars evaluated differed significantly ($P \leq 0.01$) in days to flowering (Table 4.1). Cultivars such as Krokodil and Steenbrass flowered earlier whilst cultivars SST 356 took the longest days to flower. The other cultivars were intermediate. Krokodil and Steenbrass which were the first cultivars to flower also reached physiological maturity earlier in contrast with SST356 which was the last to reach physiological maturity. Krokodil was significantly ($P \leq 0.01$) taller than all except Steenbrass.SST347 was significantly ($P \leq 0.01$) shorter than all other cultivars at 38.50 cm. All cultivars except SST 347 were above 45 cm in height. Duzi, SST 347 and SST 356 were significantly ($P \leq 0.05$) higher in number of tillers per plant than all the other cultivars, with Krokodil being the lowest among all cultivars at 10 tillers per plant whilst others had intermediate values ranging from 12 to 14 tillers/plant. CNR 826 was significantly ($P \leq 0.01$) higher in grain yield than all the other cultivars except Olifants, Steenbrass and Krokodil. SST 347 was significantly lower in grain yield than all the other cultivars except SST 356 at 311.1kgha^{-1} (Table 4.1). All cultivars except SST 347 and SST 356 were above 1000kgha^{-1}in grain yield. SST 347 was significantly ($P \leq 0.01$) shorter in plant height but higher in number of tillers and also low in grain yield per hectare. Krokodil was significantly ($P \leq 0.01$) higher in plant height at 61.75 cm and significantly ($P \leq 0.05$) lower in number of tillers per plant but higher in grain yield (1547.3 kgha^{-1}) than the control which had 1393.8 kgha^{-1} (Table 4.1).

Table 4.1: Phenological development, plant height, yield and yield components of different wheat cultivars under irrigation at Syferkuil, Limpopo.

Cultivars	Days to flowering	Days to physiological maturity	Plant height (cm)	Number of tillers per plant	Grain Yield $kgha^{-1}$
Olifants	95^{abc}	155^{abc}	49.50^{cd}	12^{bc}	1825.3^{ab}
CNR 826	91^{cd}	151^{cd}	53.25^{bc}	14^{abc}	2371.9^{a}
SST 347	96^{ab}	156^{ab}	38.50^{e}	19^{a}	311.1^{d}
Baviaans	91^{d}	151^{d}	45.75^{d}	12^{bc}	1400.1^{bc}
Krokodil	91^{d}	151^{d}	61.75^{a}	10^{c}	1547.3^{ab}
Steenbrass	91^{d}	151^{d}	57.75^{ab}	13^{abc}	1957.3^{ab}
SST 356	98^{a}	158^{a}	47.25^{cd}	17^{ab}	469.8^{cd}
Duzi (control)	93^{bcd}	153^{bcd}	49.50^{cd}	19^{a}	1393.8^{bc}
Significance	**	***	**	*	**
$Tukey_{0.05}$	3.77	3.94	6.72	6.39	956.48
CV (%)	2.76	1.75	9.07	30.57	46.14

N: B. Means followed by the same letter in a column are not significantly different at P≤0.05, Tukey, CV= coefficient of variation, *, **and *** = significantly different at P≤0.05, 0.01and 0.001,respectively.

From Table 4.2, Cultivar CNR 826 was significantly (P≤0.001) higher than all the other cultivars in hectolitre mass (HLM) with a mean value of 75.13 $kghl^{-1}$whilst cultivars Olifants and Duzi were the lowest with mean values of 72.20 $kghl^{-1}$and 72.60 $kghl^{-1}$,respectively and were not significantly different from each other. All the other cultivars had intermediate values. Cultivars SST 347 and SST 356 had the highest numbers of vitreous kernels at 75.50 and 64.75%, respectively, but were not significantly different from each other whilst the rest of the cultivars had vitreous kernels of 50% on average. SST 347 had the highest falling number in seconds but was not significantly different from SST 356 and Krokodil. Steenbrass showed lowest falling number as compared to the rest of other cultivars. However, Steenbrass had highest peak time as compared to other cultivars. All cultivars were not significantly different in break flour yield, flour extraction and flour protein content %. Steenbrass, Krokodil, Olifants and SST 347 was significantly (P≤0.01) higher in peak time than all the other cultivars except CNR 826, Baviaans and SST 356. Duzi was significantly lower in peak time than all the other cultivars except CNR 826, Baviaans and SST 356 at 2.60min (Table 4.2). All cultivars except Duzi and SST 356 were above 3.00min in peak time.

Table 4.2: Evaluation of grain quality and flour yield parameters on different wheat cultivars under irrigation at Syferkuil, Limpopo.

Cultivars	Hectolitre mass (kg hl^{-1})	Vitreous kernels (%)	Falling number (sec)	Break flour yield (%)	Flour extraction (%)	Flour protein content (%)	Peak time (min)
Olifants	72.20^{c}	50.00^{b}	97.50^{cd}	21.38	69.08	9.73	3.85^{a}
CNR 826	75.13^{a}	50.75^{b}	103.50^{bcd}	21.25	73.40	10.85	3.50^{ab}
SST 347	73.85^{b}	75.50^{a}	187.00^{a}	24.35	69.88	11.48	3.75^{a}
Baviaans	73.68^{b}	50.50^{b}	146.75^{abc}	23.25	71.03	10.25	3.23^{ab}
Krokodil	73.60^{b}	50.00^{b}	139.50^{abcd}	25.30	71.93	9.63	3.95^{a}
Steenbrass	73.73^{b}	51.00^{b}	81.50^{d}	20.95	69.18	10.60	3.95^{a}
SST 356	73.55^{b}	64.75^{a}	164.50^{ab}	22.60	68.73	10.78	2.95^{ab}
Duzi (control)	72.60^{c}	50.25^{b}	105.25^{bcd}	23.03	70.08	10.58	2.60^{b}
significance	***	***	***	ns	ns	ns	**
Tukey$_{0.05}$	0.94	10.99	65.13	-	-		1.11
CV (%)	0.54	8.36	21.42	9.07	3.93	11.36	13.46

N: B. Means followed by the same letter in a column are not significantly different at P≤0.05, Tukey, CV= coefficient of variation,**and *** = significantly different at P≤ 0.01, and 0.001 respectively.

Wheat cultivars evaluated, including control (Duzi), were similar in water absorption (Table 4.3). Baviaans was significantly (P≤0.001) higher in dough strength than all cultivars except for Duzi, SST 347 and SST 356. Steenbrass was significantly (P≤0.001) lower than all the other cultivars except Olifants and Krokodil at 32.68% (Table 4.3). All cultivars except Steenbrass were above 34% in dough strength. They varied from 44.5% for Baviaans to 33.95% for Krokodil. The wheat cultivars evaluated differed significantly (P≤0.001) in dough stability. Olifants (66%) and Baviaans (66.75%) were the highest in dough stability whilst cultivar Steenbrass was the lowest in dough stability, together with Duzi at 48% and 51%, respectively. The other cultivars ranged between 55.25 and 57.25%.

The wheat cultivars evaluated differed significantly (P≤0.001) in dough distensibility. Duzi (control) was the highest in dough distensibility at 172.25% whilst cultivar Olifants was the lowest in dough distensibility at 89.0%. All the other cultivars were intermediate and ranged from 99.25% to 126.5%. The wheat cultivars evaluated differed significantly (P≤0.001) in P/L value. Olifants was the highest with P/L mean (0.76) value whilst Duzi which was the control being the lowest with P/L mean value of 0.29 but all the other cultivars were intermediate between the two and were not significantly different from each other. SST 347 was significantly (P≤0.01) higher in wet gluten content than all the other cultivars except CNR 826, Baviaans, Duzi, Steenbrass, SST 356, and Krokodil which were not significantly different from control (Duzi). Olifants was significantly (P≤0.01) lower than all the other cultivars at 24.55% (Table 4.3). All cultivars were above 24% in wet gluten content. Cultivar SST 347 was significantly (P≤0.05) higher in sedimentation volume than SST 356. All the other cultivars did not differ in sedimentation value and ranged from 95.0 to 97.25ml

Table 4.3: Evaluation of bread making qualities of different wheat cultivars under irrigation at Syferkuil, Limpopo.

Cultivars	Water absorption (%)	Dough strength (%)	Dough stability (%)	Dough distensibility (%)	P/L-value	Wet gluten content (%)	Sedimentation volume (ml)
Olifants	56.48	34.98^{cd}	66.00^{a}	89.00^{c}	0.76^{a}	24.55^{b}	96.75^{ab}
CNR 826	55.74	38.78^{bc}	57.25^{b}	126.50^{b}	0.47^{b}	27.05^{ab}	95.50^{ab}
SST 347	54.48	41.63^{ab}	57.13^{b}	121.50^{b}	0.50^{b}	32.13^{a}	98.25^{a}
Baviaans	56.17	44.50^{a}	66.75^{a}	123.00^{b}	0.51^{b}	27.25^{ab}	97.25^{ab}
Krokodil	55.23	33.95^{cd}	55.25^{bc}	99.25^{bc}	0.56^{b}	24.85^{ab}	96.75^{ab}
Steenbrass	54.50	32.68^{d}	48.00^{d}	120.50^{b}	0.42^{b}c	26.53^{ab}	95.50^{ab}
SST 356	54.48	40.63^{ab}	57.13^{b}	121.50^{b}	0.50^{b}	31.90^{ab}	90.75^{b}
Duzi (control)	56.96	40.98^{ab}	51.00^{cd}	172.25^{a}	0.29^{c}	31.10^{ab}	95.00^{ab}
Significance	ns	***	***	***	***	**	*
$\text{Tukey}_{0.05}$	-	5.49	5.24	28.04	0.14	7.54	6.86
CV (%)	2.91	6.02	3.85	9.71	12.01	11.30	3.02

N:B. Means followed by the same letter in a column are not significantly different at P≤0.05,Tukey, CV= coefficient of variation,*, ** and *** = significantly different at P ≤0 05, 0.01 and 0.001, respectively

There was a negative and linear relationship between number of tillers per plant and grain yield, and the number of tillers per plant accounted for 36.8% variation in yield (Fig 4.1). Number of days to physiological maturity was positively and linearly related to the number of day to flowering (Fig 4.2).

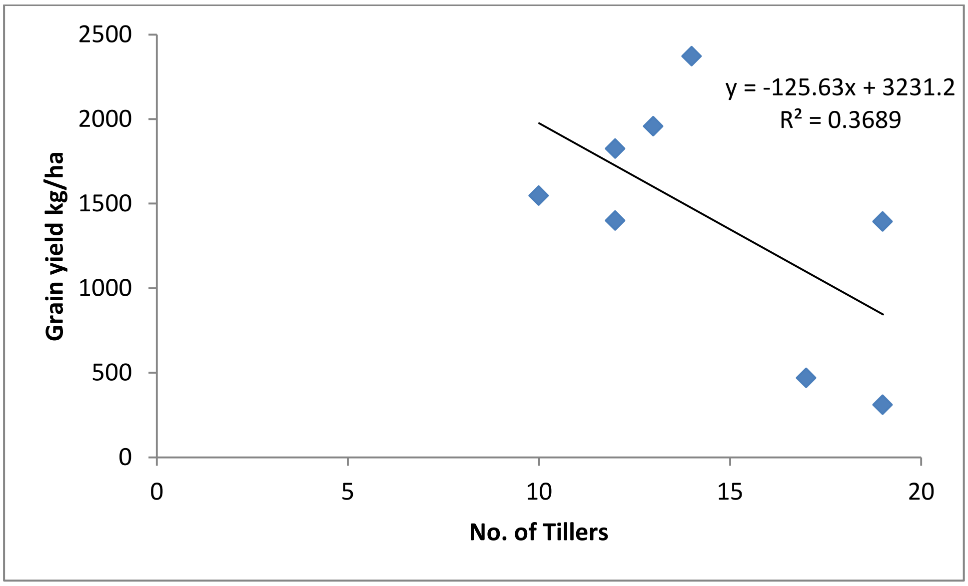

Fig 4.1: Relationship between grain yield and number of tillers per plant.

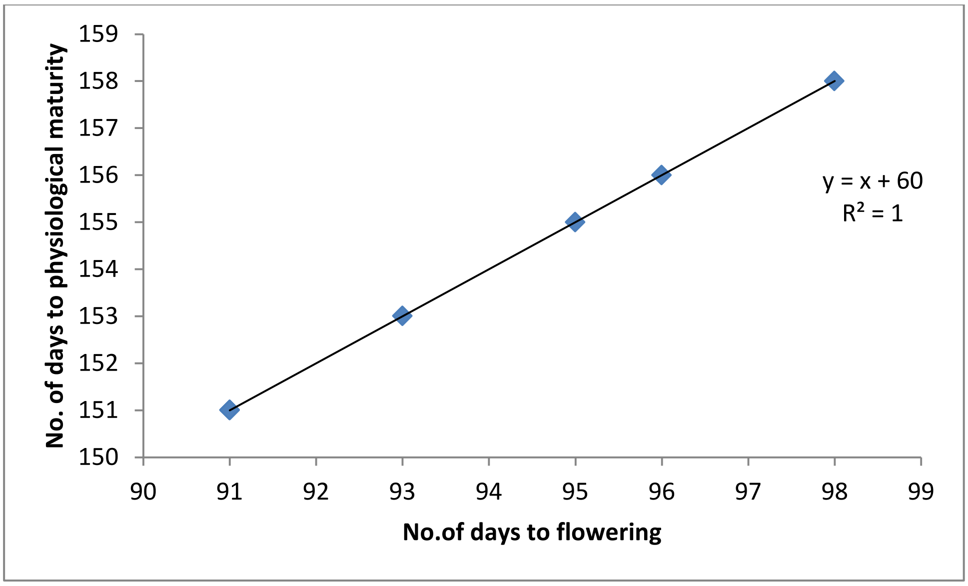

Fig 4.2: Relationship between number of days to physiological maturity and number of days to flowering.

CHAPTER 5

5. DISCUSSION

5.1 Wheat phenology and growth

Mean square showed significant differences in days to flowering, in cultivars used. Krokodil was the first to produce flowers with a mean value of 91 and produced flowers before control (Duzi) which flowered two days after Krokodil (Table 4.1). The other wheat cultivars took approximately 90 to 97 days to 50% flowering days after planting (DAP). Krokodil was also the first to reach 50% physiological maturity with a mean value of 151 DAP and it took approximately 60 days from heading to physiological maturity. The control took approximately three days more to reach physiological maturity after Krokodil has matured. It means that with the increase in days to flowering, there was a significant increase in days to physiological maturity. These results suggest that the genotypes that produced flowers earlier were likely to mature earlier and *vice versa (*Ahmad and Chaudhry, 1987). There was a positive and linear relationship between number of days to flowering and number of days to physiological maturity at R^2 =1. Ahmad *et al.* (1980) reported similar results that coefficient of genotypic correlation showed highly significant and positive association of days to flowering with days to maturity.

All the cultivars matured within 150-157 days. This implies that under Syferkuil conditions planting in late May is ideal as it will ensure that the cultivar will still be in the vegetative stage in the June-early July period of high frost probability, and mature in October ahead of the onset of summer rains. Any of the tested cultivars can therefore be successfully grown at Syferkuil and surrounding environment.

In this study, the wheat cultivars evaluated were significantly different in plant height. Krokodil was the tallest with a mean value of 61.75 cm and was 12.25 cm taller than the control (Duzi) which was 49.50 cm in height. Krokodil was approximately 22.02% taller than the control. The height of the other cultivars ranged between 38.50 cm and 61.75 cm. Increase in the plant height is usually associated with lodging in most of the times. However, this is not always applicable. In a study conducted by (Narang *et. al*., 1994) wheat variety called Baviacora, a tolerant variety despite having 103 cm plant height recorded low lodging (6%) due to low number of tillers/m^2 (413). On the contrary, Pastor with similar height (101 cm) was prone to lodging (55%) due to higher number of tillers /m^2 (482). In this study, the wheat cultivars were not affected by lodging, implying that they are amenable to combine harvesting.

5.2 Yield components and grain yield

There were significant differences in number of tillers per plant with Duzi (control) having the highest number of tillers with a mean value of 19 tillers per plant. CNR 826 had the lowest number of tillers compared to the control but with the highest grain yield of 2371.9 kgha^{-1} followed by Steenbrass, Olifants, and Krokodil with grain yield mean values of 1957.3 kgha^{-1}, 1825.3 kgha^{-1} and 1547.3 kgha^{-1}respectively (Table 4.1). CNR 826 achieved 51.95% higher grain yield but had 32.05% lower number of tillers per plant than the control. A negative relationship was observed between grain yield and number of tillers per plant at R^2 =0.368. Future research should count the number fertile tillers to see the relationship between number of tillers and grain yield. The results are similar to those of Gallagher and Biscoe (1978), who reported that the total number of tillers eventually developed will not all produce grain bearing heads. The number of tillers a plant develops is not a constant and will vary because of two factors, namely; genetic potential and environmental conditions and will therefore affect grain yield.

The cultivars evaluated in the trial yielded between 311 and 2372 kgha^{-1}. Olifants, CNR 826, Krokodil and Steenbrass yielded above 1500 kgha^{-1}thus showing good potential under Limpopo conditions. These cultivars could be included in future performance evaluations in Limpopo. SST 347 and SST 356 yielded below 500 kgha^{-1} and should be excluded from future trials as they exhibited extremely low potential. The relatively high CV values obtained for grain yield suggest the need to increase replications in future trials. One of the weakness of the current study is failure to measure harvest index (HI), which has often been closely linked to yield.

5.3 Grain and milling characteristics of wheat

Hectolitre mass is an important wheat grading factor (Donelson *et al*., 2002) and some cultivars might have the ability to always have higher HLM than others grown under similar conditions. HLM is affected by growing conditions as well as genetic factors (Bordes *et al*., 2008). HLM values obtained ranged from 72.20 kghl^{-1} to 75.13 kghl^{-1}. The required grade met in HLM was B4 with 72.20 kghl^{-1} (Olifants) and 72.60 kghl^{-1} (Duzi) and protein content of 9.73% (B4) and 10.58% (B2) respectively. All the other cultivars fall under B3 with 75.13 kghl^{-1} (CNR 826), 73.85 kghl^{-1} (SST 347) 73.68 kghl^{-1} (Baviaans), 73.73 kghl^{-1} (Steenbrass), 73.55 kghl^{-1} (SST 356) and 73.60 kghl^{-1} (Krokodil) with the protein contents of 10.85% (B2), 11.48% (B2), 10.25% (B3), 10.60% (B2) ,10.78% (B2) and 9.63% (B3) ,respectively. Only CNR 826, SST 347, Baviaans, Krokodil, SST 356 and Steenbrass. HLM values are indicative of an acceptable grade and should therefore be of acceptable milling quality, exhibiting the potential for high flour yields, since a HLM of 74.00 kg hl^{-1} is required for bread making purposes (Nel *et al*., 1998; SAGL, 2010). However, Koekemoer (2003) reported that 76.00 kghl^{-1} and above is preferable when potential breeding lines are submitted for cultivar classification.

Vitreous kernel values obtained ranged from 50.00% to 75.50%. Czarnecki and Evans (1986) found that a delay in harvest affects the amount of vitreousness in wheat cultivars. Similar results reported by Pomeranz and Williams (1990) that vitreousness occurs in all wheat cultivars because of conditions during the maturing of the wheat. They reported that high temperatures and sufficient nitrogen availability promote vitreousness in wheat. Environmental conditions therefore play a large role in whether vitreousness will occur or not. Therefore, SST 356 and SST 347 performed better than other cultivars including control (Duzi) under environmental conditions of Limpopo Province (Table 4.2). Syferkuil experienced maximum and minimum temperature of 28.18°C and 12.56°C, respectively and rainfall of 60.46 mm during the maturity of the tested wheat cultivars. These conditions were generally favourable for grain filling (Table 3.1.1).

Falling numbers were below 250s all these cultivars did not reach the required grade of 220 seconds in falling numbers but only SST 356 and SST 347 met the requirement for utility grade with164.50 and 187.00 seconds respectively, acceptable falling number for bread production is between 200s and 350s. Falling numbers below 150s result in sticky bread and falling numbers above 350s result in bread with a dry crumb and diminished loaf volumes (Perten, 1964). The exact falling number value desirable depends on the type of product to be produced, thus falling number for bread flour will have to differ with those for crackers. Dowell *et al*. (2008) reported that flours exhibiting low falling numbers, and a decrease in their water-absorbing capacity, which might have an effect on loaf volume. The results therefore suggest that all the cultivars are not acceptable for bread production when grown under Limpopo conditions.

Results revealed no differences in break flour yield and flour protein content. However, a weak negative and linear relationship was observed between break flour yield and flour protein content at $R^2 = 0.004$. Break flour yield obtained is accepted by the South African processing industry as it ranged from 20.95% to 25.30% and the accepted range is between 19.81% and 30.30% (SAGL, 2010). Flour protein content obtained ranged from 9.63 to 11.48 with highest values being not desirable range of the South African processing industry (SAGL, 2010). Koemoer (2003) confirmed that the desirable levels of protein content for South African industry is 12% or above. These results are similar with the findings of Gaines (1991) who reported a negative correlation between break flour yield and flour protein content for red wheat cultivars. The results might have been affected by the environmental conditions as protein content is strongly affected by environment and less affected by genotype (Hoseney, 1994), which confirms that, depending on environmental conditions, wheat grain protein content can vary between 6% and 25% as affected by nitrogen availability (Blackman and Payne, 1987). Total protein as well as the amount of each different protein is mainly determined by genotype.

Flour yield (Flour extraction) is important because genotypes yielding higher volumes of flour are more profitable to millers (Bass, 1988). From Table 4.2, there was no significant difference observed in flour extraction although the results found to be ranging from 68.73-73.40% in flour extraction. Extraction rates for commercial mills vary between 70 and 80%, although the average wheat kernel contains approximately 85% endosperm (Campbell *et al.,* 2007). Steve *et al*. (1995) reported flour yield as a complex trait affected by factors influencing the ease of endosperm-bran separation. Such factors include kernel hardness, endosperm-bran adherence, kernel plumpness and the endosperm-bran ratio. Pumphrey and Rubenthaler (1983) reported poor growing conditions resulting in shrivelled kernels that lead to lower endosperm-bran ratios and therefore lower flour yields. The flour extraction obtained in this study ranged from 68.73% to 73.40% (Table 4.2) and is acceptable for South African processing industries as the acceptable values for flour extraction lie between 68.24% and 74.91% (SAGL, 2010)

From the cultivars evaluated, peak time values ranged from 2.60 min to 3.95 min. Acceptable PT values as required by the South African industry range between 2.5 to 4.0 min (SAGL, 2010). Therefore, all the cultivars evaluated were found to be within the required range by the South African industry.

5.4 Rheological characteristics of wheat cultivars

The cultivars evaluated did not show any differences in water absorption percentage. Koppel and Ingver (2010) reported that high absorption values are desirable in bread baking as added moisture slows staling. However, higher water absorption also means that less flour is needed to make a loaf of bread. The results of the study showed more than 50 % in water absorption across all genotypes. Water absorption is said to be an important quality factor for the baker as it is related to the amount of bread wheat produced from a given weight of flour. Baviaans performed better than all other cultivars in Dough strength percentage and it was followed by cultivar SST 347 and Duzi which was the control.

Dough stability indicates the time when the dough maintains maximum consistency and is a good indication of dough strength. Baviaans and Olifants were found to be high in dough stability whereas cultivar Steenbras was lower. Good quality dough has stability of 4-12 min (Kulhomäki and Salovaara, 1985). There was a weak positive linear relationship between dough strength and dough stability at R^2 =0.146. The results are in accordance with what was reported by Kulhomäki and Salovaara (1985) who found a positive relationship between dough stability and strength.

For P/L-value, which is influenced by the ratio of stability to distensibilty, Olifants was found to be high due to the high value of stability and low value of distensibilty (0.76) which is undesirable. This ratio is thought to indicate general gluten performance. In general, values of 0.40-0.70 are thought to be appropriate for bread baking by the South African milling industry. Olifants was the only cultivar that had highest ratio of stability to distensibility which is more than the required range (0.40-0.70). According to SAGL (2010), as the number rises, there will be a certain point where the dough will be too elastic-resistant, yielding a less developed loaf with compact crumb. Low P/L values indicate dough that is too extensible. However, there is no absolute perfect value.

Wrigley and Bietz (1988) gave an overview of the composition and molecular characteristics of gluten. High protein does not necessarily indicate high gluten content and high gluten does not necessarily indicate high quality (Wang *et al*., 2004). It is both the quantity and structure of gluten proteins that determine dough properties and baking performance and this is strongly dependent on genotype and growing conditions (Wieser and Seilmeier, 1998). The highest value of sedimentation volume recorded was 98.25 ml by SST 347 while SST 356 was the lowest. It can be concluded that testing of the genotypes needs to be conducted at different locations over different years for a reliable evaluation of sedimentation volume performance of genotypes (Oelofse, 2008).

CHAPTER 6

6. SUMMARY AND CONCLUSION

The results obtained in the study showed that only cultivar CNR 826 showed good yield potential under Limpopo conditions (Syferkuil area). Cultivars SST 347 and SST 356 yielded poorly and should be excluded in future evaluations. In terms of wheat quality, CNR 826, SST 347, Baviaans, Krokodil, Steenbrass and SST 356 showed a good potential on hectolitre mass and protein content but Krokodil and Baviaans had poor protein contents. Only cultivar SST 356 met the minimum standards in several parameters. In future, there is need to evaluate performance of wheat cultivars in the Limpopo lowveld where most irrigation schemes are located. Future research should use large plot size to facilitate complete flour quality tests.

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APPENDICES

Summaries of Analysis of Variance (ANOVA) tables

Appendix 1. Days to flowering

Source of variation	DF	SS	MS	F	P
Treatment	7	211.719	30.2455	4.60	0.0030
Replication	3	17.094	5.6979		
Error	21	138.156	6.5789		
Total	31	366.969			

Appendix 2. Days to Physiological Maturity

Source of variation	DF	SS	MS	F	P
Treatment	7	210.875	30.1250	4.18	0.0050
Replication	3	13.625	4.5417		
Error	21	151.375	7.2083		
Total	31	375.875			

Appendix 3. Plant height

Source of variation	DF	SS	MS	F	P
Treatment	7	1462.97	208.996	10.01	0.0000
Replication	3	148.09	49.365		
Error	21	438.66	20.888		
Total	31	2049.72			

Appendix 4. Number of tillers per plant

Source of variation	DF	SS	MS	F	P
Treatment	7	329.219	47.0313	2.49	0.0511
Replication	3	27.594	9.1979		
Error	21	396.656	18.8884		
Total	31	753.469			

Appendix 5. Grain yield

Source of variation	DF	SS	MS	F	P
Treatment	7	1.403E+07	2004603	4.74	0.0025
Replication	3	3470512	1156837		
Error	21	8884604	423076		
Total	31	2.639E+07			

Appendix 6. Hectolitre mass

Source of variation	DF	SS	MS	F	P
Treatment	7	21.3747	3.05353	19.36	0.0000
Replication	3	2.7309	0.91031		
Error	21	3.3116	0.15769		
Total	31	27.4172			

Appendix 7. Vitreous kernels

Source of variation	DF	SS	MS	F	P
Treatment	7	2564.97	366.424	17.10	0.0000
Replication	3	138.34	46.115		
Error	21	449.91	21.424		
Total	31	3153.22			

Appendix 8. Falling number

Source of variation	DF	SS	MS	F	P
Treatment	7	38028.4	5432.62	7.21	0.0002
Replication	3	7830.6	2610.21		
Error	21	15831.9	753.90		
Total	31	61690.9			

Appendix 9. Break flour yield

Source of variation	DF	SS	MS	F	P
Treatment	7	67.160	9.59429	2.25	0.0710
Replication	3	29.912	9.97083		
Error	21	89.522	4.26298		
Total	31	186.595			

Appendix 10. Flour extraction

Source of variation	DF	SS	MS	F	P
Treatment	7	72.635	10.3764	1.43	0.2461
Replication	3	13.293	4.4311		
Error	21	152.479	7.2609		
Total	31	238.407			

Appendix 11. Flour protein content

Source of variation	DF	SS	MS	F	P
Treatment	7	10.3647	1.48067	1.04	0.4314
Replication	3	18.3184	6.10615		
Error	21	29.7791	1.41805		
Total	31	58.4622			

Appendix 12. Peak time

Source of variation	DF	SS	MS	F	P
Treatment	7	7.0872	1.01246	4.64	0.0029
Replication	3	1.4109	0.47031		
Error	21	4.5866	0.21841		
Total	31	13.0847			

Appendix 13. Water absorption

Source of variation	DF	SS	MS	F	P
Treatment	7	26.2780	3.75400	1.43	0.2445
Replication	3	17.0419	5.68064		
Error	21	54.9980	2.61895		
Total	31	98.3178			

Appendix 14. Dough strength

Source of variation	DF	SS	MS	F	P
Treatment	7	494.160	70.5943	13.15	0.0000
Replication	3	62.893	20.9642		
Error	21	112.703	5.3668		
Total	31	669.755			

Appendix 15. Dough stability

Source of variation	DF	SS	MS	F	P
Treatment	7	1181.75	168.821	34.59	0.0000
Replication	3	40.12	13.375		
Error	21	102.50	4.881		
Total	31	1324.37			

Appendix 16. Dough distensibility

Source of variation	DF	SS	MS	F	P
Treatment	7	16619.4	2374.20	16.99	0.0000
Replication	3	1791.4	597.13		
Error	21	2934.1	139.72		
Total	31	21344.9			

Appendix 17. P/L value

Source of variation	DF	SS	MS	F	P
Treatment	7	0.49374	0.07053	19.51	0.0000
Replication	3	0.04011	0.01337		
Error	21	0.07594	0.00362		
Total	31	0.60979			

Appendix 18 . Wet gluten content

Source of variation	DF	SS	MS	F	P
Treatment	7	268.294	38.3277	3.79	0.0083
Replication	3	193.881	64.6271		
Error	21	212.634	10.1254		
Total	31	674.809			

Appendix 19. Sedimentation volume

Source of variation	DF	SS	MS	F	P
Treatment	7	144.719	20.6741	2.48	0.0509
Replication	3	26.344	8.7812		
Error	21	175.406	8.3527		
Total	31	346.469			