CANOLA GROWTH, GRAIN AND OIL YIELD RESPONSE TO PLANTING DATE UNDER DIVERSE CLIMATIC CONDITIONS IN LIMPOPO PROVINCE

By

ASNATH SHILA DOLO

MINI-DISSERTATION

Submitted in (partial) fulfilment of the requirements for the degree of

MASTERS OF SCIENCE in AGRICULTURE (SOIL SCIENCE)

in the

FACULTY OF SCIENCE AND AGRICULTURE

(School of Agricultural and Environmental Sciences)

at the

UNIVERSITY OF LIMPOPO

SUPERVISOR: Prof K.K. Ayisi

CO-SUPERVISOR: Prof A. Belete

CO-SUPERVISOR: Dr B.M Petja

2016

DECLARATION

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

…………………………………………… ……………………………………

Surname, Initials (title) Date

DEDICATION

This work is dedicated to important people in my life, my mother Ms. M.N Dolo, my adorable Son Mr. T.M Dolo, my three lovely sisters Mrs. P.M Mohololа, Mrs. F.M Molepo and Mrs. J.L Kobyana, and a special thanks to my former secondary high school principal Mr. M.J Machaba and my dearest aunt Ms A.C Tolo; I have witnessed their love and support in providing for my needs every step of the way. They always expected the best from me. They always motivated me in being determined, dedicated and have perseverance in life.

ACKNOWLEDGEMENTS

I would like to thank the almighty God for giving me life, strength and courage throughout this work.

I appreciate my supervisor Prof K.K Ayisi for his patience, motivation, support and valuable comments throughout this study, my co-supervisors for their support and contributions, this study would not have been successful without them.

Thanks to my mentor Mrs. M.P Mabapa for the advice, support and strength that she gave me, and not forgetting my fellow RVSC students for their support on this study.

The National Research Foundation (NRF) through the Risk and Vulnerability Science Centre (RVSC) and VLIR-IUC Programme are acknowledged for their financial support. The acknowledgement is further extended to the University of Limpopo and farmers at Ofcolaco for providing the study sites.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of variance
Ca	Calcium
Cm	Centimeter
DAE	Days after emergence
DAP	Days after planting
DM	Dry matter
GDD	Growing degree days
K	Potassium
Kg ha^{-1}	Kilogram per hector
Mg	Milligram
Mg Kg^{-1}	Milligram kilogram per hector
mm m^{-1}	Millimeter per meter
N	Nitrogen
Na	Sodium
^{o}C	Degrees Celsius
P	Phosphorus
PC	Principal component
PCA	Principal component analysis
RHn	Minimum relative humidity
RHx	Maximum relative humidity
Rs	Solar radiation
T	Temperature
T_{max}	Maximum temperature
T_{min}	Minimum temperature

ABSTRACT

Canola (*Brassica napus*) is an important oil crop which is not well grown in Limpopo Province. Planting date is identified as a critical management decision in canola production for enhanced biological and economic returns as it has direct influence on the growing condition at which the crop is exposed to. The objective of the study was to determine the impact of planting date on growth, grain yield, oil content and economic returns on canola production as a winter crop option in the province. The study was conducted at two climatically diverse locations; the University of Limpopo experimental farm at Syferkuil and an Ofcolaco farmers' field in 2013 and 2014. Canola was planted at four different dates (April, May, June and July) and (March, April, May) during 2013 and 2014 growing seasons, respectively, in a randomised complete block design (RCBD) under four replications, using AG-Muster cultivar. Weather parameters were obtained from Agricultural Research Council and University of Limpopo experimental farm. Plant parameters measured were days to seedling emergence, flowering and physiological maturity, plant height, number of main and sub branches, dry matter at onset of flowering and crop residues after threshing, number of pods per plant, number of seeds per pod, unshelled and shelled weight, and grain yield. The results revealed that, days to seedling emergence responded significantly *($P\leq0.01$) and ($P\leq0.05$)* to planting date at both locations and years except in 2014 at Syferkuil. Plant height was significantly influenced by planting date in 2013 at both locations but in 2014, the effect was significant at maturity and flowering at Syferkuil and Ofcolaco respectively. At Ofcolaco, planting date influenced days to 50% flowering, physiological maturity and plant height in both growing seasons. The influence of planting date on days to flowering and physiological maturity was significant *($P\leq0.01$)* at both locations and seasons. Canola dry matter accumulation at flowering responded significantly *($P\leq 0.01$)* to planting date only at Syferkuil in 2013 across seasons and locations whereas residue after seed threshing responded significantly at both locations and seasons. Grain yield was significantly *($P\leq0.01$)* influenced by planting dates at all locations and seasons ranging from 292 to 2983 kg ha^{-1}. At Syferkuil, planting canola not later than April resulted in higher grain yield whereas at Ofcolaco, planting between April and May produced the highest grain yield. The number of pods per plant influenced grain yield more than the other yield components studied and regarding weather variables, minimum temperature was found to be most important in influencing growth and grain yield of canola. Oil yield ranged from 155 to 539 kg ha^{-1} at Syferkuil, in 2013 whilst in 2014, the range was 252 to 614 kg ha^{-1}. At Ofcolaco, significant response of oil yield to planting dates was observed in both seasons. Economic returns at Syferkuil ranged from -R6213.00 to +R2130.00 whereas at Ofcolaco the range was +R793.00 to +R6555.00.

The study revealed that Ofcolaco appeared to be better suited for canola production compared to Syferkuil due to higher grain yield and positive economic returns at the former.

Keywords*:* canola; grain yield; oil yield; plant density, planting dates, weather parameters.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Canola is an oil seed which is widely grown for its high quality oil for human consumption. The meal produced after extraction is also a good protein supplement for livestock. Canola production so far in South Africa is restricted to few areas in the Western Cape and North West Provinces with virtually no production in the Limpopo Province. There had been earlier attempt by the Limpopo Provincial Department of Agriculture to introduce the crop in the province but lack of adequate agronomic information on the crop has stalled this initiative. To successfully introduce canola in the Limpopo Province, critical environmental and management factors influencing growth and yield of the crop as well as its economic returns need to be understood.

Planting date is identified as a critical management decision in canola for enhanced biological and economic productivity as it has direct influence on the growing condition at which the crop is exposed to (Martin, 2006; Yasamin and Bagheri, 2013). Taylor and Smith (1992) reported a declined seed yield of canola when sowing date is delayed. In a separate study, Daly and Martin (1988) mentioned that early planting date resulted in greater seed and biomass yields than late planting. Identifying favourable climatic conditions for canola is critical if the crop is to be successfully reintroduced in the Limpopo province.

1.2 Problem statement

Canola production in South Africa is lower than its demand, primarily due to fewer areas currently devoted to the crop. Establishment and winter survival are two major challenges limiting successful cultivation of the crop in most production areas. In South Africa, canola is mainly grown in the Western Cape with a minimal production in the North West Province. There is no record of canola production in the Limpopo Province, even though climatic requirements of the crops reveal that the crop could be planted in the province and become an important economic crop for farmers. Planting date is an important production practice that significantly influences crops’ survival and productivity and hence, identifying the appropriate period of planting will contribute to successful cultivation of canola in the province.

1.3 Motivation of the study

Canola is an important source of good quality vegetable oil due to its low erucic acid and glucosinolates content and high monounsaturated fatty acid. The cake is also a nutritious feed for animals after the oil is pressed out of the seed. Enhanced production of oil from canola can also promote the crop as a feed stock for biodiesel production to support the campaign of cleaner energy. Canola is fairly a new crop in South Africa and currently, commercial cultivation of the crop is restricted to the southern part of Western Cape Province (DAFF, 2010). According to Agricultural Statistics (2011), the Western Cape accounts for more than 95% of South Africa's total canola production while other provinces contribute less than 5%.

The crop is not yet cultivated in the Limpopo Province even though the potential to cultivate it do exist. The existing agronomic practice recommendations for canola production are those derived from the Western Cape Province. The choice of planting date(s) in the Limpopo Province is a key factor in profitable canola production. There is a need for more investigation on best growing location of the crop and its interactive effects with planting date.

1.4 Aim and objective of the study

1.41 Aim

The aim of this study is to enhance the productivity of canola in Limpopo Province through optimization of planting date.

1.4.2 Objectives

The objectives of the study were to:

i. Determine the impact of planting date on growth, grain and oil yield of canola.
ii. Assess the effect of prevailing weather conditions on growth and yield of canola.
iii. Analyse profitability of canola as influenced by different planting dates.

1.5 Hypotheses

i. Planting date has no effect on growth, grain and oil yield of canola.
ii. The prevailing weather condition has no effect on growth and yield of canola.
iii. Planting date will not influence profitability of canola production.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin of canola

Canola (*Brassica napus* L.) is a member of the *Brassicaceae* family with its cultivation dating back to the 13 century when the crop was known as rapeseed. The first edible rapeseed was developed in Canada in 1956 and the “canola” name was registered in the late 1970s (Boland and Brester, 2008). The term canola is a registered trademark of the Canadian canola association which is derived from Canadian oil low acid. Raymer (2002), reported that canola is a new cultivars of rapeseed that produce oil with less than 2% erucic acid content and meals with less than 30 mmol of aliphatic glucosinolates per gram.

2.2 Cultivation and distribution worldwide

Canola plant (*Brassica napus* L.) is an important oilseed crop grown primarily for its edible oil and oil extraction remains oblige as a protein meal for the livestock feed industry (Jensen et al. 1996).The production of canola worldwide was 47.6 million tons in 2006/2007 and US shared 1% of the global production. Canola is extensively produced in Canada, Europe, China and Australia and to a limited extent in the United States (Economic Research Services, 2008). Production of Canola in South Africa is only limited to few areas in the Western Cape and North West Provinces with no production in the Limpopo Province. In 1994, only 500 tons were produced, but this increased to 44 200 tons in 2005 (DAFF, 2010).

According to Ehrensing (2008), Canada is the largest canola-producing country in the world, reaching an annual production on 12 million acres (4 856 228 hectares) (Ehrensing, 2008). In the United States, Minnesota and the Northern plains of North Dakota account for more than 90 percent of about 1 million acres (400,000 hectares) of canola (Berglund et al. 2007; Ehrensing, 2008).

It has been grown in Europe since the 13th century (Frier and Roth (2007), and Oplinger et al. 1989; Shahidi, 1990).

2.3 Production and distribution of canola in South Africa

Canola is a relatively new in South Africa. The production of canola in South Africa is usually lower than the demand and favourable prices could be achieved under successful production. Although canola is a summer crop in the temperate and cool areas of the world, it is mainly grown in the Western Cape Province as a winter crop. In the summer rainfall areas, canola can be produced under irrigation during the winter period (DAFF, 2010).

2.4 Description of the canola crop

Canola is an oil seed which is widely grown for its high quality oil for human consumption. The meal produced after extraction is also a good protein supplement for livestock. Canola plant was ranked third on account of its high percentage of oil and second in protein among the oil seed crops (Crubbens and Denton, 2004). The authors reported that Canola grows annually in favourable weather conditions.

In 1971, the first low erucic acid-content variety called Span was released in Canada. In two decades following Span’s release, Tower, which was low in both erucic acid and glucosinolates, was released. Tower was the first variety to become a true canola crop (Kansas Agricultural Experiment Station, 1996).

The name canola refers to rape seeds with genetically lower erucic acid and glucosinolates (Oplinger et al. 1989), trademarked by the Western Canadian Oilseed Crushers Association in 1978 (Kansas Agricultural Experiment Station, 1996; Oplinger et al. 1989; Raymer, 2002).

In order for rapeseed to be used as edible oil, it must have an erucic acid content of less than 2 percent and the glucosinolate content should not exceed 30 micromoles per gram (Atkinson et al. 2006; Berglund et al. 2007; Parsons et al. 2012).

2.5 Soil and fertility on canola production

Canola is well adapted to clay-loam soils, with no crusting. The crop requires good field infiltration, and it does not tolerate waterlogging field conditions (Berglund et al. 2007; Ehrensing, 2008; Kansas Agricultural Experiment Station, 1996; Shahidi, 1991). It can also perform well on medium-textured soils with adequate drainage (Kansas Agricultural Experiment Station, 1996 ; Oplinger et al. 1989) and can be grown under acidic soil with pH of as low as 5.5 (Oplinger et al. 1989).

Nutritionally, canola has a high requirement for nitrogen (Holmes, 1980), and it has been grown as a break crop immediately after a legume-based pasture. The high soil N status following the pasture is helpful for canola to disrupt the cycle of soil-borne cereal diseases carried by pasture grasses (Angus et al. 1991; Hocking et al. 1997; Kirkegaard et al. 1994).

Nitrogen fertilizer plays a vital role in enhancing crop yield (Rathke et al. 2005). Nitrogen increases yield by influencing a number of growth parameters such as number of branches and pods per plant, seeds per pod and 1000 seed weight by producing more vigorous growth and development (Taylor et al. 1991; Qayyum et al. 1998).

2.6 Uses and importance of canola

Canola (*Brassica napus L.*) has both the food and non-food uses. It is an important agricultural crop, grown commonly for oil or biofuel production. It is reported as one of the main sources used to produce biodiesel (Ministry of Economic Development, 2012). The oil and meal are desired products for both human as well as livestock consumption, (Shahidi, 1990).

Canola can be used as a rotational crop with several crops including small grains, grass seeds and potatoes and should not be planted in a rotation for more than once every 3 to 4 years (Ehrensing, 2008; Shahidi, 1991; Berglund et al. 2007). If planted continuously or an alternating years, potential disease build ups and outbreaks are possible (Ehrensing, 2008; Shahidi, 1991). Shahidi (1991) recommends not growing canola in a field where any Brassica crop was grown within the last 4 years.

2.7 Canola productions constrains

Growing canola still faces many problems including heavy infestation by various insect pests that attack canola causing poor growth and low yield production (Lamb, 1989; Saljoqi et al. 2006; Dosdall and Mason, 2010). According to Wang et al, (2003), factors such as heat, cold, drought, salinity, and nutrient stress are the most important abiotic stress factors that have huge impact on world canola production.

2.7.1 Disease and insect pests

According to Great Plains Canola Production Handbook (2012), the Blackleg fungus (*Leptosphaeria maculans*), which is a common disease is considered the most serious threat to canola production. The disease creates stem cankers and basal stem decay that causes lodging, premature death and reduces plant growth and yield.

Another important disease of canola is the *Sclerotinia* stem rot which is caused by the fungus *Sclerotinia sclerotiorum*. It is a serious problem in many areas throughout the world. It is most severe when warm, wet conditions occur during the flowering period. The fungus has a wide host range including field crops such as dry beans, sunflowers, and soybeans (Great Plains Canola Production Handbook, 2012).

2.7.2 Disease and Pest Management

Diseases and pest are major constrains in canola production. To keep the incidence of disease low, a well-managed rotation is necessary. Blackleg, white rust, stag head, downy mildew, alternaria blackspot, aster yellows and sclerotinia wilt are major diseases in canola (Berglund et al. 2007). Blackleg is particularly likely to occur in fields continuously planted to canola. Therefore, canola varieties that are moderately or completely resistant to blackleg should be selected, if 3 year or 4 year rotation is not possible.

In terms of insects that attack canola plants, flea beetles can cause considerable damage to newly emerged seedlings. Over-wintering populations of flea beetles can cause severe damage to canola plants through plant development.

Adult flea beetles, which feed on the cotyledons and first true leaves, can cause typical shot-holed appearance. The affected seedlings usually have slow recovery and growth. In case of severe injury, seedlings may die. When the injury is moderate, the plants may suffer a reduction in vigour and stamina (Berglund et al. 2007).

Besides flea beetles, cabbage seedpod weevil and several species of aphids, especially cabbage aphid, turnip aphid, and green peach aphid, are found on canola (Ehrensing, 2008).

2.7.3 Weeds

Kumar et al, (2007) reported that weed infestation is one of the major limitations in canola production in the Southern U.S.A with the competition causing up to 50% loss in yield. Jennifer et al (2000) further reported that weeds reduced canola yield up to 77 to 91%. According to DAFF (2010) canola seedlings are sensitive to weed competition however once established, canola becomes a good competitor as its growth rate is higher than that of most weeds. The yields of spring canola in these areas are considerably lower and this is attributable to reduced seed-filling periods, and increased pressure from the spring weeds and pests.

2.9 The effect of planting dates on canola production

Planting dates has a major effect of canola yield and yield components. According to Martin (2006) and Fink et al. (2006) planting date is one of the most important production decisions for farmers. Several studies reported that timely planting of canola has proven a key to maximize yield potential and reduce risk. Different researches indicate that delayed planting date results in decline in the pod number per plant (Asgari and Moradie-dalini 2008; Angadi et al. 2003; Hocking and Stapper 2001; Nanda et al. 1999), plant height, stem number per plant (Ozer, 2003) and finally, seed yield and oil quality. Similar results were reported by several authors (Hodgson 1978; Degenhardt and Kondra 1981; Wright et al. 1988; Taylor and Smith 1992; Hocking 1993; Hocking and Stapper 2001).

Plating date of canola is one of the most important management practices for obtaining high yield (Ozer, 2003). Arezoo and Golparvar,(2013) concluded that determination of the response of different crop varieties to environmental variables from planting to harvest is one of the fundamental pillars of agricultural planning to achieve maximum yield and desirable quality.

2.10 The effect of climate on growth of canola

The current climate prediction models indicate that average surface temperatures will rise by 3–5 °C in the next 50–100 years, drastically affecting global agricultural systems (Intergovernmental Panel on Climate Change, 2007). This will be concurrent with an increased frequency of drought, flood, and heat waves (Intergovernmental Panel on Climate Change, 2008; Mittler and Blumwald, 2010). A change in variability of rainfall and temperature may itself affect yields as well as adversely affecting nutritional quality of crops (Porter and Semenov, 2005).

Schmidhuber and Tubiello, (2007) reported that climate has a direct impact on crop production, basically the biophysical factors such as plant and animal growth. Gregory et al. (2009) further reported that rising temperatures and changes in rainfall patterns have direct effects on crop yields, as well as indirect effects through changes in irrigation water availability.

The Intergovernmental Panel on Climate Change (2009) reported that rising temperature, drought, floods, desertification and weather extremes will severely affect agriculture especially in the developing world. Richards (2006) reported that the increases in plant temperature accelerate growth rate, which reduces the window of opportunity for photosynthesis since life cycle is truncated while both heat and drought stress may also inhibit growth directly at the metabolic level.

Canola is adapted to a wide range of climates; however it prefers cool extremes of temperate zones. It can survive in temperatures as low as 0 °C the crop germinates and emerges at a soil temperature of 5 °C, and the optimum temperature for growth is 10 °C (Oplinger et al. 1989).

In agricultural fields, environmental stresses are responsible for limiting the crop productivity and quality (Pahlavani et al. 2007; Sinha et al. 2010). Factors such as planting date (Adamsen and Coffelt, 2005; Faraji et al. 2008), soil moisture (Gan et al. 2004), assimilate availability (Habekotte, 1993), and temperature (Johnson et al. 1995; Morrison and Stewart, 2002) affect seed development.

2.11 The effect of temperature on oil concentration of canola

According to Ehrensing (2008), dry weather conditions during seed germination, late crop stand establishment, and high temperature shortly after seedling emergence are the factors that can negatively affect winter canola production.

It is likely that increased temperature and water stress during seed filling was a major cause of reduced oil concentration. Similar results have been reported by Hocking and Stapper (2001) and Özer (2003). Hocking and Stapper (2001) reported that oil concentration reduced by 3% when canola planting was delayed. They concluded that every 1°C increased in temperature during the grain filling stage results in oil percentage reduction. So, an optimum planting time in changing climate will increase the yield potential of canola. The earliest possible planting dates can be also determined by the risk of frost at the end of flowering or during early grain-filling (Robertson et al. 2001).

Hall (1992) reported that flowering is the most sensitive stage in canola production, for temperature stress damage probably due to vulnerability during pollen development, anthesis and fertilization leading to reduced crop yield. High temperature in Brassica production enhanced plant development and caused flower abortion with appreciable loss in seed yield (Rao et al. (1992). According to Nuttall et al. (1992) the flowering duration has a strong influence on seed yield and a rise of 3°C in maximum daily temperature (21-24° C) during flowering a decline of 430 kg ha^{-1} was obtained in canola seed yield.

Saran and Giri (1987) and Soleymani et al. (2010) reported that early planting gives earlier flower, this variation might have occurred due to temperature and moisture stress.

2.12 Growing degree days

Gordon and Bootsman, (1993) state Growing Degree-Days (GDD) are frequently used as a weather-based indicator for assessing crop development. For example, many farm weather radio broadcasts or climatological bulletins convey daily or weekly accumulations as insight into the current and on-going status of the growing season.

Canola growth from seedling emergence to blooming is controlled by photo-thermal factors and from blooming to maturity by temperature (Nanda et al. 1996). Each 1°C increase in ambient temperature brings about 4.6 days shortening of the periods (Nanda et al. 1994). Also, producing the highest grain and oil yields in canola depends on atmospheric temperature and is likely to be obtained at day/night temperatures of 20/15 and 15/13°C (Kuo et al. 1980).

Photo-period tends to alter the phenological development stages of Brassica species, with a general shortening of phases as daylength increases (Agarwal, 1971 for *B. napus*; Bose, 1973 for *B. juncea*; Neelam Kumari et al., 1992 and Neelam Kumari and Bhargava, 1994 for *B. campestris* and *B. carinata*). Several authors reported that some Brassica species can develop more rapidly and complete their life cycle in short period after exposure to cool conditions (Scott et al., 1973; Hodgson, 1978a; Dhawan et al., 1983; Wilen et al., 1994), though; in general, rate of development within each phenological stage is accelerated by increasing temperature (Hodgson, 1978b; Morrison et al., 1989). Therefore all these environmental and genetic factors interact to determine the number of calendar days between sowing and maturity date of the crop.

Determining when certain plant stages will occur for accurate crop management can be done using the simple and accurate method of calculating growing degree days. It is known that every plant requires a specific amount of heat to develop from one point in their life cycle to another, to mature (Miller et al. 2001).

Sediqi (2012) reported that, among environmental factors such as water availability and length of the growing season, the number of growing degree days has a major impact on the potential for successful cultivation of a crop species. The concept of growing degree days, developed by Reaumur proposes that the crop requires a minimum amount of heat over the growing season to develop and mature. Delaying sowing date reduces the time between sowing and flowering and hence reduces biomass at flowering which can consequently reduce yields (Farre et al. 2002).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

This study was conducted during 2013 and 2014 growing seasons at two climatically diverse locations, namely the University of Limpopo Experimental Farm at Syferkuil in Polokwane Municipality, Capricorn District and at Ofcolaco farmers' field in Maruleng Municipality, Mopani District, Limpopo Province. The Ofcolaco site lies approximately 120km south-east of Syferkuil (Figure. 1).

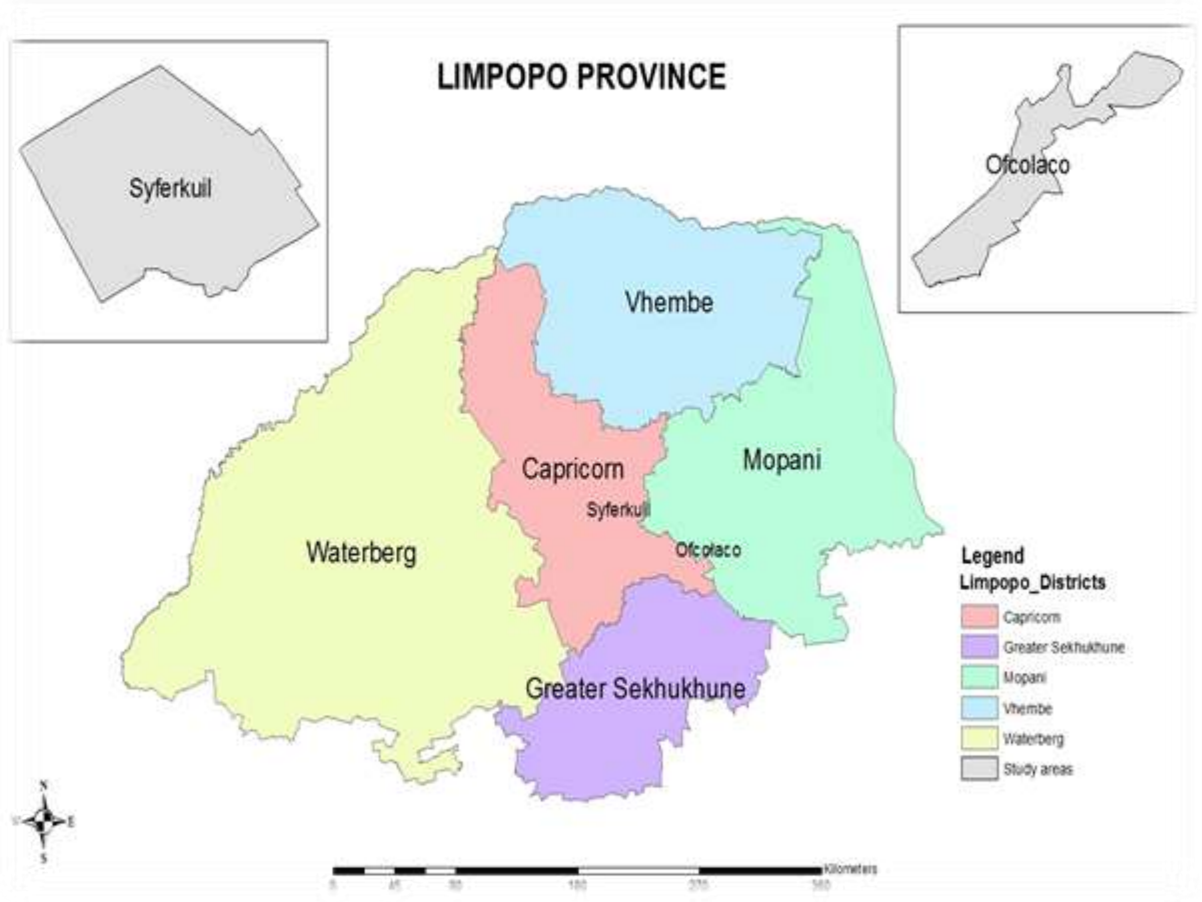

Figure: 1 Locality map of the study locations

3.2 Experiment layout

The experiments were established in a Randomized Complete Block Design with three planting dates as treatment in 2013 and four planting dates in 2014 replicated four times at each location and season. At Syferkuil, canola was planted on 17 April, 15 May, and 12 June in 2013, and on 18 March, 14 April, 12 May and 9 June in 2014. At Ofcolaco, the crop was planted on 19 April, 16 May and 13 June in 2013 and on 9 March, 15 April, 13 May and 10 June in 2014. The canola cultivar planted was AG-Muster. The experimental unit was 3 m × 3 m at spacing of 30 cm inter-row and 10 cm intra row at both locations

3.3 Soil sampling

Prior to establishment of the experiments, a simple random sampling was used to collect four soil samples with auger at a depth of 0-30 cm at each location and season. A composite soil sample was made for analysis of Physical properties (silt, clay and sand %), Chemical properties (pH $_{(H2O)}$, Bray 1 P (mgkg^{-1}) and Organic Carbon (%) Cations ((Amm. Acetate. K (mgkg^{-1}), Ca (mgkg^{-1}), Mg (mgkg^{-1}), Na (mgkg^{-1}), N (mgkg^{-1})).

3.4 Soil characterization

The Syferkuil and Ofcolaco sites were characterised into two soil horizons (Orthic A and Red apidal B), respectively, before the trial establishment. At Syferkuil the top soil has 26 percent clay whereas the subsoil has 30 percent. The soil structure is granule with good infiltration state and an effective soil depth of 90cm. The heavy clay soil after 100 cm acts as a limiting factor to water infiltration and root penetration. At Ofcolaco, the topsoil has 32 percent clay whereas the subsoil has 35 percent with granular soil structure. The soil had good drainage characteristics, with the effective soil depth of 120 cm. However, highly weathered manganese concretions were observed at 100 cm. The soil form at the two sites is classified as Hutton.

3.5 Land preparation

The experimental areas were ploughed followed by disking to provide a fine seedbed to accommodate the small seeds of canola.

3.6 Management practices

3.6.1 Fertiliser application

Nitrogen was applied as ammonium sulphate $(NH_4)_2SO_4)$, it contains 21% of nitrogen and 24% sulfur at a rate of 150kg N ha^{-1} in split at planting (75kg N ha^{-1}) and 20 days after (75kg N ha^{-1}) at the two locations. Phosphorous was applied as Super phosphate at planting at a rate of 20mg ha^{-1} at Syferkuil and 10mg kg ha^{-1} at Ofcolaco.

3.6.2 Weeds control

Weeds were manually controlled throughout the growing period with a hand hoe when necessary. Pesticides *Chloropyrifos* and Malathion were used when pest were observed. Chlorpyrifos is an organophosphate insecticide.

3.7 Irrigation

Irrigation was done once a week to field capacity.

3.8 Crop history of the experimental sites

At Syferkuil, the demarcated experimental site was fallow in both 2011 and 2012 growing seasons, whereas at Ofcolaco, the site cropped to Tomato in 2011 and in 2012 prior to planting canola in 2013 and was fallow prior to planting the 2014 trial.

3.9 Climate record

The climatic data in this study is summarised in terms of daily, weekly and monthly changes of weather over a long period and it is influenced by latitude, altitude, direction, intensity of wind and the presence of large bodies of water such as dams and rivers.

Yearly weather record of Syferkuil was obtained from a weather station located at the University of Limpopo Research Station at Syferkuil and that for Ofcolaco was obtained from Agricultural Research Council (ARC) weather station located at Metz. The Metz weather station is about 10km away from the experimental site. Analysis of the climate data indicates different weather conditions for the two experimental sites. Syferkuil is characterized by low erratic rainfall of about 450 – 500 mm per annum and minimum and maximum temperature of 18^{o}C and 28^{o}C respectively. Ofcolaco is characterized by an annual rainfall in excess of 700 mm and minimum and maximum temperature of 19^{o}C and 35^{o}C, respectively.

3.10 Data collection

3.10.1 Emergence

Days to emergence were scored when 90% of the hypocotyl (seedlings) within an experiment appeared above the ground surface (Vigil et.al. 1997).

3.10.2 Plant height

Plant height was taken at 50% flowering, pod development and at physiological maturity at both Syferkuil and Ofcolaco. Measurements were taken from the ground surface to the tip of the youngest fully expanded leaf on five plants from each experimental unit using a measuring tape.

3.10.3 Days to flowering and physiological maturity

Days to flowering was scored when 50% of the plants within an experimental unit have flowered. Days to physiological maturity was scored when 90% of the pods have changed the colour from green to brown (Elias and Copeland, 2001).

3.10.4 Biomass

When the plant was at 50% flowering, aboveground biomass from five plants from each experimental unit was sampled for biomass analysis. The samples were oven dried at the temperature of 60^{o}C to constant weight. Analytical scale was used to weigh the dried samples.

3.10.5 Pests and diseases scoring

The accumulation of pests and the occurrence of diseases were scored visually for all the experimental units at both experimental sites. The scale ranged from 0 to 5 where 0 refers to no infestation,1 is poorly infested , 2 is little infestation, 3 is moderate ,4 severely and 5 more severely .

3.10.6 Grain yield and yield components

The grain yield was taken from plants at harvest maturity from 1.5 m ×1.5 m area at both locations and seasons. Grain yield was determined by threshing all the pods from the harvested samples and seeds further dried at 60% to constant weight.

Main branches, sub branches, number of pods per plant, number of seed per pod were counted from five randomly selected plants samples per harvest area and weight of 100 seed was taken.

3.10.7 Harvest index

The harvest index was calculated as follows:

Grain yield / (Dry matter +Grain yield)

3.10.8 Lodging

Crop lodging was visually scored at physiological maturity at a scale of 0 to 5 where 0 indicates no lodging and 5 full lodging per experimental unit.

3.10.9 Oil percentage and yield per hector

Seed oil percentage was analysed using Foss ASN 3304 based on AOCS Ai3-75 by the SGS Agri Food Laboratory. Oil yield was calculated as:

Oil Yield = *oil percentage* × *dry weight of sampled grains*. (Tobe et al. 2013)

3.11 Growing degree days (GDD)

The daily minimum and maximum temperatures were used to calculate the growing degree days. The formula used was as follow:

$GDD = (T_x+T_n)/2 - Base\ T$ *(Gordon and Bootsam1993)*

Where: T_{max}= daily maximum temperature

T_{min}= daily minimum temperature

Base T= 5^{o}C (Vigil et al. 1997)

The daily growing degree days were summed according to the growing stages, from planting until physiological maturity.

3.12 Data analysis

Data collected form the trial were subjected to analysis of variance (ANOVA) using STATISTIX 10.0 and mean separation tests were done using least significant difference (LSD) at ($\alpha \leq 0.05$) for mean comparison (Gomez and Gomez 1996).

Weather parameters for the field were subjected to the principal component analysis (PCA) using Statistical Package Social Science version 22 (Garth, 2008).

3.13 Economic analysis

Economic viability of canola production was assessed through enterprise budget. The budget was developed for each planting date at Syferkuil and Ofcolaco in the 2013 and 2014 growing seasons. Key components of the budget were gross receipt, production cost, contingency cost and gross margin. Canola sales price ranges from R4.00 to R5.00 per kilogram. In the enterprise budget development, a sale price of R4.90 was used.

CHAPTER 4: RESULTS

4.1 Pre-plant soil analysis

The initial soil analysis results at the two locations are presented in Table 1. The pH is basic at Syferkuil can generally be described as basic and that of Ofcolaco as slightly acidic (Peverill, et al.1999). They are both suitable for crop production.

Table: 1 Pre-plant topsoil (0-30cm) chemical and physical analysis

	Location	
Soil pH and Nutrients	*Syferkuil*	*Ofcolaco*
pH(H_2O)	8.2	6.5
	------------ *mg kg^{-1}* ------------	
N	15.5	8.4
P	19.8	49.3
K	257	275
Ca	894	774
Na	32.4	34.2
Mg	582	585
Carbon (%)	0.9	1.1
Physical properties		
Silt (%)	10	10
Clay (%)	22	26
Sand (%)	68	64
Textural Class	*Sandy Clay Loam*	*Sandy Clay Loam*

N=available nitrogen, P=phosphorus, K=potassium, Ca=calcium, Na=sodium, Mg=magnesium

Available nitrogen

The plant total nitrogen concentration in the topsoil (0-30 cm) was 15.5mg kg^{-1} at Syferkuil and 8.4mg kg^{-1} at Ofcolaco. These values are lower as compared to the critical concentration of 45 to 65 mg kg^{-1} for canola (Lewis et al.1987). Supplementary nitrogen application was required at both locations to sustain good crop growth.

Phosphorous

The topsoil phosphorous concentration was slightly low (19.8 mg kg^{-1}) at Syferkuil but adequate at Ofcolaco given a critical concentration of 25 mg kg^{-1} for canola (Reuter et al. 1995), where the concentration was moderate. Phosphorous fertilization was required at Syferkuil.

Potassium (K)

The soil potassium concentration at Syferkuil was 257mg kg^{-1} and 275mg kg^{-1} at Ofcolaco. The concentration in the topsoil was deemed adequate for crop growth and yield at both locations. The optimum K content of the topsoil is 80mg kg^{-1} for clay soils and 60mg kg^{-1} for sandy soils (DAFF, 2010).

Soil Organic Carbon

Soil organic carbon provides an indication of the organic matter content in a soil. According to Peverill et al. (1999) and Hughes et al. (1996), under relatively low rainfall condition, and for soils intended for crop production**,** soil organic carbon is classified as follows: low: <9.0g C per kg soil (<0.9%); Normal: 9.0-14.5g C per kg soil (0.9 to 1.45%); high: >14.5g C kg^{-1} soil (>1.45). When the field is intended for pasture production, the following classes are used: Low: <17.4g C per kg soil (<1.74%); Normal: 17.4 **-** 26.2g C per kg soil (1.74 to 2.62%); High: >26.2g C kg soil (>2.62%). The organic carbon content of the topsoil at both Syferkuil and Ofcolaco is within the normal range.

Calcium and magnesium

The topsoil calcium concentrations at the study locations are largely adequate for canola production. A concentration of 130 mg kg^{-1} is adequate for crop production. Absolute deficiency of calcium (Ca) is not common in many soils of South Africa.

Values of magnesium concentration lower than 80 mg kg^{-1} could potentially limit canola growth and development .Topsoil magnesium concentration was in excess of 500 mg kg^{-1} at both locations which is adequate for canola production.

Sodium and Chloride

The concentration of sodium in the topsoil is less than 40 mg kg^{-1} at the two locations which is low to be of concern. Sodium levels of more than 200 mg kg^{-1} will be of concern.

Soil texture

The silt content was 10% at both sites and that of sand 68% at Syferkuil and 64% at Ofcolaco. The clay content of the soil at Syferkuil was 22% and 26% at Ofcolaco. The textural class of the soil can be described as sandy clay loam (Brady, 1974).

4.2 Weather variables

Rainfall and temperature at the study sites during the two growing seasons are the main weather variables and their means are presented (Figures 3 and 4).

4.2.1 Rainfall

The total monthly rainfall (Jan to Dec), at Syferkuil ranged from 0 to 188.47mm/m in 2013 and ranged from 0 to 2.71mm/m in 2014 (Figure 3). At Ofcolaco, the total for the two seasons ranged from 2.29 to 399.8mm/m and 0.0mm/m to 18.74mm/m in 2013 and 2014, respectively.

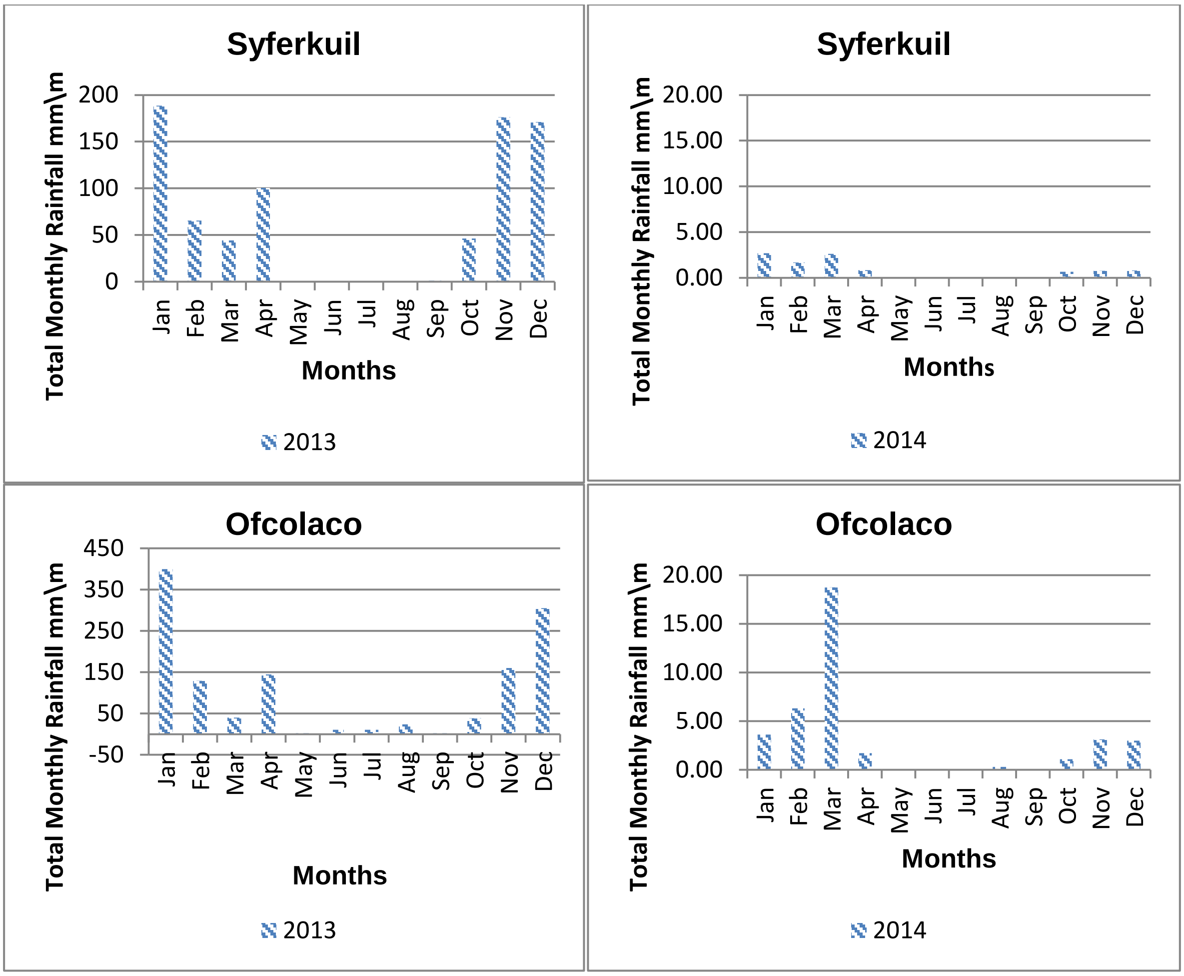

Figure 2: Total monthly rainfall at Syferkuil and Ofcolaco in 2013 and 2014 growing seasons.

4.2.2 Temperature

Syferkuil experienced relatively cooler temperatures than Ofcolaco based on the average temperatures (Figure 3). The minimum temperatures indicated the occurrence of frost at Syferkuil during the two growing seasons whereas no frost was experienced at Ofcolaco. The variation between the maximum and minimum temperatures increased significantly from the months of April to August at Syferkuil but this was not the case at Ofcolaco.

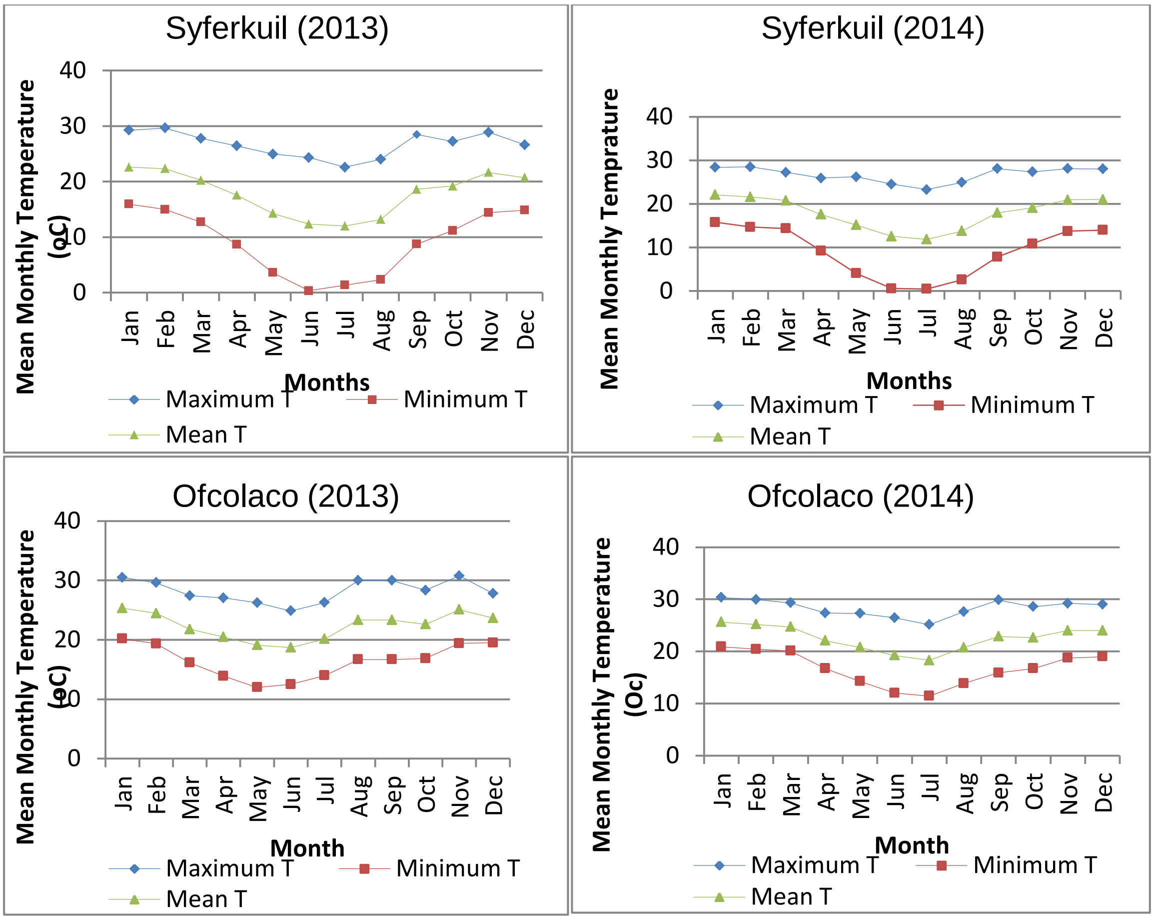

Figure 3: Monthly averaged temperature experienced at Syferkuil and Ofcolaco in 2013 and 2014 growing seasons.

4.3 Principal Component Analysis (PCA)

The weather results at Syferkuil during the 2013 growing season revealed that component 1 and component 2 explained 38% of the variances in weather parameters whilst in 2014, a percentage of 43 was explained in Principal Components (PC) 1 and 2. Only components loading more than 0.8 were regarded significant (Naotah and Wakindiki, 2012).

The 2013 growing season PC1 and PC2 results, the loadings indicated the following order in terms of decreasing importance RHn>T_{min}>T_{max}>Rs>Rain >Hu while Heat Units (Hu), rainfall (Rain) and maximum relative humidity (RHx) did not show any significant contribution. Minimum relative humidity (RHn) - accounted for the highest loading in PC 1 while the minimum and maximum temperature (T_{min} and T_{max}) and radiation (Rs) had the highest significant loading in PC 2 in 2013. (Table 2).

In 2014 growing season PC1 and PC 2 loadings showed the following order in terms of decreasing importance RHn >T_{max} >T_{min} >Rs with no significant contribution from Hu, Rain and RHx. Minimum temperature and minimum relative humidity accounted for the highest loading in PC 1(Table 2). In the same year, the maximum temperature and radiation showed the highest significant loading in PC 2.

Table 2: The component matrix for Syferkuil and Ofcolaco weather parameters, in 2013 growing season.

Syferkuil				
Weather parameters				
	2013		2014	
	1	2	1	2
T_{max}	-0.48	0.76	-0.24	0.80
T_{min}	0.58	0.78	0.77	0.61
Hu	-0.94	-0.23	-0.95	-0.15
Rain	0.39	0.21	0.26	-0.52
Rs	-0.31	0.73	0.96	-0.09
RHx	0.21	-0.44	-0.25	0.75
RHn	0.96	-0.68	0.41	-0.02

At Ofcolaco during the 2013 growing season, Component 1 and 2 explained 56% of the variances and 49% in 2014 growing season.

Principal components 1 and 2 showed that the loadings decreased in the following order T_{min}>Hu>T_{max}> RHx whilst Rain, Rs and RHn indicated no significant different contribution in 2013 growing season. In 2013 growing season, the PCA results in terms of correction matrix indicated that Hu, T_{max} and RHx accounted for the highest loading in PC 1. However in PC 2, the T_{min} had the highest significant loading.

Therefore in 2014 growing season, RHn and RHx accounted for the highest loading in PC 1 which has the highest variance. Whilst in PC 2 the T_{min} and T_{max} had the highest significant loading.

In 2014 a decreasing trend in terms of importance RHn >T_{min} >T_{max} >RHx whilst Hu, Rain, Rs and RHn indicated no significant different contribution in 2013 growing season.

Table 3: The component matrix for Syferkuil and Ofcolaco weather parameters, in 2014 growing season.

Ofcolaco				
Weather parameters				
	2013		2014	
	1	2	1	2
T_{max}	0.78	0.59	-0.60	0.78
T_{min}	-0.81	0.92	0.40	0.90
Hu	0.91	-0.16	-0.94	-0.05
RHx	-0.68	0.27	0.72	0.22
RHn	-0.93	0.27	0.95	0.15
Rs	0.77	0.44	-0.70	0.50
Rain	-0.68	0.41	0.31	0.34

4.4 Days to emergence

Days to seedling emergence responded significantly (*P≤0.01*) to planting date at Syferkuil in 2013 but not in 2014 (Table 4). Seeds emerged in 10 DAP in April planting compared to 23 DAP in the June planting. At Ofcolaco, significant response (*P≤0.01*) of seedling emergence to planting date was observed in both 2013 and 2014 growing seasons. Similar to Syferkuil, days to seedling emergence was shorter in the early plantings and prolonged in the later plantings. No data was recorded at Syferkuil for June planting due to wild animals' damage.

Table 4: The effect of planting dates on days to emergence at Syferkuil and Ofcolaco.

Planting Dates	Days to emergence			
	Syferkuil		Ofcolaco	
	2013	2014	2013	2014
March	ƚ	10	ƚ	8^{c}
April	10^{c}	10	8^{c}	9^{b}
May	12^{b}	9	12^{b}	14^{a}
June	23^{a}	н	20^{a}	н
P(≤0.05)	**	*ns*	**	**
CV%	9.80	6.90	23.67	5.73

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ƚ not planted, н damaged by wild animals.*

4.5 Plant height

Canola plant height at 50% flowering, and physiological maturity responded significantly (*P≤0.01*) to planting date at Syferkuil in the 2013 growing season (Table 5). The tallest plants at these two growth stages in 2013 were from the April planting followed by May. Planting in June produced the shortest plants. At physiological maturity, canola height ranged from 65 to 119 cm. In 2014, significant planting date effect on plant height at Syferkuil was only observed at 50% flowering and not at physiological maturity. Plants grown earlier were again taller than those grown later.

At Ofcolaco, the plant height was highly influenced (*P≤0.01*) by planting date at 50% flowering in 2013 (Table 5). The effect was also significant (*P≤0.05*) at physiological maturity at this location in the same season. The plants were generally taller in the April planting and shorter in the June planting. At physiological maturity, canola height ranged from 123 to 147 cm. During the 2014 growing season, canola height was only influenced (*P≤0.05*) by planting date at physiological maturity with no significant difference at 50% flowering. The March and April plantings resulted in the tallest plant relative to the May planting at physiological maturity. Plant height ranged from 134 to 149 cm at this growth stage.

Table 5: Plant height at selected growing stages of canola at Syferkuil and Ofcolaco in 2013 and 2014 growing seasons

	Plant height (cm)							
	Syferkuil				Ofcolaco			
	2013		2014		2013		2014	
Planting Dates	50% Flowering	Physiological Maturity	50% Flowering	Physiological maturity	50% Flowering	Physiological Maturity	50% Flowering	Physiological maturity
March	ɫ	ɫ	75[a]	145[a]	ɫ	ɫ	36[a]	149[a]
April	78[a]	119[a]	66[ab]	139[a]	99[a]	147[a]	40[a]	148[ab]
May	65[b]	100[b]	53[b]	139[a]	87[b]	140[ab]	33[a]	134[bc]
June	35[c]	65[c]	#̶	#̶	72[c]	123[bc]	#̶	#̶
P(≤0.05)	**	**	*	*ns*	**	*	*ns*	*
CV%	7.76	8.12	12.35	2.70	3.13	7.13	16.74	3.99

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɫ not planted, #̶ damaged by wild animals.*

4.6 Flowering and physiological maturity

There was a highly significant (*P≤0.01*) influence of planting date on days to flowering and physiological maturity at both locations and growing seasons (Table 6).

Flowering

At Syferkuil, days to flowering ranged from 46 to 68 and 54 to 68 in the 2013 and 2014 seasons, respectively while days to physiological maturity ranged from 128 to 145 in 2013 and 136 to 164 in 2014 (Table 6). In 2013, the April planting resulted in earlier flowering relative to the May and June plantings, whereas no significant difference in flowering was observed in the May and June plantings in the 2013 growing season. In the 2014 growing season, March planting resulted in earlier flowering followed by April and May.

At Ofcolaco, days to flowering ranged from 40 to 62 and 43 to 85 days after emergence in 2013 and 2014 respectively. In both seasons, the early plantings flowered earlier compared to the late planting. Days to physiological maturity ranged from 135 to 153 and 184 to 208 in 2013 and 2014 respectively (Table 6).

The pattern of days to physiological maturity was inconsistent between the 2013 and 2014 growing seasons at both locations. A decreasing trend from earlier to later planting was observed in 2013 whereas the reverse occurred in 2014 (Table 6).

Table 6: Days to flowering and physiological maturity at Syferkuil and Ofcolaco in 2013 and 2014

Days to Flowering and Physiological Maturity								
	Syferkuil				Ofcolaco			
Planting Dates	Days to Flowering		Days to Physiological Maturity		Days to Flowering		Days to Physiological Maturity	
	2013	2014	2013	2014	2013	2014	2013	2014
March	ƚ	54^{c}	ƚ	136^{c}	ƚ	43^{c}	ƚ	186^{b}
April	46^{b}	63^{b}	145^{a}	147^{b}	40^{b}	72^{b}	153^{a}	184^{b}
May	54^{a}	68^{a}	130^{b}	164^{a}	47^{c}	85^{a}	150^{a}	208^{a}
June	68^{a}	#	128^{b}	#	62^{a}	#	135^{b}	#
P(≤0.05)	**	**	*	**	**	**	**	**
CV%	5.34	1.61	4.58	2.02	6.93	2.90	2.02	1.57

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ƚ not planted, # damaged by wild animals.*

4.7 Number of main branches and sub branches

Planting dates significantly (*P≤0.01*) affected the number of main and sub branches at Syferkuil in the 2013 growing season while no significant difference was observed in 2014 growing season. In 2013, more main branches were produced in the May planting than in April and June, while more sub branches were obtained during the April planting, than of plants planted in May and June (Table7).

At Ofcolaco no significant difference was observed in 2013 growing season while in the 2014 growing season, planting dates significantly (*P≤0.05*) affected the number of main and sub branches (Table7). March planting resulted in less main and sub branches in the both seasons.

.

Table 7: Response of main and sub-branches to planting date at Syferkuil and Ofcolaco in 2013 and 2014

Branches								
	Syferkuil				Ofcolaco			
	2013		2014		2013		2014	
Planting Dates	Main branches	Sub branches	Main branches	Sub branches	Main branches	Sub branches	Main branches	Sub branches
March	ɫ	ɫ	3	6	ɫ	ɫ	2^b	3^b
April	1^a	2^a	3	6	2	5	4^a	6^a
May	2^b	1^b	3	4	2	5	4^a	5^a
June	1^a	1^b	#	#	2	5	#	#
P(≤0.05)	**	**	*ns*	*ns*	*ns*	*ns*	*	*
CV%	20.38	19.42	28.60	25.80	17.27	21.62	18.98	25.00

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɫ not planted, # damaged by wild animals.*

4.8 Dry matter accumulation

Syferkuil

Canola dry matter accumulation at flowering stage responded significantly ($P \leq 0.01$) to planting date at Syferkuil in the 2013 growing season but not in 2014 (Table 8). However, planting date significantly ($P \leq 0.01$) had an effect on crop residues after threshing in both 2013 and 2014 growing seasons. In 2013, the highest dry matter production at flowering occurred in the April planting followed by the May planting with the June planting accumulating the least. The trend of crop residues after threshing was similar to that of dry matter at flowering, with the highest dry matter occurring in the April planting and the least in the June planting during the 2013 growing season (Table 8). In 2014, the highest crop residues after threshing was recorded in the March planting whereas the April and May planting resulted in similar dry matter accumulation. Crop residues after threshing ranged from 855 to 11146 kg ha^{-1} in the 2013 growing season while in 2014; it ranged from 4470 to 10100 kg ha^{-1} (Table 8).

Ofcolaco

No significant effect of planting date on dry matter accumulation at flowering was obtained at Ofcolaco during the 2013 and 2014 growing seasons. Crop residues after threshing, however, responded significantly ($P \leq 0.01$) and ($P \leq 0.05$) to planting date in both 2013 and 2014 growing seasons, respectively. The highest dry matter production occurred in the April planting followed by the May and June planting in the 2013 growing season. In the 2014 growing season, the highest dry matter was produced in the March and April plantings (Table 8). Crop residues after threshing ranged from 9020 to 11834 kg ha^{-1} in 2013 growing season while in 2014 growing season, it ranged from 5438 to 10431kg ha^{-1} (Table 8).

Table 8: Dry matter (DM) accumulation at flowering and crop residues after threshing at Syferkuil and Ofcolaco in 2013 and 2014

	Dry matter accumulation (kg ha^{-1})							
	Syferkuil				Ofcolaco			
	2013		2014		2013		2014	
Planting Dates	DM at flowering	Crop residues	DM at flowering	Crop residues	DM at flowering	Crop residues	DM at flowering	Crop residues
March	ɫ	ɫ	190	10100^{a}	ɫ	ɫ	150	10431^{a}
April	206^{a}	7802^{a}	173	4618^{b}	176	8284^{a}	193	7413^{a}
May	159^{b}	4868^{b}	143	4470^{b}	185	6387^{ab}	183	5438^{b}
June	137^{c}	598^{c}	ꟸ	ꟸ	165	4735^{b}	ꟸ	ꟸ
P(≤0.05)	**	**	*ns*	**	*ns*	*	*ns*	*
CV%	6.8	24.5	29.62	23.39	19.59	17.69	22.92	17.08

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɫ not planted, ꟸ damaged by wild animals.*

4.9 Grain yield

Grain yield was significantly (*P≤0.01*) influenced by planting date (Figure 4) at both Syferkuil and Ofcolaco in the two growing seasons. A general trend of decreasing grain yield with delayed planting was observed at both locations except in 2014 at Ofcolaco where early planting resulted in reduced yield.

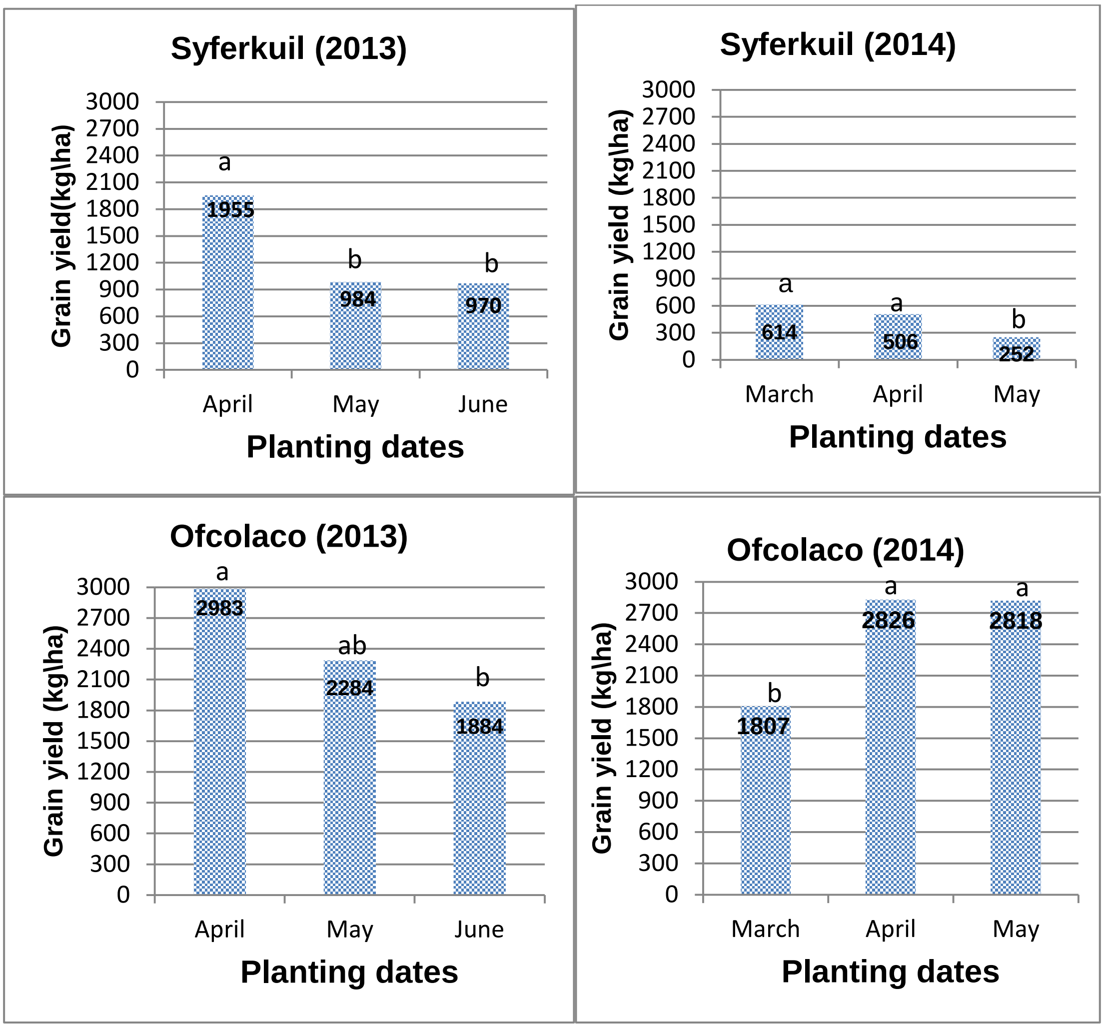

Figure 4: The response of canola grain yield (kg ha^{-1}) to planting dates in 2013 and 2014 growing seasons at Syferkuil and Ofcolaco.

At Syferkuil in 2013, the highest grain yield of 1955 kg ha^{-1} was obtained in the April planting and the lowest in the May and June plantings. On average, the grain yield from the May and June plantings was 50.03% lower relative to the yield from April planting. In 2014 at Syferkuil, the grain yield from the March and April plantings were similar but each was significantly (*P≤0.01*) higher than the May planting. Seeds planted in June did not emerge due to extremely cold temperature.

At Ofcolaco, the highest grain yield was obtained from the April and May plantings in both two seasons (Figure 4). On average, the yield from the May and June plantings was 51% lower than that of the April planting in 2013 season. When canola was planted in March at this location, during 2014 growing season, grain yield of 1807 kg ha^{-1} was obtained which was significantly lower (36%) than yields from the April and May plantings.

4.10 Oil percentage

The results from this study indicate that, seed oil percentage ranged from 25.3 to 27.6% in the 2013 growing season and 20.6 to 24.4% in 2014 at Syferkuil (Table 9.). At Ofcolaco, the range was from 32.3 to 35.7% in 2013 and 32.1 to 33.9% in 2014 growing season. Generally, oil percent at Syferkuil was 24 and 33 percentage point lower than that of Ofcolaco in the 2013 and 2014 growing seasons, respectively.

Table 9: Response of canola oil percentage to planting date

Oil percentage (%)				
Planting date	Syferkuil		Ofcolaco	
	2013	2014	2013	2014
March	ɫ	20.6	ɫ	33.7
April	27.6	21.6	35.7	34.2
May	25.8	24.4	35.1	32.1
June	25.3	ⱨ	32.3	ⱨ

ɫ not planted, ⱨ damaged by wild animals.

4.11 Oil yield

At Syferkuil, no statistical analyses were done due to low yield. However, representative results were obtained per planting date. The highest oil yield was obtained in April (539 kg ha^{-1}) and the lowest in June (155 kg ha^{-1}) planting in 2013 growing season, the highest (126 kg ha^{-1}) oil yield was obtained in March planting and the least (61kg ha^{-1}) in May planting (Table 10). Generally a decrease in oil yield was observed as the planting was delayed in both growing seasons.

Table 10: Oil yield responding to planting dates at Syferkuil

	Syferkuil	
planting date	Oil yield (kg ha^{-1})	
	2013	2014
March	ł	126
April	539	109
May	249	61
June	155	ħ

ł not planted, ħ damaged by wild animals.

At Ofcolaco, significant response of oil yield to planting dates was observed during the 2013 (*$P \leq 0.05$*) and 2014 growing seasons. In 2013 growing season, the highest oil yield of 1063 kg ha^{-1} was obtained in the April planting, followed by May planting with 802 kg ha^{-1} and the lowest in the June planting. However in 2014 growing season, the highest of 208 kg ha^{-1} was obtained in the March planting, followed by April 172 kg ha^{-1} and the lowest 81 kg ha^{-1} in the May planting (Table 11).

Table 11: Response of oil yield to planting date at Ofcolaco

	Ofcolaco	
	Oil yield (kg ha^{-1})	
Planting Date	2013	2014
March	ɨ	208^{a}
April	1064^{a}	172^{a}
May	802^{b}	81^{b}
June	612^{b}	ɨɨ
P(≤0.05)	*	**
CV%	21.29	19.43

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɨ not planted, ɨɨ damaged by wild animals.*

4.12 Response of harvest index to planting date

The results from this study revealed a significant (*P≤0.01*) and (*P≤0.05*) difference at Syferkuil in 2013 and 2014 growing season. Contrary to Syferkuil, significant (*P≤0.01*) difference was obtained in 2014 and not in 2013 growing season at Ofcolaco. A range of 17 to 53 % and 5.8 to 11.3 % in 2013 and 2014 growing season at Syferkuil was obtained, respectively. At Ofcolaco, the range was from 17.0 to 52.6 % in 2014 (Table 12).

Table 12: Response of canola harvest index to planting date

	Harvest Index %			
	Syferkuil		Ofcolaco	
Planting Dates	2013	2014	2013	2014
March	ɨ	6.4b	ɨ	17.3b
April	20.0b	11.3a	27.1	38.1a
May	17.0c	5.8b	26.0	52.6a
June	53.0a	ɨ	23.0	ɨ
P(≤0.05)	**	*	*Ns*	**
CV%	6.75	28.80	19.67	17.08

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɨ not planted, ɨɨ damaged by wild animals.*

4.13 Yield components

The yield components of canola at the two locations in both seasons are shown in Table 13. With the exception of number of pods per plant, the two other yield components did not respond to planting date at the two locations and seasons. There were no significant difference to planting date except for the number of pods per plant ($P \leq 0.01$) and ($P \leq 0.05$) in 2013 and 2014 growing season at both locations respectively, and hundred seed weight at Ofcolaco($P \leq 0.05$).

4.13.1 Number of pods per plant

At Syferkuil, the number of pods per plant responded significantly ($P \leq 0.01$) to planting date in the two seasons (Table 13). In 2013, the highest pod per plant was obtained in the March planting followed by April and then the May plantings. In 2014, the early planting, March produced the highest number of pods per plant was produced in the early planting and then decreased with consequent planting dates. Across the two season, the number of pods per plant ranged from 124 to 133 in 2013 and then from 309 to 490 in 2014.

At Ofcolaco, the number of pods per plant responded significantly ($P \leq 0.01$) and ($P \leq 0.05$) to planting date in 2013 and 2014 growing seasons, respectively. A decrease in number of pods per plants was obtained as planting was delayed in 2013 growing season. The highest number of pods per plant (558) was obtained in April and the least (346) in June during the 2013 growing season. In 2014, the highest grain yield was obtained in April planting and the least (327) in March planting

4.13.2 Number of seed per pod

No significant response on number of seed per pod to planting date was observed at both the locations in the 2013 and 2014 growing seasons (Table 13).

4.13.3 Hundred seed weight

The hundred seed weight was only significantly ($P \leq 0.01$) influenced by planting in 2013 at Ofcolaco. The highest seed weight was produced in the April and May plantings and the least in the June planting which was 12.5% lower than the average of the April and May plantings.

Table 13: Yield components responding to planting date at Syferkuil and Ofcolaco in 2013 and 2014

	Yield components											
	Syferkuil						Ofcolaco					
	2013			2014			2013			2014		
Planting Dates	# pods plant^{-1}	# seeds pod^{-1}	100 seed weight (g)	# pods plant^{-1}	# Seeds pod^{-1}	100 seed weight (g)	# pods plant^{-1}	# seeds pod^{-1}	100 seed weight (g)	# pods plant^{-1}	# Seeds pod^{-1}	100 seed weight(g)
March	ƚ	ƚ	ƚ	490^{a}	17^{a}	0.2	ƚ	ƚ	ƚ	327^{a}	22	0.40
April	333^{a}	17	0.2	429^{b}	13^{ab}	0.2	558^{a}	21.50	0.40^{a}	476^{b}	24	0.40
May	225^{b}	16	0.2	309^{c}	10^{b}	0.2	458^{b}	22.25	0.40^{a}	342^{c}	24	0.37
June	124^{c}	16	0.2	ʜ	ʜ	ʜ	346^{c}	20.00	0.35^{b}	ʜ	ʜ	ʜ
P(≤0.05)	**	*ns*	*ns*	**	*ns*	*ns*	**	*ns*	**	*	*ns*	*ns*
CV%	21.62	6.65	22.98	4.83	29.06	13.86	10.80	9.60	2.06	13.59	5.82	7.37

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ƚ not planted, ʜ damaged by wild animals.*

4.14 Crop Lodging

A highly significant difference (*P≤0.01*) in lodging at physiological maturity resulting from planting date was observed at both locations during the 2013 and 2014 growing seasons (Table 14). There was very minimal lodging at Syferkuil in 2013 compared to 2014. The April planting resulted in lodging of the plantings whereas no lodging occurred in the May and June plantings. In the 2014 growing season at the same location, the highest lodging of 70% percentage was obtained in March planting followed by 34% in the April planting and no lodging in the May planting.

At Ofcolaco, severe lodging occurred in both seasons with the highest lodging percentage recorded in the April and May plantings in 2013 and the March and April planting in 2014. Lodging percentage ranged from 41.3 to 93.8% in 2013 and 41.3 to 83.7% in 2014. Although lodging was observed at both locations, a greater effect was experienced at Ofcolaco, where the highest lodging percentage was over 90% as compared to Syferkuil where the lodging was only 70% (Table 14).

Table 14: Crop lodging at physiological maturity at Syferkuil and Ofcolaco in 2013 and 2014 growing season

	Lodging percentage			
	Syferkuil		Ofcolaco	
Planting Dates	2013	2014	2013	2014
March	ƚ	70.0^a	ƚ	72.50^a
April	4.0^a	34.0^b	93.8^a	83.75^a
May	0.0^b	0.0^c	82.8^a	41.25^b
June	0.0^b	ǂ	41.3^b	ǂ
P(≤0.05)	**	**	**	**
CV%	35.36	32.95	13.45	10.82

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ƚ not planted, ǂ damaged by wild animals.*

4.15 Insect-pest and disease scoring

The major insect-pest on canola observed during the study was *Aphis gossypii*. At Syferkuil, no significant response of pest infestation to planting date was observed in the 2013 growing season at both flowering and pod development stages while in 2014, significant (*P≤0.05*) difference was observed at pod development at this location (Table 15).

At Ofcolaco, no significant difference in pest infestation was observed during the 2013 growing season, but in the 2014 growing season, pest infestation was significantly (*P≤0.01*) influenced by planting date at both flowering and pod development (Table 15). The highest pest infestation occurred in the March planting, whereas infestation in the April and May plantings were similar.

Table 15: Score of insect-pest infestation at Syferkuil and Ofcolaco in 2013 and 2014 growing season

Planting Dates	Syferkuil 2013 flowering	Syferkuil 2013 Pod development	Syferkuil 2014 flowering	Syferkuil 2014 Pod development	Ofcolaco 2013 flowering	Ofcolaco 2013 Pod development	Ofcolaco 2014 flowering	Ofcolaco 2014 Pod development
March	ɫ	ɫ	3.00	2.5^{a}	ɫ	ɫ	4.0^{a}	4.0^{a}
April	1.1	1	2.00	1.5^{ab}	1	1	2.5^{b}	2.5^{b}
May	1.5	1.5	1.75	1.0^{b}	1	1	2.2^{b}	2.25^{b}
June	1.1	1	ħ	ħ	2	1	ħ	ħ
P(≤0.05)	*ns*	*ns*	*ns*	*	*ns*	*ns*	**	**
CV%	23.09	28.57	45.18	40.00	48.43	57.74	12.78	12.78

*Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level,*Significant at p≤0.05, **significant at 0.001, ns Not significant.ɫ not planted, ħ damaged by wild animals.*

4.16 Grain yield correlation

Out of the plant parameters (Table 16) the ones found to correlate with grain yield is plant height at flowering and physiological maturity, days to flowering and physiological maturity, crop residues, lodging percentage and pod per plant.

Plant height at flowering had a strong positive correlation with grain yield at Syferkuil, in both growing seasons whereas at Ofcolaco, a strong positive correlation was obtained in 2013 growing season whilst no correlation was obtained in 2014. The correlation between plant height at physiological maturity and grain yield at Syferkuil was strongly positive in 2013 whilst no correlation was obtained in the 2014 growing season. Similar to the relationship between plant height at flowering at Ofcolaco, a strong positive correlation between plant height at physiological maturity and grain yield was observed in 2013 growing season whilst no correlation was obtained in 2014 growing season.

Comparing the relationship between days to flowering and grain yield, strong negative correlation between the days to flowering and grain yield was observed in 2013 growing season at Syferkuil, whilst a strong positive correlation was obtained in 2014 growing season. At Ofcolaco, no correlation was found between days to flowering and grain yield during 2013 growing season, however, a weak positive correlation was found in 2014 growing season. During the 2013 growing season, days to maturity and grain yield showed a moderate positive correlation with a strong positive correlation in 2014 growing season.

No correlation between dry matter accumulation at flowering and grain yield was found at both the locations in 2013 and 2014 growing seasons. A strong positive correlation between crop residues and grain yield was found at Syferkuil and Ofcolaco in 2013 growing season. In 2014, no correlation was obtained between the two parameters.

The correlation between lodging and grain yield was positive at both the locations in 2013 whilst no correlation was found in 2014 growing season. A strong positive correlation was found between number of pods per plant and grain yield at both the locations in 2013 and 2014 growing seasons. At Syferkuil, a moderate correlation was found between seeds per pod and grain yield in 2013 growing season whilst no correlation was found in 2014 growing season. At Ofcolaco, no correlation was found between both parameters in 2013 and 2014 growing seasons.

Table 16: Correlation of grain yield and growth parameters at Syferkuil and Ofcolaco in 2013 and 2014

Correlation of grain yield and growth parameters				
Growth parameters	Syferkuil		Ofcolaco	
	2013	**2014**	**2013**	**2014**
Days to Emergence	0.831**	-0.920**	*ns*	*ns*
Plant height at flowering	0.834**	0.635*	0.839**	*ns*
Plant height at physiological maturity	0.845**	ns	0.713**	*ns*
Days to Flowering	-0.849**	0.846**	*ns*	0.570*
Days to Maturity	0.695*	-0.896**	0.695*	0.800**
Dry matter at flowering	*ns*	*ns*	*ns*	*ns*
Crop residues	0.897**	*ns*	0.706**	ns
Lodging percentage	0.882**	*ns*	0.666*	ns
Pest and diseases	ns	0.819**	ns	-0.592*
Harvest index	-0.570*	*ns*	0.806**	ns
Main-branches	0.657*	*ns*	*ns*	0.653*
Sub-branches	0.891**	*ns*	*ns*	0.779**
Pod/plant	0.920**	0.748**	0.824**	0.704**
Seed/pod	0.611*	*ns*	*ns*	*ns*
100Seed weight	*ns*	*ns*	0.73**	*ns*

4.17 Prevailing temperature during growth

The prevailing maximum, minimum and average temperature ranges from planting to physiological maturity for the different planting dates are presented in Tables 16 and 17. The results indicate relatively cooler conditions for the later planted crops compared to the earlier plantings. It is also evident that, at Ofcolaco the crops were exposed to a much warmer conditions during growth than those at Syferkuil.

At Syferkuil in 2013, the plants established in April was exposed to a minimum temperature range of 2.0 to 9.3 ^oC and that of the May and June plantings were 1.1 to 3.1 ^oC and -3.2 to 7.9 ^oC, respectively. In comparison to the 2014 growing season, the minimum temperature range were 3.8 to 15.5 ^{o}C for the March plantings, 2.6 to 8.4 ^{o}C for the April planting and 0.9 to 4.7 ^{o}C for the May planting.

At Ofcolaco, the minimum temperature range in 2013 was 14.0 to 18.0 ^{o}C for the April planting, 12.4 to 14.1 ^{o}C for the May planting, and 9.9 to 16.2 ^{o}C for the June planting. In 2014, the minimum temperature range were 14.3 to 22.2 ^{o}C for the March planting, 13.27 to 20.21 for the April planting and 10.57 to 14.66 ^{o}C for the May planting,

Table 17: Planting dates and ambient temperature at Syferkuil in 2013 and 2014 growing seasons

Growing stages	Temperature (^0C)																	
	2013									2014								
	April			May			June			March			April			May		
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave
Planting	30.9	9.3	20.1	25.3	2.61	14	23.6	-3.2	10.2	26.1	15.5	20.8	24.3	6.75	15.5	26.9	4.72	15.8
Emergence	24.84	8.18	16.5	25	3.06	14	23.4	-0.05	11.7	27.5	12.2	19.9	26.1	8.35	17.2	25	4.14	14.6
Flowering	25.23	3.93	14.6	24.5	1.11	13	26.3	7.27	16.8	26.1	7.75	16.9	25.5	2.77	14.2	24.3	0.9	12.6
Maturity	24	1.99	13	23.5	1.14	12	26.2	7.92	17.1	25	3.81	14.4	25.3	2.59	13.9	25.7	4.5	15.1

Table 18: Planting dates and ambient temperature at Ofcolaco for 2013 and 2014 growing season

	Temperature (^{0}C)																	
	2013									2014								
Growing stages	April			May			June			March			April			May		
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave
Planting	26.1	18	22.08	28.8	14.06	21.4	26.81	9.89	18.4	31.09	22.2	26.65	30.09	16.63	23.36	25.56	10.57	18.07
Emergence	24.79	15	20.11	27.8	13.75	20.8	26.27	11.7	19.0	29.38	20.23	24.81	30.0	20.21	25.1	26.23	13.63	19.93
Flowering	27.16	14	20.6	26.8	12.44	19.6	27.57	15.18	21.4	28.02	17.73	22.87	26.87	13.27	20.07	26.31	12.45	19.38
Maturity	27.77	14	20.76	26.0	12.96	19.5	27.89	16.21	22.1	26.86	14.23	20.55	27.53	14.45	20.99	27.79	14.66	21.23

4.18 Growing degree days response to planting date

At Syferkuil, the growing degree days ranged from 1128.0 to 1292.1 in 2013 and from 1553.2 to 1632.1 in 2014 (Table 19). At Ofcolaco, the range was 1687.1 to 1927.9 in 2013 and in 2014 1721.9 to 2043.1. Similar to the ambient temperature, higher growing degree days was experienced at Ofcolaco than at Syferkuil.

The growing degree days experienced by the crops influenced the final grain yield each season at each location. A strong positive correlation between grain yield and growing degree days was observed in 2013 (0.89) and in 2014 *(*0.72*).*

Table 19: Growing degree days response to planting date

	Growing Degree Days			
	Syferkuil		Ofcolaco	
Planting date	2013	2014	2013	2014
March	ǂ	1570	ǂ	2040
April	1289	1632	1928	1722
May	1292	1553	1687	2043
June	1128	‡	1687	‡

ǂ not planted, ‡ damaged by wild animals.

4.19 Summary of enterprise budget of canola productivity

Details of the enterprise budgets for the two locations and two growing seasons are presented in Table 19. The sale price was assumed to be R4.90 per kilogram of canola grain.

The results from this study indicated that, the gross margins from producing canola at Syferkuil ranged from a *loss* of R2626.00 to a positive margin of R2130.00 per hectare during the 2013 growing season (Table 20.). The positive return was realised only when planting was done in April at this location. At Ofcolaco, the gross margins were positive across planting dates, ranging from R1170.00 to R6555.00 per hectare. Similar to Syferkuil, the highest return was obtained in the April planting and the least, in the June planting.

Table 20: Summary of enterprise budget of canola productivity in 2013 growing season

	2013					
	Syferkuil			Ofcolaco		
	April	May	June	April	May	June
Gross Receipt	9578	4822	3283	14617	11192	9232
Production Cost						
* Total pre-harvest	6753	6753	7633	7338	7338	7338
* Harvest cost	340	340	340	340	340	340
* Total cost shown	7093	7093	7973	7678	7678	7678
* Contingency (5%)	355	355	797	384	384	384
* Grand total cost	7448	7448	8770	8062	8062	8062
Gross Margin	**R 2 130**	**-R 2 626**	**-R 5 487**	**R 6 555**	**R 3 130**	**R 1 170**

In 2014, the gross margins at Syferkuil were negative in all the planting dates, ranging from a loss of R4 439.00 to R6 213.00 (Table 21). The loss increased with delay in planting. Similar to the 2013 growing season, the gross margins were all positive at Ofcolaco in 2014 with a range of R7 93.00 to R5 785.00 per hectare. The highest return was obtained in the April planting and the lowest in March planting. Thus, planting before April at this location resulted in reduced gross margin.

Table 21: Summary of enterprise budget of canola productivity in 2014 growing season

	2014					
	Syferkuil			Ofcolaco		
	March	April	May	March	April	May
Gross Receipt	3009	2479	1235	8854	13847	13808
Production Cost						
* Total pre-harvest	6753	6753	6753	7338	7338	7338
* Harvest cost	340	340	340	340	340	340
* Total cost shown	7093	7093	7093	7678	7678	7678
* Contingency (5%)	355	355	355	384	384	384
* Grand total cost	7448	7448	7448	8062	8062	8062
Gross Margin	**-R 4 439**	**-R 4 968**	**-R 6 213**	**793**	**R 5 785**	**R 5 747**

CHAPTER 5

DISCUSSION

5.1 Weather and crop development

Syferkuil has a semi-arid climate and can experience monthly minimum temperatures as low as 0^oC, maximum of 30^oC, low relative humidity and maximum rainfall of 450-500 mm per annum. In comparison, Ofcolaco has a semi-humid climate, with minimum temperatures of above 10^oC, maximum above 30^oC, high relative humidity with a rainfall in excess of 700mm per annum. In 2013, mild frost was experienced at Syferkuil while a severe frost was experienced in 2014 during the month of June. Although weeds and all other crops that were planted at that period died, canola remained but plant growth was delayed while flowering was prolonged.

At Ofcolaco, the minimum temperature was above 10 ^oC in both seasons which is higher than the base temperature of canola. Neither frost nor severe cold was experienced at Ofcolaco, which promoted the canola growth and hence the higher grain yield observed at this location compared to Syferkuil. The significance of favourable ambient temperature in enhancing canola growth and yield had been reported by Kutcher et al. (2010).

5.2 Phenological and growth parameter of canola

5.2.1 Effect of planting date on days to emergence

The timing of seedling establishment is critical to grain yield in canola. Many authors have reported that, planting either too early or too late is unfavourable for canola seedling establishment (Hocking and Stapper 2001; Robertson et al. 2004; Uzun et al. 2009). The significant differences in seedling emergence observed at both locations and in the two seasons (Table 4) could be the result of differences in ambient temperatures during the time of planting. There were significant drops in minimum temperatures with each delayed planting at the two locations. Kondra et al. (1983) and Christensen and Drabble (1984) reported that when canola is planted too late, seed germination is prolonged and this leads to limited seedling development.

Vigil et al. (1997) also reported 99% Inconsistency in seedling emergence when canola is planted below a base temperature. According to DAFF (2010) temperatures below 10 °C result in progressively poorer germination and emergence of canola. It was further indicated that low temperature damages the production of sufficient protein that is required for proper germination and early seedling development

5.2.2 Plant height response to planting date

This study revealed the importance of planting date on growth of canola. Delay in planting generally resulted in decrease in height of canola. This could be attributed to the amount of heat received by the plant during the growing stages. Similar results were found by Robertson et al. (2004) and Uzun et al. (2009), in rapeseed where plant height was decreased with delayed planting. Sattar et al. (2013), also reported that different planting dates significantly affected the height of canola and further indicated that, late planted canola were shorter compared to the earlier planted ones. The negative relation between delayed planting and height of canola has been reported in several other studies (Oz, 2002. Shirani and Ahmadi, 1996; Mondal and Islam, 1993; Shahidullah et al., 1997, Kurmi, 2002; Panda et al., 2004).

5.2.3 Effect of planting date to days to flowering and physiological maturity

The change in weather condition, particularly temperature affects crop development and yield. Hall (1992) indicated that flowering stage is the most sensitive and vulnerable stage to temperature stress damage in canola as it influences pollen development. Thus, flowering stage is one of the crucial stages that determine the grain yield of canola. The amount of heat that the crop receives is related to the duration of flowering and days to which the plants flowers. In this study, days to flowering were longer as planting was delayed and this could be attributed to the decrease in temperature at the two locations as the season progressed.

In general, the ambient temperature at Syferkuil was cooler than that of Ofcolaco. The results from this study indicated that early planting enhanced early flowering which could be attributed to the favourable ambient and soil temperatures. Days to physiological maturity was shorter at Syferkuil compared to that at Ofcolaco due to cooler ambient temperature experienced by the crop, at Syferkuil. This partly explains the relatively reduced grain yield at Syferkuil compared to Ofcolaco. A similar observation has been made by Mendham *et al*. (1990) where delayed planting accelerated growth and decreased the number of days from planting to flowering by 50%. Furthermore, Khan *et al*. (1994) reported that delayed planting led to decreased the number of days to flowering and physiological maturity as well as grain yield. The study conducted by Vaezi et al. (2009) revealed a significant difference in branching stages of canola cultivars in relation to some important agronomical traits such as days to flowering. This was attributed to genetic variations among the cultivars. In another study, Asgari and Moradie-Dalini (2008) indicated that, days to flowering differ depending on the variety planted.

5.3 Response of grain yield to planting date

This study generally revealed a significant reduction in canola grain yield as planting was delayed or done too early at the warmer environment. A study conducted by Kirkland and Johnson (2000) stated that seed yield was greater in early planting dates and lower in the later planting dates. Horton (2006), also reported that highest yield of canola was observed from earlier planting. Similarly, Sattar et al. (2013) reported that late planting significantly reduced seed yield which might be due to variation in temperature in late planting canola.

The reduction of grain yield with delayed planting could be attributed to variation in ambient temperature that was experienced at both the locations. Seasonal dry matter accumulation was also found to have contributed significantly to final grain yield at Syferkuil in 2013 as inferred by a positive correlation.

From this study, differences in grain yield were primarily due to difference in ambient temperature, heat units and the duration of vegetative and reproductive growth stages and number of pods per plant. A study conducted by Gan et al. (2004), shows that abiotic stress are the most important challenges in canola production

5.4 Harvest index response to planting date

The results from this study revealed no particular trend in harvest index with planting dates at Syferkuil in 2013 but in 2014, a decrease in harvest index as planting was delayed. At Ofcolaco, harvest index was reduced with later planting date in both seasons. Scarisbrick et al. (1982) revealed that harvest index reduction due to delayed planting was one of the most important factors that contribute to decrease seed yield in canola. Moreover, Johnson et al. (1995) concluded that delayed planting significantly resulted in decreased harvest index.

Negative correlation was observed between grain yield and harvest at Syferkuil whilst positive correlation was observed at Ofcolaco in 2013 growing season. No correlation was found in 2014 growing season at both the locations.

5.5 Oil percentage and oil yield response to planting date

This study generally revealed difference in oil percentage per location. Syferkuil resulted in high oil yield of 27.55% and 24.4% in 2013 and 2014, respectively, whilst at Ofcolaco; the highest oil percentage obtained was 35.67% in 2013 and 34.15% in 2014 growing seasons. This could be attributed to the amount of minimum ambient temperature received at Syferkuil, which was lower than 10^{o}C during flower whilst at Ofcolaco was above 10^{o}C.

This range has been reported by number of authors (Ayisi et al. 1997 and Mailer et al. 1998). The difference in oil percentage could be attributed to the difference in study location and growing seasons. Mailer et al. (1998) reported that the oil content of Australian canola crops can vary from less than 35% to over 45% depending on the season and the growing area.

The oil yield decreased as the planting was delayed at both locations in 2013 and 2014 growing seasons. Johnson et al. (1995) concluded that delayed planting not only decreases the grain yield and other traits effective on the yield, but also the oil content of the grain.

5.6 Yield and yield components

5.6.1 Number of pods per plant

In this study, a decreasing trend in number of pods per plants was obtained in both growing seasons as planting was delayed. This trend could be attributed to the lower ambient temperature associated with delayed planting. In a study on canola, Degenhart and Kondra (1981) reported that number of pod per plant decreased as planting was delayed. Thurling (1974) also reported that increased canola grain yield was the result of increased in the number of flowers and pods per plant. Several other researchers have reported that a decrease in pods per plant and seed weight is influenced by delayed planting (Allen et al. 1971; Mendham et al. 1981; Pechan and Morgan, 1985; Taylor and Smith, 1992; Degenhart and Kondra 1981, Ghosh and Chatterjee, 1998).

5.6.2 Number of seed per pod

The result obtained from this study revealed no significant difference in number of seed per pod at both locations and seasons. Numbers of seeds are usually genetically determined and hence under non-limiting growth conditions may not be influenced by the environment. There was also no correlation between the number of seeds per pod and grain yield at Syferkuil in 2014 but a weak correlation was found in 2013 growing season. At Ofcolaco, no correlations with grain yield were observed in the 2013 and 2014 growing seasons.

5.6.3 Hundred seed weight

Hundred seed weight was significantly influenced by planting date only in 2013 at Ofcolaco. At this location, the 100-seed weight decreased as planting was delayed. Similar results were reported by Panda et al. (2004) where delay in planting reduced 1000-seed weight. Robertson et al. (2004) and Bhuiyan et al. (2008) also reported that 1000-seed weight was reduced with the delayed planting date. In relation to grain yield, no correlation was found between the 100-seed weight and the grain yield at Syferkuil. However, a strong positive correlation was found at Ofcolaco in both 2013 and 2014 growing seasons. This could be attributed to the relatively longer growth duration and the ambient temperature experienced at Ofcolaco. According to Rafiei et al. (2011), seed weight depends mainly on growth rate and length of filling period which is directly related to current photosynthesis in the plant.

5.7 Number of main branches and sub branches

Planting dates significantly affected the number of main and sub branches at Syferkuil in the 2013 growing season while no significant difference was observed in 2014. At Ofcolaco no significant difference was observed in 2013 growing season while in the 2014 growing season, planting dates significantly affected the number of main and sub branches. Generally, an increasing trend in number of branches was observed as planting was delayed. The observation is contrary to that reported by Mendham et al. (1981) who stated that late planting of winter rapeseed produced short stems, reduced branching and green areas of the plants and consequently a reduction in assimilates production and pods per plant. In relation to grain yield, main and sub branches correlated moderately positive and strongly positive with grain yield at Syferkuil in 2013 and moderately positive and strongly positive at Ofcolaco in 2014.

5.8 Dry matter accumulation response to planting date

This study revealed that, crop residues after threshing were accumulated more with earlier planting relative to later at Syferkuil in both growing seasons. A similar trend was observed at Ofcolaco in the two seasons. A study conducted by Shuijin et al. (2014), revealed that, planting date significantly affected the biomass production. Siadata and Hemayati (2009) stated that delayed planting significantly reduced biomass and harvest index. The results were paralleled with other studies (Rao and Mendham, 1991; Taylor and Smith, 1992; Whitefield, 1992).

The observed differences resulting from planting dates could be attributed to meteorological variations, specifically temperature and sunlight. No correlation between dry matter accumulation at flowering and grain yield was found at both the locations in 2013 and 2014. A strong positive correlation between crop residues after threshing and grain yield was found at Syferkuil and Ofcolaco in 2013 growing season. However, there was no correlation between the two parameters in 2014.

5.9 Effect of planting date to crop lodging

The results obtained from this study indicated an influence of planting date on crop lodging at both locations in the 2013 and 2014 growing seasons. Lodging was more severe at Ofcolaco compared to Syferkuil. This could be attributed to the generally heavier pod per plant and the heavier seed weight at Ofcolaco. The correlation between lodging and grain yield was positive at both the locations in 2013, because the grains were harvested before any shattering, no grains where lost at harvest and less insect pest were observed whilst no correlation was found in 2014. This is in contrast to many other studies where lodging generally resulted in reduced grain yield (Lambertus, 2014; Armstrong and Nicol 1991; Ramburan and Greenfield 2007; Gebre et al. 2012). Such reduction had been attributed to decreased supply of assimilates, grain sprouting increasing disease severity and harvesting problems.

5.10 Temperature and Growing degree days effect on canola production

It was observed from the study that, the prevailing temperature during the season played a key role in growth and development of the canola. The base temperature for spring canola is reported to be 5 ^{o}C (Vigil et al. 1997). According to DAFF (2010) temperatures below 10 °C result in progressively poorer germination and emergence of canola. Carmody and Walton (1998) reported that the optimum temperature for canola is between 20^{o}C and 25°C.

Results from the study indicate that canola plants established earlier in the season resulted in higher biomass and grain yield relative to those planted later. The later planted crops were exposed to reduced minimum temperature which might have contributed to the observed differences in yield. The importance of temperature was also enhanced by the location effect in this study. Syferkuil was generally exposed to temperature below the base temperature. In comparison, the minimum seasonal temperatures at Ofcolaco were above the base temperature. This might have contributed to the higher biomass and grain yield observed at Ofcolaco.

Results from this study revealed that growing degree days of canola differ with the growing location. At Syferkuil, the growing degree days ranged from 1128 to 1292 in 2013 whilst in 2014 a ranged of 1687 to 1928 was obtained. At Ofcolaco, the growing degree days ranged from 1553 to 1632 in 2013 and 1722 to 2040 in 2014.

Generally, more degree days were observed at Ofcolaco than at Syferkuil.The Canola Council of Canada's Canola Growers Manual (2003), reported that canola typically requires 1500-1600 GDDs to reach physiological maturity. This number can vary substantially depending on environmental conditions other than temperature, such as drought, fertility levels or excessive moisture, and weeds, pests and diseases. (The Canola Council of Canada's Canola Growers Manual, 2003).

5.11 Economic returns

The findings from the two years study over two climatically diverse locations in the Limpopo province revealed that, Syferkuil with relatively cooler climate compared to Ofcolaco is not economically viable for canola production as evidenced by negative gross margins. The main reason being the low grain yields resulting from persistent minimum temperatures at this location which fall below the base temperature for canola of $5^{o}C$. Ofcolaco on the other hand experienced minimum temperature which is above $5\,^{o}C$ and hence produced significantly higher grain yields in the two growing seasons. The gross margins were positive at all planting dates and seasons at Ofcolaco with the month of April appearing to offer the best returns. Thus, for economically viable canola production, Ofcolaco is ideal. Other locations in the province with similar favourable minimum temperatures can be explored for canola expansion.

CHAPTER 6

SUMMARY AND CONCLUSION

SUMMARY

The results obtained from this study indicated that, seasonal minimum temperature had more influence on canola production at both the locations in 2013 and 2014 growing seasons. Syferkuil received the minimum temperature lower than the base temperature (1^{o}C) of winter canola whist the minimum temperature at Ofcolaco never fell below canola base temperature.

Days to seedling emergence responded significantly to planting date at Syferkuil in 2013 but not in 2014. At Ofcolaco, significant response of seedling emergence to planting date was observed in both 2013 and 2014 growing seasons. At the two locations, days to seedling emergence was shorter in the early plantings and prolonged in the later plantings. No data was recorded at Syferkuil for June planting due to wild animal's damage.

Canola plant height at 50% flowering, and physiological maturity was delayed by planting date in both seasons and locations. Regarding days to 50% flowering and physiological maturity, early planted canola flowered and reached physiological maturity earlier than late planting in both growing seasons. Planting dates significantly affected the number of main and sub branches at Syferkuil in the 2013 growing season at Syferkuil while no significant difference was observed in 2014 growing season. At Ofcolaco, no significant difference was observed during the 2013 growing season while in the 2014 season; planting dates significantly affected the number of main and sub branches.

Canola dry matter accumulation at flowering stage was influenced by planting date at Syferkuil in the 2013 growing season but not in 2014. However, crop residue production after threshing was effected by planting date in both seasons. At Ofcolaco, no significant effect of planting date on dry matter accumulation at flowering was obtained during both growing seasons. Crop residue production was however, influenced by planting date during both growing seasons.

Planting date significantly influenced canola grain yield in both growing seasons at both the locations. The early planting resulted in high grain yield and decreased as planting was delayed. This study also revealed the difference in canola oil percentage as planting was delayed. The oil percentage and oil yield decreased as planting was delayed at both the locations. Comparing the two locations, grain and oil yield were observed to be higher at Ofcolaco in both growing seasons relative to syferkuil.

There were no significant difference in yield components to planting date except for the number of pods per plant and 100 seed weight at Syferkuil. At Ofcolaco, the number of pods per plant responded significantly to planting date in both growing seasons. A decrease in number of pods per plants was obtained as planting was delayed at both the locations. The hundred seed weight was only significantly influenced by planting date in 2013 at Ofcolaco. Similar trend of number of pods per plant was obtained in hundred seed weight at both the locations.

A highly significant difference in lodging at physiological maturity resulting from planting date was observed at both locations during the 2013 and 2014 growing seasons. The early planting resulted in high lodging percentage and decreased as planting was delayed.

The major insect-pest on canola observed during the study was *Aphis gossypii*. At Syferkuil, no significant response of pest infestation to planting date was observed in the 2013 growing season at both flowering and pod development stages whilst in 2014, significant difference was observed at pod development at this location. At Ofcolaco, no significant difference in pest infestation was observed during the 2013 growing season, but in the 2014 growing season, pest infestation was significantly influenced by planting date at both flowering and pod development. The growing degree days of canola was observed to be higher in 2014 growing season at both the locations. However, Ofcolaco appeared to have more growing degree days in both growing seasons. The results from this study indicated that, the economic return of canola at Syferkuil was negative and the loss increased as planting was delayed in 2013. In 2014, it was a loss in all the planting dates. At Ofcolaco, the economic return was positive in both growing seasons, which reduced as planting was delayed.

CONCLUSION

The results from this study indicated that planting canola not later than April at Syferkuil resulted in higher grain yield. At Ofcolaco, planting between April and May and not earlier than April produced the highest grain yield. The seed oil content ranged from 20.6% to 27.6% at Syferkuil and 32.1% to 35.7% at Ofcolaco. Number of pods per plant had more influence on grain yield than the other yield components studied. Earlier planting resulted in more crop lodging at both the locations. No significant difference in aphid infestation was observed in 2013, but in 2014, the earlier plantings resulted in more pest infestation at both the locations

Minimum temperature was found to be most important weather variable that significantly influenced growth and grain yield of canola. At Syferkuil, where minimum temperature fell below the base temperature of 5^{o}C, growth and development of the crop were severely affected compared to Ofcolaco where minimum temperature was above the base temperature in both seasons. Economic returns for canola production at Syferkuil ranged from -R6213.00 to +R2130.00 per hectare whereas at Ofcolaco, the range was +R793.00 to +R6555.00. It can be concluded from the study that Syferkuil is not ideal for canola production when planted later than April due to high risk of loss. Based on the conducive environmental conditions at Ofcolaco, it is recommended that further studies at this location be conducted to assess the response of different canola cultivar using April as recommended planting date.

In relation to the original hypothesis, the null hypotheses are rejected due to the following reasons: Planting date influenced growth, grain yield and oil yield of canola; the prevailing weather had an effect on growth and yield of canola and thirdly, planting date influenced profitability of canola production.

RECOMMENDATIONS

Due to favourable environmental conditions at Ofcolaco, it is recommended that further studies at this location be conducted to assess the response of different canola cultivar using April as recommended planting date.

REFERENCES

ADAMSEN, F.J. and COFFELT, T.A. 2005. Planting date effects on flowering, seed yield, and oil content of rape and crambe cultivars. *Industrial Crops and Products*, 21: 293-307.

AGARWAL, P.K. 1971. Effect of photoperiod on oil content, fatty acid composition and protein content of rape (Brassica napus L.) and flax (Linum usitatisimum L.) seeds. Indian Journal of Experiment Biology, 9: 252-254.

AGRICULTURAL STATISTICS. 2011. Canola/Rape Seed. Market value chain Profile 2010/2011 season.

ALLEN, D.J., MORGAN D.G. and RIGDMAN, W.J. 1971. A physiological analysis of the growth of oilseed rape. *Journal of Agricultural Science*. Cambridge, 77: 339-341.

ANGADI, S.V., CUTFORTH, H.W., MCCONKEY, B.G. and GAN, Y. 2003. Yield adjustment by canola grown at different plant population under semi-arid Conditions. *Crop Science Journal*, 43: 1358-1366.

ANGUS, J.F., VAN HERWAARDEN A.F. and HOWE G.N. 1991. Productivity and break-crop effect of winter growing oilseeds. *Australian Journal of Experimental Agriculture,* 31: 669-677.

AREZOO, A. and GOLPARVAR A.R. 2013. Effect of planting dates on seed and oil yield of canola (*Brassica napus* L.) cultivars. *International Journal of Modern Agriculture*, 2, 15: 461-463.

ARMSTRONG, E.L. and NICOL, H.I. 1991. Reducing height and lodging in rapeseed with growth regulators. *Australian Journal of Experimental Agriculture,* 31: 245–250.

ASGARI, A. and MORADIE-DALINI, A. 2008. Evaluation, yield components and vegetative characters of rapeseed cultivars in different planting date. *Seed and Plant Journal*, 23: 419-430.

ATKINSON, A.D., RICH, B.A., TUNGATE, K.D., GREEN, J.T., CREAMER, K.S. and MOORE, A.D. 2006. North Carolina Canola Production. http://ncsc.ncsu.edu/wp-content/uploads/2011/09/Canol-Guide-Final. Accessed: 20 August 2014.

AYISI, K.K., PUTNAM, D.H., VANCE, C.P., RUSSELLE, M.P. and ALLAN, D.L. 1997. Strip intercropping and nitrogen effects on seed, oil and protein yield of canola and soybean. *Agronomy Journal*, 89: 23-29.

BERGLUND, D.R., MCKAY, K., and KNODEL, J. 2007. Canola Production. North Dakota-State-University-Extension-Services. http://www.ag.ndsu.edu/pubs/plantsci/crops/a686w.htm . Accessed: 21 June 2014.

BHUIYAN, M.S., MONDOL, M.R.I., RAHAMAN, M.A., ALAM, M.S. and FAISAL, A.H.M.A. 2008. Yield and Yield Attributes of Rapeseed as Influenced by Date of Planting. *International Journal of Sustainable Crop Production*, 3:3, 25-29.

BOLAND, M. and BRESTER, G. 2008. Canola Profile. http://www.agmrc.org/agmrc/commodity/grainsoilseeds/canola/canolaprofile.htm. Accessed: 20 May 2014.

BOSE, T.K. 1973. Effect of temperature and photoperiod on growth, flowering and seed formation in mustard (B. juncea Coss). Indian Journal of Agricultural Sciences, 17: 75-80.

BRADY, N.C. 1974. The nature and properties of soils. 8th edition. Macmillan Publishing Company. New York.

CANOLA COUNCIL OF CANADA. 2003. Determining the area of arable land suited to canola production in the Western Cape http://www.canolacouncil.org/contents5aspx. Accessed: 20 May 2014.

CARMODY, P. and WALTON, G. 1998. Canola: Soil and Climatic Requirements. In 'Soil Guide: a handbook for understanding and managing agricultural Soils'. (Ed G. Moore.) Bulletin 4343. Department of Agriculture, Western Australia.

CHRISTENSEN, J.V. and DRABBLE, J.C. 1984. Effect of row spacing and seeding rate on rapeseed in Northwest Alberta. *Canadian Journal of Plant Sciences,* 64: 1011-1013.

CRUBBENS, G.T.H. and DENTON, O.A. 2004. Plant Resources of Tropical Africa. Vegetables. PROTA Foundation, Wageningen, Netherlands. backhuys Publishers, Leiden, Netherlands/CTA, Wgeningen Netherlands. Http://www/hort. purdue/edu/newcrop. duke_energy/moringa, htm. Accessed: 14 August 2014.

DAFF. 2010. Department of Agriculture Forestry and Fisheries. Canola Production Guideline.2. Republic of South Africa.

DALY, M.J. and MARTIN, R.J. 1988. Oilseed rape: The effect of rate, timing and form of nitrogen application on a depleted in more soils. Proceeding. Annual. Conference. *Agronomy Science Journal*. New Zealand ,18: 97-102.

DEGENHARDT, D.F. and KONDRA, Z.P. 1981. The influence of seeding date and seeding rate on seed yield and yield components of five genotypes of *Brassica napus* L. *Canadian Journal of Plant Science*, 61: 175-183.

DHAWAN, A.K., CHABRA, M.L. AND YADAVA, T.P. 1983. Freezing injury in oilseed Brassica species. Annuals of Botany, 51: 673-677.

DOSDALL, L.M. and MASON, P.G. 2010. Key pests and parasitoids of oilseed rape or canola in North America and the importance of parasitoids in integrated management. In: Williams, I.H. (Ed.), Biocontrol-Based Integrated Management of Oilseed Rape Pests. Springer, 6:167–213.

ECONOMIC RESEARCH SERVICE (ERS). 2008. Oil crops situation and outlook. OCS- 2008, ERS, USDA.

EHRENSING, D.T. 2008. Canola. Oregon State University. Extension Services-EM 8955-E.http://extension.oregonstate.edu/catalog/pdf/em/em8955-e. Accessed: 2 August 2014.

ELIAS, S. G., and COPELAND, L. O. 2001. Physiological and harvest maturity of canola in relation to seed quality. *Agronomy journal*, 93: 5, 1054-1058.

FARAJI, A.A., LATIFI, N., SOLTANI, A, and SHIRANI RAD A.H. 2008. Effect of sowing date and supplemental irrigation on dry matter accumulation, yield and harvest index of two canola (*Brassica napus L*) cultivars. *Journal of Agricultural Sciences and Natural Resources,* 15: 95–107.

FARRE, I., ROBERTSON, M.J., WALTON, G.H. and ASSENG, S. 2002. Simulating phenology and yield response of canola to sowing date in Western Australia using the APSIM model. *Australian Journal of Agricultural Research*, 53: 1155-1164.

FINK, N.S.C. and CHRISTMAS, E. 2006. An evaluation of the effects of planting date and seeding rate on the yield of winter canola grown at three different geographic areas. The ASA-CSSA-SSSA International Annual Meetings.

FRIER, M.C. and ROTH, G.W. 2007. “Canola or Rapeseed Production in Pennsylvania.” Department of Crop and Soil Sciences, Pennsylvania State University.http://downloads.cas.psu.edu/RenewableEnergy/CanolaProduction . Accessed: 2 August 2014.

GAN, Y., ANGADI, S.V., CUTFORTH, H, and McDONALD C.L. 2004. Canola and mustard response to short periods of temperature and water stress at different developmental stages. *Canadian Journal of Plant Science*, 84: 697-704.

GARTH A. 2008. Analysing data using SPSS. A practical guide. Sheffield Hallam University.

GEBRE, E., SCHLÜTER, U., HEDDEN, P, and KUNERT, K. 2012. Gibberellin biosynthesis inhibitors help control plant height for improving lodging resistance in E. tef (Eragrostis tef). *Journal of Crop Improvement*, 26:3, 375-388.

GHOSH, R.K. and CHATTERJEE, B.N. 1998. Effect of dates of sowing on oil content and fatty acid profiles of Indian mustard. *Indian Journal, Oilseed Research*, 5:2, 144-149.

GOMEZ, AK, AND GOMEZ, A.A. 1996. Statistical Procedures for Agricultural Research, 2nd Ed., John Willey and Sons. New York.

GORDON, R. AND BOOSTMA A. 1993. Analyses of growing degree-days for agriculture in Atlantic Canada. Climate Research, 3: 169-179.

GREAT PLAINS CANOLA PRODUCTION HANDBOOK. 2012. Oklahoma State University. Kansas State University. University of Nebraska. Great Plains Canola Association. United State of Canola Association, 60.

GREGORY, P. J., JOHNSON, S. N., NEWTON A. C., and INGRAM J. S. I. 2009. Integrating pests and pathogens into the climate change/food security debate. *Journal of Experimental Botany*, 60: 2827–2838.

HABEKOTTE, B. 1993. Quantitative analysis of pod formation, seed set and seed filling in winter oilseed rape (*Brassica napus* L.) under field conditions. *Field Crops Research,* 35: 21-33.

HALL, A.E. 1992. Breeding for heat tolerance, help control plant height for improving lodging resistance in *E. tef* (*Eragrostis tef*). *Plant Breeding*, 10: 129-168.

HOCKING, P.J. 1993. Effect of sowing time and plant age on critical nitrogen concerntrations in canola (Brassica napus L.). Plant and Soil, 155:156, 387-390.

HOCKING P.J., KIRKEGAARD J.A., ANGUS, J.F., GIBSON, AH, AND KOETZ EA. 1997. Comparison of canola, Indian mustard and canola in two contrasting environments. I. Effects of nitrogen fertilizer on dry matter production, seed yield and seed quality. *Field Crops Research*, 49:2, 107-125.

HOCKING, P.J. and STAPPER, M. 2001. Effect of sowing time and nitrogen fertilizer on canola and wheat, and nitrogen fertilizer on Indian mustard. I. Dry matter production, grain yield, and yield components. *Crop and Pasture Science,* 52: 623-634.

HODGSON, A.S. 1978a. Rapeseed adaptation in Northern New South Wales. I. Phenological responses to vernalization, temperature and photoperiod by annual and biennial cultivars of Brassica campestris L., Brassica napus L.

and wheat cv. Timgalen. Austrian Journal Agricultural Research, 29: 693-710.

HODGSON, A.S. 1978b. Rape seed adaptation in north new south wales II. Predicting plant development of brassica napus L. and its implications for planting time, designed to avoid water deficit and frost. Crop and Pasture Science, 29:711-726.

HOLMES, M.R.J. 1980. Nutrition of the Oilseed Rape Crop. Applied Scientific. Publishers, London, 158.

HORTON, D. S. 2006. Determination of optimum planting date of seven species of winter oil seeds in Mississippi, The ACSSA-SSSA. In International Annual Meeting.http://acs. confex. com/crops/2006am/techprogramstaticfiles/banner

HUGHES, B, JACKA., LEWIS, D., and PRANCE, T. 1996. Guidelines for international of soil results. South Australia. Soil and plant analysis service, primary industries South Australia.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). 2007. SOLOMON, S., QIN, D., MANNING, M., CHEN, Z., MARQUIS, M., AVERYT, K.B., TIGNOR, M. and MILLER, H.L. (eds), 2007. Climate change: the physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York, NY, USA: Cambridge University Press.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). 2008. KUNDZEWICZ, Z.W., PALUTIKOF, J. and WUS (eds), Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York, NY, USA: Cambridge University Press.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). 2009. The Intergovernmental panel on climate change available at: htt://www.ipcc.ch.

JOHNSON, B.L., K.R. MCKAY, A.A. SCHNEITER, B.K. HANSON and B.G. SCHATS. 1995. Journal of Production Agriculture, 1995, 4: 594-599.

JENNIFER, N.J., GLOGOZA, P., MACRAE, I., OELKE, E. and MERONUCK, R. 2000. Crop profile for canola in minnesota. http://www.google.com/search?hl=en&ie=ISO-88591&q=Crop+Profile+for+Canola+in+Minnesota+%2C2000&btnG=Search. Accessed: 15 October 2014.

JENSEN, C.R., MOGENSEN, V.O., MORTENSEN, G., ANDERSEN, M.N., SCHJOERRING, J.K., THAGE, J.H. and KORIBIDIS, J. 1996. Leaf photosynthesis and drought adaptation in field grown oilseed rape (*Brassica napus* L.). *Australian Journal Plant Physics*, 23:631-644.

KANSAS AGRICULTURAL EXPERIMENT STATION. 1996. Canola Production for the Great Plains. Agriculture Experiment Station, Kansas State University, Manhattan,KS.

KHAN, R.U., MUENDEL and CHAUDHRY, H.H. 1994. Influence of tipping rapeseed on yield components and other agronomic characters under varying dates of planting. Pakistan Journal of Botany, 26: 167-171.

KIRKEGAARD, J.A, GARDNER, P.A., ANGUS, J.F. and KOETZ, E. 1994. Effects of Brassica break crops on the growth and yield of wheat. *Crop and Pasture Science,* 45:529-545.

KIRKLAND, K. and JOHNSON, E. 2000. Alternative seeding dates (fall and April) affect Brassica napus canola yield and quality. *Canadian Journal of Plant Science,* 80: 713-719.

KONDRA, Z.P., CAMPELL, D.C., and KING J.R. 1983. Temperature effects on germination of rapeseed (*Brassica napus* L. and *Brassica Campestris* L.). *Canadian Journal Plant Science*, 63: 1063-1065.

KUMAR, S., BISHNOI U.R. and CEBERT, E. 2007. Impact of rotation on yield and economic performance of summer crops-winter canola cropping systems. *American-Eurasian Journal Sustainable Agriculture*, 1: 68-76.

KUO, N.C., CHEN, C. and CHENG, H.H. 1980. The effect of different temperatures on agronomic characters, seed yield, oil content and fatty acid composition of rapeseed. Memoirs of the College of Agriculture, National Taiwan University, 20: 2, 45-53.

KURMI, K. 2002. Influence of sowing date on the performance of rapeseed and mustard varieties under rain-fed situation of Southern Assam. *Journal of Oilseeds Research*, 19:2, 197-198.

KUTCHER, A.R., WARLAND, J.S. and BRANDT, S.A. 2010. Temperature and precipitation effects on canola yields in Saskatchewan, Canada. *Agricultural and Forest Meteorology,* 150:161–165.

LAMB, R.J. 1989. Entomology of oilseed Brassica crops. Annual review of entomology, 34: 211–229.

LAMBERTUS L.E. 2014. Reducing height and lodging in canola (*Brassica napus* L.) using plant growth regulators. Stellenbosch University, South Africa. Master of Science in Agriculture,(Agronomy).

LEWIS, D.C., POTTER, T.D., WEEKERT, S.E and GRANT, I.L. 1987. Effect of nitrogen and phosphorus fertilisers on the seed yield and oil concentration of rape (*Brassica napus* L) and the prediction of responses by soil tests and past paddock use. *Australian Journal of Experimental Agriculture*, 27: 713-20.

MAILER, R.J., COLTON, R.T. and O'BREE, B.L. 1998. Quality of Australian Canola. Canola Association of Australia, 1322-9397.

MARTIN V.L. 2006. Planting date effect on winter canola production in Kansas, the ACSSASSSA. International Annual Meeting. www.ksre.ksu.edu/water quality /KSNMHatch.htm . Accessed: 20 September 2014.

MENDHAM, N.J., RUSSELL, J. and JAROS, N.K. 1990. Response to sowing factors of oilseed rape. Rosliny Oleiste, 17: 223-234.

MENDHAM, N.J., SHIPWAY P.A. and SCOTT, R.K. 1981. The effects of seed size, autumn nitrogen and population density on the rapeseed to delay sowing oilseed rape (*Brassica napus* L). *Journal of Agricultural Science.* Cambridge, 96:417-28.

MILLER, P., LANIER, W., and BRANDT, S. 2001. Using Growing Degree Days to Predict Plant Stages. Montana Guide. Extension Factsheet No. 200103. Montana State University- Extension Service. Montana State University. http://msuextension.org/publications/AgandNaturalResources/MT200103AG.

MINISTRY OF ECONOMIC DEVELOPMENT. 2012. Biofuels. http://www.med.govt.nz/sectors-industries/energy/liquid-fuel-market/biofuels. Accessed: 2 May 2014.

MITTLER, R. and BLUMWALD, E. 2010. Genetic engineering for modern agriculture: challenges and perspectives. *Annual Review of Plant Biology*, 61: 443–462.

MONDAL, M. R. I. and ISLAM, M.A. 1993. Effect of seed rate and date of sowing on yield and yield components of rapeseed. *Bangladesh Journal of Agricultural Science,* 20:1, 29-33.

MOORE, M.K. and GUY, S. 1997. Agronomic response of winter rapeseed to rate and data of seeding. *Agronomy Journal*, 89: 521-529.

MORRISON, M.J., MCVETTY, P.B.E. and SHAYKEWICH, C.F. 1989. The determination and verification of a baseline temperature for the growth of westar summer rape. Canadian Journal of Plant Science, 69: 455-464.

MORRISON, M.J. and STEWART, D.W. 2002. Heat stress during flowering in summer Brassica. *Crop Science Journal*, 42: 797- 803.

NANDA, R., BHARGAVA, S.C. and TOMAR D.P.S. 1994. Rate and duration of siliqua and seed-filling period and their relation to seed yield in Brassica species. *Indian Journal of Agricultural Sciences*, 64: 4, 227-232.

NANDA, R., BHARGAVA, S.C., TOMAR D.P.S. and RAWSON, H.M. 1996. Phenological development of *Brassica campestris*, *Brassica juncea*, *Brassica* *napus* and *Brassica carinata* grown in controlled environments and from 14 sowing dates in the field. *Field Crops Research*, 46: 1, 93-103.

NANDA R., BHARGAVA, S.C., TOMAR, D.P.S. and RAWSON, H.M. 1999. Phenological development of Brassica compestris. Field crops, 46:1, 93-103.

NAOTAH A.D and WAKINDIKI I.C. 2012. Particulate organic matter soil texture and mineralogy relations in some Eastern Cape ecotopes in South Africa, *South Africa Journal of Plant and Soil*, 29:1, 39-46.

NEELAM KUMARI, BHARDWAJ, S.N. and BHARGAVA, S.C.1992. Physiological basis of growth in rapeseed-mustard with reference to photoperiod. Indian Journal of Plant Physiology, 35: 377-388

NEELAM KUMARI and BHARGAVA, S.C.1994. Physiological basis of yield and its components in rapeseed-mustard with reference to photoperiod. Indian Journal of Plant Physiology, 37: 142-146.

NUTTALL, W.F., MOULIN, A.P. and TOWNLEY-SMITH, L.P. 1992. Yield response of canola to nitrogen, phosphorus, precipitation and temperature. *Agronomy Journal*, 84: 765-768.

OPLINGER, E.S., HARDMAN, L.L., GRITTON, E.T., DOLL, J.D. and KELLING, K.A. 1989. Canola (Rapeseed). Alternative Field Crop Manual. University of Wisconsin, Madison, and University of Minnesota, Saint Paul. http://www.hort.purdue.edu/newcrop/afcm/canola.

OZ, M. 2002. The effect of different sowing time on the yield and yield components in winter rapeseed varieties under Bursa, Mustafakemalpaşa Conditions. Uludag Universitesi Ziraat Fakultesi Dergisi, 16: 1-13.

OZER, H. 2003. Sowing data and nitrogen rate effects on growth, yield and yield components of two summer rapeseed cultivars. *European Journal of Agronomy*, 19: 453-463.

PAHLAVANI, M.H., SAEIDI, G. and MIRLOHI, A.F. 2007. Genetic analysis of seed yield and oil content in safflower using F1 and F2 progenies of diallel crosses. *International Journal of Plant Production*, 1:129-140.

PANDA, B.B., BANDYOPADHYAY, S.K. and SHIVAY, Y.S. 2004. Effect of irrigation level, sowing dates and varieties on yield attributes, yield, consumptive water use and water-use efficiency of Indian mustard (Brassica juncea). *Indian Journal of Agricultural Science*, 74: 6, 339-342.

PARSONS, C.E., KELLY, J., BACON, R., SALTON, N., LORENZ, G., KRING, T. and CARTWRIGHT, R. 2012. Canola Production in Arkansas. University of Arkansas. Division of Agriculture. Cooperative Extension Services. http://www.uaex.edu/Other_Areas/publications/PDF/FSA-2154.

PECHAN, P.A. and MORGAN. D.G. 1985. Defoliation and its effects on pod seed development in oilseed rape. *Journal of Experimental Botany*. 458-68.

PEVERILL, K.I., SPARROW, L.A. and REUTTER. D.J. 1999. Soil Analysis, an Interpretation Manual. CSIRO Publication. Collingwood, Victoria. Australia.

PORTER, J.R. and SEMENOV M.A. 2005. Crop responses to climatic variation. Philosophical Transactions of the Royal Society B: *Biological Sciences*, 360:1463, 2021-2035.

QAYYUM, S.M., KAKAR, A.A. and NAZ. M.A.1998. Influence of nitrogen levels on the growth and yield of rape (*Brassica napus* L.) Sarhad. *Journal of Agriculture*, 15:263-268.

RAFIEI, S., DELKHOSH, B., RAD, A. H. S., and PEIMAN, Z. 2011. Effect of Sowing dates and Irrigation regimes on Agronomic traits of Indian mustard in semi-arid area of Takestan. *Journal of American Science*, 7:10, 721-728.

RAMBURAN, S. and GREENFIELD, P.L. 2007. The effects of chlormequat chloride and ethephon on agronomic and quality characteristics of South African irrigated wheat. *South African Journal of Plant and Soil*, 24:2, 106–113.

RAO, G.U., JAIN, A and SHIVANNA, K.T. 1992. Effect of high temperature stress on Bassica pollan: viability, germination and ability to set fruits and seeds. *Annals of Botany*, 69: 193-198.

RAO, M.S. and MENDHAM. N.J. 1991. Comparison of Chinoli (Brassica compestris, Olefera spp. chinensis) and Brassica napus oil seed rape using different growth regulators, population densities and irrigation treatments. *Journal of Agricultural Science,* Cambridge, 177:177-187.

RATHKE, G.W., CHRISTEN, O. and DIEPENBROCK. W. 2005. Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. Field Crops Research, 94:103-113.

RAYMER, P.L. 2002. Canola: An emerging Efficacy of Pre-emergence oilseed crop. 122-126. In: J. Janick and Whipkey A (eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA. Canola: *An Emerging Oilseed Crop. Research*, 49: 107–125.

REUTER, D.J., DYSON, C.B ELIOTT, D.E., LEWIS, D.C., and RUDD, C.L. 1995. An appraisal of soil phosphorus testing data for crops and pastures in South Australia. *Australian Journal of Experimental Agriculture*, 35: 979-95.

RICHARDS, R.A. 2006. physiological traits used in the breeding of new cultures for water-scarce environments. Agricultural water management, 80: 197-211.

ROBERTSON. M.J., HOLLAND, J.F., CAWLEY, S., BAMBACH, R., COCKS, B. and WATKINSON, A.R. 2001. Phenology of canola cultivars in the northern region and implications for frost risk. In proceedings of the 10th Australian agronomy conference. Hobart`, www.regional.org.au.au.asa/2001/.

ROBERTSON, M.J., HOLLAND, J.F. and BAMBACH. R. 2004. Response of canola and Indian mustard to sowing date in the grain belt of north-eastern Australia. Australian. Animal Production Science, 44:1, 43-52.

SALJOQI, A.U.R., REHAMN, S., HUSSAIN, N. and KHAN, S.A. 2006. Insect pest of canola crop (other than aphid). *Journal of Agriculture in Biological Science*, 1:4, 19–21

SARAN, G., and GIRI, G. 1987. Influence of dates sowing on Brassica species under semi-arid rain-fed condition of north-east India. *Indian Journal of Agricultural Sciences*, 108: 561-566.

SATTAR, A., MUMTAZ., A., CHEEMA., M.A., WAHID., M., FARRUKH S., GHAFFARI., M.A., SHABIR H. and ARSHAD M.S. 2013. effect of sowing time on seed yield and oil contents of canola *varieties Journal of Global Innovation. Agriculture. Society. Science*, 2311-3839

SCARISBRICK, D.H., DANIELS H. and RAWI A.B.N. 1982. The effect of varying seed rate on the yield and yield components of oilseed rape (*Brassica napus* L). *Journal of Agricultural Sciences*. Cambridge, 99:561-568.

SCHMIDHUBER, J. and TUBIELLO, F.N. 2007. Global food security under climate change. *Proceedings of the national academy of science of the united states of America*,104:50, 19703-19708.

SCOTT, R.K., OGUNREMI, E.A., IVINS, J.D. and MENHAM, N.J. 1973.The effect of sowing date and season on growth and yield ofoilseed rape (Brassica napus). Journal of Agricultural Science, 81: 277-285.

SEDIQI, M.N. 2012. Adaptability of oilseed species at high altitudes of Colorado and technology transfer to Afghanistan. Department of Soil and Crop Sciences, Colorado State University.

SHAHIDI, F.1990. Rapeseed and canola: Global production and distribution in ‘’canola and rape seed: production, chemistry, Nutrition and processing Technology’’ F. Shahidi. edition. 13. Van Norstrand Reinhold, New York.

SHAHIDI, F. 1991. Canola and Canola, Production, Chemistry, Nutrition, and Processing Technology, 355.

SHAHIDULLAH, M., ISLAM, U., KARIM, M.A. and HUSSAIN, M. 1997. Effect of sowing dates and varieties on yield and yield attributes of mustard. *Bangladesh Journal of Scientific and Industrial Research*, 32:4, 515-516.

SHIRANI RAD, A.H. and AHMADI, M.R. 1996. Study of sowing date and plant density on growth of two rapeseed cultivars. Iranian Journal of Agricultural Science, 28:2, 27-36.

SHUIJIN, H., BAOGANG, L., HUSSAIN, N., YAOFENG, Z., HUASHENG, Y., YUN, R. AND DONGQING, Z. 2014. Delayed planting affects seed yield, biomass production, and carbohydrate allocation in canola (*Brassica napus* L). *International Journal of Agriculture and Biology*, 16:4, 671-680.

SIADATA, S.A. and HEMAYATI, S.S. 2009. Effect of sowing date on yield and yield components of three Oilseeds rape varieties. *Plant Ecophysiology*, 1:31-35.

SINHA, S., SINAM, G., MISHRA, R.K., and MALLICK, S. 2010. Metal accumulation, growth, antioxidants and oil yield of *Brassica juncea* L. exposed to different metals. *Ecotoxicology and environmental safety*, 73:6, 1352-1361.

SOLEYMANI, A., SHAHRI, M.M., SHAHRAJABIAN, M.H. and NARANJANI, L. 2010. Responses of cultivars of canola to sulphur fertilizer and plant densities under climatic condition of Gorgan region. *Iranian Journal of Food, Agriculture and Environments,* 8:3, 298-304.

TAYLOR, A.J. and SMITH, C.J. 1992. Effect of sowing date and seeding rate on yield components of irrigated canola (*Brassica napus* L.) grown on a red-brown earth in south-eastern Australia. *Australian Journal Agricultural Research,* 43: 1629-1641.

TAYLOR, A.J., SMITH, C.J. and WILSON, I.B. 1991. Effect of irrigation and nitrogen fertilizer on yield, oil content, nitrogen accumulation and water use of canola (*Brassica napus* L.) Fertilizer Research, 29:249-260.

THURLING, N. 1974. Morphophysiological determinants of yield in rapeseed. *Australian Journal Agricultural Research*, 25: 711-21.

TOBE, A., HOKMALIPOUR, S., JAFARZADEH, B. and DARBANDI, M.H. 2013. Effect of Sowing Date on Some Phenological Stages and Oil Contents in Spring Canola (*Brassica napus* L.) Cultivars. *Middle-East Journal of Scientific Research,* 13:9, 1202-1212.

UZUN, B., ZENGIN, U., FURAT, S. and AKDESIR, O. 2009. Sowing date effects on growth, flowering, seed yield and oil content of canola cultivars. *Asian Journal of Chemistry*, 21: 1957-1965.

VAEZI, B., HATAM-ZADEH, H., NARKY, H. and RAHMANI-MOGHADAM, N. 2009. Evaluation of yield of Brassica napus species, B. rapa and B. guncea in dryland tropical conditions of Gachsaran. Journal of Plant Seed and Breeding, 25: 194-183.

VIGIL, M.F., ANDERSON, R.L. and BEARD, W.E. 1997. Base temperature and growing degree-hour requirements for the emergence of canola. *Crop Science*, 37: 844-849.

WANG, W., VINOCUR, B. and ALTMAN, A. 2003. Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 218: 1–14.

WHITFIELD, D.M. 1992. Effect of temperature and nitrogen on colza exchange of pods of oil seed rape. *Field Crops Research*, 22: 4-10.

WILEN, R.W., GUSTA, L.V., LEI, B., ABRAMS, S.R. and EWAN, B.E. 1994. Effects of abscisic acid (ABA) and ABA analogs on freezing tolerance, low-temperature growth, and flowering in rapeseed. Journal of Plant Growth Regulation, 13: 235-241.

WRIGHT, G.C., SMITH, C.J. and WOODROOF, M.R. 1988. The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napus* L) production in south-eastern Australia. Growth and Seed Yield. *Irrigation science*, 9: 1-13.

YASAMIN, M. and BAGHERI, H. 2013. Evaluation Planting Date on Agronomical Traits of Canola (*Brassica napus* L.). *International Research Journal of Applied and Basic Sciences*, 4: 601-603.

APPENDICES

Appendix A-1: Analysis of Variance (ANOVA) table for days to emergence at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	6.917	2.306		
Date	2	355.167	177.583	83.03	0.0000
Error	6	12.833	2.139		
Total	11	374.917			

Appendix A-2: Analysis of Variance (ANOVA) table for plant height at flowering at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	146.84	48.95		
Date	2	3940.96	1970.48	92.96	0.0000
Error	6	127.18	21.20		
Total	11	4214.99			

Appendix A-3: Analysis of Variance (ANOVA) table for plant height at physiological maturity at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	489.23	163.08		
Date	2	5997.37	2998.69	50.47	0.0002
Error	6	356.46	59.41		
Total	11	6843.06			

Appendix A-4: Analysis of Variance (ANOVA) table for days to flowering at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	32.92	10.972		
Date	2	1016.17	508.083	56.63	0.0001
Error	6	53.83	8.972		
Total	11	1102.92			

Appendix A-5: Analysis of Variance (ANOVA) table for days to physiological maturity at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	187.58	62.528		
Date	2	712.17	356.083	9.40	0.0141
Error	6	227.17	37.861		
Total	11	1126.92			

Appendix A-6: Analysis of Variance (ANOVA) table for dry matter flowering at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	104.9	34.97		
Date	2	9878.2	4939.08	66.17	0.0001
Error	6	447.8	74.64		
Total	11	10430.9			

Appendix A-7: Analysis of Variance (ANOVA) table for crop residues after threshing at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	3789352	1263117		
Date	2	1.050E+08	5.249E+07	44.71	0.0002
Error	6	7043413	1173902		
Total	11	1.158E+08			

Appendix A-8: Analysis of Variance (ANOVA) table for number of main-branch at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.25000	0.08333		
Date	2	2.16667	1.08333	13.00	0.0066
Error	6	0.50000	0.08333		
Total	11	2.91667			

Appendix A-9: Analysis of Variance (ANOVA) table for number of sub-branches at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.13333	0.04444		
Date	2	1.88667	0.94333	11.63	0.0086
Error	6	0.48667	0.08111		
Total	11	2.50667			

Appendix A-10: Analysis of Variance (ANOVA) table for number of pods per plant at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	5049	1682.9		
Date	2	87475	43737.3	18.11	0.0029
Error	6	14493	2415.5		
Total	11	107016			

Appendix A-11: Analysis of Variance (ANOVA) table for number of seeds per pod at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	1.8241	0.60804		
Date	2	3.6121	1.80603	1.59	0.2799
Error	6	6.8317	1.13861		
Total	11	12.2679			

Appendix A-12: Analysis of Variance (ANOVA) table for 100 seeds weight at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.00390	1.300E-03		
Date	2	0.00872	4.358E-03	1.90	0.2292
Error	6	0.01375	2.292E-03		
Total	11	0.02637			

Appendix A-13: Analysis of Variance (ANOVA) table for Grain yield at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	278108	92703		
Date	2	3591419	1795709	39.04	0.0004
Error	6	275960	45993		
Total	11	4145486			

Appendix A-14: Analysis of Variance (ANOVA) table for lodging percentage at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.6667	0.2222		
Date	2	42.6667	21.3333	96.00	0.0000
Error	6	1.3333	0.2222		
Total	11	44.6667			

Appendix A-15: Analysis of Variance (ANOVA) table for harvest index at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.00148	0.00049		
Date	2	0.31824	0.15912	390.32	0.0000
Error	6	0.00245	0.00041		
Total	11	0.32217			

Appendix A-16: Analysis of Variance (ANOVA) table for pest scoring flowering at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.25000	0.08333		
Date	2	1.50000	0.75000	9.00	0.0156
Error	6	0.50000	0.08333		
Total	11	2.25000			

Appendix A-17: Analysis of Variance (ANOVA) table for pest scoring pod development at Syferkuil in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.33333	0.11111		
Date	2	0.66667	0.33333	3.00	0.1250
Error	6	0.66667	0.11111		
Total	11	1.66667			

Appendix A-18: Analysis of Variance (ANOVA) table for days to Emergence at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	3.33333	1.11111		
Date	2	2.66667	1.33333	3.00	0.1250
Error	6	2.66667	0.44444		
Total	11	8.66667			

Appendix A-19: Analysis of Variance (ANOVA) table for Plant height at flowering at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	276.92	92.306		
Date	2	981.50	490.750	7.79	0.0215
Error	6	377.83	62.972		
Total	11	1636.25			

Appendix A-20: Analysis of Variance (ANOVA) table for plant height at physiological maturity at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	18.917	6.3056		
Date	2	108.500	54.2500	3.75	0.0878
Error	6	86.833	14.4722		
Total	11	214.250			

Appendix A-21: Analysis of Variance (ANOVA) table for Days to flowering at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.917	0.306		
Date	2	358.167	179.083	184.20	0.0000
Error	6	5.833	0.972		
Total	11	364.917			

Appendix A-22: Analysis of Variance (ANOVA) table for Days to physiological maturity at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	11.58	3.861		
Date	2	1562.17	781.083	88.15	0.0000
Error	6	53.17	8.861		
Total	11	1626.92			

Appendix A-23: Analysis of Variance (ANOVA) table for number of main-Branches at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	1.58333	0.52778		
Date	2	0.66667	0.33333	0.43	0.6699
Error	6	4.66667	0.77778		
Total	11	6.91667			

Appendix A-24: Analysis of Variance (ANOVA) table for number of sub-branches at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	13.6667	4.55556		
Date	2	10.6667	5.33333	3.43	0.1016
Error	6	9.3333	1.55556		
Total	11	33.6667			

Appendix A-25: Analysis of Variance (ANOVA) table for number of pods per plant at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	866.3	288.8		
Date	2	67560.5	33780.2	86.56	0.0000
Error	6	2341.5	390.3		
Total	11	70768.2			

Appendix A-26: Analysis of Variance (ANOVA) table for number of seeds per pod at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	65.667	21.8889		
Date	2	92.167	46.0833	3.15	0.1162
Error	6	87.833	14.6389		
Total	11	245.667			

Appendix A-27: Analysis of Variance (ANOVA) table for 100 seed weight at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	2.500E-03	8.333E-04		
Date	2	1.667E-03	8.333E-04	1.00	0.4219
Error	6	5.000E-03	8.333E-04		
Total	11	9.167E-03			

Appendix A-28: Analysis of Variance (ANOVA) table for dry matter at flowering at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	1233.3	411.11		
Date	2	4616.7	2308.33	0.93	0.4453
Error	6	14916.7	2486.11		
Total	11	20766.7			

Appendix A-29: Analysis of Variance (ANOVA) table for crop residues after threshing at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	1265234	1686979		
Date	2	8.237E+07	4.118E+07	18.40	0.0028
Error	6	1.343E+07	2237800		
Total	11	9.706E+07			

Appendix A-30: Analysis of Variance (ANOVA) table for Grain yield at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	22321	7440		
Date	2	276099	138049	33.09	0.0006
Error	6	25035	4172		
Total	11	323454			

Appendix A-31: Analysis of Variance (ANOVA) table for days to harvest index at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	2.752	0.9173		
Date	2	74.004	37.0022	7.39	0.0241
Error	6	30.056	5.0093		
Total	11	106.812			

Appendix A-32: Analysis of Variance (ANOVA) table for lodging percentage at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	689.6	229.86		
Date	2	9804.2	4902.08	37.75	0.0004
Error	6	779.2	129.86		
Total	11	11272.9			

Appendix A-33: Analysis of Variance (ANOVA) table for pest scoring at flowering at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.2500	0.08333		
Date	2	10.1667	5.08333	6.78	0.0289
Error	6	4.5000	0.75000		
Total	11	14.9167			

Appendix A-34: Analysis of Variance (ANOVA) table for pest scoring at pod development 2 at Syferkuil in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	1.33333	0.44444		
Date	2	4.66667	2.33333	5.25	0.0481
Error	6	2.66667	0.44444		
Total	11	8.66667			

Appendix A-35: Analysis of Variance (ANOVA) table for days to emergence at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	6.250	2.083		
Date	2	312.167	156.083	15.48	0.0043
Error	6	60.500	10.083		
Total	11	378.917			

Appendix A-36: Analysis of Variance (ANOVA) table for Plant height at flowering at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	50.00	16.667		
Date	2	1488.50	744.250	102.66	0.0000
Error	6	43.50	7.250		
Total	11	1582.00			

Appendix A-37: Analysis of Variance (ANOVA) table for Plant height at physiological maturity at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	958.92	319.639		
Date	2	1239.50	619.750	6.57	0.0308
Error	6	565.83	94.306		
Total	11	2764.25			

Appendix A-38: Analysis of Variance (ANOVA) table for number of main-branches at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	5.21000	1.73667		
Date	2	0.18667	0.09333	0.58	0.5868
Error	6	0.96000	0.16000		
Total	11	6.35667			

Appendix A-39: Analysis of Variance (ANOVA) table for number of sub-branches at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	9.7467	3.24889		
Date	2	1.1467	0.57333	0.54	0.6088
Error	6	6.3733	1.06222		
Total	11	17.2667			

Appendix A-40: Analysis of Variance (ANOVA) table for number of pods per plant at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	17823	5941.1		
Date	2	90188	45093.8	18.79	0.0026
Error	6	14398	2399.7		
Total	11	122409			

Appendix A-41: Analysis of Variance (ANOVA) table for number of seeds per pod at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	23.1134	7.70446		
Date	2	11.4008	5.70039	1.31	0.3381
Error	6	26.1821	4.36368		
Total	11	60.6962			

Appendix A-42: Analysis of Variance (ANOVA) table for 100 seed weight at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	6.250E-04	2.083E-04		
Date	2	3.717E-03	1.858E-03	31.86	0.0006
Error	6	3.500E-04	5.833E-05		
Total	11	4.692E-03			

Appendix A-43: Analysis of Variance (ANOVA) table for Days to flowering at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	42.92	14.306		
Date	2	1003.17	501.583	42.49	0.0003
Error	6	70.83	11.806		
Total	11	1116.92			

Appendix A-44: Analysis of Variance (ANOVA) table for Days to physiological maturity at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	98.000	32.667		
Date	2	744.000	372.000	42.92	0.0003
Error	6	52.000	8.667		
Total	11	894.000			

Appendix A-45: Analysis of Variance (ANOVA) table for Grain yield at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	358254	119418		
Date	2	2472054	1236027	5.34	0.0466
Error	6	1389424	231571		
Total	11	4219733			

Appendix A-46: Analysis of Variance (ANOVA) table for harvest index at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.01090	3.634E-03		
Date	2	0.00123	6.136E-04	0.21	0.8129
Error	6	0.01716	2.861E-03		
Total	11	0.02929			

Appendix A-47 Analysis of Variance (ANOVA) table for dry matter at flowering at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	3300.0	1100.00		
Date	2	3950.0	1975.00	1.68	0.2633
Error	6	7050.0	1175.00		
Total	11	14300.0			

Appendix A-48: Analysis of Variance (ANOVA) table for dry matter at physiological maturity at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	6206252	2068751		
Date	2	2.522E+07	1.261E+07	9.63	0.0134
Error	6	7854394	1309066		
Total	11	3.928E+07			

Appendix A-49: Analysis of Variance (ANOVA) table for lodging percentage at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	241.67	80.56		
Date	2	6112.50	3056.25	32.12	0.0006
Error	6	570.83	95.14		
Total	11	6925.00			

Appendix A-50: Analysis of Variance (ANOVA) table for pest scoring at flowering at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	0.33333	0.11111		
Date	2	1.50000	0.75000	1.42	0.3125
Error	6	3.16667	0.52778		
Total	11	5.00000			

Appendix A-51: Analysis of Variance (ANOVA) table for pest scoring at pod development at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
REP	3	2.00000	0.66667		
Date	2	1.972E-31	9.861E-32	0.00	1.0000
Error	6	2.00000	0.33333		
Total	11	4.00000			

Appendix A-52: Analysis of Variance (ANOVA) table for days to Emergence at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.2500	0.0833		
Date	2	82.6667	41.3333	124.00	0.0000
Error	6	2.0000	0.3333		
Total	11	84.9167			

Appendix A-53: Analysis of Variance (ANOVA) table for Plant height at flowering at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	72.917	24.3056		
Date	2	112.500	56.2500	1.53	0.2908
Error	6	220.833	36.8056		
Total	11	406.250			

Appendix A-54: Analysis of Variance (ANOVA) table for Plant height at physiological maturity at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	16.667	5.556		
Date	2	554.167	277.083	8.49	0.0178
Error	6	195.833	32.639		
Total	11	766.667			

Appendix A-55: Analysis of Variance (ANOVA) table for days to flowering at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	46.00	15.33		
Date	2	3590.17	1795.08	478.69	0.0000
Error	6	22.50	3.75		
Total	11	3658.67			

Appendix A-56: Analysis of Variance (ANOVA) table for days to physiological maturity at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	15.58	5.19		
Date	2	2673.17	1336.58	142.78	0.0000
Error	6	56.17	9.36		
Total	11	2744.92			

Appendix A-57: Randomized Complete Block AOV Table for number of branches at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.33333	0.11111		
Date	2	5.16667	2.58333	7.15	0.0258
Error	6	2.16667	0.36111		
Total	11	7.66667			

Appendix A-58: Analysis of Variance (ANOVA) table for number of sub-branches at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	2.1067	0.70222		
Date	2	18.9600	9.48000	8.60	0.0173
Error	6	6.6133	1.10222		
Total	11	27.6800			

Appendix A-59: Analysis of Variance (ANOVA) table for number of pods per plant at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	1154.2	384.7		
Date	2	53575.2	26787.6	9.97	0.0124
Error	6	16121.5	2686.9		
Total	11	70850.9			

Appendix A-60: Analysis of Variance (ANOVA) table for number of seeds per pod at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	6.9167	2.30556		
Date	2	7.1667	3.58333	1.98	0.2180
Error	6	10.8333	1.80556		
Total	11	24.9167			

Appendix A-61: Analysis of Variance (ANOVA) table for 100 seed weight at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	2.500E-03	8.333E-04		
Date	2	1.667E-03	8.333E-04	1.00	0.4219
Error	6	5.000E-03	8.333E-04		
Total	11	9.167E-03			

Appendix A-62: Analysis of Variance (ANOVA) table for Grain yield at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	480015	160005		
Date	2	2744348	1372174	9.72	0.0131
Error	6	847403	141234		
Total	11	4071767			

Appendix A-63: Analysis of Variance (ANOVA) table for Harvest index at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	96.28	30.09		
Date	2	2519.70	1259.85	30.80	0.0007
Error	6	245.45	40.91		
Total	11	2861.43			

Appendix A-64: Analysis of Variance (ANOVA) table for Dry matter at flowering at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	7.000	2.3333		
Date	2	39.500	19.7500	1.23	0.3572
Error	6	96.500	16.0833		
Total	11	143.000			

Appendix A-65: Analysis of Variance (ANOVA) table crop residues after threshing physiological maturity at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	5039694	1679898		
Date	2	4.716E+07	2.529E+07	14.39	0.0051
Error	6	2.233E+07	1757004		
Total	11	9.527E+07			

Appendix A-66: Analysis of Variance (ANOVA) table for lodging percentage at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	408.33	136.11		
Date	2	3879.17	1939.58	38.26	0.0004
Error	6	304.17	50.69		
Total	11	4591.67			

Appendix A-67: Analysis of Variance (ANOVA) table for pest scoring at flowering at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.91667	0.30556		
Date	2	7.16667	3.58333	25.80	0.0011
Error	6	0.83333	0.13889		
Total	11	8.91667			

Appendix A-68: Analysis of Variance (ANOVA) table for pest scoring At pod development at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
REP	3	0.91667	0.30556		
Date	2	7.16667	3.58333	25.80	0.0011
Error	6	0.83333	0.13889		
Total	11	8.91667			

Appendix A-69: Analysis of Variance (ANOVA) table for Oil content at ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
Reps	3	7.529E-04	2.510E-04		
Planting	2	2.665E-03	1.332E-03	3.49	0.0988
Error	6	2.291E-03	3.819E-04		
Total	11	5.709E-03			

Appendix A-70: Analysis of Variance (ANOVA) table for Oil yield content at Ofcolaco in 2013 growing season

Source	DF	SS	MS	F	P
Reps	3	55405	18468		
Planting	2	411541	205770	6.65	0.0300
Error	6	185567	30928		
Total	11	652512			

Appendix A-71: Analysis of Variance (ANOVA) table for Oil content at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
Reps	3	2.200E-03	7.333E-04		
Planting	2	4.317E-03	2.158E-03	7.40	0.0240
Error	6	1.750E-03	2.917E-04		
Total	11	8.267E-03			

Appendix A-72: Analysis of Variance (ANOVA) table for Oil yield content at Ofcolaco in 2014 growing season

Source	DF	SS	MS	F	P
Reps	3	102387	34129		
Planting	2	308005	154003	9.52	0.0138
Error	6	97041	16174		
Total	11	507434			

ENTERPRICE BUDGET

Appendix B-1: Enterprise budget of canola production at Syferkuil in the April planting in 2013 growing season

SYFERKUIL :APRIL 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			**(Rand)**	**(Rand)**
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	1955		
	Sales of canola @ R85/kg			4,9	9578
1,1	**Gross income**				**9578**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R110/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	1	260	260
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**6753**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7093**
	Contingency: unknown (5%)				355
	GRAND TOTAL COST				**7448**
	MARGIN ABOVE COST SHOWN				**R 2 130,22**

Appendix B-2: Enterprise budget of canola production at Syferkuil in the May planting in 2013 growing season

SYFERKUIL: MAY 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			**(Rand)**	**(Rand)**
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	984		
	Sales of canola @ R85/kg			4,9	4822
1,1	**Gross income**				**4822**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	1	260	260
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**6753**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7093**
	Contingency: unknown (0.5%)				355
	GRAND TOTAL COST				**7448**
	MARGIN ABOVE COST SHOWN				**-2626**

Appendix B-3: Enterprise budget of canola production at Syferkuil in the June planting in 2013 growing season

SYFERKUIL:JUNE 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			**(Rand)**	**(Rand)**
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	670		
	Sales of canola @ R85/kg			4,9	3283
1,1	**Gross income**				**3283**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	5	100	500
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	4	260	1040
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**7633**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7973**
	Contingency: unknown (10%)				797
	GRAND TOTAL COST				**8770**
	MARGIN ABOVE COST SHOWN				**-5487**

Appendix B-4: Enterprise budget of canola production at Syferkuil in the March planting in 2014 growing season

SYFERKUIL: MARCH 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	614		
	Sales of canola @ R85/kg			4,9	3009
1,1	**Gross income**				**3009**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	1	260	260
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**6753**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7093**
	Contingency: unknown (0.5%)				355
	GRAND TOTAL COST				**7448**
	MARGIN ABOVE COST SHOWN				**-4439**

Appendix B-5: Enterprise budget of canola production at Syferkuil in the April planting in 2014 growing season

SYFERKUIL: APRIL 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	506		
	Sales of canola @ R85/kg			4,9	2479
1,1	**Gross income**				**2479**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	1	260	260
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**6753**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7093**
	Contingency: unknown (0.5%)				355
	GRAND TOTAL COST				**7448**
	MARGIN ABOVE COST SHOWN				**-4968**

Appendix B-6: Enterprise budget of canola production at Syferkuil in the May planting in 2014 growing season

SYFERKUIL: MAY 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	252		
	Sales of canola @ R85/kg			4,9	1235
1,1	**Gross income**				**1235**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	1	260	260
	LAN 28 (50kg bag) urea 46%/50kg	bag	5	325	1623
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**6753**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7093**
	Contingency: unknown (0.5%)				355
	GRAND TOTAL COST				**7448**
	MARGIN ABOVE COST SHOWN				**-6213**

Appendix B-7: Enterprise budget of canola production at Ofcolaco in the April planting in 2013 growing season

OFCOLACO: APRIL 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	2983		
	Sales of canola @ R85/kg			4,9	14617
1,1	**Gross income**				**14617**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				**6555**

Appendix B-8: Enterprise budget of canola production at Ofcolaco in the May planting in 2013 growing season

OFCOLACO: MAY 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			**(Rand)**	**(Rand)**
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	2284		
	Sales of canola @ R85/kg			4,9	11192
1,1	**Gross income**				**11192**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				3130

Appendix B-9: Enterprise budget of canola production at Ofcolaco in the June planting in 2013 growing season

OFCOLACO: JUNE 2013

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	1884		
	Sales of canola @ R85/kg			4,9	9232
1,1	**Gross income**				**9232**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				**1170**

Appendix B-10: Enterprise budget of canola production at Ofcolaco in the March planting in 2014 growing season

OFCOLACO: MARCH 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	1807		
	Sales of canola @ R85/kg			4,9	8854
1,1	**Gross income**				**8854**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Fuel	month	4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				**793**

Appendix B-11: Enterprise budget of canola production at Syferkuil in the April planting in 2014 growing season

OFCOLACO: APRIL 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			**(Rand)**	**(Rand)**
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	2825,9		
	Sales of canola @ R85/kg			4,9	13847
1,1	**Gross income**				**13847**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				5785

Appendix B-12: Enterprise budget of canola production at Syferkuil in the May planting in 2014 growing season

OFCOLACO: MAY 2014

Items	Activity	Unit	Qty	Price or cost/unit	Valve or cost/ha
	Production of canola/annum			(Rand)	(Rand)
	Total size of enterprise	ha	1		
1	**Gross receipts**				
	Yield of canola/ ha	kg	2818		
	Sales of canola @ R85/kg			4,9	13808
1,1	**Gross income**				**13808**
2	**Operating costs**				
2,1	**Pre harvest**				
	Seed @R120/kg	kg	1,5	110	165
	Herbicide(roundup)@5L/ha@R400/L	L	4	100	400
	Fertilizer:				0
	Superphosphate(50kg/bag)	bag	2	260	520
	LAN 28 (50kg bag) urea 46%/50kg	bag	6	325	1948
	Pest control:				0
	Pesticide	L	12	30	360
	Casual labour: @R75.00/d/12 labourers	day	12	85	1020
	Irrigation (Electricity)		4,5	650	2925
2,2	**Total pre-harvest costs**				**7338**
	Harvest costs:	ha	1	340	**340**
	Total harvesting costs				**340**
	TOTAL COST SHOWN EXCLUDING CAPITAL COST				**7678**
	Contingency: unknown (5%)				384
	GRAND TOTAL COST				**8062**
	MARGIN ABOVE COST SHOWN				**5747**