Wheat and canola establishment in the Western Cape: Openers, nitrogen placement and planting depth

by

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Declaration

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ABSTRACT

Wheat, the main cereal crop and canola, the main oilseed crop are the two most prominent crops established in the Western Cape under dryland conditions. Tine openers are most commonly used to establish these crops, but disc – and double chute openers are emerging as viable alternatives. The suitable planting depth for each opener has not yet been evaluated in the Western Cape. These openers place nitrogen (N) fertiliser at different depth in soil. Tine openers place N below the seed and disc openers mix N with seed and place it at the same depth. The double chute places N fertilser in between two twin rows of seed. The aim of the study was to determine the efficiency of establishment of wheat and canola using a tine, disc, and double chute openers, with different fertiliser placement.This study was divided into three trials, each with a specific objective: i) The first trial was conducted in a growth room to determine the effect of N rate on wheat and canola sown at different depths (1, 2, 4, and 8 cm) and in different soil types. ii) The second trial was conducted in the field to evaluate the effectiveness of a tine or disc opener to establish canola and wheat at different depths. iii) The third was another field trial to evaluate the efficiency of tine, disc, and double chute openers on wheat and canola establishment. There was no clear effect of N rate in almost all soil types for wheat and canola, but planting depth had an effect (Objective i). Most established well when sown at depths of 1 or 2 cm. Though overall canola seed establishment was poor in most soils, it is possible that the canola seeds or seedlings were damaged by coming into contact with the N fertiliser since it was previously observed that canola seeds are sensitive to N fertiliser. The tine opener planted the seed acurate at a deeper depth (Objective ii), while the disc opener planted the seed well at a shallower depth, particularly for wheat. In contrast, for canola, planting depth was not successfully controlled by either tine or disc opener. Wheat and canola seeds were affected by the N fertiliser placement (Objective iii). When the double chute and tine openers were used in placing N fertiliser, the differences were significant in comparison to when N was broadcasted or placed using the disc opener. Plant population and biomass production was determined after 30, 60, 90 and 120 days of plant emergence, while the leaf area index (LAI) was only determinedafter 30, 60 and 90 days of plant emergence. Yield was also quantified. In most cases there were no differences between broadcasted N (control) and the disc opener for plant population, biomass production and LAI; yet, there were noticeable differences to double chute and tine opener with regard to plant population,

biomass production and LAI. No yield differences were observed between the various openers.

UITTREKSEL

Koring, die hoof graangewas, en canola, die hoof oliesaadgewas, is die twee meer prominente gewasse wat onder droëlandtoestande in die Wes-Kaap gevestig word. Tandoopmakers word algemeen gebruik om die gewasse te vestig, maar skyf- en dubbelsaadskut-oopmakers word toenemend beskikbaar as alternatiewe opsies. Die optimale plantdiepte vir elke oopmaker is nog nie in die Wes-Kaap evalueer nie. Die oopmakers plaas stikstof-(N)-bemesting op verskillende dieptes in die grond. Tandoopmakers plaas N onder die saad, terwyl skyfoopmakers N op die selfde diepte as saad plaas. Die dubbelsaadskut plaas N tussen twee treinspoorrytjies saad in die middel van die ry. Die doel van die studie was op die effektiwiteit van vestiging van koring en canola te bepaal, deur van tand, skyf en dubbelsaadskut-oopmakers gebruik te maak, met verskillende plasing van N. Die studie was in drie gedeeltes verdeel, elk met sy eie objektief: i) Die eerste proef was in ‘n groeikamer uitgevoer om die effek van N-peil op koring en canola wat op verskillende dieptes (1, 2, 4, en 8 cm) en in verskillende gronde gevestig is, te bepaal. ii) Die tweede proef was uigevoer onder veldtoestande om die effektiwiteit van tand en skyfoopmakers om koring en canola te vestig op verskillende dieptes te bepaal. iii) Die derde proef was ook ‘n veldproef om die effektiwiteit van tand, skyf en dubbelsaadskut oopmakers op koring en canola te bepaal, met ‘n fokus op N. Daar was geen defnitiewe effek van N-peil in byna alle grondtipes vir koring en canola nie, maar plantdiepte het wel ‘n effek gehad (objektief 1). Die meeste saad het gevestig teen dieptes van 1 of 2 cm. Alhoewel canola-vestiging oor die algemeen swak was, was dit moontlik dat canolasaailinge deur kontak met N-bemesting beskadig was. Die tandoopmaker het saad op ‘n akkurate diepte geplaas, terwyl die skyfoopmaker saad vlakker geplaas het, veral koring. Teenstaande, vir canola was plantdiepte nie suksesvol deur die tand of skyfoopmaker beheer nie. Koring en canola was wel deur N-plasing beinvloed (objektief iii). Wanneer dubbelsaadskut- en tandoopmakers gebruik was om N te plaas, was daar betekenisvolle verskille vergeleke met wanneer N breedwerpig toegedien of met ‘n skyf geplaas was. Oor die algemeen was daar geen verskille tussen N wat breedwerpig toegedien was en die skyfoopmaker i.t.v. planpopulasie, biomassaproduksie en BOI nie, alhoewel daar wel verskille tussen die dubbelsaadskut en tandoopmaker was. Geen opbrengsverskille was waargeneem nie.

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Abbreviations

Ha^{-1}	Per hectare
m^{-2}	Per meter square
cm	Centimetre
LAI	Leaf Area Index
N	Nitrogen
G	Gram
kg	Kilogram
CA	Conservational Agriculture
T	Ton
mm	Millimetre
EU	European Union
A	Langgewens experimental farm soil
B	Crushers soil from Paarl
C	Welgevallen experimental farm soil C
D	Welgevallen experimental farm soil D
E	Welgevallen experimental farm soil E
Fig.	Figure
C	Carbon
L	Litre
ml	Millilitre
m	Meter
HLM	Hectolitre mass
TKM	Thousand kernel mass
DAFF	Department of Agriculture, Forestry and Fisheries
GRDC	Grains Research and Development Corparation
USDA	United State Department of Agriculture

CHAPTER 1

General Introduction

1. Background

The increasing world population and food demand necessitates an improvement in the efficiency of cropping systems to increase production. An increase in farming efficiency requires a strategy or practice that will protect the environment by using machinery that will reduce the cost of production, improve soil fertility, and avoid the removal of soil cover. Moreover, the practice should include minimum tillage, maximum crop cover, suitable crop rotation, and avoid over grazing. These principles form the basis for conservation agriculture (CA) practices, where great importance is placed on maximising production per land surface area, with minimum cost to the environment. Western Cape farmers were some of the early adopters of CA in South Africa, mainly as a means to facilitate soil moisture preservation in order to reduce economic losses, especially under drought conditions.

1.2 Rationale

Several Western Cape farmers still use the tine opener, but the use of the disc opener has become widespread. Tine and disc openers operate by positioning the seeds and covering them in the soil to a certain pre-defined depth. One of the disadvantages of using a tine opener is that it is laborious to cut through heavy stubble, which is often the case under CA practices, where plant residue from the previous crop is left on the land. For this reason, the tine or double chute opener works more efficientlyto achieve optimum soil disturbance. A perceived advantage of the tine opener is its capability to band fertiliser better than a disc opener (Baker 2009). However, a disc opener is ideal under CA because it can easily situate the seed in shallow sowing depths and cause minimal soil disturbance (Hobbs 2007 & Zonglu et al. 2007).

In the Western Cape, there has been no investigation on the impact of seed-furrow openers (tine, disc or double chute openers among others) on suitable sowing depth, N placement, and seed distribution in wheat and canola cultivation. Currently, most farmers in the Western Cape are using 25 kg ha^{-1} fertiliser during planting (DAFF 2010), but some are advocating for a reduction to 20 kg ha^{-1}. The optimal rate has also not been investigated.

1.3 Aim

The aim of the study is to determine the efficacy of openers, tine or disc, in relation to sowing depth and fertiliser placement in wheat and canola establishment.

1.4 Objectives

a) To determine the suitable N rate under the different soil types and different sowing depths. This objective will be covered in Chapter 3.

b) Evaluate the effect of sowing depth, using tine or disc opener on wheat and canola establishment. This objective will be covered in Chapter 4.

c) To assess N fertiliser placement for wheat and canola by the different openers.This objective will be covered in Chapter 5.

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CHAPTER 2

Literature review

2.1 Overview

The common types of planting implements used in farming systems are furrow-type (shovel, shoe, hoe, runner, chisel, double chute), mostly used in zero till and disc type openers (single disc, double disc, disc-type furrow), primarily used in conventional till (Choudhuri 2001). It is important to note that soil moisture availability and evaporation rates, which are affected by the type of planter used, are critical factors affecting plant emergence (Chaudhuri, 2001). There are several disadvantages associated to some of the commonly used openers. For example, furrow-type openers generally do not perform well under zero tillage, especially when soils are exceptionally dry, which may result in the implement pushing dry soil and stubble into the furrows (Chaudhuri 2001). Although, hoe-type furrow openers tend to have a higher rate of soil moisture loss because of greater soil disturbance, it has been demonstrated that they perform better when it comes to seedling emergence and plant stand due to the humid environment created in the furrow (Chaudhuri 2001). Therefore, hoe-type furrow openers are more suitable for both zero and conventional tillage systems.

Farmers in the Western Cape are more inclined to use tine and disc openers, particularly for wheat and canola production under dry-land conditions. In fact, most farmers in the Western Cape use tine, discs and double chute openers, whereby the implements place nitrogen (N) fertiliser at different depths; e.g. the tine opener places N below the seed and the disc opener mixes N with the seed during planting. Similarly, the double chute places one or two different types of seed at the same time as N fertiliser application. According to Baker (2009), tine openers are capable of banding fertiliser better than disc openers, whereas the disc openers manage residues better.

Furthermore, since seed damage caused by the planter could potentially reduce establishment and eventual crop yield, it is important to choose a planter that will not cause too much damage to seedto obtain maximum crop yield. Ideally, a planter should be able to accurately deliver seed at the required plant spacing and soil depth while the tractor is pulling the planter across the field at its maximum working speed

(Holmes 1985), which will reduce costs and time. Kirkegaard et al. (1995) encourage shallow sowing of crops under direct drilling with the purpose of avoiding further reduction in early growth, particularly where soil moisture conditions permit. A reason for this is that under direct drilling, the soil profile receives water very slowly, especially inloamy sand soils. This may result from increased soil strength that could cause soil compaction and slower root extension rates (Kirkegaard et al.1995). According to Hamblin et al. (1982), grain yield on ploughed soil was 20% greater than that of crops sown by direct drilling. Mahdi et al. (1998) suggested that if farmers want to use seed drills, they should acquire drills that can sow to depths of between 5 and 6 cm. While shallow sowing is known for faster emergence and increase seedling growth, directly drilled seeds grow slower than those on cultivated soil, irrespective of sowing depth (Kirkegaard et al. 1995).

In addition to sowing depth, fertiliser placement is an important factor when deciding on the type of implement to be used. Fertiliser banding is recommended because it results in better agronomic performance and when it comes to the application of N fertiliser, it is important that N is not applied too close to the seed during planting as it can negatively affect seed development (Lemke et al. 2009). Johnston et al. (2001) conducted an experiment to determine spring wheat and canola response to Nplacement with five no-till side band openers, with the fertiliser applied as urea between the furrows at rates of 0, 40, 80 and 120 kg N ha^{-1}. It was found that three out of five canola openers showed poor seedling emergence and displayedinadequate seed fertiliser separation (Johnston et al. 2001). Lemke et al. (2009) identified the effects of N fertiliser application in the form of urea in canola and reported that straw, seed yield and N uptake were higher on side banding than broadcast and mid row banding (Lemke et al. 2009).

These factors, i.e. the suitable planting depth for different openers, the distribution of seed by planters or seed drills, as well as fertiliser placement have not been quantified in the Western Cape's wheat and canola fields.

2.2 Wheat production in the Western Cape

Wheat (*Triticum aestivum*) is a grain crop, which is important to make bread, whisky, beer and cereal. It is produced mainly in the Western Cape, North West, Kwa-Zulu Natal, Mpumalanga, Free State, and Northern Cape Provinces (Matsei 2016). Approximately 25% of South Africa's total wheat is produced under irrigation, with the other 75% sown under dryland conditions (DAFF 2010a). The Western Cape produces about 50% of the 90% of South Africa's total wheat under dryland conditions (DAFF 2016b; USDA 2018). In 2016, the Western Cape Department of Agriculture reported a 14.2% decrease in yield in the winter cereal region for the 2015/16 season compared to 5 years ago (2010-2015) (DAFF 2016b). This decrease in production was attributed to the prevailing drought that has been occurring in the region since the 2014/2015 season. Therefore, normal wheat production potential was not reached because of delayed sowing, i.e. From May to mid-July (USDA 2018). Moreover, the drought contributed to the reduction of the country's total yields for the 2015/16 season from 3.67 ton ha^{-1} to 3.52 ton ha^{-1}. This, in part, is the reason why South Africa is no longer self-sufficient in wheat production, with the country importing about 51% of wheat for its local consumption (Fourie 2013).

2.1.1 Sowing depth for wheat

Photiades & Hadjichristodoulou (1984) conducted trials in a Mediterranean type climate and stated that the optimum period for sowing date depends on rainfall patterns. Moreover, in order to get maximum yield in Mediterranean environments, Mahdi et al. (1998) reported that it is important sow at the appropriate depth. Mahdi et al. (1998) further reported that wheat that is sown relatively deep (*ca*. 12 cm) may provide better establishment and emergence of seedlings, because it is in better contact with soil water in the deeper soil layer (Mahdi et al. 1998). However, planting depths in excess of 12 cm caused a reduction in seedling vigor, with seedlings developing longer and thinner shoots than those at shallower depths (Mahdi et al 1998).

Furthermore, Kirkegaard et al. (1995) found that deeper sowing delayed emergence and reducedtotal root length, overall plant fresh weight, leaf area and shoot dry weight.

However, Kirkegaard et al. (1995) also reported that sowing at shallow depths (*ca*. 3 cm) consistently gave poorer formation and lower yields than at 6 cm depth. At shallow planting depths, soil has the propensity to dry quicker than at deeper depths, 6 – 12 cm (Mahdi et al. 1998). At deeper planting depths, the soil will take longer to dry, thereby allowing the roots more time to penetrate lower in the profile before the soil dries. In addition, it is recommended that if sowing in winter, damage by mice and slugs of crops such as wheat, can be prevented. Varieties such as Hongwangmai, which are tolerant of deeper sowing should be sown deeper into the soil profile depth (5 to 7 cm) to reduce the chance of predation (Brown et al. 2003; Glen et al. 1990; Incerti& Leary 1990; Matsui et al. 2003). For this reason, the recommended planting depth for wheat is 5 cm, which is also the ideal for optimum soil parameters for a greater emergence rate index (Raoufat and Matbooei 2007).

2.1.2 Band placement for wheat

Mesbah and Miller (1999) conducted two experiments over a three-year study period to evaluate fertiliser placement on winter wheat and weed (e.g., 'jointed goatgrass') pressure in the USA. In the first experiment, fertiliser was placed in a deep furrow 5 cm below and 2.5 cm to the side of the wheat row with an N application rate of 45 kg ha^{-1}. In the second experiment, N fertiliser was broadcasted on soil surface and/or injected by spoke wheel 10 cm and 5 cm to the side of the wheat row. Mesbah and Miller (1999) found that by placing fertiliser deep in the soil and closer to wheat seeds favoured wheat seedling emergence. Therefore, winter wheat was able to accumulate and utilize available nutrients bettercompared to the jointed goatgrass, because it circumventedcompetition for water and light (Mesbah and Miller 1999). Mesbah and Miller (1999) concluded that fertiliser banding reduces weed biomass and could potentially increase yields of wheat. In another study conducted over three seasons, the effects of broadcast and N band placement in winter wheatwere compared (Cochran et al. 1990). It was reported that under band applied N, wheat N uptake, growth and grain yields were consistently higher than that of weeds (Cochran et al. 1990). Also, dry weights and N uptake increased with increased in N rates in both N banded and surface broadcast treatments (Cochran et al. 1990). Weed densities, biomass and N uptake wereon average 20 to 40% lowerin the growing season, with 12% average increase in grain yield where side band placement was used compared to broadcast treatments**.** Kirkland & Beckie (1998) proposed that side banding is the most precise method of fertiliser placement favoured by crops. On the whole, side banding tended to be superior to broadcast-applied fertiliser in reducing broad leaf weed emergence and growth inspring wheat. Kirkland & Beckie (1998) concluded that banding fertiliser at recommended rates can be used as effective cultural practice for managing weeds in no till and conventional tillage wheat cropping systems.

2.2 Canola in the Western Cape

Canola is an oil seed (De Kock and Agenbag 2009) that is predominantly produced in the European Union (33%), Canada (24%), China (19%), India (10%), and the Ukraine (2%) – these combined make up nearly 90% of the global canola production (Business Report 2016). Canola cultivars are usually divided into winter-, intermediate-, and spring types. Winter type cultivars (*Brassica napus*) require very low temperatures and moist conditions during flowering and pod development. These particular winter cultivars are planted in the Western Cape Province of South Africa due to a winter rainfall regime and cold temperatures (DAFF 2010b). Canola production has markedly increased by over 70% in Western Cape over a six year period (DAFF 2016a). DAFF (2016a) reported that there is an upward trend in canola production and that the canola area of sowing has increased from 17 000 hectares, producing *ca*. 21 000 tons in 1998/99, to 71 050 hectares with a yield of *ca*. 93 000 tons in the 2015/16 season. However, the province experienced a decline in yield during the 2014/2015 and 2015/2016 seasons due to drought (Business Report 2016). Similarly, canola production declines were also experienced globally due to drought crises, with overall production declining from 71.6 million tons in the 2013/14 season to 65.1 million tons in the 2016/17 season (Business Report 2016).

2.2.1 Sowing depth for canola

Hanson et al. (2008) demonstrated that percent emergence and plant density was significantly higher at a planting depth of 1.9 cm compared to seed planted at 3.8 cm. In that study, it was concluded that low percentage canola seed emergence can be avoided by sowing at the recommended depth of 2.5 cm (Hanson et al. 2008). However, seed size, which differs between and within cultivars, should be considered by farmers when determining seeding rate and planting depth (Hanson et al. 2008). The GRDC (2016) distinguished seed sizes and seeding rates by sieving different cultivars. For example, within the Hyola 559TT canola cultivar, the smallest seds (<2 mm in size) must be planted atabout 2.75 kg ha^{-1}, while medium seeds (2.0 – 2.36 mm) should be planted at*ca*. 4.15 kg ha^{-1}, and large seeds (>2.36) at about 5.29 kg ha^{-1} seeding rate (GRDC 2016).

2.2.2 Band placement for canola

Malhi and Gill (2004) conducted a study to determine the effect of band fertiliser placement, row opener, and seeding depth on silty clay loam for canola production. The experiment was performed at a placement depth of 1.5 cm and 4.5 cm deep for canola and N fertilizer respectively with N fertiliser at rates of 0, 40, 80 and 120 kg N ha^{-1}. In addition, side banding and seed row placement was achieved by using 2 cm spread knives and 20 cm spread shovels. An increase in N rate resulted in increased yield, N uptake, and protein content in canola when side banding was used. In contrast, under seed row fertiliser placement, the yield, N uptake, and protein content increased only at an N rate of 40 kg N ha^{-1}. At lower levels of N, knives produced better seedling emergence, while shovels tended to give superior seedling emergence at higher rates of seed row placed N. Malhi and Gill (2004) noted that the negative impact of seed row placement was more severe with deeper seeding, higher N rate, and narrower width of seed row fertiliser placement band when compared to side band placement of N. In order to enhance N response in canola, fertiliser and seed should be placed in a way that maximises seedling emergence and minimises fertiliser damage to seedlings.

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CHAPTER 3

Effect of nitrogen rates on establishment of wheat and canola sown at different depths and in different soil types in pots

3.1 Introduction

Most farmers in the Western Cape Province plant wheat (*Triticum aestivum*) and canola (*Brassica napus*) in rotation with other small grain and pasture crops (Swanepoel et al. 2016). Nitrogen (N) is an essential nutrient required in large amounts by both crops and is often the most limiting nutrient to production (Jarvis et al. 1996). Canola has a high N consumption, with approximately 55 kg ha^{-1} taken up by the crop to produce one ton of seed per hectare (DAFF 2016). Conversely, wheat has higher N use efficiency as it requires *ca*. 27 kg N ha^{-1} per ton of grain produced (DAFF 2010). Due to the large N requirement of these crops, N fertiliser makes a significant contribution to the production costs for wheat and canola.

Nitrogen fertiliser is applied according to the fertiliser guidelines that differ between areas with different environmental conditions, particularly soil (Ozer 2003). The N guidelines for wheat under irrigation is based on the target wheat yield. For example, if the farmer is targeting 4 to 5 tons ha^{-1} of wheat yield, 80 to 130 kg ha^{-1} N should be applied. Under rainfed conditions, such as Western Cape, N rates for wheat are based on crop production or management systems and climate. For example, if 2 to 4 ton ha^{-1} is the target for wheat, 60 to 140 kg ha^{-1} N should be applied under minimum-tillage with canola as the preceding crop in rotation (DAFF 2016).

For canola, the guidelines are based on wheat or on literature because guidelines tailored for the Western Cape are currently being developed (Coetzee 2017). When planting wheat in moist soils, many farmers use 20 to 25 kg ha^{-1} of N band-placed with no-tillage seed-drills on tine openers. This is reduced to 5 to 15 kg ha^{-1} when planting in dry soil. Although the amount of N may be optimal for tine openers, it may probably be too high for disc planters because seed and fertiliser are not independently placed in the soil during the planting process. Having the seeds in direct contact with N often results in damage to the seed during establishment stages. Thus, it is recommended that N be broadcasted or banded 5 cm away from the seed (DAFF 2016). Under irrigation, the recommended N rates for canola production are 180 kg ha^{-1} on clay soils and 200 kg ha^{-1} on sandy soils (DAFF 2010). Under rainfed conditions, as in the Western Cape, recommendations are made based on the production area. For example, at Swartland farms with the rainfall ranging between 350 – 425 mm per year, the recommended N rate is 80 to 100 kg ha^{-1} for a target yield of 1.5 ton ha^{-1} (DAFF 2016). Since the response of plants to N may differ between highly variable soils of the Western Cape, it is important to evaluate N placement with seed and planting depth in different soil types. Therefore, the aim was to determine the most suitable N rate under the different soil types and at different sowing depths.

3.2 Material and methods

3.2.1 Site description

The experiment was conducted in 2016 in a growth room set at 20°C/18°C day/night temperature at the Welgevallen Experimental Farm (33.9427° S, 18.8664° E), Stellenbosch University, South Africa.

3.2.2 Experimental layout and treatments

Two independent trials were laid out for canola and wheat as randomised block designs (RBD) with two factors (sowing depth and nitrogen rate), each factor replicated in four blocks in five soil types. Wheat (cv. SST087) was sown on 13 May 2016 and the canola (cv. 555TT) was sown on 26 May 2016. Pots with a volume of 126 cm^3 were used. Four sowing depths (1, 2, 4, and 8 cm) and five nitrogen rates (0, 10, 20 30, and 50 kg ha^{-1}) were used to plant canola and wheat. Urea was dissolved in water to facilitate accurate application of N per pot. Five soils with varying texture, pH, organic C and total N contents were used (Table 3.1).

Table 3.1 Soil characteristics for soils used in pots.

Soil type	Origin	pH (KCl)	Texture	Sand (%)	Silt (%)	Clay (%)	Carbon (%)	Total N (%)
A	**Langgewens**	5.7	Sandy loam	77	14	9	0.59	0.069
B	**Paarl**	6.1	Sand	87	2	11	0.08	0.003
C	**Welgevallen**	4.7	Sandy loam	77	12	11	0.06	0.049
D	**Welgevallen**	4.4	Sandy loam	75	18	7	0.46	0.048
E	**Welgevallen**	5.6	Loamy sand	85	6	9	1.95	0.130

3.2.3 Wheat and canola sowing trial procedure used in growth room

Each of the pots (400 for wheat and 400 for canola) wasfilled with soil to a measured depth and four seeds per pot of each crop (i.e., wheat or canola) were sown at the measured soil depth. Pots were subsequently topped-up with soil to the height of 18 cm and irrigated to field capacity by using the exact calculated amount of N solution per pot.

3.2.4 Establishment

The number of established seedlings per pot, out of four seeds that were planted, were counted after first plant establishment for each crop. The results were interpreted as percentages.

3.2.5 Statistical analyses

An analysis of variance (ANOVA) was performed on data using STATISTICA version 13.2 (Dell Inc. 2016). Fisher's Least Significant Difference (LSD) was calculated at 5% level to compare treatment means. Variances were homogenous and residuals were normally distributed.

3.3 Results

3.3.1 Wheat Establishment; Soil A: Sandy loam, moderate organic C, moderate inherent N content

When four wheat seeds per pot were established at 1 cm depth, there was no effect ($p > 0.05$) on establishment when fertilised at the 0, 10 and 50 kg ha^{-1} N treatments (Fig. 3.1). The lowest wheat seed establishment was obtained at the 20 N rate, but did not differ ($p > 0.05$) with 30 kg ha^{-1} N at 1 cm depth. Wheat seed establishment reflected no differences ($p > 0.05$) between any of the N rates at 2 cm depth (Fig. 3.1). At 4 cm depth, there was no difference ($p > 0.05$) in establishment when using 0, 10, 20 and 30 kg ha^{-1} N rates. However, 50 N rate differed ($p < 0.05$) from the 20 N rate, where higher number of seeds established at 50 kg ha^{-1} N rate than 20 kg ha^{-1} N rate at a depth of 4 cm. Similarly, at 4 cm depth, the number of wheat seeds that established decreased drastically in all N rates as compared to 1 and 2 cm (Fig. 3.1). At 8 cm depth no wheat seeds established (Fig. 3.1).

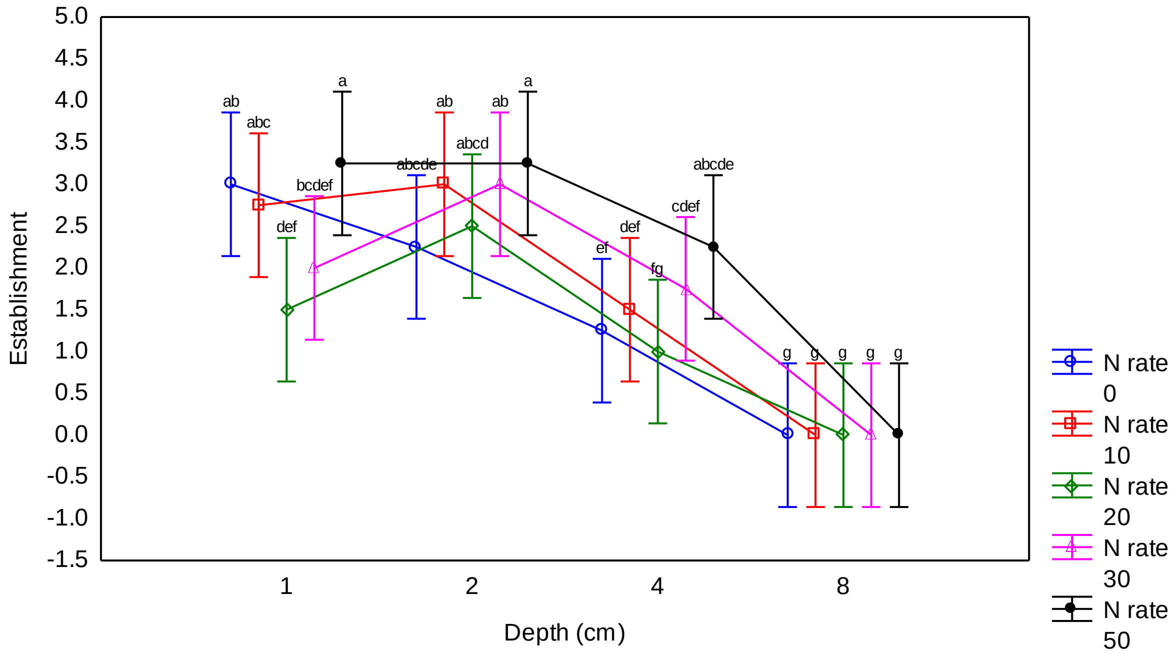

Figure 3.1. Wheat seed establishment in soil A using rates of 0, 10, 20, 30 and 50 kg ha^{-1} N, and planting depths of 1, 2, 4, and 8 cm. Establishment is the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.3.2 Wheat establishment; Soil B: Sandy, low organic C, low inherent N content

At 1 and 2 cm depths, 75 to 100% of wheat seeds that were sown established reardless of the N rate (Fig. 3.2). Moreover, there were no differences (p >0.05) between N rates (0, 10, 20, 30, or 50 kg ha^{-1}). At 4 cm depth, seeds that were sown in 10, 20 and 30 kg ha^{-1} N rates had a lower establishment than the 0 kg ha^{-1} N rate treatment (Fig. 3.2). The 50 kg ha^{-1} N rate did not differ (p > 0.05) from 10 and 20 kg ha^{-1} N rate when seeds were planted 4 cm deep (Fig. 3.2). Although, the 0 kg ha^{-1} N rate was not different (p > 0.05) from the 50 kg ha^{-1} N rate, it differed (p < 0.05) from 10, 20, 30 kg ha^{-1} N rate at the 4 cm depth. Seed establishment was inversely correlated to sowing depth, with more seeds establishing at the 1 and 2 cm depth than at 4 cm (Fig. 3.2). No seeds in any of the N rate treatments at the 8 cm depth.

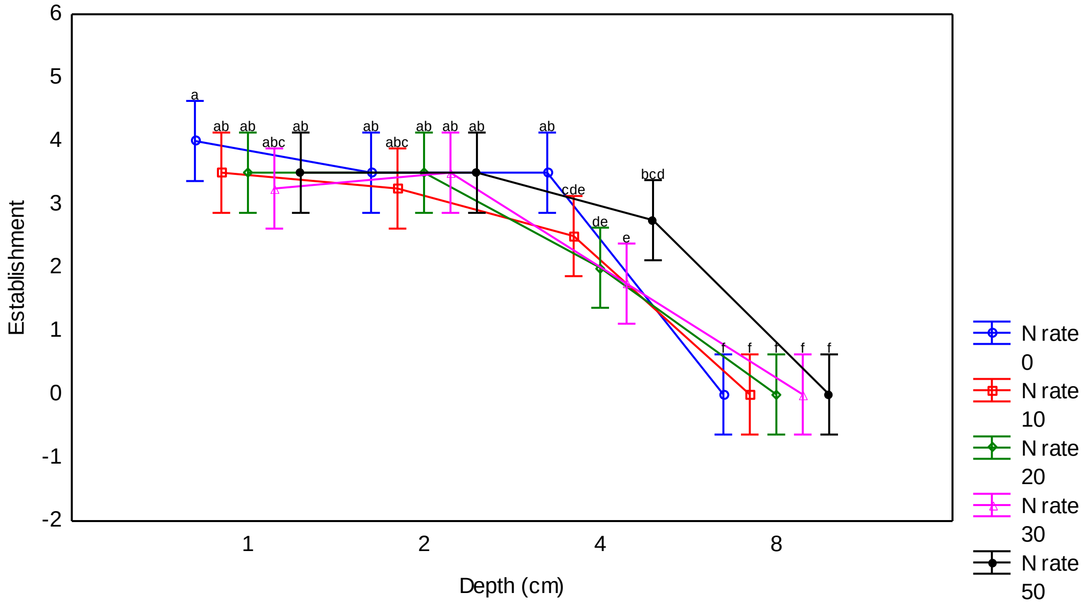

Figure 3.2. Wheat seed establishment in soil B using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at $p = 0.05$.

3.3.3 Wheat establishment; Soil C: Sandy loam, moderate organic C, moderate inherent N content

More than 50% of seeds that were sown at 1 cm depth established (Fig. 3.3). Seed establishment for 0 kg ha^{-1} N rate did not differ ($p > 0.05$) from the 10, 30 and 50 kg ha^{-1} N rates, but differed ($p < 0.05$) from the 20 kg ha^{-1} N rate at 1 cm depth (Fig. 3.3). Seeds that established for 0 kg ha^{-1} N rate were considerably lower than those in 20 kg ha^{-1} N rate at 1 cm depth. Wheat seed establishment did not differ ($p > 0.05$) at 2 cm depth, irrespective of N rate (Fig. 3.3). Moreover, wheat establishment at 4 cm depth did not differ ($p > 0.05$) between N rates, but the level of establishment was lower compared to 1 and 2 cm depths (Fig. 3.3). At a depth of 8 cm, no seed established.

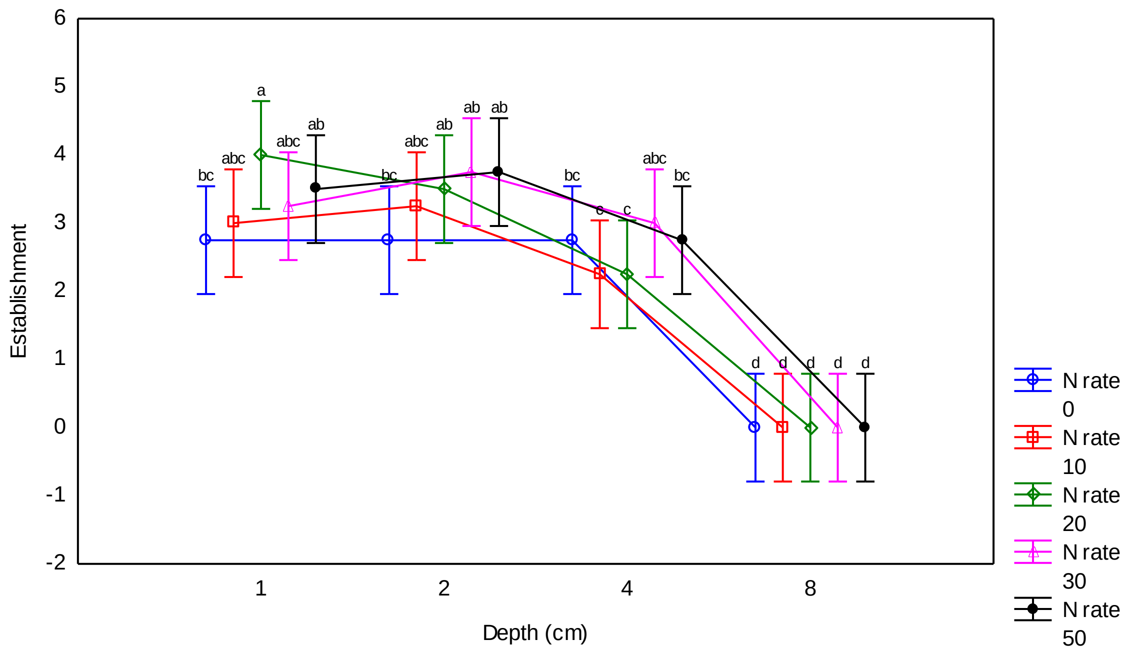

Figure 3. 3. Wheat seed establishment in soil C using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at $p = 0.05$.

3.3.4 Wheat establishment; Soil D: Sandy loam, moderate organic C, moderate inherent N content

Wheat seed establishment did not differ ($p > 0.05$) at any of the N rates at 1 cm depth (Fig. 3.4). At 2 cm depth 30 kg ha^{-1} N rate did not differ ($p > 0.5$) from 0, 20 and 50 kg ha^{-1} N rate but it differed ($p < 0.05$) from 10 kg ha^{-1} N rate. Seed established for 30 kg ha^{-1} N rate was lower than 10 kg ha^{-1} N rate at 2 cm depth. At 4 cm depth, more than 50% of seeds geminated in all N rates, excluding 20 kg ha^{-1} N rate (Fig. 3.4). There were no differences ($p > 0.05$) in establishment between 10, 20, 30, and 50 kg ha^{-1} N rates, however, the 0 kg ha^{-1} N rate was different ($p < 0.05$) from the 20 kg ha^{-1} N rate (Fig. 3.4). Higher number of seeds established for 0 kg ha^{-1} N rate as compared to 20 kg ha^{-1} N rate at 4 cm depth. In most cases, seed establishment at 4 cm was not different ($p > 0.05$) from 1 and 2 cm depths, though none of the seeds established at 8 cm depth.

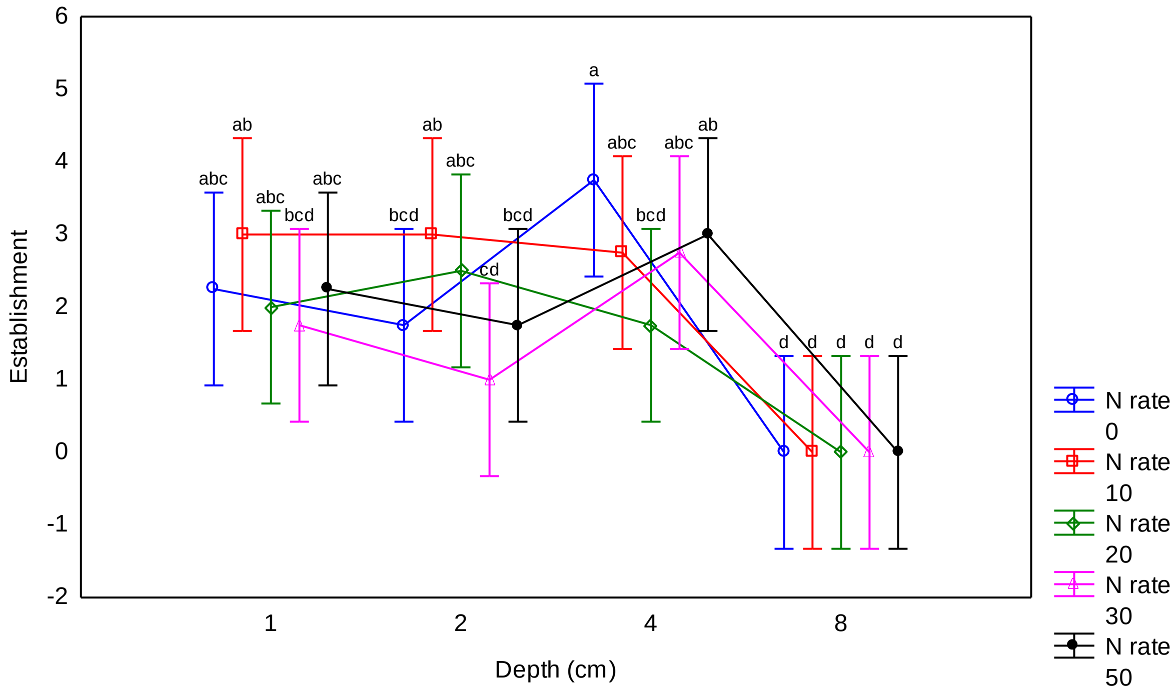

Figure 3.4. Wheat seed establishment in soil D using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment is the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.3.5 Wheat establishment; Soil E: Loamy sand, high organic C, high inherent N content

At least 75% of wheat seeds that were sown at 1 and 2 cm depths emerged in all N rates, excluding the 50 kg ha^{-1} N rate, which resulted in poor establishment (Fig. 3.5). The seed establishment of 50 kg ha^{-1} N rate differed ($p < 0.05$) from 0, 10, 20 kg ha^{-1} N rate, but it did not differ from 30 kg ha^{-1} N rate at the depth of 1 cm. The lowest number of seeds established were obtained from 30 and 50 kg ha^{-1} N rate compared to 0, 10 and 20 kg ha^{-1} N rate at 1 cm depth (Fig.3.5).

There was no difference in seed establishment when 0, 10, 20, 30 N rate ($p > 0.05$) was used at 2 cm depth (Fig. 3.5). The seeds that were sown using 30 kg ha^{-1} N were different ($p < 0.05$) from the seeds that were sown using the 50 kg ha^{-1} N at 2 cm depth. A greater number of seeds established from 30 kg ha^{-1} N rate than 50 kg ha^{-1} N rate at a depth of 2 cm (Fig. 3.5). However, seeds that were sown with 50 kg ha^{-1} N did not differ ($p > 0.05$) from seed sown using 0, 10 and 20 kg ha^{-1} N at 2 cm depth. Also, there were no differences ($p > 0.05$) in establishment by N rate (0, 10, 20, 30, and 50 kg ha^{-1} N) at a depth of 4 cm. There were also no differences (p > 0.05) between seed establishment at 4 cm and at 1 and 2 cm. No wheat seeds established at 8 cm depth (Fig.3.5).

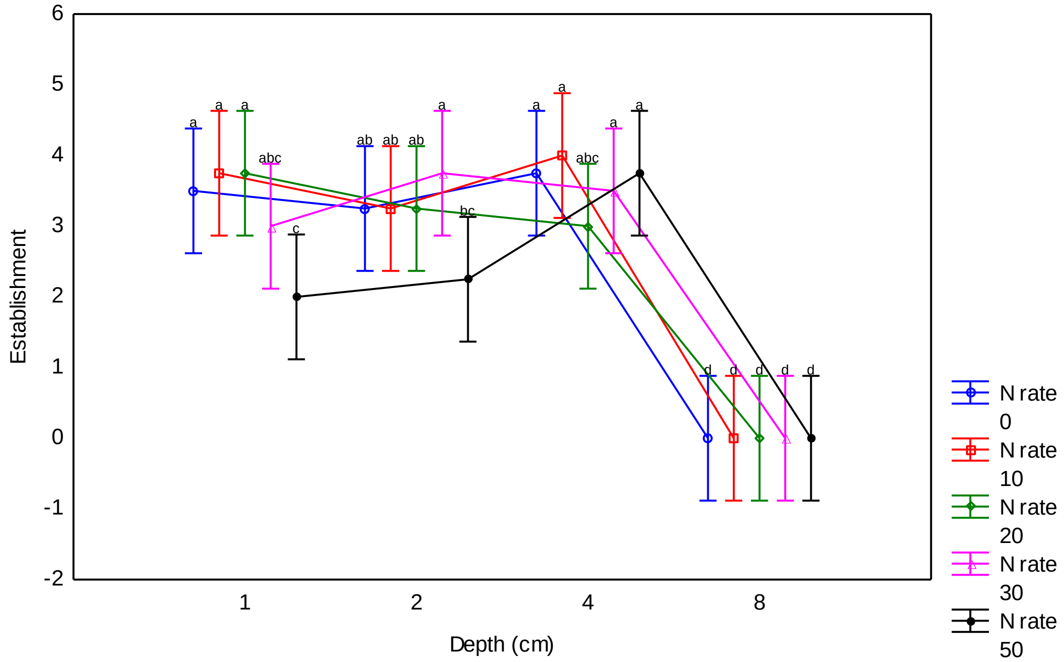

Figure 3.5. Wheat seed establishment in soil E using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.3.6 Canola establishment; Soil A: Sandy loam, moderate organic C, moderate inherent N content

The establishment for this sandy soil type (A) was particularly poor (Fig. 3.6). Few seeds established at a depth of 1 cm and at 0 kg ha^{-1} N, yet establishment was higher (p < 0.05) than at 20 N and 30 kg ha^{-1} N (Fig. 3.6). No seeds emerged at depths of 2, 4, and 8 cm irrespective of N rates (Fig. 3.6).

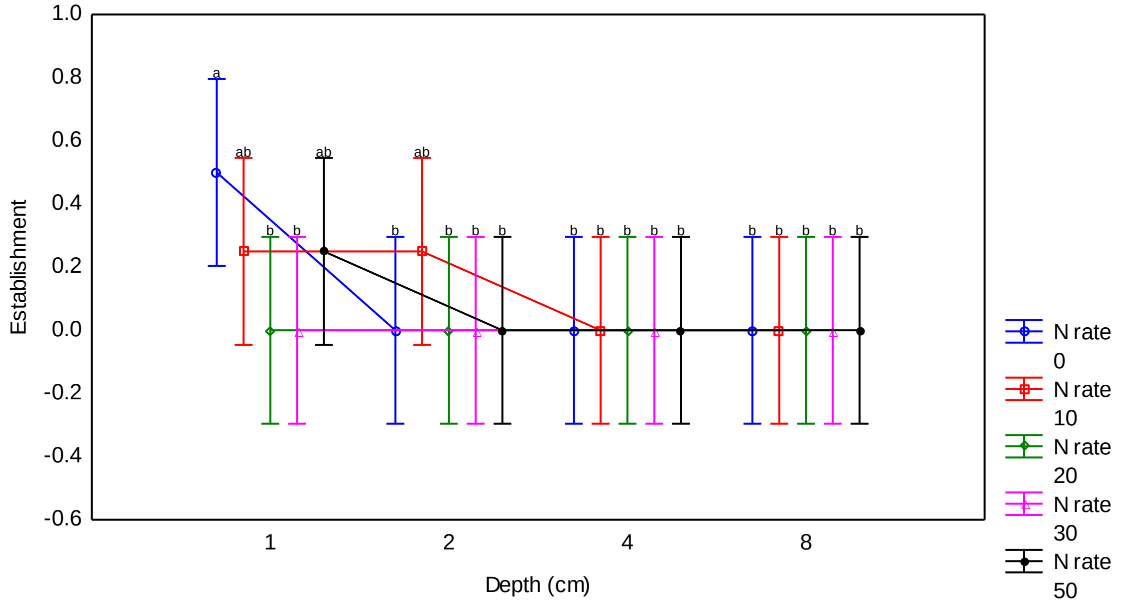

Figure 3.6. Canola seed establishment in soil A using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.3.7 Canola establishment; Soil B: Sandy, low organic C, low inherent N content

As depicted in Figure 3.7, there were no differences ($p > 0.05$) in canola establishment between 1 and 2 cm depth at 0, 10, 20, 30 and 50 kg ha^{-1} N rate and more than 75% seeds geminated in soil B. In contrast, at a 4 cm depth, 0 kg ha^{-1} N rate differed ($p <$ 0.05) from 10, 20, and 30 kg ha^{-1} N rate, but it did not differ ($p > 0.05$) from the 50 kg ha^{-1} N rate (Fig. 3.7). The 50 kg ha^{-1} N rate did not differ ($p > 0.05$) from the 10 and 20 kg ha^{-1} N rates, but differed ($p < 0.05$) from the 30 kg ha^{-1} N rate. At 4 cm depth, seed establishment decreased when compared to sowing depths of 1 and 2 cm. As was the case for the other soil types and wheat, none of the planted seeds emerged at 8 cm depth.

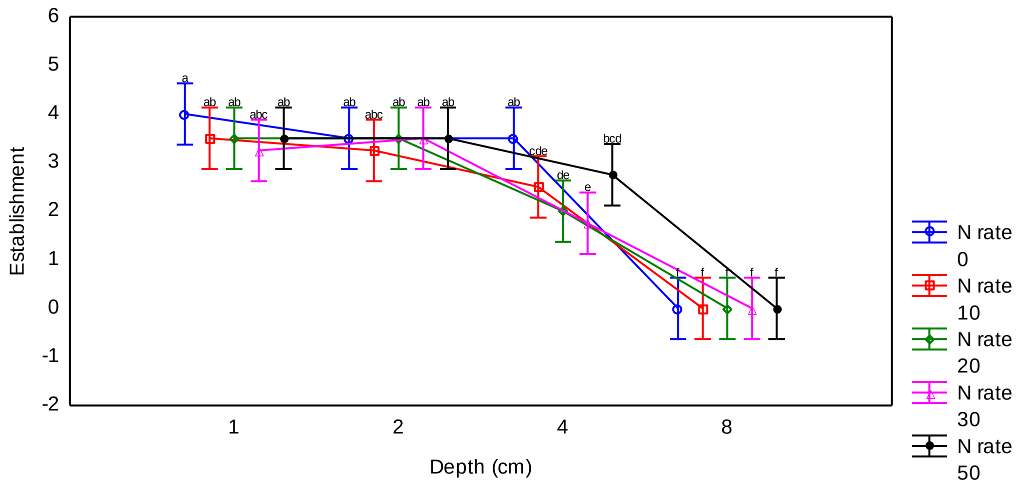

Figure 3.7. Canola seed establishment in soil B using 0, 10, 20, 30 and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment refers to the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.3.8 Canola establishment; Soil C: Sandy, moderate organic C, moderate inherent N content

Canola seed establishment was poor at 1 and 2 cm depth for 0, 10 and 20 kg ha^{-1} N rate, ranging from 25% to 45% (Fig. 3.8). However, when the 30 and 50 kg ha^{-1} N rates were applied at depths of 1 and 2 cm, seed establishment improved, ranging from 50% to 100%. The highest establishment was recorded at 30 kg ha^{-1} N, although it did not differ from the 50 kg ha^{-1} N rate (Fig. 3.8). There was no difference (p > 0.05) in seed establishment between 0, 10 and 20 kg ha^{-1} N rate at 1 and 2 cm depths. The 50 kg ha^{-1} N rate was different (p <0.05) from 0, 10, and 30 kg ha^{-1} N rate but did not differ (p > 0.05) from the 20 kg ha^{-1} N at 4 cm depth. There was not much effect on seed establishment between 1, 2, 4, and 8 cm depth. Interestingly, at 8 cm depth, between 25% and 50% seeds emerged (Fig. 3.8).

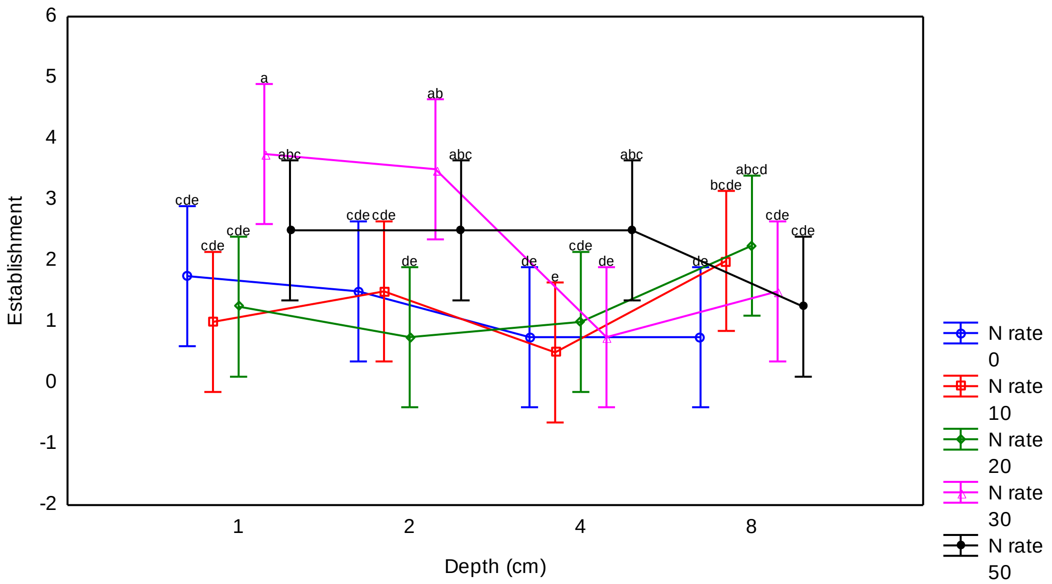

Figure 3.8. Canola seed establishment in soil Cusing 0, 10, 20, 30, and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at $p = 0.05$.

3.3.9 Canola establishment; Soil D: Sandy loam, moderate organic C, moderate inherent N content

Seed establishment was generally good at a depth of 1 cmcompared to other depths; between 50% and 75% of seeds established (Fig. 3.9). Seed establishment at 1 cm depth was not different ($p > 0.05$) between 0, 10, 20, 30, and 50 kg ha^{-1} N rates. At a planting depth of 2 cm, seed establishment decreased and less than 50% established regardless of N rate, except at the highest N rate of 50 kg ha^{-1}, where 75% seeds geminated.There were no differences ($p > 0.05$) in establishment at 0, 10, and 20 kg ha^{-1} N rates at 2 cm depths. Seed establishment at 50 kg ha^{-1} N did not differ ($p > 0.05$) from 0 and 20 kg ha^{-1} N rates, but was different ($p < 0.05$) from 10 and 30 kg ha^{-1} N rates at 2 cm depth (Fig. 3.9). Higher numbers of canola seeds established from 50 kg ha^{-1} N rate compared to 10 and 30 kg ha^{-1} N rates at 2 cm depth.

Seed establishment at 4 cm depth was generally poor as less than 50% seeds geminated (Fig. 3.9). Seed establishment at 0 and 10 kg ha^{-1} N rates were different ($p < 0.05$) from 20, 30, and 50 kg ha^{-1} N rates at a depth of 4 cm. At 4 cm depth, seed establishment did not differ from 1 and 2 cm depths, although it was generally different

($p < 0.05$) from 8 cm depth where less than 25% of seeds established but there were no differences ($p > 0.05$) at any of the N rates.

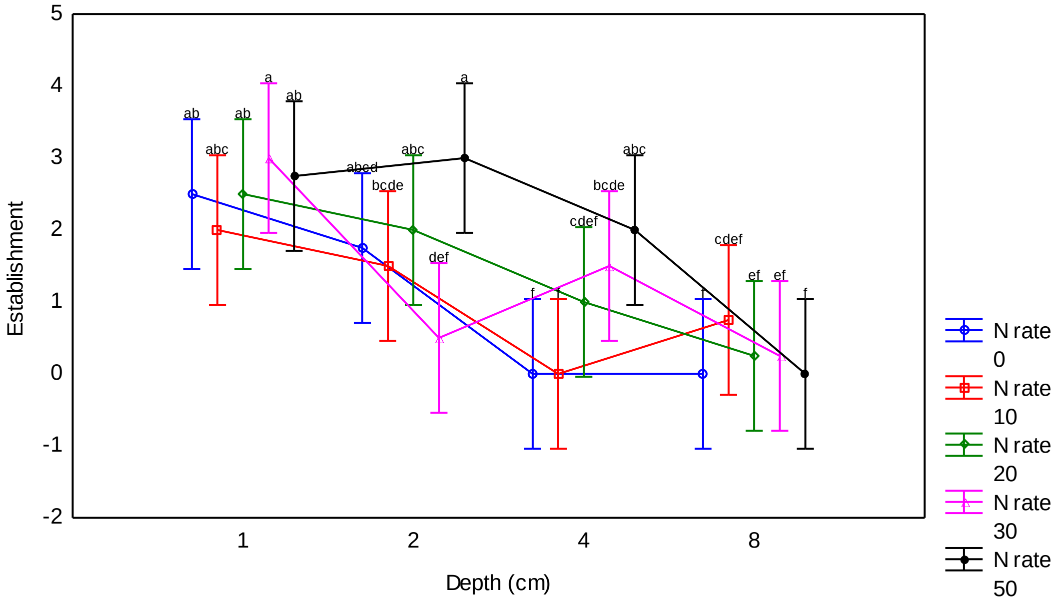

Figure 3.9. Canola seed establishment in soil D using 0, 10, 20, 30, and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at $p = 0.05$.

3.3.10 Canola establishment; Soil E: Loamy sand, high organic C, high inherent N content

Canola establishment at a depth of 1 and 2 cm was poor as less than 35% of seeds established regardless of N rate (Fig. 3.10). At these aforementioned depths, there were no differences ($p > 0.05$) in seed establishment across the whole range of applied N (Fig. 3.10). Seed establishment was low, especially when 30 kg ha^{-1} N rate was applied at 4 cm depth. Seed establishment at 30 kg ha^{-1} N rate was different ($p < 0.05$) from 0, 10, and 50 kg ha^{-1} N at 4 cm depth, but it did not differ ($p > 0.05$) from the 20 kg ha^{-1} N rate (Fig. 3.10). Seed establishment at 4 cm did not differ ($p > 0.05$) from 1 and 2 cm depth, yet it was different ($p < 0.05$) from 8 cm depth. A small number of canola seeds established at 8 cm depth at 50 kg ha^{-1} N, but it did not differ ($p > 0.05$) from the other N rates where no seeds established (Fig. 3.10).

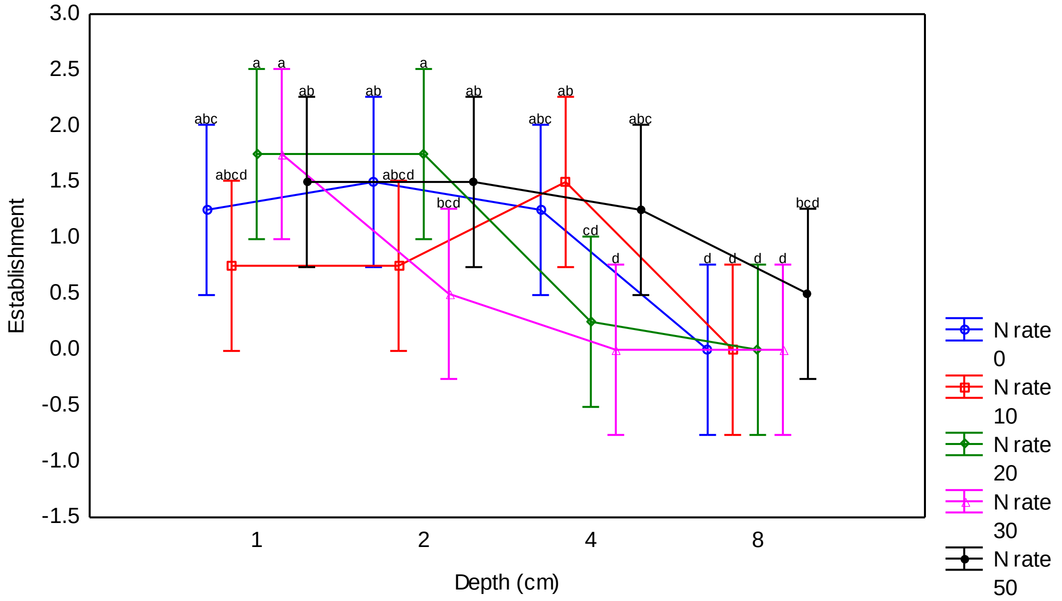

Figure 3.10. Canola seed establishment in soil E using 0, 10, 20, 30, and 50 kg ha^{-1} N rates, and planting depths of 1, 2, 4, and 8 cm. Establishment indicates the number of seeds that established out of four seeds that were sown per pot. Points with the same letters are not significantly different at p = 0.05.

3.5 Discussion

3.5.1 Wheat

Wheat establishment decreased as the soil depth increased in most soil types. This corroborates a study by Gulshan and Dasti (2012), where seed establishment also decreased with an increase in sowing depth. There may generally be a delay in seedling emergence at deeper planting depths, especially in the case of smaller seed types. A shallow planting depth, particularly 2 cm deep, was the most suitable planting depth in most soil types regardless of N rates. It was formerly suggested that wheat seed should not be planted at depths in excess of 5 cm (DAFF 2010). Moreover, seeds that were planted at a depth of 2 cm did not differ in terms of establishment regardless of soil type. However, it appears the maximum wheat seed establishment percentage was obtained in sand and sandy loam soil types (soils B and C). Similarly, Gulshan & Dasti (2012) obtained maximum establishment of seeds in soils with a sandy loam texture.

At 8 cm depth, none of the wheat seeds planted established in any of the soil types because it has been shown that deeper sowing prevents or reduces the seed establishment of wheat (Ren et al. 2002). In addition, N rates did not affect the establishment of wheat in this study.The effects of N rate on wheat seed establishment percentage at various sowing depths are inconclusive in this study as several studies either showed an increase (Abedi et al. 2011; Mason and Brennan 1998), whilst other studies showed no effect (Stephen et al. 2005; Johnson et al. 2001). Abedi et al. (2011) and Mason and Brennan (1998) used the same wheat cultivar to conduct their respective trials.

3.5.2 Canola

Canola establishment was poor, which may be a result of sensitivity of canola seed to the urea fertiliser (Johnson et al. 2001). Moreover, when the Langgewens soil was irrigated, the soil became compacted and this soil compaction made very difficult for canola seed to establish. Lemke et al. (2008) recommended that high N rates should not be applied too close to the seed because it may negatively affect canola seedlings. Seed establishment was better at 2 cm depth than at depths of 1, 4, and 8 cm. DAFF (2010) recommended a planting depth of not more than 3 cm for canola since deeper planting may delay plant establishment and increase the chances of seed to be subjected to soilborne pathogens.

Planting of canola seed at a shallow depth (1 to 3 cm) may help seedlings to establish quicker and become competitive against weeds (DAFF 2016). Nitrogen rates applied at 2 cm depth did not differ in most soil types for canola. However, Malhi et al. (2004) conducted a similar canola experiment and found superior seedling establishment at higher N rates of same depths tested in their study. Brandt et al. (2007) found that canola seed establishment declined at high N fertiliser rates due to fertiliser-induced seedling damage. This might also be the reason most of the canola seed did not establish well at higher N rates in this study.

3.6 Conclusion

In general, wheat seeds established well at 1 and 2 cm depths with no clear effects from the amount of N applied across all soil types. Most interestingly, highest establishment was obtained in pure sandy soils for wheat at all N rates. In contrast, canola establishment was poor in all soil types and more than 60% of seeds failed to establish. From the results it became clear that seeds for both crops established well at shallow depths (1 or 2 cm) compared to deeper depths (4 and 8 cm). Evidence presented here corroborates results from several previous studies, but it would be interesting to see if this holds true particularly for canola (given its status as a relatively new crop in the rotational systems for the Western Cape) under field conditions and different climatic conditions.

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CHAPTER 4

Effectiveness of a tine or disc opener to establish canola and wheat at different depths

4.1 Introduction

Minimal or no disturbance to soil prior to and during planting is used as one of the most important practices in conservation agriculture (CA) (Hobbs 2007). The Western Cape has a characteristically Mediterranean-type climate and receives winter rainfall between April and October, therefore CA is vital to ensure sustainable production of field crops. Most Western Cape farmers following CA practices rely on tine openers to establish wheat and canola. Due to the success with disc openers elsewhere in the world, the interest of farmers to start using disc openers locally has increased.

The placement of the seeds differs for tine and disc openers and may have an impact on seedling establishment for both wheat and canola. Kirkegaard et al. (1995) reported that shallow sowing of canola promotes faster seed emergence and increases seedling growth. Furthermore, placing seed deeper may be beneficial in dryland conditions where soil moisture from the top few centimetres may be lost quickly. It was reported that deeper sowing delay plant growth wich affect the dry mass, length of elongating and primordial leaves of wheat (Kirby 1993; Tomlinson et al. 1997).

The depth of seed placement through using tine or disc openers has not yet been assessed in the Western Cape, and data elsewhere is also obscure. The aim in this trial was to evaluate the effectiveness of tine or disc openers to establish canola and wheat at different depths.

4.2 Material and methods

4.2.1 Site description

This trial was conducted in 2016 at Langgewens Research Farm, near Moorreesburg (33°17’00” S, 18°42’00” E; 191 m above sea level) in the Western Cape Province (South Africa). This region has a good production potential for wheat and canola, compared to the surrounding regions (Van Zyl 2017). The soils are derived from Malmesbury and Bokkeveld shales, dominated by reddish soil with a pH (KCl) of 5.7.

The soils are shallow with an average carbon (C) content of 0.59% and are 77% sand, 14% silt, 9% clay, and a high stone content.

The climate is a characterised by winter rainfall with an average annual rainfall of 400 mm. The trial was laid out on 24 May 2016, which is later than the recommended sowing date. The drought experienced by the Western Cape prior to planting resulted in dry soils, hence the delay in planting in order to avoid seed lying in the soil for a long time (DAFF 2016). Shortly after planting, 5 mm of rain was received and, thereafter, the first good rain fell in early June 2016.

4.3.2 Experimental layout and treatments

Plots were 50 m long and 2.3 m wide, and row spacing was 300 mm for both tine and disc openers. Two separate trials for wheat and canola were laid out as a randomised block designs with two factors (seed-drill opener and planting depth), replicated in four blocks. An Equalizer planter with exchangeable disc and tine openers was used to plant wheat (cv. SST087) and canola (cv.555TT) at three different depth settings on the seed-drill (shallow, moderate and deep).

During planting, 5 kg N ha^{-1} was applied, followed by 40 kg N ha^{-1} at 40 days, and 40 kg N ha^{-1} at 90 days after plant emergence for both wheat and canola. Weeds in plots were sprayed with herbicides: Axial (125 mL ha^{-1}) in wheat and atrazine (1.5 L ha^{-1}) in canola plots.

4.3 Data collection

4.3.1 Evaluation of seed placement

Four weeks after emergence, 15 plants were carefully uprooted (with intact root systems) with a spade in each of the six rows per plot. For wheat, the depth of the seed was determined by measuring the distance between the points on the hypocotyl with white discolouration to the remnant of the seed. For canola, the seed was no longer visible, but the distance between the discolouration on the hypocotyl and the branch of the first secondary root was used as an indicator of seed depth.

4.3.2 Plant population and biomass production

Thirty days after plant emergence, the numbers of plants were counted in 0.5 m^2 quadrats per plot. Wheat and canola biomass was determined by sampling five plants per plot prior to harvesting. The samples were weighed before and after drying at 60 °C for 72 hours.

4.3.3 Leaf Area Index (LAI)

Thirty days after plant emergence, ten plant samples for wheat and five plant samples for canola per row were collected and analysed using Li-Cor Leaf Area Machine (model-3100) to determine the leaf area. Leaf Area Index (LAI) was calculated for wheat and canola per plot.

4.3.4 Yield and seed quality

Canola and wheat were harvested using a small plot harvester and the yield per hectare was quantified as well as thousand kernel mass (g). Protein content (%) and hectolitre mass (kg hL^{-1}) were determined for wheat.

4.3.5 Statistical analyses

An analysis of variance (ANOVA) was performed on the data using STATISTICA version 13.2 (Dell Inc. 2016). Fisher's Least Significant Difference (LSD) was calculated at 5% level to compare treatment means. Variances were homogenous and residuals were normally distributed.

4.4 Results and Discussion

4.4.1 Wheat and canola depth

DAFF (2017) suggested that wheat seeds can be planted up to 50 mm in depth with any type of opener, but if the soil is dry or compacted, a tine opener should be used. In this trial, the tine opener placed wheat seeds at 22.3, 36.8, and 46.1 mm for the shallow, medium and deep settings, respectively (Fig. 4.1). There were differences ($p < 0.05$) between opener settings (shallow, moderate and deep) for wheat when a tine opener was used. In contrast, when the disc opener was used, there were no differences between depths. It was previously observed that a single disc opener distributed seed better than a hoe opener at a depth of 50 mm (Karayel and Özmerzi, 2007). However, in this trial, the tine opener distributed wheat seed at 50 mm better than the single disc opener (Fig. 4.1).

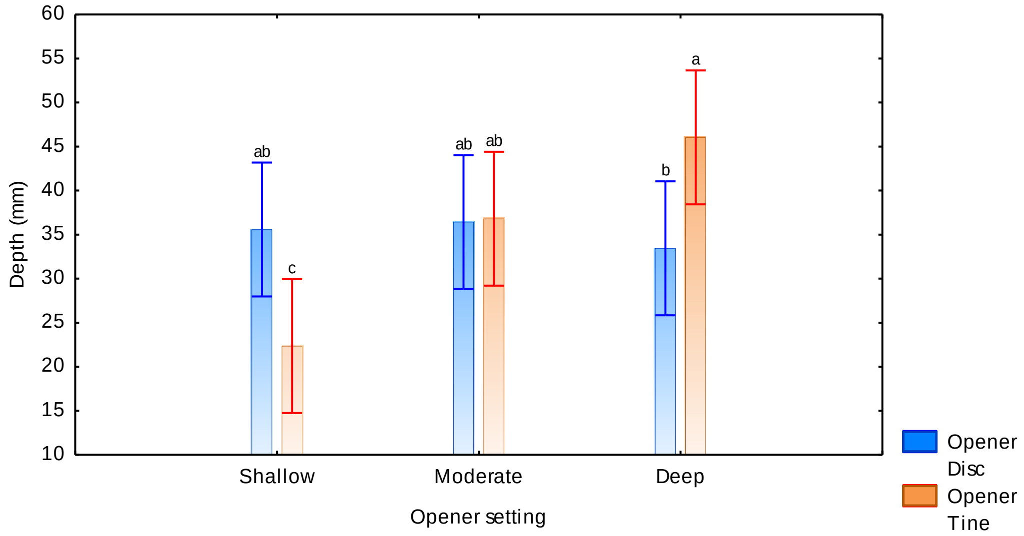

Figure 4.1. Depth (mm) of wheat seed placement with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote significant differences *(p* <0.05).

The disc opener placed the seeds more uniformly (Fig. 4.1), therefore, this type of opener would be ideal if seeds need to be placed at a consistent shallow depth, just beneath the surface. However, there was no difference ($p > 0.05$) between the placing of the wheat seed with either the tine or disc opener under the moderate depth setting. Also, when the deep setting was used on the tine opener, seeds were placed deeper than the disc opener. Rovic & Leers (2015) emphasised that disc openers were designed to place seeds at shallow depths, while tine openers were designed to place seed deeper in the soil profile. Better seedling establishment was observed when seeds were placed at shallow depth with the disc, while tine opener performed well at deeper depths. It is well established that to obtain maximum emergence, seedlings require light and oxygen (Benvenuti 1998) and, normally, more soil disturbance assures better oxygen diffusion into the soil, which could be the reason why the tine opener resulted in higher seed emergence than the disc opener. A similar pattern was observed for canola, but seeds were generally placed shallower than wheat when using the disc opener. DAFF (2017) recommended shallow placing of canola seeds, which ranges between 10 and 30 mm, since canola seed is smaller in size than wheat, it requires shallower planting depths (DAFF 2010A). The disc opener placed wheat seed at an average depth of 35.5 mm (Fig. 4.1) and canola seed at 8.9 mm (Fig. 4.2), regardless of the depth setting ($p > 0.05$).

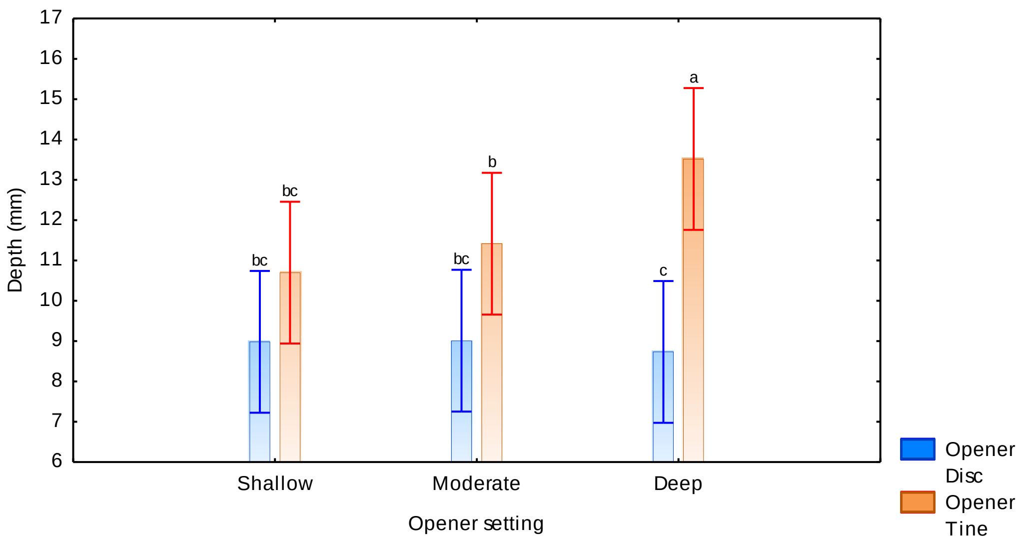

Figure 4.2. Depth (mm) of canola seed placement with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote significant differences ($p < 0.05$).

Similar to wheat, the canola seed depths were better controlled by the tine in comparison to the disc opener (Fig. 4.2). At the time of planting the canola seed, the soil was dry, which compromised the efficiency of the disc opener to cut through the soil. DAFF (2017) recommended that under dry or compacted soils, tine opener should preferably be utilised. Seemingly, this could be ascribed to the tine opener's increased efficiency compared to the disc opener under these conditions. When the tine opener was used for canola, there were no differences ($p > 0.05$) between shallow and moderate settings (Fig. 4.2). As there were no differences ($p > 0.05$) in seeding depth when the disc opener was used, more depreciation of the disc parts may be expected.

4.4.2 Plant population

Plant population for wheat was affected ($p < 0.05$) by the seeding depth and opener (Fig. 4.3), whereascanola plant population was unaffected (Fig. 4.4). Optimum plant population for wheat ranges between 220 to 250 plants m^{-2} (Basera and Soko 2017). In this study, wheat plant population was sufficient, ranging between 150 and 250 plants m^{-2}, when established with the tine opener, contrary to the disc opener, which ranged between 100 and 150 plants m^{-2} (Fig. 4.3). The most wheat plants (230 plants m^{-2}) established when seeds were placed at a depth of 4.61 cm and it did not differ ($p > 0.05$) from when it was placed at a depth of 3.68 cm (197 plants m^{-2}).

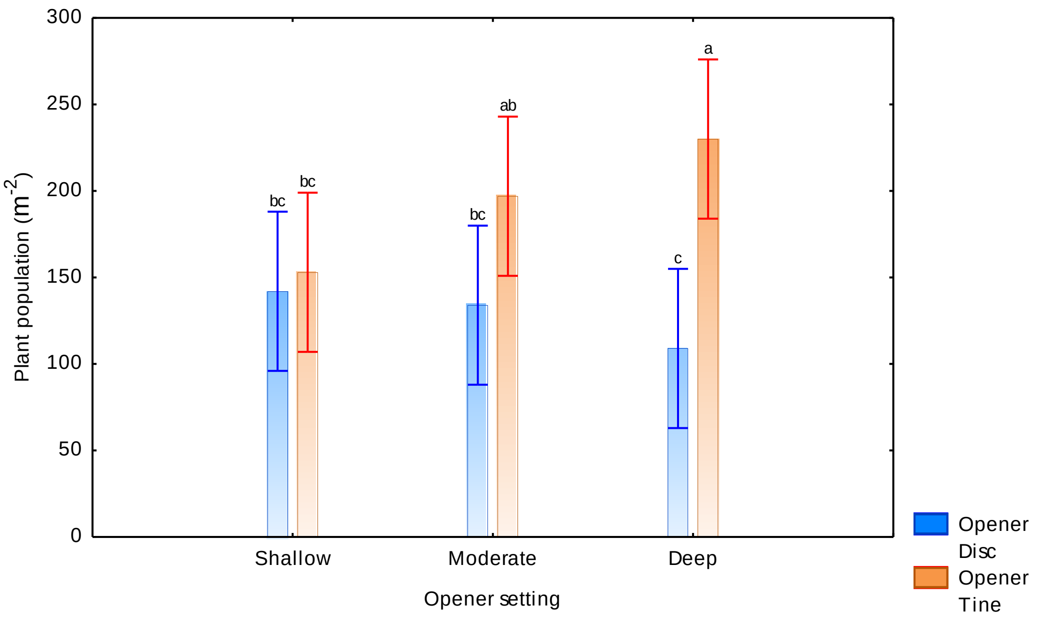

Figure 4.3. Wheat plant population (m^{-2}) with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote significant differences ($p < 0.05$).

There was no difference ($p > 0.05$) between shallow and moderate settings, but the deep setting differed ($p < 0.05$) from shallow setting for wheat (Fig. 4.3). In comparison, the disc opener showed no differences for plant population between depth settings.

Kirkegaard et al. (1995) found that shallow planting of wheat seed promoted faster emergence and increase seedling growth. In contrast, Chaudhuri (2001) reported that a hoe opener had greater soil moisture loss, but gave best plant emergence because of the moist environment created in the furrow. A hoe opener closely resembles a tine opener, and similarly gave the best performance with regards to plant emergence compared to the disc opener (Choudhuri, 2001).

Canola plant population did not differ ($p > 0.05$) at any of the planter settings irrespective of whether the disc opener or tine opener was used (Fig. 4.4). Contrary, Riethmuller et al. (2003) found that a tine opener established more canola plants at the same depth as compared to a disc opener.

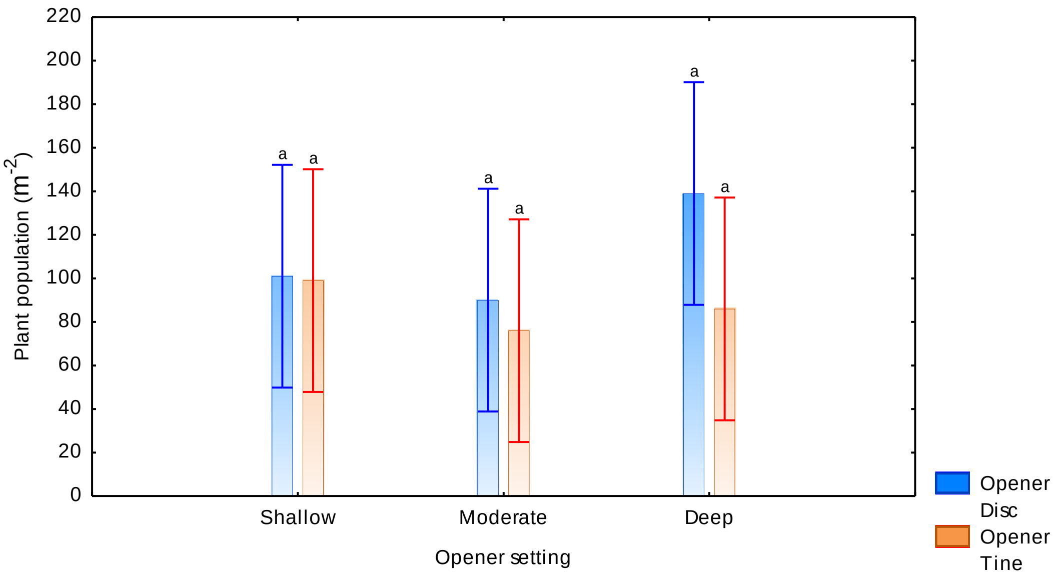

Figure 4.4. Canola plant population (m^{-2}) with a tine and a disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where same letters denote no significant differences ($p > 0.05$).

The disc opener resulted in a high canola plant population, ranging between 80 and 160 plants m^{-2}, while the tine opener resulted in a low canola plant population ranging between 60 and 100 plants m^{-2}. However, there were no differences ($p > 0.05$) that could be ascribed to either the opener or the depth setting (Fig. 4.4). Canola plant population was unaffected by the type of opener used and the recommended canola plant population should range between 50 and 80 plants m^{-2} for highest yield (DAFF, 2017).

4.4.3 Plant biomass

Wheat plant biomass was consistently higher at all depth settings when planted with the tine opener compared to those planted using the disc opener although it was only significant ($p < 0.05$) at the deep setting (Fig. 4.5). Zonglu et al. (2017) also observed that single disc opener planting resulted in lower plant biomass than tine openers.

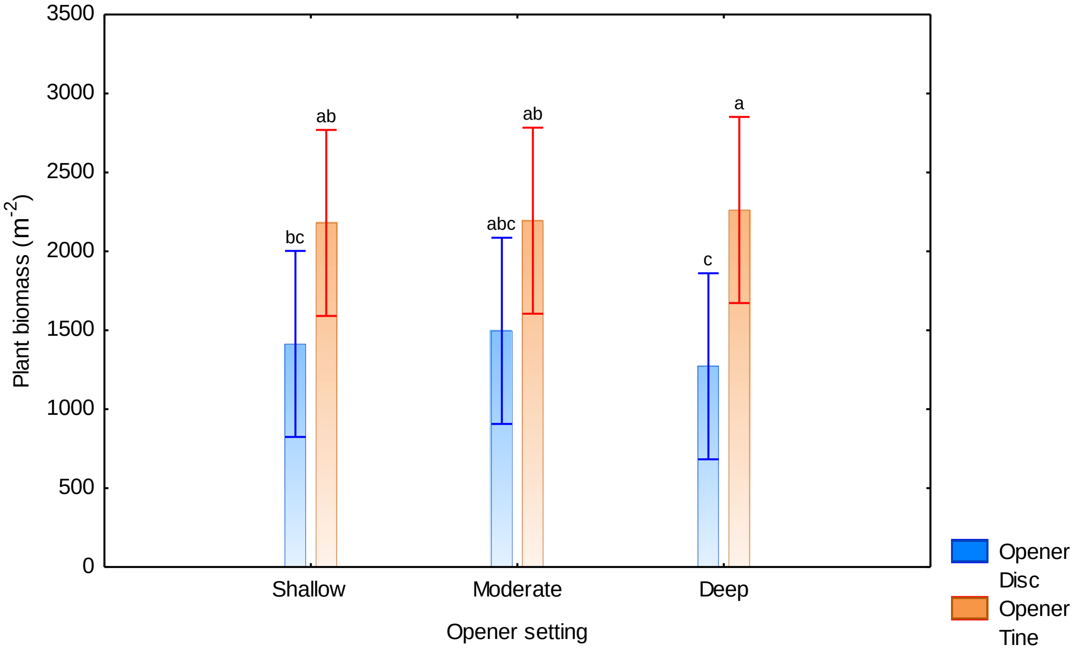

Figure 4.5. Wheat plant biomass (m^{-2}) with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

There was nodifference ($p > 0.05$) in wheat biomass production when a tine was used at any of the depth settings (Fig. 4.5). Similarly, there were also no differences ($p > 0.05$) in biomass production between the three depth settings when canola was established with a tine opener (Fig. 4.6). Moreover, when the disc opener was used, plant biomass accumulated at all depth settings, but the highest plant biomass was obtained with the deep setting ofthe disc opener (Fig. 4.6). In other words, there was no difference (p > 0.05) in plant biomass between the shallow and moderate depth settings, but the deep setting differed ($p < 0.05$) when the disc opener was used. It appears that deeper depth provided more availability of soil moisture than shallow and moderate depth, this can lead to more plant population.

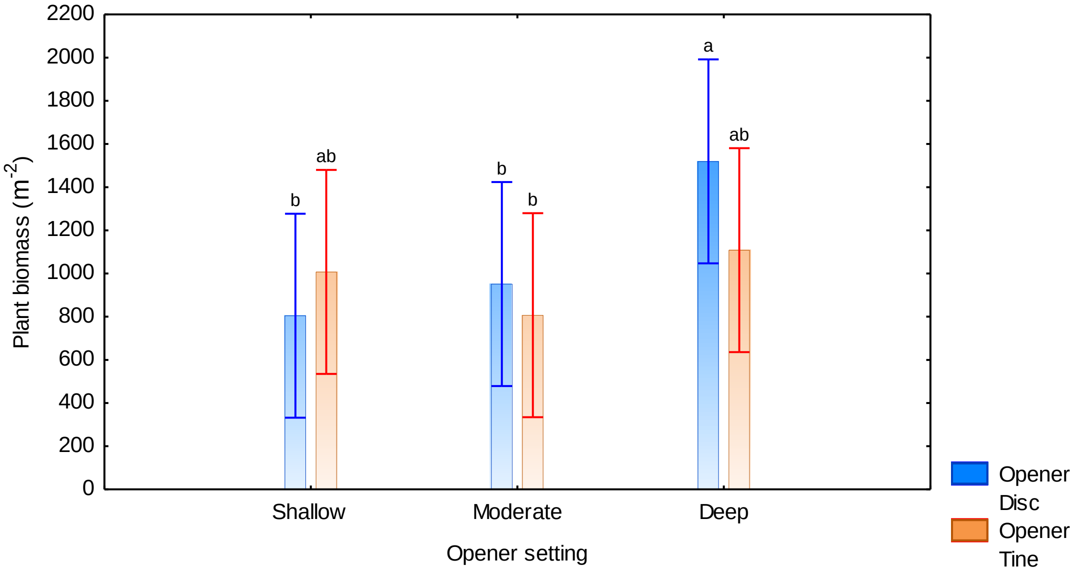

Figure 4.6. Canola plant biomass (m^{-2}) with a tine and a disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

4.4.4 Leaf area Index (LAI)

The LAI was affected ($p < 0.05$) by the type of the opener used to plant wheat, predominantly at the shallow setting (Fig. 4.7). The wheat planted using the tine opener had a higher LAI when compared to that planted using a disc opener at the shallow setting. Moderate and deeper depth settings had no influence on wheat LAI, irrespective of the type of opener used (Fig. 4.7). There was no difference ($p < 0.05$) when LAI was compared across all opener settings for the disc opener (Fig. 4.7). A similar trend was observed for the tine opener, (Fig.4.7).

The planting time for the experiments was delayed due to a delay in the start of the winter rainfall in 2016. It has been stated that a delay in planting often results in a negative effect on canola LAI due to the reduced duration of the photoperiod during the winter growth season (Coetzee 2017).

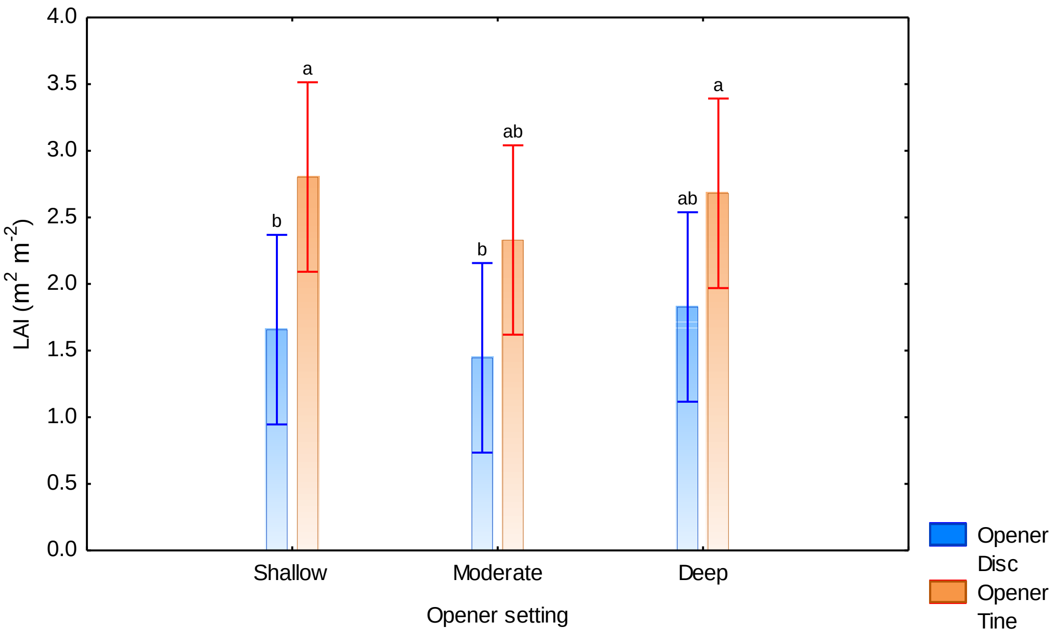

Figure 4.7. Wheat LAI (m^2 m^{-2}) with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

This means that the canola LAI for both disc or tine opener would probably have been higher if planting had been done earlier in the season (Fig. 4.8). Canola LAI was unchanged at shallow and moderate settings when utilising the disc opener (Fig. 4.8). However, at the deep setting, LAI of disc opener was different ($p < 0.05$) when compared to the shallow and moderate settings. Similarly, LAI did not differ ($p > 0.05$) when planted using the tine opener, although, in this instance, it was at all depth settings. In addition, the disc opener showed a superior ($p < 0.05$) LAI at the deep setting, but not at other depth settings, compared to the tine opener. Thus, for canola, the deeper the setting of the disc opener into the soil profile, the higher the LAI when compared to tine opener. Canola LAI was not affected ($p > 0.05$) by the type of opener when planted in shallow and moderate depths but was affected ($p < 0.05$) when planted deeper into the soil profile (Fig. 4.8).

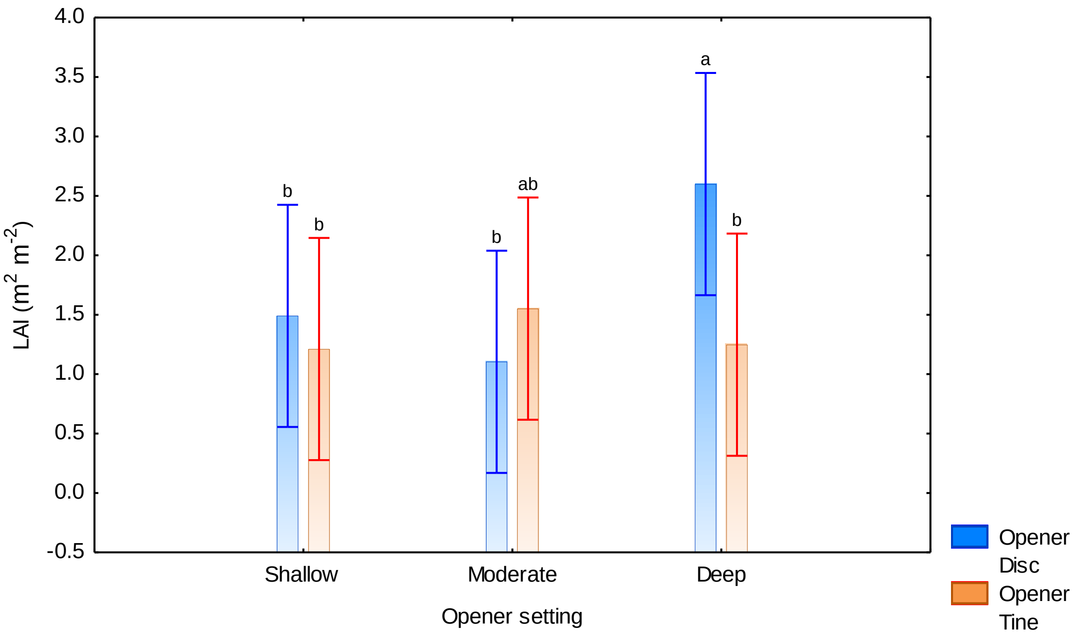

Figure 4.8. Canola LAI (m^2 m^{-2}) with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference ($p<0.05$).

4.4.5 Hectolitre mass (HLM) and Protein content of wheat

There was no difference (p > 0.05) in HLM of wheat either at the various depths (shallow, moderate, and deep) or betweenthe respective openers (disc vs. tine) (Fig. 4.9). Wheat protein content was also not different (p > 0.05) between tine and disc openers, even when compared across depth settings (Fig. 4.10). Therefore, the depth settings did not have any effect on protein content of wheat.

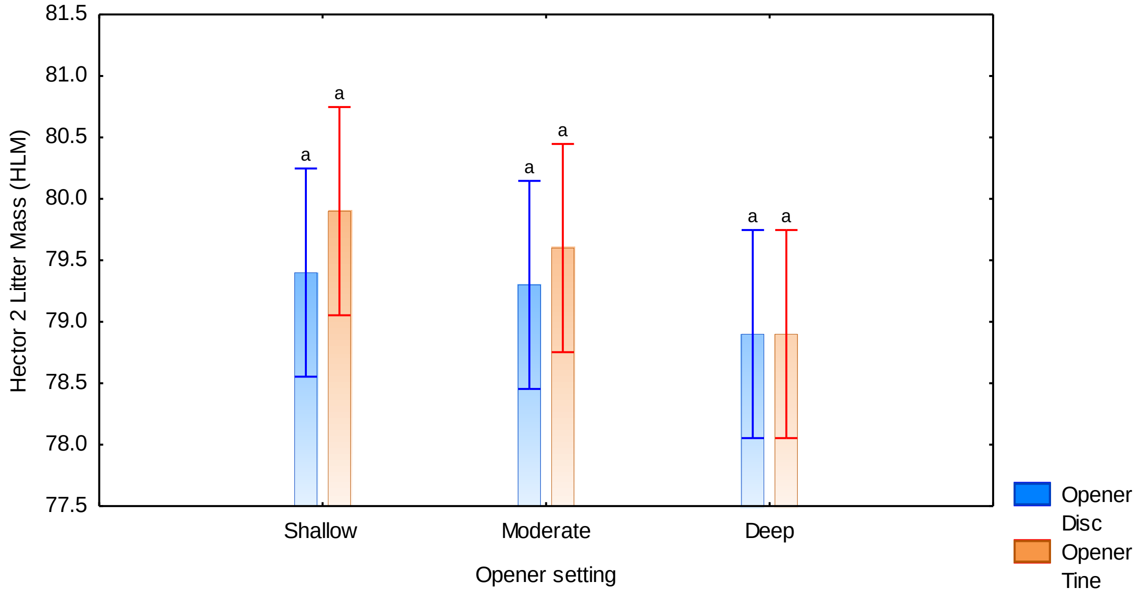

Figure 4.9. Wheat Hectolitre Mass (HLM) with a tine and disc opener at three settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

4.4.6 Wheat and canola thousand kernel mass (TKM)

Wheat TKM did not differ ($p > 0.05$) across all settings when planted using the disc opener (Fig. 4.11). Similarly, the TKM of wheat planted using the tine opener was also not different ($p > 0.05$) when compared across depth settings. Thus, wheat TKM was unaffected by the type of opener.

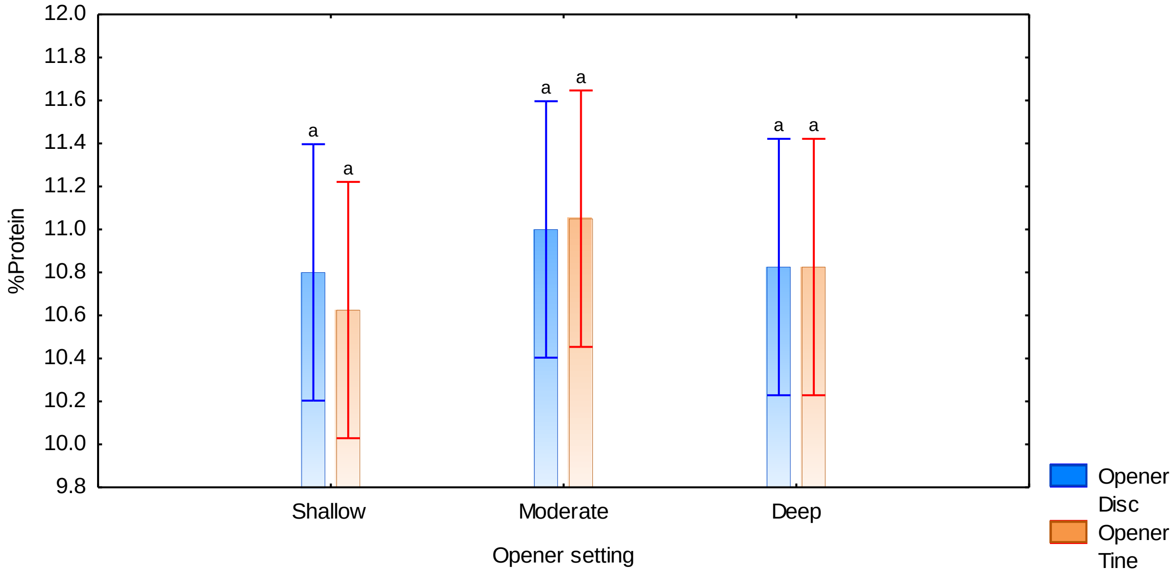

Figure 4.10. Wheat protein content with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

Similarly, canola TKM was not different ($p > 0.05$) between depth settings when planted using the disc opener (Fig. 4.12). Moreover, a similar result was obtained for canola TKM when the tine opener was used, irrespective of depth setting. When canola TKM was compared betweentine- and disc openers, there was no opener effect ($p > 0.05$) per depth setting (Fig. 4.12). Therefore, TKM was not affected ($p > 0.05$) by the type of the opener that was used to plant canola.

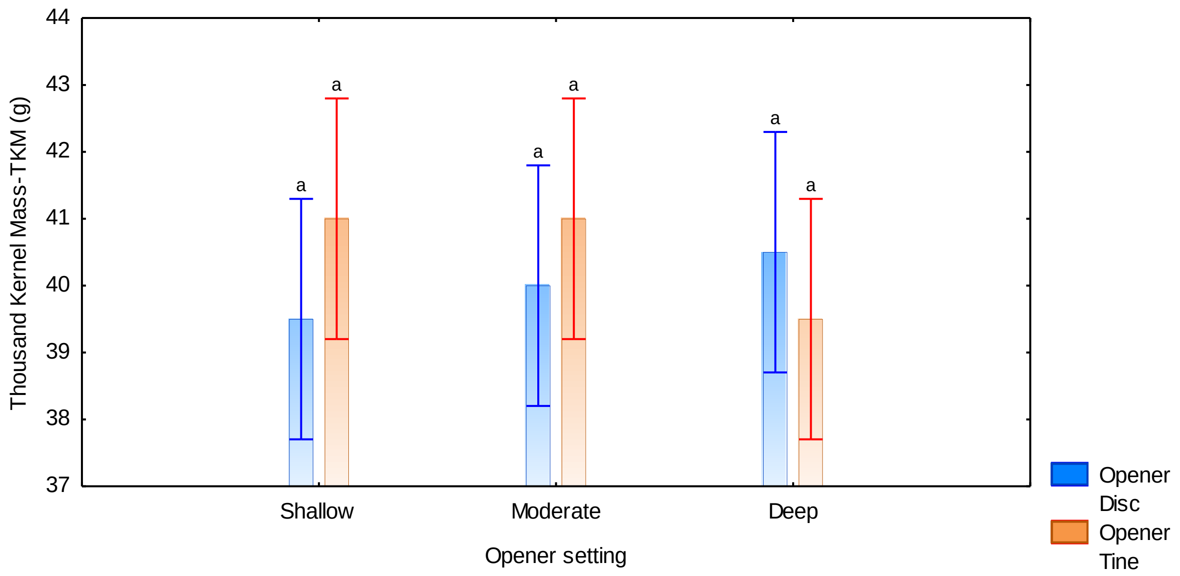

Figure 4.11. Wheat Thousand Kernel Mass (TKM) with a tine and disc opener at three depth settings (shallow, moderate, deep). Significance between depth and opener settings is indicated using alphabetic letters, where same letters denote no difference (*p* > 0.05).

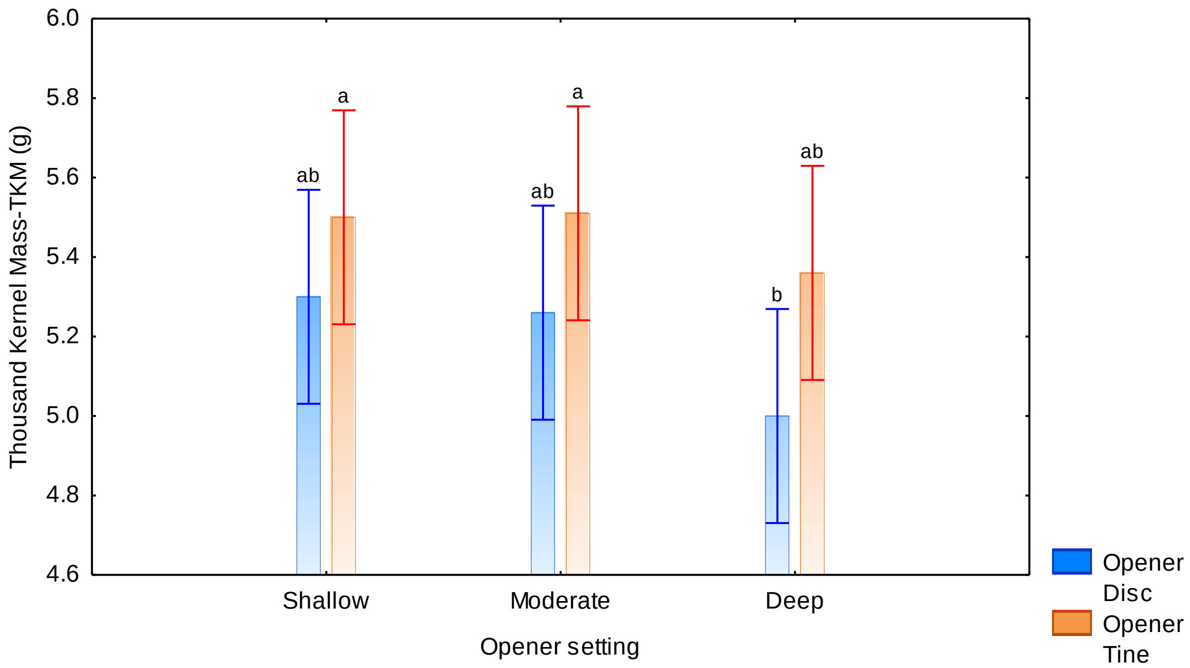

Figure 4.12. Canola Thousand Kernel Mass (TKM) with a tine and disc opener at three depth settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference (P<0.05).

4.4.7 Wheat and canola yield

Although there appeared to be a progressive increase in wheat yield from lowest to highest seeding depth, wheat yield did not differ *(p* > 0.05) between disc and tine opener in shallow and moderate depth settings (Fig. 4.13).

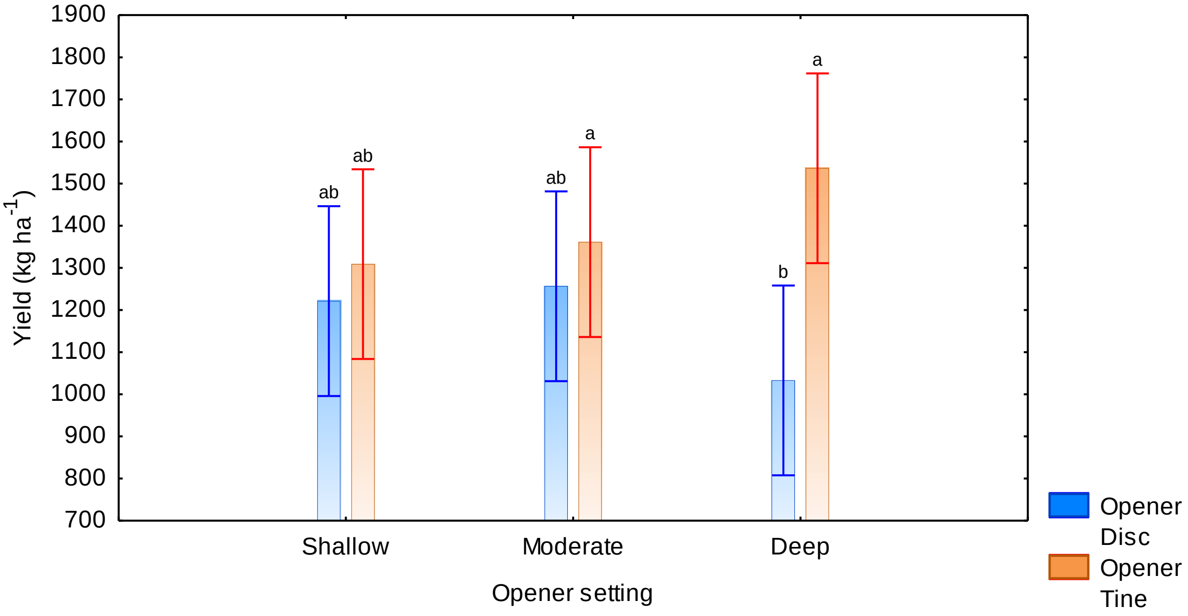

Figure 4.13. Wheat yield (kg ha^{-1}) with a tine and disc opener at three settings (shallow, moderate, and deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference *(p* <0.05).

However, there were differences (p < 0.05) at the deep setting between the two openers, with the tine opener showing better yields; 33% more than the discopener (Fig. 4.13). Hamblin et al. (1982) found that wheat grain yield was 20% percent higher on ploughed soil than when planted using direct drilling. Thus, chances of increasing yield are better when soils are disturbed. It is however important to recognise that CA can only start to play a positive role in yield after a few years of following the CA principles. Optimum wheat yield in South Africa in dryland ranges from 2 to 2.5 tons ha^{-1} (DAFF 2016). However, in this study wheat yield was lower than this optimum, with yields ranging between 1 and 1.3 tons ha^{-1} with the disc opener and between 1.3 and 1.6 tons ha^{-1} when planted with the tine opener. Some of the contributing factors to these low yields with the two openers may be due to late sowing and insufficient rain during the growing season.

The production year (2016) in which the trial was conducted was a dry year, with an average rainfall that was almost half (208 mm) of the normal rainfall of 400 mm.

Likewise, for canola yield, there were no differences ($p > 0.05$) between shallow and moderate settings when the disc opener was used. However, the deep setting differed from the shallow setting ($p < 0.05$) when the disc opener was used (Fig. 4.14). When the tine opener was used, the yield did not differ ($p > 0.05$) across all three depth settings.

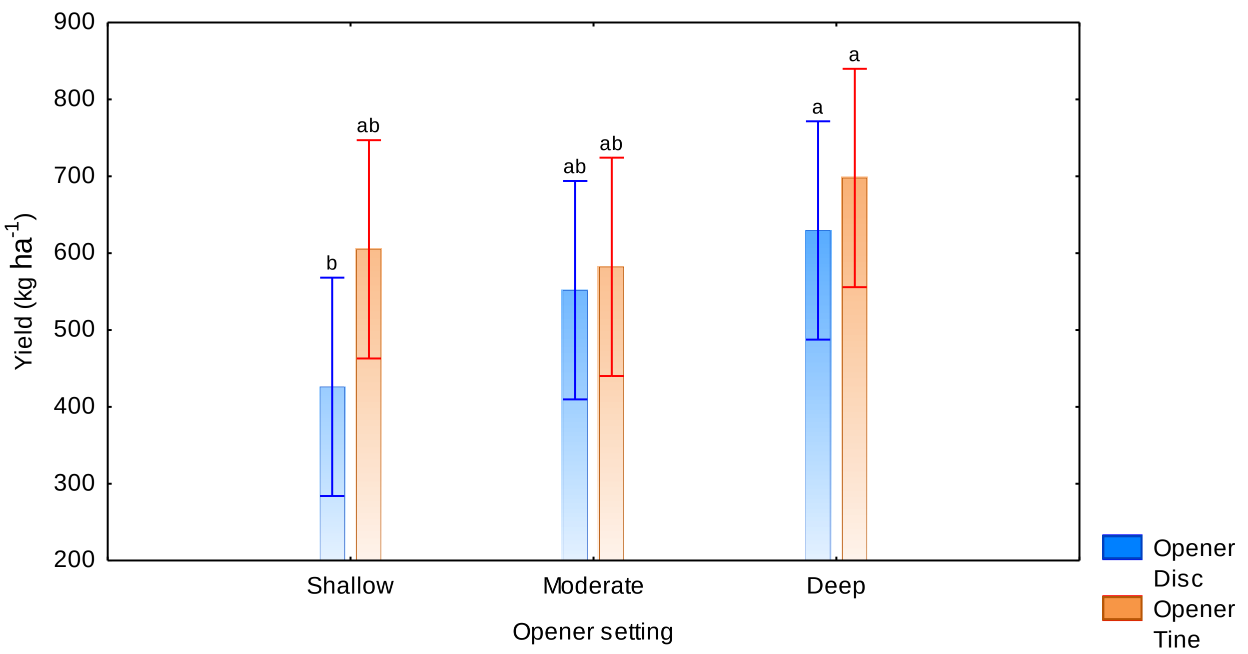

Figure 4.14. Canola yield (kg ha^{-1}) with a tine and disc opener at three depth settings (shallow, moderate, deep). Significance between depth and opener settings is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

There was nodifference ($p > 0.05$) in canola yield between the two openers. Riethmuller et al. (2003) sowed canola seed at 2, 4, and 6 cm and found that at 4 cm, a tine opener produced a better yield than a disc opener. The yield at 2 and 6 cm for the tine opener was equal to the yield of the disc opener (Riethmuller 2003). However, in this trial, yields for both openers were the same when compared at the same planting depths.

4.4.8 Conclusion

Control of planting depth was found to be more effective when using a tine opener, with the best wheat establishment observed when planting deeper with the tine opener. In contrast, planting depth was not effectively controlledfor canola, regardless of the type of opener. The disc opener placed seed well at a shallow depth, while tine opener performed well at moderate and deeper depths. Plant biomass was consistently higher when tine opener was used for wheat. However, there was not much difference between disc and tine opener in plant biomass for canola. The type of opener used did not have any effect on the seed quality.

4.4.9 References

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CHAPTER 5

The effect of nitrogen fertiliser placement on wheat and canola growth and yieldusing tine, disc, or double chute openers

5.1 Introduction

Conservation Agriculture (CA) is a concept that was introduced to maintain and improve the agricultural crop production based on integrated soil, water and biological resource management (Reicosky 2015). Conservation Agriculture is based on three key principles: continuous soil cover on the soil surface, continuous minimum soil disturbance or no-tillage and using diverse crops or crop rotations (Hobbs 2007).

With the emergence of CA management, such as zero-tillage and/or minimum-tillage, in Western Cape, direct seeding and fertiliser placement with sowing in soils have become common practice. Western Cape farmers are using different seeding equipment to place seed directly into soil ('seed-drills'), including those with tine, disc, and double chute openers. However, seed and nitrogen (N) fertiliser placement of these openers have not been evaluated scientifically for wheat and canola in Western Cape.

Tine openers have been designed to place N fertiliser just below the seed in the soil. Reinertsen et al. (1984) reported that N fertiliser placed below the seed becomes more available to the seed as compared to broadcasted N. Double seed chutes have been designed to plant more than one type of seed at the same time and it place N fertiliser between rows of the seed in the soil (Rovic & Leers 2015). It has been reported that the placement of N fertiliser next to the seed is better than broadcasting (Kirkland and Beckie 1998; Lemke et al. 2009). Disc openers are designed to disturb the soil minimally, but they mix the seed with fertiliser during planting, which increases the risk of damage to seedlings.

There is a need to evaluate the effect of N fertiliser placement in relation to seed placement using tine, disc, or double chute openers. This will assist the farmers in minimizing the yield losses that normally result from fertiliser-induced seedling damage (Brandt et al. 2007). The aim of the study was to evaluate the effectiveness of N placement through tine, disc, or double chute openers on wheat and canola production.

5.2 Material and methods

5.2.1 Site description

The trail was conducted in 2017 at the Langgewens Research Farm, near Moorreesburg (33º17’00” S, 18º42’00” E; 191 meters above sea level) in the Western Cape Province (South Africa). This region has a high production potential for wheat and canola (Van Zyl 2017). The soils are derived from Malmesbury and Bokkeveld shales, dominated by reddish soil with a pH of 5.7. The soils are shallow with 0.59% carbon, 77% sand, 14% silt, and 9% clay, with a high stone content. The climate is a typical Mediterranean-type climate with an average annual rainfall of 400mm.

5.2.2 Experimental layout and treatments

Two separate trials were laid out as randomised block designs, one for wheat and one for canola, with four treatments (tine, disc, double chute, and control), replicated eight times. An Equalizer planter with exchangeable double chute, disc, and tine openers were used to plant wheat and canola on 5 May 2017. Fifteen kg N ha^{-1} was band placed with the planting. For the control treatment no N was placed in the soil, but 15 kg N ha^{-1} was broadcasted at planting using hand. Since Western Cape soils vary substantially, four plots were laid out for each crop wheat and canola on separate areas on the farm. Four plots were 1.5 x 15 m and another four were 1.5 x 60 m.

The wheat (cultivar SST087) was planted at a seeding rate of 90 kg ha^{-1} and canola (cultivar 555TT) was planted at a seeding rate of 3.5 kg ha^{-1}. During planting, 15 kg N ha^{-1} was applied, thereafter, 40 kg N ha^{-1} at 60 days and at 90 days after plant emergence. Weeds were sprayed with Axial (125 mL ha^{-1}) in wheat and atrazine (1.5 L ha^{-1}) in canola.

5.3 Data collection

5.3.2 Plant population and biomass production

Thirty days after plant emergence, the number of plants were counted using three 0.5 m^2 quadrats per plot to determine plant population. After 30, 60, 90 and 120 days, wheat and canola biomass was quantified by sampling ten plants per plot for wheat and five plants per plot for canola prior to harvesting. The samples were chopped and weighed before and after drying at 60 °C for 48 hours.

5.3.3 Leaf Area Index

After 30, 60 and 90 days, ten wheat plants and five canola plants were collected per plot using the plastic bags from the field and analysed using Li-Cor Leaf Area Machine (model-3100) to determine the leaf area. Leaf Area Index (LAI) was calculated for wheat and canola per plot.

5.3.4 Yield

Canola and wheat were harvested using a small plot harvester and the yield per hectare was determined.

5.3.5 Statistical analyses

An analysis of variance (ANOVA) was performed on the data using STATISTICA version 13.2 (Dell Inc. 2016). Fisher's Least Significant Difference (LSD) was calculated at 5% level to compare treatment means. Variances were homogenous and residuals were normally distributed.

5.4 Results and Discussion

5.4.1 Wheat and canola plant population after 30 days

After 30 days, wheat plant population was affected ($p < 0.05$) by opener type (Fig. 5.1). The lowest wheat plant population was obtained from disc openers, ranging between 110 and 150 plants m^{-2}, but it did not differ ($p > 0.05$) from broadcasted N treatment (Fig. 5.1). The highest wheat plant population was found when N was placed with a tine opener, but did not differ ($p > 0.05$) from N placement using the double chute opener, which ranged between 140 and 170 plants m^{-2} (Fig. 5.1).Reinertsen et al. (1984) proposed that N that is placed below the seed becomes more available to the seed than broadcasted N fertiliser. In this study, the tine opener, which places the N below the seed gave a higher wheat plant population than that of broadcasted N fertiliser.

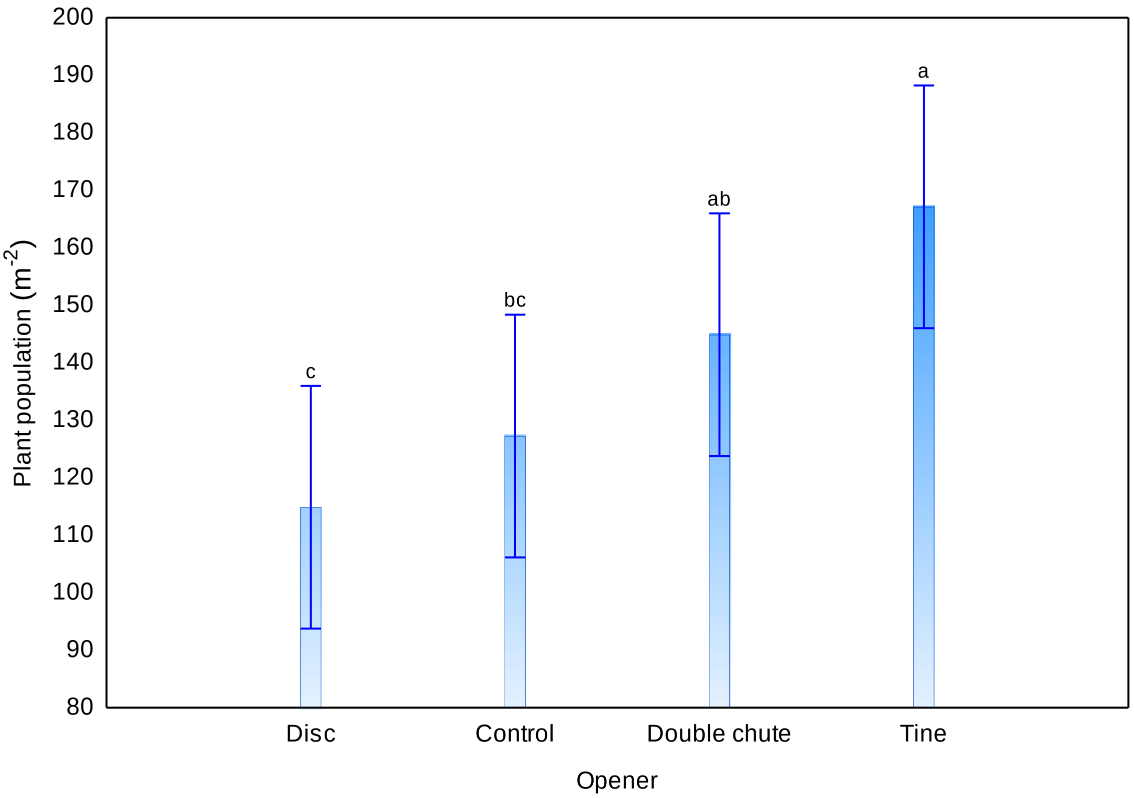

Figure 5.15. Wheat plant population (m^{-2}) after 30 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where different letters denote a difference (p < 0.05).

The lowest canola plant population was established when N fertiliser was broadcasted for the control and did not differ (p > 0.05) from the disc opener, ranging between 30 and 50 plants m^{-2} (Fig. 5.2). Most canola plants were established when N fertiliser was placed using tine opener, but did not differ (p > 0.05) from the double chute opener, and ranged from 70 to 80 plants m^{-2} (Fig. 5.2). The establishment of the canola plant population using double chute and tine openers was different (p < 0.05) from the control and disc opener.

Choudhari (2001) found that tine openers caused more soil disturbance, which activated the moisture that is stored in the soil, subsequently dissolving N to make it readily available to the plant roots for uptake**.** This may be the reason why tine and double chute openers had the highest plant population because both openers create more soil disturbance than disc openers. The soils of Western Cape were very dry during the first 30 days of planting, therefore even a small amount of moisture could have been beneficial for plant population establishment.

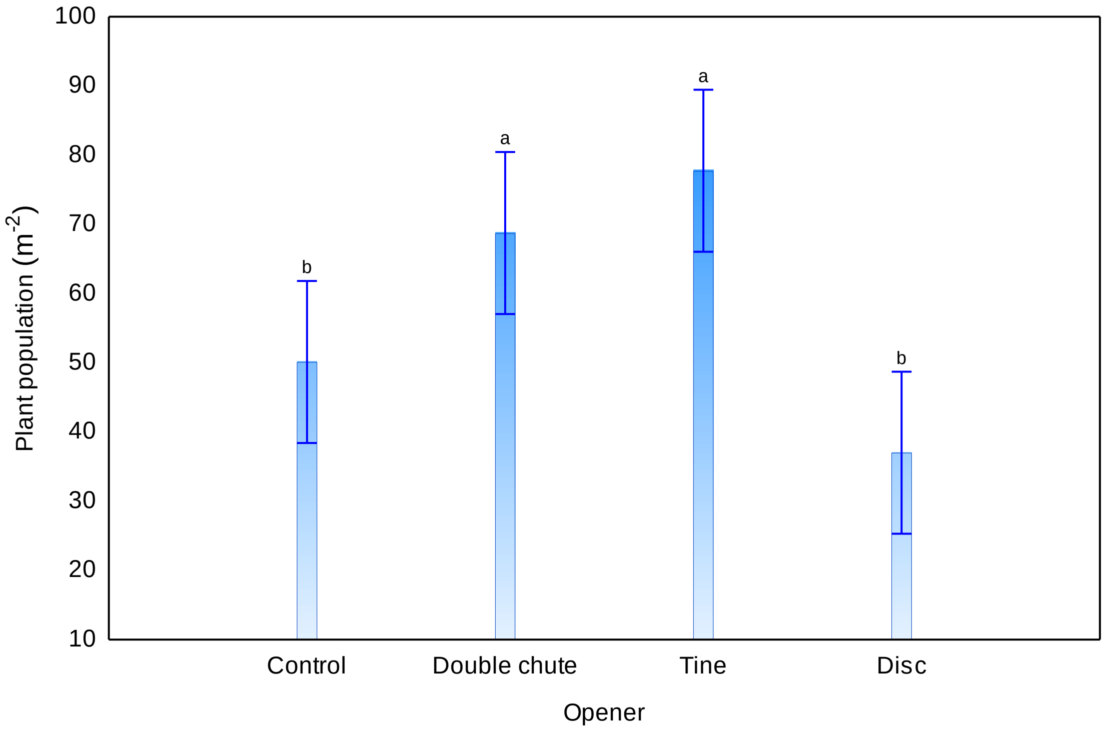

Figure 5.16. Canola plant population (m^{-2}) after 30 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where different letters denote a difference (p < 0.05).

5.4.2 Wheat and canola biomass after 60 days

The type of opener used, and which is associated with the placement of N did not influence (p > 0.05) wheat biomass after 60 days (Fig. 5.3).

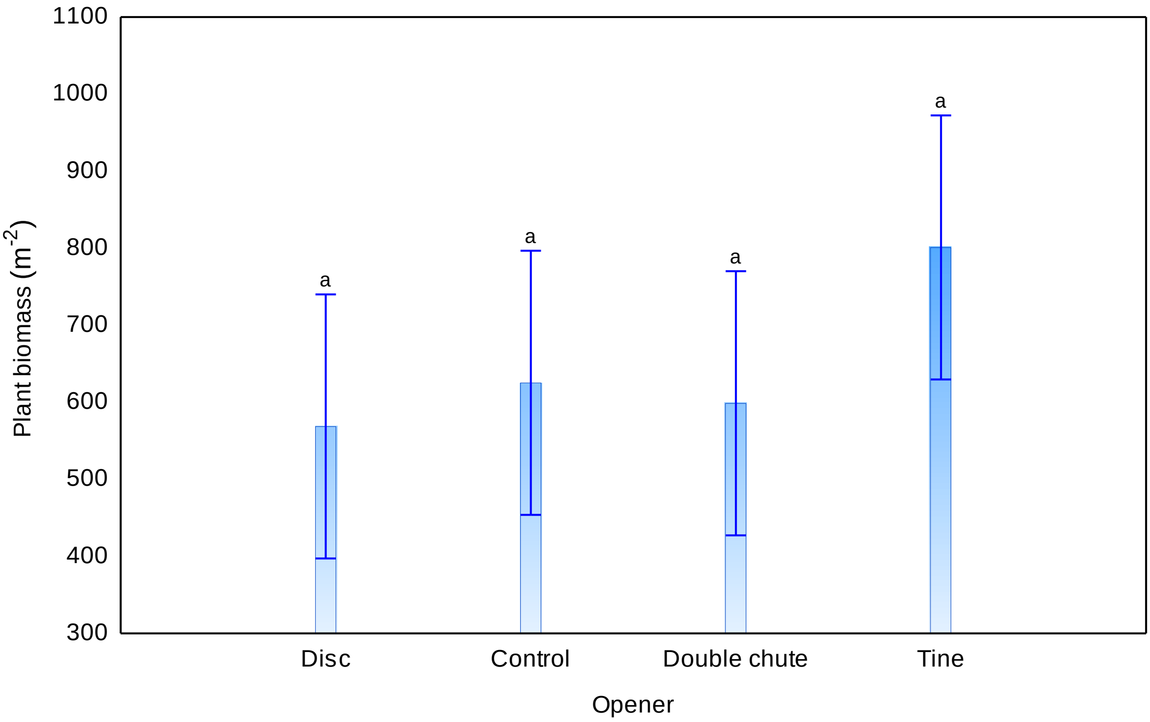

Figure 5.17. Wheat plant biomass (m^{-2}) after 60 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

The biomass accumulation of canola was influenced ($p < 0.05$) by the type of opener used after 60 days of plant emergence (Fig. 5.4). The effect of N fertiliser placement using the tine opener did not differ ($p > 0.05$) from that of the double chute opener, but was different ($p < 0.05$) from the control and disc opener. This markedly lower biomass accumulation when using the disc opener may be ascribed to seed scorching by N (Brandt et al. 2007). Therefore, it is advisable that the seed is placed in a way that maximizes seedling emergence, but minimizes N fertiliser damage to seedlings (Malhi et al. 2004). The double chute opener biomass did not differ ($p > 0.05$) from the broadcasted N (control treatment) but it differed ($p < 0.05$) from disc opener canola biomass (Fig. 5.4).

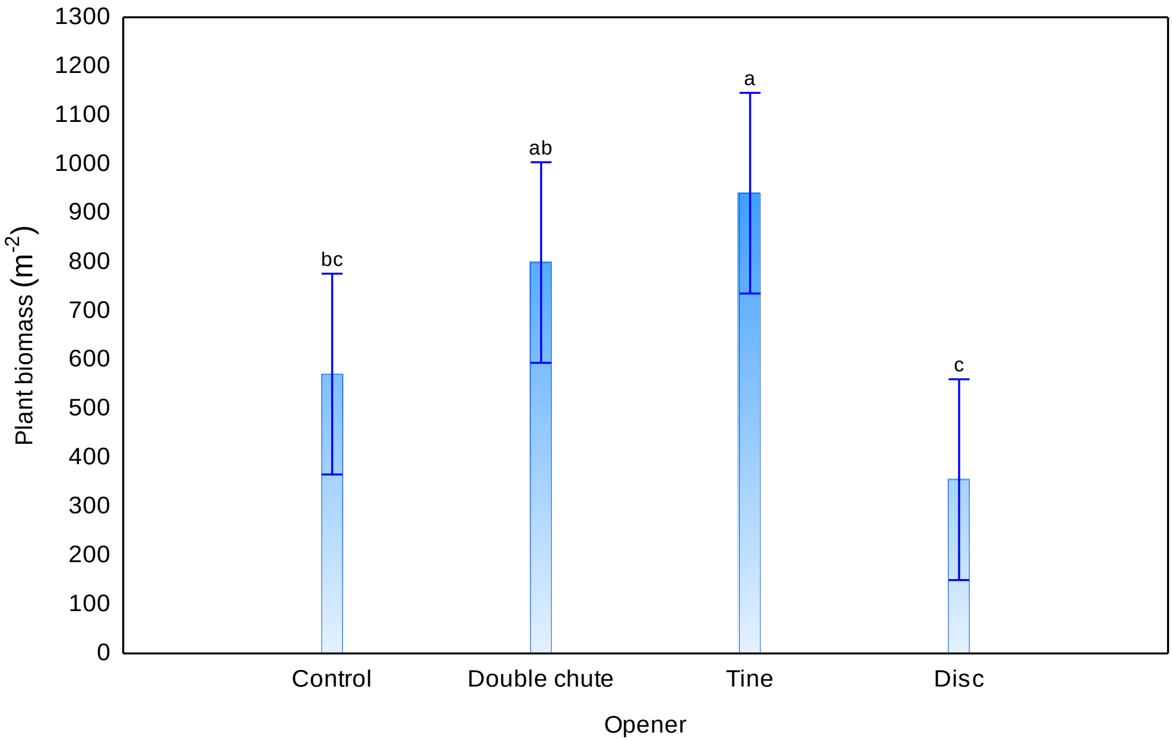

Figure 5.18. Canola plant biomass (m^{-2}) after 60 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

The biomass from the disc opener did not differ ($p > 0.05$) from broadcasted N (control treatment) for the canola plant biomass (Fig. 5.4). However, Young et al. (2012) reported that N fertiliser placed using the disc opener gave higher canola plant biomass than broadcasted N.

5.4.3 Wheat and canola Leaf Area Index (LAI) after 60 days

The LAI of wheat was not affected ($p > 0.05$) by N placement for any type of opener used after 60 days (Fig. 5.5).

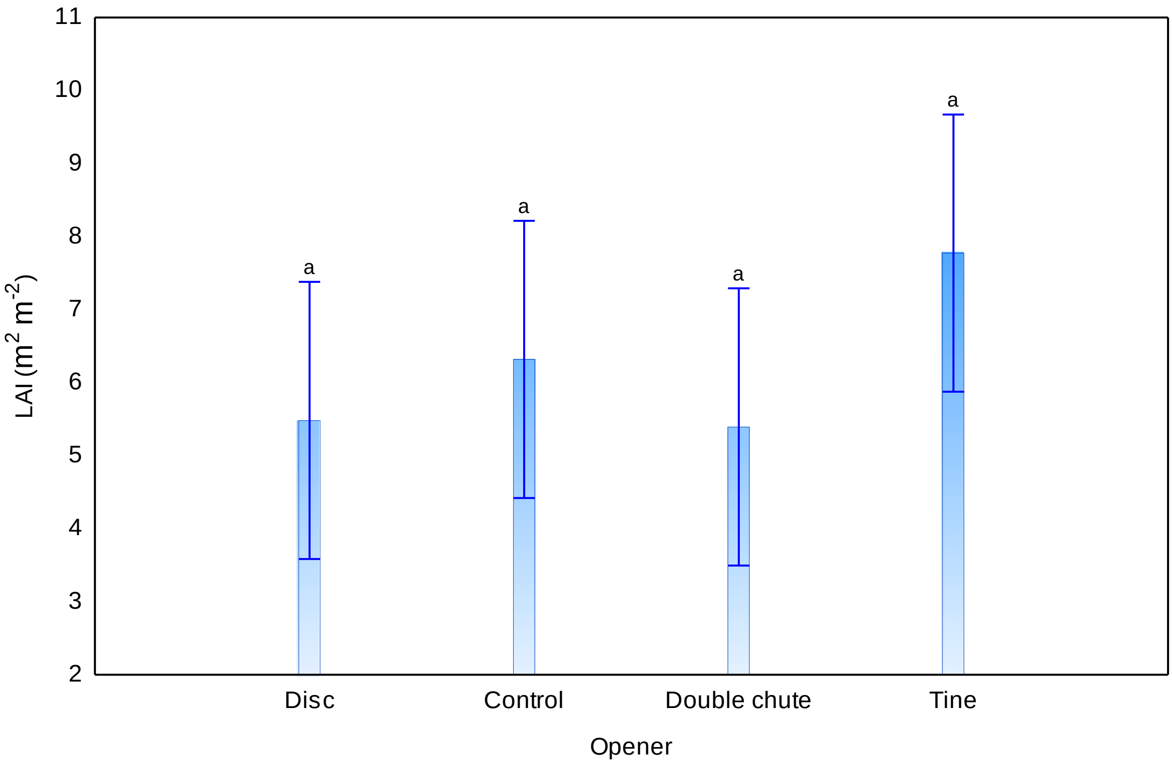

Figure 5.19. Wheat LAI (m^2 m^{-2}) after 60 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

For canola, LAI 60 days after planting was influenced ($p < 0.05$) by N placement for the types of openers (Fig. 5.6). The LAI of canola differed ($p < 0.05$) when N was placed using the double chute opener compared to the disc opener, but it did not differ ($p > 0.05$) from the control and tine opener. Where N was placed in the row with a disc, LAI differed ($p < 0.05$) from the tine planter where N was placed beneath the seed, but did not differ ($p > 0.05$) from the control treatment.

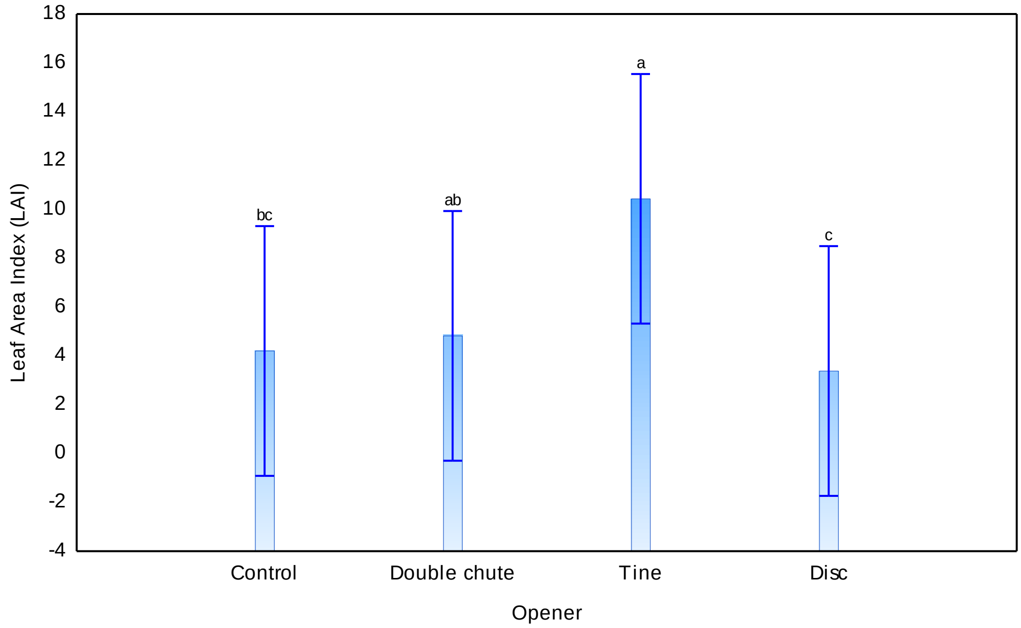

Figure 5.20. Canola LAI (m^2 m^{-2}) after 60 days of planting with tine, double chute, disc openers, and the control. Significance between opener settings is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

5.4.4 Wheat and canola plant biomass after 90 days

The type of opener used did not have any effect ($p > 0.05$) on wheat plant biomass accummulatiom, judging from the wheat plant biomass accumulation after 90 days of plant emergence (Fig. 5.7).

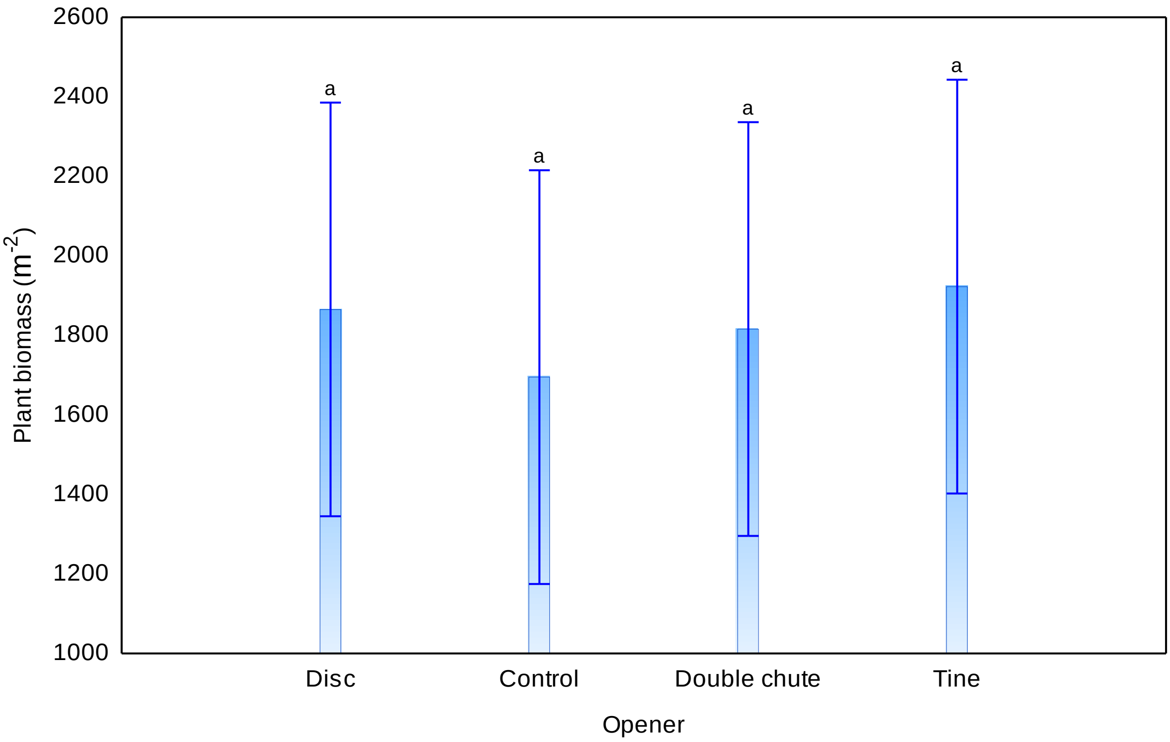

Figure 5.21. Wheat plant biomass (m^{-2}) after 90 days of planting with tine, double chute, disc openers, and control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

Nitrogen placement by different openers affected canola plant biomass production 90 days after plant emergence (Fig. 5.8). Where N was placed using a double chute in the middle of two twin rows, plant biomass did not differ ($p > 0.05$) from that of the tine opener (Fig. 5.8). Similarly, where N was placed with the disc opener, plant biomass did not differ ($p > 0.05$) from the control, but differed ($p < 0.05$) from the double chute and tine openers. In addition, plant population markedly increased 90 days after plant emergence and ranged between 200 and 225 plants m^{-2}, when the N was placed using the double chute or tine openers. In contrast, the lowest plant population, which ranged between 100 and 150 plants m^{-2} was observed in the control treatment and where N was placed using the disc opener. This is likely due to more optimum placement of N with the tine and/or double chute openers, because the N that was placed below or adjacent to the seeds possibly increased plant N uptake and subsequently plant biomass (Cochran et al. 1990).

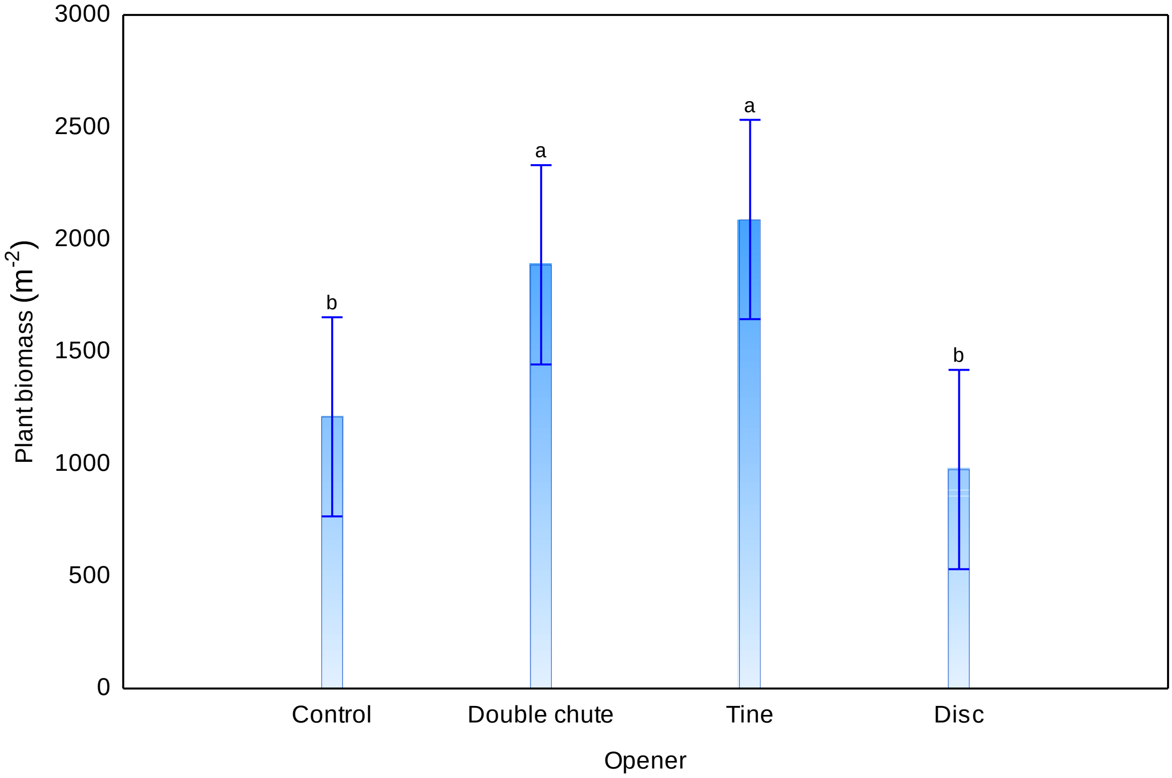

Figure 5.22. Canola plant biomass (m^{-2}) after 90 days of planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where different letters denote a difference (p<0.05).

5.4.5 Wheat and canola Leaf Area Index (LAI) after 90 days

The N placement did not influence (p > 0.05) wheat LAI for any of the openers 90 days after planting (Fig. 5.9).

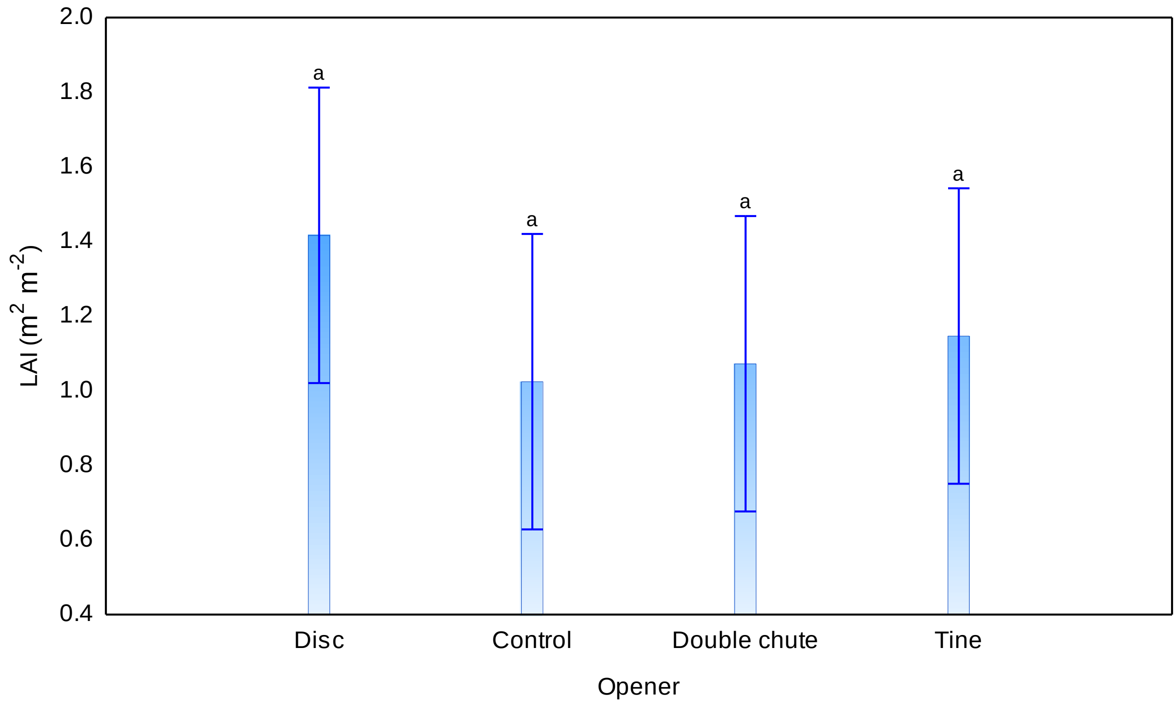

Figure 5.23. Wheat LAI ($m^2\ m^{-2}$) after 90 days of planting with tine, double chute, disc opener, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

The N placement influenced ($p < 0.05$) canola LAI after 90 days (Fig. 5.10). Where N was broadcasted, LAI differed ($p < 0.05$) from the disc, double chute and tine openers, and LAI did not differ ($p > 0.05$) between N placement with the disc, double chute and tine openers.

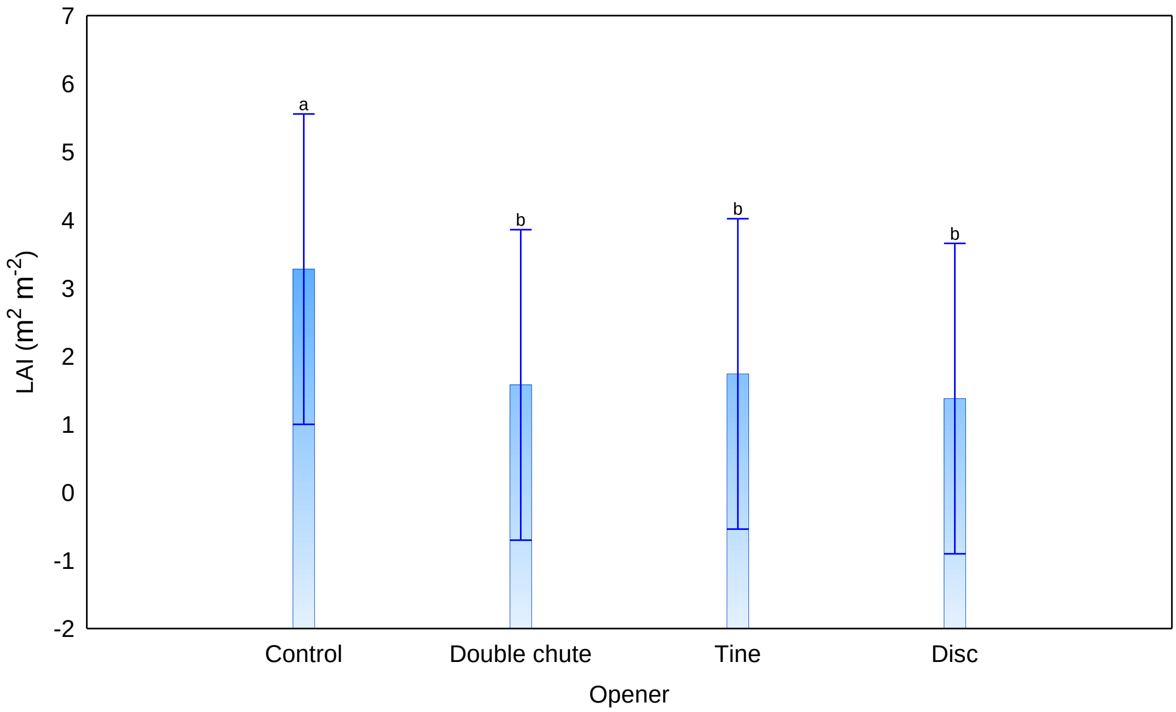

Figure 5.24. Canola LAI (m^2 m^{-2}) after 90 days of planting with tine, double chute, disc opener, and the control. Significance between openers is indicated using alphabetic letters, where different letters denote a difference ($p < 0.05$).

5.4.6 Wheat and canola plant biomass after 120 days

Neither the wheat (Fig. 5.11) nor the canola plant biomass (Fig. 5.12) were influenced ($p > 0.05$) by treatments used 120 days after plant emergence.

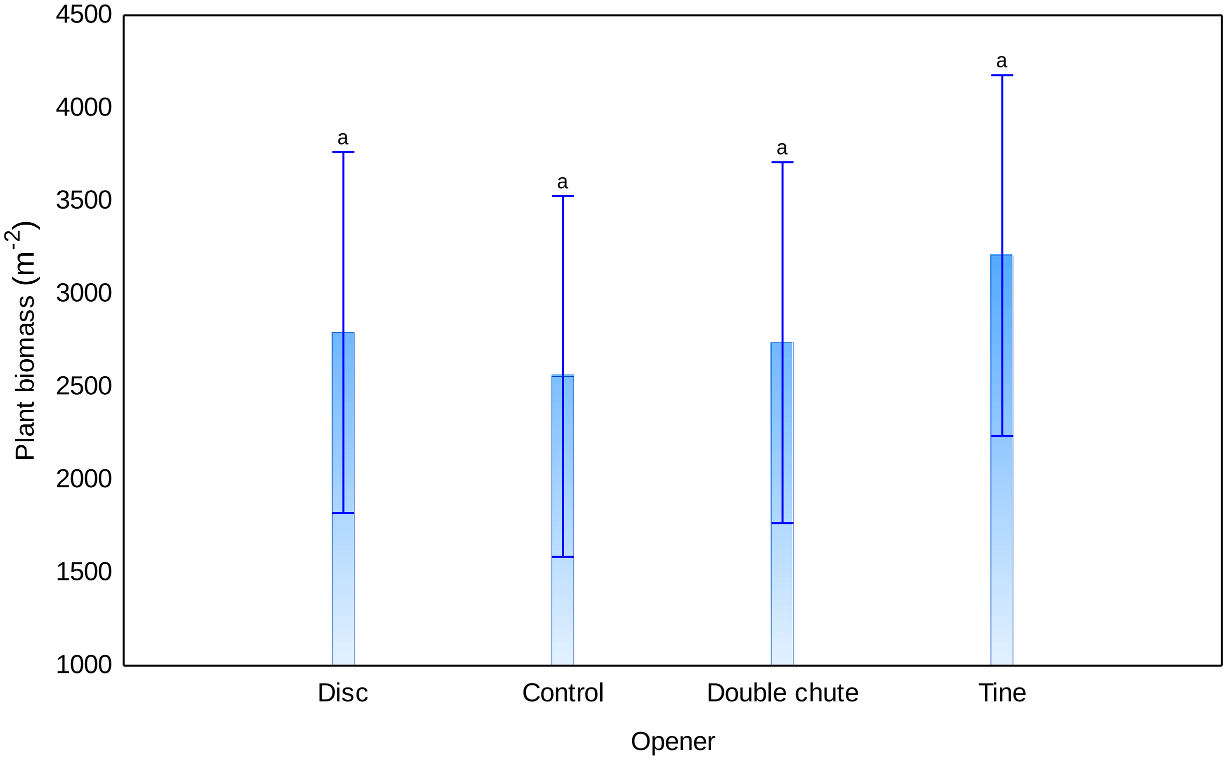

Figure 5.25. Wheat plant biomass (m^{-2}) after 120 days from planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

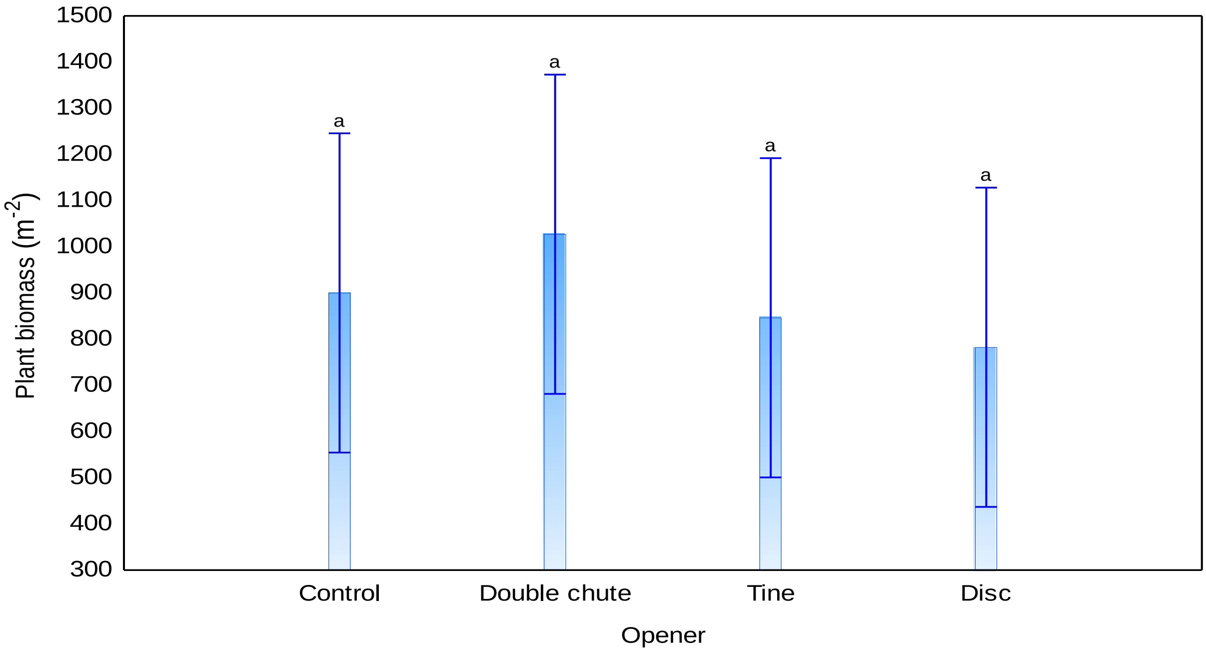

Figure 5.26. Canola plant biomass (m^{-2}) after 120 days from planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote no difference ($p > 0.05$).

5.4.7 Wheat and canola yield

Wheat yield was not influenced (*p*> 0.05) by N placement with any type of opener (Fig. 5.13). This means that the openers and associated N placement used does not have an effect on the yield of the wheat. However, Cochran et al. (1990) reported that N side- or band placement increased growth and grain yields compared to broadcasted N.

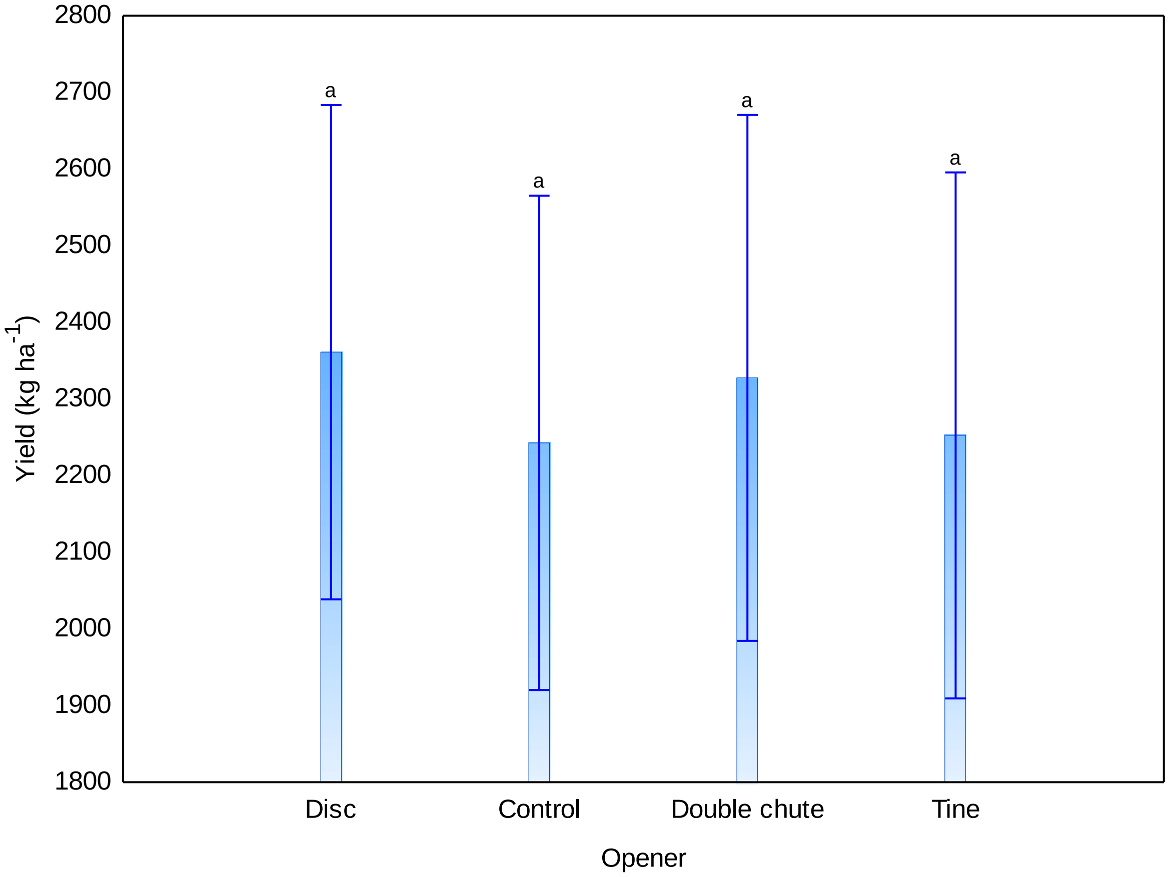

Figure 5.27. Wheat yield (kg ha^{-1}) when planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote nodifference (*p* > 0.05).

There was no difference (*p* > 0.05) in the yield of canola when the different types of openers were used (Fig. 5.14). Since N placement methods employed in this study did not affect wheat and canola yields, it is possible that any type of N placement such as broadcasting, sides, below and above N placement can be utilised. However, Young et al. (2012) reported that broadcasted N method gave lower yield than disc opener.

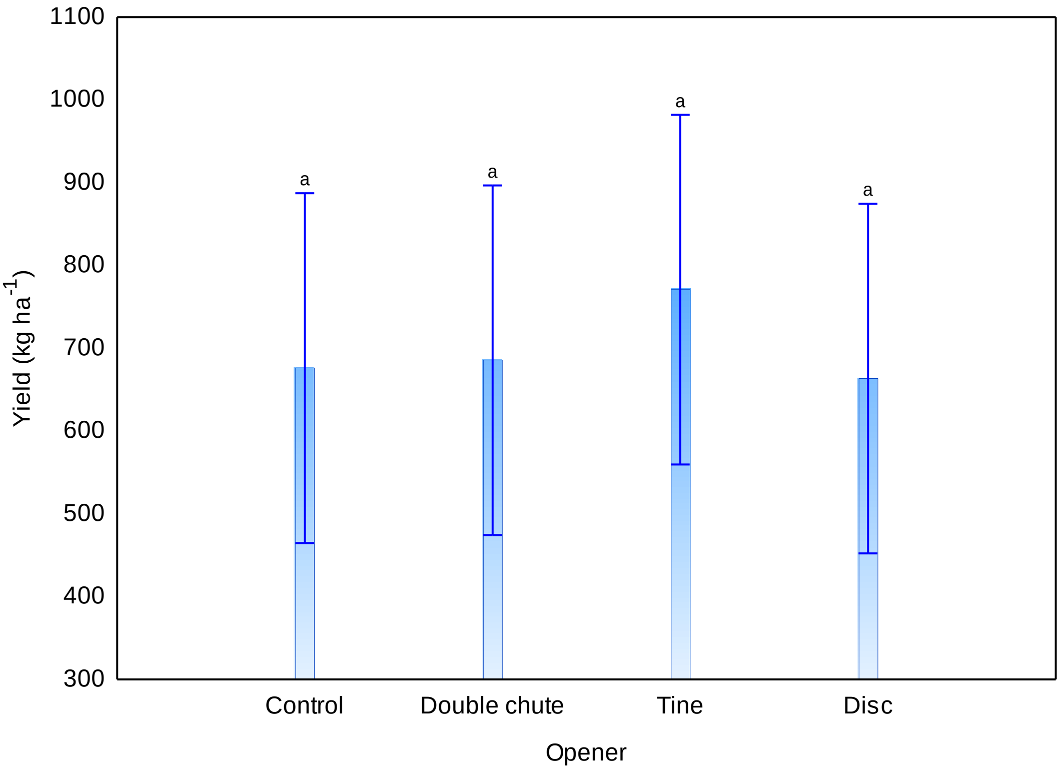

Figure 5.28. Canola yield (kg ha^{-1}) when planting with tine, double chute, disc openers, and the control. Significance between openers is indicated using alphabetic letters, where same letters denote nodifference ($p > 0.05$).

5.4.8 Conclusion

In most instances, for both wheat and canola, double chute and tine openers had positive effects on N placement compared to the disc opener and broadcasted N (control treatment). This may be resultant from the proximity of N placement relative to the seed placement by the openers. Tine opener places N below the seed, while the double chute opener places the N between the seed, and the disc opener mixes the N with the seed. Therefore, from the results, it was clear that placement of N in contact with the seed, which was done through the disc opener in this case, may have damaged the seed, leading to problems that include seed scorching (Brandt et al. 2007). Tine and double chute openers disturb the soil more than disc openers, which is not advisable in CA practises. Therefore, a disc opener is still the most suitable, but the opener needs some improvement whereby the N will be separated from the seed to place N below the seed. This separation and placing of N below the seed will make N more available to the seed and avoid seed scorching by N which is observed when disc openers are used. Nonetheless, there was no influence of N placement on both canola and wheat yields. However, it is not clear if positive the results obtained from the double chute and tine openers were caused by how and where these two openers placed the N to the seed or whether this might have been due to the availability of soil moisture resulting from the soil disturbance caused by the double chute or tine opener.

5.4.9 References

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CHAPTER 6

Conclusion and Recommendations

6.1 Synopsis

The world population is increasing rapidly, which directly increases food demand (Sadik 1991). Moreover, it is predicted that frequent droughts will exacerbate food production efforts by farmers adversely (Benson & Clay 1998). This will require various innovative approaches to maintain food production so as to keep up with the envisaged food demand. In this regard, several farmers worldwide are moving towards conservation agriculture (CA) practices. One of the principles of CA is that of disturbing soils as little as possible (Koller & Titi 2003). For this reason, some farmers have willingly switched to disc openers to optimise their farming operations and to align their activities with this principle. However, some local farmers are sceptical of the efficiency of disc openers, particularly under local conditions in the Western Cape. Most farmers in the Western Cape are still using tine openers to plant wheat and canola (DAFF 2010). However, as more evidence becomes available on the efficacy of disc openers, more farmers are moving towards CA practices in their farming operations elsewhere around the world. Tine openers disturb soil more than disc openers and place the N below the seed, while disc openers cause less soil disturbance and mixes N with the seed. Moreover, further refinement with the double chute openers place seeds at the same time in twin rows and places N fertiliser in between the seed. Notwithstanding the success with typical disc openers, there remains some pessimism, especially regarding issues with seed scorching. Therefore, there was a need to conduct an investigation to determine which opener between tine, disc and double chute will give better results in relation to N rates, planting depth and N placement for wheat and canola establishment.

For the efficient establishment of wheat or canola, the success of establishment decreases with the increase with planting depth. With increasing depth of planting (deeper than 2 cm), success of establishment decreased, as observed in both growth room and field trails. Seed established well at a depth of 2 cm for wheat and canola regardless of N rate (Agenbag 2012). The disc opener the seed more uniformly at shallow depths than tine opener.While the tine opener planted the wheat and canola seed more uniformly at deeper depth than disc opener in most cases. According to the N placement trail, N that was placed below or beside of the seed was more effective than N that was broadcasted or N that was mixed with seed. In the 2017 trial, the double chute and tine openers gave better results than broadcasted N and the disc opener. However, it is not clear if positive the results obtained from the double chute and tine openers were caused by how and where these two openers placed the N to the seed or whether this might have been due to the availability of soil moisture resulting from the soil disturbance caused by the double chute or tine opener. Thus, the study should be repeated using varying N levels before the results can be used to develop an effective opener that will be beneficial for seeding without seed damage due to contact with N fertiliser, with minimum soil disturbance.

6.2 Limitations of the study

6.2.1 Objective 1: To determine the suitable N rate under the different soil types and different sowing depths

The first limitation was soil compaction caused by watering in certain soils. When the pots were manually watered to field capacity, the water compacted the soil, which retarded establishment of canola, and this was particularly exacerbated when seeds were planted deeper.

The second limitation was when the N rate was dissolved in water and applied in solution to the field capacity immediately after seed placed in the soil. The different soils had different hydraulic conductivities and water holding capacities, leading to varying movement of the wetting front.

6.2.2 Objective 2: Effect of sowing depth using tine or disc opener forwheat and canola

The most notable limitation was a poor rainfall distribution and late onset of the rainy season. The first rain was received towards the end of May 2016, which delayed the planting of the wheat and canola trails. Although this situation was similar to what farmers experienced, the yield could have been compromised. Therefore, evaluations in multiple years is required to overcome this limitation. Earlier planting of wheat and canola is key to ensure high yields. In addition, it was difficult to determine the canola seed placement after plant emergence for canola, since the original seed was not visible 30 days after planting. However, to circumvent this problem, the distance between the discolouration on the hypocotyl and the branch of the first secondary root was used as an indicator of seed depth.

6.2.3 Objective 3: The effect of nitrogen fertilizer placement on wheat and canola seed using tine, disc or double chute opener

Similar climatic conditions prevailed for the 2017 field trial when another very dry season was experienced in the Western Cape, which may have affected the response of the crops to N. When there is little rain, the applied N cannot be utilized by the plant since plants take up nutrients in ionic forms that is brought about by dissolution of granular fertilisers in water.

6.3 Recommendations for future research

The growth room trial should be repeated and the soil that is used to plant the seed into pots should be mixed with the mineral (vermiculite) that prevents soil compaction. Nonetheless, this study reaffirmed the notion that the most suitable planting depth for wheat and canola was about 2 cm. The disc opener is recommended to plant wheat and canola to farmers mainly because the disc opener is effective at shallow depths (*ca*. 2 cm) and it does not cause more soil disturbance when compared to tine or double chute openers. Moreover, tine openers are only recommended in stony soil conditions because tine openers cause more soil disturbance. For future research it is recommended that a canola trial be repeated since the determination of seed placement was not effectively controlled. This could be achieved through measuring the seed placement from the flange to the colour change of the plant.

6.5 References

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