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Research Article

Evaluating the Impact of Starter Fertilizer on Winter Canola Grown in Oklahoma

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Increased canola production costs and acres have driven Oklahoma (OK) farmers to ask more questions about their nutrient management recommendations in their production system. A study was conducted in 2011–2013 at Lahoma and Perkins, OK, to evaluate the effect of applying diammonium phosphate (DAP, 18-20-0:N-P-K) directly with seed on crop stand, grain yield, and grain quality of canola. In addition, the impact of proportion nitrogen (N) applied as a preplant and topdress was also evaluated. Diammonium phosphate was banded with the seed at planting at 0, 17, 34, 51, 67, and 84 kg DAP ha^{-1}. Remaining N was applied as urea (46-0-0) either as split (40% preplant and 60% topdress) application or as topdress only. Stand count reduction of up to 71% was observed with seed-placed DAP. However, loss of stand did not impair grain yield due to canola's ability to compensate for open areas via branching. Application of DAP of up to 84 kg ha^{-1} with seed may be possible; however, soil and climatic conditions should be considered when deciding how much DAP will be placed with seed. Moreover, when climatic conditions limit early season growth and favor late spring growth, applying all N at topdress (no preplant) tended to provide greater canola grain yield.

1. Introduction

Canola (*Brassica napus* L.) is an agronomic crop primarily grown for its seeds as a source of edible oil and animal meal qualities. In Oklahoma (OK), canola is grown in rotation with wheat to help disrupt wheat disease cycles and expand weed control options. It is typically seeded between September and October and harvested in May or June. Winter canola has grown considerably in Oklahoma where plantings for the crop years 2010 to 2015 doubled, from 24,000 to 56,000 hectares [1]. In 2015, Oklahoma was ranked as the second largest canola producing state in the US next to North Dakota.

Starter fertilizer is a small amount of fertilizer nutrients applied in close proximity to the seed at planting. In general, a seedling root system lacks the size and density to be able to intercept the necessary nutrients within the soil. Starter fertilizers enhance the development of emerging seedlings by placing a readily available supply of nutrients which the undeveloped root system of the seedling can easily access. Nitrogen (N) and phosphorus (P) are key nutrient components in a starter fertilizer. Phosphorus is important for promoting vigorous root growth. Phosphorus, however, is immobile in the soil. To be absorbed by the plant, the roots must be very close to the phosphate. Hence, P should be strategically placed close to the seed to obtain an early boost to growth. Nitrogen, on the other hand, is a mobile nutrient, so placement may not be as critical as P, but N in the starter fertilizer may help avoid early season N deficiency due to the slow release of N in organic matter particularly during cold conditions. Also, ammonium (NH_4, nitrogen in available form) from starter fertilizers can enhance P uptake from the starter and from the soil [2, 3].

It is a common practice for many Oklahoma winter wheat producers and crop producers with small acres of winter wheat to put down starter fertilizer in row with seed as they do not use additional starter attachments due to considerable equipment costs. A primary concern with in-furrow or seed-placed starter fertilizer in canola is the potential for salt injury to germinating seed, especially with N fertilizer. Rates of N that would normally cause little or no injury to wheat can cause severe injury and reduction in germination and emergence of canola when placed with the seed [4].

Nitrogen in nitrate (NO_3) form can damage canola seedlings by desiccation through salt effect. Ammonia toxicity from N-containing fertilizers also damages canola seedlings [5]. Phosphate, on the other hand, has no salt effect but common starter fertilizers are compound fertilizers containing both P and N.

In Oklahoma, the most commonly used starter fertilizers are diammonium phosphate (DAP, 18-20-0:N-P-K), monoammonium phosphate (MAP, 11-23-0:N-P-K), and ammonium polyphosphate (APP, 10-15-0:N-P-K). Among the three, DAP has become popular to farmers due to high N and P content, relatively lower prices, and greater availability, but the higher N component of DAP puts a limit on safe rates of seed-placed phosphate compared with MAP and APP.

An additional concern in the production of winter canola is the potential for excessive top growth and limited root system into winter dormancy due to N applied close to seeding and the impact this may have on winter hardiness and survivability. At this time, impacts of N applied on canola winter survivability are all speculative as there is little information on timing of N applications impact on winter canola.

The objectives of this research were to determine the yield response to fertilizer DAP applied with seed at planting; to identify the critical level at which salt injury negatively impacts stand and yield when DAP is applied with seed; and to evaluate the impact of N application method on canola yield.

2. Materials and Methods

2.1. Site Selection. Two sites were established in Oklahoma in 2011-2012 and 2012-2013. One was at the Cimarron Valley Research Station near Perkins, OK, USA (lat.: 35.99, long.: −97.033). The soil at Perkins location was Konawa (fine-loamy, mixed, active, Thermic Ultic Haplustalfs) and Teller (fine-loamy, mixed, active, Thermic Udic Argiustolls) loam soils. Teller and Konawa series soils are deep, well drained, and moderately permeable. Potential rooting depth is 2 to 3.5 m if there are no major restrictive layers. The average annual precipitation in this location is 94.13 cm with an average summer high temperature of 33°C and an average winter low temperature of −3°C. The other location was at the North Central Research Station near Lahoma, OK, USA (lat.: 36.38, long.: −98.10). The soil at the Lahoma location was Grant silt loam (fine-silty, mixed, super active, Thermic Udic Argiustolls). These soils are well drained, deep, and moderately permeable and rooting depth potential is similar to Teller and Konawa soil series. The average annual precipitation at this location is 82.02 cm with an average summer high temperature of 34.22°C and average winter temperature of 7.78° C. The Perkins location was a no-tillage cropping system, while the Lahoma location was a conventional tillage system. Both locations were established after wheat in both years.

2.2. Soil Sampling and Analysis. Soil samples were taken a month prior to planting to determine soil nutrient levels. In the second year, experimental plots were established adjacent to the previous year's test plots to prevent residual N and P levels from affecting the test area. Top soil (top 0 to 15 cm) and subsoil (lower 15 to 30 cm) were collected for each soil sample that consisted of 15 to 20 cores. Soil samples were analyzed for soil pH, nitrate-N (NO_3-N), extractible P, potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). Soil test results are shown in Table 1. Soil samples were dried at 65°C overnight and ground to pass through a 2 mm sieve prior to extraction and analysis. The soil pH was measured using a combination electrode within a 1 : 1 ratio of soil to water suspension and Sikora buffer solution [6, 7]. Soil NO_3-N was extracted with a 2 M KCl solution and quantified by a Flow Injection Autoanalyzer [8]. Mehlich III solutions were used to extract plant available P, K, Ca, and Mg [9] and quantified using a Spectro CirOs ICP spectrometer [10]. Total N was determined using the LECO Truspec dry combustion carbon analyzer [11].

2.3. Planting and Treatment Establishment. A popular canola variety in Oklahoma, Dekalb brand "DKW 46-15," was planted with a John Deere 450 grain drill with double disk seed openers at 38.1 cm spacing at a target rate of 5.6 kg seeds ha^{-1}. Planting dates in 2011 were 26 and 27 September in Perkins and Lahoma locations, respectively. In 2012, canola was planted in 18 September at Perkins location and 2 October at Lahoma location. Plots were 6 m long by 2.5 m wide (6 rows) with a 6 m alley between replications. The experimental design was a randomized complete block with three replications. Table 2 lists the treatment structure used in this study. The starter fertilizer, DAP, was banded with the seed at planting at 0, 17, 34, 51, 67, and 84 kg DAP ha^{-1}. Remaining nitrogen was applied as urea (46-0-0) either as split (40% preplant and 60% topdress) application or as topdress only. All plots received a total of 140 kg N ha^{-1} except for the unfertilized check. For treatments that received split application, all topdress N were applied at 84 kg ha^{-1}; preplant N rates were computed based on the difference between the recommended N rate (140 kg ha^{-1}) and the topdress N (84 kg ha^{-1}) plus N from DAP. Preplant plus topdress and topdress only plots were also included for comparison. Preplant fertilization and topdress fertilization were applied as broadcast incorporated and broadcast, respectively. Topdressing was applied in the spring when canola was in the vegetative stage prior to bolting (stem elongation). Experimental plots were maintained weed-free using glyphosate. Insects were controlled using the Lambda-cyhalothrin insecticide as needed.

2.4. Data Collection. Canola stand counts were taken at each location two weeks after planting, by randomly placing a meter stick along the crop rows of each plot and counting the number of canola plants that emerged. Stand counts were collected at five locations per plot.

To determine the biomass production during the growing season, normalized difference vegetation index (NDVI) readings were obtained using GreenSeeker™ one week before and two weeks after topdress N application. In the second year, additional NDVI readings were collected four weeks after topdress N application. Normalized difference vegetation

Table 1: Preplant composite soil sample results in Perkins and Lahoma, OK, in 2011 and 2012. Samples were collected in the summer, a month prior to planting.

Location	Year	pH[†]	Buffer index	NO_3-N[‡] 0–15 cm	NO_3-N[‡] 15–30 cm	STP[§] 0–15 cm	STP[§] 15–30 cm	STK[¶] 0–15 cm	STK[¶] 15–30 cm	SO_4-S[††] 0–15 cm	Ca[‡‡] 0–15 cm	Mg[§§] 0–15 cm
				ppm								
Perkins	2011	4.5	6.6	27	—[*]	76	—	406	—	31	717	175
Perkins	2012	4.5	6.3	4.5	—	122	—	436	—	—	—	—
Lahoma	2011	6.1	7.0	11	7	32	—	474	—	—	—	—
Lahoma	2012	6.0	7.0	21	—	40	—	470	—	38	3326	1140

[†] pH: 1 : 1 soil : water.
[‡] NO_3-N: nitrate-nitrogen; 1 M KCl solution.
[§] STP: soil test phosphorus; Mehlich III.
[¶] STK: soil test potassium; Mehlich III.
[††] SO4-S: available sulfur; Mehlich III.
[‡‡] Ca: calcium; Mehlich III.
[§§] Mg: magnesium; Mehlich III.
[*] — (dash): no data available.

Table 2: Canola stand count as influenced by seed-placed diammonium phosphate (DAP) and nitrogen (N) application method two weeks after emergence at Lahoma and Perkins, OK, in 2011–2013.

Treatment	DAP with seed	N/P in DAP	N preplant	N topdress[†]	Stand count Lahoma	Stand count Perkins
	kg ha^{-1}				Plants m^{-2}	
1	0	0/0	0	0	87	44
2	0	0/0	56	84	88	38
3	0	0/0	56N/14P	84	82	43
4	17	3/3.5	53	84	65	41
5	34	6/7	50	84	50	35
6	51	9/10.5	47	84	33	24
7	67	12/14	44	84	31	23
8	84	15/17.5	41	84	18	23
9	0	0/0	0	140	90	58
10	17	3/3.5	0	137	57	43
11	34	6/7	0	134	50	29
12	51	9/10.5	0	131	33	30
13	67	12/14	0	128	25	26
LSD					15	19

[†] All treatments received at total of 140 kg N ha^{-1} except for the unfertilized check.

index values were collected twice from the middle of each plot approximately 70 to 100 cm directly above the crop canopy.

Seven to ten days prior to harvesting, four middle rows of each plot were swathed and pressed with a press wheel attached behind the swather to prevent seed shattering and for uniform seed drying. The swather was run low enough to get all the seed pods, leaving approximately 25 to 30 cm stubble height after swathing. A Massey Ferguson 8XP plot combine equipped with a Harvest Master yield monitor was used to harvest the grain and determine yields. Subsamples were collected and analyzed for protein and oil content using a Diode Array Near-Infrared instrument [12].

2.5. Statistical Analysis. Analysis of variance was performed on canola stand count, NDVI readings, grain yield, and oil and protein content using PROC MIXED (SAS Version 9.4, SAS Institute). Year, location, and treatments were considered as fixed effects while replications were considered as random effect. Mean comparisons were separated using Fisher's Protected LSD at the $P \leq 0.05$ significance level. Homogeneity of variances and normality of distribution were tested and all data showed normal distribution and equal variances. Regression analyses were performed using Sigma Plot 13 procedures to evaluate the relationship between percent canola stand and seed-placed DAP rate and canola stand count and NDVI readings. Correlation coefficient analysis on stand count versus grain yield was done by using PROC CORR of SAS 9.4.

3. Results and Discussion

3.1. Climatic Conditions. The 2011-2012 sowing at Perkins and Lahoma occurred in what could be considered optimum conditions for canola germination and growth. Timely rainfall

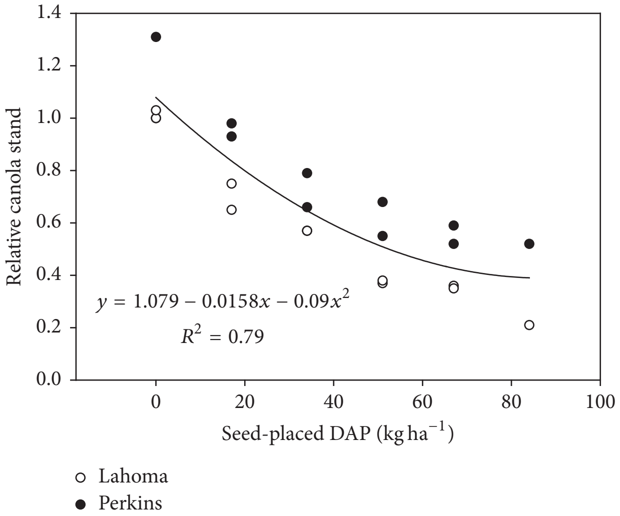


Figure 1: Canola stand relative to the untreated check as influenced by rate of seed-placed diammonium phosphate (DAP). Relative canola stand includes data from Lahoma and Perkins, OK, 2011–2013.

throughout October, November, and December, combined with the warmest winter on record, resulted in rapid canola growth. Temperatures during the 2011-2012 season were never cold. In mid-April, a wave of heat occurred in Oklahoma that quickly depleted soil water reserves, but by early May temperatures were near normal and moisture returned.

The 2012-2013 cropping season was generally a dry start for canola planting in Oklahoma. Drought conditions were observed in the fall of 2012. A few timely rains in September allowed good germination and rapid start for the crop but no substantial rain was received until early 2013. Rain in early 2013 was not much but enough to enable the crop to recover. Spring temperatures were generally cooler than normal which were beneficial for canola grain fill but delayed harvest by approximately two to three weeks compared to the previous cropping season.

3.2. Stand Count. Application of DAP with seed caused stand loss of canola plants in both locations (Table 2). Stand loss severity increased with increasing DAP rate (Figure 1). Loss of stand count from application of DAP at 51, 67, and 84 $kg\,ha^{-1}$ was more pronounced than at 17 and 34 $kg\,ha^{-1}$ DAP rate. Stand counts of plots applied with seed-placed DAP at 17 and 34 $kg\,ha^{-1}$ were comparable with the unfertilized check at the Perkins location but caused 25 to 35% stand reduction at the Lahoma location. Seed-placed DAP at 51 and 67 $kg\,ha^{-1}$ (contains 9 to 12 $kg\,N\,ha^{-1}$) caused 45 to 71% reduction in stand compared to the unfertilized check. Where no starter fertilizer was used, canola stand counts were approximately 38,000 to 58,000 and 82,000 to 90,000 plants per hectare in Perkins and Lahoma locations, respectively.

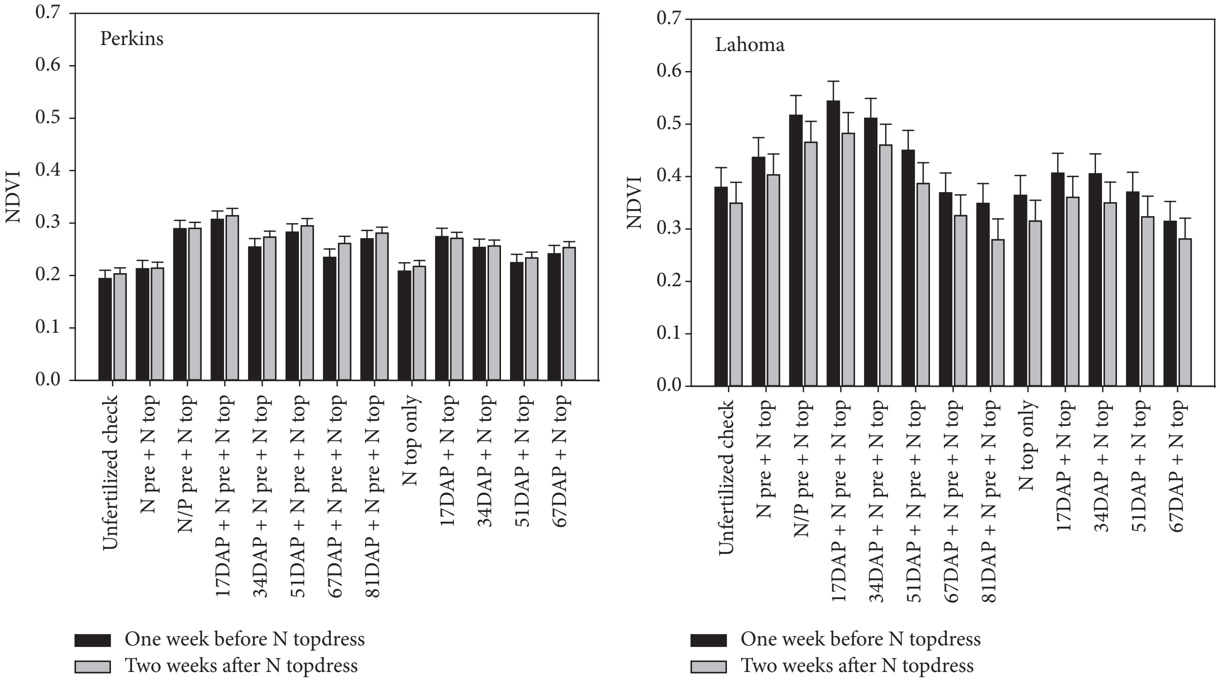
Between the two locations, a lesser stand count reduction was noted in Perkins (6–48%) than in Lahoma location (25–71%) although overall emergence was higher in Lahoma than in the Perkins location. Canola at Perkins location was planted in a no-till system and the grain drill used was not ideally suited for no-till sowing. Moreover, emergence may have been influenced by low soil pH condition. It is also hypothesized that stand count difference between locations is due to temperature and soil moisture conditions. Temperatures at the Lahoma location had dropped below 10°C for four consecutive days, three days after seeding. Also, soil moisture was low (<0.12 mm) at seeding and in the first week after sowing, thereby increasing the chances of salt injury. Placing fertilizer in furrow increases salt concentration around the seed; if concentration is too high, the seed will be unable to germinate [13, 14]. Application of preplant broadcast N did not affect canola stand count, as number of seedlings in plots applied with preplant N was similar in plots with no preplant N applied.

3.3. NDVI Readings

3.3.1. 2011-2012. Normalized difference vegetation index readings recorded one week prior to topdress N and two weeks after topdress N had little variations within treatments (Figure 2). At both locations and at both sensing times, plants applied with N at preplant + topdress (treatment 2) and at topdress only (treatment 9) recorded NDVI values that were similar to the unfertilized check. Interestingly, plants supplied with preplant N and P + topdress N (treatment 3) yielded NDVI values that were significantly higher than the unfertilized check. The application of 17 $kg\,ha^{-1}$ DAP + preplant N + topdress N provided the highest NDVI readings among the treatments regardless of sensing time. In addition, application of 34 $kg\,ha^{-1}$ DAP + preplant N + topdress N gave higher NDVI values than the checks (unfertilized, preplant + topdress N, and topdress N only).

At Lahoma location, NDVI values decreased with increasing rate of DAP (Figure 2). This trend is similar to that of the crop stand count results. Values of NDVI were the lowest in plants applied with 84 $kg\,ha^{-1}$ DAP compared with plants applied with 17 and 34 $kg\,ha^{-1}$ but were comparable with the unfertilized check. Plants that received split application of N had higher NDVI values than plants with no preplant applications. NDVI values of plots receiving preplant N were either similar or higher compared to the unfertilized check. Similar results were reported in a wheat study using optical sensors and variable rate wherein split rate N provided higher NDVI values than N fertilizer applied at topdress only [15, 16]. Lower NDVI values were observed two weeks after topdress N at the Lahoma location most likely because sensing was delayed (due to unfavorable weather condition) and the crop had started to bolt.

At Perkins location, recorded NDVI values were generally low (0.19 to 0.31) due to low stand count and biomass. Soil analysis result in this location showed low pH of 4.5 (Table 1). Low soil pH reduces plant availability of several nutrients, increases levels of some elements to phytotoxic concentrations (i.e., Al^{3+} toxicity), and influences microbial activity or other soil properties [3, 17, 18]. These poor growth conditions can lead to reductions in root development which consequently causes slow vegetative growth and low total biomass per unit area. However, the low stand count due to



(a) (b)

Figure 2: Normalized difference vegetation index (NDVI) values at one week before and two weeks after topdress nitrogen (N) as influenced by seed-placed diammonium phosphate (DAP) and N application method at Lahoma and Perkins, OK, in 2011-2012; pre: preplant; top: topdress.

seed-placed starter fertilizer (Table 2) did not affect NDVI values. Plants applied with seed-placed DAP had higher NDVI readings compared to plants with no seed-placed DAP except for the N/P preplant plus topdress treatment. The addition of DAP with the seed may have provided a readily available nutrient to the seedling causing enhanced root growth and consequently above-ground biomass.

3.3.2. 2012-2013. Normalized difference vegetation index values were similar in all treatments (data not shown). For both locations, little change was seen in NDVI values recorded two weeks after topdress compared to NDVI collected priorly (Figure 3). The low NDVI values were likely due to environmental factors like temperature and lack of precipitation. It was not until shortly after the second NDVI readings that temperatures started to increase and regular precipitation events occurred creating a suitable environment for rapid crop growth and nutrient uptake. This allowed plants to have an increase in biomass production which resulted in considerably higher NDVI values at four weeks after topdress N.

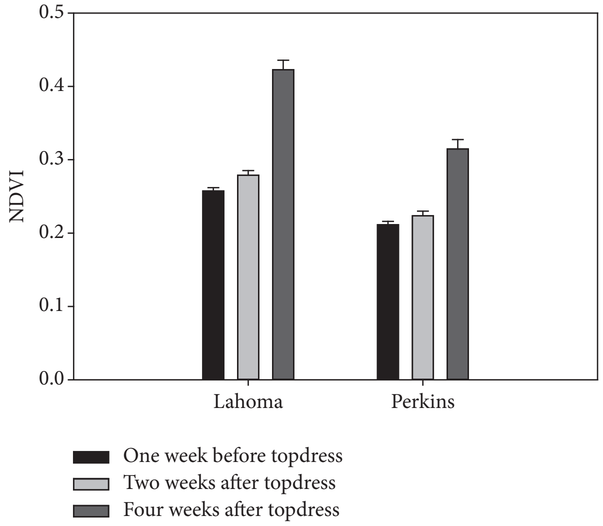


Figure 3: Normalized difference vegetation index (NDVI) values at one week before and two and four weeks after topdress nitrogen (N) at Lahoma and Perkins, OK, in 2012-2013. NDVI values are average across treatments.

3.4. Grain Yield. Canola grain yields at Lahoma location ranged from 1048 to 1748 kg ha^{-1} and 568 to 2194 kg ha^{-1} in 2011-2012 and 2012-2013, respectively (Table 3). In 2011-2012, no significant difference in yield was observed in all treatments. The lack of yield variation between treatments may have been influenced by the uncommonly warm winter and timely rains in the spring, which is not typical in Oklahoma. Warm weather with adequate soil moisture during winter likely increased the rate of mineralization, adding significant amounts of plant available N. Moreover, this condition allowed the plants to mature and produce additional branches and set additional seed pods due to the favorable weather pattern. In a study by Johnston et al. [19], canola was reported

Table 3: Canola grain yield as influenced by seed-placed diammonium phosphate (DAP) and nitrogen (N) application method at Lahoma and Perkins, OK, in 2011–2013.

Treatment	DAP with seed	N/P in DAP	Preplant N	Topdress N	Lahoma		Perkins	
					2011-2012	2012-2013	2011-2012	2012-2013
				$\mathrm{kg\,ha^{-1}}$				
1	0	0/0	0	0	1558	568	467	259
2	0	0/0	56	84	1338	1753	543	364
3	0	0/0	56N/14P	84	1175	2194	395	1324
4	17	3/3.5	53	84	1048	1721	752	938
5	34	6/7	50	84	1290	1826	212	751
6	51	9/10.5	47	84	1718	1708	375	1120
7	67	12/14	44	84	1610	1764	272	1107
8	84	15/17.5	41	84	1399	1426	339	1064
9	0	0/0	0	140	1423	2106	387	309
10	17	3/3.5	0	137	1629	2017	400	997
11	34	6/7	0	134	1748	1976	336	1784
12	51	9/10.5	0	131	1257	2012	352	989
13	67	12/14	0	128	1649	1540	198	1163
LSD					NS	712	224	591

to produce more branches and compensate for lack of crop stand and allowed for maximum yield to be obtained when weather conditions were suitable for growth. In 2012-2013, the environment was less conducive to vegetative growth and propagation of branches; hence, differences in yields were observed among fertilizer treatments (Table 3). Regardless of DAP application, plants that were applied with topdress and no preplant N (treatments 10 to 13) tended to have greater yields than plants that received preplant (treatments 4 to 8). Lower grain yields in 2011-2012 compared to 2012-2013 may be attributed to delayed canola harvesting due to rain which may have resulted in shattering of pods even after swathing.

At Perkins location, grain yields were unusually low (198 to 752 $\mathrm{kg\,ha^{-1}}$) during the first year (Table 3), which was likely enhanced by soil pH and by moisture deficit resulting from below-normal precipitation and above-normal temperatures during boot, bloom, and grain filling stages of the crop. These extreme environmental conditions during critical reproductive stages of canola can increase flower abortion and reduce translocation of assimilates to grain, collectively reducing grain yield [20]. In the second year, higher grain yields (259 to 1784 $\mathrm{kg\,ha^{-1}}$) were observed in most treatments as there was an increase of available soil moisture during the period of bolting and seed fill. Plants that did not receive P fertilizer, however, had lower grain yields (259 to 364 $\mathrm{kg\,ha^{-1}}$) than the rest of the fertilized plants (751 to 1163 $\mathrm{kg\,ha^{-1}}$). This may be attributed to the low soil pH (4.5) condition at Perkins. At low pH, P is often tied by iron and aluminum rendering it unavailable for plant uptake [21]. Phosphorus is an important nutrient for winter survival of canola. At spring green up, plots that did not receive P had few to no plants that survived over the winter even though these plots had the highest recorded stand counts.

In general, canola grain yield was not significantly reduced despite the loss in stand count two weeks after planting. Stand loss was not well correlated with yield ($r^2 = 0.3$, $P \leq 0.00001$). This response indicates that canola could compensate the level of stand loss observed without yield reductions, which was consistent with previous research [22].

3.5. Oil and Protein Content. Canola is grown primarily for oil; therefore, oil content is the most important parameter when assessing canola quality. No significant three- and two-way interactions were found; thus, oil content data are presented by year across locations. In 2011-2012, there were no significant differences among treatments; however, in 2012-2013, oil content differences were observed among treatments (Table 4). In general, plants that received P, whether through seed-placed DAP or preplant, had higher oil content (40.5 to 43.27%) than plants that were not applied with P (40.15 to 43.21%). Similar findings were also reported by Tomar et al. [23] and Gaydou and Arrivets [24] who observed that P application increased oil contents of soybean. Differences in oil content were also noted among plants applied with different rates of P. Plants with higher P applied produced more grain oil than with lesser P applied. These results suggest that P is an essential nutrient in increasing oil content in canola.

Protein content data was similar for both years. Seed protein content ranged from 20% in the unfertilized plot to 22% in plot which received the broadcast N and P fertilizer (Table 4). Significant differences were observed between fertilized and unfertilized plots but not among fertilized plots in both locations. Regardless of location, protein contents of all treatments were lower than the typical canola protein content of 23%, although protein content in whole canola seed is dependent on variety and growing conditions. According to Canola Council of Canada [25], P fertilization has little or no effect on canola quality. Studies conducted in western Canada showed that P fertilizer showed no specific effect on canola protein content except in very P-deficient locations.

4. Conclusions

This study demonstrated that application of DAP with the seed causes stand count reduction to canola. Placement

Table 4: Oil and protein content of canola as influenced by seed-placed diammonium phosphate (DAP) and nitrogen (N) application method in 2011–2013.

Treatment	DAP with seed	N/P in DAP	Preplant N	Topdress N	Oil content		Protein content	
					2011-2012	2012-2013	2011-2012	2012-2013
	kg ha^{-1}				%			
1	0	0/0	0	0	43.21	—*	19.89	20.32
2	0	0/0	56	84	42.43	40.15	20.93	21.12
3	0	0/0	56N/14P	84	43.14	41.14	20.82	21.50
4	17	3/3.5	53	84	42.97	40.62	21.01	21.97
5	34	6/7	50	84	43.21	40.94	21.00	21.62
6	51	9/10.5	47	84	43.27	41.38	20.94	21.28
7	67	12/14	44	84	43.16	41.28	21.98	21.69
8	84	15/17.5	41	84	43.06	41.39	21.20	21.42
9	0	0/0	0	140	42.86	—	21.05	21.33
10	17	3/3.5	0	137	42.87	40.50	21.32	21.95
11	34	6/7	0	134	42.89	41.22	21.12	21.90
12	51	9/10.5	0	131	43.21	41.25	20.95	21.56
13	67	12/14	0	128	43.03	41.28	21.04	21.48
LSD					NS	0.49	0.75	0.75

*— (dash): no data available.

of starter fertilizer with the seed even at the lowest rate of DAP (17 kg ha^{-1}) significantly reduced stand, but stand count reduction was not associated with yield. Since canola plants were able to compensate stand count losses through additional branching, application of DAP of up to 84 kg ha^{-1} (contains 15 kg N ha^{-1}) with seed may be possible. However, soil conditions that tend to increase potential damage to seed and environmental factors that induce stress to the crop should be considered when deciding how much DAP will be placed with seed. In addition, the targeted seeding rate of 5.6 kg ha^{-1} is well above the amount needed. Currently, some producers are using seeding rates as low as 3 kg ha^{-1} when using a grain drill and as low as 2.2 kg ha^{-1} when using a planter. While little to no yield reduction due to stand loss was observed in this study, it could be hypothesized that if seeding rate had been reduced a negative impact on yield would have been more likely. Thus, further research is needed to document impact of stand loss on reduced planting population in canola.

Broadcasting of N and P at preplant resulted in yield equal to or greater than the seed-placed treatments. When producers have some flexibility concerning application methods, broadcasting N and P at preplant may be the preferred method over seed-placed DAP because of lesser to no effect on canola stand.

Seasonal environment had a great impact on the effect of N application method. When climatic conditions limit early season growth and favor late spring growth, applying all N at topdress (no preplant) will tend to provide greater canola grain yield.

Phosphorus significantly influenced oil content but not protein content in canola. Plants with higher P applied produced more grain oil than with lesser P applied. This indicates that P is an essential nutrient in increasing oil content in canola. Due to the lack of available research on fertility impact on canola seed oil production, further research needs to be conducted on these areas of canola production.

Competing Interests

The authors declare that there are no competing interests regarding the publication of this paper.

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