Supporting Alternative Crop Options through Improved Fertility Recommendations for Canola in Central and South Texas.

Fernando Guillen-Portal[1], Clark Neely[2], Brandon Gerrish[2], Russ Garetson[1]

[1]Texas A&M AgriLife Extension, College Station, TX; [2]Washington State University, Pullman, WA

Research study sponsored by:

Summary

Winter wheat production in Texas has been in decline in recent years due to fluctuations in the agricultural commodity market. Incorporation of canola as a rotational crop in cropping systems involving wheat would diversify the farm operation, enhance crop sustainability by shortening the fallow periods, rotate herbicide chemistry, and break disease and pest cycles of wheat. Field research in canola indicates the crop has adaptability to the growing conditions in Central Texas, where grain yields above 2,000 lb ac^{-1} can be attained. However, further agronomic research on canola is required for the identification and adoption of the best management practices for this crop. A critical aspect for the success of canola production in Texas relates to rapid plant establishment. Furrow application of monoammonium phosphate (MAP) and diammonium phosphate (DAP) have proven to positively contribute to early growth and good stand establishment. The objective of this on-farm research study was to determine best in-furrow rates for starter MAP and DAP fertilizer that maximize economic returns for canola in a representative site of the Blacklands region.

A field study was implemented near Perry in Central Texas in which spring canola 'CP9978F'was evaluated under the furrow application, at planting, of 14 fertilizer treatments plus one control arranged in a randomized complete block design with four replications. Fertilizer treatments consisted of different rates of MAP and DAP fertilizers with and without the addition of $ZnSO_4$.

A cold front that went across Texas in early February 2020 affected the crop by delaying its early growth, and excess soil moisture during maturity significantly and negatively impacted yield performance and grain quality. Although no response in grain yield to the fertilizer application was observed, freeze damage, maturity, and test weight showed significant variation. Freeze damage was accentuated under treatments 136 MAP, 91 MAP, 45 MAP, and 28 DAP. It is inferred this was the result of an increased vegetative tissue under these treatments which were exposed to freezing temperatures. Control plants and those under ZnSO4 treatment matured early and yielded relatively low, suggesting these conditions provided inadequate soil nutrients available for proper development of the crop. The crop under the MAP fertilizer treatments tended to mature relatively late but also yielded low, which was probably the result of a reduced phosphorus mobilization in the soil after the initial stages of growth, the freeze damage observed during early growth and the excess soil moisture during the grain filling stage, which in turn caused lodging and seed shatter, or by a combination of all.

Introduction

Fluctuations in agricultural commodity markets in recent years have had an impact on the dynamics of winter wheat production in the US. As a result of that, in the last 10 years US winter wheat acres have dropped from 31 million acres to 23 million acres (USDA-NASS, 2021). In general, producers need more crop options in their cropping systems to diversify and take advantage of alternative markets, and that is especially true for wheat. In addition to mitigating economic risk, crop rotation constitutes a practical strategy in cropping systems that often increases crop yields (Lopez-Bellido et al., 1996; Bushong et al., 2012), helps to break up pest and disease cycles (Bokus and Claassen, 1992), and allows producers to rotate chemicals to reduce development of herbicide resistance and improve weed control (Liebman & Dyck, 1993).

Wheat is a cool-season crop and is one of the top two crops planted in Texas (5.5 million acres; USDA-NASS, 2021). All other dominate crops in Texas are warm season – cotton, corn, and grain sorghum. Since there are few cool-season crop rotation options, rotating warm season crops with wheat generally leads to a prolonged fallow period from early summer (wheat harvest) through the following spring before the subsequent crop can be planted. Fallow ground is less economically productive in areas with adequate rainfall and it does not provide any soil health benefits. Alternatively, a cool-season rotational crop would shorten fallow periods and be a more sustainable choice by providing ground cover for more months out of the year.

Canola provides an excellent rotational opportunity with wheat since both are cool-season crops. Canola is a broadleaf crop which is advantageous in breaking disease and insect cycles in wheat. By rotating wheat with canola, fallow periods would be reduced from eight or ten months down to four when compared to a wheat rotation followed by warm season crops like corn or cotton. Cover crops are sometimes used during these fallow periods to provide soil cover, which reduces erosion, and also feeds the soil microbial community; however, they often do not generate a direct income (Snapp et al., 2005). Canola would reduce the need and additional seed costs for a cover crop, but still provide many of the same soil benefits. Many Brassica species, like canola, are known to help breakup plow pans using their extensive taproots (Williams and Weil, 2004) and scavenge nutrients from deep within the soil profile. Also, canola provides the opportunity to rotate herbicide chemistry to control grassy weed problems in wheat. Italian ryegrass (*Lolium multiflorum*) is a major weed problem for wheat in the Texas Blacklands with documented cases of ALS and ACCase resistant biotypes. Other grassy weeds such as cheatgrass (*Bromus tectorum*), wild oats (*Avena fatua*), rescue grass (*Bromus catharticus*) and others can be problematic as well. While herbicide tolerant canola cultivars are currently available which allow the use of glyphosate (Roundup®), glufosinate (Liberty®), and imazamox (Beyond®; non-GMO) post emergence on canola, even non-GMO canola cultivars provide post emergence herbicide options not possible with wheat, such as sethoxydim (Poast®), clethodim (Select 2EC®) and quizalofop (Assure II®) to control many of these difficult grassy weeds. By rotating herbicide modes of action, producers reduce the risk of developing herbicide tolerant weeds and thus improve sustainability.

Canola has shown great potential in the Southern Great Plains as a good cool-season rotational crop with wheat. In just 12 years, canola acres in Oklahoma went from none to 270,000 planted acres in 2014 (Oklahoma Agricultural Statistics, 2016). Canola is one of the few alternative crops that has an established market in the state (ADM Crushing Facility, Lubbock, TX) and lower price volatility, which makes it an attractive choice. Field research in canola conducted in Central and South Texas indicates this crop is highly adaptable to the growing conditions in this part of the state, with average yields above 2,000 lb ac^{-1} (Wynne et al., 2020). Now that adapted cultivars have been identified for Central and South Texas, more agronomic work needs to be done to identify proper management practices for the crop.

One of the biggest obstacles in canola production relates to proper stand establishment. While canola can be a robust crop and tolerate many weather extremes once established, it is quite vulnerable as a young seedling (Martin et al., 2001). A nutrient deficiency at this stage is likely to reduce plant stands and plant vigor, but little to no work has been done on canola fertility on Texas soils, particularly in the Texas Blacklands Region. This is a highly productive crop region in the state stretching from Oklahoma to San Antonio (Haag et al., 1992). These calcareous soils are characteristically high in clay content and pH, which can limit plant availability of some nutrients including phosphorous, zinc, manganese, and boron. Research is warranted to determine best management practices for canola fertility in this region since some key nutrients can be affected by high pH soils. One proven method to assist in stand establishment and early season vigor is the use of starter fertilizer.

Starter fertilizers have been documented to increase yields of canola and other crops (McKenzie et al., 2003), but must be used judiciously as severe crop damage and even complete stand loss can occur when over-applied (Roberts and Harapiak, 1997). Since potassium is typically high in Blackland soils, nitrogen and phosphorus are likely to have the biggest impact on canola stand and yield. Phosphorus is critical in root development and a deficiency for this nutrient may lead to other deficiencies as plant roots are unable to explore enough soil to meet plant nutrient demands. Monoammonium phosphate (MAP) and diammonium phosphate (DAP) are two common sources of starter fertilizer used in cropping systems. Placing phosphorus in-furrow is particularly important as this nutrient is largely immobile in the soil and even more so in high pH soils (Larsen, 1967). Research by Miller (1998) also found that banding phosphorus allowed Texas wheat producers to cut application rates essentially in half, thereby reducing input costs without reducing yield. Therefore, in-furrow placement of phosphorus has potential to increase plant use efficiency and reduce overall application rates. Based on communication with the cooperating producer, applying zinc sulfate in-furrow has improved stand establishment in other crops in the region. Therefore, improved fertility recommendations for starter fertilizers in canola may be an important component in a comprehensive program for successful canola production in this region.

This project aims to increase crop sustainability by promoting the adoption of canola, a potential rotational crop for the Blacklands Region of Texas, which would shorten fallow periods in wheat rotations and improve weed control through better chemical rotation. This study focused on soil fertility; its objective was to determine the effect of in-furrow rates of starter fertilizer on canola yield, seed protein and oil content in a representative site of the Blacklands region.

Materials and Methods

A field study was implemented at a farm near Perry, TX (31º25'13'' N, 96º54'39.6'' W) in the Blacklands Region of Texas in a fallow, no-till Wilson silty clay loam soil. Pre-plant soil analysis indicated this field had a pH of 6.7, 107 lb ac^{-1} N, 71 lb ac^{-1} P, and 599 lb ac^{-1} K in the top 30 cm of soil. Climatic conditions in this area of the Blacklands are characterized for being prevalently warm and humid during the growing season. Spring canola variety 'CP9978F', a glyphosate resistant spring variety with good agronomic performance in the Great Plains, was planted on December 9, 2020, with a Hege 500 (Hege Co. Waldenburg, Germany) single cone, double-disk plot drill, using a seeding rate equivalent to 465,000 seeds ac^{-1} on plots 5 ft. wide and 30 ft. long.

The experiment consisted of the application of in-furrow fertilizer treatments arranged in a randomized complete block design with four replications, where a plot constituted the experimental unit. Fertilizer treatments consisted of 14 different N-P-Zn-S rates applied at the time of planting plus one with no fertilizer application to be used as control (Table 1). Treatments corresponded with the monoammonium phosphate (MAP) and diammonium phosphate (DAP) formulas such that each product was applied at three N rates: 5, 10, and 15 lb ac^{-1} N, which corresponded with 3 and 5 phosphorus rates per N rate applied, respectively. Also, every MAP and DAP treatment occurred with and without the application of $ZnSO_4$ applied at 14 lb a^{-1}. In addition, DAP was also applied at a rate of 139 lb a^{-1}, which represents approximately 1/3 of total N required, corresponding with current fall N and P fertilizer recommendations for a crop expected to yield 1,500 lb a^{-1}. During the planting process seed and fertilizer mix were emptied separately into the drill for each plot to prevent seed fertilizer contact.

Table 1. Description of fertilizer treatments used in the agronomic evaluation of Spring Canola near Perry, TX in 2020-2021.

Treatment	Nitrogen	P_2O_5	Zinc	Sulfur	Product
	-------------------	(lb a^{-1})	-------------------		
1	5	23	0	0	45 lb MAP
2	10	47	0	0	91 lb MAP
3	15	71	0	0	136 lb MAP
4	5	13	0	0	28 lb DAP
5	10	26	0	0	56 lb DAP
6	15	39	0	0	84 lb DAP
7	5	23	5	2.6	45 lb MAP+14 lb $ZnSO_4$
8	10	47	5	2.6	91 lb MAP+14 lb $ZnSO_4$
9	15	71	5	2.6	136 lb MAP+14 lb $ZnSO_4$
10	5	13	5	2.6	28 lb DAP+14 lb $ZnSO_4$
11	10	26	5	2.6	56 lb DAP+14 lb $ZnSO_4$
12	15	39	5	2.6	84 lb DAP+14 lb $ZnSO_4$
13	0	0	5	2.6	14 lb $ZnSO_4$
14	25	64	0	0	139 lb DAP
15	0	0	0	0	0

On February 3, 2021, glyphosate (Roundup PowerMax) was applied at an equivalent rate of 32 oz ac^{-1} for the control of henbit (*Lamium amplexicaule*). Stand notes were taken approximately 48 days after planting using a scale from 1 to 9 (1=extremely poor plot cover, 9=complete plot cover), freeze damage notes were taken on February 25, 2021, approximately 10 days after winter snowstorm Uri impacted the area, using a scale from 1 to 9 (1=no damage, 9=plants burned down). Flowering notes were collected as the number of days at which 50% of the plants in the experimental unit reached full flowering. On May 31, 2020, 173 days after planting, maturity notes were collected using a scale from 1 to 9 (1=very early, 9=very late). The study was harvested on June 12, 2021, 195 days after planting. Lodging notes were collected prior to harvest using a scale from 1 to 9 (1=no lodging at all, 9=complete lodging).

On May 26, 2021, a field day was implemented at the site of the study. Falls County Extension agent Pasquale Swaner was invited to join the initiative and to assist in the process of reaching out to local producers in Falls County and neighboring counties as well. The overall purpose of the activity was to explain local producers in the area the importance of crop rotations to achieve high crop productivity, to introduce those unfamiliar with canola to the crop, to provide a brief overview of management practices of canola production and the importance of availability of soil nutrients during early growth for rapid plant establishment and growth, key features for optimum production in canola. The collaborator of this study, producer Jerry Nowaski, was asked to provide a brief overview on his experience on canola and on his view about the importance of the study for canola production in Central Texas. I prepared a brief overview on canola production in Central Texas and central management issues needed attention for effective production of the crop, specifically on the aspect concerning identification of best management practices conducive to optimum growth during the establishment phase of the crop.

Plots were harvested on June 12, 2021, with a Wintersteiger (Wintersteiger Ag. Ried, Austria) plot combine. The harvested seed was dried at 95ºF for three days in an oven drier and then run for test weight and moisture content, protein content, and seed oil concentration. Test weight and grain moisture were determined with a Dickie-John GAC 2100 (Churchill Industries, Minneapolis) Agri Bench grain moisture tester machine, grain protein was determined with a Foss Infratec 1226 (Foss Analytical, Denmark) Grain Analyzer instrument, and oil content with a Perten DA 7250 NIR (Perkin Elmer, Massachusetts) instrument. The data collected was subjected to standard statistical analysis using SAS 9.4 (SAS Institute, Cary, NC) in which the PROC GLM procedure was used to test the effects in the linear model, the LSMEANS procedure was used for estimation of means, and the LSD procedure was used for mean separation purposes.

Results and Discussion

Temperature and precipitation conditions during the growing season at the site of the study are shown in Figure 1. During mid-February, approximately 66 days after planting, winter storm Uri brought extreme low temperatures to the area (11ºF). As a result of that, the average temperature in February 2021 was only 47ºF. This unprecedented cold front delayed the growth of canola and had an indirect impact on the performance of the crop, as we will see later. Also, starting approximately at the second week of May, 2021 (about 120 days after planting) seasonal precipitation became incessantly intense in the area and did not stop until the end of the season, time in which the cumulative precipitation reached about 1250 mm (49 inches). This relentless rain affected the seed maturation process and caused significant lodging across treatments, lowered grain test weight, and presumably caused seed loss due to seed shattering.

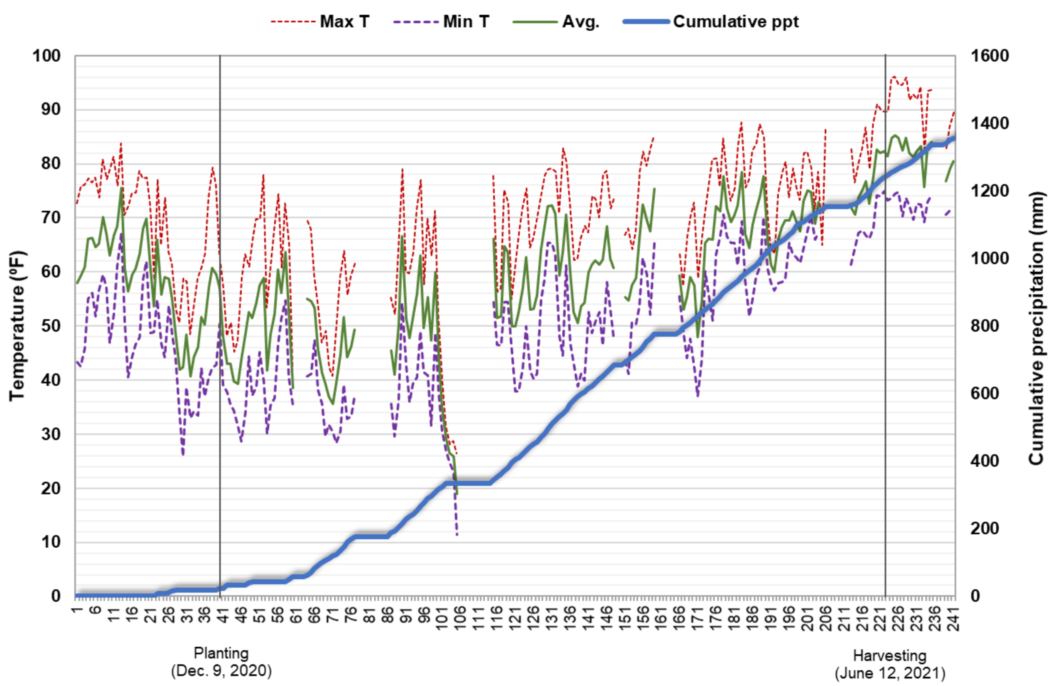

Figure 1. Temperature conditions and total cumulative precipitation during the 2020-2021 growing season observed at Perry, TX. Data compiled for the period November 1, 2020 through June 30, 2021. (*Grassland Soil and Water Research Laboratory, Riesel Climatic Data*)

Agronomic response

Despite the humid, warmer conditions observed throughout the growing season in the area, no diseases or pests affected the crop. No significant response in grain yield or seed quality attributes to the application of fertilizer was observed in the study (Table 2). However, freeze damage, maturity, and test weight showed significant variation. Photos 1 – 12 provide a graphic description of the study. Increased freeze damage was observed in canola under treatments 136 MAP, 91 MAP, 45 MAP, and 28 DAP (scale values of 3, 2, 1.8, and 1.8, respectively), suggesting that plants grown under these treatments developed greater biomass, in which the negative effect of cold temperatures was more pronounced. In a study involving the banding application of, among others, MAP and DAP fertilizers, Thomas and Rengel (2002) found increased early growth of canola under the application of these fertilizers, although the response was greater under the DAP fertilizer. If that was the case in this study, subsequent growth of plants under these treatments after the freezing front of early February might have been significantly delayed.

Plants under the control and under treatment ZnSO4 showed a relative early maturity (scale values of 4.3 and 4.8), whereas plants under treatments 136 MAP, 91 MAP, 139 MAP, and 136 MAP + ZnSO4 were late in maturity (scale values of 7.5, 7.3, 7.3, and 7.3). This disagrees with previous research that indicates that lack of available phosphorus in the soil can delay the maturity of canola (Canola Encyclopedia, 2021). It is possible that the observed delay in maturity in plants under these MAP treatments was the result of the freezing temperatures observed during early growth. Average test weight was relatively low across all treatments, with an overall mean value of only 44.4 lb Bu^{-1}. plants under treatments 28 DAP, 84 DAP + ZnSO4, and ZnSO4 developed grain with relative high test weight (46 lb Bu^{-1} whereas plants under treatment 136 MAP with low test weight (41.8 lb Bu^{-1}).

A significant correlation between stand and maturity (r = -0.53), stand and grain yield (r = -0.81), freeze damage and maturity (r = 0.52), freeze damage and test weight (r = -0.74), and maturity and test weight (r = =-0.59) was found (Table 3, Figure 2). This strongly suggests that the freeze damage caused by snowstorm Uri in mid February significantly delayed the maturity of the canola, which in turn caused a negative correspondence between stand and maturity and between stand and grain yield. Freeze damage and maturity altogether significantly and negatively affected test weight as well. Given that a significant variation in maturity among the treatments was observed, it was considered pertinent to further assess the effect of this trait on grain yield. A regression analysis of maturity on grain yield suggested a quadratic response (Figure 3). As it was already pointed out, relative early maturity was observed under the control and treatment 14 $ZnSO_4$, and late maturity under treatments 136 MAP, 136 MAP + ZnSO4, 91 MAP, and 139 MAP. The observed low yields under the control and treatment 14 $ZnSO_4$ might have been the result of inadequate soil nutrient available for proper development of the crop. There is no clear explanation for the observed low yields under the MAP fertilizer treatments. It could have been the consequence of reduced mobilization and availability of phosphorus after the early growth phase, it could have been caused by the freeze damage observed during early growth and by excess soil moisture during the grain filling stage, which in turn caused lodging and seed shatter, or by a combination of both. Considering all this it is plausible that freeze damage during early growth and excessive moisture during maturity were central events in the observed response of canola to the application of fertilizer, causing a confounding effect driven by altering plant density and delaying maturity.

Table 2. Mean values and standard statistics parameters for major agronomic characteristics in spring canola variety 'CP9978F' subjected to the furrow application of 14 fertilizer treatments (plus control) at planting in Perry, TX, 2021.

No	Treatment	Nitrogen	P_2O_5	Zinc	Sulfur	Stand note	Freeze damage	Lodging note	Maturity note	Grain yield	Test weight	Protein conc.	Oil content
						scale	scale	scale	scale	lb/ac	lb/Bu	%	%
1	45 MAP	5	23	0	0	7.5	1.8	9.0	5.5	696.9	43.1	21.5	41.3
2	91 MAP	10	47	0	0	6.8	2.0	9.0	7.3	732.4	43.8	21.5	40.4
3	136 MAP	15	71	0	0	7.5	3.0	9.0	7.5	528.8	41.8	21.9	40.6
4	28 DAP	5	13	0	0	7.3	1.8	9.0	5.0	739.2	45.7	22.1	40.6
5	56 DAP	10	26	0	0	7.0	1.3	9.0	6.0	691.1	45.0	21.6	41.1
6	84 DAP	15	39	0	0	7.0	1.3	9.0	6.3	824.6	44.1	22.1	41.1
7	45 MAP + 14 ZnS	5	23	5	2.6	6.5	1.0	9.0	6.8	729.9	44.1	22.0	40.8
8	91 MAP + 14 ZnS	10	47	5	2.6	7.0	1.5	9.0	6.5	840.2	43.9	21.7	40.8
9	136 MAP + 14 ZnS	15	71	5	2.6	7.5	1.5	9.0	7.3	622.4	43.7	22.0	41.3
10	28 DAP + 14 ZnS	5	13	5	2.6	7.3	1.0	9.0	5.0	617.3	44.6	22.2	40.8
11	56 DAP + 14 ZnS	10	26	5	2.6	6.8	1.0	9.0	6.0	896.0	45.0	21.8	40.4
12	84 DAP + 14 ZnS	15	39	5	2.6	6.8	1.0	9.0	5.8	914.4	45.7	22.0	40.6
13	14 ZnS	0	0	5	2.6	7.8	1.0	9.0	4.8	442.5	45.5	21.8	40.5
14	139 DAP	25	64	0	0	6.8	1.5	9.0	7.3	793.5	45.0	21.9	40.5
15	Control	0	0	0	0	8.0	1.0	9.0	4.3	490.6	45.1	22.2	40.3
Mean						7.2	1.4	9.0	6.1	704.0	44.4	21.9	40.7
Pr > F						NS	*	--	**	NS	*	NS	NS
LSD (0.05)						--	1.1	--	1.7	--	2.1	--	--
CV (%)						11	55	--	20	34	3	2	2

*, Significant at the 0.05 probability level.

Table 3. Simple (Pearson) correlation coefficients among response variables in spring canola variety ‘CP9978F’ subjected to the furrow application of 14 fertilizer treatments (plus control) at planting in Perry, TX, 2021.

	Stand	Freeze damage	Maturity	Grain yield	Test weight	Protein conc.	Oil content
	scale	scale	scale	Lb ac^{-1}	Lb Bu^{-1}	%	%
Stand	1.00	0.13	**-0.53***	**-0.81*****	-0.08	0.21	0.01
Freeze damage		1.00	**0.52***	-0.18	**-0.74****	-0.31	0.05
Maturity			1.00	0.29	**-0.59***	-0.31	0.17
Grain yield				1.00	0.20	-0.15	0.07
Test weight					1.00	0.29	-0.36
Protein conc.						1.00	-0.16
Oil content							1.00

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels.

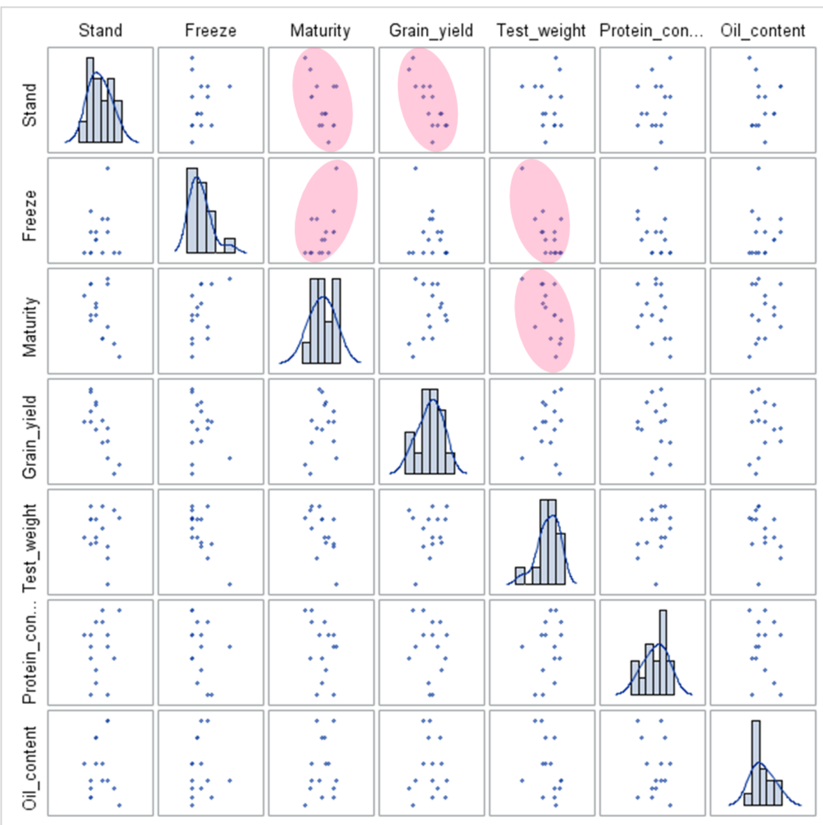

Figure 2. Scatter plots among variables in spring canola variety ‘CP9978F’ subjected to the furrow application of 14 fertilizer treatments (plus control) at planting in Perry, TX, 2021.

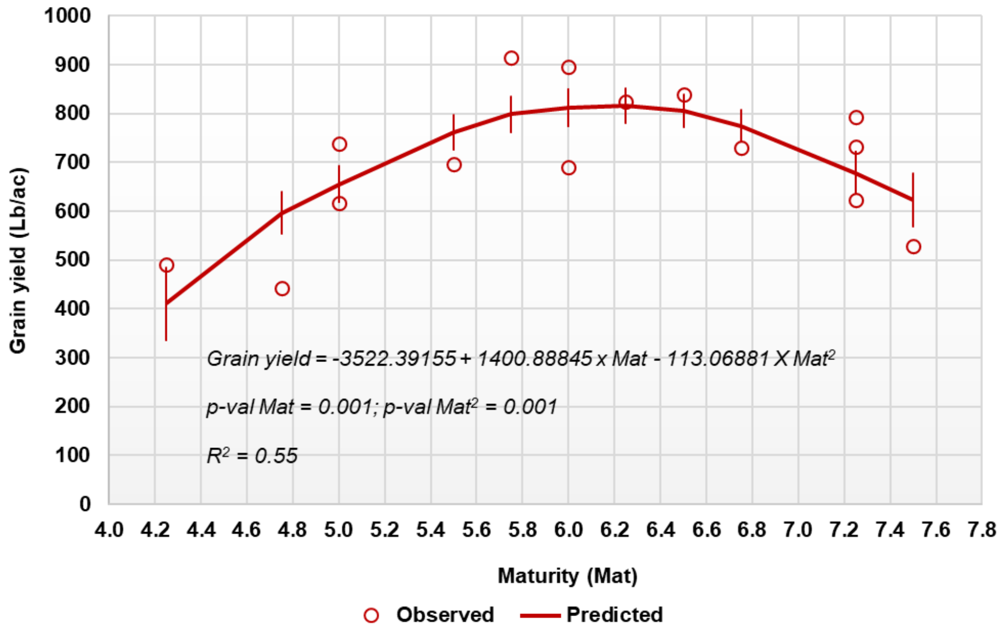

Figure 3. Effect of maturity on grain yield in spring canola variety 'CP9978F' subjected to the furrow application of 14 fertilizer treatments (plus control) at planting in Perry, TX, 2021.

Conclusions

No response in grain yield and grain quality to the fertilizer application was observed in this study. It is likely that the response was greatly affected by climatic events observed during early growth and crop maturity. For instance, the freeze damage caused by a snowstorm early in February 2021 was accentuated under treatments 136 MAP, 91 MAP, 45 MAP, and 28 DAP, which appeared to be the result of increased vegetative tissue exposed to freezing temperatures. Excessive and relentless rains during the seed filling stage delayed the maturity of the crop, causing severe lodging and negatively affecting test weight. Under these drastic growing conditions, plants that grew in absence of DAP or MAP fertilizer appeared to have inadequate soil nutrients available for proper development and were also negatively affected by those climatic events; and those that grew with the application of fertilizer were negatively impacted by both climatic events.

Considering all this it is plausible that freeze damage during early growth and excessive moisture during maturity were central events in the observed response of canola to the application of fertilizer, causing a confounding effect driven by altering plant density and delaying maturity.

References

Bokus, W.W. and M.M. Claassen. 1992. Effects of Crop Rotation and Residue Management Practices on Severity of Tan Spot of Winter Wheat. Plant Disease. 76:633-636.

Bushong, J.A., A.P. Griffith, T.F. Peeper and F.M. Epplin. 2012. Continuous Winter Wheat Versus a Winter Canola– Winter Wheat Rotation. Agronomy J. 104:324-330.

Canola Encyclopedia. 2021. Canola Council of Canada. https://www.canolacouncil.org/canola-encyclopedia/fertility/phosphorus/

Haag, S., P. Jaska, and J. Semple. 1992. Assessing the relative efficiency of agricultural production units in the Blackland Prairie, Texas. 24:559-565.

Larsen, S. 1967. Soil Phosphorus. Advances in Agronomy. 19:151-210.

Liebman, M. and E. Dyck. 1993. Crop Rotation and Intercropping Strategies for Weed Management. Ecological Applications. 3:92-122.

López-Bellido, L., M. Fuentes, J. E. Castillo, F. J. López-Garrido, and E. J. Fernández. 1996. Long-Term Tillage, Crop Rotation, and Nitrogen Fertilizer Effects on Wheat Yield under Rainfed Mediterranean Conditions. Agronomy Journal. 88:783-791.

Martin, S.G., R.C. Van Acker, and L.F. Friesen. 2001. Critical period of weed control in spring canola. Weed Science. 49:326-333.

McKenzie, R.H., E. Bremer, L. Kryzanowski, A.B. Middleton, E.D. Solberg, D. Heaney, G. Coy, and J. Harapiak. 2003. Canadian Journal of Soil Science. 83:431-441.

Miller, T. 1998. Deep P Placement in Wheat in the Texas Rolling Plains. Texas Agricultural Extension Service.

Oklahoma Agricultural Statistics. 2016. 2015 Crop Production Review. https://www.nass.usda.gov/Statistics_by_State/Oklahoma/Publications/Annual_Statistical_Bulletin/ok_bulletin_2016.pdf

Roberts, T.L. and J.T. Harapiak. 1997. Fertilizer Management in Direct Seeding Systems. Better Crops. 81:18-20.

Snapp, S.S., S.M. Swinton, R. Labarta, D. Mutch, J.R. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating Cover Crops for Benefits, Costs and Performance within Cropping System Niches. Agronomy Journal. 97:322-332.

Thomas, B.M, and Z. Rengel. 2002. Di-ammonium phosphate and mono-ammonium phosphate improve canola growth when banded in a P-fixing soil compared with triple superphosphate. Australian Journal of Agricultural Research. 53(11): 1211-1218.

USDA-NASS. Quick Stats. Accessed Sep 8, 2021. https://www.nass.usda.gov/Quick_Stats/index.php

Williams, S.M. and R.R. Weil. 2004. Crop Cover Root Channels May Alleviate Soil Compaction Effects on Soybean Crop. Soil Science Society of America Journal. 68:1403-1409.

Wynee, K., C.B. Neely, C. Adamas, E. Kimura, P.B. DeLaune, D. Hathcoat, B. Gerrish. 2020. Testing row spacing and planting rate for fall-planted spring canola in the Southern United States. Agronomy Journal. 112:1952-1962.

Photo gallery


Photo 1. Early growth


Photo 2. Henbit (*Lamium amplexicaule*) infestation


Photo 3. Freeze damage


Photo 4. Freeze damage

Photo 5. Vegetative stage

Photo 6. Vegetative stage

Photo 7. Flowering

Photo 8. Grain filling

Photo 9. Differences in maturity (early)

Photo 10. Differences in maturity (early)

Photo 11. Differences in maturity (late)

Photo 11. Differences in maturity (late)

Photo 12. Differences in maturity (late)

Photo 13. Field day sign

Photo 14. Field day sign

Photo 15. Field day. Collaborator Jerry Nowaski (right), Extension Programming Specialist Russ Garetson (center), CEA Pasquale Swaner (left).