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Residue Management Impacts on Winter Canola in the Southern Great Plains

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Abstract

The integration of winter canola in the southern Great Plains has allowed producers to diversify their cropping systems by offering an alternative winter crop. Canola is proven to be beneficial at managing grassy weeds and improving yields compared with continuous wheat systems. However, winter canola has been known to be susceptible to harsh winter conditions in the Southern Great Plains. The greatest losses in systems growing winter canola are generally caused by cold or freeze induced damage. The objective of this study was to evaluate impact of different residue management strategies on survival and yield of winter canola in the southern Great Plains. The management treatments included no-till; vertical tillage at gang angle 0°, 3°, and 6°; harrowing; and prescribed burning. The effects of residue management strategies were evaluated by analyzing plant population, crown height, and yield during the growing season from 2014 to 2017 near Fairview, OK. Stand count was significantly different at different dates of measurement; however, the treatment differences were inconsistent. The burn treatment had significantly lower crown height than all treatments except no-till in 2014. Vertical tillage gang angle 6° had significantly lower crown height than all treatments except the burn and harrow treatments in 2016. Canola yield combined across years showed no significant difference among the residue management treatments except for harrow, which showed significantly lower yield than rest of the treatments.

Canola (*Brassica napus* L.) is a broadleaf oilseed crop that has continued to gain popularity around the world. Production acres of canola in the Southern Great Plains has increased from about 400,000 acres in 1998 acres to 1.5 million acres in 2018 (US Canola Association, 2019). There are two main characteristics of canola that contribute to its popularity. First, canola has low erucic acid oil content, making its oil a healthier alternative to many cooking oils (Grant and Bailey, 1993). Second, its meal has a low glucosinolate content, making it a high quality supplement for livestock (Assefa et al., 2014). The United States imports the equivalent of 2 million acres of production each year, and the demand for canola continues to grow (Boyles et al., 2004).

In the Southern Great Plains, wheat is the most dominant crop. Monocultures of wheat have led to stagnation in yields due to increases in weeds, pests, and diseases that thrive in this type of system. Crop rotations have proven a successful management

Crop Management

Core Ideas

- Different wheat residue management strategies were evaluated for winter canola survival and yield.
- Plant stand declined during the course of growing season for all treatments.
- Plant stand and crown height data showed significant differences among treatments; however, the differences were inconsistent.
- This study showed that conservation tillage strategies did not significantly impact yield of winter canola.
- This study suggests that stand analysis data is not indicative of final yield data.

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Conversions: For unit conversions relevant to this article, see Table A.

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Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
0.405	acre	hectare, ha
0.454	pound, lb	kilogram, kg
2.54	inch	centimeter, cm (10^{-2} m)
0.304	feet	meter, m
1.12	pound per acre, lb acre^{-1}	kilogram per hectare, kg ha^{-1}
9.35	gallon per acre, g acre^{-1}	liters per hectare, L ha^{-1}
5/9(oF-32)	Fahrenheit, °F	Celsius, °C
2.24	ton per acre, ton acre^{-1}	megagram per hectare, Mg ha^{-1}

practice to reduce weeds in wheat throughout the world (Daugovish et al., 1999). Winter canola is considered to have a high rotational capability with winter wheat systems, allowing producers the chance to reduce competitive grass weeds in their fields. As winter canola is a broadleaf crop, many studies have noted the effectiveness of more effective, less expensive herbicides on grass weeds compared with those needed in cereal crops (Norton et al., 1999; Zollinger, 2013; Assefa et al., 2014). According to Bushong et al. (2012), incorporating winter canola into a winter wheat rotation resulted in significantly higher wheat yield than could be achieved in a continuous wheat system.

In the Southern Great Plains, winter canola is grown instead of spring canola because harsh summer conditions reduce the grain filling period and reduce yields (Boyles et al., 2006). Winter canola has had a significant yield advantage over spring canola species by as much as 50% (Waalen et al., 2011). However, winter survival of winter canola is crucial for achieving these yields, as winter canola is sensitive to the rapid freezing conditions that are typical for the Great Plains. The development of winter-hardy canola varieties has been a continuous process. An increase in winter hardiness is required if winter canola is going to be successfully adopted across the Great Plains.

Genetics, planting date, growth stage during winter, crop residue management, and climate are major factors responsible for winter survivability of winter canola (Boyles et al., 2004; Siemens et al., 2004; Balodis and Gaile, 2010; Assefa et al., 2014). A common perception is that residue management is key in producing a successful winter canola crop in the Great Plains. In conservation systems, residue cover, residue thickness, and lack of seed-to-soil contact are the factors that negatively affect plant emergence, density, and winter survival (Siemens et al., 2004). The height of the growing point, or crown height, is an important factor in winter survival with higher crowns being more susceptible to winter damage (Holman et al., 2011, 2015).

Winter canola grown under conservation tillage has been suggested to be less successful compared with conventional tillage. Conventional tillage in this region typically consists of primary tillage with a chisel or disks followed by seed bed preparation and weed control using a cultivator, which results in less than 30% residue cover. In conservation tillage systems such as no-till, the residue is thought to force crown elongation and make the canola plant less winter hardy (Wuest et al., 2000; Godsey et al., 2008; Jones, 2015). Several studies have been conducted to evaluate some of these claims; yet, the research on tillage and its effect on plant density, winter survival, and yield have been mixed (Holman et al., 2011; Assefa et al., 2014). For example, Holman et al. (2011) reported no significant difference in winter survivability of winter canola under no-till compared with conventional tillage while Assefa et al. (2014) noted that conventional tillage resulted in better winter survival than no-till. However, both studies also reported that planting time in fall was critical for higher rate of survival.

The idea behind residue management for a successful canola stand is to increase the seed-to-soil contact. Poor planting into high-residue conditions may lead to germination of seed below residue but above the soil surface, resulting in exposed crowns, increasing the potential to have higher winter-kill. There are several residue management strategies, which include conventional tillage, burning of residue, modified drills for seeding, and modified tillage equipment. Each residue management strategy has its benefits and drawbacks regarding soil health and weed management (Bailey and Lazarovits, 2003; Mills and Fey, 2004; Chan et al., 2003), the discussion of which is beyond the scope of this manuscript. In this study, vertical tillage, harrow till, no-till, and burning of previous crops residue were evaluated on winter canola survival, stand count, and yield. These treatments were selected because they offer alternatives to no-till producers who do not want to revert back to conventional tillage in their efforts to grow canola. Therefore, the objective of this research was to evaluate and compare the impact of different residue management strategies on stand count, winter survival, and yield of winter canola compared with no-till in the Southern Great Plains.

Field Experiment

Field experiments were established in 2014 and continued through 2016. Since the experiment was set in rotation with wheat, the experiment site was relocated every year

Table 1. Agronomic operations dates during each growing season.

Operation	2014	2015	2016
Harrow	14 Aug. 2014	02 Sept. 2015	19 Aug. 2016
Vertical tillage	14 Aug. 2014	02 Sept. 2015	19 Aug. 2016
Burn	02 Sep. 2014	12 Sept. 2015	20 Aug. 2016
Planting	17 Sep. 2014	20 Sept. 2015	10 Sept. 2016
Harvest	6 June 2015	31 May 2016	

Table 2. Dates of collection for stand count, crown height and yield data

Sites	Stand count/crown height			Yield
Site 1, 2014	3 Oct. 2014	19 Nov. 2014	13 Feb. 2015	6 June 2015
Site 2, 2015	15 Nov. 2015	15 Dec. 2015	1 Feb. 2016	31 May 2016
Site 3, 2015	15 Nov. 2015	15 Dec. 2015	1 Feb. 2016	31 May 2016
Site 4, 2016	11 Nov. 2016	12 Dec. 2016	2 Feb. 2017	

to follow winter wheat. A total of four experimental sites were established in Fairview, OK. Site 1 (36.255N, 98.501W) was established in 2014, Site 2 (36.275N, 68.492W) and Site 3 (36.275N, 98.491W) were established in 2015, and Site 4 (36.212N, 98.460W) was established in 2016. Two sites were established in 2015 due to differences in prior wheat performance. In 2015, Site 2 was specifically established in wheat stubble from a 30 bu acre^{-1} wheat crop, which is typical for the area. In contrast, the wheat stubble in the field where Site 3 was established was from a wheat crop yielding approximately 49 bu acre^{-1}. The soil type on Site 1 was Mclain Silty Clay loam (fine, mixed, superactive, thermic Pachic Argiustolls), Site 2 and 3 had Port Silt Loam (fine, mixed, superactive, thermic Pachic Argiustolls), and Site 4 had Pond Creek Silt Loam (fine-silty, mixed, superactive, thermic Pachic Argiustolls). The mean annual rainfall in Fairview is 28.1 inches, and mean annual temperature is 59°F. The experiment design at all locations was a randomized complete block design consisting of six treatments that were replicated three times. There were six treatments, including three vertical tillage treatments (at three different levels of disruption), harrow, burn, and no-till. Weeds and insects were controlled using standard procedures recommended for this area. Plots were 30 ft wide and 100 ft long.

Vertical tillage treatments were applied using a Great Plains Turbo-Max 3000TM (Great Plains Manufacturing, Inc., Salina, Kansas) at three different gang angles of 0°, 3°, and 6° set at 3 inches deep, which represents three vertical tillage treatments. These three gang angles resulted in increasing levels of surface disturbance and residue burial with the 0° treatments having the least disturbance and 6° having the greatest. The Turbo-Max was pulled at 9.5 mph. A harrow was also applied the same day, and it was pulled twice in the opposite direction the same day. For burn treatment, a roto-tiller was applied to the borders of the burn treatment to facilitate containment, and fire was prescribed 8 days later. Canola was planted at 3.5 lb acre^{-1} on 15-inch rows with Sitro cultivar (Rubisco Seeds LLC, Philot, KY) planted in 2014 and Dekalb hybrid 44–10 planted in 2015 and 2016 (two different cultivars were used because of cooperator preferences). Diammonium phosphate was applied in furrow at the rate of 10 lb acre^{-1} at planting, and in early March, urea ammonium nitrate and ammonium thiosulfate (12–0–0–26S) were topdressed at rates of 15.0 and 3.0 gal acre^{-1}, respectively. Canola was harvested using a Winterstiger plot combine (Winterstiger Inc., Salt Lake City, UT), which harvested 4.92 ft from the center of each plot. Table 1 shows the timeline for tillage, harrowing, burn, planting, fertilization, and harvesting.

Stand counts were conducted in each experiment during growing season using five 3.3 ft long rows in each plot, which were marked to allow for continual assessment throughout the season. Crown heights were measured in three of the 3.3 ft long rows that were previously marked for stand count. This procedure was done on each plot. Canola yield was determined using a Winterstiger plot combine (Winterstiger Inc., Salt Lake City, UT) used for harvest. The dates for measurement for each location are provided in Table 2.

Stand count, crown height, and yield were analyzed using the SAS 9.2 (SAS institute, Cary, NC) statistical software package. Analysis of variance to evaluate treatment effects on yield was conducted using PROC GLIMMIX where treatment was considered a fixed effect, and site and replication as well as all associated interactions were considered as random effects. For stand count and crown height, analysis of variance was conducted using PROC GLIMMIX with treatment, sampling date and their interaction as fixed effects, and site and replications along with their associated interactions as random effects. Means for yield, stand count, and crown height were separated using the LINES option (SAS, 2006). Treatment differences were considered significant at the $P < 0.05$ level.

Weather

Figure 1 shows air temperature and rainfall measured at the local mesonet station (within 5 mi of experimental sites) during growing seasons from planting to crop maturation (assumed to be 31 May of following year). The average maximum temperature was 62.3°F, 65.3°F, and 66.9°F for the 2014–2015, 2015–2016, and 2016–2017 growing seasons. The average minimum temperature was 39.8°F, 41.1°F and 42.3°F during 2014–2015, 2015–2016, and 2016–2017 growing seasons, respectively. Despite slightly higher average maximum and minimum air temperature, year 2016–2017 registered minimum air temperatures of 4°F in the last week of December. Minimum temperature in 2014–2015 and 2015–2016 occurred in January and was 13.9°F and 17.2°F, respectively. Maximum air temperature was observed to be 95.4°F (September) in 2014–2015, 94.0°F (May) in 2015–2016, and 97.3°F (September) in 2016–2017. Rainfall followed regular seasonal trends with the majority of the rain received from April onward when the crop was progressing toward maturation. Cumulative rainfall was maximum in the first growing season (23.9 inch)

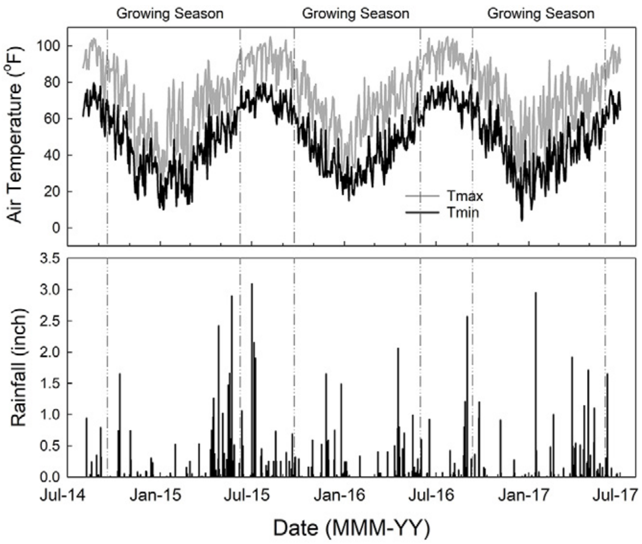

Fig. 1. Daily maximum and minimum air temperature and rainfall measured at the local mesonet station in Fairview, OK. The gray dashed-dotted lines indicate growing seasons (planting to harvest) 2014–2015 and 2015–2016. Plants did not survive during the 2016–2017 growing season; however, growing season termination was assumed to be 31 May.

while cumulative rainfall was almost similar in the later two growing seasons (19.2 and 20.4 inches in the 2015–2016 and 2016–2017 growing seasons, respectively).

Stand Count

Stand count data are presented for each site and sample date collected to allow for an assessment of stand loss over time (Fig. 2). The stand count data were presented for individual sampling dates, as a significant treatment by sampling date by site interaction was observed. At Site 1, only the first sampling date (3 Oct. 2014) showed a significant difference in stand counts among treatments. At this sampling date, vertical tillage at gang angle 0° and 3° was significantly higher than the no-till and harrow treatments. Also, the harrow treatment was lower than all treatments except the no-till treatment. At the other two sampling dates, no significant differences were noted between any treatments. At Site 2, analysis of individual sampling date did show that stand count for vertical tillage at the 3° gang angle was significantly higher than the vertical tillage at the 0° and 6° gang angle on last date of sampling. At Site 3, sample date had a significant impact on stand count as the stand count declined from 11 Nov. 2015 to 2 Feb. 2016. Furthermore, analysis of data within individual sampling date showed significant differences at the second sampling date of 12 Dec. 2015. At this date, no-till was significantly higher than the

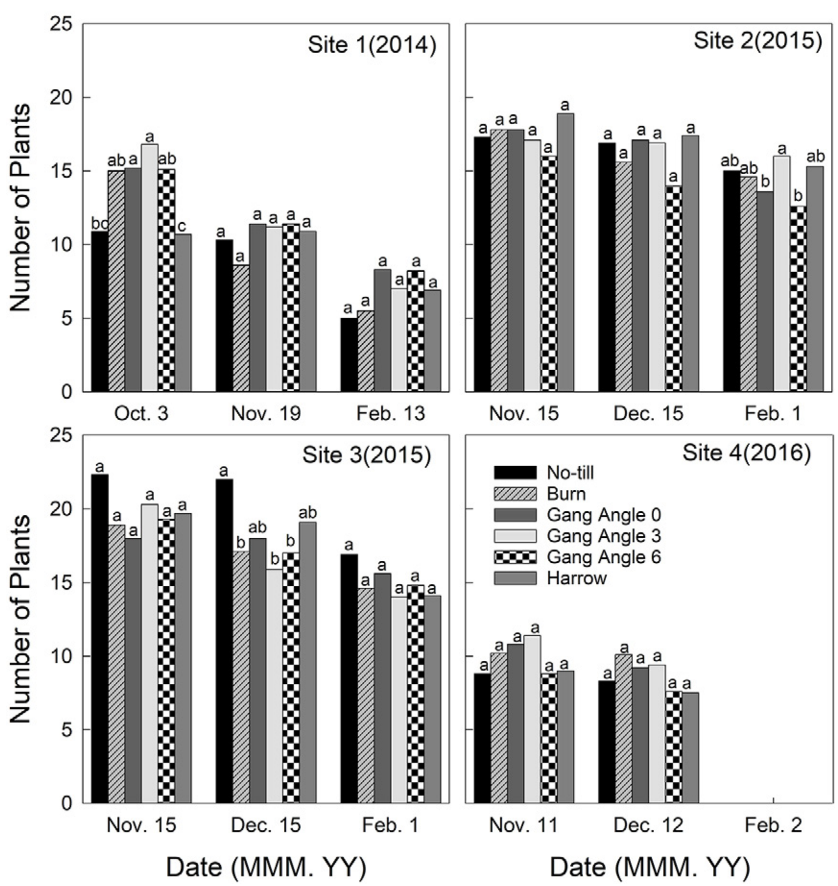

Fig. 2. Average stand count in five random 3.3-ft-long strips in each plot for treatments, measured at different dates. Bars with different letters are significantly different at p < 0.05.

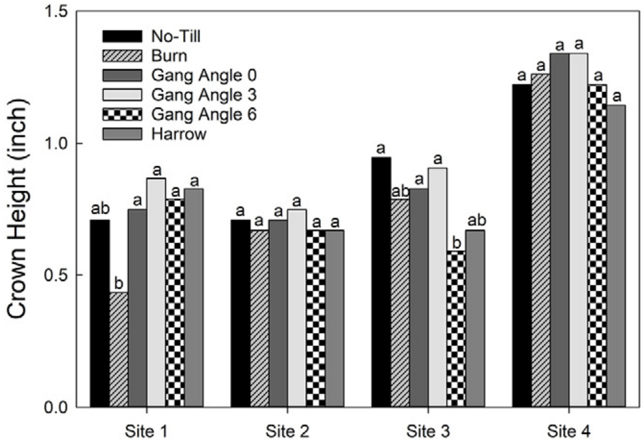

Fig. 3. Average crown height (inch) measured at three random 3.3-ft-long strips in each plot measured at different sites. Bars with different letters are significantly different at $p < 0.05$.

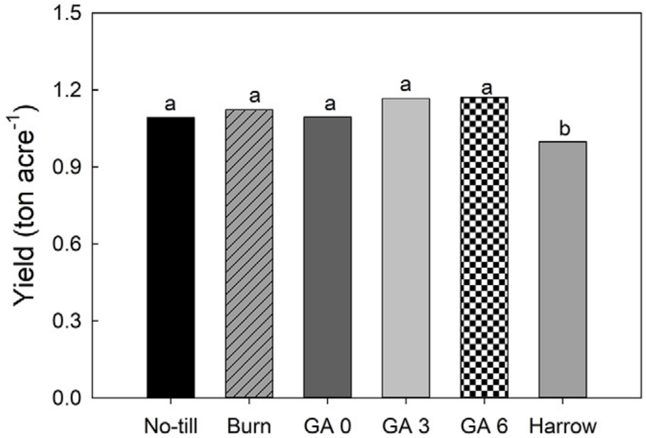

Fig. 4. Canola yield average across site-years. No treatment by site-year interaction was found in the data; therefore, the yield data was average across site and year. GA stands for gang angle. Bars with different letters are significantly different at $p < 0.05$.

burn and vertical tillage gang angle 3° and 6° treatments. At Site 4, there was no significant differences detected among treatments. However, the greatest loss in stand occurred at this location when complete termination of the crop occurred prior to 2 Feb. 2017. The minimum air temperature between 3 Dec. 2016, and 25 Dec. 2016 was much lower than in the previous 2 years. The temperature during this period was below freezing and reached its lowest on 15 Dec. 2016 (Fig. 1). Minimum air temperature was also lower between the periods of 1 Jan. 2017 to 3 Jan. 2017 than the previous years. During this period, minimum air temperature was below freezing and reached its lowest at 10°F (Fig. 1). A similar situation was reported by Showalter (2013) in Kansas where winter canola research plots were abandoned due to plant mortality resulting from extreme low temperature.

The significant difference in stand count on first sampling date was observed only on Site 1, where no-till and harrow resulted in a lower stand count than other treatments, indicating that surface residue impacts stand establishment in only 1 out of 4 site year. Site 2 was the only site year where the stand in February was significantly impacted by treatment. Here the 0° and 6° vertical tillage treatments had lesser stands than the 3° vertical tillage treatment. Collectively, the data show that treatment effect on stand count is highly inconsistent and that lower stands are not always associated with treatments containing elevated surface residue (no-till). In fact, the stand count in the no-till treatment was not found to be significantly lower than the burned treatment on any of the observation dates.

Crown Height

Crown height measurements showed treatment by year (site) interaction, but no treatment by sampling date interaction; therefore, data were pooled across observation dates, and treatment means were analyzed and presented for each site (Fig. 3). At Site 1, the burn treatment had a significantly shorter crown when compared with all other tillage treatments except the no-till treatment, which was not significantly different than the remaining treatments. At Sites 2 and Site 4, there were no significant differences detected across treatments. Our results from Site 1 agree with those of Showalter (2013), who reported a significantly lower crown height in the burn treatment compared with other residue management practices. At Site 3, significant differences were detected across treatments. At Site 3, gang angle 6° registered a lower crown height than no-till and gang angle 0° and 3 ° treatments but was not statistically different than burn and harrow treatments. The elevated crown height observed in Site 3 can be attributed to above-average temperatures in the 2016 fall combined with sufficient moisture for rapid canola growth. The limited occurrence of a significant treatment response and inconsistency in treatment response suggests that differences across years is more important in determining crown height than tillage treatments. This conclusion agrees with that of Showalter (2013) and Wysocki and Sirovatka (2009) who reported that environmental conditions were a major factor for canola survival response and yields in row-spacing treatments.

Canola Yields

Canola grain yields averaged across all sites are presented in Fig. 4. There was no treatment by site interaction for yield data; therefore, yield was averaged across sites. No significant difference in yields were found among the treatments, except for harrow treatment, which resulted in significantly lower yield than all other treatments. The harrow treatment had the lowest yield at 1.0 ton acre^{-1}. The no-till treatments had a mean grain yield of 1.1 ton acre^{-1} and were not statistically different compared with the vertical tillage treatments. A possible explanation for the lower yield in the harrow treatment could be due to crusting of the soil surface (visual observations), which resulted in lower water infiltration capacity (Panachuki et al., 2006; Santos et al., 2014). Research by Angadi et al. (2003) found that the number of pods produced by the main and secondary branches increased as plant population decreased. This would suggest that stand analysis data are not indicative in final yield data. Holman et al. (2011) also noticed that earlier-planted winter canola, which had a higher crown height and lower plant density, displayed higher winter survival compared with later planting dates. As stated earlier, in Site 4, winter freeze terminated the canola crop before sampling could be done. Yield data were not available for Site 4, so it was not included in data analysis. The range of yields from different treatments in our study were within the range reported by McCauley (2014) and Showalter (2013) in Kansas.

Conclusions

Crown height and stand count data showed that although differences were detected in some site years, they were not consistent. Canola yield analysis resulted in no significant treatment by site year interactions. However, canola yield averaged across sites showed the harrowed treatment was significantly lower than all other treatments. The no-till treatment yield was not significantly different compared with the vertical tillage or burn treatments. These data show that residue management did not improve overall yield. Overall, our data would suggest that conservation tillage does not significantly impact crown height, stand density, and yield of winter canola.

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