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Effects of Planting Date on Winter Canola Growth and Yield in the Southwestern U.S.

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Abstract

Canola (*Brassica napus* L.) has potential to become alternative cash crop (healthy oil for human and meals for animal uses) with tremendous rotational benefits in the Southwestern U.S., a region dominated by cereal-fallow cropping systems. However, information on optimum planting date for its successful production is limited. Field experiments were conducted in 2011-12 and 2012-13 seasons under irrigation condition to study the response of canola growth and yield to planting dates at Clovis, NM. Three planting dates (mid-September, late-September and early-October) and four canola varieties (early flowering: DKW41-10 and DKW46-15; medium flowering: Riley and Wichita) are studied. Fall plant stand density is significantly higher for early-October than mid- and late-September plantings. However, a ratio of fall to spring plant stand density indicates a greater reduction in spring plant stand density with early-October (25%) and mid-September (19%) than late-September (7%). Vegetative (by 13 days) and flowering (by 7 days) duration phases are significantly shortened with delay in planting. The decline in aboveground dry matter (DM) due to delayed planting resulted in significant seed yield reduction in both 2011-12 (26%) and in 2012-13 (8%) when early-October and mid-September plantings were compared. There was a positive relationship between final DM and canola seed yield, accounting for 84 and 34% variation for 2011-12 and 2012-13 seasons, respectively with the 2011-12 environmental conditions being conducive for genetically controlled variation in DM production to be more apparent and strong in explaining the variation in seed yield among varieties. Medium-flowering varieties produced higher DM (9741 vs. 8371 $Kg \cdot ha^{-1}$) and seed yield (2785 vs. 2035 $Kg \cdot ha^{-1}$) than early-flowering varieties. In addition to seed yield, DM can be used as an indirect selection criterion for seed yield in variety selection and appropriate planting dates including a guarantee for high crop residues (~75% of the total aboveground biomass) production to make canola a potential alternative cash and rotational break crop in the Southwestern U.S.

Keywords

Alternative Potential Crop, Planting Dates, Yield, Diversity, Southwestern U.S.

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1. Introduction

Canola has become the second largest oil crop after soybean in the world in just two decades [1] [2]. Recent rapid increase in production is associated with increases in demand for oil (as healthy oil for human use) and meal for animal feed [3]. USA's share of the world canola production was still small (spring and winter canola combined with 0.655 and 1.002 million tons in 2008 and in 2013, respectively) but had increased substantially. Canola's benefits as a good break/rotational crop are also another factor for the increase in canola production in a region with cereal-fallow or continuous cereal based cropping systems [4]-[8]. Grower's interest in winter canola in the Southern Great Plains of the USA is increasing in part to the benefits mentioned above and the crop's good fit to the growing conditions and cropping systems of the region. Winter canola production area has increased from about 20,000 in 2009 to over 73,000 ha in 2012 in the Southern Great Plains [8]. Moreover, the value of canola's meal after oil extraction from seed crushing is potential protein rich animals feed for the large dairy and beef industries that exist in west Texas and eastern New Mexico. Thus, there is a market for growers to sell their seeds to a crushing company easily since seed crushing plants are available in the region. However, there is limited information on optimum planting date for winter canola in this region, the Southwestern U.S. in particular.

Planting date is one of the most important and manageable agronomic practices that affect growth, dry matter production, quality and yield of crops [9]-[16]. With other plant growth affecting factors being unlimiting, early planting has been generally found to improve crop growth and yield compared to late planting of both spring and winter type crops. Unlike spring crops, winter crops have to overwinter and appropriate planting date is even more crucial for the crops to establish well in the fall and overwinter and resume growth in spring and make economical yield. Finding winter survival canola varieties for the region has been a challenge but progress has been made by breeders of both public and private organizations with the development of varieties that are winter tolerant and yields comparable to other winter canola growing areas of the world [8]. New Mexico, as part of the Southwestern U.S., is one of the states where the national winter canola variety test is being conducted and its winter survival and yield potentials being documented [17].

The planting window for canola in the Southern Great Plains is wide ranging from mid-August to mid-October. Planting too early can lead to large plants resulting in excessive water and nutrient use while too late planting can produce small plants that are prone to winter kill [15] [16]. For canola seed to emerge and have two unfolded leaves, it will require about 218-324 growing degree days [18] which can be achieved with even early-October planting in the Southwestern U.S. Unlike spring crops, however, good emergence in winter crops is not a guarantee for final good plant stand since final plant stand is determined by spring not by fall plant stand, and this in turn can be affected by weather and cultural practices including planting date. It was reported that later planting date (October 15) for canola in Kansas produced higher fall plant stand than mid-August, early-, mid- and late-September plantings in one of two years studies. In this study, spring plant stand was reported to be not different among the earlier planting dates, however later planting dates (late-September and mid-October) despite having higher fall plant stand, plants did not survive the winter [15]. A study done in China showed that winter extreme low temperatures resulting from late plantings (passed early-October) damaged established canola leading to significant yield reduction [16]. A study done in Australia on canola and mustard showed that a yield potential of early planting over later planting if plants of early plantings are not affected by spring frost damage during flowering and grain filling [13]. Generally, vegetative growth and maturation periods are affected by planting date leading to dry matter production and yield difference between early and late planting dates.

Several researchers have reported a positive relationship between dry matter production (both at flowering and maturity) and seed yield of many crops including canola, with the higher the dry matter the higher the seed yield which, in turn, can be affected by planting dates [9]-[14] [16] [19] [20]. A biomass of 5000 $Kg \cdot ha^{-1}$ at flowering has been suggested for canola as maximum enough for maximum yield with little yield advantage for crops with higher levels of biomass [21] [22]. However, several studies done in different parts of the world showed an increase in seed yield with an increase with biomass both at flowering and maturity [13] [16] [20] [23]. A study done in Australia [19] using measured data and a simulation model reported a 3% to 9% canola seed yield reduction per week of planting date delay for the high and low rain regions, respectively. A study done in China using method mentioned above reported a yield penalty due to delayed planting (passed early-October) by as much as 20% [16]. A study done in Kansas showed that seed yield reduction by 18% with mid-September and mid-August compared to early-September plantings. The Kansas research, canola planted after September 15 did not consistently survive winter resulting in no seed production [15]. In the Southeastern U.S. where winter is milder than the above mentioned regions, canola seed yield was significantly reduced with mid- and late-October planting compared to early-October planting [24]. On the other hand, oil content was reported to be positively related to harvest index and seed size and negatively to temperature conditions post-anthesis [13] [16]. The economy of winter oilseed rape cultivation is determined primarily by the achievable seed yield and less by oil content [25]. The biological yield of winter oilseed rape is the product of growth rate, duration of vegetative period, and seed filling [26] [27] which, in turn, can be affected by genetic, environmental, agronomic factors and the interaction between them [28]-[31]. Planting date is one of the most important and manageable agronomic factors that can affect crop production including canola. However, there is limited information on optimum planting date for successful winter canola production and hence an increase in production areas in the Southwestern U.S. The objective of this study was to investigate the response of growth and yield of canola to planting dates under Southwestern U.S. growing conditions.

2. Materials and Methods

2.1. Experimental Site and Design

The study was conducted during the 2011-12 and 2012-13 growing seasons at the New Mexico State University Agricultural Science Center at Clovis (34.60˚N, 103.22˚W, elevation 1331 m). Soil type was Olton clay loam (Fine, mixed, superactive, thermic aridic paleustolls). Soil test resulted in 29.1 ppm N, 32.8 ppm P and 606 ppm K with pH of 7.5 and organic matter of 1.4% in 2011-12 and 28.9 ppm N, 16.7 ppm P and 456 ppm with pH of 7.5 and organic matter of 1.9% in 2012-13 growing seasons. Fertilizer was pre-plant soil incorporated (100.8-0-39.2-15.9 and 78.4-0-28.0-12.7 Kg·ha^{-1} N-P_2O_5-K_2O-S for 2011 and 2012, respectively) based on soil test results. The previous crop for both growing seasons was corn. In both years, herbicide Treflan (trifluralin) at the rate of 2.4 L·ha^{-1} was soil incorporated before planting for weed control. Hand-hoeing was also done as needed. Insecticide Intrepid (methoaxyfenozide and propylene glycol) at16.8 L·ha^{-1} and Corgan (chlorantraniliprole) at 350 mL·ha^{-1} were applied in spring to control insects, diamondback moth (*Plutella xylostella*) in particular in 2011-12 season. In 2012-13 season insecticides mixture of Dimethoate at 1.4 L·ha^{-1} and Acephoate, and Lannate (methomyl) at 4.2 L·ha^{-1} targeting flee beetle (*Phyllotreta* spp.) in particular and a mixture of Baythroid (beta-Cyfluthrin and cyclohexanone) at 196 mL·ha^{-1}, and Prevathon (chlorantraniliprole) at 980 mL·ha^{-1} targeting harlequin bugs (*Murgantia histrionica*), flee beetle, lygus bugs (*Lygus* spp.) and moth larvae in fall and Trimax (imidacloprid) at 350 mL·ha^{-1} targeting false chinch bugs (*Nysius raphanus*), green peach aphid (*Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*) and harlequins in particular were applied in late spring and a mixture of Dimethoate at 1.4 L·ha^{-1}, Brigade (bifenthrin) at 420 mL·ha^{-1} and Brinstar at 5.6 L·ha^{-1} targeting harlequins, lygus bugs was applied in June of 2012-13 growing season. The application rates of herbicide and insecticides were determined based on the recommendation for weed and insect control indicated in the Great Plains canola production handbook.

In both years, canola was planted into a conventionally tilled seedbed under sprinkler irrigations. The row spacing was 0.15 m with a plot having 11 rows. Plot size was 9.14 by 1.68 m. Canola was planted with a plot drill (Model 3P600, Great Plains Drill) at seeding rate of 6.7 Kg·ha^{-1} in both years and this is within the recommended seeding rate for canola production in this region. The experimental design was a randomized complete block with split plot arrangement replicated four times. The main plots had three planting dates (September 19 as mid-September, September 28 as late-September and October 7 as early-October). The subplots were 4 canola varieties (early flowering/maturing: DKW 41-10, DKW 46-15 and medium flowering/maturing: Riley and Wichita). The canola varieties were selected based on yield potential, flowering/maturity groups and seed availability. The early flowering/maturing (open pollinated and Roundup Ready) varieties were from Monsanto while the medium flowering/maturing (open pollinated) varieties were from Kansas State University.

Growing season weather data were collected from a National Weather Service station located at the Agricultural Science Center at Clovis. Sprinkler irrigations were applied as needed throughout the growing season and more so from the time the crop started regrowth in spring (**Figure 1**). In April and early May of 2012-13 crops were irrigated more to encourage more regrowth so that the damage caused by the unusual repeated freeze occurred that year could be compensated. Precipitation was not adequate in both growing seasons (with total precipitation from planting to final harvest was only 215 and 193 mm for 2011-12 and 2012-13 growing seasons,

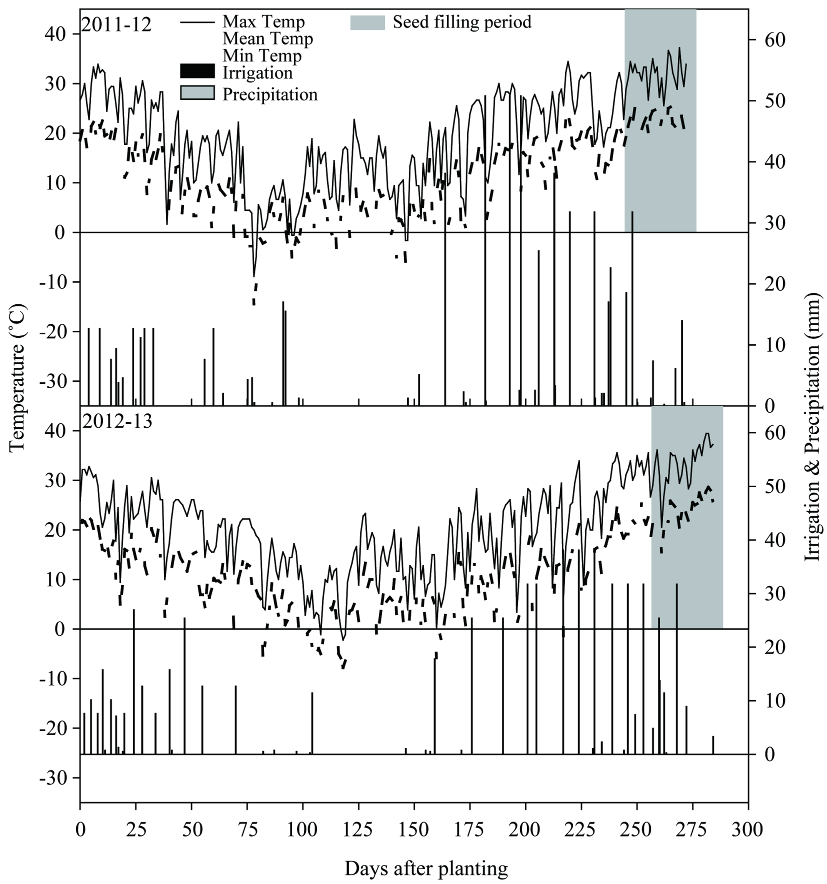

Figure 1. Daily minimum, mean and maximum temperature and daily irrigation and precipitation during 2011-12 and 2012-13 growing seasons.

respectively) resulting in 453.4 and 518.2 mm of irrigation water used in 2011-12 and 2012-13 seasons, respectively. Irrigation was terminated on May 26 and June 14, respectively, in 2011-12 and 2012-13 growing seasons. Daily irrigation and precipitation amounts along with daily minimum, maximum and mean temperature are presented in **Figure 1**.

2.2. Data Collection

Plots were assessed for fall and spring plant stand 2 rows of 1 meter taken from the center rows and converted into plant stand m^{-2}. A fall to spring plant stand ratio was also calculated which is a good indicator of winter survival. When there was 50% of the plants in the plot with 1 flower or more the date was noted as bloom date. In 2012 the bloom date occurred between March 24 through April 4, 2012 and while in 2013 because of cooler temperatures it occurred between April 4 through 21, 2013. In 2013 there was a repeated freeze (**Figure 1**) resulting in plant parts being damaged including flower parts, buds and small pods leading to a regrowth and re-bloom of plants. In the 2012-13 season, beside the above parameters, vegetative growth was assessed on samples harvested 2.5 cm aboveground within 0.25 m^2 area of each plots three times during the growing season. All plant samples were bagged and dried to a constant weight at 65˚C to calculate the aboveground dry matter. Final harvest at 2.5 cm aboveground within 2 m^2 of each plots were done on June 18 and July 2 for 2012 and 2013 seasons, respectively. Bagged plants samples were dried to a constant weight at 65˚C. Once total weight of each sample was recorded, samples were threshed with a plot combine (Model Elite Plot 2001, Wintersteiger, Ried, Austria) and seed were collected and weighed. Harvest index, the ratio of grain to total biomass (grain plus aboveground dry matter) was calculated for each plot. Seed oil content was also determined on seed samples sent to the Brassica Breeding and Research Lab at the University of Idaho and this also allowed calculation of oil yield (Oil yield, seed yield multiplied by seed oil content).

2.3. Statistical Analysis

Statistical analyses were performed using SAS PROC MIXED procedures in SAS 9.3 [32] to detect if differences existed between planting dates and varieties and their interactions with year. Significance was considered at $p < 0.05$ and protected LSD was obtained using the PDIFF statement in the LSMEANS option within SAS PROC MIXED to decide where differences occurred within significant interactions [33]. Regression functions were also fitted to the data and planting date of each growing season.

3. Results and Discussion

3.1. Environmental Conditions

The distribution of precipitation during the experimental periods varied between the years. Precipitation received during crop establishment and early plant growth stage (September through November) in the 2011-12 season (5 rain events with only one above 10 mm) was lower than the 2012-13 season (8 rain events with three above 10 mm). The opposite occurred during the later plant growth stage, especially during the month of March, April and May the time the crop is most active with flowering and podding process (9 rain events with two above 10 mm and 4 rain events with all below 10 mm, for the 2011-12 and 2012-13 seasons, respectively) (**Figure 1**). The number of rain events and amounts during seed filling in 2011-12 and 2012-13 seasons were similar (8 and 6 rain events for 2011-12 and 2012-13 seasons, respectively with 2 of them above 10 mm) and the growing period in both seasons can be considered as dry since the benefit from such rainfall events to the plants was limited. Total precipitation amount received during the 2011-12 (215 mm) and the 2012-13 (193 mm) growing seasons were similar (a difference of only 22 mm) but still not enough to grow a crop with only precipitation. Thus, this study was done under limited irrigation and 104 and 137 mm of irrigation water was applied for 2011-12 and 2012-13 growing seasons, respectively, during the early growth stage "emergence through roseate" (September through November). Irrigation amount applied during the latter active part of the growing seasons (flowering and seed filling periods) were 279 and 32 mm in 2011-12 and 241 and 89 mm in 2012-13 seasons (**Figure 1**).

Temperature pattern during the crop cycle varied between the 2011-12 and 2012-13 seasons. Daily temperature ranged from −8˚C to 34˚C (early growth stage), from −9˚C (12 minimum temperature events with below 0˚C) to 27˚C (beginning of regrowth to beginning of flowering), from −8˚C (6 minimum temperature events with below 0˚C, flowering and podding stages) to 34˚C (with 37 maximum temperature events above 21˚C), ranged from 9˚C to 37˚C (with 32 maximum temperature events above 21˚C and this is during the whole seed filling period) in 2011-12 season. Whereas in 2012-13 season, daily temperature ranged from −11˚C to 32˚C (early growth stage), from −12˚C (26 minimum temperature events with below 0˚C) to 28˚C (beginning of regrowth to beginning of flowering), from −9˚C (12 minimum temperature events with below 0˚C, flowering and podding stages) to 34˚C (with 44 maximum temperature events above 21˚C), from 9˚C to 39˚C (with 30 maximum temperature events above 21˚C during the whole seed filling period) in 2012-13 season. As seen with the above minimum temperature events, the 2012-13 season was a lot colder than the 2011-12 season during early growth, flowering and pod formation stages leading to longer time requirement for plants to reach those different stages including maturity (**Table 1**). The extreme and potentially yield limiting weather that occurred in 2012-13 season during flowering and early podding stages resulted in the loss of plant parts including flowers, buds and small pods. This, in turn, resulted in plants investing some of the resources for regrowth which otherwise could have been used for more pods and hence more seeds and possibly more yield.

3.2. Crop Establishment and Plant Stand

Canola establishment and subsequent fall plant stand density were good for all of the three planting dates (mid-September, late-September and early-October) in both 2011-12 and 2012-13 seasons. This was expected since the growing conditions including moisture through irrigation was favorable for the crop to establish well. Although the crop established well, as expected plants of late planting date were much smaller when winter arrived reflecting the shorter time and accumulated degree days resulting from the delay in planting. There was a significant year x planting date interaction effect ($p < 0.0001$) on fall plant stand density. The highest fall plant stand density was recorded for early-October (133 plants·m^{-2}) and mid-September (128 plants·m^{-2}) plantings in 2011-12 and mid-September planting in 2012-13 (127 plants·m^{-2}) seasons. Groups with second and third for fall

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