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Effects of row-spacing and stubble height on soil water content and water use by canola and wheat in the dry prairie region of Canada

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ABSTRACT

Studies were conducted to examine the effects of row spacing and stubble height on surface soil water content, water use, yield, and water use efficiency of canola and wheat in the drier regions of the Canadian prairies. For this purpose, randomized complete block design trials were implemented separately in canola and wheat fields at Central Butte and Swift Current in the Brown soil zone of southwestern Saskatchewan. At each experimental site, two factors and two levels for each factor, i.e., 30- and 60-cm row spacing and 15- and 30-cm stubble heights, were included. Wider row spacing and taller stubble generally increased soil water content for the surface 0–30 cm soil depth, and taller stubble often had greater spatial variability of surface soil water content at both locations. Row spacing or stubble height had minimal effect on water use for both crops at both locations over the two years (2012 and 2013). Yield and water use efficiency of 30-cm row spacing were 1.3–1.6 (Central Butte) and 1.0–1.2 (Swift Current) times greater than those of 60-cm row spacing. Stubble height had little effects on yield and water use efficiency. There were no interactions of row spacing and stubble height on water use, yield, and water use efficiency for either crop. Overall, 30-cm row spacing and 30-cm stubble tended to increase surface soil water content, yield, and water use efficiency for most crop type, year, and site combinations.

1. Introduction

Row spacing affects crop access to water and nutrients, competition with weeds, use of sunlight, and energy consumption. Numerous studies have demonstrated that the yield of cereal crops increased with reduced row spacing in different regions of the world (Tompkins et al., 1991; Amjad and Anderson, 2006; Chen et al., 2008). However, there were no row spacing effects on spring wheat and winter wheat in Saskatchewan, Canada (Lafond and Gan, 1999; Johnston and Stevenson, 2001) and in the North China Plain (Chen et al., 2010). While most studies found that canola yield was higher for narrower row spacing in different regions (Kutcher et al., 2013; Liu et al., 2014), a higher canola yield was also observed for wider row spacing under coastal climatic conditions of Lasbela (Waseem et al., 2014). Therefore, row spacing effects may depend on specific climatic conditions of an area, and yield component compensation may contribute to non-decreasing crop yields with wider row spacing in some regions.

In the Brown and Dark Brown soil zones of the Canadian prairies, the potential evaporative demand for water usually exceeds the water available to the crop, representing the greatest limitation to crop production in this semiarid region (Cutforth et al., 2002). Therefore, to improve water use efficiency (WUE), especially in the drier regions of the prairies, is an important consideration for increasing yield. However, little information is available on yield and WUE for different row spacings in this area. Furthermore, most previous studies on wheat and canola focused on relatively narrow row spacings that is no wider than 30 cm, and few studies determine the row spacing effects at wider row spacing. The first hypothesis of this study was that the yield and WUE in the Canadian prairies are not affected by further increasing the row spacing due to the yield component compensation. If wider row spacings greater than 30 cm do not lead to significantly reduced yield and

Abbreviations: ANOVA, analysis of variance; SWC_s, soil water content of surface 0–30 cm depth; SWS, soil water storage; T_{mx}, daily maximum temperature; WU, water use; WUE, water use efficiency; Y, yield.

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WUE, the benefit associated with wider row spacing would be significant because the draft requirement for a given width of seeding implement can be reduced.

Studies in the Brown soil zone of the Canadian prairie have indicated that seeding into tall stubble (30 cm) increased yield and WUE of wheat, pulse, and canola by more than 10% compared to seeding in cultivated cereal stubble (Cutforth and McConkey, 1997; Cutforth et al., 2002). Recently, Cutforth et al. (2011) observed that extra-tall (45 cm) stubble can further increase crop yield of canola, pulse, and wheat. However, the effects of stubble height on crop yield and WUE were evaluated with row spacing narrower than 30 cm (i.e., 18–23 cm). The stubble height effects may decrease due to less stubble height effects on microclimate at wider row spacing. In addition, soil temperature and mid-canopy radiation are reduced by tall stubble compared to short or cultivated stubble, especially in early growth stages, adversely affecting crop growth (Wilkins et al., 1988). Therefore, the second hypothesis of this study was that stubble height effects on crop yield and WUE are absent at wider row spacing (≥30 cm) in the dry region of the Canadian prairies.

While the effects of agricultural management such as irrigation, tillage, and surface cover (Elmaloglou et al., 2010; Huang et al., 2014) on surface soil water content are well documented, little research has been done on the combined effects of row spacing and stubble height on surface soil water content and its spatial variability. Row spacing and stubble height may affect soil surface exposure to rainfall, snow, radiation, and wind, resulting in changes in surface soil moisture and its spatial variability, which in turn affect both water and temperature conditions for crop growth.

The objective of this study was to examine whether row spacing and stubble height had any significant impact on surface soil water content, water use (WU), yield, and WUE of canola and wheat at two locations in southwestern Saskatchewan where soil water stress is likely to be encountered.

2. Materials and methods

2.1. Experimental treatments

Two study sites were selected. The Swift Current site located in the semiarid prairie in the middle of Brown soil zone and is generally drier than the Central Butte site which is located within the Brown soil zone but close to the boundary between the Brown and Dark Brown soil zones. The Swift Current site is dominated by Swinton loam soil (Orthic Brown Chernozem), with the A horizon underlain by a brownish B horizon with prismatic macrostructure. The Central Butte site is dominated by Ardill loam soil (Rego Brown Chernozem), which has a thin (<15 cm) A horizon under which is a very thin (<5 cm) B horizon. The bulk density, pH, and organic carbon content of surface soil (0–15 cm) were 1.3 g cm^{-3}, 6.5, and 1.7% (Swift Current) and 1.1 g cm^{-3}, 6.8, and 1.2% (Central Butte), respectively. The soils at both sites are loamy textured with well drained conditions.

At each location, two separate randomized complete blocks, one for wheat and one for canola, with four treatments—row spacing's of 30-cm and 60-cm and stubble heights of 15-cm and 30-cm tall, were seeded in 2012 and 2013. Each treatment was replicated three (Swift Current) or four (Central Butte) times in both years. Each plot measured 3 m by 15 m at Central Butte and 15 m by 30 m at Swift Current. The Central Butte field was gently rolling while the Swift Current field was flat.

At Central Butte, wheat (Hard red spring wheat var. Waskeda) was seeded in the canola stubble and canola (Argentine canola var. LL120) was seeded in the wheat stubble. At Swift Current, wheat (durum wheat var. Stronfield) was seeded in the canola stubble and canola (Argentine canola var. LL120) was seeded in the wheat stubble. Direct seeding was used in this study with an opener configuration on the seeder of point-type openers with a one inch spread. Seeding rates were 85 kg ha^{-1} for wheat and 4.7 kg ha^{-1} for canola at Central Butte, and the rates were 100 kg ha^{-1} and 9 kg ha^{-1}, respectively, at Swift Current. Adequate and uniform levels of N and P across the seeding area were provided at both locations by a preplant broadcast of 60 kg N ha^{-1} as urea and 30 kg P_2O_5 ha^{-1} as mono-ammonium phosphate so that the effect of row spacing could be evaluated without confounding effects of differences in fertilizer placement. No deficiencies of other nutrients were detected. Seeding, flowering, and harvest dates are shown in Table 1.

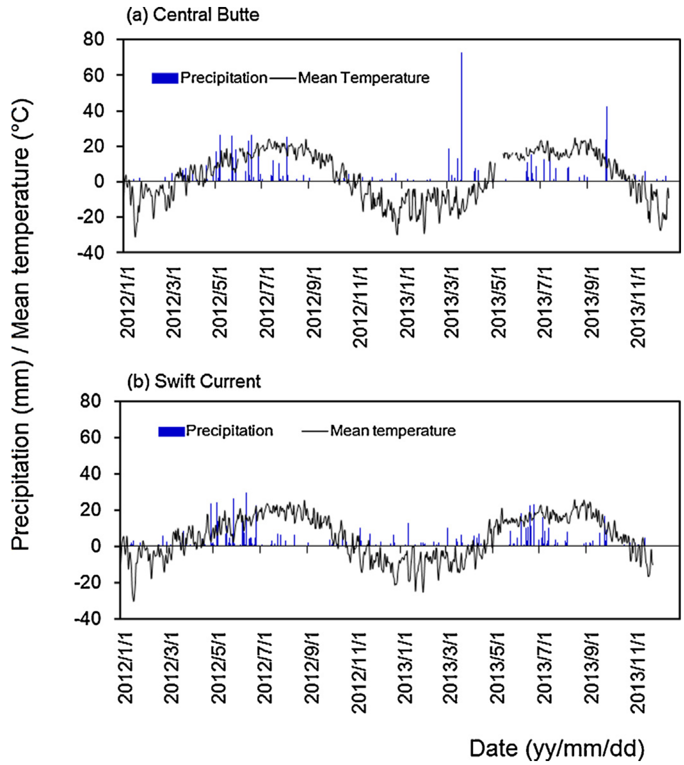

Fig. 1. Daily mean temperature and precipitation at (a) Central Butte and (b) Swift Current in years 2012 and 2013.

2.2. Measurements and calculations

2.2.1. Precipitation and temperature

Weather data for the Central Butte site was collected from the nearest weather station located at ELBOW CS station, which is 20 km north of Central Butte. Although spatial variability of precipitation existed, the monthly total rainfall amounts at these two locations was very close to justify the use of the detailed weather data of ELBOW CS station for calculating WU at the Central Butte site during the growing period. At Swift Current, weather data was obtained from a weather station within 1 km of the experimental field. Fig. 1 shows the daily precipitation (mm) and mean temperature (°C) in 2012 and 2013 at each location. Yearly total precipitation during the crop growing period was almost the same for the two years (211 vs 205 mm) at Swift Current, while it was much greater in 2012 (225 mm) than 2013 (121 mm) at Central Butte.

2.2.2. Soil water content of surface 0–30 cm layer

In 2013, the soil water content of the surface 0–30 cm depth (SWC_s) (in % on a volumetric basis) was measured at seven points along a transect 60 cm long with intervals of 10 cm using time