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Canola versus wheat rotation effects on subsequent wheat yield

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ABSTRACT

Winter canola (*Brassica napus* L.) (WC) is considered the most promising oilseed crop for diversifying wheat (*Triticum aestivum* L.)-based cropping systems in the Inland Pacific Northwest, USA (PNW). Canola serves as a break or non-host crop for many important soilborne pathogens of wheat and helps farmers control weeds. Most studies in the literature report that canola has a positive effective on subsequent wheat yield. We conducted a 6-yr field experiment near Davenport, WA to measure the effects of WC versus winter wheat (WW) on the subsequent production of spring wheat (SW). Averaged over the years, there were no differences between WC and WW in soil water use or overwinter water recharge into the soil following these crops. Subsequent SW had excellent plant stands, was weed free, was adequately fertilized, and had no foliar or root diseases. Root lesion nematode populations were miniscule and insignificant. Average SW seed yield following WC was 3292 kg/ha versus 3897 kg/ha following WW; a 17% reduction ($p < 0.0001$). Visual differences in SW plant height and spike density between treatments were also apparent. Spring wheat grain yield differences could not be attributed to the variables measured. This study provides novel information for ongoing efforts to promote and expand canola production and the influence of brassica crops on the subsequent performance of wheat.

1. Introduction

Crop rotation is considered an important tool for dryland wheat-based production in the intermediate precipitation (300-to 450-mm annual) region of the Inland PNW. This region encompasses 970,000 cropland hectares (Schillinger et al., 2006). The climate is Mediterranean-like with most precipitation occurring in late fall, winter, and early spring (Douglas et al., 1992). The typical 3-yr crop rotation in the intermediate precipitation zone is WW-SW-no-till summer fallow (SF). However, in the past 15 years, canola has been an important rotation crop in this area due to favorable economics with the increased interest in regionally-produced edible oil and oilseed feedstock for biodiesel production (Long et al., 2016; Maaz et al., 2018; Pan et al., 2016). This intermediate precipitation zone has been identified as especially suitable for WC production because successful plant stands from shallow planting depth in late August-early September can most often be readily obtained after a year of fallow.

Inserting a broadleaf "break crop" into a wheat-based rotation has been shown to provide rotational benefits to the subsequent wheat crop (Seymour et al., 2012; Kirkegaard and Ryan, 2014). This has been well documented around the world with legumes such as pea (*Pisium sativum* L.) and lentil (*Lens culinaris* L.) (Krupinsky et al., 2006; Arshad et al., 2002; Williams et al., 2014; Miller et al., 2003) as well as canola (Kirkegaard et al., 2008; Bushong et al., 2012; Harris et al., 2002; Irvine et al., 2013; Angus et al., 2015). There are several reasons for this phenomenon. Canola and/or legumes may use less soil water than wheat, an important benefit in Mediterranean rainfed cropping regions where crop yield is heavily dependent on stored soil water (Cutforth et al., 2013; Larney and Lindwall, 1994). Canola can serve as an excellent break or non-host crop for many important soilborne pathogens of wheat such as take-all (*Gauemannomyces graminis* var. *tritici*) (Smith et al., 2004; Angus et al., 2015). Canola provides a biofumigant effect against soilborne pathogens because of the breakdown products of glucosinolates (Smith et al., 2004; Smith and Kirkegaard, 2002; Angus et al., 2015). In-crop grass-weed herbicides can be used with canola and other broadleaf crops to effectively control downy brome (*Bromus tectorum* L.), jointed goatgrass (*Aegilops cylindrica* L.), and other troublesome grass weeds that are common in cereal monoculture cropping systems. Finally, some have attributed crop yield increases following canola to suppression of arbuscular mycorrhiza fungi (AMF) as canola is not a host of AMF which could be a sink for photosynthates in a wheat crop that does not need the benefit of increased phosphorous (P) update (Harris et al., 2002).

Research in the PNW has shown total optimal nitrogen (N) required

Abbreviation: PNW, Inland Pacific Northwest USA; SF, no-till summer fallow; SW, spring wheat; WC, winter canola; WW, winter wheat

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by WC and soft white WW (10% protein) is about the same (Koenig et al., 2011; Maaz et al., 2016; Pan et al., 2016). Phosphorous requirements for WC and WW are also similar for unit quantity of seed produced (Pan et al., 2016). Winter canola requires a higher rate of sulfur (S) than WW for optimum yield potential (Wysocki et al., 2007; Koenig et al., 2011; Assefa et al., 2018).

The objective of the field research described here was to evaluate the performance of WC versus WW as a prior crop to SW in a no-till dryland cropping system. The study was initiated on land that had been in monoculture cereal production for 140 years. Canola, or any other broadleaf crop, had never been previously grown on this land. We hypothesized that WC would provide a rotation benefit to the following SW crop. We documented soil fertility, soil water dynamics, plant stand establishment, weed pressure, foliar and soilborne diseases, and root-lesion nematodes in these two 3-yr cropping systems.

2. Materials and methods

2.1. Overview

A 6-yr on-farm dryland crop rotation experiment was conducted during the 2008–2014 crop years at the Hal Johnson farm (47.680667, −118.017391) located 9 km east of Davenport, WA. Long-term annual precipitation at the site averages 432 mm. Crop-year precipitation during the study period ranged from 342 to 510 mm (Table 1) and averaged 396 mm. Precipitation was recorded with a gauge installed and monitored by the Lincoln County Conservation District at Mondovi Corner within 0.5–3.0 km of all experiment sites through the years.

Soil is a Hanning silt loam (fine-silty, mixed, superactive, mesic Pachic Argixerolls) with no rocks or restricted layers and a depth of > 180 cm. Soil pH in the surface 30 cm at the site ranged from 5.5 to 5.9. Soil organic matter in the surface 30 cm at site locations ranged from 2.8 to 3.5% and averaged 3.2%. This site is considered among the most productive for rainfed farming in Lincoln County due to the deep soil, gently rolling terrain, and relatively abundant precipitation.

Two 3-yr crop rotations were compared. These were WC-SW-SF versus WW-SW-SF. Winter canola and WW were planted in a different area of the farm every year. No brassica, legume, or other broadleaf crop had ever been grown during the 140-year farming history of the land where the experiment was established in any of the six years. Winter canola and soft white WW were planted into SW stubble after a 12-month fallow period during the first two weeks of September. Spring wheat was planted directly into the standing stubble of the WC and WW (these crops were harvested the previous August) during the last two weeks of April. Thus, two sets of plots were present every year: (i) the WC and WW, and (ii) the SW after the harvest of WC and WW the previous year. All crops were direct seeded into the standing stubble of the previous crop with a no-till hoe-opener drill with 10 cm paired rows on 30 cm row spacing. Experimental design was a randomized complete block with six replications. Dimension of individual plots was 30 × 5 m.

Table 2
Quantity of nitrogen (N), phosphorous (P), and sulfur (S) fertilizer applied in late summer, spring-applied topdress fertilizer, and winter wheat (WW) and winter canola (WC) cultivars used and their seeding rates for each year of the study. Data for 2010 is not included because WC winterkilled that year.

Crop year	Summer-applied fertilizer (kg/ha)[a]	Spring-applied fertilizer (kg/ha)[b]	WW cultivar[c]	WC cultivar[d]
2008	99N-11P-22S	0	Tubbs/Eltan mix	Rapier
2009	99N-11P-22S	0	Tubbs/Eltan mix	Rapier
2011	78N-6S	78N-6S	Tubbs/Eltan mix	Amanda
2012	56N-11S	28N-6P	Legion	Amanda
2013	56N-11S	90N-22S	Xerpha	Amanda

[a] Summer-applied fertilizer was injected in Solution 32 formulation with the drill at time of planting in 2008 and 2009 and injected with a coulter implement with aqua NH_3 + thiosol S immediately before planting in 2011, 2012, and 2013.

[b] Spring-applied fertilizer was injected with a coulter implement with aqua N + thiosol S in 2011 and 2013. A Solution 32 formulation of N + P was stream jetted onto the soil surface before a spring rain event in 2012.

[c] Seeding rate for WW was 78 kg/ha in 2008, 2009, and 2011, and 90 kg/ha in 2012 and 2013.

[d] Seeding rate for WC was 6 kg/ha all years.

2.2. Fertilization, planting, and weed control

2.2.1. Winter canola and winter wheat

During the 12-month fallow cycle prior to planting WC and WW, glyphosate herbicide was applied to standing and undisturbed stubble from the previous SW crop at rates that ranged from 0.43 to 0.64 kg acid equivalent (ae)/ha to control weeds. An average of three glyphosate applications were made during the fallow period.

Cultivars used and fertilizer applications rates for WC and WW for every year are shown in Table 2. Fertilizer rates and application timing for WC and WW were always identical. During the first two crop years (2008 and 2009), all N, P, and S fertilizer was applied in Solution 32 formulation at time of WC and WW planting in a deep band between the paired seed rows and below the depth of seed placement. In subsequent years, aqua-N and thiosol-S fertilizer was injected into the soil with a low-disturbance fluted-coulter implement a few days before planting. The same fluted-coulter implement was then used to topdress N and S or N and P in mid-April as shown in Table 2.

Winter canola always received an in-crop application of quizalofop *p*-ethyl grass-weed herbicide at labeled rates in late April/early May to control wild oat (*Avena fatua* L.) and downy brome (*Bromus tectorum* L.). This herbicide was highly effective in controlling these weeds that are otherwise troublesome and difficult to control in cereal monocultures (Ostlie and Howatt, 2013).

During the six years, two different in-crop herbicide formulations were applied to WW at labeled rates in late April/early May to control both broadleaf and grass weeds. These herbicides were bromoxynil + MCPA and bromoxynil + fenoxaprop-*p*-ethyl.

Table 1
Crop-year (Sept. 1–Aug. 31) precipitation during the 6-year experiment at the Hal Johnson farm near Davenport, Washington. Data courtesy of the Lincoln County Conservation District.

Crop year	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Total
2008	14	22	31	79	85	17	43	16	20	23	10	15	375
2009	8	7	43	90	33	33	46	18	28	11	10	15	342
2010	15	51	35	50	39	25	38	36	64	71	18	5	447
2011	20	52	75	77	49	16	69	52	58	30	9	3	510
2012	4	18	32	26	41	25	82	39	26	79	1	20	394
2013	0	27	80	67	26	14	8	24	34	57	0	15	352
2014	39	10	38	15	13	46	65	35	23	41	0	25	351