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Wide row spacing for deep-furrow planting of winter wheat

William F. Schillinger[a,*], Stewart B. Wuest[b]

[a] Department of Crop and Soil Sciences, Washington State University, Dryland Research Station, Lind, WA 99341, USA
[b] USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, OR 97801, USA

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ABSTRACT

A tillage-based winter wheat (*Triticum aestivum* L.)-summer fallow rotation is practiced on 1.56 million cropland hectares in the low-precipitation (<300 mm annual) region of the Inland Pacific Northwest of the United States (PNW). Farmers use deep-furrow drills with rows spaced 40–45-cm apart to plant winter wheat (WW) as deep as 20 cm below the soil surface to reach moisture in summer fallow (SF). Conservation tillage methods have been successfully developed that preserve ample residue during SF to control wind erosion, but existing drills cannot pass through heavy residue without plugging; thus farmers are reluctant to adopt conservation-tillage practices. We conducted field experiments over 3 years at three sites using the same number of seeds row^{-1} (8 site years) and same number of seeds ha^{-1} (3 site years) with row spacing of 40, 45, 50, 55, 60, and 80 cm and measured effects on grain yield, grain yield components, straw production, and weed dynamics. With same number of seeds row^{-1} (seeding rate declined as row spacing widened) the highest average grain and straw yield was achieved with the 40 and 45-cm spacing with gradual decline as row spacing widened due to fewer spikes unit area^{-1} (SPU) and despite increased kernels spike^{-1} (KPS). Kernel weight (KW) was not a factor. With same number of seeds ha^{-1} (more seeds row^{-1} as row spacing widened) there were no overall differences in SPU, KPS, KW, and straw production among treatments and only a slight grain yield reduction at the two widest spacing treatments. Weeds were not an agronomic problem with any spacing treatment due to timely and effective in-crop herbicide application although weed dry biomass did increase slightly as row spacing widened. Our research suggests that row spacing for WW production in the dryland PNW can be widened to at least 50 cm and most likely 55 cm to facilitate conservation-tillage farming with equal grain and straw production compared to narrower row spacing currently used by farmers.

1. Introduction

The 2-year winter wheat-summer fallow (WW-SF) rotation is practiced on >90% of rainfed cropland in the dry region of the PNW because it is more stable and profitable than any other crop rotation scheme yet tested (Schillinger and Papendick, 2008). Tillage is used during the spring of the SF year to break soil capillary continuity to reduce water evaporation during the dry summer (Papendick et al., 1973; Wuest, 2010) to allow planting of WW into carryover soil moisture in late August or early September. Farmers use specially designed "deep-furrow" drills to push dry surface soil into ridges between furrows to place wheat seed into moist soil and to reduce the thickness of the soil layer through which WW seedlings must emerge. In order to place seed into moisture below the tillage layer without having it covered by more than 9–13 cm of soil, the row spacing must be wide enough to provide ample room for stacking dry soil into tall furrow ridges. Essentially all farmers in the region use either John Deere™ HZ or International Harvester™ 150 deep-furrow drills with 40 and 45 cm row spacing, respectively. When WW stands are successfully achieved from late-summer planting, plants have ample time to produce tillers before the onset of cold weather, and will grow rapidly when temperatures warm in late winter-early spring.

The sandy-loam and silt-loam soils found throughout the region are low in organic matter and susceptible to substantial wind erosion and dust emission during high-wind events when SF fields are pulverized from excessive tillage and lacking in surface residue (Sharratt et al., 2010). Conservation tillage methods that retain equal soil moisture as traditional tillage during SF have been successfully developed, but farmers are reluctant to practice conservation tillage due to fear their drills will plug from too much residue during planting. The ability of a drill to function well under high-residue conditions in tilled SF is improved when the row

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Abbreviations: KPS, kernels per spike; KW, kernel weight; PNW, Inland Pacific Northwest of the United States; SPU, spikes per unit area; SF, summer fallow; WW, winter wheat.

[*] Corresponding author. Tel.: +1 509 235 1933.
E-mail address: william.schillinger@wsu.edu (W.F. Schillinger).

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spacing is widened. This makes it important to understand the relationship between row spacing and WW grain yield potential under PNW growing conditions.

The literature on row spacing and spacing between seeds within rows for wheat often indicates a decrease in grain yield as row spacing gets wider. For spring wheat, or in short season winter environments like the Canadian Great Plains, a decrease in grain yield is often measured as row spacing is increased from about 16–32 cm, and an even greater decrease as row spacing is widened further (Kleemann and Gill, 2010; Tompkins et al., 1991a,b; Xie et al., 1998). In the same environment there can be a decrease in grain yield when seeds are closer together within a row (Boström et al., 2012). Maximum grain yield is generally achieved when the greatest number of productive spikes are realized at harvest (Lloveras et al., 2004; Tompkins et al., 1991a), and more equidistant within-row seed spacing often augments grain yield due to reduced inter-species competition and better light interception (Anderson and Barclay, 1991). Similarly, some wheat grain yield decrease has been credited to crowding of seeds within the row (Boström et al., 2012). In that case, drills that spread seed in a band within each row has been credited with increasing yield (Amjad and Anderson, 2006), but seed spreading and paired rows are not practical for deep-furrow planting.

In several studies, especially where water stress is experienced, increasing row spacing from 10 to 30 cm had little or no effect on grain yield (Chen et al., 2010; Hiltbrunner et al., 2005; Lafond and Derksen, 1996; McLeod et al., 1996). In drier environments with long growing season and lower grain yield potential, the number of productive spikes required to maximize yield is lower and there is more time for tillering if individual plants have the water and fertility resources to do so. It is also possible for higher density plantings to experience early senescence or loss of productive tillers during grain fill because more water has been used earlier (Benbella and Paulsen, 1998; Hiltbrunner et al., 2005).

In the studies cited above, 30 cm was considered wide row spacing. Given that the narrowest row spacing of the deep-furrow drills used in the PNW is wider than most of the row spacing widths reported in the literature, one might assume that any further widening of row spacing would cause a decrease in WW grain yield potential. For example, Kleemann and Gill (2010) calculated a decrease in yield of 5–8% when the rows were widened from 18 to 36 cm, and a 16–26% reduction when the rows were widened from 18 to 54 cm. Under low-moisture conditions, width of row spacing may not adversely affect WW grain yield (Ketata et al., 1976; Vander Vorst et al., 1983), but no such experiments have previously been conducted in the dryland PNW.

The hypothesis for our experiment was that row spacing can be widened to some given distance beyond the 40 and 45 cm of existing commercial drills without adversely affecting WW grain yield, straw production, and weed control. The objective was to promote conservation-tillage farming by providing scientific evidence of little to no grain yield reduction using new deep-furrow drill prototypes that employ row spacing >45 cm in order to pass through and retain high quantities of surface residue in tilled SF during planting without drill plugging. Specific objectives were to determine the effects of wider row spacing on: (i) grain yield, (ii) grain yield components, (iii) straw production, and (iv) weed dynamics.

2. Materials and methods

2.1. Establishment of treatments

A 3-year experiment was conducted at three sites during the 2011–2013 crop years to determine if row spacing could be widened from the traditional 40–45 cm used by farmers throughout the low-precipitation region of the PNW for deep-furrow planting of WW. The three study sites were representative of those found throughout the WW-SF region (Fig. 1). Soils at all sites are sandy silt loam in texture, more than 180 cm deep, with no rocks or restrictive layers. Slope at all sites was <2%. Long-term average annual precipitation is 242, 280, and 266 mm at Lind, Ritzville, and Echo, respectively.

Soil management during the 13-month SF period differed somewhat across sites. At all sites, WW stubble was left standing from harvest in July through the winter to trap snow and otherwise increase over-winter soil water storage (Williams, 2004), although at Ritzville, aqua NH_3—N and thiosol S was knifed into WW stubble at a 15-cm depth with narrow shanks spaced 30 cm apart in early November after the onset of fall rains. Glyphosate [*N*-(phosphonomethyl) glycine] herbicide was applied at all sites in late March–early April to control volunteer WW and other weeds.

Primary spring tillage was conducted at an average depth of 10 cm in late April. At Lind, primary spring tillage and simultaneous fertilizer injection was conducted with a wide-blade undercutter sweep with attached rotary hoe for soil clod sizing. The undercutter implement causes minimal soil lifting or disturbance and is considered a best management conservation tillage practice for WW-SF farming in the region (Papendick, 2004). At Ritzville, a field cultivator with attached Phoenix^{TM} rolling harrow was used for primary spring tillage. Although a field cultivator causes considerably more soil disturbance and residue burial compared to an undercutter sweep, primary spring tillage implements used at Lind and Ritzville are considered "conservation tillage" because WW grain yield and straw production is considerably higher at Ritzville compared to Lind and practices used at these sites typically retain approximately 30% surface residue cover after deep-furrow planting of WW into SF. However, WW stubble is generally cut at a height of 30 cm or shorter to minimize the risk of drill plugging at planting as already discussed. Retention of much higher quantities of surface residue in SF is possible; thus, the need for the present study. Traditional tillage practices were used at the Echo site. A tandem disk was used for primary spring tillage followed soon after with a field cultivar plumbed to inject fertilizer. Although not measured, very little residue remained on the soil surface after deep-furrow planting of WW at Echo.

An across-site and year average of 56 kg aqua NH_3—N + 11 kg thiosol S ha^{-1} was injected into the soil during the field operations discussed above. Following primary spring tillage, the soil was rodweeded once or twice as need from June to August at a depth of 8 cm to control Russian thistle (*Salsola kali* L.) and other weeds.

Row spacing treatments were 40, 45, 50, 55, 60, and 80 cm. Experimental design was a randomized complete block with four replications. Individual plots were 2.4 m × 30 m. The same 2.4-m-wide John Deere HZ split-packer deep-furrow drill was used at all sites. The factory row spacing of this drill is 40 cm. We modified the row spacing to the desired treatment widths by moving the seed boots and placing different-length spacers between the packer wheels. Changing the row spacing width for each treatment was easily accomplished in the field by two people within 30 min, thus the experiment was always planted at a given site in one day. During the 3 years, the experiments were planted between August 31–September 6 at Lind, September 9–16 at Ritzville, and September 22–October 4 at Echo. These dates are considered optimum WW planting windows at each of the sites.

There were two separate studies. In study #1, which was conducted during all 3 years, all row-spacing treatments had the same number of seeds per row; thus, the default 56 kg ha^{-1} seeding rate for the 40-cm spacing treatment was reduced to 28 kg ha^{-1} for the 80-cm spacing. Data from Lind in the 2013 crop year was not collected due to plugging of one of the drill openers in two of the 80-cm plots, therefore 8 site years of data were obtained for this