Rainfall impacts seedling emergence of winter wheat from deep planting depths

A two-year winter wheat–summer fallow rotation is practiced on more than 90% of dryland crop acreage in the low-precipitation region of the Pacific Northwest, which has a Mediterranean-like climate with wet winters and dry summers. While no-till fallow is successfully practiced in many regions of the world, farmers in the winter wheat–summer fallow region of the Pacific Northwest till the soil during the spring of the fallow year to break soil capillary continuity and best retain seed-zone soil water. Winter wheat seed is placed below the pre-planting soil surface in late summer with deep-furrow drills to reach adequate water for germination, and seedlings emerge through dry soil cover.

Although planting winter wheat into stored soil water in fallow is practiced in certain regions of Australia as well as numerous countries surrounding the Mediterranean Sea, nowhere else in the world is the crop planted as deep as in the Pacific Northwest. Due to the extreme depth of seed placement in the Pacific Northwest, it is not the coleoptile (the pointed protective sheath that covers the emerging shoot in monocotyledons such as oats and grasses) that emerges from the soil, but rather the first leaf after pushing through the tip of the coleoptile. The first leaf is thin, has weak structural support, is most often emerging under low soil water potential, lacks emergence force or lifting capacity, and is susceptible to kinking (resulting in no emergence) if it meets even slight surface resistance.

Farmers in the Pacific Northwest plant into stored soil water in late August to early September. This is because as much as 30% of the total seed-zone water may be lost during the first three weeks of September due to the high vapor concentration gradient caused by increasingly low night temperatures that drop soil surface temperatures below those at lower depths. Grain and straw yield potential decline dramatically if adequate stands from planting into stored water cannot be achieved and seed must instead be “dusted in” at a shallow depth or planted after the onset of fall rains in mid-October or later. There are generally two scenarios where early-planted winter wheat stands are not adequately achieved: (i) when seed-zone water potential is not sufficient for the elongating first leaf to reach the surface and (ii) when rainfall occurs after planting, but before emergence, causing the formation of a thin, fragile surface soil crust that the first leaf cannot penetrate.

There have been many studies conducted on soil crusting and its effect on crop seedling emergence. Structural soil crusts are formed when raindrops detach silt and clay-size particles from larger aggregates, and these fine sediments then form a thin, low-porosity layer on the soil surface. Subsequent soil surface drying, especially rapid drying with high air temperature under intense sunlight, enhances formation of thin, rigid soil crusts. Soils with silt as the dominant particle size and those with low organic matter content and low aggregate stability, such as those found throughout the low-precipitation region of the Pacific Northwest, have been identified as particularly susceptible to crusting.

In the May–June 2011 issue of *Agronomy Journal*, researchers set out to determine the effects of rainfall intensity, timing of rainfall after planting, cultivar, surface residue load, and air temperature on the emergence of winter wheat from a deep planting depth. Due to the multiple factors and complexity of the study, the research was conducted under controlled laboratory conditions. There were five factors involved in the experiment:

1. Rainfall intensity and duration: 1.25 mm/hour for three hours and 2.50 mm/hour for two hours.
2. Timing of rainfall: one, three, and five days after planting + controls (i.e., no rain).

3. Winter wheat cultivar: Eltan (semi-dwarf) and Buchanan (standard height).

4. Surface residue: 0, 750, and 1,500 lb/ac.

5. Air temperature: 70°F (no sunlamp) and 86°F (with sunlamp).

The experimental design was a split-plot factorial with one whole-plot factor (air temperature) and four subplot factors (rainfall intensity, timing of rainfall, cultivar, and surface residue) in a completely randomized layout. A total of 84 pots were required for each run of the study. These were two rainfall intensities × two cultivars × three rainfall timings × three surface residues × two air temperatures + 12 controls (the controls were three surface residues × two cultivars × two air temperatures). Three separate runs were conducted, with each run serving as a replicate.

Preparing pot experiments

Soil used in the experiment was Shano silt loam (coarse-silty, mixed, superactive, mesic Xeric Haplocambids) with <1% organic matter. Shano silt loam soil and its close relative the Ritzville silt loam (coarse-silty, mixed, superactive, mesic Calcic Haploxerolls) are the major soil types of the roughly three million acres covering the low-precipitation winter wheat–summer fallow region of east-central Washington. Textural size distribution of soils used in this study was 10% clay, 51% silt, and 39% fine sand. Shano soils lack structure and are highly susceptible to wind erosion when pulverized by excessive tillage and when residue cover is lacking. These soils contain significant quantities of fine particulates that are readily suspended and transported long distances during windstorms.
Dry soil was collected from the surface of tilled summer fallow at the Washington State University Dryland Research Station in early September and sifted through a fine mesh screen to remove clods and residue. Water content of the soil (3% water by mass) was determined using an oven-drying method. A measured mass of dry soil was placed in a slowly revolving portable cement mixer, and a pressurized backpack sprayer was then used to uniformly mist a known quantity of water into the mixer to achieve the desired soil water content of 11% by mass. Wetted soil was placed at the bottom of each tall pot to achieve a volumetric soil water content of 13.7%. The 13.7% volumetric soil water content is considered slightly greater than what is normally experienced in field conditions but was deemed necessary because trial and error indicated that soil drying in pots occurred at a much faster rate than under field conditions.

A hand-held patterned dimpling device was then used to create 25 uniformly spaced deep indentations in the moist soil in which 25 seeds were placed. A mixture of wetted soil and field dry soil was then placed over the surface to cover the seeds. The remaining pot depth was loosely filled with field dry soil and then leveled at the lip of the pot. These methods mimicked the soil conditions of deep furrow planting of winter wheat into tilled summer fallow.

Two winter wheat cultivars were used on the basis of their strong (Buchanan) and moderate (Eltan) emergence capabilities. Buchanan is a standard-height, hard-red, common cultivar with a long coleoptile, whereas Eltan is a semi-dwarf, soft-white, common cultivar with a medium-length coleoptile. Buchanan is renowned for its excellent emergence ability from deep planting depths. Due to its high grain yield potential, Eltan has been the most widely planted cultivar in the winter wheat-summer fallow region of east-central Washington for the past 20 years.

Standing stubble from winter wheat grown at the Washington State University Dryland Research Station was allowed to weather in the field for 13 months before being clipped into short segments. The dry residue segments were spread uniformly on the surface soil of pots at rates corresponding to 0, 750, and 1,500 lb/ac. All 84 pots in each run were prepared as described above within a 10-hour time period.

Rainfall simulation and seedling emergence

A Palouse Rainfall Simulator was used to simulate the low-intensity, small-drop-size rains typical in the Pacific Northwest. The simulator was equipped with two independent rotating heads with two different nozzles. Model 2.8w and 4.3w wide-angle, full-jet nozzles were fitted on the heads to deliver rainfall at two amounts, one twice as much as the other. The nozzles sprayed vertically downward, and heads were located slightly above the surface to generate drop size and drop velocity similar to naturally occurring, low-intensity rainfall common in the Pacific Northwest. For both heads, there was <5% variability in uniformity of rain across the distribution area. Selected pots were gently lifted from the laboratory bench and placed on a concrete floor under the two heads of the rainfall simulator on one, three, and five days after planting. The control pots received no rain.

Immediately after each of the three rainfall simulations, half of the pots were kept on a laboratory bench at constant 70°F air temperature with the remainder placed in cardboard boxes under a sunlamp. Air temperature within the boxes was kept at 86°F for nine hours during each 24-hour period to simulate daytime field temperatures in early September.

Unsuccessful attempts were made to measure soil penetration resistance with two different instruments in pots six days after planting. Neither penetrometer was sensitive enough to obtain viable readings in the extremely fragile crusts that formed on these soils. The number of emerged seedlings in each pot was counted beginning 7 days after planting. Emerged seedlings were thereafter counted at 24-hour intervals until 14 days after planting when no further emergence occurred.

Results and discussion

Rainfall intensity, cultivar, and surface residue had highly significant (P < 0.001) impacts on seedling emergence. Timing of rainfall and air temperature (heat) had no overall statistically significant effect on emergence. Among the five factors, the only interactions that occurred were timing of rainfall × cultivar and heat × cultivar. These interactions are explained by the fact that (i) timing of rainfall had no effect on the semi-dwarf cultivar Eltan, whereas emergence was lowest on the one-day-after planting rainfall treatment for the standard-height cultivar Buchanan and (ii) heat from the sunlamp had no effect on Eltan but reduced emergence in Buchanan (Fig. 1).

Final emergence as influenced by individual factors is shown in Fig. 2. Combined for the two cultivars, the high-intensity rain reduced emergence to 16% compared with 36% for the low-intensity rain. Emergence in the control pots averaged 86%. The standard-height cultivar Buchanan had a fourfold increase in emerged seedlings compared with the semi-dwarf cultivar Eltan. Surface residue benefited emergence, most likely by intercepting rain drops. Conservation tillage management systems to retain maximum quantities of surface residue during fallow have been developed.

In retrospect, the low-intensity treatment should have received rain for four hours so that the total volume of wa-
ter applied from both heads would be the same. There was a general trend that the greater the surface residue, the better the emergence. This was the case with the relationships for residue × timing of rainfall, residue × air temperature, and especially for residue × cultivar. Buchanan emergence was significantly greater than for Eltan with all residue levels, once more strongly indicating that the longer coleoptile and first leaf of standard-height cultivars significantly improve seedling emergence compared with semi-dwarf cultivars.

Air temperature appeared to be a slightly more important indicator of emergence than timing of rainfall. As previously discussed, the only statistically significant two-way interactions that occurred were timing × cultivar and air temperature × cultivar. All three-way, four-way, and five-way interactions were not statistically significant.

Conclusions

Fragile soil crusts formed on silt loam soils after low-intensity rainfall impede emergence of winter wheat planted deep into summer fallow in eastern Washington. Crusts formed in this study were almost imperceptible, and although soil penetration resistance could not be measured with the available penetrometers, rainfall after planting had a marked negative impact on winter wheat seedling emergence. Of the five factors evaluated, only cultivar selection and quantity of surface residue can be controlled by the farmer.

Data conclusively show that when rainfall occurs after planting and before emergence: (i) the standard-height cultivar had an overall fourfold increase in seedling emergence compared with the semi-dwarf cultivar and (ii) greater surface residue led to improved seedling emergence. These results bolster work currently in progress to enhance winter wheat seedling emergence from deep planting depths through plant breeding and other research and extension efforts to promote the adoption of conservation-tillage summer fallow.


Fig. 1 (top). Individual cultivar response to air temperature (heat) and timing of rainfall. There were only two statistically significant interactions in the experiment out of 26 interaction possibilities. The significant interactions were timing of rainfall × cultivar and heat × cultivar. Timing of rainfall had no effect on the emergence of Eltan whereas emergence of Buchanan one day after planting (DAP) was reduced compared with rainfall three and five DAP. Similarly, heat had no effect on Eltan emergence, but it did with Buchanan. Fig. 2 (bottom). Percent emergence of winter wheat planted deep into pots as affected by air temperature (heat), rainfall intensity, rainfall timing, cultivar, and surface residue. Data are the average from three runs. Winter wheat emergence in the control pots averaged 86%.