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Winter Wheat Emergence After 30 Minutes Simulated Rainfall

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ABSTRACT

Rainfall occurrence within a few days of winter wheat (*Triticum aestivum* L.) planting with a furrow drill can significantly reduce furrow ridge height and emergence. A 30-min, five-year frequency storm of 30 mm reduced emergence more than 50% for wheat planted with V-shaped press wheels or in loose, clean-tilled soil conditions. Reduced tillage or increased surface residue along with the use of 75 mm wide, flat press wheels increased emergence significantly. Wheat planted in heavy residue and no-till soil conditions had full emergence with 0 to 40 mm water application in 30 min. Deeply planted (80 to 100 mm) wheat had slightly less emergence and showed no benefit to reduced tillage or increased surface residue.

INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is a major crop in the Central Great Plains region of the United States. It is primarily grown using two-year, wheat-fallow, clean-till management that leaves very little or no crop residue on the soil surface at planting time. Farmers will commonly till the soil four to eight times using sweep plows, rod weeders, one-way disks, tandem disks or field cultivators to control weeds during the fallow season. As a result of these tillage operations, the surface soil becomes a dry mulch which helps reduce soil water evaporation. Reduced-tillage and chemical-fallow systems are being adopted which leave residue or stubble from the previous wheat crop on the soil surface at planting time.

Winter wheat is planted primarily with grain drills that have disk or hoe-shoe openers at a desired depth of 25 mm to 40 mm. Typically, the drills will have steel V-shaped press wheels, steel flat press wheels with or without a center rib, or rubber flat press wheels among others, all located behind the furrow openers. These drills will push or throw aside the dry surface soil mulch to form V-shaped furrows with seed placement below the furrow bottoms. The V-shaped furrows may also reduce soil water evaporation around the wheat seed and reduce wind erosion if the furrows are oriented perpendicular to prevailing winds.

Rain storms occurring after wheat planting can inhibit emergence because soil from the ridge and sides of the furrow will erode or slump into the bottom of the furrows. When this happens, the wheat plants must emerge through the normal planting soil depth plus the additional eroded soil deposition in the bottom of the furrow that may have also formed a surface seal or crust. If populations of the remaining emerged wheat plants are too low, grain yields may be reduced the following year.

Soil, residue, planting, and storm factors can affect the amount and pattern of soil deposited in the bottom of wheat furrows. Soil factors affecting wheat furrow slump and emergence may include soil type, land slope, and plant residue levels. The planting characteristics of the grain drill can also affect wheat furrow slump. Row spacing and the type of furrow opener affect furrow slope, height, and shape. The shape of the furrow can be affected by the type of press wheels. V-shaped steel press wheels generally leave a V-shaped furrow regardless of soil tillage or residue levels. Flat press wheels used with reduced tillage and increased surface residue conditions leave a flatter-bottomed furrow.

Increasing intensity and duration of a rain storm increases the amount of soil slump in wheat furrows. High intensity storms generally pond water on the surface sooner, eliminating soil water matrix potential at the surface which reduces aggregate stability. Amount of soil eroded also increases generally with storm duration with rain intensity normally declining with time for the longer duration storms. Objectives of this research were to quantify any changes in wheat plant populations and furrow height due to 30 min of uniform sprinkler-applied artificial rain that was applied within four days after planting.

PROCEDURE

The research was conducted in 1987 and 1988 during the normal winter wheat planting period of late September and early October at various locations within 10 km of the U.S. Central Great Plains Research Station near Akron, Colorado. Variables in this study were amount of applied water, residue level, tillage, planting depth, and soil texture. Increased residue levels can help dissipate the impact energy of raindrops so it can be an important variable. Tillage practices are varied and some of the more common ones were included in this study. Soil texture and planting depth may also affect emergence. The soils, tillage treatments, residue levels, and planting depths are summarized in Table 1. The soils were described by Peterson et al. (1986). Planting depth was measured from the bottom of the furrows to seed placement. Disk treatment plots were actually sweep-plowed during the fallow period and then diske just before planting, which is a common practice.

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TABLE 1. Site numbers, soils, tillage treatments, residue levels, and planting depths of the winter wheat emergence and rainfall plots

Year	Site	Soil Series and and texture	Tillage treat. during fallow	Residue at planting (kg/ha)	Planting depth (mm)
1987	1.	Ascalon sandy loam	no-till	5860	40 - 60
			clean-tilled	0	40 - 60
	2.	Weld silt loam	disked	1790	40 - 60
1988	3.	Ascalon sandy loam	sweep-plowed	4880	40 - 60
			disked	2060	40 - 60
	4.	Platner loam	no-till	6540	80 - 100
			sweep-plowed	4060	80 - 100
			clean-tilled	0	80 - 100

Check plots that received no simulated rain between planting and emergence were also included in the study. No natural precipitation occurred between planting and emergence except site 3 which received 6 mm of light rain over a 12-h period. The plots at site 3 exhibited little or no soil movement due to this precipitation and were allowed to dry for 36 h before the simulated rain treatments were applied.

A rainfall simulator, built from a design developed by Shelton et al. (1985), was used to apply different depths in 30 min. Water application was monitored with a flowmeter to attempt to maintain approximate water application levels but wind and humidity varied water application amounts somewhat between treatments. The simulator had nine spray nozzles arranged in a three by three array with variable spacing of approximately 2 m. Different continuous application rates were obtained by varying the nozzle spacing or by injecting air into the water just before it exits the nozzle which reduces application rates by displacing water flow. The simulator was built as a portable unit mounted on a four wheel trailer which was towed by a tractor.

The simulator was operated at conditions that produce water drops with velocities and sizes similar to rainfall (Shelton et al., 1985). The nozzles used were Spraying Systems* Fulljet HH30WSQ which at low nozzle pressures of 14-20 kPa produce a range of drop sizes up to 6 mm. The nozzles were positioned 2.9 m above the plots to guarantee that water drop impact velocities were within a few percent of terminal velocities. Application uniformity was measured with 16 catch cans and had Christiansen's (1942) Uniformity Coefficient between 70 to 90%. Water application amounts in the field plots were measured using four catch cans. Application amounts between 25 to 50 mm in 30 min were used, which correspond to 5 to 50 year annual-frequency storms, respectively (Hershfield, 1961) in the U.S. Central Great Plains region.

Winter wheat was planted at all sites with grain drills that had identical hoe-shoe furrow openers and either V-shaped steel or 75 mm flat rubber press wheels. Row spacing was 280 mm (11 in.). The wheat was planted in moist soil. The seeding rate was 51 kg/ha using "Carson" variety in 1987 and "TAM 107" in 1988. Both varieties have a medium-length coleoptile. Simulated

*Note: The mention of trade names or commercial products does not constitute their endorsement or recommendation for use by the USDA-ARS.

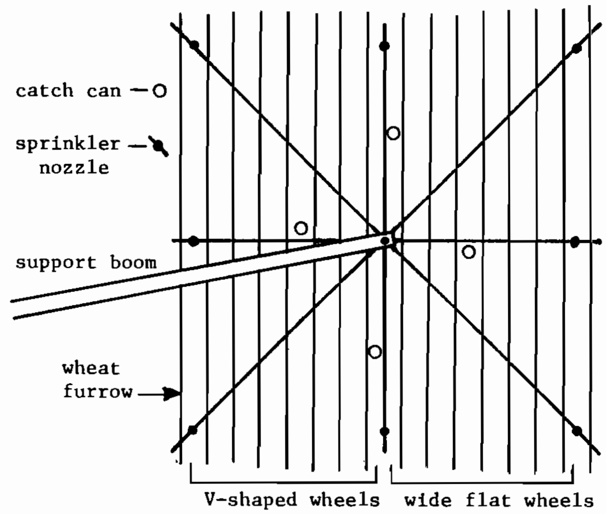

Fig. 1—Rainfall simulator sprinkler array, plot layout, and catch can location.

rainfall was applied to all plots within four days after planting and emergence started seven to ten days after planting. Land slope at all sites was less than one-half of one percent. Almost all non-infiltrated water ponded in the furrows and eroded soil did not move laterally along the furrows.

Each time the rainfall simulator was set up, water was applied to two plots. One plot was seven furrows formed with the V-shaped press wheels adjacent to another plot which was seven furrows formed with the flat press wheels. The rainfall simulator was then moved a few meters to adjacent plots for the different combinations of application amount and tillage. Four replicated tests were made on each plot. Applied water depth was the average of depths collected in the four catch cans for each application. A diagram of the simulator nozzle array, plot layout and catch can location are shown in Fig. 1. Plant populations were determined by counting the plants in a 1-m length of the 3 middle rows of each plot.

RESULTS

Winter wheat plant populations and furrow height were reduced by the application of 30 min of simulated rainfall after planting. Increased application amounts caused a greater reduction of winter wheat plant populations and furrow height. The use of flat press wheels with reduced tillage and increased surface residue increases plant emergence.

The 5 860 kg/ha of crop residue on the soil surface after planting in 1987 and/or the firmer no-till soil conditions, and the flat press wheels improved plant populations significantly at site 1, as shown in Fig. 2. The 1 790 kg/ha of residue in the disked plots at site 2 also caused a lesser but still significant increase in populations over the clean-tilled or V-shaped press wheel plot. Wheat planted with the flat press wheels in the clean-tilled plots (no residue) on the Ascalon sandy loam had similar reductions in plant population to the plots planted with the V-shaped wheels. The shape and geometry of the furrows made by the flat press wheels in the clean-tilled plots were V-shaped and similar to

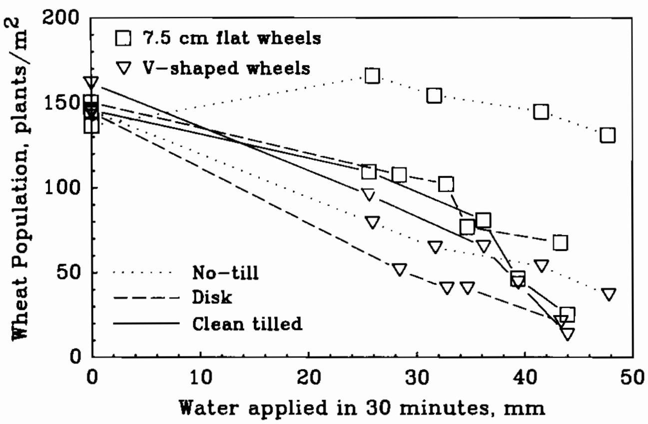

Fig. 2—Winter wheat population vs. water applied in 30 min for sites 1 and 2 from 1987.

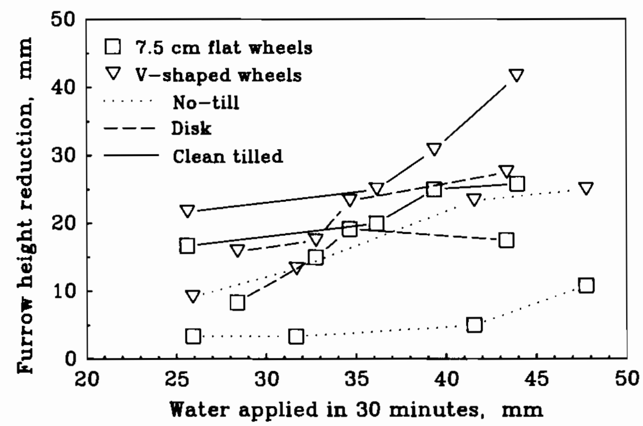

Fig. 3—Furrow height reduction vs. water applied in 30 min for sites 1 and 2 from 1987.

furrows made with the V-shaped press wheels. The surface soil in the clean-tilled plots was so loose that soil moved by the hoe-shoe furrow openers fell back into the furrows behind the flat press wheels. Therefore, flat press wheels appear to have had no effect in changing the furrow geometry in clean-tilled soil with no surface residue after planting.

Planting with flat press wheels in no-till, firm soil conditions produced furrows in which the furrow bottoms were almost as wide and flat as the press wheels. The no-till soil conditions with surface residue and flatter-bottomed furrows reduced the amount of soil from the top and sides of the furrows that eroded into the furrow bottoms. The eroded soil was deposited over a wider area and consequently, left shallower soil deposition over the seed. This shallower soil deposition tended to be most shallow at the center of the furrow, where the drying soil crust would more easily crack and provide easier emergence. The V-shaped furrows did not exhibit this type of soil drying and cracking.

Statistical analysis was made of plant population after emergence among the different tillage and wheel treatments for the different water application levels. Duncan's Multiple Range Test (MRT) of plant population means at the 5% alpha level are shown in Table 2. The no-till, flat wheel treatment is significantly different for all treatments and the flat wheel, disk treatment is significantly different from the V-wheel, disk treatment, for all water levels, so these two treatments will be treated separately. The other four treatments have population means not clearly different among the four water levels.

Furrow height reduction for the plots at sites 1 and 2 are shown in Fig. 3. Furrow height decreases with greater amounts of water applied in 30 min. Furrows formed by the flat press wheels in the no-till plots at site 1 had significantly less furrow height reduction than any of the other plots, as shown in Table 3.

Plant populations after emergence in the check plots that received no artificial or natural rain were similar and averaged 147 plants/m². Plant populations on the no-till, flat press wheel plots with the two lowest water appliations were greatest at 166 and 155 plants/m². The

TABLE 2. Duncan's Multiple Range Test of plant population means to the various wheel type and tillage treatments at sites 1 and 2

Winter wheat plant population after emergence, plants/m²					
Wheel, Tillage Treatment	Site	Average water applied in 30 min, mm: 26.6	33.5	38.5	45.0
Flat wheels, No-till	1	166a*	154a	145a	131a
Flat wheels, Disk	2	108a	102b	68b	77b
Flat wheels, Clean-till	1	109b	81bc	46bc	25c
V-wheels, No-till	1	79bc	65bc	54b	37c
V-wheels, Disk	2	51c	40c	21c	40cd
V-wheels, Clean-till	1	96bc	65bc	44bc	13d

*Means within a column that are followed by the same letter are not significantly different at the 5% level.

TABLE 3. Duncan's Multiple Range Test of furrow height reduction means to the various wheel type and tillage treatments at sites 1 and 2

Winter Wheat Furrow Height Reduction, mm					
Wheel, Tillage Treatment	Site	Average water applied in 30 min, mm: 26.6	33.5	38.5	45.0
Flat wheels, No-till	1	3.3a*	3.3a	5.0a	10.8a
Flat wheels, Disk	2	8.3b	15.0b	19.2b	17.5b
Flat wheels, Clean-till	1	16.7c	20.0c	25.0c	25.8c
V-wheels, No-till	1	9.2b	13.3b	23.3bc	25.0c
V-wheels, Disk	2	15.8c	17.5bc	23.3bc	27.5c
V-wheels, Clean-till	1	21.7d	25.0d	30.8d	41.7d

*Means within a column that are followed by the same letter are not significantly different at the 5% level.

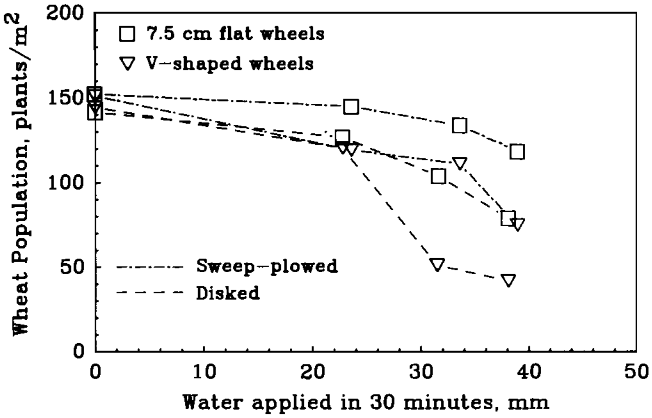

Fig. 4—Winter wheat population vs. water applied in 30 min for site 3 from 1988.

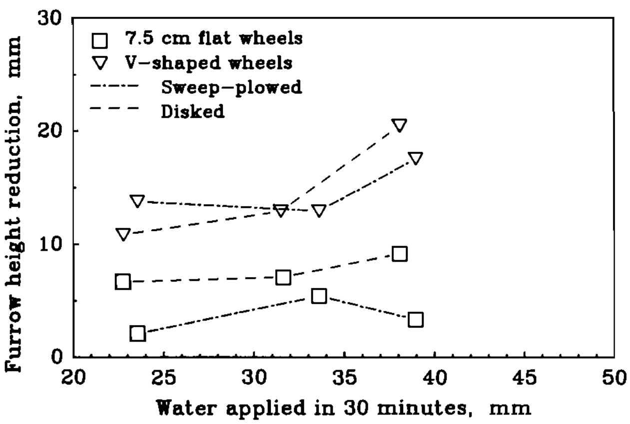

Fig. 5—Furrow height reduction vs. water applied in 30 min for site 3 from 1988.

applied water may have increased seed germination more than reduced emergence caused by soil sedimentation into the furrow bottoms.

Plant populations and furrow height reduction Figs. 4 and 5, respectively) on a Ascalon sandy loam soil in 1988 (site 3) were similar to those observed in 1987. Again, more surface residue and the use of the flat press wheels increased wheat population and generally decreased furrow height reduction. Average plant population in the dryland check plots was again 147 plants/m². Plant populations for the V-shaped wheel plots and at the lowest water application are greater than expected from comparisons to the V-shaped press wheel emergence results and were not statistically different from flat wheel plots with the same tillage as shown in Table 4. However, the flat wheel plots had significantly greater plant population than the V-wheel plots for the same tillage, at the greater water application levels. Duncan's MRT on furrow height reduction means at site 3 (Table 5) also confirms statistical differences in four of the six comparisons between wheel types for the two tillages and three water levels.

Two-year combined results from sites 1, 2, and 3 which had a planting depth of 40 to 60 mm are shown in Fig. 6 for the four tillage and residue conditions. A single linear-regression line is shown and represents all plots planted with the V-shaped press wheels or in clean-tilled, no residue plots, and is

TABLE 4. Duncan's Multiple Range Test of plant population means to the various wheel type and tillage treatments at site 3

Winter Wheat Plant Population after Emergence, plants/m²			
Wheel, Tillage Treatment	Average water applied in 30 min, mm		
	23.1	32.6	38.5
Flat wheels, Sweep-plow	145a*	133a	118a
Flat wheels, Disk	127a	104a	79b
V-wheels, Sweep-plow	119a	111ac	75b
V-wheels, Disk	120a	51b	42c

*Means within a column that are followed by the same letter are not significantly different at the 5% level.

TABLE 5. Duncan's Multiple Range Test of furrow height reduction means to the various wheel type and tillage treatments at site 3

Winter Wheat Furrow Height Reduction, mm			
Wheel, Tillage Treatment	Average water applied in 30 min, mm		
	23.1	32.6	38.5
Flat wheels, Sweep-plow	2.1a*	5.4a	3.3a
Flat wheels, Disk	6.7ab	7.1ab	9.2ab
V-wheels, Sweep-plow	13.7b	12.9b	17.5bc
V-wheels, Disk	10.8b	12.9b	20.4c

*Means within a column that are followed by the same letter are not significantly different at the 5% level.

$$y = 151 - 2.62x, r^2 = 0.83 \quad \ldots\ldots\ldots\ldots [1]$$

y = winter wheat plant population, plants/m²,
x = water applied in 30 minutes, mm,
r = correlation coefficient, -.

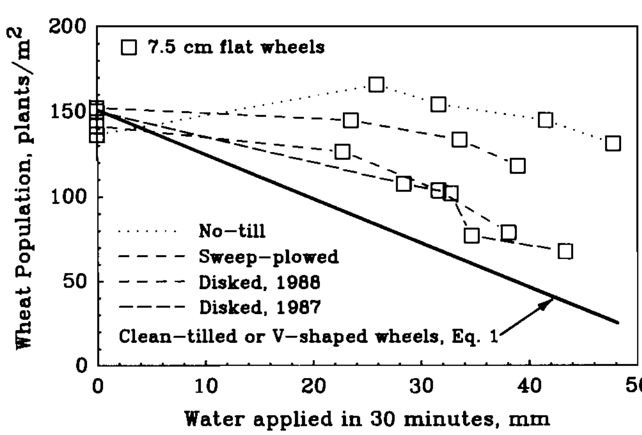

Fig. 6—Combined winter wheat population vs. water applied in 30 min for sites 1, 2, and 3 from 1987 and 1988.

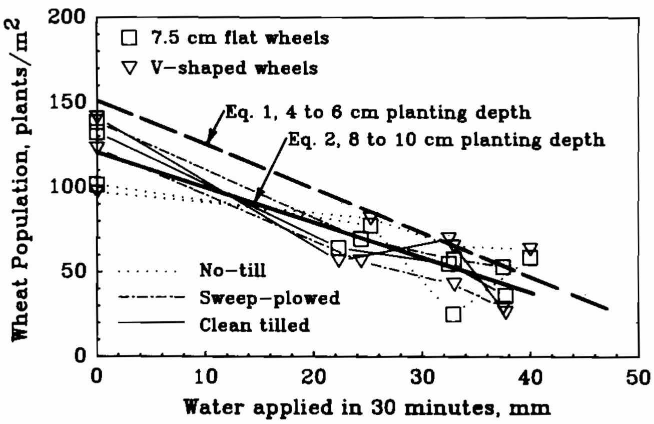

Fig. 7—Deeply planted (8 to 10 cm) winter wheat population vs. water applied in 30 min for site 4 from 1988.

The regression equation will be useful for predicting relative differences in winter wheat plant populations after 30 min rainfall in fields planted with V-shaped press wheels or clean-tilled fields. If predicted plant populations are low enough to greatly reduce yields, then the decision to replant could be made sooner than waiting for full emergence to occur.

Soil texture ranging from sandy loam to silt loam appeared to have little effect on wheat populations. Plant populations among the plots planted with V-shaped press wheels or in clean-tilled soil, and likewise among the disked plots with 1 790 to 2 060 kg/ha of residue show no significant difference between silt loam and sandy loam soils. Reduced tillage and/or increased surface residue appear to be the major factors that affect plant population and furrow height change for the same application depth.

Plant populations of winter wheat planted at a depth of 80 to 100 mm was slightly less overall than that planted at a depth of 40 to 60 mm, Fig. 7. The average dryland check plot population was 121 plants/m^2. However, there was no significant difference due to tillage or residue. The average additional soil depth of 40 mm that the wheat plants had to emerge through evidently negated any benefit of reduced tillage or surface residue. A linear regression for the 80 to 100 mm planting depth populations is shown in Fig. 7, along with equation [1], and is

$$y = 120 - 2.04x, \; r^2 = 0.79 \quad \ldots\ldots\ldots\ldots [2]$$

where

y = winter wheat plant population, plants/m^2,
x = water applied in 30 minutes, mm,
r = correlation coefficient, -

Furrow height reduction was similar to that of the 4 to 6 cm planting depth plots.

SUMMARY AND CONCLUSIONS

Heavy rainfalls occurring within a few days after winter wheat planting significantly reduced wheat plant populations. A 30 mm rainfall in 30 min can reduce wheat populations by 50%. Wheat planted with more traditional V-shaped press wheels and wheat planted in clean-tilled, loose soil conditions exhibited significantly greater population reductions with increased water application after planting than plots with residue or planted with flat press wheels. A linear equation of plant population versus water application can be used to predict the decreased plant populations.

Use of wide flat press wheels in reduced-tillage conditions with surface residue significantly increased plant populations. How much of the population differences are due to tillage or due to residue is not known and should be a topic of future research. No-till plots with 5 860 kg/ha of surface residue exhibited population reduction only when water applications were greater than 40 mm in 30 min. Plots that were only sweep-plowed had slightly less plant populations than in no-till plots followed by plots that were sweep-plowed during the fallow season, then disked just before planting.

Furrow height was reduced more with increasing water application and was reduced most for the furrows planted with the V-shaped press wheels. Wheat planted at 80 to 100 mm soil depth exhibited less plant population than the other plots planted at 40 to 60 mm soil depth. At a depth of 80 to 100 mm, reduced tillage and surface residue did not result in increased plant populations. The additional 40 mm of soil appears to have negated any benefits of reduced tillage or surface residue.

Reduced wheat emergence is a significant problem if heavy rains occur within a few days after planting. Wheat planted at normal soil depths in fields with reduced tillage, increased surface residue and with wide flat press wheels will significantly increase wheat plant populations. If sprinkler irrigation is applied to germinating wheat to guarantee emergence, then flat press wheels should be used in combination with reduced tillage and surface residue.

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