

Effect of Seedbed Firming on the Establishment of Crested Wheatgrass Seedlings¹

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While soil compaction usually reduces crop yields and water infiltration, there is strong evidence that firming the seedbed is desirable for seedling establishment when seeding rangeland. Hyder and Sneva (1956) reported that on firmed seedbed, soil-moisture retention, seedling growth, seedling survival, and lateral root distribution were substantially better than on a loose seedbed. A wheel-track planter was developed in Oregon (Hyder, *et al.*, 1961) to provide a firm seedbed in the row where the seed was to be planted before seed placement. On loose, sandy areas, seedling establishment was much better with the wheel-track planter than with a conventional drill on the unfirmed seedbed. Adams², in a greenhouse study, reported that packing the soil improved emergence, particularly where the soil was not kept moist. In a Michigan study, Triplett and Tesar (1960) reported that packing the soil after planting alfalfa (press-wheel packing) decreased soil-moisture stress one day after planting and increased seedling emergence when no supplemental irrigation was provided. When the plots were irrigated immediately after planting, soil packing gave a much smaller benefit. Stout, *et al.* (1961), reported that in a laboratory study packing the soil after planting

using pressures of 5 and 10 pounds per square inch reduced seedling emergence of sugar beets, beans, and corn. They attributed the reduction in emergence to poor aeration resulting from compaction and the inability of the seedlings to penetrate the compacted soil. Applying pressures of 5 and 10 pounds per square inch directly on top of the seed to firm the soil beneath the seed and get a good seed-soil contact and then covering the seed with loose soil substantially improved emergence. The improvement was greater at the heavier pressure. Stout, *et al.*, concluded that for the species studied, the ideal planter would in one operation pack the soil below the seed, press the seed into the compacted soil, and cover the seeds with loose soil.

The studies reported below were initiated to evaluate further the effects of firming the seedbed on seedling emergence and establishment in range seeding. There were three primary objectives (1) to determine the effects of several degrees of seedbed firming on seedling emergence and establishment; (2) to compare the relative effectiveness of cultipacking and wheel-track pre-packing; and (3) to compare press-wheel post-packing with wheel-track pre-packing and cultipacking.

Methods

In this paper pre-packing refers to packing a band of soil into which the seed is then drilled; the soil between the rows remains unpacked. Pre-packing is essentially the same as the procedure called "wheel-

track planting". In cultipacking, the entire soil surface is packed with an ordinary cultipacker; the seed is then drilled into the packed soil in the usual manner. Post-packing refers to packing a narrow band of soil over the previously drilled seed; this corresponds to the usual press-wheel drilling.

The studies were conducted at the Colorado State University Foothills Experimental Range west of Fort Collins, Colorado, (called 'Foothills') in 1959, 1960, and 1961, and at Central Plains Experimental Range, northeast of Nunn, Colorado, (called CPER) in 1960 and 1961. The soil at the Foothills is a Cass fine sandy loam. Before plowing for this study, the area was a pubescent wheatgrass pasture, but the nearby native vegetation is a mixture of short- and mid-grasses typical of the foothills site. The soil at CPER is unnamed but is classed as a sandy loam. This plains upland site is dominated by shortgrasses. Average annual precipitation is 15 inches at the Foothills and 13 inches at CPER.

The experimental areas were plowed with a moldboard plow in the fall of each year before planting. The plowed land was double-disked the following spring just before seeding; the discing left the seedbed smooth and moderately loose. To avoid the possibility of planting in a tire track, all plowing and discing was done in a north-south direction and the planting was done east-west.

Each plot consisted of 2 seeded rows 15 feet long and 21 inches apart. There were six replications each year at each location. Planting was done as early in the spring as weather permitted. Planting dates were April 3, 1959, March 26, 1960 and April 18, 1961, at the Foothills, and April 6, 1960, and April 27, 1961 at CPER. Nordan crested wheatgrass was seeded at 25 seeds per foot of row.

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²Unpublished M.S. thesis, University of Wyoming, 1958.

All planting was done with a special one-row press-drill designed and built by the Agricultural Engineering Department of Colorado State University. The drill used double-disc openers equipped with depth bands to provide a 3/4-inch seeding depth. Seed was metered into the openers from a small brush-agitated seed hopper. The seed was covered by hinged strap-iron coverers following the opener. A press-wheel was on a hinged frame following the seed coverers and a weight-box operating through a push-rod permitted application of any desired packing pressure with the press-wheel. Two-inch and 4-inch wide zero-pressure rubber-tired press-wheels of 12 inches diameter could be interchanged for studying press-wheel width. The pre-packing treatments, which simulate wheel-track planting, required two trips over the plot with this experimental drill because the press-wheel follows the planting disc. When used for pre-packing, the drill first was run along the rows to be planted with the seed-box disconnected allowing the press-wheel to form the pre-packed band, or wheel-track. Planting was then done by making a second trip over this previously pre-packed row with the seed-box operating. Postpacking, which is in effect using a press drill, was done with the drill operating in the normal manner where the press-wheel follows behind the planting discs and packs the seeded row after seed placement.

All press-wheel and wheel-track pressures listed are the dead-weight pressures of the wheel against the ground surface; computing pressure in pounds per square inch is not possible or meaningful. For "O" pre-pack and post-pack treatments, the press-wheel was removed from the drill.

All pre-packing and post-packing treatments were applied to plots that had been left un-

Table 1. Crested wheatgrass seedlings per foot of drill row as influenced by cultipacking and pre-packing at the Foothills and CPER in 1960 and 1961.

Treatment	Foothills			CPER		
	1960	1961	Mean	1960	1961	Mean
Cultipacking						
none	6.6	10.2	8.4	3.6	14.6	9.1
once	8.0	11.7	9.8	2.9	15.3	9.1
3 times	10.5	12.3	11.4	4.0	15.4	9.7
Pre-packing						
none	6.9	10.8	8.8	3.3	14.4	8.9
light	9.0	11.6	10.3	3.4	15.3	9.3
heavy	9.2	11.8	10.5	3.7	15.6	9.6
Pre-packing followed						
by post-packing						
no post-packing	7.6	11.5	9.6	3.4	15.4	9.4
post-packing with						
2-inch wheel	8.9	11.3	10.1	3.3	15.2	9.2
post-packing with						
4-inch wheel	8.6	11.3	10.0	3.7	14.7	9.2
Mean	8.4	11.4	9.9	3.5	15.1	9.3

cultipacked, cultipacked once, and cultipacked three times. Cultipacking was done with 2-axle cultipackers. All cultipacking was done with travel at a right angle to the drill rows. At the Foothills, the cultipacking was done with a small cultipacker that required four passes to cover the plot once. Because of the number of trips made across the plots, considerable additional packing was done by the tractor tires. At CPER, a larger cultipacker was used and less tractor-tire packing resulted.

The pre-packing was done just before seed placement with the 4-inch width press-wheel at three pressures. These three pre-packing pressures were "none" (no pre-packing), "light" (70-pound pressure on wheel) and "heavy" (300-pound pressure on wheel). After planting the pre-packed wheel-tracks, three post-packing treatments were applied to each of the pre-packing treatments; these were no post-packing, post-packing with a 2-inch width wheel at 70-pound pressure, and post-packing with a 4-inch width wheel at 70-pound pressure.

The post-packing treatments were applied after seed place-

ment with both 2-inch and 4-inch wide wheels. Dead-weight pressures of 0, 70, 130, 200, and 300 pounds were used with both wheel widths. For the "0" pressure treatments, no press-wheel was used.

The pre-packing treatments were applied in 1960 and 1961 at both locations. The post-packing treatments were applied in 1959, 1960, and 1961 at the Foothills and in 1960 and 1961 at CPER.

After seedling emergence, seedlings on 10 feet of drill row in each plot were counted. Late-spring counts are presented. Counts at other times during the seasons showed differences in total numbers, but the differences seemed to reflect only losses normally observed as the season progresses. The relations between treatments remained the same. The seedlings were difficult to count accurately at the Foothills in 1961 because the heavy precipitation produced almost solid rows.

Soil bulk density was determined for the three cultipacking treatments in 1961 at both locations.

Although all the plots at each location were in one large study area, the study was broken into

Table 2. Mean effects of pre-packing and cultipacking on number of crested wheatgrass seedlings per foot of row (1960 and 1961)

Location and Treatment	Cultipacking			Mean
	none	once	3 times	
Foothills				
Pre-packing levels				
none	6.7	8.8	11.0	8.8
light	9.2	10.3	11.5	10.3
heavy	9.3	10.4	11.7	10.5
Mean	8.4	9.8	11.4	9.9
CPER				
Pre-packing levels				
none	8.5	8.6	9.5	8.9
light	9.2	9.2	9.6	9.3
heavy	9.6	9.4	9.9	9.6
Mean	9.1	9.1	9.7	9.3

two balanced complete block experiments for analysis so that the pre-packing and post-packing phases were analyzed separately. Apparent discrepancies in the tables and in the text result from compiling and analyzing the data in two phases.

Precipitation at the Foothills in 1959 was nearly normal in amount and monthly distribution. At both locations, 1960 precipitation was substantially below normal. The 1961 precipitation at the Foothills was so great that new records were set for the location; the 1961 precipitation at CPER was also much above normal.

Results And Discussion

Cultipacking was relatively more effective in increasing seedling counts at the Foothills than at CPER. At the Foothills, seedling counts per foot of row were 6.7, 8.9, and 10.8 for no cultipacking, cultipacking once, and cultipacking three times, respectively when no pre-packing or post-packing was involved (average for 1959, 1960, and 1961). At CPER, the counts were 7.8, 8.3, and 9.6 seedlings per foot of row, respectively, (average for 1960 and 1961). At the Foothills, an increase in seedling counts from cultipacking was observed in all years. However, on the sandy soil at CPER, the results were erratic. In 1960, cultipacking three times was significantly better than no or

one cultipacking. In 1961, both cultipacking treatments were significantly better than no cultipacking, but no difference between cultipacking once and three times was observed.

At the Foothills, soil bulk density in 1961 was 0.93, 1.26, and 1.42 grams per cubic centimeter for no cultipacking, cultipacking once, and cultipacking three

times, respectively. The coefficient of correlation between bulk density and number of seedlings was +0.82 (sig. .001) indicating a fairly close linear relation between degree of seedbed firming and seedling counts. Bulk densities of the soil at CPER were 1.04, 1.22, and 1.34 grams per cubic centimeter for the no cultipacking, cultipacking once and cultipacking three times, respectively, but bulk density and seedling numbers were not significantly correlated.

The general effect of pre-packing was the same as cultipacking, but to a lesser degree, in both 1960 and 1961 at both locations (Table 1). The increase in seedlings resulting from pre-packing was relatively greater at the Foothills than at CPER and the increase was relatively greater in the dry year of 1960 than in the wet year of 1961. The difference in seedling numbers

Table 3. Effects of post-packing press-wheel width, post-packing press-wheel pressure, and cultipacking on number of crested wheatgrass seedlings per foot of row.

Presswheel width and pressure	Foothills ¹				CPER ²			
	Cultipacking			Mean	Cultipacking			Mean
	none	once	3 times		none	once	3 times	
2 inches:								
0 pounds	6.6	8.7	10.4	8.6	8.4	8.4	10.0	9.0
70 "	7.1	9.9	11.6	9.5	8.0	8.5	9.5	8.6
130 "	7.3	9.5	10.8	9.2	8.5	9.2	9.7	9.1
200 "	7.1	9.6	11.1	9.3	7.4	9.0	9.6	8.7
300 "	5.9	9.1	11.3	8.8	5.0	8.5	9.3	7.6
Mean	6.8	9.4	11.0	9.1	7.4	8.7	9.6	8.6
4 inches:								
0 pounds	6.7	9.0	11.1	8.9	7.2	8.1	9.3	8.2
70 "	7.4	8.9	10.2	8.8	9.2	8.9	9.1	9.0
130 "	7.7	9.6	11.1	9.4	9.2	9.6	9.4	9.4
200 "	8.2	10.6	11.4	10.1	8.9	10.0	9.3	9.4
300 "	8.0	10.4	12.2	10.2	8.3	9.4	9.2	9.0
Mean	7.6	9.7	11.2	9.5	8.6	9.2	9.3	9.0
Means for pressure:								
0 pounds	6.7	8.9	10.8	8.8	7.8	8.3	9.6	8.6
70 "	7.2	9.4	10.9	9.2	8.5	8.7	9.3	8.8
130 "	7.5	9.6	10.9	9.3	8.8	9.4	9.6	9.3
200 "	7.6	10.1	11.2	9.7	8.1	9.5	9.5	9.0
300 "	6.9	9.7	11.8	9.5	6.7	9.0	9.3	8.3
Grand mean	7.2	9.5	11.1	9.3	8.0	9.0	9.5	8.8

¹ Average of 1959, 1960, and 1961.

² Average of 1960 and 1961.

Table 4. A comparison of the mean effects of cultipacking, pre-packing, and post-packing on number of crested wheatgrass seedlings per foot of row, 1960 and 1961.

Cultipacking	No prepacking or post-packing	Pre-packing only ¹	Post-packing only ¹
Foothills			
none	6.3	9.0	7.4
once	8.4	9.7	9.4
3 times	11.1	11.3	11.3
CPER			
none	7.8	9.4	8.7
once	8.3	9.4	9.2
3 times	9.6	10.1	9.2

¹ Pre-packing and post-packing data are averages for 4-inch wheel-width treatments at 70- and 300-pound pressures.

between light and heavy pre-packing pressures was not significant.

At the Foothills a highly significant interaction between cultipacking and pre-packing was observed. Pre-packing was equivalent to cultipacking once in increasing seedling numbers (Table 2). Prepacking also increased seedling counts on the cultipacked-once treatment but increased seedling counts only slightly on the cultipacked-three-times plots. At CPER, the interaction between pre-packing and cultipacking was not significant, but the results seem to follow the same pattern as at the Foothills.

The use of the post-packing with light pressure following seeding of pre-packed wheel-tracks produced no improvement in seedling numbers except a slight gain at the Foothills in 1960.

Post-packing with press-wheels following seed placement was found both to increase and decrease seedling counts because of interactions involving press-wheel width, pressure on the press-wheel, and the degree of seedbed firmness from cultipacking. The general effect of the post-packing treatments was to improve seedling stands (Table 3). The 4-inch wheel was significantly better than the 2-inch wheel because of the interaction between wheel width and wheel pressure. The interaction

was most pronounced on the not-cultipacked plots. Table 3 shows a significant drop in seedling numbers on the not-cultipacked plots when the 300-pound pressure was applied to the 2-inch wheel. When the heavier pressures were applied to the 2-inch wheel, the wheel cut into the soil as much as 4 inches. As the wheel rolled on, loose dirt fell back into the furrow left by the press-wheel and covered the seed too deeply. The better flotation of the 4-inch wheel resulted in a wider, shallower furrow and no harmful effects of heavy pressures on this wheel could be detected. On the cultipacked plots at the Foothills, post-packing was slightly beneficial, apparently because of additional seedbed firming and better seed coverage. At CPER, the effect of post-packing on the cultipacked treatments was negligible or non-existent. No press-wheel width and pressure post-packing combination at the Foothills was as effective as cultipacking once in improving seedling stands. At CPER, post-packing at a moderate pressure with the 4-inch wheel appeared to be as effective as cultipacking for increasing seedling stands.

There was no evidence that the soil compacted by the press-wheels from post-packing above the seeds hindered seedling emergence as reported by Stout, *et al.* (1961). Nor were there any

signs of increased soil crusting from post-packing with press-wheels at the two locations, although crusting has been observed on other soils subjected to packing by press-wheels.

The heavy pressures did not appear to damage the seed mechanically. In a laboratory test, seed of crested wheatgrass was mixed with both soil and sharp sand and subjected to pressures up to 200 pounds per square inch with no effect on germination.

The press-wheels used for pre-packing and post-packing produced furrows of depths varying with pressure and previous cultipacking treatments. When the 4-inch wheel was used, even at the 300-pound pressure, soil sloughing seldom resulted in the seeds being covered too deeply as happened with the heavier pressures on the 2-inch wheel. Furrows have been reported to have beneficial effects on seedling establishment (McGinnies, 1959), but no evaluation of possible beneficial effects of the press-wheel furrows was attempted.

While firming the seedbed undoubtedly improved soil moisture conditions (Hyder and Sneva, 1956; Triplett and Tesar, 1960), of equal importance is the effect of seedbed firming on accurate seed placement. On the not-cultipacked soil, the depth bands would sink into the soil and the seed would be planted as much as 1½ inches deep. When a post-packing press-wheel followed, additional soil was pushed into the slight furrow created by the depth bands covering the seed even deeper. Pre-packing, while not as effective as cultipacking, was of considerable help in controlling seeding depth.

Conclusions

The general effects of cultipacking, pre-packing, and post-packing were to improve seedling stands (Table 4). Pre-packing was more effective than cultipacking once. At the Foothills,

post-packing was less effective than cultipacking once, but the two treatments were equal at CPER. On once-cultipacked plots, both pre-packing and post-packing improved seedling stands. At the Foothills, both pre-packing and post-packing treatments on cultipacked-once plots produced better stands than they did on the not-cultipacked plots indicating that the packing effects of the pre-packing and post-packing were additive with the packing effects of the cultipacking. At CPER, the post-packing had an additive effect to cultipacking-once while pre-packing did not; pre-packing was additive to cultipacking-three-times while post-packing was not.

Packing in any manner was less effective in increasing seedling numbers on the sandy soils at CPER than on the more loamy soil at the Foothills. One gets the impression that after the soil at CPER has been packed once, additional packing only breaks down the weak aggregate structure and fails to increase seedling counts noticeably. Thus, there appears to be a point of diminishing returns from packing very sandy soils. At the Foothills, the heavier the packing, the better the seedling stands, at least within the limits reached in this study. However, packing before planting appeared to be more beneficial than packing after planting. Had this study been conducted on soils that would form a hard crust, post-packing might have been detrimental.

Most of the results reported would be considered successful. Under less favorable growing conditions, all stands would probably be poorer than reported. The assumption is that the treatments that gave the best seedling stands in this study would also give the best stands under less favorable conditions; the data in Table 1 tend to confirm this assumption. If this reasoning is correct, the better stands anticipated from some of the packing treatments could easily be the difference between failure or success of the seedling.

Summary

The effects of cultipacking, pre-packing (wheel-track planting), and post-packing (press-wheel drilling) on the establishment of crested wheatgrass seedlings were evaluated at the Foothills Range near Fort Collins, Colorado, and at Central Plains Experimental Range (CPER) near Nunn, Colorado. Nordan crested wheatgrass was planted on areas not cultipacked, cultipacked once, and cultipacked three times. Significant increases in numbers of seedlings resulted from cultipacking at the Foothills and slight improvement at CPER.

Pre-packing improved seedling stands, but light and heavy wheel pressures caused little difference. Pre-packing was most effective on uncultipacked plots and least effective on heavily cultipacked plots.

Press-wheels of 2- and 4-inch width and dead weight pressures

of 70 to 300 pounds were used for post-packing after seed placement. Post-packing generally improved seedling stands but less than pre-packing. When heavy pressures were applied to the 2-inch press-wheel, the wheel cut into the uncultipacked soil too deeply, placed the seed too deeply, and thus reduced seedling numbers.

Cultipacking and pre-packing provide a firm seedbed and permit the depth bands on disc openers to work effectively. On loose seedbeds, depth bands frequently were not effective in accurately controlling planting depth and the seed was planted too deeply.

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