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Packing Summer Fallow in the Pacific Northwest: Agronomic Benefits and Environmental Concerns

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ABSTRACT

Winter wheat (*Triticum aestivum* L.) is sown as deep as 20 cm below the summer fallow soil surface in dry years in the semiarid Pacific Northwest (PNW). Many growers pack the summer fallow mulch in late August before seeding winter wheat to improve stand establishment. But packing may increase blowing dust, which is a major soil loss and air quality concern. A 2-yr study was conducted on two silt loam soil types in 280 mm and 230 mm average annual precipitation zones in eastern Washington to determine the agronomic benefits and potential wind erosion hazards associated with packing. Packing a loose, thick surface mulch increased soil bulk density (BD) between the 5- to 12-cm depth. This significantly benefited wheat seedling emergence and stand establishment, which subsequently increased grain yield 9% over nonpacked plots. But packing a soil with a thin mulch layer overlying a high BD tillage pan had no effect on soil BD, wheat seedling emergence, or grain yield. Packing rendered the soil more vulnerable to wind erosion at both locations by reducing soil clod mass 55% and surface residue 38% compared with not packing. There are agronomic benefits from packing summer fallow mulch before seeding, but packing should be practiced judiciously, and not considered when surface residue or soil clods are lacking. This is especially true for poorly aggregated coarse-textured soils where soil structure is difficult to maintain.

STAND ESTABLISHMENT is the most important single factor affecting wheat yields under dryland conditions in the Pacific Northwest (PNW) (Bolton, 1983). Early establishment of winter wheat on summer-fallowed soils in low (<300 mm annual) precipitation areas of the PNW is frequently limited by insufficient seedzone water. In most years, soil water content is adequate for germination and establishment just below the firm layer created by rodweeders (Pikul et al., 1985). Rodweeders are typically operated <12 cm deep during late spring and summer to control weeds and maintain a dry soil mulch. The soil mulch reduces evaporation of stored water during dry summer months by disrupting capillary flow which reduces both liquid and vapor flow to the atmosphere (McCall, 1925; Papendick et al., 1973). In drier fallow cycles, however, soil drying extends below depth of rodweeding. Lindstrom et al. (1976) reported that −0.7 MPa water potential was the lower limit at which to expect winter wheat emergence from deep seeding on silt loam soils in eastern Washington.

The time from seeding to emergence of wheat seedlings increases, and final stand count decreases, as soil water potential drops below field capacity (Hanks and Thorp, 1956; Lindstrom et al., 1976). The time to emergence and variability in emergence also increases as seeding depth increases. Emergence is impeded by soil crusting when rain showers occurring between seeding and emergence are followed by rapid drying. Soil crust is harder and less penetrable if surface soil has been pulverized by excessive tillage or is deficient in residue (Hadas and Stibbe, 1977). Residue within the seed row benefits wheat emergence following a rain by reducing rain drop impact on the soil surface (Awadhwal and Thierstein, 1985).

The need to improve the practice of summer fallowing has become an important environmental concern in the PNW. Traditional tillage practices are often intensive and can leave the soil vulnerable to wind and water erosion. Growers frequently have difficulty maintaining the minimum 390 kg ha^{-1} surface residue required at the end of the fallow cycle to participate in government farm programs. Blowing dust from excessively worked soils makes driving hazardous and closes roads. Very fine particulates, with diameters 10 × 10^{-6} m and smaller (PM-10), are

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Abbreviations: BD, soil bulk density; DAS, days after seeding; OM, organic matter; PNW, Pacific Northwest.

Table 1. Field operations conducted during the 1992-1993 and 1993-1994 fallow cycles.

Month	1992-1993 fallow cycle	1993-1994 fallow cycle
July	2010 kg ha^{-1} winter wheat harvested	3030 kg ha^{-1} winter wheat harvested
October	Subsoil 45 cm deep, 150 cm spacing	Subsoil 45 cm deep, 150 cm spacing
March	Primary tillage with tandem disk	Primary tillage with tandem disk
April	Aqua N injection, 56 kg ha^{-1}	Aqua N injection, 50 kg ha^{-1}
May	First rodweeding	First rodweeding
June	Second rodweeding	Second rodweeding
July	Third rodweeding	Third rodweeding
August	Fourth rodweeding	
August	Seed winter wheat, 47 kg ha^{-1}	Seed winter wheat, 50 kg ha^{-1}

easily transported into urban regions and may be a health hazard, particularly to people with respiratory problems (Piper, 1989). The wind erosion problem in very dry (<250 mm annual precipitation) wheat-fallow areas is threefold: (i) not enough crop residue is produced; (ii) soils are generally coarse textured and low in organic matter, making it difficult to retain soil clods; and (iii) traditional tillage techniques reduce soil roughness and bury excessive amounts of crop residue (Papendick and McCool, 1994). By the end of the fallow period the surface soil mulch is often powdery and deficient in residue.

Growers in low-precipitation dryland areas of the PNW have mixed attitudes towards packing summer fallow before seeding winter wheat. Advocates report packing enhances wheat seedling emergence and allows them to obtain stands in dry years where it would otherwise not be possible. This is achieved by (i) reducing the thickness of the dry surface mulch, thus allowing deeper penetration of grain drill openers into wetter soil, (ii) providing improved seed-soil contact through increased soil BD, and (iii) rendering a thinner layer of soil covering the seed. Opponents feel packing often creates an unacceptable wind erosion hazard through excessive pulverization of soil clods and residue burial.

Seedzone water loss from summer-fallowed soils tends to increase in August and September in the PNW after the annual shift in the direction of coupled heat and water flows. Packing the summer fallow surface increased soil BD in Oregon (Schillinger and Bolton, 1996), resulting in increased soil volumetric water content to a depth of 10 cm. But at time of seeding 1 mo after packing, there were no differences in seedzone water content or in wheat seedling emergence between packed and nonpacked plots. This suggests that, if wheat seedling emergence is to benefit, seeding should be performed soon after packing.

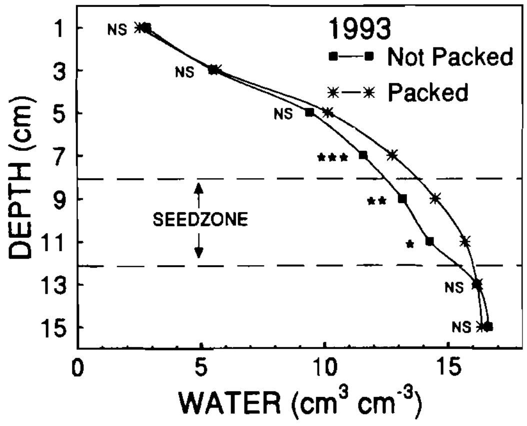

Fig. 2. Seedzone water content as affected by packing in 1993.

My objective was to determine the effects of packing the surface mulch of summer fallow immediately prior to seeding on (i) soil BD, (ii) seedzone water content, (iii) reduction in soil cloddiness, (iv) surface residue burial, and (v) emergence, stand establishment, crop growth characteristics, and grain yield components of winter wheat.

MATERIALS AND METHODS

A 2-yr on-farm experiment was conducted during August and September of 1993 and 1994 at field sites in Adams County, Washington. Annual precipitation at the 1993 site averages 280 mm. The soil was a Ritzville silt loam (coarse-silty, mixed, mesic Calcidic Haploxeroll), with 1.5% OM in the surface 0 to 10 cm. The 1994 experimental site receives an average of 230 mm annual precipitation and soil was a Shano silt loam (coarse-silty, mixed, mesic Xerollic Camborthid) with <1.0% OM in the surface 0 to 10 cm. Soils at both test sites are >180 cm deep to underlying bedrock and representative of the loess soils found extensively in the semiarid climatic zone of eastern Washington and north-central Oregon (Lenfesty, 1967).

The experimental design in 1993 was a split block (Little and Hills, 1978) with six replications. Main plots consisted of tillage method (packed vs. nonpacked), and subplots were seeding depth (deep vs. shallow). Each subplot was 21 by 12 m. In 1994, a randomized complete block experimental design with six rep-

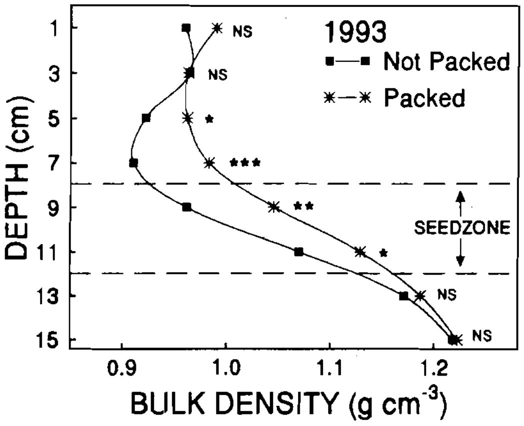

Fig. 1. Soil bulk density as affected by packing in 1993.

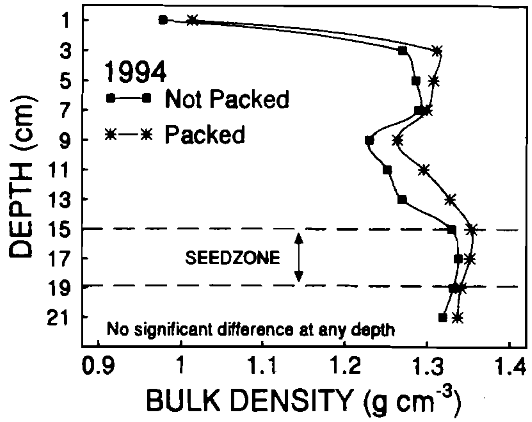

Fig. 3. Soil bulk density as affected by packing in 1994.

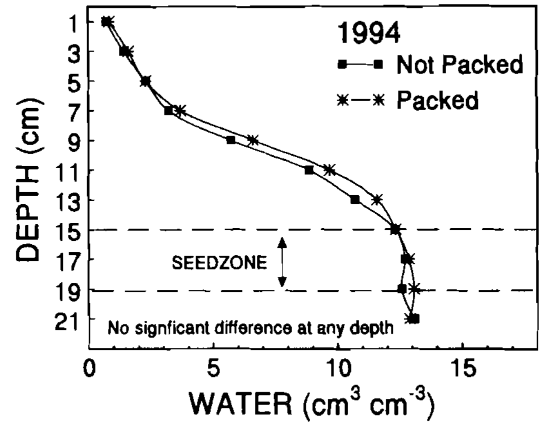

Fig. 4. Seedzone water content as affected by packing in 1994.

lications included packed and nonpacked treatments but not seeding depth. Each plot was 21 by 90 m.

At both locations, soils were subsoiled at the beginning of the fallow cycle to a depth of 45 cm with shanks spaced 150 cm apart (Table 1). In late March, primary spring tillage was conducted to a depth of ≈ 15 cm with a conventional tandem disk with 28-cm-radius blades. Plots were fertilized in April, at a rate of 56 kg ha^{-1} in 1993 and 50 kg ha^{-1} in 1994, with aqua NH_3 injected through 2-cm wide shanks spaced 45 cm apart (Table 1). During late spring and summer the plots were rodweeded, three times in 1993 and four times in 1994, to control weeds and maintain a dry soil mulch. Packing was conducted immediately prior to seeding winter wheat by making one pass through each designated 21- by 90-m plot with a coil packer pulled by a crawler tractor on 24 Aug. 1993 and 29 Aug. 1994. The coil packer had 4-cm thick solid steel coils with a radius of 25 cm. Individual coils were spaced 8 cm apart and exerted a pressure of 6.23 kPa. Total width of the implement was 21 m.

Soil BD and volumetric water content were determined gravimetrically, as described by Gardner (1986), within 1 d after packing from both packed and nonpacked treatments. These measurements were obtained in 2-cm increments to a depth of 16 cm in 1993 and to 22 cm in 1994 using an incremental sampler specially designed for sampling in loose dry surface soil conditions (Pikul et al., 1979). Wheel tracks were avoided. Three sample cores were obtained from each plot.

Plots were seeded 1 d after packing. In 1993, soft white common winter wheat (cv. Lewjain) was seeded in 0.4-m rows with John Deere HZ deep furrow split-packer drills at a rate of 47 kg ha^{-1}. As seeding conditions in 1993 were the wettest many growers had ever experienced, seeds were placed at two depths: (i) shallow, 10 cm below the soil surface, and (ii) deep, 15 cm below the soil surface. In 1994, soft white winter club wheat (cv. Moro) was seeded in 0.46-m rows with an International Model 150 deep furrow split-packer drill at a rate of 50 kg ha^{-1}. Seeding conditions were very dry in 1994 (Fig. 4) and the drill was adjusted to place seed as deep as possible.

Soil cloddiness was determined within 3 d after seeding by individually measuring the diameter and mass of soil clods within a 1-m diameter sampling hoop randomly positioned within each plot. All clods with diameters >5 cm were sorted into 1-cm size increments and the mass of each size group determined. Measurements were obtained from three sample hoops in each plot. Surface residue after seeding was determined by clipping all aboveground dry matter within three 1-m diameter sample hoops randomly placed in each plot.

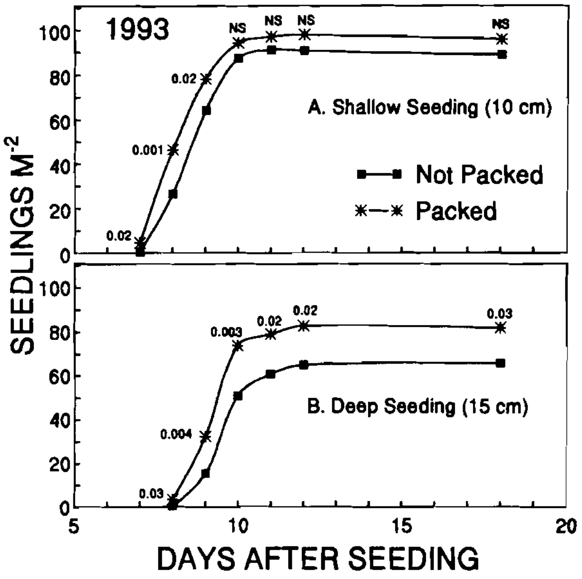

Fig. 5. Wheat seedling emergence from shallow and deep seeding depths as affected by packing in 1993.

Wheat seedling emergence was measured by counting individual plants in 1-m row segments at 24-h intervals beginning 8 d after seeding (DAS). Three row segments were selected and marked within each plot prior to emergence of wheat seedlings. The same rows were consistently used in each plot to avoid any difference due to openers. No precipitation occurred during the packing, seeding, and emergence portion of the study (August, September) in either year.

Spike density was measured from hand-cut samples obtained from three 1-m row sections in each plot at harvest in July. Clean grain yield, kernels $spike^{-1}$, 1000 grain wt, and dry matter were then determined from these samples.

An analysis of variance was conducted for soil BD and volumetric water content at each sampling depth, wheat seedling emergence on each sampling date, soil cloddiness, surface residue (Year 2 only), and yield components and crop characteristics. Treatments were considered significantly different if the P-value was <0.05. Treatment means were separated by Fisher's protected least significant difference.

RESULTS AND DISCUSSION

Soil Bulk Density and Seedzone Water Content

The BD of the soil mulch at the end of the 1992–1993 fallow cycle was low near the surface and increased grad-

Table 2. Yield components and crop characteristics of 'Lewjain' winter wheat in the 1993–1994 season.

Component or characteristic	Packed-deep seeded	Nonpacked-deep seeded	Packed-shallow seeded	Nonpacked-shallow seeded	Signif.	CV, %	LSD (0.10)
Grain yield, Mg ha^{-1}	3.93	3.56	3.60	3.27	*	4.9	0.32
Kernels $spike^{-1}$	30.1	31.5	28.0	29.2	NS	9.2	
1000-grain wt., g	36.6	37.0	34.6	33.7	***	5.2	2.3
Spikes m^{-2}	357	307	374	332	**	11.9	49
Residue dry wt., Mg ha^{-1}	5.13	4.52	4.82	4.36	NS	5.2	

*,**,*** significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

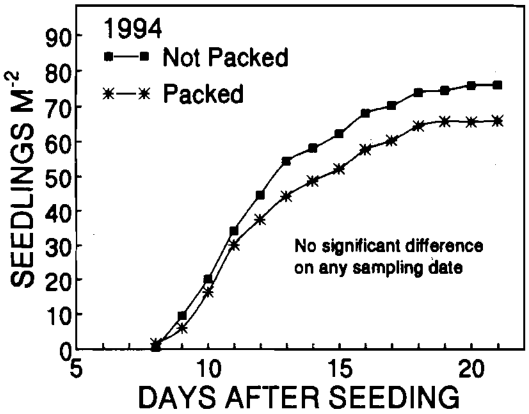

Fig. 6. Wheat seedling emergence as affected by packing in 1994.

ually with depth (Fig. 1). Loose, relatively thick, low BD dry layers such as this are formed above depth of rodweeding and are typical of summer fallow mulches in the PNW (Pikul et al., 1985; Schillinger and Bolton, 1996). Packing significantly increased soil BD in the seedzone (Fig. 1), resulting in increased volumetric water content to a depth of 11 cm (Fig. 2). Seedzone water conditions in late August 1993 were the most favorable many wheat growers in low-rainfall dryland regions of eastern Washington had ever experienced.

Soil BD in 1994 increased abruptly 3 cm below the surface then remained quite stable, between 1.25 and 1.35 g cm^{-3}, to a depth of 22 cm (Fig. 3). The high BD layer near the surface was likely formed by the first rodweeding operation conducted when the soil was too wet; 4 d after 38 mm of rain in mid-May. Packing had no significant effect on either BD (Fig. 3) or volumetric water content (Fig. 4) at any depth to 22 cm. Soil drying extended below the rodweeder depth in 1994 and BD bore little relationship to volumetric water content (Fig. 3 and Fig. 4).

Wheat Seedling Emergence and Grain Yield

Packing significantly increased wheat seedling emergence in 1993. With shallow seeding, plants in packed plots emerged faster until 10 DAS, after which there were no differences (Fig. 5a). With deep seeding, differences in emergence between packed and nonpacked treatments were significant on all sampling dates (Fig. 5b). We did not expect to find these emergence differences because of the wet 1993 seeding conditions (Fig. 2). Plants survived the mild 1993-1994 winter with little injury. Grain yield components and crop characteristics at harvest are shown in Table 2. Packing combined with deep seeding resulted in the highest grain yield. More grain-bearing spikes were produced and significantly higher grain yield was achieved with packing in both deep and shallow seeded plots. Deep seeding produced heavier kernels and higher grain yield compared with shallow seeding.

Table 3. Yield components and crop characteristics of 'Moro' winter wheat in the 1994-1995 season.

Component or characteristic	Packed	Nonpacked	Signif.	CV, %
Grain yield, Mg ha^{-1}	3.44	3.36	NS†	20.7
Kernels spike^{-1}	46.7	46.1	NS	13.9
1000-grain wt., g	33.4	33.9	NS	2.1
Spikes m^{-2}	232	239	NS	26.2
Residue dry wt., Mg ha^{-1}	4.48	4.75	NS	24.0

† NS, no significant differences at the 0.05 probability level.

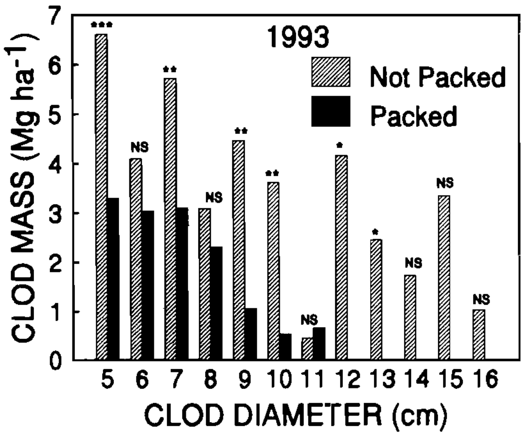

Fig. 7. Soil clod mass and size distribution as affected by packing in 1993.

In 1994, high BD beginning 3 cm below the surface and dry soil impeded uniform penetration of grain drill openers, as evidenced by recoil of springs controlling opener placement. An average of 8.2 cm and 8.8 cm of soil covered the seed in packed and nonpacked plots, respectively. Seedling emergence was variable in both packed and nonpacked treatments. There were no differences between treatments in wheat seedling emergence on any date in 1994 (Fig. 6), or in any yield component and crop characteristic at harvest (Table 3).

Soil Clod Mass and Residue Reduction

Packing reduced the mass and size distribution of soil clods both years (Fig. 7 and 8; Table 4). Although method and timing of tillage operations were similar throughout both fallow cycles (Table 1), differences in clod retention between the Ritzville and Shano soil types were readily apparent. Clod mass was 3 to 5 times greater in the Ritzville soil compared with the Shano soil for packed and nonpacked treatments, respectively (Table 4). The coil packer eliminated clods >11 cm in diameter (Fig. 7), which may have benefited wheat seedling emergence by reducing large clod rollback into the furrow. Clods were more

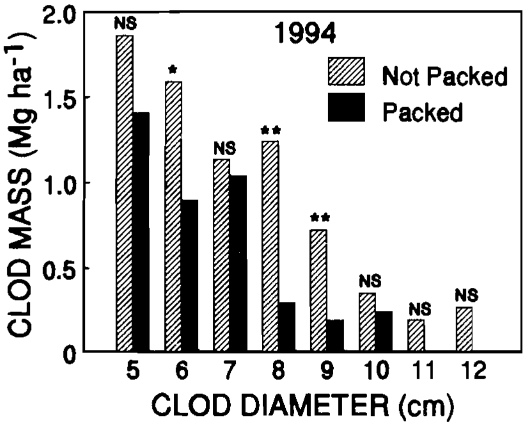

Fig. 8. Soil clod mass and size distribution as affected by packing in 1994.

Table 4. Surface clod mass and residue at the end of the fallow cycle as affected by packing in 1993 and 1994†.

	Clod mass		Residue
	1993	1994	1994
	Mg ha^{-1}		
Nonpacked	40.7	7.3	1.3
Packed	14.0***	4.0***	0.8***

*** Significant within-column differences at the 0.001 probability level.
† Surface residue was not measured in 1993.

difficult to retain during the 1993-1994 fallow cycle (Table 4) because Shano soil is coarser-textured, lacks structure, and is low (<1%) in organic matter: Thus, maintenance of surface residue on this soil type is more critical to prevent soil loss from wind erosion. Surface residue was significantly reduced by packing in 1994 (Table 4) but, due to above average grain production in the preceding crop cycle (Table 1), surface residue levels still exceeded the minimum quantity required on highly erodible land for compliance with government farm programs.

CONCLUSION

Packing summer fallow just before seeding winter wheat may be a viable option for improving stand establishment and increasing grain yield in semiarid regions of the PNW. Packing, however, reduces soil clod mass and buries residue. Surface residue and soil cloddiness are the primary factors affecting wind erosion that growers can control to some degree.

On finer-textured soils and under higher annual precipitation, growers using conservation tillage can generally maintain adequate surface residue and soil cloddiness to minimize wind erosion throughout the fallow cycle. Packing may provide agronomic benefits without undue risk of soil loss under these circumstances.

In the drier (<250 mm annual precipitation) wheat-fallow areas, soils are generally coarse-textured and residue production potential is low. Surface roughness and clods are difficult to retain throughout the fallow cycle on these soils, often leaving residue as the only defense against wind erosion. Packing summer fallow should not be practiced under these conditions.

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