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Moldboard plowing in wheat–fallow systems of the Pacific Northwest: Effect on yields, organic matter

By Surendra Singh, Rakesh Awale, Stephen Machado

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Depth-wise stratification sampling using tractor-mounted probe.

A two-year winter wheat–fallow system in the Pacific Northwest is practiced in areas with annual precipitation <16 inches. Wheat is planted in the fall and harvested in the summer, followed by 13 to 14 months of fallow. The summer fallowing often involves different types of tillage practices to facilitate water storage and weed control, which can influence vertical distribution of soil acidity and nutrients in the profile, possibly affecting crop yields. Long-term studies could help us understand soil nutrients and yield responses across different tillage and N rate applications.

More information

View the related article in *Agrosystems, Geosciences & Environment*, "Soil Chemical Properties and Wheat Yields Under Tillage and Nitrogen Managements in Eastern Oregon" (DOI: 10.1002/agg2.20272).

Abbreviations

PNW	Pacific Northwest
SOM	soil organic matter
WF	wheat–fallow

A two-year winter wheat–fallow (WF) system in the Pacific Northwest (PNW) is practiced in areas with annual precipitation <16 inches. In these systems, wheat is planted in the fall and harvested in July–August (next year), followed by 13 to 14 months of fallow to recharge the soil profile water prior to another cropping cycle. In the traditional WF system, summer fallowing often involves different types of tillage practices using a moldboard plow, offset disk, and subsurface sweep to facilitate water storage and weed control (Machado, **2011**; Fuentes et al., **2004**).

Different tillage intensities can influence vertical distribution of soil acidity and nutrients in the profile, possibly affecting crop yields. The influences of different tillage types on soil properties may also interact with fertilizer N applied since it can induce soil acidity (Mahler, **2002**). Additionally, soil acidification from N fertilizer application has become one of the major environmental concerns for wheat production in PNW. This could be worsened if soil acidity is stratified in the crop root zone, leading to a decrease in crop yields (Ghimire et al., **2017**). Further, the use of N fertilizers is on the rise in wheat production systems of PNW. Research suggests that reduced tillage concentrates the fertilizers in the seed zone, which increases the soil acidity in topsoil layers.

Long-term studies could help us understand soil nutrients and yield responses across different tillage and N rate applications for the sustainability of wheat production in the region.

Methodology

To determine the combined effects of these tillage practices and N rates on soil acidity, yields, and nutrient distribution, we collected and analyzed soils and wheat yields from the long-term tillage–fertility experiment established in 1940 at the Oregon State University's Columbia Basin Agricultural Research Center in Pendleton, OR. The study includes three tillage types (moldboard plow, 9 inches; offset disk, 6 inches; and subsurface sweep, 6 inches—hereafter, referred to as plow, disk, and sweep, respectively) and three N rate treatments (0, 80, and 160 lb/ac—hereafter referred to as N_0, N_{80}, and N_{160}, respectively) with three replicates each. All of the tillage types were implemented during the fallow period, and each was followed by cultivation (4–6 inches), harrowing, and rod-weeding four to five times to control weeds and retain seed-zone moisture.

Soil samples were collected in 2016 during the fallow phase of the WF system before implementing primary tillage treatment operations. Four sub-samples were combined to make a composite sample from each plot. A tractor-mounted Giddings probe was used to collected sub-samples at depth increments of 0 to 4, 4 to 8, and 8 to 12 inches using 1.4-inch-diameter soil cores. Additional soil samples were also collected from a grassland (undisturbed/unmanaged since 1931) in proximity to a WF system experiment to compare soil acidity and soil organic matter (SOM).

The grassland was maintained without fertilizer input and soil disturbance under native vegetation of tall fescue and blue-bunch wheatgrass as dominant species. However, data from the grassland site were not used in statistical analyses.

Samples were processed and analyzed for an array of soil chemical properties, but this study includes only SOM and soil pH. The SOM was measured using Walkley–Black titration method, and soil pH was analyzed in a 1:1 soil to deionized water mixture. Wheat yields were included as average crop yield data from 2011 through 2017.

Response of Soil Organic Matter, pH, and Wheat Yields

The SOM and soil pH were influenced by tillage and N rates, respectively, whereas wheat yields were influenced by both tillage and N rates. Interactions of tillage and sampling depths affected both SOM and soil pH (Table 1).

Table 1. Influence of tillage, N rates, and depths on soil organic matter, soil pH, and wheat yields

[a] Yes: Statistical difference at $P \leq .05$.[b] No: No statistical differences at $P \leq .05$.

	Treatments				
	Tillage (T)	**N rates (N)**	**T × N**	**Depth (D)**	**T × D**
Soil organic matter	Yes[a]	No	No	Yes	Yes
Soil pH	No[b]	Yes	No	Yes	Yes
Wheat yields	Yes	Yes	No	–	–

Tillage × depth significantly influenced soil pH and organic matter within the surface 0- to 12-inch profile (Table 1). Sweep and disk tillage exhibited strong vertical stratification for SOM and soil pH, but soil properties were uniform across 0- to 12-inch soil under plow tillage (Figure 1). At the surface 0 to 4 inches, sweep and disk treatments showed 29% more SOM, but 0.61 units less pH compared with the plow treatment. Below a 4-inch soil depth, SOM levels were statistically similar among all tillage treatments, whereas pH was significantly higher under sweep (6.51) and disk (6.67) treatments than under plow (5.84).

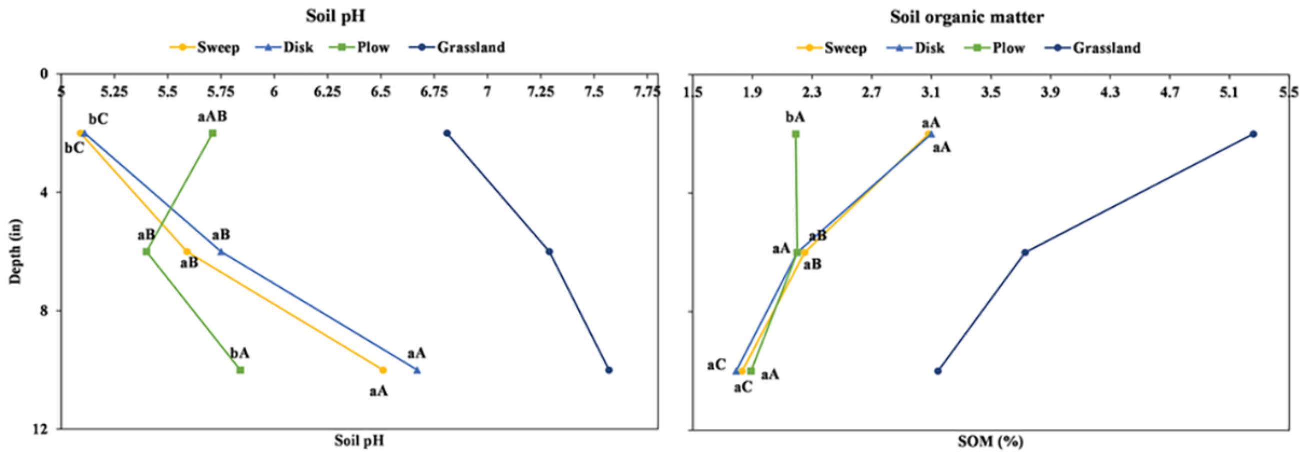

Figure 1, *Depth-wise distribution of soil pH and soil organic matter under different tillage treatments. Lowercase letters show statistically different means among different depths within each treatment level while different uppercase letters show statistically different means among different tillage treatments within each depth at P ? .05.*

Fertilizer-derived soil acidity mostly concentrates in the zone of fertilizer application in drylands and could be exacerbated by shallow mixing of soils under reduced-tillage systems (Ghimire et al., 2017). Soil organic matter and acidity are accumulated at the surface 4-inch layer with reduced tillage (sweep and disk) but distributed throughout the 0- to 12-inch soil profile under intensive tillage (plow). Intense soil disturbance under plow increases crop residue–soil contact and facilitates microbial action on residue decomposition, leading to low SOM, particularly in the topsoils (Halvorson et al., 2002).

Across tillage treatments and depths, soil acidity increased with N application (from 6.04 under N_0 to 5.71 under N_{80}) but was statistically similar between 80 lb/ac and 160 lb/ac N (5.47 under N_{160}) application rates. Additionally, in the 0- to 4-inch depth, sweep and disk had 20% lower Ca and 26% lower Mg while 9 times higher Al than plow across N rates (data not shown). Across tillage and depths, soil pH, Ca, and Mg generally decreased while P, K, and Al increased with increasing N rate (data not shown). Despite increased yields under higher N rates and plow treatments, SOM levels decreased overall compared with other treatments, which suggests that the biomass inputs from WF systems of PNW may not be sufficient to improve SOM levels (Ghimire et al., 2017). This is also corroborated by a decline in SOM levels at all depths under WF systems compared with the grassland site (Figure 1).

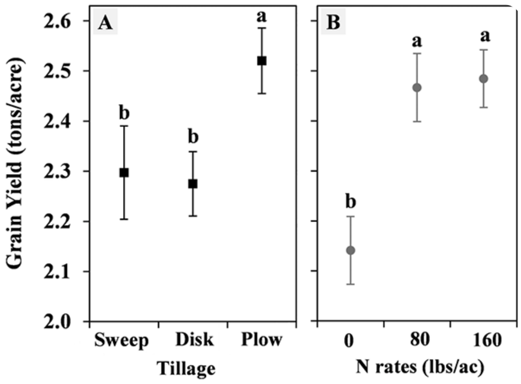

Figure 2, *Wheat grain yields under different (A) tillage and (B) N rate treatments under a wheat–fallow system. Error bars represent standard errors of means (n = 27). Means with different letters are significantly different at P ? .05.*

Tillage influences on SOM, soil pH, and nutrients were reflected in wheat yields. Both tillage and N rates affected wheat yields, but there were no interactions of these treatments (Table 1). Across N rates, mean yields under sweep and disk were 9% lower than the yield under plow (Figure 2). Across tillage, mean yields under N_{80} and N_{160} were greater than the yield of N_0 but did not differ between 80 and 160 lb/ac N rates (Figure 2). Lack of grain yield response to high N rate addition (N_{160}) confirmed the adverse impacts of increased soil acidity on crop root growth, yields, and nutrient uptake. Our results comply with previous research at the same experimental plot that documented yield reduction with sweep and disk over plow and no yield response to N-addition beyond the application of 80 lb/ac N (Camara et al., 2003; Ghimire et al., 2017).

Although sweep and disk tillage increased SOM in topsoil, soil pH and wheat yields were higher under plow. The increased yields under plow could be due to the uniform distribution of soil pH (Figure 1) that controls nutrient availability to plants in the root zone. This was also evident from the fact that topsoils were relatively more acidic under sweep and disk than plow. Additionally, previous studies also revealed that under WF systems, plow controls weeds better than sweep and disk tillage and reduces the weed pressure on the subsequent wheat crop. Long-term N application >80 lb N/ac combined with reduced tillage (sweep and disk) can result in reduced yields, mainly due to increased topsoil acidity and weed pressure.

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