Soil Physical Characteristics of Contrasting Cropping Systems in the Great Plains: Preliminary Findings

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Abstract

Agricultural systems may produce both damaging and beneficial effects on soil physical condition. We conducted a multi-location study during 1999 to 2002 to evaluate physical, chemical, and biological attributes of soil quality. Our hypothesis was that increased diversity of cropping system improves soil quality attributes. This report provides preliminary findings of cropping systems effects on water infiltration, aggregate size distribution (expressed as mean weight diameter, MWD), and bulk density (BD). We identified no significant cropping system effect on water infiltration for locations having the same tillage operations within the cropping system. MWD was significantly greater at Bushland and Fargo; locations that have different cropping intensity or no tillage. Tillage resulted in increased, decreased, or unchanged BD near the soil surface, when compared with no tillage, depending on time of year. Measurements of infiltration, MWD, or BD made at only one time in a rotation cycle do not convey meaningful information on soil quality because of significant temporal variation in these properties.

Introduction

The state of the soil physical environment is important for maintaining sustained agronomic production, a concept embodied in the presumption that good soil tilth is a precursor to high crop productivity. Agricultural systems may produce both damaging and beneficial effects on soil physical condition. Soil compaction frequently occurs when agricultural equipment passes over a field but little is known about the long-term interaction of crop systems, residue and fertilizer management on soil physical condition. Soil organic matter (SOM) is linked to fertility and a desirable soil physical state and often has a disproportionate effect on soil physical behavior (Boyle, et al. 1989). Maintenance of SOM seems to be the key to sustaining the soil resource and crop productivity (Doran et al., 1998). A multi-location study was conducted during 1999 to 2002 to evaluate a number of physical, chemical, and biological properties associated with assessment of soil quality. Objectives were to 1) quantify temporal dynamics of soil quality attributes in established cropping systems, 2) assess soil quality attributes between treatments of contrasting management intensity, and 3) evaluate recently developed methods for assessing soil quality (Wienhold, et al. 2003). The purpose of this report is to present preliminary findings on selected soil physical attributes.

Materials and Methods

Contrasting management treatments within eight long-term cropping system located near Akron, CO, Brookings, SD, Bushland, TX, Fargo, ND, Mandan, ND, Mead, NE, Sidney, MT, and Swift Current, SK were used in the study. Treatments selected at each site differed in management intensity as characterized by either type or frequency of tillage, cropping intensity, and/or crop rotation diversity. Varvel et al. (2003) describes these long-term field experiments.

Soils were sampled prior to planting, at peak crop biomass, and after harvest during a period of four years at each location. Samples were collected in the same plots throughout the duration of the study. Soil cores from depth increments of 0 to 7.5, 7.5 to 15, and 15 to 30 cm were collected using stratified sampling so within- and between-row areas of plots comprised a proper proportion of the composite sample. The composite sample was used to determine gravimetric water content (Gardner, 1986) and bulk density (Blake and Hartge, 1986). Surface soil (0 to 50 mm) was collected with a shovel in order to measure dry aggregate size distribution and stability. After air drying, aggregate size distribution was determined by a rotary sieve (Chepil, 1962), and mean weight diameters (Kemper and Rosenau, 1986) were calculated to express the results.

Infiltration was determined at each location using a single ring infiltrometer (Lowery et al., 1996). An aluminum infiltration ring 14.9 cm diameter by 12.7 cm long was inserted into the soil to a depth of 7.6 cm. The surface was covered with plastic wrap, distilled water was added (2.5 cm depth in the ring), the plastic wrap was removed from the ring, and the time required for the water to infiltrate into the soil was measured. To reduce the confounding effect of antecedent soil water content on water infiltration rate, a second volume of water (2.5 cm depth in the ring) was added (wet run) and the time required for water infiltration was measured. Duplicate infiltration measurements were made within the row for row crop systems and duplicate measurements were made in the trafficked interrow and non-trafficked interrow for all systems. Infiltration rate for the wet run was tested for statistical differences. Analysis of variance was used to determine differences among soil property values between treatments and across sampling times. Differences were considered significant at $P \leq 0.05$.

Results and Discussion

<u>Infiltration</u> Cropping system had a significant effect on infiltration for at least one position at the Akron, Fargo, and Mandan sites (Table 1). Differences in cropping systems at these sites included a tillage variable as well as a cropping intensity and crop species variable in the cropping system.

Table 1. Cropping system (Tmt) and time (T) effects on infiltration. Locations identified in bold type used tillage in the cropping system (Tmt).

Location	Position	Tmt.	Time	Tmt * T
Akron, CO	no track	**[1]	**	**
	track	NS	**	NS
Brookings, SD	row	NS	**	NS
	no track	NS	**	NS
	track	NS	**	NS
Fargo, ND	row	**	**	**
	no track	NS	**	NS
	track	NS	NS	NS
Mandan, ND	row	NS	NS	NS
	no track	**	**	**
Mead, NE	row	NS	**	NS
	no track	NS	NS	NS
	track	NS	**	NS
Sidney, MT	row	NS	NS	NS
Swift Current, SK	no track	NS	NS	NS
	track	NS	**	NS

[1]** denotes significant treatment effects at P=0.05 and NS indicates not significant

Sites that had the same tillage system but only different cropping intensity or crop species in the cropping system did not have significant cropping system effects on infiltration. All sites had a significant time effect on infiltration except at the Sidney location. Actual infiltration rates varied considerably among locations. Rates varied from about 1 cm/h at the Akron and Mandan locations for the track position to over 100 cm/h at the Fargo location. Generally the track position had lower infiltration rates than the no track or row positions.

A system by time interaction was significant at the Akron, Fargo, and Mandan locations indicating that the significant cropping system effects were not consistent throughout the time of the experiment. The significant time effect on infiltration rate at the Brookings location (Table 1) exhibited a cyclic pattern through the growing season. For the non-trafficked position, infiltration rate increased during the year. At the row-position and trafficked-position, infiltration rate was lowest at first sampling of the year, increased at the time of the second sampling, then decreased again. A similar, but less pronounced pattern occurred at the Mead location.

Aggregate size distribution Cropping system significantly affected MWD at Fargo and Bushland (Table 2). Cropping systems at Fargo have a tillage variable; no tillage was compared to conventional tillage. Both systems at Bushland are under no tillage. Soil organic C at Bushland was greatest under continuous wheat (CW) compared to a wheat-sorghum-fallow (WSF) rotation. Average (all dates) MWD at Bushland was 10.85 mm under CW and 8.95 mm under WSF. At Fargo, MWD was greater under the no-tillage system. A large MWD value represents an aggregate size distribution having a large portion of large aggregates. Data suggest that soil aggregates formed under no tillage (a system having elevated organic C) resist disintegration compared with aggregates under tillage. Studies at Brookings of a no tillage and conventional tillage corn-soybean rotation (Pikul, 2003, unpublished data) support the observation that dry aggregate stability (represented by MWD) is greater under no tillage compared with conventional tillage. There was a significant effect of time on MWD at all locations (Table 2). At Brookings, MWD under the alternative system (4-year rotation) was significantly greater than the continuous corn (CC) system in the 4th year of the rotation (alfalfa phase). A similar comparison at Mead showed a smaller MWD under a 4-year rotation compared with CC.

Bulk density At the eight locations (Table 2), BD ranged from 0.8 Mg m^{-3} at the surface (0 – 75 mm) under native grassland (grassland not shown) to 1.6 Mg m^{-3} for the lower depth increment (clay loam to clay textures) at two locations (analysis not shown). Bulk densities were greatest for cropped land as compared with native grassland. Greatest source of variation in BD was observed with time of sampling especially below the 75 mm depth. Differences in BD between cropping systems were most frequently observed for the surface depth increment (5 locations). Changes in BD over time displayed no obvious trends but they probably represent seasonal and annual variations generated by phases in the rotation, tillage and subsequent reconsolidation, and wetting-drying histories.

Table 2. Analysis of variance for mean weight diameter of surface soil (top 50 mm) and bulk density (0 – 75 mm). Locations identified in bold type used tillage in the cropping system (Tmt).

Effect	Akron	**Brookings**	Bushland	Fargo	Mandan	**Mead**	Sidney	**Swift Current**
	----------------------- p-value, mean weight diameter -----------------------							
Tmt		NS	0.051	0.016	NS	NS		NS
Time (T)		<0.001	<0.001	<0.001	0.004	<0.001		0.001
Tmt * T		0.056	0.083	NS	NS	<0.001		NS
	---------------------------- p-value, bulk density ----------------------------							
Tmt	NS	NS	0.014	0.005	0.004	0.018	0.012	NS
Time (T)	NS	<0.001	<0.001	NS	NS	<0.001	0.013	NS
Tmt * T	NS	NS	0.039	NS	NS	NS	NS	NS

Conclusions

Infiltration There were no significant cropping system effects on infiltration for locations that had the same tillage system but only different cropping intensity or crop species in the cropping system. A cyclical pattern of infiltration rate was present for most cropping systems and locations. A snap-shot of water infiltration (one-time measurement) would not be an appropriate soil quality indicator because of significant temporal variation in infiltration rate.

<u>Mean weight diameter</u> Greater MWD's were found under systems with greater cropping intensity and less tillage at Bushland and Fargo, respectively. Analysis of dry aggregate stability following a second sieving with a rotary sieve may be a sensitive indicator of soil quality (data not shown). A one-time measurement of aggregate size distribution, expressed as MWD, would not be an appropriate soil quality indicator because of significant temporal variation in aggregate stability.

<u>Bulk density</u> We cannot identify or recommend a single given rotation phase or time of year in which BD should be measured to obtain the most reliable data for use in soil quality assessments. For locations in which no-tillage was compared with conventional tillage, tillage resulted in increased, decreased, and unchanged BD near the surface. Soil texture and the time of tillage relative to sampling time probably influenced how tillage influenced BD. Some BD in the lower depth increment approached threshold densities restrictive to root growth (Jones, 1983).

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