Controlled Wheel Traffic Effects on Soil Properties in Ridge Tillage

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ABSTRACT

Ridge-till is gaining widespread use on highly erodible land. Matched-width equipment has allowed producers to establish permanent traffic lanes in ridge-till. The establishment of permanent traffic lanes and a lack of preplant tillage has increased concern about soil compaction. The purpose of our study was to assess the effects of long-term controlled tractor wheel traffic on soil properties of a ridge tillage system. This research was conducted on a Sharpsburg silty clay loam (fine, montmorillonitic, mesic Typic Argiudoll) in southeastern Nebraska. A split-split-plot design was employed to evaluate differences in soil properties among corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] crops; row, trafficked interrow, and nontrafficked interrow positions; and depths of 0 to 7.5, 7.5 to 15, and 15 to 30 cm. Axle load of the tractor used on the plots was 4 Mg. Sampling was conducted in the summer after ridging. Most variability in soil properties among positions was confined to the 0- to 7.5-cm depth. Bulk density, soil strength, aggregate mean weight diameter (MWD), water content at field capacity (FC), and water content at wilting point (WP) tended to be highest in the trafficked interrow and least in the row. Saturated water content and gravitational water (GW) were generally highest in the row and least in the trafficked interrow. Soil strength in the trafficked interrow was 56% greater than the nontrafficked interrow and 104% greater than the row. Similar, but less pronounced differences among positions were also observed for bulk density. Aggregate mean weight diameter in the trafficked interrow indicated that wheel traffic resulted in larger aggregates while ridging resulted in smaller aggregates in the 0- to 7.5-cm depth of the row. Mean saturated hydraulic conductivity (K_{sat}) in the trafficked interrow was approximately one-quarter of the mean value for the nontrafficked interrow and row. Organic C and TN were greater in the row than the interrow positions. The influence of tractor wheel traffic on soil properties was largely dissipated by the 15- to 30-cm depth. Because of the dissimilarity in soil properties among positions, ridge-tilled fields should be conceptualized and managed as three distinct soil zones, not as a single unit.

ADOPTION OF RIDGE TILLAGE is increasing. While first promoted to enhance crop production on poorly drained soils, it is gaining widespread use on highly erodible land (Soil and Water Conservation Society, 1990). In addition to increased erosion control, ridge-till has been found to offer benefits of reduced fuel, chemical, and labor inputs compared with conventional tillage systems. Agricultural management systems such as ridge-till that increase resource efficiency while maintaining crop and soil productivity are essential for producers to meet future production demands while avoiding environmental degradation.

Ridge tillage is characterized by a permanent row–interrow configuration where the row is elevated 12 to 20 cm above the interrow throughout most of the year (Fig. 1). Producers often use matched-width equipment in ridge till so that tractor wheel traffic for herbicide and fertilizer application, planting, and ridging is confined to the same interrows. Combine wheel traffic is also controlled in ridge-till but typically confined to interrows at a wider interval than the tractor. As a result, three distinct soil environments exist in ridge-till: trafficked interrows, nontrafficked interrows, and rows.

Because of the development of permanent traffic lanes and lack of preplant tillage, there is concern about soil compaction in the trafficked interrow of ridge-till and its potential impact on root growth, nutrient and water availability, weed control, and yield. Numerous studies involving conventional, reduced, and no-tillage treatments have documented increased bulk density and soil strength in trafficked interrows, compared with nontrafficked interrows and rows (Voorhees et al., 1978; Fausey and Dylla, 1984; Gerik et al., 1987; Larney and Kladivko, 1989). High bulk density and soil strength created by wheel traffic can lower crop yields by impeding root growth and may persist for many years (Voorhees et al., 1986). Ridge-till root densities have been reduced in trafficked interrows by >50%, compared with nontrafficked interrows (Bauder et al., 1985; Kaspar et al., 1991).

Wheel traffic has been found to decrease the porosity and proportion of larger pores in trafficked interrows resulting in differences in soil-water drainage and retention characteristics among positions. Reduced infiltration capacity in ridge-till interrows compared with rows has been observed (Hamlett et al., 1990). Less water has been found to be retained between 0 and −100 kPa in trafficked interrows than in nontrafficked interrows or rows of moldboard plow, chisel, ridge-till, and no-till systems (Johnson et al., 1984). Similarly, wheel traffic was reported to reduce the volume of pores >15 μ diam. in the upper 17.8 cm of moldboard plow interrows (Hill and Meza-Montalva, 1990).

Few studies have documented the effects of ridge tillage on soil properties with regard to compaction in rows. Significant increases in soil strength in ridge-till rows below 7.5 cm have been reported (Bauder et al., 1985). It has been suggested that increased soil strength in the row may be attributed to compaction created by planting operations when soil is at or above field capacity (Larney and Kladivko, 1989).

The purpose of our study was to assess the effects of long-term controlled tractor wheel traffic on soil properties of a ridge tillage system.

MATERIALS AND METHODS

The research site is located at the University of Nebraska–Lincoln Rogers' Memorial Farm located approximately 19 km east of Lincoln, NE (Lancaster County). The site is a nearly level (0–3% slope) Sharpsburg silty clay loam with 10% sand, 57% silt, 33% clay, 23 kg organic C m^{-3} soil, and 2.3 kg total N m^{-3} soil. This long-term tillage study was established on

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Abbreviations: MWD, aggregate mean weight diameter; K_{sat}, saturated hydraulic conductivity; SAT, water content at saturation; GW, gravitational water; FC, water content at field capacity; WP, water content at wilting point; AWHC, available water-holding capacity; OC, organic carbon; TN, total nitrogen.

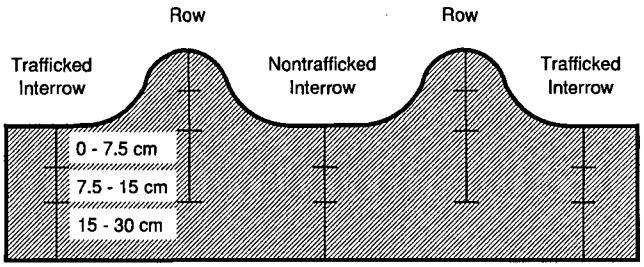

Fig. 1. Idealized cross-section of a ridge-tilled field showing the trafficked interrow, nontrafficked interrow, and row with associated sampling depths. Sampling depths are equivalent in each position.

the site in 1980 by the USDA-ARS. Ridge-till was one of six tillage treatments in the study. Corn and soybean were grown continuously in ridge till since 1980 and 1985, respectively. Each tillage–crop plot is six 0.76-m rows wide and 22.9 m long. Controlled wheel traffic has been used on all plots since their establishment.

Tractor tires operated in the interrows between Rows 2 and 3 and Rows 4 and 5. Axle load for the tractor was 4 Mg. Combine tires operated in the interrows between Rows 1 and 2 and Rows 5 and 6. Axle load for the combine with a six-row header was 8 Mg. Other equipment used on the plots included a six-row ridge-till planter with trash whippers and a six-row ridge-till cultivator–ridger. The general sequence of operations were as follows: spring application of liquid herbicide using a six-row spray boom attached to the tractor, hand broadcast of NH_4NO_3, planting, row crop cultivation to a depth of 10 cm followed about 2 wk later by a single 10-cm-deep ridging operation, and harvest in late September to early October.

Soil sampling was conducted on 27 June 1991. Ridge height at the time of sampling was approximately 15 cm. Samples were collected at three depths, in three positions of both crops. Depths of 0 to 7.5, 7.5 to 15, and 15 to 30 cm were evaluated in one row, tractor-trafficked interrow, and nontrafficked interrow in each ridge-till plot (Fig. 1). The nontrafficked interrow was located between Rows 3 and 4 of each plot. A single trafficked interrow and row were randomly selected for sampling in each plot. Trafficked interrows were located between Rows 2 and 3 and between Rows 4 and 5. Rows considered for sampling included Rows 3 and 4.

Samples were collected for bulk density and particle-size distribution using a 2.26-cm i.d. sampling probe (Doran and Mielke, 1984). Undisturbed cores for soil strength and soil water properties were collected with an 8.2-cm i.d. sampling probe (Blake and Hartge, 1986). Cores from the 15- to 30-cm depth were obtained from the middle of the depth increment. Bulk samples for aggregate-size analysis and chemical properties were collected using a long-bladed shovel. All samples were placed in separate sealed containers and immediately transported to the laboratory. Small soil cores (2.26-cm i.d.) were oven dried at 105 °C for 24 h. Undisturbed cores were placed directly into cold storage at 5 °C. Bulk samples for aggregate-size analysis and chemical properties were dried in a greenhouse and then placed in cold storage.

Bulk density was calculated on an oven-dry basis. Particle-size distribution was determined using the hydrometer method (Gee and Bauder, 1986).

Water-tight end caps were placed on the undisturbed cores and K_{sat} was determined using a constant-head method (Klute and Dirksen, 1986). Three outflow readings at steady state were taken on each core and averaged. After K_{sat} measurements, the bottom end cap on each core was fitted with a −100 kPa porous plate. Cores were rewetted from the bottom and then desorbed at pressures of −1, −5, −10, −30, −50, and −100 kPa. Mass of the effluent was determined at each pressure step.

After the −100 kPa pressure step, end caps were removed and a subsample from the bottom of each core was used to determine gravimetric water content. Soil strength was determined using a fall-cone penetrometer on the upper surface of each core at a pressure of −0.5 kPa (Hansbo, 1957). Five penetrometer measurements were taken on each core and averaged. After soil strength measurements, a Pamona ring (5.0 cm i.d. by 2.5 cm). was inserted to a depth of 5.0 cm into the center of each core. Soil surrounding each Pamona ring was removed, placed in a soil moisture can, and dried at 105 °C for 24 h for determination of soil water content.

Pamona cores were subjected to pressures of −500 and −1500 kPa using a pressure plate (Klute, 1986). Pressure values were logarithmically transformed and volumetric water content at field capacity (−33 kPa) and wilting point (−1500 kPa) were predicted using a first-order equation. Water content at saturation was set equal to the porosity of the undisturbed core. Gravitational water was calculated as the difference in water content between saturation and field capacity. Available water-holding capacity was calculated as the difference in water content between field capacity and wilting point.

A dry-sieving procedure was employed to determine aggregate-size distribution. Each sample was initially passed through an 8.0 mm sieve. A 100-g subsample was separated into aggregate-size fractions of ≥2.0, 1.0 to 2.0, 0.5 to 1.0, and <0.5 mm using a sieve shaker for 5 min. The aggregate-size distribution for each sample was expressed as MWD (Kemper and Rosenau, 1986).

Organic C and TN were determined on each aggregate-size fraction using a Carlo Erba Model NA1500 CNS analyzer (Carlo Erba Strumentazione, Milan, Italy).[1] Each fraction was ground in a ball mill for 3 min prior to analysis. Organic C and TN for each sample was calculated on a mass basis using the weighted average of aggregates in each fraction.

Crop, position, and depth effects for all soil properties were evaluated by analysis of variance with crop as the whole-plot factor, position as the split-plot factor, and depth as the split-split-plot factor. Because depth cannot be randomized, caution was exercised while interpreting results (Cassel and Nelson, 1985). Treatment combinations were replicated three times. Comparisons for main and interactive effects were made using least significant differences at $P \leq 0.05$ (SAS Institute, 1990).

RESULTS AND DISCUSSION

Analysis of variance indicated that crop influenced bulk density and MWD (Table 1). Bulk density in continuous soybean (1.39 Mg m^{-3}) was significantly greater than continuous corn (1.37 Mg m^{-3}). Although the difference in bulk density between crops was relatively small, soil strength was greater and K_{sat} was lower in continuous soybean than in continuous corn (results not shown).

Smaller MWD was observed in continuous soybean (2.8 mm) than in continuous corn (3.0 mm). The MWD of water-stable aggregates has been found to decrease as soybean is introduced into rotation (Kladivko et al., 1986). Leguminous soybean roots, being high in N, favor more rapid decomposition than roots containing less N (Fahad et al., 1982). If this decomposition were focused on temporary binding agents, the formation of smaller aggregates in soils cropped to soybean wold be expected (Tisdall and Oades, 1982).

Position and depth main effects and the depth × position interaction significantly influenced bulk density, MWD, and soil water properties. Depth and depth ×

[1] Mention of commercial products and organizations in this publication is solely to provide specific information. It does not constitute endorsement by the University of Nebraska or USDA-ARS over other products and organizations not mentioned.

Table 1. Summary of *F*-test significance levels for analysis of variance, showing main and interactive effects of crop, position, and depth on soil physical and chemical properties† in ridge-till.

Source of variation	Bulk density	Soil strength	MWD	K_{sat}	SAT	FC	WP	GW	AWHC	OC	TN
Crop	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Position	**	NS	*	*	NS	**	**	*	NS	NS	NS
Position × crop	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Depth	**	NS	**	NS	**	**	**	**	NS	**	**
Depth × crop	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Depth × position	**	NS	**	NS	**	*	**	**	**	**	**
Depth × position × crop	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**,* Significant at $P \leq 0.01$ and 0.05, respectively; NS = not significant at $P \leq 0.05$.
† MWD, aggregate mean weight diameter; K_{sat}, saturated hydraulic conductivity; SAT, water content at saturation; FC, water content at field capacity; WP, water content at wilting point; GW, gravitational water; AWHC, available water-holding capacity; OC, organic carbon; TN, total nitrogen.

position influenced OC and TN (Table 1). Only MWD was significantly influenced by the depth × crop interaction.

Bulk Density and Soil Strength

Over three depths, mean bulk density in the trafficked interrow was 3% greater than the nontrafficked interrow and 10% greater than the row (Table 2). Mean soil strength differences among positions were more pronounced than for bulk density. Soil strength in the trafficked interrow averaged 56 and 104% more than the nontrafficked interrow and row, respectively (Table 2). A similar response to wheel traffic was observed by Voorhees et al. (1978), providing further evidence that soil strength is a more sensitive indicator of compaction than bulk density.

Differences in bulk density and soil strength among positions were greatest at 0- to 7.5-cm depth. At this depth, bulk density of the trafficked interrow was 8 and 25% greater than the nontrafficked interrow and row, respectively. Soil strength at 0- to 7.5-cm depth was 89 and 350% greater in the trafficked interrow than in the nontrafficked interrow and row, respectively. Lowest bulk density and soil strength among all treatments was observed at 0- to 7.5-cm depth of the row because of the loose soil condition caused by ridging and lack of traffic. Below 7.5 cm, differences in bulk density and soil strength among positions diminished.

Bulk density was greatest in the trafficked interrow followed by the nontrafficked interrow and row for all depths. Bulk density in the trafficked interrow did not change with depth, whereas it generally increased with depth in the nontrafficked interrow and row. These different trends account for the significant depth × position interaction.

Soil strength was greatest in the upper 15 cm of the trafficked interrow. At 15- to 30-cm depth, soil strength in the trafficked interrow was nearly equivalent to the nontrafficked interrow. Soil compaction induced by wheel traffic has been found to be confined to the upper 15 cm of wheel-trafficked lanes for swelling, silty clay soils (Gerik et al., 1987). In general, wheel traffic effects on bulk density and soil strength had dissipated by the 30-cm depth (Hill and Meza-Montalvo, 1990; Bauder et al., 1985).

Aggregate Mean Weight Diameter

Wheel traffic increased mean MWD in the trafficked interrow by 5 and 8%, compared with the nontrafficked interrow and row, respectively (Table 2). Most variability in MWD among positions was confined to the soil surface. At 0- to 7.5-cm depth, the trafficked interrow had a MWD 10 and 23% greater than the nontrafficked interrow and row, respectively. Below 7.5 cm, MWD increased and differences among positions diminished.

Aggregate mean weight diameter differed among positions with depth and increased with depth in the row. In the interrow positions, however, MWD was greatest at 7.5 to 15 cm followed by the 15- to 30- and 0- to 7.5-cm depths, respectively. At each depth, the trafficked interrow had the greatest MWD, compared with the nontrafficked interrow and row. The nontrafficked interrow had greater MWD than the row except at 15- to 30-cm depth.

Tractor wheel traffic and planting and ridging operations were responsible for the large differences in MWD between the trafficked interrow and row. Smaller aggregates in the trafficked interrow were consolidated into

Table 2. Mean comparisons of bulk density, soil strength, and aggregate mean weight diameter among positions and depths averaged across crops. Least significant differences (LSD) at $P \leq 0.05$ are given for the interactions.

Depth	Trafficked interrow	Non-trafficked interrow	Row	Mean	LSD for positions within depths
cm					
	Bulk density, Mg m^{-3}				
0–7.5	1.43	1.33	1.14	1.30 a†	0.08
7.5–15	1.45	1.40	1.39	1.41 b	0.06
15–30	1.46	1.45	1.37	1.43 b	0.03
Mean	1.45 z	1.41 y	1.32 x		
LSD for depths within positions	0.06	0.04	0.05		
	Soil strength, kPa				
0–7.5	34.9	18.5	7.8	20.4 a	33.1
7.5–15	29.6	12.4	12.1	18.1 a	24.3
15–30	13.4	13.8	12.5	13.2 a	7.7
Mean	22.8 x	14.6 x	11.2 x		
LSD for depths within positions	46.6	20.3	4.8		
	Aggregate mean weight diameter, mm				
0–7.5	2.89	2.64	2.63	2.63 a	0.30
7.5–15	3.14	3.04	2.97	3.05 b	0.19
15–30	3.08	2.96	3.00	3.01 b	0.21
Mean	3.05 z	2.90 y	2.83 x		
LSD for depths within positions	0.23	0.19	0.17		

† Values for main effects followed by the same letter within a column (a, b, c) or row (x, y, z) are not significantly different at $P \leq 0.05$.

larger aggregates or clods by the compressive forces of wheel traffic. Greater aggregate geometric mean diameter has been observed in the wheel-racked interrow than the nontracked interrow prior to spring tillage operations (Voorhees et al., 1978). The creation of larger aggregates by wheel traffic can increase erosion control by promoting soil cloddiness (Lyles and Woodruff, 1962) but can also substantially restrict root elongation (Voorhees, 1977).

Planting and ridging operations most likely decreased MWD in the row at 0- to 7.5-cm depth. The potential for mechanical disruption of aggregates during both operations was high. Additionally, the disturbances caused the soil to be more exposed to wetting, drying, and other environmental factors that could weaken the bonds associated with larger aggregates.

Soil Water Properties

Wheel traffic decreased mean K_{sat} to approximately one-quarter of values measured for the nontrafficked interrow and row (Table 3). Extremely low K_{sat} values were observed in the upper 15 cm of the trafficked interrow, substantiating the existence of compaction by wheel traffic to this depth. Differences in K_{sat} between the interrow positions below 15 cm were small, indicating little or no influence of wheel traffic at this depth. The greatest value for K_{sat} was observed in the row at 0- to 7.5-cm depth. Channels created by roots may have contributed to greater K_{sat} in the row than in interrow positions at 15- to 30-cm depth.

Average K_{sat} values in each position indicate that drainage would be much greater in the row and nontrafficked interrow than the trafficked interrow. Thus, anaerobic conditions, which promote denitrification, are less likely to occur in the row and nontrafficked interrow. During wet periods, greater runoff would be expected from trafficked interrows than rows and nontrafficked interrows due to lower infiltration.

Wheel traffic decreased mean values for SAT and GW but increased mean values for FC and WP in the trafficked interrow, compared with the nontrafficked interrow and row (Table 3). Available water-holding capacity was relatively uniform among positions and depths. Most variability in SAT, FC, WP, and GW among positions was confined to the 0- to 7.5-cm depth as a result of the compact condition in the trafficked interrow and the loose, porous condition of the row. Largest SAT and GW values and smallest FC and WP values were observed in the row at 0- to 7.5-cm depth. Below 7.5 cm, differences in SAT, FC, WP, and GW among positions decreased.

For each depth, FC and WP tended to be greatest in the trafficked interrow and least in the row. No consistent trend among positions was observed for SAT or GW at each depth. In the trafficked interrow, SAT increased with depth, whereas it remained constant with depth in the nontrafficked interrow. Field capacity and WP changed little in the trafficked interrow with depth; however, both properties tended to increase with depth in the nontrafficked interrow and row. Gravitational water decreased with increasing depth in the nontrafficked interrow and row. Differences in SAT and WP between interrow positions at 15- to 30-cm depth were small, thus indicating that wheel traffic had little effect at this depth.

Table 3. Mean comparisons of saturated hydraulic conductivity and water retention properties among positions and depth averaged across crops. Least significant differences (LSD) at $P \leq 0.05$ are given for the interactions.

Depth	Trafficked interrow	Non-trafficked interrow	Row	Mean	LSD for positions within depths
cm					
	Saturated hydraulic conductivity, cm h^{-1}				
0–7.5	0.7	10.2	11.8	7.5 a†	6.3
7.5–15	0.5	10.9	6.1	5.8 a	8.2
15–30	4.0	5.6	7.3	5.6 a	10.0
Mean	2.3 x	8.8 y	8.1 y		
LSD for depths within positions	7.3	10.5	6.3		
	Water content at saturation—0 kPa, m^3 m^{-3}				
0–7.5	0.503	0.554	0.603	0.554 b	0.045
7.5–15	0.518	0.546	0.512	0.525 a	0.049
15–30	0.566	0.563	0.546	0.558 b	0.027
Mean	0.538 x	0.557 x	0.552 x		
LSD for depths within positions	0.028	0.029	0.037		
	Water content at field capacity—33 kPa, m^3 m^{-3}				
0–7.5	0.399	0.351	0.326	0.358 a	0.024
7.5–15	0.422	0.390	0.366	0.393 b	0.030
15–30	0.391	0.416	0.404	0.403 b	0.042
Mean	0.401 y	0.393 xy	0.375 x		
LSD for depths within positions	0.040	0.029	0.042		
	Water content at wilting point—1500 kPa, m^3 m^{-3}				
0–7.5	0.291	0.244	0.205	0.247 a	0.040
7.5–15	0.289	0.270	0.273	0.277 b	0.028
15–30	0.296	0.294	0.261	0.284 b	0.032
Mean	0.293 z	0.276 y	0.250 x		
LSD for depths within positions	0.022	0.021	0.039		
	Gravitational water, m^3 m^{-3}				
0–7.5	0.104	0.203	0.277	0.196 b	0.056
7.5–15	0.096	0.156	0.146	0.132 a	0.061
15–30	0.175	0.147	0.142	0.155 a	0.060
Mean	0.137 x	0.164 y	0.177 y		
LSD for depths within positions	0.048	0.045	0.066		
	Available water-holding capacity, m^3 m^{-3}				
0–7.5	0.108	0.107	0.121	0.111 a	0.032
7.5–15	0.133	0.120	0.093	0.166 a	0.031
15–30	0.095	0.122	0.143	0.119 a	0.025
Mean	0.108 x	0.117 x	0.125 x		
LSD for depths within positions	0.035	0.026	0.025		

† Values for main effects followed by the same letter within a column (a, b, c) or row (x, y, z) are not significantly different at $P \leq 0.05$.

Differences in water retention characteristics among positions reflect management-induced changes in total porosity and pore-size distribution. Wheel traffic decreased total porosity and the proportion of larger pores in the upper 15 cm of the trafficked interrow, while ridging had an opposite effect in the upper 7.5 cm of the row. A lack of available water in the row and nontrafficked interrow during periods of low rainfall might limit early crop growth until roots explored soil zones where a greater proportion of smaller pores existed, such as the trafficked interrow or deeper into the soil profile. In periods of below-normal precipitation, surface compaction induced by wheel traffic has been found to increase soybean yield over nontracked treatments (Johnson et al., 1990). This type of yield enhancement may result from

Table 4. Mean comparisons of organic C and total N among positions and depths averaged across crops. Least significant differences (LSD) at $P \leq 0.05$ are given for the interactions.

Depth	Trafficked interrow	Non-trafficked interrow	Row	Mean	LSD for positions within depths
cm					
	Organic C, kg C m^{-3} soil				
0–7.5	25.4	23.8	22.6	23.9 b†	1.5
7.5–15	24.3	24.3	24.5	24.4 a	1.3
15–30	17.5	18.9	23.0	19.8 b	1.6
Mean	21.2 x	21.5 x	23.3 x		
LSD for depths within positions	1.5	1.5	1.5		
	Total N, kg N m^{-3} soil				
0–7.5	2.20	2.05	1.96	2.07 a	0.16
7.5–15	2.08	2.05	2.13	2.08 a	0.16
15–30	1.52	1.63	1.96	1.70 b	0.16
Mean	1.83 x	1.84 x	2.00 x		
LSD for depths within positions	0.12	0.15	0.16		

† Values for main effects followed by the same letter within a column (a, b, c) or row (x, y, z) are not significantly different at $P \leq 0.05$.

increased water-holding capacity and restricted drainage of compacted soil.

Organic Carbon and Total Nitrogen

Mean OC and TN were greater in the row than the interrow positions (Table 4). We observed crop roots to be most abundant in the row. Thus, OC and TN levels were expected to be greatest in that position. This was especially evident at 15 to 30 cm, where OC in the row was 22% greater than the nontrafficked interrow and 31% greater than the trafficked interrow. Root densities in ridge-till have been observed to be approximately three- and fivefold greater in the row than the nontrafficked and trafficked interrows, respectively (Kaspar et al., 1991).

Trends in OC and TN differed with depth between the interrow positions and row. A 21 to 28% decrease in OC and TN was observed between the 7.5- to 15- and 15- to 30-cm depths in the trafficked and nontrafficked interrows, whereas in the row the decrease was only 6 to 8%. Thus, C and N levels were clearly enhanced in the 15- to 30-cm depth of the row, compared with the interrow positions. These differences may be due to increased crop root density in the row but also reflect topography and field operations. The row was elevated about 15 cm above the typical soil surface. If the surface elevation of the furrow had been used as a plane of reference, OC and TN at the 15- to 30-cm depth of the row would be comparable to the 0- to 15-cm depth of the interrows. The construction of the elevated portion of the row position from residue- and organic-matter-enriched soil originating from the furrow further reduced variation on OC and TN values among depths.

CONCLUSIONS

Management-related activities of tractor wheel traffic and ridging were largely responsible for the significant position and depth × position effects on soil properties. Wheel traffic created a highly compact soil condition in the trafficked interrow. Compared with the row and nontrafficked interrow, the trafficked interrow had greater bulk density, soil strength, MWD, FC, and WP, while K_{sat}, SAT, and GW were less. Organic C and TN were greater in the row than the interrow positions. At the 15- to 30-cm depth, soil properties were not significantly different except for AWHC. Thus, the influence of wheel traffic was largely confined to the upper 15 cm of the trafficked interrow for this soil.

Ridging created a very loose and porous soil condition in the upper 7.5 cm of the row. Compared with the interrow positions, the upper 7.5 cm of the row had significantly greater SAT and GW, whereas bulk density, MWD, FC, and WP were significantly less.

Wheel traffic and ridging created three distinct soil zones. Because of this, ridge-tilled fields should be conceptualized and managed as three soil zones, not as a single unit.

Potential increases in fertilizer and water use efficiency as well as enhanced trafficability can be gained from zonal-specific management in ridge-till. Fertilizer use efficiency may be increased if fertilizer is placed in nontrafficked interrows and rows where the crop is most likely to have roots and extract nutrients. For ridge-tilled fields that are furrow irrigated, decreased runoff could be realized if water is applied only to nontrafficked interrows where K_{sat} is relatively high and uniform. Additionally, the existence of permanent traffic lanes would enhance traction and floatation during machinery passes, resulting in improved trafficability.

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