One-Time Tillage of No-Till Systems: Soil Physical Properties, Phosphorus Runoff, and Crop Yield

J. A. Quincke, C. S. Wortmann,* M. Mamo, T. Franti, R. A. Drijber, and J. P. García

ABSTRACT

Continuous no-till (NT) has numerous benefits, including improved soil aggregate stability in the surface soil and increased rate of water infiltration, but accumulation of soil P at the soil surface with NT can increase P concentration in runoff. We hypothesized that occasional one-time tillage of NT land, conducted once in 10 or more years, can reduce P runoff and improve crop yields without reducing soil aggregation or increasing runoff. Research was conducted in long-term NT fields under rainfed corn [*Zea mays* (L.)] or sorghum [*Sorghum bicolor* (L.) Moench.] rotated with soybeans [*Glycine max* (L.) Merr.] at two locations in eastern Nebraska. Tillage treatments were applied in the spring or fall and included continuous NT, tandem disk (disk), chisel with 10-cm-wide twisted shanks, moldboard plow (MP), and mini-moldboard plow (miniMP). Subplots had either 0 or 87.4 kg P ha^{-1} applied as composted feedlot manure before tillage. Yield and yield components were measured for 2 and 3 yr after the spring and fall one-time tillage, respectively. In Year 2 or 3 after tillage, soil sorptivity, field-saturated infiltration rate, runoff volume, runoff P loss, and soil aggregate stability were determined. Yield was not affected by the tillage × compost interaction, but was increased by compost application at one location and sorghum yield was affected by tillage treatments at the second location. Grain yield was never significantly more or less with one-time tillage as compared with NT. Soil aggregate stability was not affected by tillage treatments. Sorptivity and infiltration were increased with MP tillage compared with NT at one location but reduced at the other. One-time MP tillage reduced dissolved P loss at both locations and total phosphorus (TP) loss at one location. The benefit of one-time MP tillage in terms of reduced dissolved reactive P loss in runoff was positive with no negative effect on soil aggregate stability but no gain in yield.

The conversion of conventional tillage systems to NT often results in reduced erosion, improved soil quality, and reduced costs and time requirements due to fewer field operations (Brown et al., 1989; McCabe, 2002), with an inconsistent effect on yield (Wilhelm and Wortmann, 2004). Soil under NT typically has increased soil organic matter content and improved aggregate stability in the 0- to 5-cm depth, but these properties often are not improved in deeper soil with NT compared with deep tillage (Doran, 1987; West and Post, 2002).

An accumulation of P and reduced P sorption at the soil surface compared with deeper layers in the soil may result in increased P concentration of runoff, especially for dissolved P (Sharpley and Smith, 1994; Gaynor and Findlay, 1995; Sims et al., 1998; Daverede et al., 2003). The high P concentration at and near the soil surface can be reduced through tillage (Sharpley, 2003). García et al. (2007) found that one-time moldboard plowing (MP), but not disking, effectively reduced the concentration of available P in the surface 2.5 cm of soil when compared with NT without significant loss of soil organic C (Quincke et al., 2007).

One-time tillage of NT fields may affect soil aggregate stability, water infiltration, runoff volume, erosion, and runoff P loss. During the initial phase of a rainfall event, water infiltration is a nonsteady state process in which water gradually fills soil pores as the wetting front advances downward. With continued rainfall, the soil matrix is gradually brought to field saturation, and the flow of water reaches a reduced but near-constant infiltration rate. Soil sorptivity is the early infiltration of the soil, while infiltrability is the vertical flow of water through the soil matrix (SSSA, 1997). Sorptivity relates to the capacity of a soil to absorb water and prevent runoff, and is an especially important determinant of runoff during high-intensity, short-duration rainfall events. Increased soil porosity, and depressions that act as microcatchments, typically result from tillage and may result in increased sorptivity in the short term, but reduced sorptivity may result from reduced aggregate stability with increased aggregate turnover and increased soil dispersal under raindrop impact in the longer term (Six et al., 2000).

We hypothesized that occasional one-time tillage, such as once in 10 or more years, to redistribute nutrients, soil organic matter, and soil aggregation to deeper depths will result in increased yield and decreased P in runoff water, even though tillage may reduce soil sorptivity and the rate of water infiltration due to changes in macropore distribution. The objectives of this study were to determine the effects of one-time tillage in NT systems on grain yield, soil aggregation, soil sorptivity, water infiltration rate, runoff losses, and P content of runoff.

MATERIALS AND METHODS

Site Description, Experimental Design, and Treatments

Field research was conducted in 2003 through 2005 at two rainfed NT locations in eastern Nebraska. These upland

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Abbreviations: ARDC, Agricultural Research and Development Center; CH30, 10-cm-wide twisted shanks at the 30-cm depth; disk, tandem disk; DRP, dissolved reactive phosphorus; HI, harvest index; miniMP, mini-moldboard plow; MP, moldboard plow; NT, continuous no-till; PP, particulate phosphorus; RMF, Rogers Memorial Farm; TP, total phosphorus; WSA, water stable aggregates of soil.

locations had deep, well or moderately well drained soil formed in loess and with moderately slow permeability.

One location was Rogers Memorial Farm (RMF) of the University of Nebraska-Lincoln (UN-L), located ≈16 km east of Lincoln, NE (40°50′44″ N, 96°28′18″ W, 380 m altitude) with a 3% slope. The soil was a Sharpsburg silty clay loam (fine, smectitic, mesic Typic Argiudolls). The site occupied the area between two parallel steep-back sloped terraces that were established in the mid 1960s. Conversion to NT occurred in 1992 with a soybean crop. The NT rotation included small grain cereals and corn rotated with soybeans. Controlled traffic was practiced to minimize soil compaction. The crops that followed one-time tillage of NT were sorghum (2003 and 2005) and soybeans (2004).

The second location was at the University of Nebraska-Lincoln Agricultural Research and Development Center (ARDC), located near Mead, NE, about 48 km northeast of Lincoln (41°10′48″ N, 96°28′40″ W, 358 m altitude). The soil at this site was a Yutan silty clay loam (fine-silty, mixed, superactive, mesic Mollic Hapludalfs) with a 1–2% slope. The site occupied the unirrigated corner of a center pivot-irrigated field, under a corn–soybean rotation, which was fully converted to NT in 1996. No manure had been applied previously, but cattle grazed on corn stalks. The crop that preceded the one-time tillage operation was corn (2003) and the following crops were soybeans (2004) and corn (2005).

The experimental design was a split plot arrangement in a randomized complete block design with four replications. Five tillage treatments were the main plot treatments. At RMF, the tillage treatments were (i) NT, (ii) chisel with 10-cm-wide wide twisted shanks at the 30-cm depth (CH30), (iii) the chisel at the 20-cm depth (CH20), (iv) disk at the 10-cm depth, and (v) MP at the 20-cm depth. At ARDC, CH20 was replaced by miniMP tillage at the 20-cm depth (miniMP). MiniMP has a reduced moldboard and causes less inversion and leaves more residue cover than the MP. A second main plot factor at RMF was comprised of spring and fall tillage. The tillage treatments were conducted in 2003 on 26 Mar. and 23 Oct. at RMF, and on 26 Nov. at ARDC. The spring MP tillage at RMF was followed by disk tillage, but there was no other secondary tillage. Subplots treatments were no compost applied and composted beef feedlot manure applied at 87.4 kg P ha^{-1} shortly before tillage.

In 2004, soybean (cv. Dekalb 25–51 of Maturity Group 2 at the ARDC, and cv. Asgrow 3302 of Maturity Group 3 at RMF) was sown at both sites at a rate of 494 000 seeds ha^{-1}. Corn (cv. Pioneer 33R81, 2750 growing degrees days at physiological maturity) was sown at the ARDC in 2005 at a rate of 56 800 seeds ha^{-1}. Grain sorghum (cv. NC+7R37E of Maturity Group 1) was sown at RMF in 2003 and 2005 at a rate of 190 000 seeds ha^{-1}. The only inorganic fertilizer applied was ammonium nitrate applied to corn and sorghum at the suggested rates (Ferguson, 2000).

Data Collection Procedures

Ten adjacent plants in a row were harvested after physiological maturity to determine harvest index (HI) for all crops and yield components for soybean. Plant samples were dried at 70°C for ≈10 d to constant dry weight. The weights of stover and grain were determined for the calculation of HI. Pods plant^{-1}, kernels pod^{-1}, and 100-kernel weight were determined for soybean. Grain yield was determined from the harvest of 6 m of the center two rows. Sorghum panicles and corn ears were counted before harvest for determination of panicles and ears ha^{-1}. Grain samples were dried at 70°C and 100-kernel weights were determined for sorghum and corn, and kernels panicle^{-1} or ear^{-1} were calculated. Grain yield was adjusted to a water content of 130 g kg^{-1} for soybean, and 150 g kg^{-1} for corn and sorghum.

Data for soil and runoff properties were only collected for the NT, MP, and disk tillage treatments with compost applied. Available (Bray and Kurtz, 1945) and soil organic matter by loss on ignition (Nelson and Sommers, 1996) for the 0- to 2.5-cm soil depth were determined from soil samples collected before planting in 2005 that consisted of 10 cores of 2-cm diameter. Samples were air-dried and ground to pass a 2-mm sieve.

The percentage of soil in water stable aggregates (WSA) was determined from soil samples of the 0- to 5-cm depth comprised of soil collected with a shovel at four random points between the rows in each plot. The percentage of soil in WSA was assessed by a wet-sieving 100 g dry wt. of soil by the method of Cambardella and Elliott (1994). Classes of WSA were large macroaggregates (>2.0 mm), small macroaggregates (0.250–2.0 mm), and microaggregates (0.053–0.250) expressed as g kg^{-1} of dry soil. The total of the three classes was the percentage of soil mass in WSA.

Water infiltration rates were measured with simulated rainfall of constant intensity using Cornell sprinkle infiltrometers (Ogden et al., 1997) which consisted of a 20-L container fitted with 130 capillary tubes of 0.8 mm i.d. in the bottom. The intensity of the rainfall could be adjusted by varying the height of an air-entry tube. The simulated rain was delivered within a single 241-mm i.d. ring, which was previously inserted into the soil to a depth of 7.5 cm. This ring had an outlet tube flush with the soil surface for drainage of water from the ring into a beaker.

Two infiltrometers were used simultaneously to conduct two infiltration tests per plot. The water-containing vessel was rotated slightly every 2 to 3 min to distribute the impact of falling drops. The start time and the time when runoff began were recorded. The runoff collection beaker was replaced with an empty beaker at 3-min intervals and the volume of collected water was measured to determine runoff volume over time. This continued for >36 min, or less if the rate of infiltration stabilized earlier. The four samples from the first 12 min were mixed and the composite sample was stored in a refrigerator by the end of the day for determination of P concentration.

Concentrations of dissolved reactive phosphorus (DRP, molybdate reactive P in runoff filtered through a 0.45-μm membrane filter) and TP were determined for each runoff sample according to Pote and Daniel (2000). Total P was determined from a subsample taken after shaking the runoff sample to suspend particulate matter. The PP fraction, which included dissolved nonreactive P, was determined as the difference between TP and DRP. In both fractions, P was determined colorimetrically after hydrolyzing P to orthophosphate using a sulfuric acid–nitric acid digestion (Clesceri et al., 1998).

Calculations

During the rainfall simulation, data was collected for: height of the water level (cm) in the vessel; time to runoff (min); runoff volume (cm^3); and time (min).

The simulated rainfall rate (cm min^{-1}) and runoff rate (cm min^{-1}) were calculated for each 3-min time interval. Sorptivity has the dimensions of [L/T$^{1/2}$ where T = time, in minutes] and was estimated according to Kutilek (1980):

$$S = r \times \sqrt{2 \times t_{\mathrm{RO}}},$$

where S is sorptivity (cm min$^{-0.5}$), t_{RO} is time to runoff (min), and r is the measured rainfall rate (cm min^{-1}). Infiltration rate was calculated for the last time interval, assuming that steady-state conditions were reached, as the difference between rainfall and runoff rates, with units of cm min^{-1}.

The rainfall simulators were calibrated for an intensity of 30 cm h^{-1} to ensure that rainfall matched or exceeded the rate of infiltration but actual intensity varied. During the first 12 min of rain, measured intensity had an overall coefficient of variation of 24%. To control this variability due to instrumentation and make the volume of runoff (V_{RO}) independent of rainfall intensity, V_{RO} was computed as a fraction of the rainfall during the first 12 min according to the following:

$$V_{RO} = \frac{V_{12}}{\Delta H12 \times 457.3}$$

where V_{12} was the volume of runoff collected during the first 12 min of rain (cm^3); ΔH_{12} was the amount of rain delivered during first 12 min (cm); and 457.3 cm^2 was the inside area of the collection ring. The units of V_{RO} were cm cm^{-1}. Alternatively, multiplying V_{RO} by 100 allowed for runoff volume to be computed as a percentage fraction ($\%V_{RO}$) of the total rainfall.

Total losses of P in runoff were then calculated independent of rainfall intensity by using V_{RO} and normalizing the results to a uniform intensity of 30 cm h^{-1}:

$$\text{mass P/area} = \text{P concentration} \times V_{RO} \times 6 \times 100,$$

where P concentration (mg P cm^{-3}) was determined for DRP and TP and V_{RO} was volume (cm) of rain delivered in a 12-min event with an intensity of ≈30 cm h^{-1}. The partial result was multiplied by 100 (cm^2 ha^{-1} kg mg^{-1}), and the resulting units for *MassP Area*$^{-1}$ were kg ha^{-1}.

Statistical Analyses

Data for yield and yield components were analyzed using ANOVA and mixed model procedures in SAS (SAS Institute, 1989) by site and year. Tillage, time of tillage at RMF, site, and compost application were treated as fixed effects and replication as a random effect. Means were separated using the LSD ($\alpha = 0.05$) option if treatment effects were significant.

Data for surface soil P, soil aggregation, soil sorptivity, infiltration rate, concentration of P fractions in runoff, and mass of P lost to runoff per unit area were analyzed using ANOVA and mixed model procedures in SAS (SAS Institute, 1989) for the locations combined. Tillage and site were treated as fixed effects and replication as a random effect. Where the site × tillage interaction was significant ($\alpha = 0.05$), the effect of tillage was determined by conducting ANOVAs by location. Means were separated using the LSD ($\alpha = 0.05$) if tillage effects were significant.

RESULTS

Yield and Yield Components

Total yield and yield components were not influenced by interactions between treatments at either site (Tables 1–3). Compost increased corn and soybean yield at ARDC but did not affect yield components at ARDC or RMF.

Tillage effects were significant for sorghum yield at RMF (Table 1). In 2003, yield was less and weed growth was observed to be more with chisel tillage compared with other tillage treatments. In 2005, sorghum yield was more with MP than with disk tillage. However, none of the one-time tillage operations resulted in yields that were different from NT. Soybean yield at RMF and ARDC was not affected by tillage but corn yield at ARDC was increased ($P = 0.078$) with MP and CH30 compared with NT (Table 2).

Table 1. The effect of one-time tillage of no-till land and compost application on grain yield (Mg ha^{-1}) at Rogers Memorial Farm in eastern Nebraska.

Tillage treatment	Sorghum 2003	Soybean 2004	Sorghum 2005
	Mg ha^{-1}		
NT†	7.00a‡	4.18	8.14ab
Disk	7.13a	4.28	7.71b
CH30	5.86b	4.34	8.34ab
CH20	5.77b	4.12	8.24ab
MP	6.79a	4.34	8.99a
ANOVA results			
Tillage, T	*	NS	**
Compost, C	NS	NS	NS
T × C	NS	NS	NS
T × TT	–	NS	NS
C × TT	–	NS	NS
T × C × TT	–	NS	NS
LSD 0.05§	0.90	0.204	0.689

* Significant at $P = 0.05$.

** Significant at $P = 0.01$.

† Yields for tillage treatments are means from subplots with and without compost applied. CH20, 10-cm-wide twisted shanks at 20-cm depth; CH30, 10-cm-wide twisted shanks at 30-cm depth; disk, tandem disk; MP, moldboard plow; NT, no-till. TT = tillage time.

‡ Letters denote differences between tillage treatments ($P = 0.05$). NS, not significant.

§ Least significant difference for the tillage effect.

Some yield components of corn and sorghum, but not of soybean, were affected by tillage (Table 3). In 2003, sorghum panicles ha^{-1} were less with chisel tillage indicating early stress that was likely associated with weed competition. There was some compensation for the low number of panicles ha^{-1} by increased 100-kernel weight, but sorghum yield in 2003 was still less with chisel tillage than with other tillage treatments (Table 1). In 2005, sorghum HI was relatively low for CH30. Corn kernels ear^{-1} were less with miniMP than with MP and disk tillage although this did not translate to a significant effect on grain yield.

All yield components of soybean at both locations and the remaining yield components of corn and sorghum were not affected by tillage. The means for sorghum yield components at RMF in 2003 and 2005, respectively,

Table 2. The effect of one-time tillage of no-till land and compost application on grain yield at the Agricultural Research and Development Center in eastern Nebraska.

	Soybean 2004		Corn 2005	
Tillage treatment	C†	NC	C	NC
	Mg ha^{-1}			
NT†	3.55	3.48	7.11	6.77
Disk	3.68	3.59	7.59	6.61
miniMP	4.00	3.54	7.49	6.96
CH30	3.73	3.51	7.46	7.35
MP	3.72	3.57	7.75	7.22
ANOVA results				
Tillage (T)	NS§		0.078	
Compost (C)‡	**		***	
T × C	NS		NS	
LSD 0.05¶	0.90		0.41	

** Significant at $P = 0.01$.

*** Significant at $P = 0.001$.

† C and NC = compost applied and no compost applied; CH30, 10-cm-wide twisted shanks at the 30-cm depth; disk, tandem disk; miniMP, mini moldboard plow at the 20-cm depth; MP, moldboard plow; NT, no-till.

‡ Mean yields for soybean and corn with and without compost applied were 3.73 and 3.54 Mg ha^{-1} and 7.48 and 6.98 Mg ha^{-1}, respectively.

§ NS, not significant.

¶ Least significant difference for the tillage effect.

Table 3. Yield components that were significantly affected by one-time tillage of no-till land at the Rogers Memorial Farm (RMF) and the Agricultural Research and Development Center (ARDC) in eastern Nebraska. Compost application and the tillage × compost interaction did not affect any yield components. Treatment effects were not significant for yield components of soybean.

Tillage treatment	RMF			ARDC
	Sorghum 2003		Sorghum 2005	Corn 2005
	Panicle ha^{-1}	100 kernel wt., g	Harvest index	Kernels ear^{-1}
NT†	124 200ab‡	2.68ab	49a	484ab
Disk	137 800a	2.62b	48a	496a
CH30	113 600bc	2.78a	43b	473ab
CH20	99 000c	2.83a	49a	–
MP	131 300ab	2.62b	50a	503a
MiniMP	–	–	–	437b
ANOVA results				
Tillage (T)	***	*	**	*
Compost (C)	NS§	NS	NS	NS
T × C	NS	NS	NS	NS

* Significant at $P = 0.05$.

** Significant at $P = 0.01$.

*** Significant at $P = 0.001$.

† CH20, 10-cm-wide twisted shanks at 20-cm depth; CH30, 10-cm-wide twisted shanks at 30-cm depth; disk, tandem disk; MP, moldboard plow; miniMP, mini-moldboard plow at 20-cm depth; NT, no-till.

‡ Letters denote differences between tillage treatments ($P = 0.05$).

§ NS, not significant.

were 121 000 and 144 000 panicles ha^{-1}; 2.7 and 2.4 g 100 $kernels^{-1}$; 2006 and 2597 kernels $panicle^{-1}$; and HIs of 0.521 and 0.479. The means for yield components of soybean in 2004 at RMF and ARDC, respectively, were 17.0 and 14.6 g 100 $kernels^{-1}$; 22.5 and 31.6 pods $plant^{-1}$; 2.7 and 2.4 kernels pod^{-1}; and HIs of 41.1 and 53.9. The means for corn yield components at ARDC were: 52 000 ears ha^{-1}, 32.6 g 100 $kernels^{-1}$, 479 kernels ear^{-1}, and an HI of 50.9 for corn in 2005.

Soil Properties

The RMF site had more Bray-P1 and soil organic matter in the surface soil (0- to 2.5-cm depth) than at ARDC (Table 4). The sites were similar for total WSA, but RMF had more soil in large macroaggregates (>2 mm) and less soil in small macroaggregates (0.25–2 mm) than at ARDC. The site × tillage interaction effects were not significant for Bray-P1, soil organic matter, and soil aggregate properties. Tillage did not reduce the amount of soil in WSA (Table 4). There was, however, more soil in stable microaggregates with MP than with disk tillage.

Table 4. Available soil phosphorus and soil organic matter in the 0- to 2.5-cm depth, and water stable aggregates in the 0- to 5-cm soil depth, at 23 to 30 mo after one-time tillage of continuous no-till at the Rogers Memorial Farm (RMF) and the Agricultural Research and Development Center (ARDC) in eastern Nebraska.

	Bray-P1	Soil organic matter	Water-stable aggregates, mm†			
			0.053–0.25	0.25–2.0	>2	Total
	mg kg^{-1}	g kg^{-1}				
Site						
RMF‡	103.0	41.3	344	312	174	829
ARDC	40.5	32.3	345	412	76	834
Tillage						
No-till	97.9a§	38.9a	349ab	361	119	829
Disk	97.8a	40.9a	289b	406	145	840
Moldboard plow	19.6b	30.6b	396a	320	110	826

† Water-stable aggregates were assessed on soil samples collected in Sep. 2005 during the third and second crops after tillage at RMF and ARDC, respectively.

‡ Dates of tillage were 26 Mar. 2003 at the RMF and 26 Nov. 2003 at the ARDC.

§ Letters denote significant differences between tillage treatments ($P = 0.05$).

Soil sorptivity was higher for NT than MP tillage at RMF, indicating that NT may be more effective than tillage in preventing runoff from short, intense precipitation events (Table 5). Infiltration rate and runoff volume were not different among tillage treatments at RMF. By contrast, tillage resulted in a greater infiltration rate and tended to have greater sorptivity than NT at ARDC. Tillage effects on runoff, however, were not statistically significant at either site.

Runoff Phosphorus

Moldboard plowing reduced the concentration of DRP in runoff at ARDC, when compared with runoff samples from disk or NT (Fig. 1). Tillage did not affect concentration of particulate phosphorus (PP) in runoff, but TP concentration was reduced with MP tillage compared with NT at ARDC (Fig. 1b). Particulate and TP losses were greater with MP than disk or NT at RMF (Fig. 2). In contrast, DRP loss was less at ARDC with MP compared with disk or NT.

DISCUSSION

One-time tillage of NT did not result in increased yield or increased yield components compared with continuous NT except for a tendency to increased yield with MP and CH30 tillage ($P = 0.078$) at ARDC in 2005 (Table 2). The effects of one-time tillage on yield have been inconsistent in other studies (Varsa et al., 1997; Díaz-Zórita, 2000). Pierce and Fortin (1997) measured increases of 11–25% in corn yield in the first and second years after a one-time plowing compared with continuous NT. In a wheat-fallow system under continuous NT, Kettler et al. (2000) conducted one-time MP tillage to

Table 5. Soil hydraulic properties† in the 0- to 2.5-cm soil depth at 23 to 30 mo after one-time tillage of continuous no-till at the Rogers Memorial Farm (RMF) and the Agricultural Research and Development Center (ARDC) in eastern Nebraska.

Tillage treatment‡	Sorptivity	Infiltration rate	Runoff volume
	cm $min^{-1/2}$	cm h^{-1}	%
RMF			
No-till	1.39a§	4.0	43.9
Disk	1.21ab	4.8	44.3
Moldboard plow	0.95b	3.0	60.8
P value	0.04	0.56	0.07
ARDC			
No-till	1.13	4.7b	46.8
Disk	1.44	15.8a	34.4
Moldboard plow	1.33	16.7a	29.7
P value	0.45	<0.01	0.13

† Soil hydraulic properties were assessed in situ in September 2005, during the third and second crops after tillage at the RMF and ARDC, respectively.

‡ Dates of tillage were 26 Mar. 2003 at the RMF and 26 Nov. 2003 at the ARDC.

§ Letters denote significant differences between tillage treatments within sites ($P = 0.05$).

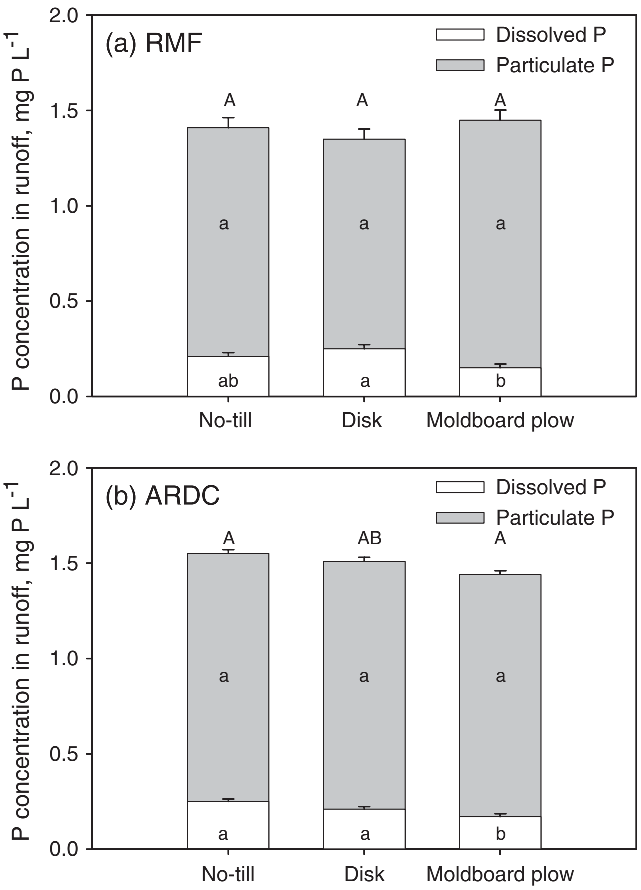

Fig. 1. Runoff P concentration during a 12-min simulated rainfall at 23 to 30 mo after one-time tillage of continuous no-till at two locations (the Rogers Memorial Farm, RMF; and the Agricultural Research and Development Center, ARDC) in eastern Nebraska. The P fractions were dissolved P (white bars) and particulate P (shaded bars). The Y-bars indicate the SEs. Differences between tillage treatments within sites are denoted by lowercase letters for dissolved or particulate P and by uppercase letters for total P (*P* = 0.05).

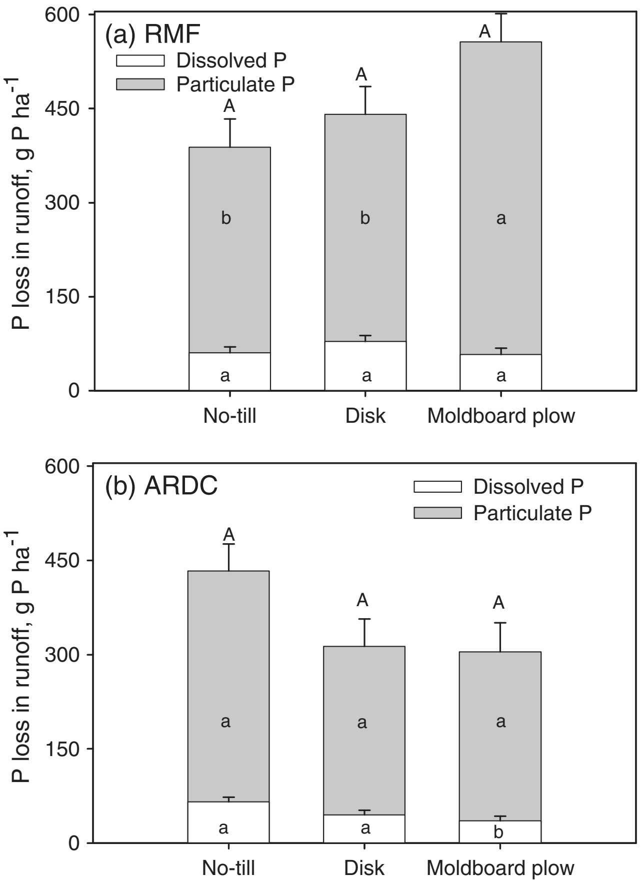

Fig. 2. The amount of runoff P loss during a 12-min simulated rainfall at 23 to 30 mo after one-time tillage of continuous no-till at two locations (the Rogers Memorial Farm, RMF; and the Agricultural Research and Development Center, ARDC) in eastern Nebraska. The P fractions are dissolved P (white bars) and particulate P (shaded bars). The Y-bars indicate the SEs. Differences between tillage treatments within sites are denoted by lowercase letters for dissolved or particulate P and by uppercase letters for total P (*P* = 0.05).

control downy brome, and wheat yields were increased in the first, third, and fifth year post-tillage. Deep tillage of NT soils improved corn yields on poorly drained, but not on well-drained, soils (West et al., 1996). In a 2-yr rotation that received conservation tillage only before the winter wheat crop, Díaz-Zórita et al. (2004) found that summer crop yields decreased and related this to reduced soil water retention when compared with continuous NT. With the exception of reduced sorghum yield associated with poor weed control following the spring chisel tillage at RMF and increased corn yield at ARDC, one-time tillage of NT had little effect on grain yield in the current study.

One-time MP tillage mixed the surface soil and reduced surface soil P. Our hypothesis was that this tillage would not affect soil aggregation. The results support this hypothesis because tillage did not reduce soil in WSA. Pierce and Fortin (1997) concluded from porosity measurements that the effects of plowing were dissipated and that the soil was physically similar to NT by Year 4 or 5 after returning to NT. Considering pore size distribution for the 2.5- to 10-cm depth, Kettler et al. (2000) concluded that a one-time plowing had no effect on NT soil structure in Year 5. Grandy and Robertson (2006), however, in a study of fine loamy and coarse loamy soils, concluded that NT soils need to be continuously maintained to protect soil aggregation. In our study, >80% of the soil mass in the 0- to 5-cm depth was in WSA. Aggregate stability may account for the lack of tillage effect on PP concentration in runoff (Fig. 1) with much PP bound within aggregates and not readily detached during simulated rain (Six et al., 2000). It may also partly account for the lack of soil organic C loss due to MP tillage in this study; macroaggregates may be especially important to soil organic C protection (Grandy and Robertson, 2006).

Concentration of DRP in runoff was effectively reduced with MP compared with NT or disk tillage, agreeing with Sharpley (2003), who attributed this benefit of plowing to dilution of the high P surface soil and to increased P sorption. In addition, Schreiber and McDowell (1985) found that much DRP is leached from crop residues during rainfall events, which can be transported in

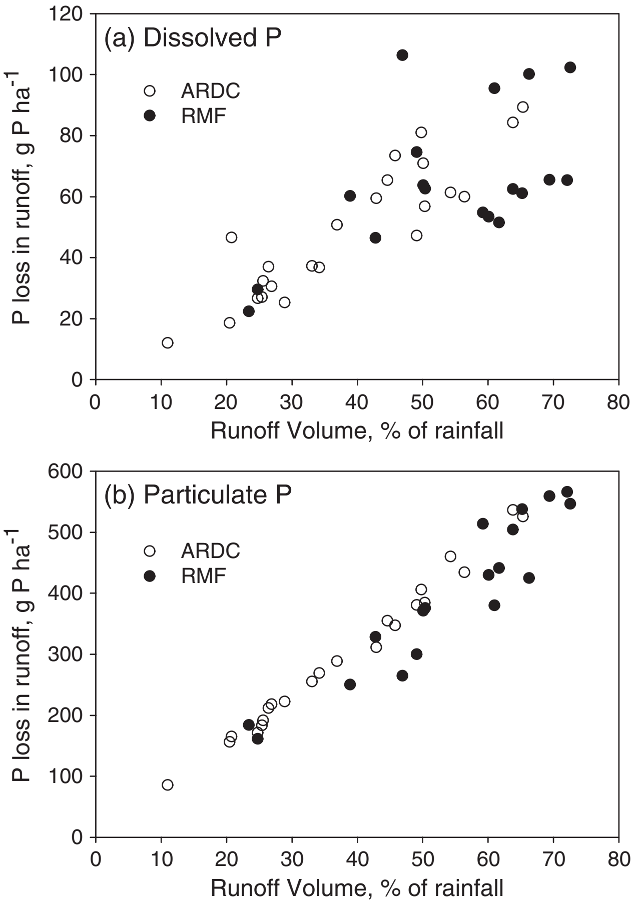

Fig. 3. Phosphorus losses in (a) dissolved and (b) particulate fractions vs. runoff volume as a ratio of total rainfall. Samples were collected periodically during a simulated 12-min rainfall events that delivered, on average, a total of 64 mm at Rogers Memorial Farm (RMF, closed symbols) and 76 mm at the Agricultural Research and Development Center (ARDC, open symbols).

runoff, suggesting that incorporation of crop residues may reduce DRP concentration in runoff.

The runoff concentration of DRP was positively but weakly related to Bray-P1 at both sites ($r = 0.63$ and 0.19 for RMF and ARDC, respectively). Other studies have shown stronger relationships between soil test P and P concentration in runoff, but these relationships were typically determined over a wider range of soil test P values than occurred in this study (Klatt et al., 2003; Wortmann and Walters, 2006). For instance, Daverede et al. (2003) found higher concentration and loads of DRP in runoff with increased Bray-P1 when Bray-P1 reached 800 mg kg^{-1}, but this relationship was not detected when Bray-P1 ranged from 0–150 mg kg^{-1}.

The tillage effect on runoff volume was not statistically significant, but volume affected P losses (Fig. 3) as found by Wortmann and Walters (2006). The differing MP tillage effects across sites on sorptivity and infiltration rate (Table 5) may be due to several factors: (i) Wheel-traffic was better confined to the same tracks year after year at RMF than at ARDC, which may have contributed to greater sorptivity with NT. (ii) One more cropping season had passed since the one-time tillage at RMF than at ARDC when the measurements for hydraulic properties were made. This gave more time for the soil to resettle after tillage and to recover the smoothness of nontilled soils, and to reduce the effect of compost application on aggregate stability. The observations were made in interrow areas with a combine wheel track, and this traffic had occurred twice at RMF compared with once at ARDC since the tillage event. (iii) The history of continuous NT was longer at RMF, giving more time for macropore and channel development than at ARDC. Time since tillage at both locations was probably insufficient for the disrupted macropores and channels to be reestablished. There was a large increase in infiltration at ARDC with MP and disk tillage that we cannot explain (Table 5). Tillage effects on water infiltration have not been fully consistent in other studies. Anteny et al. (1995) found tillage to increase infiltration compared with NT at two locations while tillage treatment effects were not significant at three other Midwestern locations. Dao (1993) and Lal (1999) observed higher infiltration with NT than with MP.

CONCLUSIONS

One-time tillage can be done without yield loss, but the evidence for increased yield in the short term due to change of surface soil properties is weak. One-time MP tillage may be effectively done to reduce Bray-P1 in the 0- to 2.5-cm soil depth, and to reduce DRP concentration and loss in runoff. The PP loss may be increased or decreased by MP tillage. MP may not affect aggregation of the surface soil but inconsistently affected sorptivity and water infiltration across locations. The benefit of one-time MP tillage in terms of reduced DRP loss in runoff was generally positive and presumably would be greater if surface soil P levels were extremely high.

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