NITROGEN-TILLAGE INTERACTION FOR DRYLAND WHEAT IN WESTERN NEBRASKA

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ABSTRACT

A tillage experiment was initiated by C. R. Fenster on a previously cultivated Alliance silt loam near Sidney, Nebraska in 1969 in which the effect of no-till, stubble mulch (subtill), and plowed fallow upon soil properties, nitrogen cycling, and winter wheat production were compared. After more than ten years of these treatments, fallow tillage at this site generally had little or no effect upon soil bulk density. However, at most sampling dates, soil water content was greater and soil temperature lower for no-till soil than for plowed soil (subtill was usually intermediate). The cooler, more humid environment of no-till soil, coupled with an ample supply of carbonaceous residues in the upper 75 mm of soil, was associated with greater organic C and N contents, greater microbial biomass, and more potentially mineralizable N in no-till than in plowed or subtilled soil. Differences below the 75 mm soil depth were generally not significant. Plant growth and grain yields, averaged over all years, were not significantly affected by tillage method; however, uptake of labeled ammonium nitrate (applied at tillering) was usually slightly greater by the wheat crops on no-till than that on plowed or subtilled fallow. Likewise, during the following year and the second crop year, more labeled N was found as soil inorganic N and in wheat residues for no-till than for other treatments. About 28% of the original isotope applied to no-till wheat was recovered in the two grain harvests or remained in crop residues left in the field, compared to 22% for the plow and subtill treatments. No-till appears to conserve more N near the soil surface and enhances recycling of this N, when compared to plow or subtill fallow.

OBJECTIVES

No-tillage and reduced tillage for winter wheat production have gained in popularity in recent years, mainly because of potential for reduced production cost. We also know that reducing tillage decreases soil loss by erosion, and thereby conserves soil organic matter and maintains soil productivity. Other benefits from reducing tillage include reducing the rate of soil organic matter oxidization. Earlier research has shown that soil organic matter generally decreases with years of cultivation, and that this decline can be retarded by leaving crop residues on the surface (even where erosion is not a factor).

Objectives of this research were to document the above changes in soil organic matter and N conservation resulting from reduced tillage, and to define the soil environment that result from use of different tillage practices. By changing soil environment, we hypothesized that we also alter the rate and distribution of microbiological activity in the soil, and subsequently the recycling of soil and fertilizer N, and uptake of N by the wheat crop. This paper describes a field experiment in which data were collected to test this hypothesis.

MATERIALS AND METHODS

In 1969, C. R. Fenster (Fenster and Peterson, 1979) initiated an experiment on an Alliance silt loam near Sidney, Nebraska, which had been cultivated since 1920. Comparisons were made between plowed, stubble mulch (subtill), and no-till fallow on the production of winter wheat with and without 45 kg fertilizer N/ha applied at tillering to each wheat crop in a wheat-fallow sequence. The primary fallow-tillage (plow, subtill, or no-till) was made in April of the year of fallow (excessive weed growth the previous fall was prevented by use of herbicides if needed). Plowing and subtillage (large sweep machines) were limited to the 10-15 cm depth, and appropriate herbicides were applied to the no-till fallow (actual herbicides used varied, but they usually included paraquat, glyphosphate, 2, 4-D, and dicamba). Secondary tillage (rod-weeder) or spraying was employed as needed for weed control throughout the fallow period. Wheat was seeded the first week of September, and ammonium nitrate was surface broadcast at 45 kg N/ha near tillering in April. Wheat was harvested in July. Two sets of plots were established, one in crop and one in fallow each year.

In the 1978-1983 period, USDA-ARS scientists sampled these plots extensively to monitor soil water status (water content, infiltration, hydraulic conductivity), aeration (CO_2 production, air permeability, O_2 and nitrous oxide, and water-filled pore space), organic matter status (organic C and N, microbial biomass, microbial populations, plant root biomass and activity), and temperature regimes. These data were used collectively to help define the environment experienced by soil microorganisms and plant roots, and to determine how the soil environment was altered by tillage. In 1979 and 1980, N-depleted ammonium nitrate was applied (45 kg N/ha) to follow the fate of the fertilizer N through that crop, the next fallow season, and the second crop season.

RESULTS AND DISCUSSION

Some effects of tillage method on soil physical properties and soil water and aeration regimes are summarized by data in Table 1 (Mielke et al., 1984; Mielke et al., 1986). These data for May, 1980, are characteristic of those obtained at several other sampling dates during this study. Effects of tillage method on soil bulk density at this site were small, but the surface soil of no-tilled soil usually contained more water than that of plowed soil. This resulted in higher percent water-filled pore space (and less air-filled pore space) for no-till than for plow or subtill (Linn and Doran, 1984). Although water infiltration and conductivity were greater for no-till soil, air permeability was less because more soil pores were filled with water. Thus, the surface of no-tilled soil was wetter and cooler (usually by about 2 to 4°C) than that of plowed soil.

Table 1. Effect of fallow tillage method on soil water and aeration status at time of winter wheat tillering, Sidney, Nebraska.

Tillage Method:	No-Till		Subtill		Plow	
Soil depth (mm)	0-75	75-150	0-75	75-150	0-75	75-150
Bulk density, Mg m^{-3}	1.29	1.30	1.25	1.38	1.25	1.31
Water content, V/V	0.28	0.30	0.24	0.28	0.22	0.27
Water-filled pores, %	54.0	65.0	45.0	62.0	43.0	56.0
Hydraulic conductivity, mm h^{-1}	32.0	21.9	33.0	10.1	19.4	15.4
Water infiltration, mm h^{-1}	--- 61 ---		--- 52 ---		--- 50 ---	
Air permeability, pm^2	2.8	-	4.1	-	11.6	-

As a result of changes in the soil environment, populations of NH_4^+ - oxidizing and NO_2^- - oxidizing microorganism (Broder et al., 1984) in the surface of unfertilized no-tilled soil were only 54 and 78% respectively of that in plowed soil (Table 2). Fertilizing greatly increased populations of NH_4^+ - oxidizers but had little effect on relative population changes with tillage. Denitrifier populations were much greater in no-till than in plowed soil, and probably resulted from higher organic matter levels and more humid conditions. Soil NO_3^- N concentrations were slightly lower while potentially mineralizable N (PMN), total N, total C, and microbial biomass in no-till soil were somewhat greater than in plowed soil. Except for higher levels of PMN, N fertilization had little or no influence on these trends. These data suggest that the environment of no-till soil results in an accumulation of both total and labile N near the soil surface, but that rate of oxidization of these N pools is less in no-till than in plowed soil. These effects of tillage method on various soil N parameters could result from the cooler, less oxidative environment of the no-till soil, compared to that of the plowed soil (Power et al., 1984).

Table 2. Effect of fallow tillage method on microbial populations and N status of 0-150 mm soil depth at Sidney, Nebraska.

	Value for no-till / Value for plow	
	No N	With N
NH_4^+ - oxidizers	0.54	0.65
NO_2^- - oxidizers	0.78	0.80
Denitrifiers	13.0	1.9
NH_4^+ - N	1.22	0.95
NO_3^- - N	0.80	0.78
PMN	1.20	1.39
Total N	1.09	1.17
Total C	1.16	1.16
Microbial biomass	1.06	1.09

The effects of tillage on soil environment and subsequent microbial activity had relatively small effects upon uptake of the labeled N by the wheat (Table 3). Generally, labeled N uptake was slightly greater for no-till than for plowed or subtilled fallow -- at the end of the second cropping season, 28% was in plant material for no-till, compared to 22 and 21% for plow and subtill, respectively (Power et al., 1986). Also for no-till, somewhat more labeled N was present in the crop residue at all times than for the other tillage methods. After harvest of the first wheat crop, often slightly more labeled N was found in inorganic soil N for no-till than for other tillage methods.

Table 3. Labeled N in plant, crop residue, and inorganic soil N, as affected by fallow tillage method for winter wheat, Sidney, Nebraska.

	First Crop			Fallow		Second Crop		
	May	June	July	Oct.	April	Oct.	April	July
	----------- % of labeled N applied -----------							
				Plowed fallow				
Plant uptake +	15	28	12	0	0	0	4	1
Grain	0	0	16	16	16	16	16	21
Residues	0	4	6	5	6	1	2	0
Soil inorganic	42	16	7	4	2	0	0	0
				Subtilled fallow				
Plant uptake+	17	30	5	0	0	0	7	2
Grain	0	0	16	16	16	16	16	19
Residues	1	4	6	6	6	4	4	1
Soil inorganic	38	11	7	4	1	2	2	0
				No-till fallow				
Plant uptake+	20	28	7	0	0	0	8	4
Grain	0	0	18	18	18	18	18	22
Residues	5	9	16	19	11	8	6	2
Soil inorganic	33	9	4	7	4	2	2	2

+Excluding mature grain

Fallow tillage method generally had little significant effect on wheat dry matter production or grain yield (Table 4) during the crop-fallow-crop cycle studied (Power et al., 1986). Also, with a few exceptions, total N uptake by either of the two crops was not greatly affected by fallow tillage method. Likewise, uptake of labeled N was generally not affected by tillage method. For all fallow tillage methods, approximately 5% of the labeled N applied to the first wheat crop was taken up by the second wheat crop, suggesting that one would expect very little additional recovery of the labeled N in future wheat crops.

Table 4. Effect of fallow method on N-fertilized winter wheat growth, yield, and plant uptake of total and labeled N (average of the two sets of plots).

Fallow method	First crop May	First crop June	First crop July Straw	First crop July Grain	Second crop May	Second crop July Straw	Second crop July Grain
			A. Dry-matter production (Mg ha^{-1})				
Plow	2.40	6.73	4.48	2.19	3.82	4.42	3.37
Subtill	2.44	6.60	4.88	2.30	3.31	4.45	3.50
No-till	1.99	7.08	5.51	2.43	3.91	5.09	3.23
			B. Total N uptake (kg N ha^{-1})				
Plow	50.4	78.8	25.6	52.6	74.2	23.9	76.1
Subtill	48.3	82.6	27.0	54.5	66.2	16.2	75.8
No-till	48.1	81.0	35.0	49.6	71.1	21.6	70.4
			C. Labeled-N uptake (kg N ha-1)				
Plow	6.7	15.2	5.2	7.4	2.0	0.5	2.2
Subtill	7.7	13.6	2.4	7.1	3.1	0.7	1.6
No-till	9.0	12.6	2.9	8.1	3.5	0.8	1.7

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