EFFECT OF ZERO TILL CONTINUOUS WHEAT ON SOIL QUALITY AFTER 4 & 6 YEARS

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ABSTRACT

After 4 & 6 years of continuous spring wheat cropping using zero-tillage on the NxPxSnow-trap test site, soil samples were taken from the test area and from the adjacent area which has been in a wheat-fallow rotation for over 70 years. Biological characterization of these soil samples have shown that zero-tillage has already improved the potential productivity of the test site. For example, the amount of organic matter C and N have been increased in the 0 - 7.5 cm depth, as have CO_2 respiration, the potentially mineralizable N (and thus N mineralization), amino acids, and the neutral phosphatase activity. However, no significant changes in microbial biomass C or N, alkaline phosphatase or urease in the 0 - 7.5 cm depth were found. There was little change in N or C mineralization or soil enzyme activity noted in the 7.5 to 15 cm depth. Evidence in support of the improvement in soil productivity is the fact that in 1986, a year of above average precipitation, yield response to N and P was insignificant on test plots where yields ranged between 2550 and 2750 kg/ha for N fertilizer ranging from 25 to 100 kg/ha. In contrast, on adjacent stubble-cropped

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land, response to N applied was substantial.

INTRODUCTION

When conventionally tilled land is subjected to extended periods of zero-tillage, soil quality of the top 7.5 cm generally improves, but at lower depths no change, or the reverse pattern may be observed (Doran 1980; Carter and Rennie 1982; Groffman 1985). In such studies soil properties such as mirobial biomass, potentially mineralizable C and N, nitrification and denitification, phosphatase and dehydrogenase activity, and organic matter in the 0 - 7.5 cm depth were found to be significantly higher for zero-tillage than for conventionally tilled systems in Western Canada and the U.S.A.

Some scientists have also reported an increase in the bulk density and a decrease in porosity of the top 15 cm of soil due to zerotillage (Mielke et al. 1986; Izaurralde et al. 1986). Volumetric water content in the top 15 cm of soil was reported to be higher (Mielke et al. 1986) and maximum soil temperatures at the 5 cm depth were lower under zero-tillage than under conventional tillage (Izaurralde et al. 1986).

The objective of this study was to determine whether 6 years of continuous spring wheat production under zero tillage has affected the soil quality of a farmer's land on which snow management was being practiced after 70 years of wheat-fallow cropping using conventional tillage.

MATERIALS AND METHODS

In 1981, a study was initiated at Swift Current to compare the effect of snow trapping using cereal trap strips (tall stubble) versus stubble left at one standard height of about 15 cm (short stubble) on spring wheat yields (Campbell et al. 1986a). Various N and P fertilizer treatments were superimposed on these main treatments. Zerotill management was used. The study was carried out on a farmer's wheat field which was cropped to a fallow-wheat rotation for the previous 70 years. The study occupied four, 2-ha replicates on Swinton clay loam, a Brown chernozemic soil. The adjacent land was kept in the wheat-fallow rotation with conventional tillage used while spring wheat was grown annually on the test site.

In May 1985, soil samples were taken from the 0 - 7.5, 7.5 - 15 and 15 - 30 cm depths from each of the tall stubble, short stubble, and the fallow phase of the adjacent fallow land. Four samples were taken from filler plots (Campbell et al. 1986a) in each replicate of the snow trap experiment and these bulked to give one sample per depth per replicate. The adjacent fallow area was split into 4 quadrats and 4 samples per depth taken and bulked per quadrat with each quadrat regarded as a replicate.

In October, 1986, after 2 more crops were taken off the snow management plots, soil samples were taken in a manner similar to 1985, from the continuous wheat short stubble and from the fallow phase and from the stubble phase of the fallow-wheat system adjacent to the zero-till study.

Soil samples were passed through a 2 mm sieve and kept in plastic bags in the cold room at 0°C till analysed. Analyses performed on both 1985 and 1986 samples were total C, total N, CO_2 respiration at 20°C for 10 days amino acids after acid hydrolysis. Analysis completed on 1985 samples alone was potentially mineralizable N by incubating and leaching periodically for 16 weeks and calculating N_o and K, by the double exponential method (Deans et al. 1986), microbial biomass C and N, (Methods for these analyses are outlined in Campbell et al. 1986b). As well, soil enzymes such as alkaline phosphatase, neutral phosphatase, and urease were determined on the 1985 samples (see Biederbeck et al. 1987 in this proceedings for methods). Aggregate stability analaysis was determined on the 1986 samples by the dry sieving technique.

RESULTS

Moisture Conserved and Yields on Zero-Till Plots

During the 5 years of experiment (6 years of zero-till cropping) the average advantage of moisture conserved in tall (cereal trap strip) stubble plots compared to short (15 cm) stubble was 15.5 mm of moisture. There were 2 dry years and 3 wet years and the average advantage in grain yield for tall stubble over short stubble treatments in dry years was 200 kg/ha and in the 3 wet years 70 kg/ha. There was no response to N fertilizer in dry years but in wet years there was a positive curvilinear response to N fertilizer between 25 and 75 kg N/ha.

Soil Quality Changes

Organic N concentration was increased in the 0 - 7.5 cm by zerotillage after 4 and 6 years of cropping but there was no significant difference in the 7.5 - 15 cm depth (Table 1). Organic C was significantly increased in both depths by zero-tillage after 4 and 6 years. The effect of zero-tillage on amino acids was not as clear cut after 4 years but after 6 years cropping there was no doubt that zero-tillage has increased the amino acid content of the top 15 cm of soil compared to the wheat-fallow system (Table 1).

Table 1. Effect of Zero Tillage on Organic C, N & Amino Acid Concentrations in surface soil.

Depth & Treatment	%N Sampled 1985 Sp.	%N Sampled 1986 Fall	%C Sampled 1985 Sp.	%C Sampled 1986 Fall	+Amino Acids (mg/kg) Sampled 1985 Sp.	+Amino Acids (mg/kg) Sampled 1986 Fall
0 - 7.5 cm						
*F-W	0.120	0.127	1.14	1.27	17.7	19.8
F-W*	--	0.131	--	1.12	--	22.7
Sh. Stubble	0.161	0.149	1.66	1.68	26.0	28.4
Tall Stubble	0.156	--	1.57	--	19.0	--
$S\bar{x}$	0.006	0.007	0.06	0.11	0.5	0.7
7.5 - 15 cm						
*F-W	0.114	0.118	1.00	1.14	15.5	17.6
F-W*	--	0.107	--	0.98	--	14.9
Sh. Stubble	0.125	0.137	1.16	1.49	15.1	20.8
Tall Stubble	0.126	--	1.26	--	16.9	--
$S\bar{x}$	0.005	0.010	0.06	0.14	0.4	0.6

\+ Mean of 17 Amino Acids
* Phase of F-W Rotation Sampled

Soil respiration for the 0 - 7.5 cm depth was increased by zerotillage after 4 and 6 years but there was no change in the 7.5 - 15 cm depth (Table 2). Enzyme analysis showed no difference in urease activity in the 0 - 7.5 cm depth while neutral phosphase concentration was increased by zero-tillage and alkaline phosphatase activity showed the same trend after only 4 years of zero tillage.

Table 2. Effect of Zero Tillage on Respiration, Phosphatase and Urease Activity in Surface Soil.

Depth & Treatment	CO_2 Respiration (µg/g soil) Sampled 1985 Sp.	1986 Fall	Phosphatase P-Nitrophenot (µg/g/hr) Alk.	Neut.	Urease (µg/g soil)
0 - 7.5 cm			1985		1985
*F-W	82	116	480	396	61
F-W*	--	126	--	--	--
Sh. Stubble	132	214	907	601	51
Tall Stubble	134	--	603	688	61
$S\bar{x}$	13	14	162	46	8
7.5 - 15 cm					
*F-W	31	38	+ND	ND	ND
F-W*	--	40	ND	ND	ND
Sh. Stubble	44	45	ND	ND	ND
Tall Stubble	43	--	ND	ND	ND
$S\bar{x}$	3	11			

+ND = Not determined
* Phase of F-W Rotation Sampled

Potentially mineralizable N (N_{01} & N_{02}) in the 0 - 7.5 cm depth were increased by 4 years of zero-tillage but the K values were not affected (Table 3). There was no effect of tillage treatment on potentially mineralizable N or on K for the 7.5 - 15 cm depth. There was a tendency for microbial biomass C in the 0 - 7.5 cm depth to increase after 4 years of zero-tillage but the difference was not significant and there was no effect on biomass N.

Table 3. ‡Effect of Zero Tillage on Net N Minerailization Constants and Microbial Biomass in Surface Soil.

Depth & Treatment	+Potential Min. N (N_0) & Rate Const. (K)				Microbial Biomass		
	N_{01}	N_{02}	K_1	K_2	C	N	C/N Ratio
0 - 7.5 cm	(µg/g soil)		(wk^{-1})		(µg/g soil)		
*F-W	13	83	-0.45	-0.08	205	43	4.8
Short Stub					263	50	5.3
Tall Stub	33	127	-0.52	-0.05	262	37	7.1
$S\bar{x}$	--	--	--	--	30	4	--
7.5 - 15 cm							
All Treats.	9	44	-1.07	-0.10	ND	ND	ND

+ Calculated from net N min in 16 wk using double exponential iteration method (Deans et al. 1986).

‡ Sampled Spring 1985.

* Only fallow phase of F-W sampled.

Soil erodibility, measured after 6 years, showed that summer-fallowing increases erodibility but even one crop can rectify this problem (Table 4).

Table 4. Effect of Cropping and Zero Tillage on Erodibility of Surface Soil.

	% +Erodibility Measured Fall 1986
0 - 7.5 cm	
*F-W	64
F-W*	40
Sh. Stubble	43
$S\bar{x}$	5

+ Measured by dry sieving of soil clods.

Yield Response to N on Zero Till & Conventional Tilled Land

In 1986, a year with above average rainfall, (206 mm for May 1 - July 31) it is customary to obtain yield response to fertilize N on both fallow and stubble land. However, as shown in Figure 1, response to N was minimal for both wheat grown on fallow and 6th year wheat grown on stubble in the zero-tilled plots, and yields in both these systems were between 38 - 43 bu/ac (2550 & 2880 kg/ha) when fertilizer N was between 25 & 100 kg N/ha. These results were no doubt partly due to relatively high residual soil test N after back to back dry years in 1984 and 1985 (soil test N for fallow-crop was 50 kg N/ha, for second year stubble crop it was 37 and for zero-till stubble crop 48 kg N/ha in fall 1985). Nonetheless, as shown in Figure 1 marked increases in yield were obtained on the second year stubble crop on the adjacent land (Figure 1). This suggests that a major part of the yield benefit on the zero-tilled land was likely due to the improved soil quality due to 6 years of continuous zero till cropping to wheat. The numerous intermittent rains probably resulted in considerable N being mineralized from the zero-tilled land, more so than the conventionally tilled land, as indicated by the potentially mineralizable N pool (Table 2).

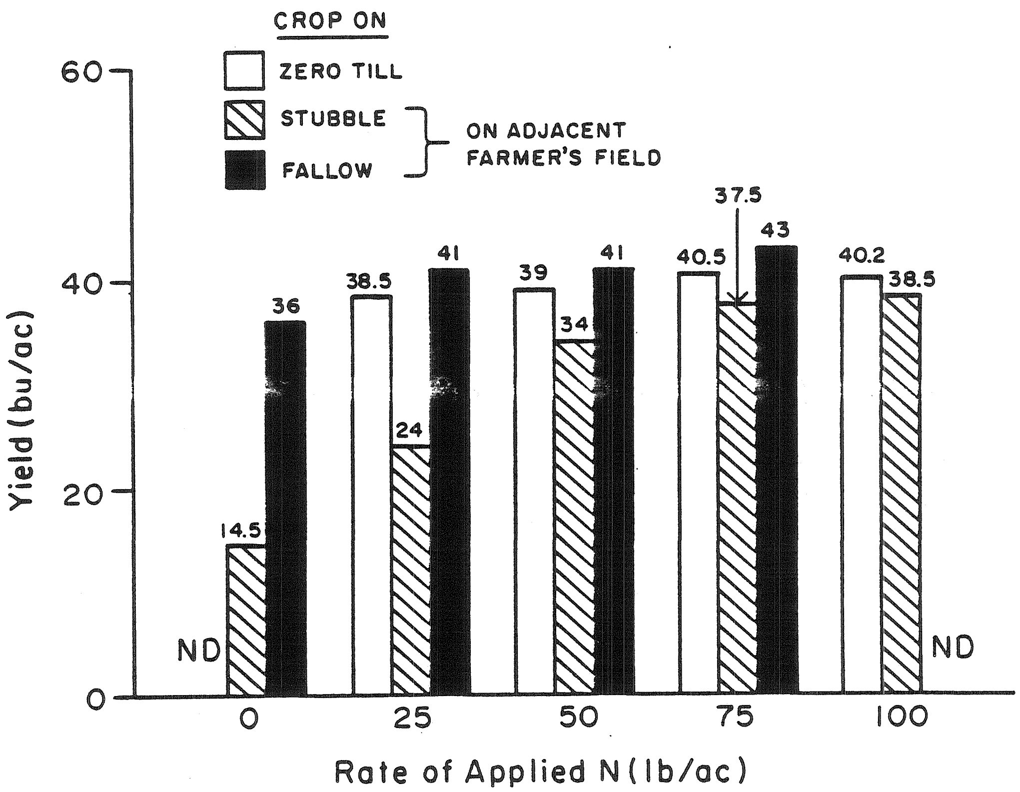

Figure 1. Yield response to N fertilizer in 1986 on zero-tillage and on adjacent wheat on fallow and wheat on first year stubble.

CONCLUSIONS

Six years of zero-till continuous cropping to spring wheat on a Brown medium textured soil using cereal trap strips to enhance soil moisture and yields, has improved the quality of the surface soil significantly. This land which had been cropped for 70 years using a wheat-fallow system has now improved to such an extent that in 1986, a year of above average rainfall, grain yields on the 6 year stubble plots showed only marginal response to N and yielded as well as wheat grown on fallow on the adjacent land, while wheat grown on stubble (second year crop) yielded less and responded significantly to N fertilizer. This confirms the soil quality improvement measured by biochemical techniques.

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