EFFECTS OF SURFACE SOIL MIXING AFTER LONG-TERM ZERO TILLAGE ON SOIL NUTRIENT DISTRIBUTION AND WHEAT PRODUCTION

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Summary. Effects of surface soil (0-10 cm) mixing with a rotary hoe after eight years of zero tillage (ZT) on nutrient distribution in soil and on wheat production were studied on a Sodosol in the semi-arid environment of central Queensland. Soil mixing reduced nutrient (e.g. P, K, Zn) stratification and increased their uptake by wheat. Improved availability of previously surface-stranded nutrients (particularly P) on mixing the ZT plots increased wheat grain yield by 28%. Ploughing/mixing the soil when nutrient stratification is experienced under long-term ZT practice may have to be accepted as part of the conservation tillage strategy.

INTRODUCTION

Traditional tillage (deep and frequent ploughing) is discouraged to minimise soil degradation. On the other hand, surface accumulation of relatively immobile nutrients like P, K and Zn (1, 2, 3) under zero tillage (ZT) is of concern. In the semi-arid sub-tropical environment of central Queensland, surface soil layers dry out quickly leaving nutrients in these layers unavailable to plants (1). Relocation of the nutrient-rich surface layer of soil to deeper in the profile should improve nutrient availability due to higher moisture content further down the profile. We studied the effects of soil mixing on nutrient distribution in surface layers and on wheat (*Triticum aestivum* L.) yield and composition.

MATERIALS AND METHODS

Site description

The trial was conducted at the Brigalow Research Station (latitude 24°50'S, longitude 149°47'E, altitude 151 m), 175 km south-west of Rockhampton in central Queensland. Climatic environment at the trial site has been described elsewhere (8). Soil at the study site is a Subnatric, Brown, Sodosol (8). Principal soil profile forms are classified as Dy3.33 and Db2.33 and resemble Typic Natrustalfs. Some of the soil properties at the trial site are given in Table 1.

Table 1. Some soil properties of the zero tillage trial site.

Depth (cm)	pH (1:5)	Organic C (%)	Total N (%)	Bicarb-P[1] (mg/kg)		Replaceable-K[1] (cmol (+) /kg)		DTPA-Zn (mg/kg)
				Soil not mixed	Soil mixed	Soil not mixed	Soil mixed	
0-5	7.3	1.40	0.080	47.2	38.7	0.94	0.76	0.97
5-10	7.4	1.23	0.073	27.6	36.7	0.55	0.72	0.77
10-15	7.1	0.80	0.050	16.3	20.8	0.35	0.42	0.47

15-20	7.1	0.73	0.043	10.7	12.0	0.25	0.27	0.43

[1] Soil samples taken 55 days after mixing zero till plot.

After clearing in 1982, a sorghum (*Sorghum bicolor* L. Moench.) crop was planted in September 1984 and wheat has been planted every year since then under ZT. Preceding the trial reported here, the site had been under ZT for eight years.

Experimental details

An overall trial site of 24 m by 17 m in the ZT bay was divided into three replications. One plot in each replication was selected by randomisation to receive the surface *soil mixed* treatment. One plot above and another one below each mixed plot were used as the control plots. The top 0-10?cm soil layer of the designated *mixed plots* was mixed by using a rotary hoe.

Fifty-five days after mixing the soil, wheat (cv. Hartog) was planted on 5 May and harvested on 9 October 1992. Individual plot size was 6 m by 1.25 m, with 5 rows of wheat and a row-to-row distance of 25 cm. Three middle rows were harvested manually for data collection. Rainfall received from soil mixing to wheat planting was 70 mm, and in-crop rainfall was 167 mm.

Sample analysis

Soil samples were analysed as follows: pH in 1:5 of soil:distilled water; organic C by Walkley and Black method; total N in Kjeldahl digest; bicarb-P in 0.5M $NaHCO_3$ (Colwell); replaceable K in 0.05M HCl extract; and Zn in 0.005M DTPA extract. In plant samples, P, S and Zn were analysed by XRF spectrometry and total N and P were analysed in Kjeldahl digest by IEC-P0.01.

Statistical analysis

Plant yield and composition data were analysed using the randomised block design model considering duplicate samples from the control treatment. With only 1 degree of freedom (df) for treatments and 5 df for error in the analysis of variance, differences between treatments had to be relatively large to be statistically significant.

RESULTS

P and K stratification

Phosphorus stratification was observed after eight years of ZT practice (Table 1). The surface 0-5 cm layer had 63% higher concentration of bicarb-P than the 5-10 cm layer. Distribution of replaceable-K in soil profile followed a trend similar to that of bicarb-P. Note also Zn stratification in the soil profile (Table 1). Mixing the surface 0-10 cm layer overcame the P and K (Table 1) and Zn (data not shown) stratification.

Wheat production

At 30 days, plant height and dry matter per plant were not affected (P=0.05) by the soil mixing treatment (data not shown). At harvest, soil mixing increased wheat grain and grain plus straw yields significantly (28% increase; Fig. 1). Straw yield increase was similar to grain yield increase but the results were not significant due to the higher coefficient of variation (cv of 17% for straw yield compared to 7.5% for grain yield).

Wheat composition

At 30 days, soil mixing had no significant effect on Ca, K, Mg, N, Cu, Fe and Zn concentrations in dry matter; it increased S but decreased Mn concentration. Soil mixing increased P concentration in wheat shoots from 0.33% to 0.40%.

At harvest, N, P, K, S and Zn levels in grain or in straw were not affected (Table 2). Uptake of N, P, K and S in grain increased due to soil mixing in the ZT plots. Nutrient uptake in straw did not change significantly (data not shown). However, uptake of N, P, K and Zn in grain plus straw increased by 31%, 29%, 29% and 26% respectively on mixing of the ZT site, with no significant increase in S uptake (Table 2).

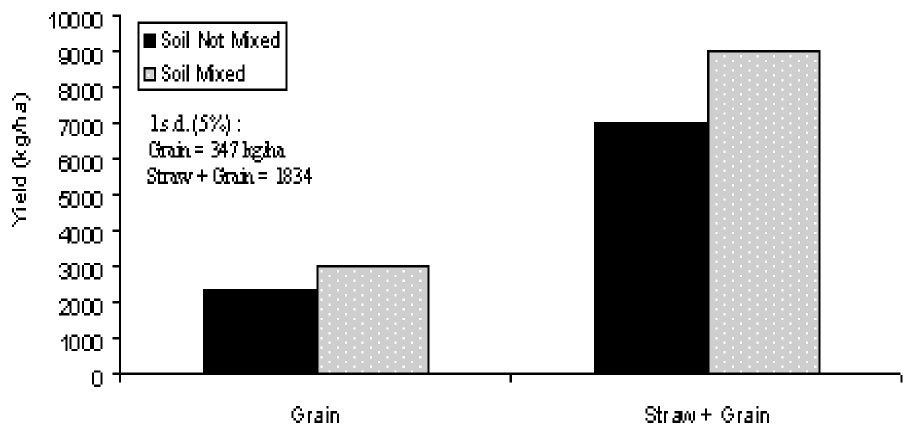

Figure 1. Effect of soil mixing on wheat yield in a previously zero tilled plot.

Table 2. Wheat composition and nutrient uptake under soil not-mixed (control) and mixed treatments.

Treatment	N	P	K	S	Zn
		(%)			(mg/kg)
Grain					
Control	2.76	0.32	0.33	0.18	48
Mixed	2.79	0.34	0.32	0.18	45
Straw					
Control	0.54	0.04	0.92	0.14	25
Mixed	0.56	0.03	0.90	0.13	25
			(mg/kg)		
Grain					
Control	64.6 b	7.49 b	7.41 b	4.29 b	0.113
Mixed	83.8 a	10.19 a	9.77 a	5.51 a	0.137
l.s.d. (5%)	13.5 4	1.92	0.98	0.89	0.029

Grain + Straw					
Control	89.9b	9.47b	50.1b	10.97	0.228b
Mixed	117.5a	12.17a	64.4a	13.13	0.287a
l.s.d. (5%)	24.7	2.12	12.8	2.69	0.056

Within columns of each plant part analysed, means followed by different letters are significantly different at P=0.05

VAM infection

Measurements after 30 days of planting wheat showed that the soil mixing treatment had decreased vesicular-arbuscular mycorrhiza (VAM) colonisation of roots from 26% in the control plots to 11% in the mixed plots (David Peck, pers commun.). At harvest, roots were not assayed for %VAM infection, but plant growth and total P uptake were increased by soil mixing.

DISCUSSION

Nutrient stratification after long-term ZT, as noted in the present study, has been documented in central Queensland (1, 3, 6) and overseas (2, 4).

Nutrient stratification can be minimised by ploughing the soil. But, soil disturbance can decrease and/or delay mycorrhizal infection of plant roots (5, 7, 9) and reduce P and Zn absorption by the plants (5, 9). In our study, however, even though soil mixing decreased VAM infection of wheat roots at 30 days, P concentration in shoots had increased. Furthermore, total P uptake by the plant in the mixed plots was significantly higher than that in the control plots. Evidently, soil mixing decreased nutrient stratification in soil profile (Table 1) and thus improved nutrient availability by moving them into deeper layer where soil moisture conditions were more favourable. Therefore, surface soil mixing increased wheat production and nutrient uptake by the plants. This suggests that overcoming the P stratification problem by mixing more than compensated the adverse effects of soil mixing on VAM populations.

Other factors like improved N mineralisation due to the exposure of soil and organic matter surfaces to the atmosphere, or overall aeration of the system could have contributed to the yield increase on mixing the ZT soil (1).

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