Effects of surface soil mixing after long-term disc, blade and zero tillage on sorghum production in central Queensland

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Summary. Mixing of surface soil (SM) of a Vertisol after 13 years of zero tillage (ZT) increased sorghum, *Sorghum bicolor,* grain and total dry matter yields significantly ($P<0.05$). The effect of SM on grain yield was greater where stubble was regularly removed (1530 kg/ha increase over control) than where it was retained (680 kg/ha increase). Fertiliser (N+P+K+Zn+S) application in combination with SM produced the highest yields. SM increased N uptake from 75.3 to 94.3 kg/ha and P uptake from 4.8 to 7.1 kg/ha. We conclude that, when nutrient stratification is experienced, strategic mixing of surface soil under continuous ZT enhances crop growth due to increased nutrient availability.

Introduction

Traditional tillage (disc ploughing and frequent cultivation) is being discouraged to minimise soil erosion and structural degradation. The extreme alternative of zero tillage (ZT) can lead to surface accumulation of relatively immobile nutrients like P, K and Zn (2, 5) and reduced N mineralisation rates (8). Cultivation accelerates organic matter decomposition by soil microorganisms through changes in soil water relationships, aeration and temperature regimes, and the nutritional environment (3).

In the semi-arid subtropics of central Queensland, the surface soil layers dry out quickly, leaving nutrients in these layers unavailable to the plant. Under such conditions, redistribution of the surface-stranded nutrients to a greater depth by cultivation would benefit plant uptake of the relatively immobile nutrients (2). Soil disturbance can decrease and/or delay mycorrhizal infection of plant roots (4, 6, 7) and reduce P and Zn absorption by the plants (4, 7). Cultivation can enhance soil N mineralisation but also encourage N immobilisation if plant residue of a high C/N ratio is incorporated into the soil.

We studied the effects of surface soil mixing by rotary hoe (SM) following continuous disc (DT), ZT and blade (BT) tillage practices on sorghum production under rainfed conditions.

Methods

The experimental site was located about 10 km north-east of Biloela (latitude 24?22'S, longitude 150?31'E) in Queensland on a grey Vertisol (Ug5.24), Entic Pellustert (9). Prior to the present study, the site had 10 successive experimental sorghum crops starting in 1978-79, no crop in 1988-89 and cotton, Gossypium hirsunim, in 1989-90.

After 13 years of DT, BT and ZT practice, with or without stubble retention and no fertiliser addition, we used a rotary hoe to mix the top 12 cm of soil and studied its effects, with and without fertiliser addition, on sorghum production. The fertilised treatments received (kg/ha): N=75. P=40. K=50, S=30 and Zn=5, banded 10 cm deep and 5 cm to the side of each row.

The plots were 3x3 m, with an interrow distance of 0.75 m. The middle two rows were harvested for data collection. Sorghum cv. DK44 was planted on 18 January 1991 (130 days after SM), and harvested on 8 May 1991. From SM to planting, the site received 283 mm rainfall, including 133 mm in 2 days. In-crop rainfall was 76 mm. including 49 mm in one day. Some soil properties of the experimental site are given in Table I. The soil had a cation exchange capacity (pH 8.5) of around 30 me/100 g in the 0-20 cm layer. Organic C and total N concentrations at corresponding soil depths (data not given) under different tillage practices were not greatly different. Note surface accumulation of nutrients and lower pH under ZT.

Table 1. Some soil properties of the "stubble retained, not mixed" plots at planting[a].

Depth (cm)	pH (1:5)			Bicarb-P[b] (mg/kg)			NH_4Cl-K (me/100 g)			DTPA-Zn (mg/kg)		
	DT	ZT	BT	DT	ZT	BT	DT	ZT	BT	DT	ZT	BT
0-2.5	7.8	7.2	7.9	15	32	14	0.30	0.42	0.34	0.5	0.9	0.4
2.5-5	7.9	7.4	8.1	16	28	16	0.29	0.29	0.32	0.4	0.6	0.4
5-10	8.1	8.1	8.4	10	8	11	0.25	0.17	0.23	0.5	0.3	0.5
10-15	8.7	8.5	8.7	5	4	4	0.16	0.14	0.15	0.4	0.2	0.3
15-20	8.9	8.8	8.8	3	4	2	0.11	0.10	0.14	0.2	0.3	0.3

[a] DT = disc, ZT = zero, and BT = blade tillage; [b] Colwell method

Results Sorghum growth and yield

1. Averaged over tillage, stubble and fertiliser treatments, at 30 days, plant height (65 vs 69 cm). and dry matter (DM) yield (3.45 vs 4.00 g/plant) were significantly (P<0.05) increased by SM. SM decreased the period for 50% of plants commencing flowering from 63 to 59 days. The biggest effect of SM was found in the ZT plots.

At harvest, SM improved shoot plus grain DM yield (6020 vs 6670 kg/ha) and grain yield (GY) (2200 vs 2590 kg/ha) significantly but not the shoot DM yield (3820 vs 4090 kg/ha); SM mainly affected the ZT plots (Fig. I a, I b).

2. Averaged over tillage, stubble and SM treatments, fertiliser addition increased sorghum GY significantly (2130 vs 2650 kg/ha). However, GY increase was significant only under ZT where fertilised plots produced 3110 kg/ha compared to 2260 kg/ha in the control.

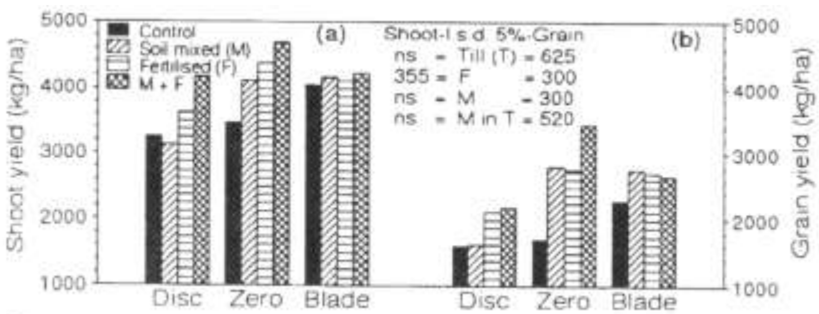

Figure 1. Effects of soil mixing and fertiliser (NPKSZn) addition under disc, zero and blade tillage on (a) shoot and (b) grain yield of sorghum

3. Fertiliser plus SM in the ZT plots gave the best GY (Fig. lb). Here, the effects of cultivation and fertiliser were cumulative, that is, the combination of both treatments resulted in a significant (P<0.10) yield increase above that due to either treatment alone.

4. The effect of SM in the not-fertilised ZT plots on sorghum GY was greater where stubble was removed regularly (1530 kg/ha or 133% increase over control) than where it was retained (680 kg/ha or 30% increase).

5. In the not-mixed and not-fertilised ZT plots, regular stubble removal decreased GY by 50%. Averaged over tillage, fertiliser and SM treatments, GY decrease due to regular stubble removal was 18%.

Sorghum composition

I. N, K, Ca, Mg, S and Zn concentrations in sorghum grain and shoot were not significantly (P <0.05) affected by SM. P concentration in grain was also not significantly affected but decreased from 0.039 to 0.034% (significant at P=0.054) in the shoots.

Nitrogen uptake in grain plus shoot was significantly increased as a result of SM (75.5 vs 84.3 kg/ha) and fertiliser addition (72.4 vs 87.4 kg/ha) (Fig. 2a). P uptake was increased by SM (5.29 vs 6.14 kg/ha) mainly through its effect in the ZT and BT plots. and by fertiliser addition (5.15 vs 6.28 kg/ha) (Fig. 2b). K uptake was significantly increased by fertiliser addition (42.4 vs 59.5 kg/ha). Overall, for every nutrient. SM plus fertiliser addition resulted in the highest nutrient uptake.

In the not-mixed and not-fertilised ZT plots (also over all tillage practices), regular stubble retention increased total nutrient uptake compared to stubble removal: N (45.6 vs 78.3 kg/ha), P (3.0 vs 5.1 kg/ha) and K (18.1 vs 41.5 kg/ha).

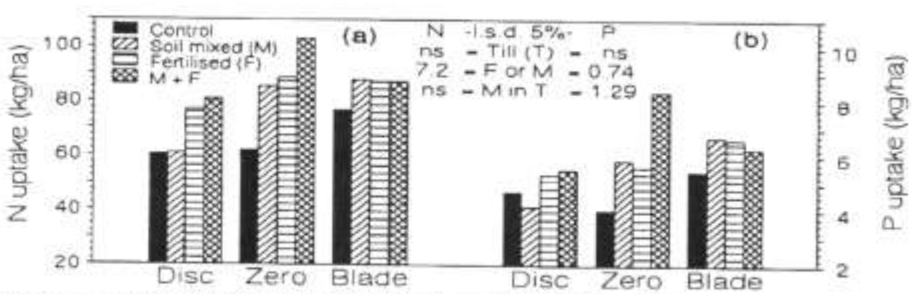

Figure 2. Effects of soil mixing and fertiliser (NPKSZn) addition under disc, zero and blade tillage on (a) N and (b) P uptake by sorghum

Discussion

The beneficial effects of cultivating ZT plots with a rotary hoe (SM) on crop production may be due to redistribution and improved availability of nutrients previously stranded in the surface layers and enhanced release of nutrients from organic matter, among others. Disturbance of a previously ZT soil is reported to significantly reduce P and Zn absorption by plants, reduce or delay mycorrhizal infection of roots (I, 4) and decrease shoot DM (7).

In our study. infection of sorghum roots by mycorrhizae was not measured. SM decreased P concentration in shoots due to the dilution effect from higher yield, and it increased total N, P, S and Zn uptake. Growing linseed, *Linum usiunissimum.* in a glasshouse on intact soil cores taken from the ZT `mixed' and 'not mixed' plots showed that, at 4 weeks, plant DM was increased more by SM in plots where stubble was regularly removed than where it was retained (J.P. Thompson. pers. comm.). In that study, P uptake per plant was increased by SM. and Zn uptake increased only in the 'stubble removed' plots.

It seems that SM redistributed the surface-stranded nutrients throughout the plough layer where they were relatively more available. In a separate study at the trial site. N application (75 kg/ha) alone had no significant effect on sorghum GY (Asghar *el al..* unpublished date), and therefore any increased N mineralisation due to cultivation of ZT plots could not explain the major beneficial effects of SM. P was the most limiting nutrient, and its application alone or in combination with other nutrients (especially Zn) had increased sorghum yield. The ZT plots had surface-stranded P. K and Zn (Table I). and SM seems to have improved their availability leading to increased sorghum production. Nutrient release from organic matter on soil cultivation would have benefited the crop. The effects of timing and type of tillage implement used for mixing surface soil after continuous ZT practice should be investigated considering the crop production and resource conservation issues.

Regular stubble retention produced significantly higher sorghum GY than stubble removal, showing the significance of this practice for the continued development of conservation land management systems for sustainable crop production.

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