SURFACE SOIL NUTRIENT DISTRIBUTION FOLLOWING ZERO TILLAGE AND TRADITIONAL TILLAGE MANAGEMENT

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Summary. In two of the three long-term tillage experiments in central Queensland, zero tillage (ZT) practised for continuous periods of 5-12 years resulted in the stratification of nutrient concentrations in the top 20 cm of soil. At one site, concentrations of bicarbonate-extractable phosphorus (P), exchangeable potassium (K), and calcium chloride ($CaCl_2$)-extractable P (Pc) were higher in the 0-2.5 and 2.5-5 cm zones with ZT. DTPA-extractable zinc (Zn) was higher in the 5-10 cm zone only. At the second site, P was higher in the 0-2.5 cm zone with ZT. Traditional tillage (TT) showed uniform P, K, Zn and Pc levels in the surface 10 cm at both sites. The third site showed stratification only of K with ZT. Nutrients released from crop residues under ZT accumulate at the soil surface. In soils with marginal levels of P, K or Zn, stratification of these nutrients can limit crop growth under ZT practice. We hypothesise that the limited stratification with ZT at the third site was due to the soil type and its behaviour and flow about planting tines at narrow row spacings; and possibly the abundance of earthworms and termites.

INTRODUCTION

A number of authors have presented data showing stratification of P, K and Zn in the surface 5 cm of soil with ZT practice (see 9). They did not note any nutritional constraints due to this phenomenon. Experimental sites have had good inherent soil fertility or received basal applications of nutrients.

Since soils in central Queensland have only recently been cultivated the producers usually do not apply fertiliser. Long-term tillage experiments in central Queensland all began with no basal fertiliser application and rarely with fertiliser treatments. This paper presents soil fertility results from three central Queensland tillage experiments with a history of no fertiliser application. Examination of soil nutrient levels over small depth increments to 20 cm began after observations of crop nutrient disorders and depressed yields after 5-7 years of ZT at two sites.

METHODS

Sites and soil

The long-term tillage experiments examined were located on major cereal cropping soils of the eastern central Queensland region. Sites were located at Brigalow Research Station (Brigalow) (24°50'S, 149°47'E), Biloela Research Station (Biloela) (24°23'S, 150°31'E) and at Mt Murchison (MtM) (24°19'S, 150°32'E). Site details are given in Table 1. Complete site location, management and treatment details are in references (6), (7), and (10) respectively.

Table 1. Soil type, site duration, cropping history and typical fallow operations for traditional tillage treatments of three long-term tillage experimental sites in central Queensland.

Site	Soil Type(5)	Established	Cropping History[a]	Traditional Tillage Fallow Operations[b]
Brigalow	(a)	1985	SW/W/W/W/W/W/	2Ch, 3Sc

Biloela	(b)	1983	S/S/S/SW/W/W/	2DP, 2OD
Mt Murchison	(c)	1978	S/S/S/S/S/S/S/S/S/S///C/	1DP, 1OD, 2Sc

[a] Chronological cropping history indicated by the abbreviations of sorghum (S), wheat (W), sunflower (Sn), cotton (C) or fallow(/).

[b] Average number and type of fallow tillage operations for the traditional tillage treatments: one-way disc plough (DP), offset disc plough (OD), chisel (Ch), scarifier (Sc). Excludes seedbed operations. Herbicides were used for fallow weed control in zero tillage treatments.

(a) Subnatric, Brown, Sodosol.

(b) Epicalcareous, Self-mulching, Black, Vertosol & Melanic, Calcic, Black, Dermosol.

(c) Epicalcareous-Endohypersodic, self-mulching, Grey, Vertosol.

Sampling

Only TT and ZT treatments with a history of no fertiliser inputs were sampled. Ten soil cores were taken from each plot and bulked. There were four replicates (reps.) at Brigalow and Biloela and three reps. at MtM. Replicate soil samples from Brigalow and Biloela were analysed separately. Replicate samples from MtM were bulked after being analysed for bicarbonate-extractable P thus precluding statistical analysis of other nutrient data. At Brigalow and Biloela, soil was sampled at depth increments of 0-2.5, 2.5-5, 5-10, and 10-20 cm. At MtM, depth increments were 0-2.5, 2.5-5, 5-10, 10-15 and 15-20 cm. The 0-2.5 cm soil zone was sampled using a square-section hand trowel. Deeper samples were taken through this depression using a 25 mm tube with a machined tip. Samples were taken at the end of fallows on 23 April 1991, 10 May 1990 and 25 January 1991 from Brigalow, Biloela and MtM respectively.

Analytical methods

Soils were analysed for bicarbonate-extractable P (P), DTPA-extractable Zn (Zn), exchangeable K (K) and $CaCl_2$-extractable P (Pc) by the methods of Rayment and Higginson (8).

RESULTS

At Brigalow (Fig. 1), soil P, K, and Pc were higher in ZT than in TT in the 0-2.5 cm and 2.5-5 cm zones; Zn was higher in the 0-2.5 cm zone only. Under ZT, soil P, K and Pc decreased with each depth (D) increment down the profile to 10 cm; Zn decreased only between the 0-2.5 cm and 2.5-5 cm zones. Under TT, soil P, K, Pc and Zn showed no significant changes with depth in the surface 10 cm (or tilled layer). Below 10 cm tillage history (T) had no effect on the measured parameters.

At MtM (Fig. 1), soil P was higher in ZT than in TT in the 0-2.5 cm and 2.5-5 cm zones, and lower in the 5-10 cm zone. Below this T had no effect on P levels. Under ZT, P levels at MtM decreased with each depth increment to 10 cm. Under TT, soil P levels did not change with depth in the surface 10 cm. While K and Zn data from MtM show a similar trend to P data, there is no statistical support since replicate soil samples were bulked before chemical analysis.

At Biloela (Fig. 1), soil P was higher under TT than ZT in the surface 10 cm. At 10-15 cm, T did not affect soil P. K was higher under ZT only in the 0-2.5 cm zone, below which T had no effect. No TxD interactions were present with soil Zn or Pc levels.

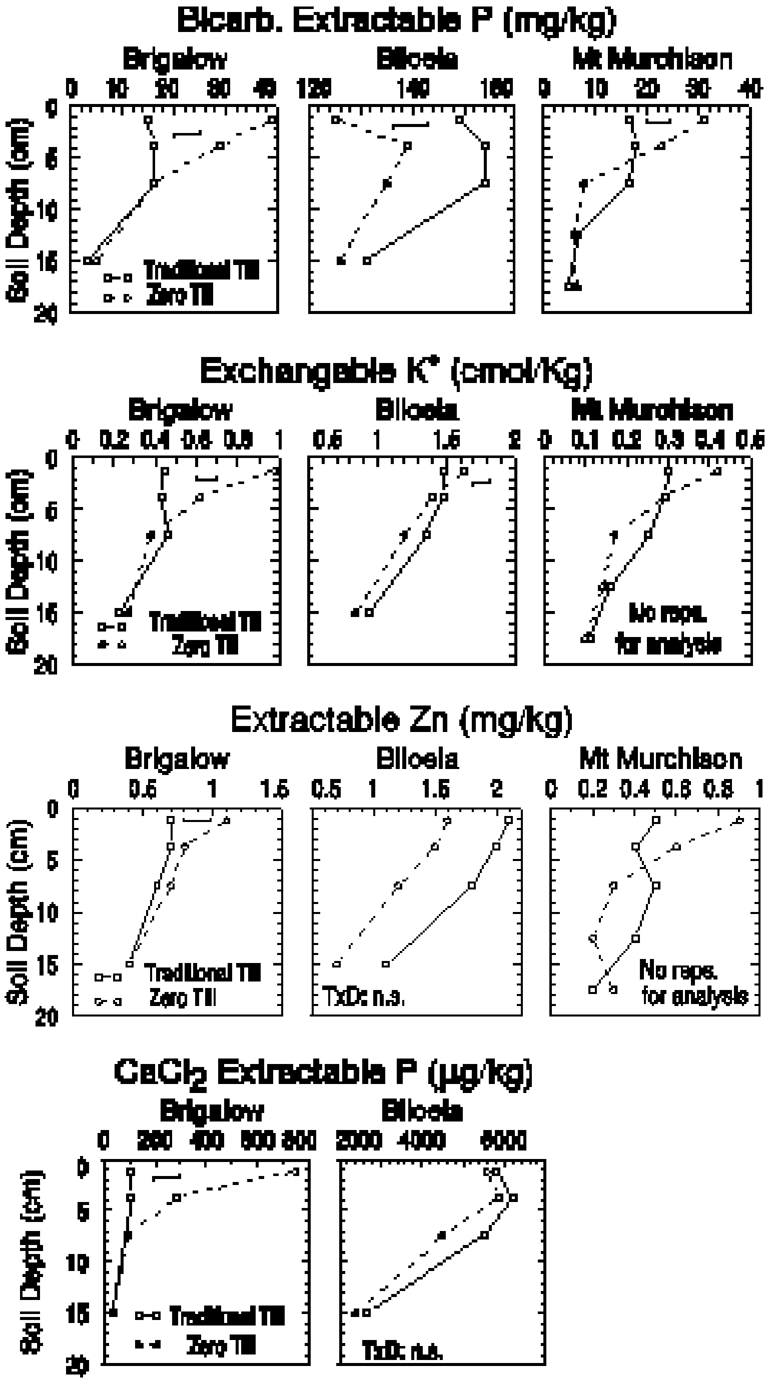

Figure 1. Effect of tillage history on bicarbonate-extractable P, exchangeable K, DTPA-extractable Zn and $CaCl_2$-extractable P levels at three long-term tillage sites in central Queensland. Horizontal bars indicate significant TxD interactions (P=0.05).

DISCUSSION

Robson and Taylor (9) discuss several reports of ZT practice leading to the stratification of nutrients such as P and K (3, 4), Zn, copper, manganese, iron and boron because of their relatively immobile nature in soils. No production constraints were attributed to P, K or Zn stratification in these studies, presumably because the soils had high inherent fertility, they received regular applications of P and K, and the surface soil remained moist enough to support good root growth (9). The view that stratification may favour cereal production by providing abundant fertility for early growth (3) is not supported by field observations at the trial sites reported here nor by Cornish (2). After 7 years and 5 years of continuous ZT at MtM and at Brigalow Research Station respectively, fertility constraints became obvious and crops responded to P application (6) and/or soil mixing (1). At these sites surface soil (0-5 cm) is most often too dry for root growth and nutrient extraction, and nutrient levels below the surface 5 cm are low.

Stratification of P, K and Zn has been recorded at the MtM site in the ZT stubble removed treatment (unpubl. data). Given that low stubble levels increase soil erosion (11), the potential for erosional nutrient losses and consequent negative off-site effects in this instance is increased. Cultivation of such soil would remove stratification but its effect on infiltration, soil erosion and nutrient export potential would vary with rainfall characteristics.

The reason for stratification of P, K and Zn with ZT at only two sites is unclear. We suggest that stratification did not occur at Biloela because the narrowly-spaced (27.5 cm) planting tines moved crusts sideways, burying most of the undisturbed inter-row area. The natural soil behaviour of cracking as well as a high level of surface casting earthworm and termite activity (7) may also act to prevent accumulations in the 0-2.5 cm zone.

Obtaining accurate soil samples of small depth increments on coarse structured soils is difficult with traditional sampling equipment. Data from other samplings of MtM (data not shown) indicate less stratification when the soil was dry (mid fallow) and more when it was moist (pre-planting). We attribute this variation to sampling imprecision. On soils of finer structure or lighter texture, soil moisture may be less important for precise sampling.

Stratification of P, K and Zn with ZT may mean the traditional 0-10 cm soil sample for assessing fertility is inappropriate; a 5-15 cm sample may be best regardless of fallow practice.

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