**Root health and nutrient accumulation in sugarcane.**

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Sugar Yield Decline Joint Venture
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**Abstract**

The Yield Decline Joint Venture has shown that productivity of the current sugarcane farming system can be increased significantly by soil fumigation or breaking the current monoculture. It was hypothesised that responses were mediated via improved root health, with more functional root systems resulting from either an increased root surface area or a more thorough exploitation of the soil volume. Uptake of K and Si were used as indicators of this effect due to the importance of diffusion in supplying these nutrients to the root surface, and the capacity of plants to accumulate luxury concentrations in biomass. Treatments had little or no effect on the concentration and availability of K and Si in the soil, but concentrations in plant tops increased significantly despite increases in biomass of between 50 and 100%. The ability to maintain or increase concentrations of K and Si may provide an index of root system functionality.

**Key words**

rotation, fumigation, nutrient uptake, root systems, sugar cane.

**Introduction**

The productive capacity of Australian sugarcane soils has declined under both historical and current cropping systems. Breaking the cane monoculture with other crops, pastures and bare fallows, or fumigating continuous cane soil with methyl bromide, increases cane yields by 20-30% over a crop cycle (2). The exact mechanisms of improved cane productivity have yet to be identified, but treatments have commonly affected the relative abundance of cane-specific pathogens and increased root biomass (6). This paper reports treatment effects on crop growth and accumulation of essential nutrients, and uses relative changes in nutrient accumulation and plant biomass as an indicator of the functionality of the crop root system.

**Materials and Methods**

Rotation and fumigation trials at Bundaberg are reported in this paper, although similar results were also obtained in studies at Tully, Ingham, Mackay and Ayr. Details of treatment and break histories are presented in detail elsewhere (2, 3). Briefly, breaks consisted of alternate annual crops, pastures or bare fallows for varying periods. At the end of the break cycles at each site, plots were re-planted to sugarcane. Growth in these rotations was compared to that in plots that grew a sugarcane monoculture during the intervening period, with or without soil fumigation (1000 kg methyl bromide/ha) prior to sugarcane planting.

Soil samples were collected from all plots immediately prior to planting sugarcane, while destructive plant samples were taken from each experiment at least once during the growing season, in addition to the yield and component assessments at maturity.

**Results and Discussion**

Soil fumigation and the rotation treatments produced significant changes in the form and concentration of some plant available nutrients in the soil – primarily total and mineral nitrogen. However, there was no effect of fumigation on concentrations of exchangeable cations (calcium, magnesium and potassium) or plant-available silicon, and effects of rotation treatments were also minimal or non-existent as crops and pastures were generally unfertilised. Both fumigation and rotation treatments (Table 1) consistently produced large increases in biomass production relative to the continuous cane reference treatments, with the differences greatest during early growth.

The growth responses to breaks and fumigation were not associated with overcoming any particular nutrient deficiency, as nutrient concentrations in indicator leaves of continuous cane treatments have been at least adequate in all experiments (data not shown). However, treatments did result in changes in nutrient concentrations in aboveground biomass (Table 1). Fumigation of continuous cane soils resulted in increased concentrations of tissue nitrogen, potassium and silicon and reduced concentrations of phosphorus, calcium and magnesium at 60 dap (data not shown), and reduced concentrations of all nutrients except potassium and silicon at 192 dap (Table 1a). Similar differences in nutrient concentrations occurred in the rotation trials (eg. Table 1b).

**Table 1. Effect of (a) soil fumigation and (b) crop rotation on plant growth and the concentration of essential plant nutrients in aboveground biomass. LSD values ($P<0.05$) are shown where applicable.**

| Rotation | Fumigation status | Biomass | N | P | K | Ca | Mg | Si |
|---|---|---|---|---|---|---|---|---|
| | | kg/ha | | | % | | | |
| | | | (a) Fumigation study (192 dap) | | | | | |
| Contin. Cane | No | 1292 | 1.20 | 0.13 | 1.72 | 0.29 | 0.33 | 2.07 |
| Contin. Cane | Yes | 2075 | 1.08 | 0.06 | 2.44 | 0.12 | 0.16 | 3.01 |
| Lsd (P<0.05) | | 440 | ns | 0.03 | 0.25 | 0.15 | 0.07 | 0.32 |
| | | | (b) Rotation trial (95 dap) | | | | | |
| Contin. Cane | No | 1810 | 2.09 | 0.23 | 2.19 | 0.26 | 0.32 | 0.37 |
| Contin. Cane | Yes | 4470 | 1.94 | 0.20 | 2.48 | 0.21 | 0.28 | 0.38 |
| Legume pasture | No | 2670 | 2.30 | 0.24 | 2.87 | 0.19 | 0.27 | 0.52 |
| Grass pasture | No | 3100 | 1.82 | 0.29 | 2.68 | 0.15 | 0.25 | 0.59 |
| Bare fallow | No | 2790 | 1.99 | 0.20 | 2.23 | 0.26 | 0.29 | nd |
| Alternate crops | No | 3130 | 1.95 | 0.22 | 2.91 | 0.17 | 0.23 | 0.36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Lsd (P<0.05) | 950 | 0.24 | 0.03 | 0.28 | ns | ns | 0.14 |

Collectively, the increased biomass production and changes in nutrient concentration associated with fumigation and break treatments have produced significant increases in nutrient accumulation. The large increases in N accumulation were not surprising given the impact of treatments on improving total N fertility or increasing the rate of N mineralisation. Increased N uptake would be expected even without improvements in root health, as increasing the concentration of mineral N in the soil solution bathing the same root surface area would result in increased nutrient uptake due to mass flow. However, the increases in uptake of other nutrients (eg. K, Si) have occurred despite treatments having had little (if any) impact on measured concentrations of these nutrients in the soil. Despite large increases in biomass accumulation and consequently a much greater demand for essential nutrients, crops have been able to maintain or increase the concentrations in the plant, compared to continuous cane.

Known sugarcane pathogens like *Pythium* sp and *Pachymetra chaunoriza* and lesion nematode (*Pratylenchus zeae*) can reduce root proliferation and remove fine roots and root hairs (4, 7), thus reducing rhizosphere volume. Given adequate soil reserves, plant nutrient uptake responds best to increases in the rhizosphere volume when diffusion plays a dominant role in supplying that nutrient to plant roots (1). Potassium, Si and P are nutrients in which diffusive supply to plant roots is important, while others like Ca and Mg are predominantly supplied by mass flow (1). It is therefore consistent that the observed reductions in pathogen incidence caused by fumigation and breaks (5) have led to greater uptake of nutrients supplied predominantly via diffusion, like K and Si. Crop P responses were inconsistent with those of K and Si, probably due to the different effects of treatments on the VAM status of roots. The decline in P concentration in cane plants grown on fumigated soil was consistent with reduced VAM colonisation of roots, while the increase in P accumulation in the grass pasture break was consistent with both improvements in root health and the positive effects of pastures on VAM inoculum levels (5).

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