Growth of different plant species in pasteurised/fumigated and untreated sugarcane soils

A.L.Garside[1], S. Berthelsen[2] and R.C. Magarey[3]

[1]BSES Townsville, Qld
[2] CSIRO Land and Water, Townsville Qld.
[3]BSES, Tully , Qld.

ABSTRACT

In glasshouse pot experiments, the growth responses of a number of plant species were compared in untreated and fumigated/pasteurised sugarcane soils with varying field histories. Those histories were, continuous sugarcane cropping, recent sugarcane cropping, and a two-year break from continuous sugarcane. Fumigation/pasteurisation improved sugarcane growth, regardless of the soils' prior field history. There was also a small positive effect of fumigation/pasteurisation on the growth of other grass species but no effect on the growth of dicotyledonous species. Surprisingly, the response of sugarcane to pasteurisation was greater in the two-year break soil than the continuous sugarcane soil. The reasons for such a response are not clear, but several possibilities are discussed. It is suggested that the magnitude of the growth response to fumigation should not necessarily be accepted as a measure of soil health.

KEY WORDS

Sugarcane, rotation species, fumigation, monoculture, fallow.

INTRODUCTION

Yield decline, defined as the loss of productive capacity of sugarcane growing soils under long-term monoculture, has been a problem in the Australian sugar industry for much of its history (4).

Studies have shown that the productive capacity of the soil is reduced by sugarcane monoculture, as evidenced by; yield responses to the fumigation of long-term sugarcane soil (7); yield increases with new land (first sugarcane crop) compared with old land (grown cane for > 20 years) (3); and growth responses following the breaking of the monoculture with rotation species (5). The fumigation response has been attributed to the removal of detrimental root pathogens (7) and the rotation response to the development of a better balanced soil biota (9). However, with the exception of a preliminary report (2), no studies have been reported assessing the effect of sugarcane soils known to produce yield decline on the growth of potential rotation species.

In this paper the results of glasshouse pot experiments that involved old, new, and rotated sugarcane land, fumigation/pasteurisation, and a number of potential rotation species are discussed.

MATERIALS AND METHODS

Experiment 1

Eight diverse crop species were planted in soil collected from a farm near Proserpine, Queensland where unthrifty sugarcane growth had been identified. Prior to planting, soil was either fumigated with methyl bromide at 0.6407 kg/m^3 for 24 hr or left untreated. The species were cabbage, capsicum, lettuce, tomato, barley, sweet corn, sorghum, and sugarcane. Design was a factorial arranged in blocks with eight species, + or – fumigation, and five replications.

The vegetables (cabbage, capsicum, lettuce, tomato) and sugarcane were pre-germinated in either fumigated or unfumigated soil and then transferred to 2 L terracotta pots. At the time of transfer, seeds of other species were sown in terracotta pots containing either fumigated or untreated soil. Pots were

watered with sub-irrigation. All pots were fertilised with a complete range of nutrients to avoid nutrient deficiencies influencing the results.

Experiment 2

In this experiment, soil from adjacent areas of old land and new land (grown cane for 2 years) at Tully, Qld was either pasteurised (autoclaved at 90 ^{0}C for 90 min) or left untreated and planted to sugarcane, maize, sunflower or peanuts. Design was a factorial arranged in blocks with two soils (old and new land), + or – pasteurisation, four species and three replications.

Sugarcane and other species were established as for experiment 1. Watering was with an overhead sprinkler system, which was set to water pots at intervals during the day to ensure that moisture stress did not occur. A complete range of nutrients was applied. The site from which the soil was collected had been managed under a green cane trash blanket system.

Experiment 3

In this experiment soil from adjacent areas at Millaroo, Qld, that had either been under continual cane for more than 20 years or had just completed a 2 year break under pumpkins was either pasteurised or left untreated and planted to sugarcane, maize, sunflower or soybean. Design was a factorial arranged in blocks with two soils (continuous cane and pumpkin break), + or - pasteurisation, four species and three replications.

The procedure for setting up and running this experiment was the same as for Experiment 2. The site from which the soil was collected had always been managed under a burnt cane system.

Measurements

All experiments were terminated at 6 - 7 weeks after planting. At harvest shoots and roots in each pot were removed and separated. Roots were washed free of soil and both were dried in a forced air oven at 70^{0}C for 7 days prior to dry weights being recorded.

RESULTS

Experiment 1

There was no significant effect ($p < 0.05$) of fumigation on any species except sugarcane for shoot dry weight and sugarcane and sorghum for root dry weight (Table 1).

Table 1. Effect of fumigation on the growth of various species in soil collected from a site with a history of long-term sugarcane culture (Experiment 1).

Species	Dry Matter (g/pot)			
	Shoots		Roots	
	Fumigated	Unfumigated	Fumigated	Unfumigated
Tomato	8.44	7.50	2.04	1.82
Lettuce	3.68	4.48	0.58	0.60
Capsicum	2.66	2.84	0.90	1.08
Cabbage	7.14	7.08	1.82	1.52

Sorghum	4.10	3.66	4.28	1.48
Maize	2.78	1.84	0.84	0.76
Barley	4.92	4.18	2.14	2.10
Sugarcane	8.32	3.66	6.92	1.90
Lsd 5%		1.24		0.92

Experiment 2

There were significant ($p<0.001$) soil, pasteurisation, soil x species and pasteurisation x species effects for both shoot (Table 2) and root dry weight (data not presented). The magnitude of the pasteurisation response was similar (60%) in both old and new land. The soil x species interaction reflected significant shoot and root biomass increases on new land for sugarcane, maize and sunflower but no effect on peanuts while the pasteurisation x species interaction reflected increased shoot and root biomass following soil pasteurisation in sugarcane and maize but not in peanut or sunflower. The significantly lower dry matter for sunflower on old land was probably associated with aluminium toxicity (2).

Table 2. Effect of pasteurisation of new and old sugarcane land on shoots dry matter (g/pot) of sugarcane, maize, peanut and sunflower 44 days after planting (Experiment 2).

Soil	Sterilised	Species			
		Sugarcane	Maize	Peanut	Sunflower
New	No	11.37	8.57	5.43	1.37
	Yes	21.10	12.77	6.27	3.17
Old	No	9.03	4.43	5.67	0.93
	Yes	17.70	7.27	6.30	0.90

Lsd 5% - soil x pasteur. x species =2.21

Experiment 3

There were significant ($p<0.05$) soil, pasteurisation, and pasteurisation x species responses in shoot dry matter (Table 3). A soil x pasteurisation effect was significant at $p< 0.10$. For root dry matter (data not presented) there was a pasteurisation effect ($p<0.001$) and a pasteurisation x species effect ($p<0.08$)

The soil pasteurisation x species response reflected an increase in shoot and root biomass of sugarcane following pasteurisation but no effect on the other species. Although only significant at $p < 0.1$ the soil x pasteurisation effect represented an increase in biomass produced by pasteurising pumpkin soil but no effect of pasteurising continual sugarcane soil.

Table 3. Effect of pasteurisation of soil from continual sugarcane or after a two year pumpkin break on the shoot dry matter (g/pot) of sugarcane, maize, soybean and sunflower 44 days after planting (Experiment 3).

Soil	Pasteurised	Species			
		Sugarcane	Maize	Soybean	Sunflower
Pumpkin Break	No	3.97	26.74	13.03	13.08
	Yes	9.50	28.39	13.98	12.20
Continual Cane	No	5.85	27.29	11.03	10.76
	Yes	8.42	25.18	10.51	11.24

Lsd 5% - soil x pasteur..x species = 3.18

DISCUSSION

In all three experiments, shoot and root growth of sugarcane was improved by fumigation/pasteurisation regardless of soil history, although non-cane soils were not tested. In other studies the sugarcane response to fumigation/pasteurisation of virgin land has been variable. However, root systems on untreated virgin rainforest land have always been healthy and any responses to fumigation/pasteurisation are more likely associated with changes in nutritional status than pathogen control (8). Regardless, the results suggest that fumigation/pasteurisation responses in sugarcane are likely to be recorded after only a short period under sugarcane. Further, responses to fumigation/pasteurisation were also recorded in sorghum roots (Experiment 1) and maize tops and roots (Experiment 2). By contrast, none of the dicotyledonous species tested in these experiments responded to fumigation of sugarcane soil, suggesting that the fumigation response was largely due to the control of soil organisms associated with grasses and more specifically sugarcane.

In Experiment 2, the pasteurisation of both old and new sugarcane land resulted in a shoot dry matter increase in sugarcane of around 60 %, although the yield levels were higher on the new land. Thus it could be expected that pasteurisation of continual cane or pumpkin break soil in Experiment 3 would result in dry matter responses of a similar magnitude between the two treatments. However, the response to pasteurisation of the pumpkin break soil (139%) was more than three times that recorded for continual sugarcane soil (44%) (Table 3). Clearly, pasteurisation had a greater influence on sugarcane soil that had a two-year break in pumpkins than soil under continual sugarcane. Magarey *et al.* (8) showed similar trends in the pasteurisation response for soil from this site (47% pumpkin soil, 27% continual cane soil) and noted that root condition in pasteurised pumpkin soil was not as good as in pasteurised sugarcane soil. No firm reasons can be identified for such a response but some possibilities can be suggested.

Other studies on soil collected from the same site as Experiment 3 have shown that under continual sugarcane the soil had extremely low microbial biomass, much lower than the soil for Experiment 2 (6). Further the growing of the pumpkin crop over a two-year period significantly increased microbial biomass. Hence it is possible that the relatively small fumigation response was associated with the very low levels of microbial biomass. Similar small or negative responses are now being recorded to fumigation of soil with very low microbial biomass associated with five years of bare fallow in a highly leached situation on the wet tropical coast (C.E. Pankhurst, B.L. Blair and R.C. Magarey, pers comm.). Alternatively, there may have been some toxin released or a nutrient imbalance developed over the break period, which could have adversely affect the growth of the sugarcane in Experiment 3. In other pot experiments with soil from this site, very poor root development was observed in the pumpkin soil that could not be attributed to any known factor (R.C. Magarey, pers. comm.). However, if a toxin or nutrient imbalance is responsible it is presumably specific to sugarcane as no effects were recorded in the growth of the other

three species (maize, soybean or sunflower). Further, field observations and resultant yields from untreated soils showed no yield difference between continuous sugarcane and pumpkin soils although the latter had better early shoot development (3), a characteristic typical of better pathogen control (1).

CONCLUSIONS

The fumigation of long-term sugarcane soil is only likely to improve the growth of sugarcane and other grasses. There is not likely to be any response in dicotyledons, indicating that non-grass species are more suitable as a rotation crop with sugarcane. The biological factors associated with yield decline appear to develop quite rapidly once sugarcane is introduced to a soil. A small response to fumigation in long-term sugarcane soil does not necessarily indicate a healthy soil that will not benefit from breaking the monoculture.

ACKNOWLEDGMENTS

These studies were conducted as part of the work program of the Sugar Yield Decline Joint Venture. Technical assistance was provided by Linda Toovey and Judy Bull.

REFERENCES

1. Bell, M.J., Garside, A.L., and Magarey, R.C. (2000). *Proc. Aust. Soc. Sugar Cane Technol. ,* **22**, 79 – 86.

2. Garside, A.L., Magarey, R.C., and Nable, R.O. (1995). Growth of different plant species in fumigated/sterilised and untreated sugar cane soil with varying cropping histories. *Proc. Aust. Soc. Sugar Cane Technol. ,* **17**, 123 -127.

3. Garside, A.L. and Nable, R.O. (1996) In: Wilson, J.R., Hogarth, D.M., Campbell, J., and Garside, A.L. (eds), *Sugarcane : Research towards efficient and sustainable production.* CSIRO, Div. Tropical Crops and Pastures, Brisbane.

4. Garside, A.L., Smith, M.A., Chapman, L.S., Hurney, A.P., and Magarey, R.C. (1997). In: Keating, B.A. and Wilson, J.R. (eds). *Intensive sugarcane production : Meeting the challenges beyond 2000,* CAB International, Wallingford, UK.

5. Garside, A.L., Bell, M.J., Cunningham, G., Berthelsen, J., and Halpin, N. (1999). *Proc. Aust. Soc. Sugar Cane Technol. ,* **21**, 69 – 78.

6. Holt, J.A. and Mayer, R.J. (1998). *Biology and Fertility of Soils* **27**: 127 – 131.

7. Magarey, R.C. and Croft, B.J. (1995).. *Proc. Internat. Soc. Sugar Cane Technol.,* **22** (2): 505-513.

8. Magarey, R.C., Bull, J.I., Blair, B.L. and Johnson, E.J. (1997). *Aust. J. Exp. Agric.* **37** : 451 - 457.

9. Pankhurst, C.E., Magarey, R.C., Stirling, G., Holt, J., and Brown, J.D. (1999) *Proc. Aust. Soc. Sugar Cane Technol. ,* **21**, 79 – 86.