Yield responses to breaking the sugarcane monoculture

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ABSTRACT

Yield decline (a loss of productive capacity of long-term sugarcane soils) is a complex issue affecting the viability of current sugarcane farming systems in Australia. It is not clear whether the problem is simply due to a long-term monoculture, the cultural practices associated with that monoculture, or a combination of both. Varying types and duration of breaks (other crops, pastures or bare fallows) and soil fumigation were used to create different soil conditions in five field experiments in coastal Queensland. In all experiments the effect of breaks/rotations was to increase yield of the plant sugarcane crop by from 14 – 84% compared with sugarcane monoculture. The type of break and its duration had some effect on the magnitude of the response, but all breaks had a positive effect on yield at all sites through effects on stalk number and stalk weight. Positive responses continue to be recorded in subsequent ratoon crops.

KEY WORDS

Sugarcane, rotations, soil fumigation, fallow, farming systems.

Introduction

The problem of 'yield decline' (the loss of productive capacity of sugarcane growing soils under long-term monoculture) has been a part of the Australian sugar industry for most of the twentieth century (1, 3). However, the impact of yield decline was not fully considered until the Australian sugar industry recorded a productivity plateau for the twenty-year period from 1970 – 1990 (9). It was assumed that this productivity plateau was largely due to 'yield decline'. Consequently, a number of organisations involved in research and development for the Australian sugar industry established a Joint Venture in 1993 to research the issue. Although subsequent studies (8, 3) have revealed that the phenomenon of 'yield decline' is only a component of the productivity plateau, it does occur and does cause substantial productivity losses.

The Sugarcane Yield Decline Joint Venture (SYDJV) started with the premise that 'yield decline' was a complex issue associated with the long-term monoculture causing a number of factors to be out of balance in the farming system. Further, these factors and their relative importance were likely to vary in response to soil and environment. It was not clear whether the problem was simply one associated with a single species being grown for long periods, the manner in which that species was grown, or a combination of both. However, there was little doubt that root pathogens were involved (6). Further, it seemed likely that soil chemical and physical, as well as other biological properties, were involved. The problem was thus tackled in large-scale experiments where different types of breaks to the monoculture, for different periods of time, were used as research tools.

Materials and Methods

Five experiments were established along the Queensland coast at Tully, Ingham, Burdekin, Mackay and Bundaberg. Details of experimental design and management are described fully in Garside *et al*., (4, 5). Briefly, breaks of other crop, pasture or bare fallow were imposed on long-term sugarcane land for various periods of time. Although break species used at each site did vary, treatments set up three basic soil management histories in all experiments. Those involving *other crops* included at least annual plantings of species such as soybean, peanut, maize and navy bean, and experienced traffic, tillage and plant growth. Pasture treatments were a mixture of signal grass (*Brachiaria decumbens*) and pinto peanut

(*Arachis pintoi*) at all sites except Bundaberg (where grass and legume pastures were planted separately), and experienced plant growth but neither traffic nor tillage after establishment. Bare fallows experienced no traffic, no tillage and no plant growth after establishment, with weeds controlled by herbicides. Break periods varied with site and treatment, ranging from short (9 months) to long (30-42 months). In addition to the breaks, at least two control treatments of continual sugarcane were included at each site in a basic randomised block design with three replications.

All treatments were re-planted to sugarcane (Q124 at Bundaberg and Q117 at all other sites) at the same time, with one of the continual sugarcane treatments fumigated with methyl bromide (1000 kg/ha) just prior to being re-planted. Nitrogen was applied at a common (high) rate across all treatments, while at some sites plots were split for differing N rates.

During the break periods and immediately prior to re-planting of sugarcane, soil chemical, physical and biological properties were monitored. Details of parameters monitored and methodology used are provided in Garside *et al.* (5). In addition, soil was collected from the cultivated layer (top 20cm) of each plot for use in a glasshouse fumigation bioassay. Soil from replicate plots was bulked and sieved, half the soil was air-dried and the remainder was placed under black plastic sheeting and fumigated using methyl bromide at a rate equivalent to 1000 kg/ha. The sheeting was then removed and the soils aired. Clay pots containing 1.4 kg of oven dry soil were used for the study, with 3-5 replicate pots used for each combination of history and fumigation. Pre-germinated setts were sown in each pot and grown for approx. 8 weeks. Shoot biomass production in the short duration bioassay was correlated with early shoot development (field shoot counts) and subsequent biomass production (destructive sampling mid-season and at harvest) in the field.

RESULTS AND DISCUSSION

In all experiments the effect of breaks/rotations was to increase yield of the sugarcane plant crop by 14 – 84% compared with sugarcane monoculture (Table 1). The response to breaks was smallest at Bundaberg, but all breaks were only short duration (9-10 months) in that cycle of the experiment. At Ingham, and to a lesser extent Mackay, there were suggestions of greater responses to cropping breaks as the break duration increased, and this will be quantified for the Bundaberg site in the next crop cycle. Increasing rates of N fertiliser did not overcome the break effects (data not shown).

Table 1. Yields of sugarcane (millable stalk, t/ha) from a cane monoculture, with or without soil fumigation or after various types and duration of breaks at five locations in coastal Queensland.

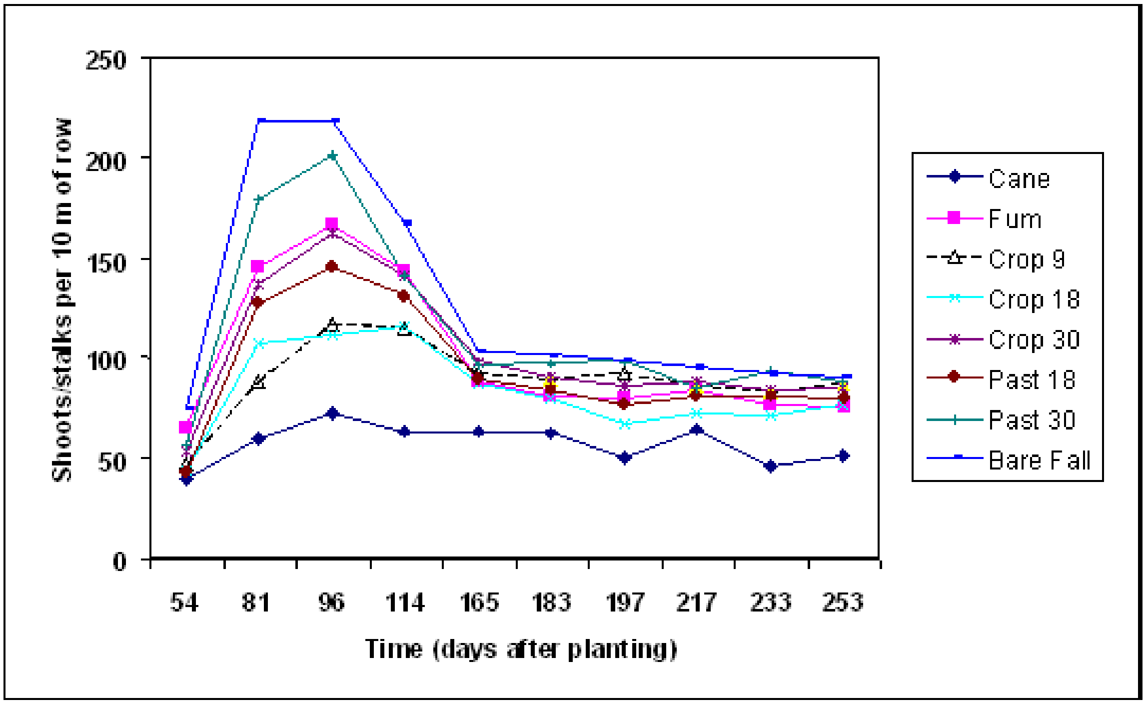
	Bundaberg	Mackay	Burdekin	Ingham	Tully
Continuous cane	107	63	119	38	52
Continuous cane - fumigated	146	104	152	83	86
Other crop – short break	124	88	-	54	-
Other crop – long break	-	92	147	66	73
Pasture – short break	119	-	-	-	-

Pasture – long break	-	103	153	64	78
Bare fallow – short break	120	-	-	-	-
Bare fallow – long break	-	116	154	53	76
lsd (P<0.05)	13	15	12	15	17

Fumigation of continuous cane soil produced significant yield increases at all sites, ranging from 28% in the Burdekin to 118% at Ingham. The magnitude of the fumigation response was not significantly different to that of a number of the longer break treatments, with the exception of the site at Ingham. However, the impact of the various breaks and soil fumigation would have created quite different soil conditions. Pankhurst *et al*. (7) reported that fumigation had greatly reduced soil biotic activity, while pasture breaks had provided better-balanced soil biology. Bare fallows decreased soil biotic activity in general, but reduced those pathogenic on cane greatly, while break crops fell somewhere between continual cane, which had the least balanced biota, and pasture.

The dynamics of yield accumulation at each site were followed by monitoring shoot development and stalk number, while a mid-season destructive sample was used to quantify the relative contributions of early and late season growth to final dry matter production and yield. At all sites, treatment differences were established very early in the life of the sugarcane crop through differential early shoot establishment. Early shoot development generally followed the order of continual cane < short duration crops < long term crops < pasture and bare fallow < fumigation. Further, the duration of the break appeared to have a more important effect on shoot establishment than the break type. For example, the data for Mackay show greater early shoot numbers following 30 month breaks than shorter breaks (Fig. 1). The very large early advantage in shoot numbers for the breaks over continual cane was moderated later in the growing period. However, in all sites except Bundaberg, harvested stalk numbers in the break treatments were still significantly greater following the break and fumigated cane treatments. While stalk number was the greatest contributor to yield variation among treatments (eg. accounting for 64% of the variation in yield in the Burdekin trial), individual stalk weight also contributed significantly. For example, individual stalk weight in the ‘Other Crop’ treatment was 20% higher than in continual cane in the Burdekin study and 11% higher than the continual cane treatment at Bundaberg.

Figure 1. Temporal changes in shoot/stalk number per 10 m of row for variety Q117 planted after different types and duration of breaks, fumigation and continual cane at Mackay. Breaks consisted of bare fallow, pasture and other crops for durations of 9, 18 and 30 months. *Lsd 5% between break types at each sample date = 15 (day 54), 48, 59, 42, 18, 15, 18, 20, 18 and 18 (day 253).*



Dry matter production in cane grown in unfumigated soil in the glasshouse studies was positively correlated to maximum shoot numbers (r = 0.7 – 0.95) in the field studies, and to a lesser extent with dry matter production in the mid-season destructive samples (r = 0.7 – 0.8) at most sites. However, there was no significant relationship between glasshouse growth and final yields or biomass production, and this was consistent with a significant re-ranking of some treatments between mid-season and maturity. The reasons for this re-ranking were unclear, but as a general observation, there was a trend for those treatments that were relatively slow in early growth to grow at a faster rate during the final part of the season, and vice versa. This suggested that there were at least two distinct components to the break/fumigation response - initial shoot development (establishing the basis for an improved yield) and the subsequent capacity to maintain and grow those shoots through to maturity.

Observations of known sugarcane pathogens in the different break soils (7) and the fumigation responses recorded for those soils in the glasshouse suggest that the only break treatment that came close to eliminating detrimental soil biota at all sites was the bare fallow. Fumigation of bare fallow soils produced no increases in cane growth in the glasshouse trials, while fumigation of other break treatments produced growth responses ranging from 15-60% (2). This finding suggests that the yield increases obtained from some of the break treatments (eg. the crop and pasture breaks) were obtained in spite of the presence of detrimental soil biota. Therefore, the magnitude of losses due to the 'yield decline' phenomenon may well be greater than the difference between continual cane and the highest yielding treatments at each site.

Subsequent ratoon performance has been assessed at the Bundaberg, Mackay and Burdekin sites. The Ingham site had to be abandoned due to prolonged waterlogging shortly after harvest of the plant crop, while ratoon yields at the Tully site were adversely affected by stool damage that occurred during mechanical harvesting of the plant crop under very wet conditions. Break and fumigation effects have shown varying degrees of persistence into the ratoons, with persistence of the pasture and other crop treatment effects > bare fallow > fumigation (Table 2). Further, the relative contribution of stalk number and individual stalk weight to yield variation among treatments in the ratoon crops has changed, relative to that in the plant crop. Whereas stalk number was the dominant component of yield variation in the plant crop, individual stalk weight accounts for more of the yield difference between treatments in the ratoon crops (data not shown). Glasshouse bioassays undertaken on 1st ratoon soils have produced results consistent with reduced differences in field shoot establishment, showing no significant break responses and a significant fumigation response in all treatments. As with the plant crop data, it would seem that the ratoon yield responses are occurring in spite of the re-establishment of a population of detrimental soil biota.

Table 2. Ratoon cane yields (millable stalk, t/ha) for the cane monoculture, soil fumigation and selected break treatments at three locations in coastal Queensland. Yields of crop and pasture treatments are means for short and long duration treatments shown in Table 1.

	Bundaberg			Mackay		Burdekin
	1st ratoon	2nd ratoon	3rd ratoon	1st ratoon	2nd ratoon	1st ratoon
Continuous cane	120	103	85	92	77	93
Continuous cane - fumigated	137	113	92	93	85	121
Legume crop	138	125	105	110	92	128
Pasture	121	114	91	106	98	142
Fallow	135	115	93	102	98	133
lsd ($P<0.05$)	18	14	15	14	13	19

CONCLUSIONS

Results have shown that there has been a substantial decline in the productive capacity of soils under sugarcane monoculture, although the magnitude of the yield penalty has yet to be fully quantified. The loss of productivity in plant crops has been due to a reduction in stalk number and reduced stalk weight, while differences in stalk weight play a more important role in ratoon yield variation. Breaks from sugarcane culture and soil fumigation have proved useful tools for studying the ‘yield decline’ phenomenon. Growth differences in response to these treatments were evident very early in the plant crop, although the persistence of these early advantages through to final yield has been variable. A practical outcome of these studies has been the resurgence in interest in grain legume break crops (soybean and peanut) in the sugarcane farming system.

Acknowledgments

These studies were conducted as part of the work program of the Sugarcane Yield Decline Joint Venture. The funding support of SRDC and the field assistance of Mr Luca Pippia and Mr Norm King is acknowledged.

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