Intensity of the production system influences the impact of yield decline in sugarcane

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Abstract

Studies conducted in different cane growing areas of Queensland have shown that yields can be increased by breaking the sugarcane monoculture with other crops, pasture, or bare fallow. The yield increase following a break crop is a result of better crop establishment due largely to improved soil health. However, the magnitude of the yield response to breaks can be substantially influenced by the amount of inputs applied in the management of the cropping system. In high input systems (high radiation, water and fertilizer) the final yield differential between sugarcane following breaks and continual monoculture can be substantially reduced due to the adverse effects of poor soil health being masked. High input systems have a capacity to promote better tillering and stalk survival, thus compensating for poorer establishment. It is argued that with improved soil health the resilience of the system will be increased and the inputs required to produce a particular cane yield could be reduced, thereby reducing the environmental consequences of excessive fertilizer and water use.

Key words

Monoculture, breaks, high input, nitrogen.

Introduction

Yield decline is defined as the loss of productive capacity of sugarcane growing soils under long-term monoculture. Although probably a part of the industry for most of the 20th century (1,2) its impact was not fully considered until a productivity plateau was recorded between 1970 and 1990. It was thought that this plateau was largely due to the intensification of the monoculture brought about by the removal of assignment restrictions (3), which promoted the adoption of a plough-out/re-plant (PO/RP) system at the expense of fallowing.

In order to quantify the effect of the long-term monoculture, rotation experiments were established in the Tully, Ingham, Burdekin (based on Ayr), Mackay and Bundaberg sugarcane growing areas of coastal Queensland. These sites covered a diverse range of soils, environment, and cultural practices. Regardless, in all experiments, yields were increased by breaking the monoculture, with other crops, pasture or bare fallow (4,5). Fumigation of continual sugarcane land with methyl bromide produced a similar response to the breaks (4,5). The basis of the yield response to breaks was better crop establishment and improved early growth, which was related to a better balanced soil biota (6,7). However, large early differences in crop establishment and growth were not necessarily reflected in final yield. The response in final yield varied between sites, ranging from 8 to 65% (8) with the smallest differentials being recorded for fully irrigated experiments in Bundaberg and Burdekin. In this paper the impact on growth and yield of the level of management applied to the Burdekin rotation experiment is discussed.

Materials and methods

Experiment details and management

The experiment was established on long-term sugarcane land (> 20 years cane with minimal fallow) in November 1994. Three break treatments (other crops, pasture, bare fallow) and continual sugarcane or plough-out/re-plant (PO/RP) and three replications were included in a randomized block design. Plot size was 12 m x 38 m, which accommodated 8 (1.5 m) rows of sugarcane. Break treatments were left in place until June 1998 (42 months). The other crops (soybean, peanuts) were planted alternately, initially on a six monthly basis and later on an annual basis, after conventional land preparation. The pasture, which was managed by regular slashing, consisted of a mixture of signal grass (Brachiaria decumbens) and pinto peanut (Arachis pintoi) planted into conventionally prepared land. Signal grass was dominant in the pasture mix. The bare fallow was initially established through conventional land preparation and thereafter was maintained with regular sprayings of herbicide. All breaks were flood irrigated on a regular basis. More detail is provided in (5).

When returning to sugarcane, land preparation, consisting of offset discing and ripping commenced on July 24, 1998. All plots were then soil sampled on August 18 at 10 cm intervals to 40 cm and then at 20 cm intervals to 100 cm. These samples were used to measure pre-plant mineral nitrogen levels. Sugarcane variety Q117 was planted with a whole stick planter on August 21, 1998 and immediately irrigated.

On September 14, 24 days after planting (DAP), superphosphate was drilled beside the setts in all plots at 106 kg/ha, to counter a possible sulfur deficiency. At the same time all plots were split into four, each 4 cane rows x 19m, for the application of four fertilizer nitrogen treatments. The nitrogen treatments were nil, nil at 24 DAP and 180 kg/ha at 90 DAP, 50 kg/ha at 24 DAP and nil at 90 DAP, and 50 at 24 DAP and 130 kg/ha at 90 DAP. The 24 DAP application is hereafter referred to as a basal application. All nitrogen was hand applied as urea and immediately incorporated with inter-row cultivation. Irrigation was scheduled, after approximately every 90 mm of cumulative pan evaporation, for the growing period of 374 days.

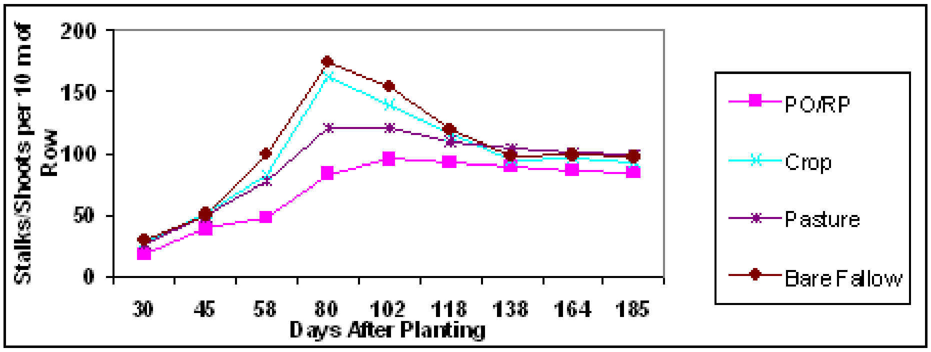
Measurements and Data Collection

Shoot development was monitored 30, 45, 58, 80, 102, 118, 138, 164, and 185 DAP by counting the number of shoots in a permanently marked 10 m of row in each plot. Although specific counts on primary, secondary and higher order tillers were not recorded, differences in shoot types were readily observable at different measurement times. Cane yield was measured by hand harvesting 2 rows x 5 m from each plot.

Results and discussion

Shoot/stalk numbers responded strongly to the breaks, with all breaks producing more than PO/RP (Figure 1). Differences were apparent early in crop growth, reached a peak at around 80 – 100 DAP and then declined. When sampling ceased (185 DAP) all break treatments had similar stalk numbers and more than PO/RP. These differences were maintained through until crop harvest (374 DAP).

Figure 1. Sequential shoot/stalk numbers per 10m of row after planting sugarcane into crop, pasture and bare fallow breaks and PO/RP (lsd 5% = 7, 6, 10, 27, 18, 19, 9, 11, 12 for samples taken from 30 to 185 DAP).



Nitrogen effects were also measured and were generally more important later in the growing period. However, at no stage was there a break x nitrogen interaction. Given that side-dress nitrogen was applied 90 DAP, shoot/stalk development was considered both prior to and after 90 DAP. Differences in mineral N between the different breaks were recorded at planting with relatively high levels following the crop and bare fallow breaks and low levels following pasture and PO/RP (data not presented – see (5)). These differences, in addition to either 0 or 50 kg/ha N being applied 24 DAP, would have established a diversity in the amount of nitrogen available to different treatments. However, there was no significant nitrogen effect on shoot numbers for the first three sampling (30, 45 and 58 DAP) for any of the breaks (Table 1).

Table 1. Shoot numbers per 10 m of row 58 and 80 days after planting sugarcane into crop, pasture and bare fallow breaks and PO/RP.

Break Type	Nitrogen Rate (kg/ha)			
	0		50	
	58 DAP	80 DAP	58 DAP	80 DAP
PO/RP	42	67	51	99
Crop	75	165	92	168
Pasture	77	106	78	132
Bare Fallow	95	178	106	174

Lsd 5% = 20 (58 DAP),32(80 DAP).

Between 58 and 80 DAP shoot numbers increased substantially in all histories (Table 1). This period co-incided with the rapid development of secondary and higher order tillers. In most treatments the increase in shoot numbers was between 70 – 100%. However, following PO/RP and the pasture break, the increase was only substantial in the presence of basal nitrogen, whereas following the crop and bare fallow breaks it occurred regardless of basal nitrogen. These results therefore suggest that N supply had virtually no effect on primary shoot development, but was critical for the development of higher order tillers.

Table 2. Shoot/stalk numbers per 10 m of row 102 and 185 DAP following the application of different rates of nitrogen fertilizer on 24 and 90 DAP to cane following crop, pasture and bare fallow breaks and PO/RP.

Break Type	DAP	Nitrogen Rate			
		0	50	50 + 130	0 + 180
PO/RP	102	78	102	114	88
	185	71	79	98	89
Crop	102	137	126	142	154
	185	89	86	94	104
Pasture	102	101	123	138	122
	185	81	97	106	112
Bare Fallow	102	164	144	162	147
	185	93	87	105	104

Lsd 5% = 25 (102 DAP), 16 (185 DAP).

Table 3. Effect of nitrogen rate on cane yield (t/ha) following breaks and PO/RP in the Burdekin rotation experiment.

N rate (kg/ha)	PO/RP Yield (t/ha)	Breaks Mean Yield (t/ha)	% Yield increase following Breaks
0	98	141	43
50	112	152	42
0 + 180	132	158	20
50 + 130	136	154	13

The side-dress application of N coincided with a general mortality of shoots that commenced around 100 DAP in all the rotation experiments (4,5) (Figure 1). This mortality was associated with the commencement of stalk development. The application of higher side-dress N rates did, to some extent, arrest the loss of shoots (Table 2) which ultimately resulted in the potential yield differential between breaks and PO/RP being substantially reduced (Table 3).

Conclusions

In all of the rotation experiments, breaks to the monoculture have resulted in improved crop establishment and early crop growth. In three of these experiments, these differences in stalk numbers have been maintained and have resulted in large yield differences between PO/RP and rotation breaks. Similar early growth differences were measured in this experiment. However, to a large extent the ultimate impact on crop yield was strongly moderated by the application of nitrogen and full irrigation. Even higher nitrogen rates to those used in this study may well have seen the 13% yield response in favour of the breaks (Table 3) disappear. In other irrigated studies in the Burdekin, Muchow et al. (9) only measured a 6% yield increase following fumigation when 270 kg/ha N was applied in three applications, while Garside and Nable (10) recorded no yield difference between PO/RP cane and cane grown after a two year (heavily fertilized) pumpkin break, despite large differences in early shoot numbers.

The general conclusion to emerge following this and other studies (4,5) is that early shoot development is always enhanced following breaks, regardless of soil, environment and management, due largely to the reduction in adverse biotic factors associated with PO/RP (6,7). However, intensive management and suitable environmental conditions can result in compensation for these early differences, largely through enhanced tillering. The Burdekin area has sufficient irrigation water and relatively high year round radiation (average 20 MJ/m^2/day). Thus, the adverse effects of poor soil health can be masked by high input farming practices. However, many cane growing areas do not have the capacity to provide optimum growing conditions. It is in these lower input environments that the adverse effects of the long-term monoculture are likely to be most pronounced. Further, improvements in soil health through breaking the monoculture may well permit yields to be maintained with lower inputs, particularly of nitrogen and irrigation water, thus allaying environmental concerns associated with excessive irrigation and fertilizer use.

References

(1) Bell, A.F. 1935. Proc. Qld. Soc. Sugar Cane Technol. 6: 9-18.

(2) Garside, A.L., Smith, M.A., Chapman, L.S., Hurney, A.P. and Magarey, R.C. 1997. Intensive sugarcane production: Meeting the challenges beyond 2000, p103-124. CAB International, Wallingford, UK.

(3) Wegener, M.K. 1985. J. Aust. Inst. of Agric. Sci. 51: 29-41.

(4) Garside, A.L., Bell, M.J., Cunningham, G., Berthelsen, J. and Halpin, N. 1999. Proc. Aust. Soc. Sugar Cane Technol., 22: 69-78.

(5) Garside, A.L., Bell, M.J., Berthelsen, J.E. and Halpin, N.V. 2000. Proc. Aust. Soc. Sugar Cane Technol., 23: 61-67.

(6) Pankhurst, C.E., Magarey, R.C., Stirling, G., Holt, J. and Brown, J.D. 1999. Proc. Aust. Soc. Sugar Cane TechnoL., 22: 79-86.

(7) Bell, M.J., Garside, A.L. and Magarey, R.C. 2000. Proc. Aust. Soc. Sugar Cane Technol., 23: 68-76.

(8) Garside, A.L., Bell, M.J. and Magarey R.C. 2001. Proc. Int. Soc. Sugar Cane Technol., 24: 16-21.

(9) Muchow, R.C., Robertson, M.J., Wood, A.W. and Spillman, M.F. 1994. Proc. Aust. Soc. of Sugar Cane Technol., 17: 187-192.

(10) Garside, A.L. and Nable, R.O. 1996. Sugarcane: research towards efficient and sustainable production. CSIRO, Div. Tropical Crops and Pastures, Brisbane.