

EFFECT OF FALLOW HISTORY ON CANE AND SUGAR YIELD OF A FOLLOWING PLANT CANE CROP

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Abstract

An experiment was conducted at the Yield Decline Joint Venture sub-station at Feluga, near Tully, into the effects of various fallow treatments in the 1994/95 summer on sugarcane planted in September 1995. Superimposed on the fallow treatments were either 0 or 140 kg/ha nitrogen. Fallows included bare, farmer fallow (cowpea broadcast), continual cane, and mungbean, cowpea, peanuts and soybeans grown on ridges and sprayed with pre-emergent herbicide. Following soybeans, which contributed the most nitrogen (over 300 kg/ha) to the soil of all the fallows, the cane and sugar yield was as good with no added fertiliser nitrogen as it was with 140 kg/ha N. All other fallows responded to applied nitrogen but the magnitude of the response was inversely related to the amount of nitrogen returned to the soil from the previous fallow. The largest responses to fertiliser N were recorded following bare fallow and farmer fallow. The results indicate that following a well grown fallow crop of soybeans, there is no need to apply nitrogen fertiliser to plant cane, thus saving considerable production costs. The effects on the first ratoon are currently being followed. The results are discussed in terms of crop management, the potential for utilising fallow legumes as a nitrogen source and the implications for sugarcane yield decline.

Introduction

The Sugar Yield Decline Joint Venture was established in 1993 to research the causes of a productivity plateau (sugar yield/harvested hectare) that existed in the Australian sugar industry for the 20-year period 1970–1990 (SRDC, 1995). When the joint venture was established the organisations involved believed the main causes of the productivity plateau were soil related factors that were the result of the long term monoculture. However, more contemporary analyses indicate that other factors associated with changes to the farming system, viz. the advent of chopper harvesters, more ratoons, more plough out/re-plant have substantially contributed to the productivity plateau (Leslie and Wilson, 1996; Garside *et al.*, 1997). Regardless, there is considerable evidence to suggest that soil health factors associated with the monoculture are adversely affecting sugarcane yield and have been for much of this century (Maxwell, 1900; Bell, 1938). Prior to the 1970–1990 yield plateau, it appears that varietal and technological advances had been substantial enough to outweigh yield losses associated with soil health (Garside *et al.*, 1997).

Studies into the adverse effects of continual sugarcane have generally shown yield responses: to fumigation of the order of 20% (Bell, 1935; Egan *et al.*, 1984;

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Muchow *et al.*, 1994; Magarey and Croft, 1995; Garside *et al.*, 1995); on new land compared with old land (Anon., 1935; Garside and Nable, 1996); and following breaking of the monoculture with rotation species (Beiske, 1965; Chinloy and Hogg, 1968). A major thrust of the joint venture program involves identifying differences in soil properties that might be contributing to yield differences when the monoculture is broken with rotation species.

Legumes appear to be ideally suited as rotation species in a sugarcane system, as they can grow equally well on both old and new sugarcane land and do not respond to the fumigation of old sugarcane land (Garside *et al.*, 1995). They have traditionally been grown over the summer fallow period between plough out of late ratoons and re-establishing a plant crop in the following autumn. However, the suitability of different legume species and their management has never been seriously considered. In fact, most fallow legume crops, particularly on the wet coast, are of a very poor standard and suffer from waterlogging, root diseases and weed infestation (Garside *et al.*, 1996)

In establishing rotation experiments within the joint venture, it was decided that the rotation species should be grown with the best possible agronomy to maximise the benefits they might provide. Initial results from some of this work in terms of legume growth and nitrogen input were reported in a paper to the 1996 ASSCT conference (Garside *et al.*, 1996). In this paper, the effects on a subsequent plant cane crop are reported.

Materials and methods

The experiment was carried out at the Yield Decline Joint Venture sub-station at Feluga near Tully on a granite gravel soil of the Thorp series (Murtha, 1986). Sugarcane variety Q138 was planted on September 26, 1995 into plots that had carried one of seven different management/species treatments during the previous 1994/95 wet season. There were four replications of a randomised block design. Each plot was split to two rates of nitrogen fertiliser — 0 or 140 kg/ha N applied as urea. Of the 140 kg/ha N, 40 kg/ha was applied at planting and the remainder when the crop was filled in on November 27. Plot size was four cane rows, 1.5 m apart, by 10 m.

The seven management/species treatments or histories have been described by Garside *et al.* (1996). Briefly, the site had been in long term sugarcane until August 1994 when preparations for the summer fallows commenced after the cane harvest. The seven treatments were continual sugarcane, bare fallow, farmer fallow, RM1 mungbean, cowpea, peanut and soybean. Continual sugarcane consisted of leaving the previous cane growing in these plots over the summer but managing cane growth by regular slashing and leaving the leaf material on the soil surface. In all other treatments, the cane was removed by several workings between August and November 1994. Bare fallow was maintained plant free by regular sprayings with glyphosate (Roundup[®]) during the summer fallow period. Farmer fallow consisted of cowpea broadcast onto a flat soil surface and incorporated by discing, a traditional practice for establishing legume fallows. The other four treatments, RM1 mungbean, cowpea, peanut, and soybean were grown on 0.75 m ridges and sprayed with a pre-emergent herbicide, metalachlor (Dual[®]) at 2.5 L/ha of product.

Sugarcane was hand-harvested on July 8 and 9, 1996 at less than 10 months of age. The early harvest was necessitated to avoid some plots lodging and confounding the biological yield. Harvest area was the centre two rows × 5 m in each plot. Stalk numbers and the fresh weight of the complete sample were recorded. Ten stalks were then randomly selected and divided into stalk, cabbage (defined as that

part of the plant above the fifth visible dewlap), and non-senesced leaf. The 10 stalks were further divided into two samples consisting of six and four stalks, and fresh weight of each was determined. The cabbage and leaf were dried in a forced air oven at 70 °C to constant weight. The larger stalk sample was used for CCS determination while the smaller sample was ground, subsampled, weighed, and dried at 70 °C until no further weight loss was recorded. As grinding of the smaller sample usually took place up to two days after harvest, care was taken to re-weigh the stalks immediately prior to grinding to account for any water loss that may have occurred in the interim period. These data were used to calculate crop biomass. Dried samples of cabbage, leaf, and stalk from all plots were finely ground and analysed for tissue nitrogen content. These data were used to calculate the nitrogen removed by the crop in the different treatments.

Meteorological data were recorded on an automatic weather station located at the site.

Results and discussion

Nitrogen contribution from fallows

Data for dry matter and nitrogen contents of the fallow treatments were reported by Garside *et al.* (1996). Briefly, these contributions were: farmer fallow — 50 kg/ha, peanuts — 80 kg/ha, RM1 mungbean — 84 kg/ha, cowpeas — 140 kg/ha, and soybean — 310 kg/ha. The 80 kg/ha quoted for peanut here conflicts with the 170 kg/ha quoted in Garside *et al.* (1996). The latter figure represents what would have been returned had the whole crop been incorporated. However, the peanuts were harvested for seed and this removed some 90 kg/ha of the nitrogen, leaving a return to the soil in crop residue of 80 kg/ha.

Seasonal conditions

Seasonal conditions between planting and harvesting of the sugarcane crop were drier than the long term average. Between September 26, 1995 and July 8, 1996 a total of 3082 mm of rainfall was recorded at the experiment site. The long term mean (68 years) for October to June inclusive at Tully is 3774 mm (Tully Sugar Ltd data).

Cane and sugar yield

There were significant ($p < 0.05$) history, nitrogen, and history \times nitrogen effects for cane yield (Table I, Figure 1), and nitrogen and history \times nitrogen effects for sugar yield (Table II, Figure 2). There was no overall history effect on sugar yield except that cane after soybean significantly ($p < 0.05$) outyielded cane following bare fallow.

TABLE I—Cane Yield (t/ha) following seven different fallow histories fertilised with 0 or 140 kg/ha N. Fallow history and nitrogen rate means.

Fallow history	Yield t/ha	N rate (kg/ha)	Yield (t/ha)
Cane	88	0 kg/ha N	81
Bare fallow	74	140 kg/ha	98
Farmer fallow	85	LSD 5%	4.3
Cowpea	95		
Mungbean	93		
Peanut	89		
Soybean	102		
LSD 5%	11.8		

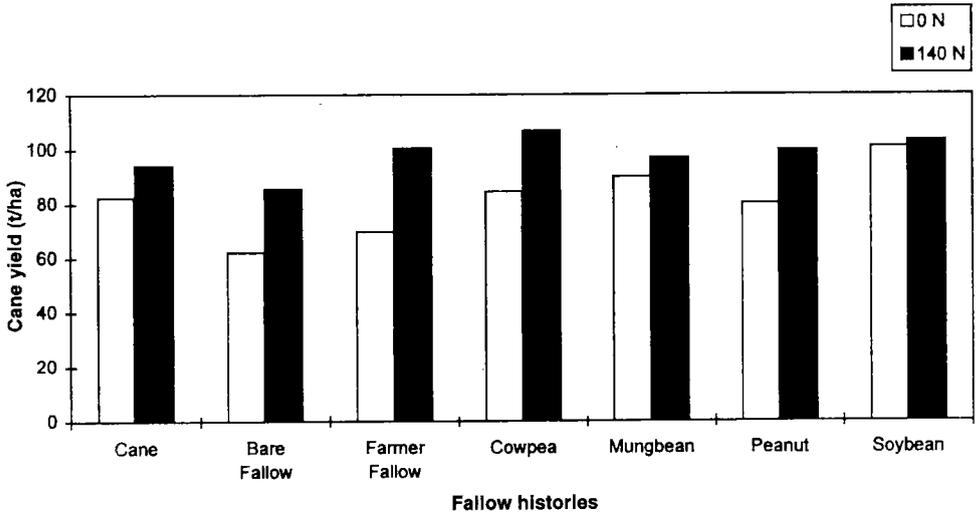


Fig. 1—Cane yield (t/ha) following seven different fallow histories fertilised with either 0 or 140 kg/ha N (LSD 5% = 11.4 for histories × nitrogen).

TABLE II—Sugar yield (t/ha) following seven different fallow histories fertilised with 0 or 140 kg/ha N. Fallow history and nitrogen rate means.

Fallow history	Yield (t/ha)	N rate (kg/ha)	Yield (t/ha)
Cane	9.81	0 kg/ha N	9.31
Bare Fallow	9.31	140 kg/ha	11.02
Farmer Fallow	9.90	LSD 5%	0.61
Cowpea	10.58		
Mungbean	9.99		
Peanut	10.20		
Soybean	11.37		
LSD 5%	1.91		

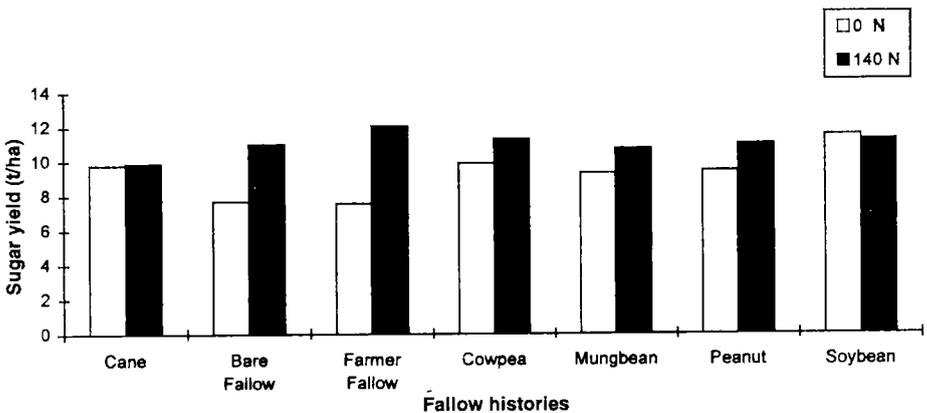


Fig. 2—Sugar yield (t/ha) following seven different fallow histories and fertilised with either 0 or 140 kg/ha N (LSD 5% = 1.62 Histories**Nitrogen*).

In the absence of applied nitrogen, cane and sugar yield tended to increase commensurate with the amount of nitrogen contributed to the system by the previous fallow treatment. For example, without fertiliser nitrogen, the lowest cane yield (62 t/ha) was recorded following the bare fallow and the highest (100 t/ha) following

soybeans. Other treatments provided intermediate yields. Further, the significant response to applied nitrogen was mainly due to large responses in treatments where the fallow contribution was small. For example, in both the bare and farmer fallows the response to applied nitrogen was of the order of 40%, whereas it was 24% following peanuts, and nil following soybean. The latter was responsible for the significant history \times nitrogen interaction.

The large difference between treatments in cane yield (38% greater for soybean than bare fallow) was not as pronounced for sugar yield, cane after soybeans producing only 18% more than cane after bare fallow. The smaller difference in sugar yield was largely associated with increased CCS in the bare fallow treatment. Nonetheless, in terms of overall productivity the higher CCS recorded for the bare fallow had little real impact on productivity trends and may reflect a concentration of sucrose when crop growth is limited.

Biomass production and tissue nitrogen concentration

Total biomass at harvest (285 days after planting) ranged from 23.5 t/ha following bare fallow to 30 t/ha following soybean with significant ($p < 0.05$) nitrogen and nitrogen \times history effects. Tissue nitrogen concentrations at harvest were unaffected by treatment except for a small response to applied nitrogen in stalk nitrogen concentration. However, levels in both stalk (0.00265 g/g) and combined leaf and cabbage (0.00945 g/g) were similar to those recorded by Wood *et al.* (1996 and pers. comm.) in the Herbert district. They studied a plant crop of the same variety (Q138) at the same time after planting (286 days) under luxurious nitrogen conditions (323 kg/ha N) and producing some 58 t/ha of biomass. The clear indication is that at harvest, nitrogen was not limiting in the current crop. However, the treatment responses in this study indicate that nitrogen availability earlier in the growing period probably varied between treatments and was limiting in many, viz. bare fallow, farmer fallow. Unfortunately, nitrogen concentration data are not available for earlier stages of growth. Hence the results from this study tend to support the general pattern that early nitrogen accumulation is important in yield determination (Borden, 1948; Wood, 1968; Haslam and Allison, 1985; Ng Kee Kwong and DeVill, 1994), and that yield differences recorded here were probably associated with varying nitrogen availability earlier in crop growth.

In this study, similar biomass production of around 30 t/ha was obtained for the most heavily fertilised treatment, soybean plus 140 kg/ha N (450 kg/ha, with 310 kg/ha from soybean residue), and for farmer fallow with 140 kg/ha (190 kg/ha, with 50 kg/ha from farmer fallow residue). Associated studies at this site show that legume nitrogen becomes readily available for plant cane use within 3–4 months of incorporation (A.D. Noble, pers. comm.). Biomass production in this experiment was similar for vastly different amounts of available nitrogen suggesting that factors other than nitrogen were limiting yield. Further, the 30 t/ha biomass produced here from a heavy nitrogen regime is little more than half that recorded for the Herbert study discussed above viz. 30 vs 58 t/ha (Robertson *et al.*, 1996). Although valid comparisons can not be made between the two studies, a major difference between the two sites was the amount of incoming solar radiation. For a 285-day period, Robertson *et al.* (1996) recorded 5646 MJ m⁻² while in the current study only 4663 MJ m⁻² were recorded. Radiation may have been responsible for the yield difference.

Influence on monoculture yield decline

All treatments with the exception of cane after cane can be deemed to have provided a break from the continual monoculture. As there was no significant difference ($p < 0.1$) in sugar yield between the fallow treatments when 140 kg/ha N was applied, and most were significantly superior ($p < 0.1$) to cane after cane with

140 kg/ha N, the mean of the fertilised fallow treatments (11.2 t/ha) compared with fertilised cane after cane (9.9 t/ha) provides an estimate of the effect of sugarcane monoculture on sugar yield, viz. 1.3 t/ha. In fact, the difference here may be an underestimate compared with a plough out/replant as the cane after cane treatment did experience a break in this experiment, being ploughed out on May 29, four months before cane was planted across the experiment.

Influence of fallow management

The results of this experiment demonstrate that there are advantages in having ground cover during the wet season fallow period. Further, there are additional advantages in having that ground cover as a well managed legume fallow with the most suitable species for the particular situation. Without additional nitrogen fertiliser, bare fallow produced the lowest cane and sugar yields closely followed by farmer fallow. When cowpea was managed on ridges with weed control, cane and sugar yields increased by 14 (70 to 84 t/ha) and 2.1 (7.76 to 9.86) t/ha compared with the farmer fallow. A further yield increase of 16 and 1.64 t/ha of cane and sugar, respectively, could be attributed to replacing cowpea with soybean.

Practical implications

For practical purposes the most important comparison is that between farmer fallow and soybean without added nitrogen fertiliser. The difference in sugar yield between these two treatments was 3.74 t/ha (11.5 vs 7.76 t/ha) worth \$1160/ha at \$310/t of sugar.

The results also show that for a relatively small input in nitrogen fertiliser (140 kg/ha) early in the growth of the crop, the differential between the two treatments is removed. Hence the important direct comparison is the cost of nitrogen fertiliser vs the cost of herbicide and planting on ridges for the fallow crop. Nitrogen applied at 140 kg/ha as urea would cost around \$110 (300 kg urea at \$357/t) compared with the herbicide Dual^R at around \$50/ha (2.5 l/ha at \$20/l), and there are other potential herbicides that are cheaper. When herbicide application is taken into account another \$10/ha would need to be included. Further, depending on soil conditions, it may be necessary for an additional cultivation with the soybean option to provide a satisfactory tilth for ridge forming. Therefore, on a direct cost basis, some \$50/ha could be saved using the soybean fallow option as opposed to the traditional fallow option with 140 kg/ha nitrogen fertiliser. However, this saving would be discounted by the number of cultivations required to produce a satisfactory tilth.

The capital cost of a planter and ridge former must also be budgeted against the soybean option. A new four-row crop planter incorporating a ridge former should be able to be purchased/built for some \$6000 and with reasonable maintenance such a unit should last a minimum of 20 years. Second-hand units are considerably cheaper. Hence, although a capital outlay, it represents a relatively small amount on a hectare per year basis. Overall, there would appear to be little disadvantage in terms of annual costs in adopting the soybean option. However, farmer perspective will determine if the more rigorous management input in growing soybean is worth accommodating.

There are other possible opportunities that a well grown soybean crop presents. First, it can have a positive effect on yield decline, estimated at around 12% from this study. Second, there is the possibility that the lack of response to nitrogen in the plant crop following soybeans may partly carry over to subsequent ratoon crops. More than 300 kg/ha was contributed by the soybeans and the data suggests that only 68 kg/ha N was removed in the stalks, the tops being returned. The experiment is being continued to measure this effect in 1997. Third, there is the potential to manage the soybean crop to regulate the release of nitrogen to periods when the

sugarcane crop most requires it. In this context, slashing the soybean crop without incorporation or simply allowing it to senesce and decompose in conjunction with a zero or minimum tillage strategy for establishing sugarcane (M.V. Braunack, pers. comm.) may have considerable potential. Finally, the use of soybean and other legumes as annual companion crops in ratoon sugarcane may be a means by which annual nitrogen inputs and positive effects on yield decline may be accomplished. All of these strategies require further investigation.

The combination of these results and those presented for the legume growth and nitrogen accumulation at the 1996 ASSCT conference (Garside *et al.*, 1996) clearly indicate that the potential exists to exploit legumes in the sugarcane farming system considerably more than has been done in the past. Apart from the direct nitrogen effects, there is the possibility that more subtle, indirect and long term positive effects on soil health will result.

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