SUCCESSFUL INTERCROPPING OF SUGARCANE

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Abstract

A five year Joint Project between SASEX and the KwaZulu-Natal Department of Agriculture and Environmental Affairs was initiated in 1996, aimed at improving the crop production capabilities of small scale cane growers. As part of this Project, research trials were conducted to investigate the economics and practicalities of intercropping cane with food crops. Results from the first two years of trials were presented in 1999, showing that the most suitable food crops for this purpose were maize harvested for green mealies, and cabbages. This paper discusses the findings from nine subsequent field trials conducted at five sites, ranging from the coastal plain to inland areas, which researched crop interactions in both plant and first ratoon cane. Maize, cabbage and sweet potatoes were shown to be the most suitable food crops at all sites. All intercrops resulted in a reduction in cane yield, even where the cane was harvested 24 months after planting. In the trials where other factors were not limiting, the productivity of each individual food crop plant was greater in the cane interrows than when grown as a sole crop, in particular for maize and cabbages. Thus, small scale cane growers wishing to produce additional crops for food security or income while waiting for their cane to mature, would benefit by planting such crops in plant cane interrows rather than cultivating them on a separate piece of land. Two complex trials conducted at Bruyns Hill demonstrated how the time and method of planting the intercrops can be manipulated to reduce the deleterious competitive effects of the food crops on cane yields.

Keywords: sugarcane, intercropping, sweet potato, cabbage, maize, small scale growers, SSG

Introduction

Joint Project

In 1996, a Joint Project between the South African Sugar Association Experiment Station (SASEX) and the KwaZulu-Natal Department of Agriculture and Environmental Affairs (KZNDAEA) was started with the aim of improving the crop production capabilities of small scale cane growers in the Province. At that time, it was estimated that a total of 52 000 small scale cane growers were producing cane in KwaZulu-Natal. It was normal for their average cane yields per hectare to be well below those of the commercial cane farmers, and with limited land area and resources their continued viability was under threat. Small scale producers often need to plant all of their land to cane alone to fulfill their responsibilities to the mill, and then suffer from a severe lack of cash income while waiting for their cane to mature. Many such farmers are forced to seek paid employment elsewhere, where they are then unavailable to actively participate in the care and cultivation of their crop.

The Joint Project co-ordinated a strong extension effort to guarantee that these small scale growers had frequent access to the latest technological and agronomic information being developed at SASEX. In addition to this extension effort, a comprehensive series of research trials was initiated to investigate the potential for these growers to produce food crops in the interrow spaces between their cane lines. It was anticipated that successful intercropping would allow the small scale growers to produce food crops for consumption and for sale in the rural areas, which would considerably improve their cash flow situation, and might encourage some of them back into full-time farming.

Intercropping systems

An intercropping system is one where two or more crops share the same piece of land for part, or for all, of their growing season. In many developing countries, more than half of the rainfed crops are normally intercropped. Long experience has taught the small scale African farmer with access to a restricted area of land, that intercropping provides a far more varied diet for the family than a single crop would. The system usually ensures that at least one crop will survive climatic problems to maturity, and it allows for a better distribution of labour requirements through the growing season (Willey, 1979). For many years, expatriate agriculturalists in the tropics tried hard to dissuade farmers from intercropping, as it was considered a backward and unproductive system which would not lend itself to mechanisation. As a result, most of the crop breeding done in developing countries has produced high-yielding varieties most suitable for sole cropping situations. In the last quarter of the twentieth century, agronomists and researchers started to realise that intercropping can often achieve a higher productivity per unit area of land than systems where each crop is grown alone, and that this system allows for a greater diversity of food production for consumption and for sale (Temple, 1976). Most developing countries began research to determine how intercropping systems could be made even more productive (Kass, 1978).

Intercropping sugarcane

Sugarcane offers a unique potential for intercropping. To ensure the optimum productivity in an intercropping system, one must ensure that the peak periods of growth of the two crops do not coincide, so that one quick-maturing crop completes its life cycle before the main period of growth of the other crop starts (Saxena, 1972). Cane is planted in wide rows, and takes several months to canopy, during which time the soil, solar energy and much of the rainfall between the rows goes to waste. Any interrow crop must therefore mature and be harvested within 90-120 days before the cane canopies. Limitations are likely to be interspecies competition between the cane and the intercrops for nutrients and water, as identified by Govinden and Arnason (1990), who stated that cane intercropping systems can only overcome the problem of reduced cane yields by ensuring adequate irrigation of both crops. Many countries where cane is produced by small scale producers have investigated intercropping of cane as a means to improve home food security, with the largest output of scientific research papers originating from India, where almost 100 different crops have been tested for their suitability as cane intercrops (Singh and Chaudhary, 1996; Garcha *et al.,* 1997; Sharma *et al.,* 1997; Gulati *et al.,* 1998; Shukla and Pandey 1999; Rathore *et al.,* 1999). The two countries where intercropping of cane is practised widely on a commercial scale are India and Mauritius.

Cane intercropping research

Mauritius has a large population for its land area, yet almost 90% of its arable area is devoted to sugarcane, leaving no new land available for the production of food crops. Mauritius started investigating the economics of intercropping cane over 50 years ago (Rouillard, 1956), but the main research was led by Govinden *et al.* (1984), whose team is still producing research results today (Cadersa *et al.,* 2001).

By 1990, over half the Mauritian groundnut, maize and potato crops were being produced commercially between rows of sugarcane (Govinden, 1990). The Mauritian researchers had found intercropping of cane so suitable a system that the author decided to trial their recommendations under KwaZulu-Natal conditions. At the start of the Joint Project, only one piece of research on the potential for intercropping cane had previously been published in South Africa (Leclezio *et al.,* 1985). These researchers had tested the suitability of dry beans as an intercrop, but their results were somewhat inconclusive due to drought.

Methods and materials

Trial design

All trials planted in the five-year project followed the same pattern: a split plot design, with the food crop as the main treatment and the sugarcane occupying half of each main treatment plot, enabling a direct comparison between the yields of the intercrop system and the sole food crop. The plots were randomised in blocks, with four replicates of all treatments. All cane was planted at 1.2 m between rows, with gross plots of 6 rows x 8 m, and net plots of 4 rows x 6 m. In all the trials, the intercrops were planted in a single row down the centre of the cane interrow. The row spacing of the sole treatment food crops were planted according to KZNDAEA recommendations, with the net plots never smaller than 4 rows x 6 metres.

Cabbages were purchased as speedlings from a reputable nursery and transported to each site in the speedling trays. For the first week following planting, the young cabbages were watered daily by hand with watering cans, and were then left to survive on their own. Sweet potatoes were planted as cuttings 30 cm long, and were similarly irrigated only for the first week in the ground. All other crops were planted from seed purchased from reputable seed merchants.

At all sites, the soils were analysed before the trials, and the cane and all food crops individually received full applications of the planting and top-dressing fertilisers recommended. No cane herbicides were used in any of the trials because of their toxicity to all food crops, but recommended rates of herbicides, fungicides and pesticides were applied as required to the food crops, both in the sole and intercropped systems.

The food crop data was analysed by the biometricians at Cedara (KZNDAEA) by multivariate analysis of variance using Genstat, and the cane data was analysed by the biometricians at SASEX. Economic data used in the results tables for the production costs and market values of food crops was obtained from Combud (KZNDAEA), from local markets, and from KZNDAEA (personal communication[1]), and the production costs and sucrose values for cane were derived from the small scale grower surveys (personal communication[2]).

Initial trials

The first trials were planted at Amatikulu on the North Coast of KwaZulu-Natal in the spring of 1996 and summer of 1997 at a site 100 m above sea level, belonging to Tongaat-Hulett Sugar Ltd. Clifton Farm was chosen as the first site because the Amatikulu mill served more than a quarter of the small scale growers in KwaZulu-Natal. Cane variety N16 was intercropped with the food crops which the small scale growers had themselves chosen, namely maize, cabbage, irish potatoes, groundnuts and beans. A large variety of different crops were planted on observation plots at Amatikulu to determine which, if any, had a better potential for use in a cane intercropping system. The only irrigated intercropping cane trial in the research series was planted at Makhathini Research Station on the Makhathini Flats in the early winter of 1997, and harvested a year later.

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Expanded trial programme

After the initial trials had indicated that there were indeed potential benefits to be gained from intercropping cane with food crops, the trial programme was expanded considerably to investigate these benefits under a number of different climatic conditions. Specific trial sites were chosen in areas where large numbers of small scale growers were based. Successful trials were planted at Sezela (10% small scale growers), Eston (6%), and Bruyns Hill (3%), as shown in Table 1 (trial numbers have been changed from those used in the field to make a logical series for this paper).

Table 1. Expanded intercropping trial programme.

Trial	Cane variety	Cane and food crops planted	Cane harvested, allowed to ratoon, food crops planted	1st ratoon harvested
Amatikulu 1	N27	15 Sept 1998 Beans, cabbage, maize, cowpeas, sweet potato	17 Sept 1999 Beans, cabbage, maize, sweetcorn, sweet potato	19 Sept 2000
Amatikulu 2	N12	23 Nov 1998 Beans, cabbage, maize, cowpeas, sweet potato	18 Nov 1999 Soyas, cabbage, maize, sweetcorn, sweet potato	16 Nov 2000
Sezela	N16	5 Oct 1998 Beans, cabbage, maize, sweet potato	15 Oct 1999 Beans, cabbage, maize, sweet potato, sweetcorn, soyas	17 Oct 2000
Eston	N12 + N16	16 Oct 1998 Beans, cabbage, maize, cowpeas, sweet potato, sweetcorn, soyas	8 Sept 2000	Not ratooned
Bruyns Hill 1	N16	28 Sept 1999 Cabbage, maize, sweet potato	13 Nov 2001	Not ratooned
Bruyns Hill 2	N12	10 Oct 2000 Cabbage, maize, sweet potato	15 Oct 2002	Not ratooned

Unsuccessful trials were planted near Eshowe, Heatonville and Wilton Park (together 20%), and at Shakaskraal (11%). As with any crop trial situated at a distance from the base of the researcher, the trials sometimes faced insurmountable risks. A small number of trials failed to produce any results for a number of different reasons. Theft of the food crops and the cane proved to be the downfall of the trials at Esiphezi (near Eshowe) in 1997, and of the two 1998 trials at Heatonville. The following year, a trial site was selected on the new SASEX farm at Wilton Park near Empangeni, situated for security inside a fence near to the housing compound. Severe drought immediately after planting resulted in an exceedingly gappy stand of cane, and those food crops which did not die from drought or wind stress became swamped with weeds. No cane was harvested from that trial. In Spring 1999, a trial was planted on a private estate on the coastal plain at Shakaskraal. Early drought, geese, and then waterlogging put paid to the food crops, and the farmer harvested the cane before SASEX had recorded any harvest information.

Amatikulu 1

The programme continued at the high profile site on Clifton Farm with the planting of a new spring 1998 trial (Amatikulu 1), where cane variety N27 was substituted for the previously grown variety N16, which had proved too susceptible to smut. The trial was designed to test the performance of the intercrops in the plant cane crop.

Immediately after harvesting the cane at 12 months of age, similar intercrops were again planted, to test their performance in first ratoon cane. Sweet corn was substituted for the poor-yielding cowpea intercrop in the ratoon cane.

Amatikulu 2

The same choice of intercrops were planted into a summer 1998 trial (Amatikulu 2) adjacent to Amatikulu 1, but, because variety N27 proved too difficult to source, this trial was planted with variety N12 cane. The performance of the cane and intercrops were again tested in both plant and ratoon cane; in this trial the dry beans and cowpeas in the plant cane crop were substituted with soyabeans and sweet corn in the ratoon crop.

Sezela

A similar trial was planted in spring 1998 at Beneva Farm, belonging to Illovo Sugar Ltd, situated on the top of a small hill a few kilometers inland from Sezela mill. The soil analysis showed the soil to have a pH (KCl) of only 3.8-4.1, with an acid saturation of up to 28%, so 6 tons/ha dolomitic lime were disced into the land before drawing the furrows for planting the cane variety N16. The intercrops were again tested in both plant and first ratoon cane.

Eston

A large trial was planted in spring 1998 on the Sweetholm Farm of Illovo Sugar Ltd, not far from the mill at Eston (29°52'S, 30°31'E) at 785 m above sea level. For every trial there was always a long discussion as to which cane variety should be planted. As the land area at Eston was large enough, a wide selection of intercrops were planted into both N12 and N16, so that a direct comparison could be made under the same conditions to determine if there were any obvious advantages to one variety over the other. The acid saturation of the soil was 3-6%, necessitating the discing-in of 1.5 tons/ha lime before planting the cane. It proved difficult to site the trial because of the large number of huge termite mounds on the land, which were avoided for all treatments. The cane was harvested after 23 months, and was not ratooned.

Bruyns Hill 1

Bruyns Hill 1 was the penultimate trial of the Joint Venture Project, sited on the SASEX research farm at Bruyns Hill (29°25'S, 30°41'E), 990 m above sea level. This trial was planted in the spring of 1999, and was designed to further refine knowledge of the interactions between cane and intercrops. Based on research findings by Souza Filho and Andrade(1985), who found that delaying planting beans in Brazil after the cane was planted significantly reduced interspecies competition, a hypothesis was made that the reduction in cane yield caused by competition from the intercrop in KwaZulu-Natal might be lessened if the cane was allowed to become established before the food crops were planted in the interrows. In this trial, the cane was planted at the end of September and, in half of the plots (T1), the food crops were planted on the same date. In the other half of the plots (T2), the cane was left for five weeks and was then planted up on 1 November 1999 with the same pattern of intercrops. As in the previous trials, Hercules was the cabbage variety grown, planted at 40 cm between the seedlings in the row. This variety was used because it does not bolt, even in the heat of summer. As cabbages are very sensitive to acid soils, and the soil at Bruyns Hill registered an acid-saturation of 8%, the whole trial site was treated with lime at the rate of 2 t/ha before planting the cane. The in-row crops were maize variety SR52, the most popular variety for green mealies, planted at 30 cm apart in the row, and the sweet potato variety Blesbok (red skinned with white flesh), with cuttings planted 30 cm apart in the row.

Bruyns Hill 2
The final trial of the series, Bruyns Hill 2, which was sited immediately adjacent to Bruyns Hill 1, occupied a site of just over one hectare and was managed by a single male labourer. Apart from the intense activity required at planting and harvesting requiring many more pairs of hands, this labourer took sole care of the entire trial. This was arranged to determine how practical it would be for a single farmer to manage this area of intercropped cane. He coped very well with the task on a full-time, five days per week basis. This final trial in the series was the most complex of all, where, in addition to testing the effect of delayed intercrop planting on competition with the cane, additional plots were planted to the food crops in alternate cane interrows as proposed by Govinden and Ramasamy (1995) in Mauritius, where it was found that deleterious competitive effects on the cane by a maize intercrop were reduced to acceptable levels by planting the maize in alternate cane interrows. The N12 cane and the T1 intercrops were planted on 10 October 2000, and the T2 intercrops were planted into the cane six weeks later. The intercrops tested in the Bruyns Hill 2 trial were Hercules cabbage, SR52 maize and Blesbok sweet potatoes, with each row of the intercrop receiving the recommended rate of fertiliser. In this trial the sole stand food crops were planted at the recommended spacing and also at a wider spacing to determine the effect of population density on yield. The results of this will be reported elsewhere.

Results and Discussion

Initial trials
The initial rainfed trials of 1996/97 at Amatikulu clearly demonstrated that all the intercrops tested competed to a varying degree with the cane, and reduced cane yields below those achieved by sole cane. This agrees with the intercropping trial results from many countries: in India for Garcha *et al.* (1997), Singh and Chauhan (1998), Gulati *et al.* (1998), for Bukhtiar and Mohamed (1988) in Pakistan, for Mendoza (1986) in the Philippines, for Imam *et al*. (1990) in Bangladesh, and for Munoz *et al.* (2001) in Cuba. Nonetheless, scientists in all cane growing countries have persevered with cane intercropping research to determine which intercrops can compensate financially to produce a much greater income per hectare than the loss in cane revenue caused by the reduced yields. Thus, Ahmed *et al.* (1987), Chaudhary *et al.* (1999) and Nazir *et al.* (2002) all found that, despite intercrop induced reductions in cane yields of up to 27%, the additional values of the intercrops substantially increased the net profit over that obtained from a pure stand of sugarcane. Even where water was not limiting, as under irrigation in the winter trial at Makhathini, the intercrops of maize and cabbage reduced cane yields. These initial trials clearly showed that Irish potatoes were not suited to intercropping with cane, and that under rainfed conditions the competition from groundnuts was so severe that the cane yields became uneconomic. Dry beans were not an economic intercrop, but continued to be tested due to the interest of local farmers in this high value crop. The observation plots at Amatikulu indicated that, with sole yields in excess of 40 tons/ha, sweet potatoes could be as suitable a choice for a cane intercrop in KwaZulu-Natal as it had been found to be in the Philippines (Mendoza, 1986), where it was found to be the most suitable crop to fully use the light available in the cane interrow. The full write-up of these initial trials was presented at SASTA in 1999 (Parsons, 1999).

Expanded trial programme
As reported by Parsons (1999), a number of researchers assess the cane intercropping system in financial terms, such as Ismael and Govinden (1990) in Mauritius, El-Gergawi and Abou-Salama (1994) in Egypt, Sinha *et al.* (1994), Miah *et al.* (1995) and Shivay and Rathi (1996) in India. This financial method of identifying the success of cane intercropping systems has continued with the work of Gana and Busari (1999) in Nigeria, Mokadem *et al.* (2000) in Egypt, and Pandey and Shukla (2000) and Nazir *et al.* (2002) in India.

The small scale growers in these countries are principally interested in the profitability of such systems as alternatives to growing cane in sole stand. This paper follows the same system, so that all the trials in this research programme have been assessed on the basis of profitability, expressed in Rand/ha for 100% cane yields. The profits were calculated by taking into account all costs for cane and intercrop, but excluded loan repayments, depreciation of assets, and withdrawals.

In all tables of results from the trials in KwaZulu-Natal, the net profit from each crop system is also calculated using only 70% of the actual cane yields obtained. This is considered to be the realistic yield that a cane farmer could have achieved commercially under the same conditions, as opposed to the research yields obtained from small trial plots. It is suggested that the full intercrop yield could be achieved on a field scale because the intercrop is in the field for a much shorter time and can be cared for efficiently by the farmer urgently needing to harvest this crop for sale or food supply. To calculate the net profit in Rands/ha for the 70% cane yield, the costs of cane production have been reduced according to the tonnage of cane which would be harvested and transported to the mill, but the full costs for the intercrop production and the profit from the full intercrop yield, are included.

To evaluate the profitability of each intercrop treatment, compared to that produced by sole cane, a calculation of a Return on Capital Employed (RoCE) ratio has been made for each trial. This ratio is derived by dividing the profit of each crop system by the costs to produce that profit. The author derived the idea of this RoCE ratio from Indian papers where a Benefit:Cost ratio was calculated (Randhawa 1976; Sharma *et al*., 1997; Rathore *et al.,* 1999). A footnote is printed below each table showing the costs of production and prices gained for each site and year, based on information from KZNDAEA and SA Canegrowers.

Amatikulu 1
The results of the combination of cane and intercrop yields and values are shown for the plant cane in Table 2 and for the ratoon crop in Table 3.

Table 2. Amatikulu 1: N27 plant cane: September 1998 to September 1999. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	% Suc-rose	Suc value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100 % yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	73.5	10.7	7 408	3 464	nil	nil	nil	3 944	1.14	1 982
Cane + Beans	63.5	10.5	6 280	3 094	0.4	1 200	1 640	2 746	0.59	1 086
Cane + Cabbage	51.9	10.7	5 231	2 957	35.7	28 560	3 750	27 084	4.04	25 632
Cane + Maize	35.7	10.2	3 430	2 766	6.9	11 523	1 440	10 747	2.56	9 644
Cane + Cowpea	52.2	10.8	5 311	2 960	0.6	600	1 200	1 751	0.42	278
Cane+ S/potato	45.9	10.4	4 497	2 886	16.1	12 880	3 540	10 951	1.70	9 648
Mean	53.8	10.6								
LSD 5%	10.6	0.8								
CV%	13.1	4.9								

Sucrose value = R942/ton
Production cost of cane: R3 092/ha sole or R2 840/ha intercropped (no herbicide) + R11.80/t for harvest and transport of cane over average yield of 42 t/ha.
Intercrop production costs:
Beans (PAN 146) = R1 640/ha, value R3 000/t
Cabbage (Hercules) = R3 750/ha, value R800/t
Maize (PAN 6363) = R1 440/ha, value R1 670/t
Cowpea (PAN 311) = R1 200/ha, value R1 000/t
Sweet potato (Blesbok) = R3 540/ha, value R800/t

Table 3. Amatikulu 1: N27 first ratoon cane: September 1999 to September 2000. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	122.7	15.8	17 009	6 143	nil	nil	nil	10 866	1.77	6 541
Cane + Beans	129.3	15.7	17 890	5 893	0.4	1 200	1 770	11 427	1.49	6 822
Cane + Cabbage	138.7	15.7	19 212	6 078	16.4	16 400	4 025	25 509	2.53	20 550
Cane + Maize	127.4	15.6	17 538	5 856	2.6	4 550	1 546	14 686	1.98	10 164
Cane + S/corn	120.0	15.3	16 304	5 710	2.6	7 046	2 500	15 140	1.84	10 871
Cane + S/potato	138.0	15.7	19 124	6 064	2.9	2 610	3 870	11 800	1.19	6 856
Mean	129.4	15.6								
LSD 5%	21.6	0.7								
CV%	11.1	2.9								

Sucrose value = R881.30/ton
Production cost of cane : R4 556/ha sole and R4 176/ha intercropped (no herbicide) + R19.67/t for harvest and transport of cane over average yield of 42 t / ha
Intercrop production costs:
Beans (PAN 146) = R1 770/ha, value R3 000/t
Soya beans (Prima) = R1 220/ha, value R1 350/t
Cabbage (Hercules) = R4 025/ha, value R1 000/t
Maize (SR52) = R1 546/ha, value R1 750/t
Sweetcorn (Paradise) = R2 500/ha, value R2 710/t
Sweet potato (Blesbok) = R3 870/ha, value R900/t

Plant cane

The trial got off to a good start with 22 mm of rain soon after planting, but the long, hot and dry spells of weather in October and November 1998 took their toll on the food crops, as did the heavy rains in early December. The severe heat in November caused water in the maize funnels to overheat, killing the top leaves and some of the tassels. The trial was also plagued with weeds as a result of the unavailability of the contractor for ploughing the trial site until only a few days prior to planting. All the food crops survived, but produced very much lower yields than those achieved on the same site in the previous year. The yield results in Table 2 show that the Sole Cane yield of 73.5 t/ha was significantly reduced by all the intercrop treatments except beans, which themselves produced a sub-competitive yield due to the weather and weeds. Competition was particularly severe in the Cane + Maize treatment, which reduced the cane yield by over 50%. This agrees with the findings of Satyanarayana Rao and Veeranna (1998) and Roodagi *et al.* (2001), who both found maize to have the most competitive effect on cane yields. The intercrop yields of beans and cowpeas were totally uneconomic. On a profitability basis, the Cane + Cabbage intercrop produced the highest income with a RoCE of 4.04 compared with that of 1.14 for Sole Cane.

Despite the significant reduction in cane yields, the treatments of Cane + Maize and Cane + Sweet potato both produced significantly better profits than did the Sole Cane, although the RoCE ratios were considerably lower than that of cabbage at 2.56 and 1.70 respectively.

Ratoon cane

The N27 cane was ratooned on 17 September 1999, the trash was cleared away, and the interrow spaces were rotovated to allow the food crops to be replanted. It proved difficult to keep the rotovator in the exact centre of each interrow, which resulted in slight damage to some of the cane stools. The ratoon cane was harvested a year later to produce significantly greater yields than those of the plant cane, which may have been partly due to the greater total rainfall of 1 000 mm during the first ratoon year, as opposed to only 790 mm in the previous 12 months. Table 3 shows an interesting trend for the intercrop treatments to increase the actual yields of cane above that of the Sole Cane treatment, particularly by Cane + Cabbage and Cane + Sweet potato (although none of these increases were statistically significant). It is suggested that this trend may have resulted from the fertilisers applied to the food intercrops being used up by the cane plants when they had successfully out-competed the food crops, which agrees with the findings of Ng Kee Kwong *et al.* (1996) in Mauritius. However, except for cabbage, this was at the expense of the intercrop yields, which were poor. The ratoon cane regrowth was much more competitive to the intercrops than the plant cane had been, so that all the intercrop yields were well below those produced in the plant cane. This agrees entirely with the results of Wallace *et al.* (1991). The sweetcorn intercrop yield was no different from that of maize, so did not exhibit any advantages despite a shorter time to reach maturity. Once again, despite the interspecies competition, Cane + Cabbage was the most profitable treatment, but the RoCE for this had been reduced from 4.04 in the plant cane to only 2.53 in the first ratoon.

Amatikulu 2

The results of the combination of cane and intercrop yields and values are shown for the plant cane in Table 4 and for the ratoon crop in Table 5.

Table 4. Amatikulu 2: N12 plant cane: November 1998 to November 1999. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	57.6	8.4	4 558	3 276	nil	nil	nil	1 282	0.39	98
Cane + Beans	61.0	8.4	4 827	3 064	nil	nil	1 640	123	0.03	-1 101
Cane + Cabbage	44.8	7.4	3 123	2 873	17.6	14 080	3 750	10 580	1.60	9 676
Cane + Maize	24.9	10.0	2 346	2 638	8.5	14 195	1 440	12 463	3.06	11 557
Cane + Cowpea	64.4	10.0	6 067	3 104	0.5	500	1 200	2 263	0.52	670
Cane + S/potato	66.2	9.9	6 174	3 126	28.9	23 120	3 540	22 628	3.40	21 011
Mean	53.1	9.0								
LSD 5%	32.4	1.6								
CV%	40.4	11.6								

Sucrose value = R942/ton

Production cost of cane: R3 092/ha sole or R2 840/ha intercropped (no herbicide) + R11.80/t for harvest and transport of cane over average yield of 42 t/ha.

Intercrop production costs:

Beans (PAN 146) = R1 640/ha, value R3 000/t
Cabbage (Hercules) = R3 750/ha, value R800/t
Maize (PAN 6363) = R1 440/ha, value R1 670/t
Cowpea (PAN 311) = R1 200/ha, value R1 000/t
Sweet potato (Blesbok) = R3 540/ha, value R800/t

Table 5. Amatikulu 2: N12 first ratoon cane: November 1999 to November 2000. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	114.0	12.7	12 779	5 972	nil	nil	nil	6 807	1.14	4 109
Cane + Soya	115.9	12.1	12 426	5 630	0.5	675	1 220	6 251	0.91	3 158
Cane + Cabbage	105.1	12.8	11 986	5 417	10.6	10 600	4 025	13 144	1.39	10 046
Cane + Maize	88.3	13.0	10 135	5 087	6.1	10 675	1 546	14 177	2.14	11 643
Cane + S/corn	115.2	12.8	13 131	5 616	1.7	4 607	2 500	9 622	1.19	6 264
Cane + S/potato	124.0	12.3	13 396	5 789	3.0	2 700	3 870	6 437	0.67	4 004
Mean	110.4	12.6								
LSD 5%	31.4	1.2								
CV%	18.9	6.5								

Sucrose value = R881.30/ton
Production cost of cane : R4 556/ha sole and R4 176/ha intercropped (no herbicide) + R19.67/t for harvest and transport of cane over average yield of 42 t / ha
Intercrop production costs:
Beans (PAN 146) = R1 770/ha, value R3 000/t
Soya beans (Prima) = R1 220/ha, value R1 350/t
Cabbage (Hercules) = R4 025/ha, value R1 000/t
Maize (SR52) = R1 546/ha, value R1 750/t
Sweetcorn (Paradise) = R2 500/ha, value R2 710/t
Sweet potato (Blesbok) = R3 870/ha, value R900/t

Plant cane

The N12 cane for Amatikulu 2 was planted in November 1998. The weed problem also affected this trial, but the worst problem was caused by heavy rains leading to prolonged waterlogging of the site, which killed the dry bean intercrop and seriously impaired the growth of the drought-tolerant cowpeas. Table 4 shows that the yields of the N12 cane were considerably lower than the N27 cane in Amatikulu 1, but the pattern of yield reduction caused by the intercrops was similar. Once again the intercrop with maize proved the most competitive, producing a serious reduction in cane yield of over 50%, but with a concurrent increase in the percentage sucrose produced in the cane. The cabbage intercrop was reduced to half of that produced in the spring planted N27 cane due to a heavy infestation of leaf-eating caterpillars of the diamond-backed moth. Despite these problems, the intercrop systems of cabbage, maize and particularly sweet potato, produced profitable yields, raising their RoCE ratio values to 1.6, 3.6 and 3.4 respectively, compared with only 0.39 for Sole Cane.

Ratoon cane

Table 5 shows the combination of cane intercrop yields and values for the ratoon trial of N12 cane at Amatikulu. Again, N12 produced lower cane yields than N27 at the same site and the maize produced a serious reduction in the cane yield, although this was not statistically significant. The Cane + Sweetcorn did not reduce cane yields at all, but neither did it produce an economic intercrop yield. Only the Cane + Cabbage and Cane + Maize treatments produced economic intercrop yields, and RoCE values higher than that of Sole Cane. The sweet potato yield was reduced by theft to below an economic value.

Sezela

Plant cane

Table 6 gives the results of the N16 plant cane trial at Beneva Farm, Sezela. The soil was a light sandy loam, and the site was very exposed to the wind, yet with a well-distributed rainfall of over 660 mm during the first six months, the cane established well, and the intercrops yielded well. There was some loss of the maize and sweet potatoes to monkeys. The Sole Cane yield was significantly reduced by the cabbage and maize intercrops but, as seen in the other plant cane trials, the cabbage, maize and sweet potato intercrop treatments all produced much higher profits than cane alone. In this trial, the Cane + Maize treatment produced the best RoCE with a figure of 3.56 compared with that of only 0.71 for Sole Cane.

Ratoon cane

Table 7 gives the results of the ratoon cane trial, where as expected the cane yields were significantly higher than had been produced in the plant cane, ably assisted by a massive 1 578 mm of rainfall during this 12 month season. However, the excellent growth of the ratoon cane resulted in very high competition with the food crops, as a result of which they all produced very low yields, apart from the Cane + Maize treatment. Cane + Cabbage and Cane + Maize treatments significantly reduced cane yields, with the best profits and hence RoCE ratio values being shown by maize and sweetcorn intercrops.

Table 6. Sezela: N16 plant cane: October 1998 to October 1999. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	77.8	14.3	10 456	6 116	nil	nil	nil	4 340	0.71	2 561
Cane + Beans	70.9	15.2	10 174	5 543	1.4	4 200	1 640	7 191	1.00	5 109
Cane + Cabbage	49.5	13.5	6 311	4 549	26.2	20 960	3 750	18 972	2.29	17 423
Cane + Maize	59.4	13.5	7 536	5 009	13.1	21 877	1 440	22 964	3.56	21 527
Cane + S/potato	67.6	14.8	9 420	5 390	22.5	18 000	3 540	18 490	2.07	16 608
Mean	65.0	14.3								
LSD 5%	12.4	1.6								
CV%	13.2	7.9								

Sucrose value = R942/ton

Production costs of cane = R4 452/ha sole or R4 200/ha intercropped (no herbicide) + R46.48/t for harvest and transport of cane over average yield of 42 t/ha

Intercrop production costs = costs on Footnote: Table 2.

Table 7. Sezela: N16 first ratoon cane: October 1999 to October 2000. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	102.8	15.2	13 748	7 972	nil	nil	nil	5 776	0.72	3 247
Cane + Beans	99.3	14.9	13 043	7 413	1.1	3 300	1 770	7 160	0.78	4 766
Cane+Cabbage	79.8	15.0	10 576	6 416	6.5	6 500	4 025	6 635	0.64	4 670
Cane + Maize	66.7	14.8	8 725	5 747	8.0	14 000	1 546	15 432	2.12	13 821
Cane+S/corn	93.0	15.4	12 603	7 091	2.8	7 588	2 500	10 600	1.11	8 258
Cane+S/potato	91.9	15.3	12 426	7 035	4.9	4 410	3 870	5 931	0.54	3 586
Cane + Soya	91.9	15.5	12 515	7 035	0.4	540	1 220	4 800	0.58	2 479
Mean	89.3	15.2								
LSD 5%	18.1	1.1								
CV%	13.5	6.0								

Sucrose value = R881.30/ton
Production costs of cane = R4 864/ha sole or R4 484/ha intercropped (no herbicide) + R51.12/t for harvest and transport of cane over average yield of 42 t/ha.
Intercrop production costs = costs on Footnote: Table 3.

Eston

Six food crops were tested in both N16 and N12 cane, with a small additional trial of N16 cane intercropped with three varieties of soyabeans alongside. The soil had been very compacted after a continuous crop of cane for the previous 16 years, and a large number of the grubbed stools remained in the field, which together with large termite hills and a heavy burden of wild sorghum made for a difficult trial site. It had been hoped that soyabeans would prove a better intercrop legume than groundnuts, cowpeas or dry beans, and would enrich the interrows with nitrogen to improve the cane yields above that of Sole Cane.

Table 8. Eston: N12 plant cane: October 1998 to October 2000. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	96.7	15.2	12 955	6 675	nil	nil	nil	6 280	0.94	3 560
Cane + Beans	70.8	15.2	9 518	5 254	0.7	2 100	1 640	4 724	0.69	2 702
Cane + Cabbage	106.5	15.5	14 542	6 689	36.2	28 960	3 750	33 063	3.17	29 993
Cane + Maize	69.9	14.7	9 077	5 218	15.0	25 050	1 440	27 469	4.13	25 572
Cane + S/corn	94.7	15.5	12 955	6 215	14.8	32 560	2 000	37 300	4.54	34 544
Cane + S/potato	60.3	15.0	8 020	4 832	11.3	9 040	3 540	8 688	1.04	6 975
Cane + Cowpea	96.9	15.3	13 396	6 303	1.3	1 300	1 200	7 193	0.96	4 348
Mean	85.1	15.3								
LSD 5%	19.8	0.6								
CV%	15.6	2.6								

Sucrose value = R881.30/ton
Production costs of cane = R4 476/ha sole or R4 096/ha intercropped (no herbicide) + R40.20/t for harvest and transport of cane over average yield of 42 t/ha
Production costs of intercrops:
Sweetcorn = R2 000/ha, value R2 200/t.
All other intercrops as Footnote: Table 2

The trial experienced a heavy hailstorm two weeks after planting followed by a very severe drought, which together necessitated the replanting of the maize, sweetcorn, dry beans and soyabeans one month later. The sweet potatoes and cabbages survived by hand watering for a total of three weeks after planting. The only seed which survived the drought was that of the PAN 311 cowpeas. The cane for all three trials was harvested at 24 months, and the results are tabulated in Tables 8, 9a and 9b.

Table 9a. Eston : N16 plant can : October 1998 to October 2000. Combination of cane and intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	105.5	15.2	14 101	7 029	nil	nil	nil	7 072	1.01	4 142
Cane + Beans	96.4	15.2	12 867	6 283	0.5	1 500	1 640	6 444	0.81	3 781
Cane + Cabbage	109.2	15.7	15 070	6 797	38.9	31 120	3 750	35 644	3.38	32 462
Cane + Maize	75.2	14.7	9 782	5 431	15.5	25 885	1 440	28 796	4.19	26 737
Cane + S/corn	111.4	15.3	14 982	6 886	14.3	31 460	2 000	37 556	4.23	34 434
Cane + S/potato	64.6	14.9	8 372	5 005	11.9	9 520	3 540	9 347	1.09	7 690
Cane + Cowpea	91.9	15.2	12 338	6 102	1.2	1 200	1 200	6 236	0.85	3 621
Mean	93.5	15.2								
LSD 5%	20.8	0.5								
CV%	15.0	2.3								

Sucrose value = R881.30/ton
Production costs of cane = R4 476/ha sole or R4 096/ha intercropped (no herbicide) + R40.20/t for harvest and transport of cane over average yield of 42 t/ha
Production costs of intercrops:
Sweetcorn = R2 000/ha, value R2 200/t
All other intercrops as Footnote: Table 2

Table 9b. Eston: N16 plant cane: October 1998 to October 2000. Combination of cane and soyabean intercrop yields and values.

Crop system	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	107.4	14.6	13 836	7 105	nil	nil	nil	6 731	0.95	3 865
Cane + Nyala	69.0	14.2	8 637	5 181	1.5	1 875	1 100	4 231	0.67	2 471
Cane + LS555	74.9	14.4	9 518	5 419	1.8	2 250	1 100	5 249	0.81	3 286
Cane + Prima	66.3	14.3	8 372	5 073	1.7	2 125	1 100	4 324	0.70	2 600
Mean	79.4	14.4								
LSD 5%	17.2	0.5								
CV%	7.2	5.6								

Sucrose value = R881.30/ton
Production costs of cane = R4 476/ha sole or R4 096/ha intercropped (no herbicide) + R40.20/t for harvest and transport of cane over average yield of 42 t/ha

Production costs of intercrops:
Soya beans = R1 100/ha, value R1 250/t
Sweetcorn = R2 000/ha, value R2 200/t
All other intercrops as Footnote: Table 2

The Sole Cane treatments in all three trials gave high yields, no doubt helped by a total rainfall of just over 1 200 mm for the 24 months, with N16 performing marginally better than N12. Most of the intercrops, particularly the soyabeans, produced a reduction in cane yields, despite the cane having had more than 18 months to recover from the intercrop competition and continue growing after the harvest of the intercrops. Despite having grown to almost a metre in height, soyabeans themselves did not produce their expected yields, largely due to the effects of a second hailstorm on 10 January 1999. Only the yields of cane from the Cane + Cabbage treatments for both N16 and N12, and for Cane + Sweetcorn in the N16, showed no reduction – in fact, they were actually higher than the Sole Cane treatment (although not significantly so). Cane + Maize and Cane + Sweet potato treatments significantly reduced cane yields in both varieties. The yields of the intercrops showed no differences caused or influenced by cane variety, which was in itself a useful discovery. It had been thought that N12 cane would be more suitable as an intercrop variety as it establishes and canopies more slowly than N16, but this did not result in any change in intercrop performance at Eston. The significant reduction in cane yield by all three soyabean varieties was a disappointment, particularly as the resulting RoCE values showed that soyabeans are definitely not a suitable intercrop for cane, which agreed with Gana *et al.* (2000). The top intercrop system for profitability at Eston was Cane + Sweetcorn with a RoCE value of 4.54 in N12 and 4.23 in N16, closely followed by maize and cabbage. All these crops could be economically produced by small scale growers in the Eston area, and sold via hawkers to the nearby market of Pietermaritzburg.

Bruyns Hill 1

Table 10 gives the results from the trial Bruyns Hill 1. Despite harvesting the cane at 26 months of age, it still demonstrated the strong competitive effect of the food intercrops, especially for the Cane + Maize and Cane + Sweet potato treatments at T1 and T2 which both showed a statistically significant reduction in cane yield compared with that of Sole Cane. Only where the cane was intercropped with cabbage, did the cane yields recover from any competition, to produce high yields at both T1 and T2. These were not statistically different from the Sole Cane yields, producing RoCE values of 5.02 and 5.68 for T1 and T2 respectively, compared with 1.30 for Sole Cane. The high yields of cane in the Sole Cane and Cane + Cabbage treatments were no doubt aided by an excellent two year rainfall of 2 230 mm.

The results of this trial did not support the hypothesis that delaying the planting of the intercrops into the cane would lessen the reduction in cane yields. In fact, the cane yields for T2, where the intercrops had been planted 34 days after the cane, were all lower than those for T1, where the food crops had been planted at the same time as the cane, although this difference was not statistically significant. It is suggested that this may have been due to the fact that the T2 planted intercrops all grew much faster than the T1 intercrops, due to higher temperatures, which actually increased the competition with the cane. This is borne out by considering the DAP (days taken to reach maturity) values for the intercrops shown in the footnote to Table 10. The T2 cabbages matured 7 days earlier, T2 maize matured 23 days earlier and T2 sweet potatoes matured 8 days earlier than the same crops planted at T1. In addition, T2 cabbages and sweet potatoes also produced significantly higher yields than at T1 (14.4% and 51.1% increase respectively), which would also have increased the competition with the cane. A practical problem which may have contributed to the reduced cane yields in the T2 intercropped treatments was that there was unavoidable trampling of the soil above the germinating cane rows when the labour was planting the interrows with food crops, which may have damaged some of the new cane shoots as they were emerging from the soil.

Table 10. Bruyns Hill Trial 1: N16 plant cane : September 1999 to November 2001. Combination of cane and intercrop yields and values.

Crop system	T1 or T2	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane	T1	129.9	15.7	21 805	9 481	Nil	Nil	Nil	12 324	1.30	7 749
	T2	121.5	15.4	20 031	8 724	Nil	Nil	Nil	11 307	1.30	6 814
Cane + Cabbage	T1	120.2	15.7	20 177	8 658	56.2	56 200	4 025	63 694	5.02	59 459
	T2	116.0	15.3	19 009	8 441	64.3	64 300	4 025	70 843	5.68	66 895
Cane + Maize	T1	84.7	15.0	13 626	6 683	15.9	27 825	1 750	33 018	3.92	30 037
	T2	77.4	14.8	12 297	6 494	14.0	24 500	1 750	28 553	3.46	26 040
Cane + S/potato	T1	87.3	14.8	13 870	6 994	22.9	20 610	3 870	23 616	2.17	20 778
	T2	85.6	15.0	13 771	6 908	34.6	31 140	3 870	34 133	3.17	31 297
Overall mean		102.8	15.22								
LSD 5%		15.6	0.75								
CV%		10.4	3.4								

1. T1 = Date of planting cane + T1 i/crops = 28/9/1999; T2 = Date of planting T2 i/crops = 1/11/1999
2. Sucrose value = R997.83/ton sucrose + R11.20/t of cane (Equivalent of RSV)
   Production cost of cane: R5 037/ha sole or R4 704/ha intercrop (no herbicide) + R50.56/t for harvest and transport of cane over average yield of 42 t/ha.
   Cane DAP = 777; Rainfall = 2 230 mm
3. Intercrop costs and values based on KZNDAEA Combud and actual practices
   Cabbage (Hercules): Production cost: R4 025/ha, value R1 000/t
   DAP T1 = 100; T2 = 93; Rainfall T1 = 622 mm; T2 = 722 mm
   Maize for green mealies (SR52): Production cost: R1 546/ha, value R1 750/t
   DAP T1 = 103; T2 = 80; Rainfall T1 = 923 mm; T2 = 753 mm
   Sweet potato (Blesbok): Production cost: R3 870/ha, value R900/t
   DAP T1 = 159; T2 = 151; Rainfall T1 = 931 mm; T2 = 829 mm
4. Where DAP = Days after Planting (to harvest) and Rainfall during DAP
5. RoCE ratio = Return on Capital Employed for 100% cane + intercrop yields

Bruyns Hill 2

Table 11 shows the combination of N12 cane and intercrop yields and values for Bruyns Hill Trial 2. The Sole Cane yield was massive at 146.4 t/ha produced on a lower two-year rainfall total of 1 884 mm, 24 months after planting, and again all intercrops caused a reduction in cane yield. However, as seen in the first Bruyns Hill trial, Cane + Cabbage at T1 and T2, in both E (every row intercropped) and A (alternate rows intercropped) all produced high cane yields, none of which were statistically significantly lower than that of Sole Cane. This complex trial covered more than one hectare of land, and was designed to determine whether the degree of cane yield reduction could be manipulated by either later planting of the food crops, and/or reducing the intercrop population in the cane interrows. The population of the intercrop in each cane plot was halved in the "A" row configuration, compared with the population in the "E" row planting. The yield results show that a certain amount of manipulation is indeed possible.

Table 11. Bruyns Hill 2: N12 plant cane : October 2000 to October 2002. Combination of cane and intercrop yields and values.

Crop system	E / A	Cane yield (t/ha)	Pol % cane	Sucrose value (R/ha)	Prod cost cane (R/ha)	I/crop yield (t/ha)	I/crop value (R/ha)	Prod cost i/crop (R/ha)	Profit +100% yields (R/ha)	RoCE ratio	Profit +70% cane yield (R/ha)
Sole Cane		146.4	16.8	31 610	10 468				21 142	2.02	13 890
DAP = 736		Rainfall = 1884 mm									
Cane + T1 Cabbage	E	126.6	16.1	26 373	9 144	53.1	58 410	4 930	70 709	5.02	64 642
	A	138.0	16.1	28 581	9 947	28.3	31 130	2 465	46 841	3.77	41 122
DAP = 85		Rainfall = 460 mm									
Cane + T2 Cabbage	E	132.1	15.3	27 047	9 413	60.6	66 660	4 930	79 364	5.53	72 599
	A	138.7	16.0	28 589	9 981	28.1	30 910	2 465	47 053	3.78	40 838
DAP = 96		Rainfall = 384 mm									
					Intercrop LSD 5% (E and A) Intercrop LSD 5% (T1 and T2)	8.06 9.77	CV 8.8%				
Cane + T1 Maize	E	88.0	15.4	17 496	7 254	13.8	25 530	1 660	34 112	3.83	30 204
	A	131.0	15.7	26 545	9 604	7.4	13 690	830	29 801	2.86	24 079
DAP = 129		Rainfall = 558 mm									
Cane + T2 Maize	E	87.5	15.8	17 251	7 229	12.6	23 310	1 660	31 672	3.56	28 239
	A	109.0	15.9	22 378	8 282	7.8	14 430	830	27 696	3.04	22 614
DAP = 121		Rainfall = 411 mm									
					Intercrop LSD 5% (E and A) Intercrop LSD 5% (T1 and T2)	2.67 2.46	CV 5.2%				
Cane + T1 Sweet potato	E	99.5	14.9	19 214	7 817	33.9	36 612	4 150	43 859	3.67	39 590
	A	104.7	15.4	20 868	8 072	21.8	23 544	2 075	34 265	3.38	29 565
DAP = 140		Rainfall = 587 mm									
Cane + T2 Sweet potato	E	109.9	15.0	21 294	8 326	32.5	35 100	4 150	43 918	3.52	39 213
	A	111.6	15.7	22 536	8 410	23.4	25 272	2 075	37 323	3.56	32 303
DAP = 140		Rainfall = 447 mm									
					Intercrop LSD 5% (E and A) Intercrop LSD 5% (T1 and T2)	3.83 6.17	CV 9.3%				
Overall Mean Cane LSD 5%		119.2 20.7	1.0	4 156			CV 11.9%				

1. T1 = Date of planting cane + T1 i/crops = 10/10/2000; T2 = Date of planting T2 i/crops = 21/11/2000
2. DAP = Days After Planting (to harvest), Rainfall during DAP
3. I/crop plant population in A (Alternate rows) = 50% of i/crop plant population in E (Every row)
4. Sucrose Value = R1 222.30/t sucrose + R11.36/t of cane (Equivalent of RSV)
   Production cost of cane: R5 600/ha sole or R5 246/ha intercropped (no herbicide) + R48.97/t for harvest and transport of cane over average yield of 47 t/ha
5. Intercrop costs and values based on KZNDAEA Combud and actual practices
   Cabbage (Hercules): Production cost R4 930/ha (E), value R1 100/t
   Maize for green mealies (SR52): Production cost R1 660/ha (E), value R1 850/t;
   Sweet potato (Blesbok): Production cost R4 150/ha (E), value R1 080/t.
6. RoCE Ratio = Return on Capital Employed for 100% cane + intercrop yields

In the Cane + Cabbage intercrop, planting the food crop in alternate rows produced a trend of increasing the cane yield, particularly at T1, but none of the cane yields showed statistically significant differences. Delaying planting the cabbage to T2 also tended to increase cane yields. As expected, halving the stand of cabbage by planting alternate rows instead of every row reduced the cabbage yields significantly, but the halved stand still produced more than a halved yield and was still highly profitable compared with the Sole Cane treatment.

Table 12. Intercrop productivity – yield data demonstrating significantly greater plant productivity in cane interrows.

Crop variety	Unit of mean yield	Year of trial	Site + cane variety[1]	Data for intercrop	Data for sole crop	LSD 5%	Level of Sig. Diff.
Cabbage (Hercules)	Single head wt (kg)	1998/1999	Amatikulu N27	2.33	1.42	0.37	**
	Head diam (mm)	1998/1999	Amatikulu N27	168.0	148.0	9.6	**
	Single head wt (kg)	1998/1999	Sezela N16	1.22	0.77	0.26	*
	Single head wt (kg)	1998/2000	Eston N16 N12	2.71 2.51	2.11	0.33	*
	Head diam (mm)	1998/2000	Eston N16 N12	184.2 181.6	166.6	14.7	*
	Single head wt (kg)	1999/2001	Bruyns Hill T1 T2	2.59 2.96	2.12 2.48	0.31	* **
Maize (SR52)	Single cob wt (kg)	1998/1999	Sezela N16	0.33	0.28	0.04	*
	Single cob wt (kg)	1999/2000	Sezela N16 Ratoon	0.31	0.22	0.04	**
	Single cob wt (kg)	1998/2000	Eston N16 N12	0.42 0.41	0.33	0.04	** **
	Cob length (mm)	1998/2000	Eston N16 N12	273.8 273.4	254.1	9.1	** **
	Single cob wt (kg)	1999/2001	Bruyns Hill N16 (T1) N16 (T2)	0.39 0.39	0.35 0.36	0.02	*
	Single cob wt (kg)	2000/2002	Bruyns Hill N12 (T1) E N12 (T2) E N12 (T2) A	0.38 0.40 0.43	0.31 0.32 0.32	0.05	* ** **
Cowpeas (PAN 311)	Seeds wt/plant (g)	1998/1999	Amatikulu N27	9.21	7.22	0.61	**
Sweetcorn (Paradise)	Cob nos/plant	1999/2000	Sezela N16 Ratoon	1.19	0.78	0.33	*
S/potato (Blesbok)	Tubers per plant (kg)	2000/2002	Bruyns Hill N12 T1 (E) T1 (A)	1.53 1.87	1.30	0.19	**
			T2 (E) T2 (A)	1.63 2.08	1.43	0.17	**

[1]Cane is all Plant cane, unless otherwise stated.
Levels of Significant difference: *$p < 0.05$, **$p < 0.01$.

In the Cane + Maize treatments, there was a large and significant increase in cane yields comparing the "E" and "A" row plantings, which meant that at T1, the "A" treatment had a cane yield not significantly different from Sole Cane, and yet the maize still produced a highly profitable yield of its own.

This finding agrees with the results of Sih Marjayanti and Arsana (1993) working in Indonesia with intercrops of soyabeans which uneconomically reduced cane yields when planted in every row, but which allowed almost full recovery of the cane before harvesting when they were planted in alternate rows. In the Cane + Sweet potato treatments, delaying planting and halving the intercrop population both increased cane yields, although not statistically. Most remarkably, the sweet potato plants compensated very well for the extra growing space they had in the "A" row treatment, in which a 50% normal stand produced a 64% yield at T1 and a 72% yield at T2. This compensation for extra space actually resulted in a greater weight of tubers per plant in the "A" row treatment, as can be seen at the bottom of Table 12.

The RoCE ratio figure for Sole Cane at 2.02 was higher than that produced in any other trial. However, *all* the intercrop treatments produced significant levels of profit, far in excess of that produced by Sole Cane, with RoCE ratio figures extending from 2.86 for Cane + Maize at T1 "A", to a high of 5.53 for Cane + Cabbage at T2 "E". These figures confirm that the upland areas of cane where the farmers must wait 24 months for an income, are ideally suited for intercropping.

Cane quality

From the many research papers written about the effect intercrops have on cane yields, there is no consensus as to the effect of intercrops on sucrose percentage or Pol % cane. For example, Nema *et al.* (1995) and Singh and Chaudhary (1996) stated that no intercrops had any significant effect on juice quality or sucrose recovery, whereas Bukhtiar and Mohamed (1988), Tema *et al.* (2000) and Nazir *et al.* (2002) all reported that intercrops tended to reduce percentage sucrose in the intercropped cane. Due to lack of space in this paper, the full tabulated measurements of the effect of intercrops on cane growth have not been included, and to this point in the paper, the intercrop effect on sucrose percentage has not been discussed. Looking at all the trials from Table 2 to Table 11 there is no set pattern discernable, with no correlation with cane variety, nor with the cane being plant or first ratoon, which rather agrees with the lack of consensus in the literature. In five trials, in Tables 2, 3, 5, 7 and 9b, all the Pol % cane figures are very uniform between treatments within a trial, whereas in the others, Cane + Maize reduced Pol % cane in five trials significantly, and Cane + Cabbage and Cane + Sweet potato treatments both reduced this variable in two trials.

Food crop productivity

In the early trials at Amatikulu and Makhathini, there were occasional indications that the productivity per individual food crop plant in an intercrop situation, was greater than that from individual food crop plants when grown in sole stand. Evidently, the interspecific competition from the cane to the intercrop was occasionally less than the intraspecific competition between individual food crop plants of the same species. Only two scientific papers have been identified where sugarcane intercropping research has shown this effect, namely Khanzada and Khan (1989) with reference to sunflowers having more seeds per head and higher seed yields per hectare when intercropped than when grown in sole stand, and Abou-Salama *et al.* (2000), who found the same effect for cane intercropped with garlic.

Despite the lack of information on this point in the literature, this effect has been found many times in this research project, as is shown in Table 12, which lists all the occasions when the differences were statistically significant. This pattern was only demonstrated once each for sweet potatoes, cowpeas and sweetcorn, but seems to be fairly common for intercropped maize and cabbage plants, which have produced significantly heavier or larger heads and cobs respectively, than from the sole crop treatments. The cane evidently protects the cabbages from much of the heat of the sun as they near maturity, and also shades the soil around the roots of the maize plants.

Conclusions

The results from the five-year intercropping trials have proved conclusively that intercropping cane in KwaZulu-Natal **is** an economic proposition, provided certain ground rules are adhered to. Cane + Maize is really the only intercrop tested which produces an economic yield in ratoon cane, because the ratoon grows so much more aggressively than the plant cane. The maize survives by growing taller than the cane. Cane + Cabbage is the most generally productive intercrop system to plant, where the cane plants can protect the maturing cabbages from the heat of the sun, often to produce a significantly greater weight of cabbage per plant than when the cabbages are planted in sole stand. If cane yields are to be protected from competition by the food intercrops, these can be planted in alternate cane rows instead of every interrow of cane. Delaying planting the intercrop into cane does not produce any guaranteed benefits, and sometimes this practice might in itself lead to lower cane yields as a result of damage done to the germinating cane. None of the legumes tested proved successful as intercrops. There was no evidence seen in any of these trials that intercropping increased disease levels or insect damage in either cane or intercrop.

The results from the Bruyns Hill 2 trial imply that a small scale grower wanting to intercrop his/her cane should seriously consider planting the intercrop in alternate cane interrows which will reduce costs and the competitive effect on the cane yield, but still produce a useful profit from the food crop. The fact that intercropped cabbages, maize and sometimes other crops can produce more yield *per plant* than when these are planted in sole stand is significant for the small scale grower, who will increase profitability by intercropping his/her vegetables rather than cultivating them on a separate piece of land.

The concept of the RoCE ratio proved to be excellent for making an instant assessment of the benefits of any intercrop system relative to those for Sole Cane.

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