A REVIEW OF GREEN MANURING PRACTICES IN SUGARCANE PRODUCTION

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Abstract

The incorporation of ecological practices into sugarcane production and management has the potential to arrest and ameliorate the negative effects of monocropping on soil degradation and yield decline. Historically, the production of green manures as cover or break crops has been shown to improve the physical, chemical, and biological properties of soil for many crops in production agriculture. This paper examines research outcomes based on the incorporation of green manure practices into sugarcane production throughout the world. Early studies conducted in South Africa revealed the benefits imparted to soil by green manures. More recent research in Australia, Louisiana, Thailand, and Swaziland has shown the use of green manures to improve soil properties and reduce the incidence of disease, with accompanying increases in sugarcane yields. Current investigations conducted by the Joint Yield Decline Venture in Australia indicate that the use of green manure break crops and rotations can result in significant yield increases as a function of improved soil properties. Field and laboratory studies with green manures are currently underway in South Africa to develop strategies for improving soil sustainability and sugarcane yields.

Keywords: green manure, legumes, organic matter, soil, sugarcane, yield

Introduction

The practice of green manuring can be defined in a variety of ways. It generally refers to the incorporation of either un-decomposed plant tissues or plant residues into the soil. Although the practice of growing and incorporating leguminous crops during fallow periods is synonymous with green manuring in the minds of many growers, green manures are not limited strictly to legumes. Production of green manure crops is often a component of fallow, cover crop, intercropping, or rotational management strategies. The concept of allowing agricultural land to rest or fallow is an ancient practice, with the need for and frequency of fallowing having been prescribed by Mosaic law as one year in seven, and in mediaeval England as one year in three (King *et al*., 1953).

A monoculture farming system is one in which a single crop is grown continuously in the absence of or with short fallow periods. Perennial cash crops, such as sugar and coffee, are frequently grown in monoculture, while annual cereal crops are also grown on a monoculture basis. Monoculture allows the farmer the advantage of tailoring production methods to the requirements of one crop, but is likely to result in reduced soil quality and crop yields despite the use of artificial fertilisers.

The significance attached to soil degradation as a result of long-term, intensive sugarcane monoculture has been linked to yield decline (Maxwell, 1900; Bell, 1935; Bell, 1938; Beiske, 1965; Chinloy and Hogg, 1968; Coleman, 1974; Garside *et al*., 1997a, 1997b; Egan *et al*., 1984; Henry and Ellis, 1995; Margarey and Croft 1995; Meyer, 1995; Prammanee *et al*., 1993 and 1995; Garside and Nable, 1996; Leslie and Wilson 1996). In recent years there has been a renewed interest in the practice of green manuring, particularly in combination with different fallowing regimes, as a means of improving the physical and chemical conditions of soil while decreasing the incidence of pests and diseases specific to sugarcane. This paper is a summary of past and current research with green manures throughout the world, with emphasis on their use in ameliorating the negative impacts of sugarcane monoculture, particularly soil degradation and yield decline.

Early work in South Africa

Early trials conducted at the South African Sugar Association Experiment Station (SASEX) at Mount Edgecombe, showed the benefits of growing velvet beans (*Stizolobium* spp.), sunn hemp (*Crotalaria* spp.), cowpeas (*Vigna unguiculata*), lupins (*Lupins angustifolius*), cannola (*Brassica* spp.), buckwheat (*Fagopyrum* spp.), and mungbeans (*Phaseolus aureus*) for rejuvenation of old cane lands (Schwikkard, 1926; Dodds, 1930). Early researchers acknowledged the importance of soil organic matter or humus, and noted that in both older sugarcane growing areas and many newer ones a marked deficiency of organic matter already existed (Dodds, 1925; Edleman, 1925). At the time it was reported that in Louisiana the exhaustion of soil fertility and organic matter after continuos sugarcane cropping had reached an acute stage; yields of cane having sharply declined from 40 Mg ha^{-1} per annum in 1921 to 16 Mg ha^{-1} per annum in 1924. As a result, a rotation came into general use in which two years of cane were followed by a crop of maize, the residues of which were ploughed in as early as possible, then by a green manure crop of cowpeas which was ploughed in before replanting sugarcane. It was noted that while this practice helped reduce the loss of soil organic matter, it did not provide sufficient nitrogen to sustain sugarcane yields (Dodds, 1925). Alternatively, a rotation of yellow sweet clover (*Melilotus indicus*) was practiced during the fallow period and ploughed under prior to the establishment of a new cane crop. As a result, 22 to 29 Mg ha^{-1} of biomass and over 45 kg nitrogen were returned to the soil with an accompanying sugarcane yield of over 31 Mg ha^{-1} compared with less than 22 Mg ha^{-1} from adjoining control plots (Dodds, 1925).

Early observation trials with buckwheat (*Fagopyrum spp.*), cowpeas (*Vigna unguiculata*), mung bean (*Phaseolus aureus*), sunn hemp (*Crotalatia juncea*) and velvet bean (*Stizolobium spp*.) on very light sandy soils at Chaka's Kraal showed the benefits of even a very short (3 months) period of green manuring which were attributed to a significant increase in soil moisture holding capacity (Dodds, 1930). Subsequent experiments conducted on heavy clay loams with poor drainage at SASEX produced sugarcane yields of 97 Mg ha^{-1} with green manure legumes compared with 92 Mg ha^{-1} and 88 Mg ha^{-1} for non-legume green manures and controls, respectively. Small non-significant residual responses were noted in the following ratoon crops in a number of trials, with legume fallows tending to be superior to non-legume fallow crops in enhancing yield (Dodds, 1930).

During the period from 1930 to 1958 research in the South African sugar industry was focused away from the practice of green manuring. Pearson (1958) presented a paper at the South African Sugar Technologists Association (SASTA) Congress which discounted the benefits of green manuring against the material gains achieved by continuous sugarcane production. The focus of the experiment was to emphasise that the time taken in growing a green manure crop could be turned to profit by planting cane after cane. At the time it was believed that while green manuring may have been a sound practice 30 years previously, the advent of inexpensive commercial fertilisers and improved varieties had shifted the economics of sugarcane production away from fallow periods and green manuring.

Monoculture, yield decline and soil degradation

Monoculture

Until recently, very little attention has been given to the effects of long-term sugarcane rotations on soil quality. While fallow periods, either bare or in conjunction with green manures or cover crops, were common in the early days of sugarcane production, the demand for increased sugar production, which began in the sixties, necessitated more intensive use of existing land giving little scope for use of long-term fallows (King *et al*., 1965).

For many years in Queensland, sugarcane cultivation on individual farms was restricted by statute to 75 per cent of the gross assigned area. The restriction was increased to 85 per cent in 1965 and removed entirely in 1974. In a study on the influence of time of harvest on crop yields, Leverington *et al.* (1978) concluded that a grower was more likely to achieve greater overall productivity if he maintained a 100 per cent rotation, with a ploughout-replant operation at the beginning of the season, than if he fallowed 20-30 percent of his farm each year. At the time this was considered feasible in spite of the fact that ratoon yields of crops cut late in November and mid-December were very poor. Interestingly, the authors noted that this practice might not prove satisfactory if continuos cropping over the long term had a negative impact on the physical condition of soils. An analysis of data from farm production records and several mills in Queensland for the period 1970-1979 failed to reveal any adverse effects on productivity as a result of increased land utilisation and reduced fallowing (Roach *et al*., 1981). However, the authors also conceded that the results of the study could not be used to predict long-term effects of increased rotations or reduced fallowing.

Yield decline

The evidence of yield decline in sugarcane was noted as early as 1959 in the United States. At that time the phenomenon was referred to as variety yield decline and was defined simply as "an unexplained or obscure gradual decrease in the yield of a clone" (Coleman, 1974). Following a symposium on the subject at the 10th Congress of the International Society of Sugarcane Technologists held in Hawaii (1959), the US Department of Agriculture undertook a comprehensive research initiative to study many aspects of variety yield decline. After 10 years of intense and diversified research carried out at the United States Department of Agriculture and Agricultural Research Service field stations in Florida, Louisiana, Puerto Rico, Hawaii, and Maryland, researchers conceded they were a long way from solving or completely understanding the problem of variety yield decline (Coleman, 1974).

The Australian sugar industry experienced a productivity plateau between 1970 and 1990 as a result of changes in farming systems and the phenomenon of yield decline. Yield decline has been defined as " the loss of productive capacity of sugarcane growing soils under long term monoculture" (Garside *et al*., 1997c). The significance attached to the yield decline syndrome in Australia resulted in the formation of a Joint Venture group in 1993 involving The Sugar Research and Development Corporation, the Bureau of Sugar Experiment Stations, the CSIRO Division of Soils and the Queensland Department of Primary Industries. The group is currently examining soil and crop problems in three systems: paired old and new sites, the breaking of monoculture followed by cultivation of other species, and after new land is planted with sugarcane and allowed to ratoon. These studies have focused on soil chemical, physical, and biological properties and their relationship to cane growth and yield (Garside *et al*., 1995; Garside and Nable 1996; Garside *et al*., 1997c; Garside and Bell, 1999). Evidence suggests that while the decline of productive capacity of sugarcane-growing land in Australia under long term monoculture (yield decline) is an important component of the productivity plateau, it is not the sole explanation (Garside *et al*., 1997c).

Soil degradation

The impacts of long-term sugarcane production on soils in Thailand were addressed by Prammanee *et al*. (1993). They reported that silty clay loam soils planted with sugarcane for extended periods of time lost their structure. The resulting effects included the formation of hard pans, decreased water-holding capacity, surface compaction, runoff, and erosion. Cane burning and the introduction of heavy harvesters and loaders exacerbated the condition with the end result being reduced cane yields.

Soil degradation as a result of sugarcane monocropping has been linked to ratoon yield decline on an irrigated Estate in Swaziland (Nixon, 1992 and Henry and Ellis, 1995). A comparative study of the chemical, physical and biological properties of oxisols and duplex soils was conducted to detect soil properties which might affect the productivity of ratoon crops (Henry and Ellis, 1995). Results indicated that cane monocropping often results in degradation of soil properties via reduction of available soil potassium (K), surface crusting, low infiltration rate, low total available moisture (TAM), low organic matter (OM), high bulk density (BD), (Table 1) and sodicity, particularly at depth.

In South Africa, some 60% of the area under sugarcane production comprises the grey group of soils (SASEX Soil identification and management working group, 1999). Poor cane growth, reduced yields, and frequent need for re-establishment have been associated with these soils. Ratoon cane management practices such as burning at harvest, harvesting under wet conditions, interrow ripping, and heavy infield transport have been implicated in soil degradation and subsequent ratoon yield reduction (Meyer, 1995). The effects of other soil degradative processes on cane productivity have also been studied in South Africa. Included are acidification (Schroeder *et al.,* 1994), compaction (Swinford and Boevey, 1984), erosion, (Platford, 1979 and 1982), intake rate decline (Meyer, 1988), irrigation water quality (Culverwell and Swinford, 1985), salinisation (Johnston, 1978), surface crusting (Dewey and Meyer, 1989), and waterlogging (Van Antwerpen *et al.,* 1991).

Benefits of green manures to sugarcane soils

As the occurrence of yield decline on sugarcane growing soils was noted in the fifties, researchers began to suspect a link with long-term monoculture. The idea of returning to break, fallow and green manure crops in sugarcane rotations began to be investigated in the form of alternative management strategies. Early work during this time focused mainly on changes in soil conditions resulting from different management strategies. A 20 year study initiated in the Deccan Canal tract in India on calcareous, high clay (montmorillonitic), deep soils investigated soil changes under different cultural and manurial practices. A comparison between ammonium sulphate, sodium nitrate, farm manure and sunn hemp revealed that while commercial fertilisers resulted in better nitrogen status of the soil, sunn hemp and farm manure significantly increased the humus content (Table 2) (Kumari *et al*., 1956).

Early experiments conducted in Louisiana between 1940 and 1950 focused on optimising the use of green manures with respect to soil type and time of incorporation (Arceneaux, 1943; Tidmore and Volk, 1945; Davidson and Arceneaux., 1948; Herbert and Davidson, 1959). The impact of the fallow period between ploughing under green manure residues and planting the succeeding cane crop was understood at an early stage (Arceneaux, 1943). It was later stated that "our practice of growing a summer legume crop in rotation with sugarcane falls short of optimum as a result of inappropriate timing with respect to availability of nitrogen and possibly other elements liberated by decomposing vegetation" (Arcenaux, 1946). Studies in Alabama concluded that while adequate amounts of nitrogen for the production of non-leguminous crops could be attained by ploughing under sufficient quantities of summer or winter legumes, care should be taken to plough under summer legumes at the right time, lest the nitrogen released be lost through leaching (Tidmore and Volk, 1945).

Davidson and Arcenaux (1948) reported an increase in cane yield on well-drained alluvial soils in Louisiana when substantial amounts of either cane leaves or soybeans were incorporated. Experiments in Puerto Rico on two sugarcane soils: (1) a well drained latosol and (2) a poorly drained heavy latosol revealed that additions of organic matter produced no effect in well drained soils, but both cane yields and organic matter were increased when organic matter was incorporated into the

Table 1. Organic carbon and bulk density of duplex and oxisol soils[1].

Depth (cm)	---[2]Carbon (%)---				Depth (cm)	----Bulk density ($g\ cm^{-3}$)----			
	Duplex		Oxisol			Duplex		Oxisol	
	V	C	V	C		V	C	V	C
0-15	1.48	1.36	2.16	1.96	15-20	1.60	1.67	1.37	1.63
15-30	1.48	1.15	1.74	1.78	45-50	1.59	1.76	1.37	1.54
45-60	1.13	0.56	1.03	0.96	85-90	1.62	1.77	1.32	1.53

[1] V: virgin soil, C: cropped soil
[2] Walkley Black method

Table 2. Humus and total nitrogen content of a montmorillonitic soil under organic manures and nitrogenous fertilisers.

(Kumari *et al.,* 1956)

	Depth (cm)	Control	Farm Yard Manure	Sunn Hemp	$(NH_4)_2SO_4$	$NaNO_3$
Humus %	0-15	1.05	1.14	1.11	0.76	0.84
	15-30	1.15	1.04	1.09	0.70	0.80
	30-45	0.89	0.96	0.91	0.69	0.80
	45-60	0.74	0.87	0.81	0.65	0.70
Total Nitrogen %	0-15	0.045	0.055	0.061	0.090	0.076
	15-30	0.043	0.041	0.058	0.084	0.071
	30-45	0.041	0.042	0.047	0.084	0.071
	45-60	0.043	0.047	0.050	0.083	0.076

poorly drained soil (Lugo-Lopez *et al.*, 1956). A summary of long-time legume rotation, winter legume and cane trash management on Louisiana sugarcane soils revealed a relationship between management strategy and soil type. On moderately well drained light silt loams and poorly drained silt loams, both cane and sucrose yields increased when cane trash and legumes were incorporated into the soil. However, the same treatments had no effect on poorly drained silty clay soil in both cane and sucrose yields (Herbert and Davidson, 1959).

In Thailand, most sugarcane in the western sugarcane belt is grown on silty clay loam soil. Prolonged monoculture has resulted in compaction, low infiltration rates and surface crusting. Field trials, ^{15}N tracer studies, and microplot experiments were conducted at the Suphan Buri Field Crops Research Centre, Thailand from 1991-94 in order to determine whether green manuring would benefit silty clay loam soils. Results of a preliminary field study indicated that incorporation of sesbania (*Sesbania rostrata*) and sunn hemp (*Crotolaria juncea*) tended to increase soil organic matter and improve soil physical conditions as a function of bulk density (Table 3) (Prammanee *et al.*, 1995).

Results showed that where green manures were incorporated, inorganic fertiliser was still necessary for profitable cane production. However, the combination of green manure and fertiliser N produced better yields than when fertiliser N was applied in the absence of green manures indicating benefits to soil physical properties *(Prammanee et al.*, 1995).

Green manures have been used in Barbados and Hawaii to reduce the incidence of erosion through their use in building soil organic matter and in providing surface protection as cover crops. Since the 1960's, soil erosion in sugarcane soils in Barbados has increased exponentially. The reasons given include monocropping, intense mechanisation, and the ceasing of green manuring and mulching practices. Green manuring has been recommended to farmers in Barbados as part of a strategy to control erosion (Cumberbatch, 1985). Hawaiian sugarcane fields have suffered erosion during high-intensity rains between harvest and when the new crop closes canopy. In 1975 green manure legumes were tested at the Soil Conservation Service Plant Materials Centre in Molokai in the hope of finding a suitable cover crop to reduce erosion. Results showed bur clover (*Medicago hispida*) provided 40 per cent ground cover within one month of planting. Although the legumes studied died after four months due to shading by cane, the remaining stubble continued to provide ground protection up to 170 days after planting (Joy, 1997) (Figure 1). In addition, of the four legumes tested Biserrula (*Biserrula pelecinus*), narrowleaf trefoil (*Lotus tenuis*) and bur clover (*Medicago hispida*) produced higher total cane volume than did controls (Table 4).

Recent research initiatives with green manures

A renewed interest in the practice of green manuring for sugarcane has arisen in conjunction with the incidence of yield decline, the majority of recent work having been done in Aus-

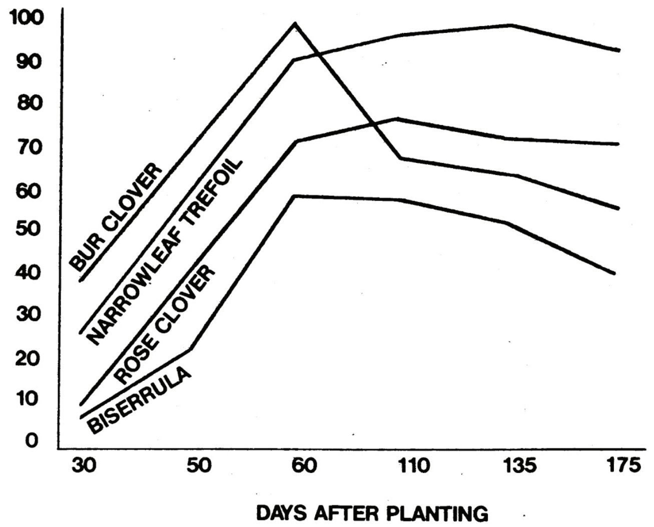

Figure 1. Legume cover (%) vs days after planting (Joy, 1977).

Table 3. Bulk density of soil[1] under sugarcane as influenced by chemical fertiliser and green manure in 1991.

(Prammanee *et al.*, 1995)

Treatment	Soil depth cm	Time after planting 3 mo	6 mo	10 mo
Green manure[2]	0-10	1.30	1.36	1.28
	10-20	1.39	1.32	1.39
	23-30	1.48	-	-
Green manure	0-10	1.39	1.32	1.34
+ chemical	10-20	1.37	1.37	1.38
fertiliser	23-30	1.43	1.38	-
Chemical	0-10	1.48	1.36	1.35
fertiliser	10-20	1.44	1.40	1.37
	23-30	1.50	-	-
Control	0-10	1.42	1.37	1.40
	10-20	1.36	1.40	1.37
	23-30	1.64	-	-

[1] silty clay loam, hydromorphic, noncalcic brown soil
[2] sesbania (*Sesbania rostrata*) + sunn hemp (*Crotalaria junceae*)

tralia. Much of the current work is centred on the use of green manure legume fallows in rotational experiments. The ability of green manure crops to produce biomass and fix nitrogen is quite often dependent on soil and seasonal conditions. In Australia, investigations have been conducted in order to optimise management of green manure fallows in wet tropical conditions. Factors under consideration include the tendency of soil to become waterlogged and the susceptibility of various legumes to disease (Garside *et al.,* 1996; Garside and Bell, 1999).

Other studies have concentrated on the relative amounts of nitrogen provided by different leguminous green manures and resulting reduction of nitrogen fertiliser inputs in various fallow regimes (Garside *et al.,* 1997a; Bell *et al.,* 1998; Garside *et al.,* 1998). Results from trials conducted by the Yield Decline Joint Venture indicate that a well managed fallow crop of soyabeans can provide sufficient nitrogen (>300 kg ha^{-1}) to eliminate the need for additional fertiliser nitrogen in subsequent plant cane crops (Figures 2 and 3) (Garside *et al.,* 1997a; Garside *et al.,* 1998). Grain legume species such as soyabean and peanut, when harvested for seed, have the benefit of functioning both as fallow legume and cash crop. However, research indicates the need for additional inputs in the form of insect and disease control and the availability of specialised harvesting equipment. In addition, the risk of seed contamination with pesticide residues from sugarcane must be controlled (Bell *et al.,* 1998). Recently published work from Australia indicates that part of the yield response in sugarcane following rotation breaks with pasture, bare fallow and green manure crops can be linked to soil microbial properties including the amount and composition of microbial biomass and reduction in some detrimental soil organisms (Pankhurst *et al.,* 2000).

In Swaziland, some excellent work has been carried out on the effects of green manuring on mainly irrigated duplex soils both at the trial and commercial field stage. In 1988, Hill. reported that the mean yields of 13 fallowed and green manured 40 ha blocks of land compared with the mean yields of 13 non fallowed blocks of land improved by 45% in the plant crop with residual effects of 25% measured in the 1st and 2nd ratoon crops. By using discounted cash flow analysis over a 30 year period, Hill showed that green manuring was on average 12.4% more profitable compared with conventional cropping.

Follow up trial work by Nixon (1992) confirmed large responses to bare fallowing (11-29%) and green manuring (10-54%) in the plant crop with small but non significant residual responses measured in the subsequent ratoon crops (Table 5). Yield increases were related to improvements in soil physical properties, particularly air- filled porosity at 10 kPa which increased on average from 11.9 to 16.1%, and the resulting improvement in rooting of subsequent cane crops. Intake rate and resistance to penetration under the green manure treatment also improved significantly due to incorporation of organic matter, with the effects being mainly restricted to the A horizon. It was noted however that soil organic matter levels were adversely affected by fallowing, probably as a result of the ploughing necessary for cane planting. Yield responses to both fallowing and green manuring were dependent on the relative condition of the soils, with more significant effects obtained on poorer soils, which are generally more sensitive to improvements than are better soils.

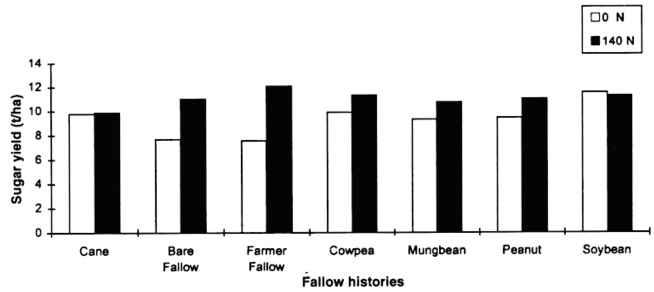

Figure 2. Cane yield (t ha^{-1}) following seven different fallow histories fertilised with 0 or 140 kg ha^{-1} N (LSD 5% = 11.4 for histories x nitrogen) (Garside *et al.*, 1977).

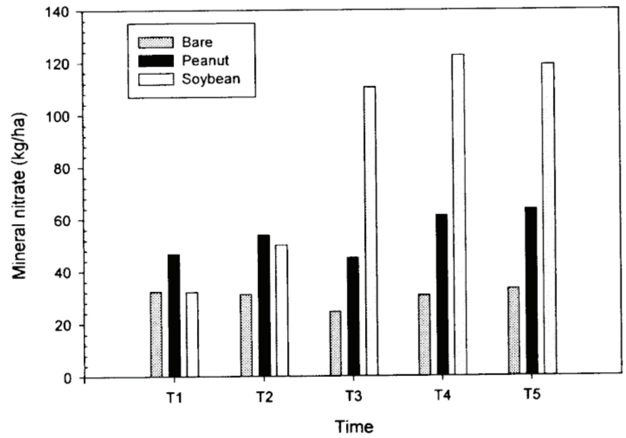

Figure 3. Cumulative mineral nitrate content over 90cm at five sampling times under treatments of bare fallow, incorporated peanuts or incorporated soyabeans. T1 = prior to incorporation, T2 = 33, T3 = 50, T4 = 83 and T5 = 137 days after incorporation (Garside *et al.*, 1998).

Table 4. Cane[1] volume dm^3 m^{-2} response to legume cover crops.

Species	Rep. 1	Rep. 2	Mean
Bisserrula[2]	30.52	24.42	27.47
Narrowleaf trefoil[3]	23.89	36.76	30.32
Bur clover[4]	24.95	37.92	31.43
Control	24.50	26.28	25.39

[1] 6 months maturity

[2] *Biserrula pelecinus*

[3] *Lotus tenuis*

[4] *Medicago hispida*

Nutrient effects were also investigated in the trials. Results showed that when the full nutritional requirements of sugarcane were applied in an inorganic form, incorporation of legumes made no significant contribution to the nitrogen nutrition of subsequent cane crops with respect to yield, percent sucrose or leaf nitrogen. However, when the supply of inorganic nitrogen was restricted, incorporation of green manures appeared to enhance cane yield (relative to controls) by supplying nitrogen. Mhlume is currently the only large irrigated sugar estate to have adopted green manuring on a commercial scale.

Future green manuring research at SASEX

Research into green manuring practices in sugarcane production has resumed in South Africa as part of a program initiated by SASEX to study the effects of soil degradation as a result of long term monoulture. Since May 1999, field trials have been installed to assess the suitability of various green manures under different production cycles. The effects of green manuring on soil physical, chemical and biological properties as well as sugarcane yields are under investigation at sites throughout the sugarcane growing region of South Africa. The goals of the green manuring program at SASEX include assessment of various legumes and non-legumes to improve a variety of soil types under different types of management strategies. Research is focused on the development of precision management techniques using green manures in rotations, intercropping and minimum tillage practices. In addition, laboratory studies are focused on the effects of green manuring on soil microbial populations, diversity and activity in sugarcane soils.

A potential benefit that has not yet been researched in the South African industry is the effect of green manuring in controlling pathogens such as ratoon stunting disease (RSD), mosaic, and nematodes. This could further improve the economics of green manuring. Undoubtedly the greatest benefit from green manuring will be in the rainfed areas of the industry on soils prone to erosion. This includes mainly the grey group of sandy soils on slopes in excess of 5% where there is insufficient clay and organic matter to maintain cohesiveness. Bottomland soils with low air filled porosities could also benefit.

An important aspect of green manuring research is to raise awareness among growers about the impacts of soil degradation and the importance of management practices that will ensure sustainable soils. To this end SASEX has compiled a three part series of information sheets on yield decline, soil sustainability and green manuring practices for distribution to growers (SASEX, 2000 a,b,c). Soil specific recommendations for green manuring are also contained in the recently revised Soil Bulletin No 19 (SASEX Soil Identification and Management Working Group, 1999). Similar bulletins addressing green manuring have been published by the Bureau of Sugar Experiment Stations (BSES) in Australia (BSES, 1993, 1994 a,b). The most integral part of any change in management practices is acceptance by growers. Future research efforts into the use of green manures in sugarcane production must proceed from the standpoint of precision management. Recommendations for green manuring will need to take into account soil type, climatic conditions and past yield and disease history. In addition, research should focus on making the practice of green manuring practical, feasible, and thus more readily acceptable to growers.

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Table 5. Mean sugarcane yields Mg ha^{-1} in response to green manure fallowing on an irrigated estate in Swaziland.

(Nixon 1992)

Crop	Fallow green manure[1]	Non-fallow	% Difference
Plant	150	103	45.6
1st Ratoon	119	95	25.3
2nd Ratoon	109	88	23.9
3rd Ratoon	90	86	4.7

[1] Sunn hemp (*Crotalaria junceae*) and cowpeas (*Vigna unguiculata*)

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