SOYBEAN IN SUGARCANE BREAKCROP SYSTEMS IN ZIMBABWE: AN ASSESSMENT OF POTENTIAL NUTRIENT AND ECONOMIC BENEFITS

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Abstract

Nitrogen fertilizer is a substantial cost component of the sugarcane cropping system. Soybean was chosen as a breakcrop during RSD fallows because it fixes nitrogen. The overall objective of the study was to determine the nutrient and economic benefits of using soybean as a breakcrop during RSD fallows. This research was conducted at Zimbabwe Sugar Association Experiment Station. A vegetable soybean variety and a grain soybean were studied. The vegetable variety fixed 234 kg N/ha and the grain fixed 58 kg N/ha. Phosphorus, calcium and organic matter were significantly different ($p<0.05$) between soybean and fallow plots. Sugarcane planted after the vegetable soybean variety produced more biomass and tillers than that planted after grain soybean plots. It can be concluded that vegetable soybean improved soil N more than grain soybean. Vegetable soybean had a sale profit margin of Z$1.1 million/ha and grain soybeans had Z$1.56 million/ha. However, considering the total economic benefits from N fertilizer savings the potential profit from vegetable soybean (Z$1.85 million/ha) was substantially greater than grain soybean (Z$1.48 million/ha).

Keywords: breakcrops, vegetable soybean, grain soybean, green manuring, economic benefits, nitrogen

Introduction

The RSD infection rate in sugarcane in Zimbabwe during 2003 was 19.8% in variety N14 and 0.1% in CP72-2086 (Anon, 2003a; Anon, 2003b). Although N14 is more susceptible to RSD, sugarcane growers still plant N14 because it is one of the highest yielding varieties (Zhou, 2004). Several methods of controlling RSD such as field hygiene, heat treatment and dipping of cane knives and implements in chemicals such as Jeyes fluid have been adopted by sugarcane growers in Zimbabwe (Anon, 2003a). These methods alone cannot control RSD in fields with volunteer cane. This has led sugarcane growers worldwide to adopt fallowing as a disease control strategy. Fallowing is, however, unattractive and considered uneconomic by sugarcane growers in Zimbabwe. Both the small-scale growers and the estates consider fallowing a waste of land use and a great loss of cane growth for 90 days. Fallowing is thus perceived to cause a loss in revenue. In Zimbabwe the rate of plough-out on estates varies from 10 to 12% per year (Clowes and Breakwell, 1998). Up to 4300 ha of land may be left fallow in any one season on these estates, hence the need to come up with a breakcrop that fits well into the 90-day fallow period.

Of the several breakcrops used, soybean has shown that it can adapt well to the climatic conditions of the sugarcane producing areas of Zimbabwe and has the greatest potential to fix nitrogen. It has the potential to fix large amounts of nitrogen of up to 300 kg N/ha (Giller *et* *al*, 1997; Viator and Griffin, 2001). Nitrogen fertilizer is a substantial cost component of the sugarcane cropping system, so any strategy that can maximise the availability of legume nitrogen and reduce the need for nitrogen fertilizer should be encouraged (Chokowo *et al.*, 2003).

The monoculture system of sugarcane production affects other nutrients such as phosphorus and potassium, and also exchangeable bases, pH and organic matter levels in the soil (Alaban *et al*, 1990; Meyer and van Antwerpen, 2001;). A cane yield of 100 t/ha removed 120 kg N/ha, 133 kg P/ha and 125 kg K/ha (Sundara, 1982; Anon, 2003a)

There is limited literature on the dynamics of nutrients other than N in crop rotation systems in Zimbabwe. This research provides some information on these dynamics. The overall objective of this study was to determine the nutrient and economic benefits of using soybeans as a breakcrop during RSD fallows in sugarcane production systems.

Materials and Methods

Site and climate

The study was carried out at the Zimbabwe Sugar Association Experiment Station (ZSAES) in the South Eastern Lowveld of Zimbabwe, at 430 m altitude 21º01'S latitude and 28º38'E longitude. The station is located on sandy clay loam soils (Clowes and Breakwell, 1998). In the top 0-30 cm the soil is sandy loam (18% clay, 5% silt and 77% sand) and is brown in colour. The average annual rainfall is 625 mm per annum, falling predominantly in the hot summer months of October to March. Mean air temperatures vary from about 26ºC in summer to 16ºC in winter (Anon, 2000). Before the initiation of this research, the whole experiment area was under sugarcane of variety NCo376 for six years.

Experiment design

The experiment plots were arranged in a completely randomised block design (RCBD) with three treatments in the first experiment, namely vegetable soybean, grain soybean and fallow. The treatments were replicated four times. The second experiment had the sugarcane varieties CP72-2086 and N14 planted after the soybean was harvested. Cane planted on fallow plots was used as a control crop. They were randomly planted. Plot sizes were 22 m x 10 m. The nett plot area was 25 m^2.

Soil sampling

Soil samples were collected per individual plot before the planting of and after the incorporation of soybean at 0-30 cm and 30-90 cm, using a 50 mm augur. The soil samples were analysed for total nitrogen using the Micro-Kjeldahl method, phosphate using the Resin method, exchangeable bases using the standard ammonium acetate extraction procedure, pH using calcium chloride, and organic matter using the Walkley-Black method.

Soybean production phase

Treatments used in this phase were vegetable soybean of variety S114, and grain soybean of variety Storm. On 19 February 2004 soybeans were planted at an interrow spacing of 0.75 m and inrow spacing of 0.05 m, at a seeding rate of 80 kg/ha. A mixture of Commando (63 ml) and Lasso (286 ml) in 15 L of water was applied for controlling weeds. Phosphorus was applied at 100 kg P_2O_5/ha using single superphosphate fertiliser before planting. The crop was furrow irrigated.

Determination of soybean biomass and nutrients in plant

All plants in the nett plot area of 5 m^2 were cut at ground level for the determination of total biomass. The dry weights of plant samples were measured after oven drying to a constant weight at 60ºC. From the positions that were marked for the collection of soybeans for biomass determination, five plants were selected per plot for nutrient analysis. From each plant 10 leaves, five pods, 10 petioles, one stem and 10 grains were analysed. The samples were wet digested and then analysed for nitrogen, phosphate and bases.

Estimation of N_2 fixation

The proportion of nitrogen fixed was estimated using the N difference method . Weeds from the unfertilised plots were used as non-fixing reference crop. The weeds were also sampled at the time of sampling the soybean plants. Both the soybean and weed samples were oven dried at 60ºC to a constant weight, and then nitrogen was determined using the Micro-Kjeldahl method. The N_2 fixation was determined at maturity of the soybean crops. Nitrogen fixation in grain soybean was determined at 120 days after planting and in vegetable soybean at 80 days after planting.

Harvesting of soybeans

Mature vegetable soybean pods were harvested green after 81 days. The above-ground parts of the vegetable soybean crop were ploughed into the soil after harvesting the pods. The grain soybeans were harvested when they were physiologically mature after 120 days. The plant parts for grain soybeans were cut at ground level and removed from the fields. Only the root component was incorporated during land preparation.

Subsequent sugarcane production

On 9 and 10 July 2004 sugarcane varieties N14 and CP72-2086 were planted after the soybeans and on fallow plots as a control crop. The crop was planted using two, three-eyed cane setts at an interow spacing of 1.5 m. The depth of the furrows was 0.3 m. Cane knives were dipped in Jeyes fluids, a disinfectant, during preparation of seedcane setts in order to prevent the spread of RSD. The seedcane setts were dipped in bayfidan to reduce the transmission of disease pathogens. A mixture of Lasso (295 ml) and Atrazine (295 ml) in 15 L water was used to control weeds. Phosphorus was applied at 100 kg P_2O_5/ha before planting and potassium was applied at 60 kg K_2O/ha. Nitrogen was applied four weeks after emergence at 120 kg N/ha. The crop was furrow irrigated.

Sampling for dry matter and tiller population started when the cane was three months old, and thereafter was done monthly until the crop was five months old. Destructive sampling was done on 1.5 m^2. All the sugarcane plants in the sampling area were cut at ground level and oven dried at 70ºC to a constant dry weight.

Economic benefits

The partial budget tool was used to analyse the economic benefits of planting soybean during the RSD fallows in sugarcane production (Ryen and Dancel, 1989). This tool was selected because there were no major changes done to the production system. All variable costs for soybean production were calculated. Variable costs included seed, fertiliser, labour, land preparation, water, inoculants, bags and herbicides. Green pods from vegetable soybeans and mature grain or seed from grain soybeans were marketed.

Statistical analyses

The soybean and sugarcane plant and soil nutrient data were subjected to analysis of variance (ANOVA) using MSTAT version 4, and means were compared at probability $P<0.05$.

Results and discussion

Soil characterisation

The average chemical characteristics of the soil on fallow and soybean plots after incorporating vegetable soybeans are given in Table 1.

Table 1. Chemical characteristics of soil on fallow and after incorporation of soybean.

Treatment	N (ppm)	P_2O_5 (ppm)	K_2O (m.e%)	Ca (m.e%)	Mg (m.e%)	OM (%)	pH ($CaCl_2$)
Fallow	20 a	36.9 a	0.38 a	10.98 a	2.23 a	0.96 a	6.09 a
Grain soy	19 a	21.5 b	0.41 a	6.93 b	2.27 a	0.84 b	5.99 a
Vegetable soy	21 a	29.5 c	0.40 a	9.96 a	2.25 a	1.01 c	5.92 a
Sig.	ns	*	ns	*	ns	*	ns
CV%	13.9	13.5	16.93	19.66	13.61	18.86	12.36

*Means within the same column are significantly different at *=P<0.05 and ns=not significant. Means within the same column followed by the same letter are non-significantly different at the 5% level and means followed by the different letters are significantly different at the 5% level.*

There were no significant differences in mineral N among soils under fallow, vegetable soybean and grain soybean (Table 1). Due to land preparation problems at the ZSAES, the vegetable soybean biomass was incorporated a bit late. Late incorporation led to high lignin and polyphenolic contents, which release nutrients slowly (Giller *et al*, 1997). Kuntashula *et al*. (2003) also found that, when incorporated late, legume biomass tends to decompose slowly and release less nutrients in the early stages of plant growth.

Phosphorus and calcium were significantly different ($P<0.05$). Fallow plots contained the highest levels of P (Table 1) since there was no crop to remove P from the soil. The low level of this nutrient in the soybean plots was due to removal of available P by the crop. However, the incorporation of vegetable soybean biomass may help to return P to the soil in the long term. This is valuable for the incoming cane crop (Sundara, 1982). The high biomass in cane from vegetable soybean plots can be due to an extensive root development after incorporation of plant material, in addition to the P already in the soils (Shoko, 2005).

Depletion of Ca from the soil profile was the greatest for grain soybean and significant when compared with the Ca status of the fallow soil, whereas the vegetable soybean showed very little depletion of Ca. The results suggest that the incorporation of vegetable soybean will be more effective than the grain soybean in maintaining the soil Ca status. The lack of any significant differences in the Mg and K contents between the two soybean treatments and the fallow treatment, suggests that the depletion of these nutrients from the soil by the two soybean crops was matched by the return of K and Mg following the incorporation of the residues.

Organic matter (OM) was significantly different ($P<0.05$) between the treatments. Vegetable soybeans plots had 13.5% more OM than fallow plots, while grain soybean plots had only 0.12% less OM than the fallow plots (Table 1). It appears that the incorporation of above ground vegetable soybean biomass improved the soil OM more as the plant material decomposes. An increase in OM can lead to improved cane yield due to good aeration, improved water holding capacity and high water infiltration rate (Sundara, 1982; Meyer and van Antwerpen, 2001). There were no significant differences in pH levels between the three treatments (Table 1).

Soybean biomass and nitrogen fixed

Above-ground dry biomass, plant populations, nitrogen concentration in tops and estimates of nitrogen fixed by vegetable and grain soybeans are given in Table 2. Studies by Chikowo *et al*., (2003) observed that only 30 % to 34% of the N fixed by soybean was returned to the soil for the subsequent crop in the first season. From the above it can be inferred that vegetable soybean probably added between 75 and 79 kg N/ha and grain soybean between 15 and 19 kg N/ha.

Table 2. Above-ground dry biomass at maturity (t/ha), plant populations (plants/ha), nitrogen (N) concentration (%) at maturity and N fixed (kg/ha).

Treatment	Plant population	Biomass (t/ha)	N (%)	N fixed (kg/ha)
Vegetable soybean	142 725	5.92	3.96	234
Grain soybean	156 575	4.43	1.31	58
SE	1.44	1.44	0.22	
CV%	15.74	15.74	8.68	

Total nutrients per plant

Total nutrient contents of vegetable and grain soybeans are given in Table 3. There were significant differences ($P<0,05$) in nitrogen, phosphorus, potassium and calcium but no significant differences for magnesium between grain and vegetable soybean. Vegetable soybean had 18, 23 and 11% more nitrogen, phosphorus and potassium, respectively, than grain soybean. Grain soybean, on the other hand, had 21 and 4% more calcium and magnesium, respectively, than vegetable soybean.

Table 3. Nitrogen (N), phosphorus (P_2O_5) and bases as percentages of total dry matter of vegetable and grain soybean plants.

Treatment	N	P_2O_5	K_2O	Ca	Mg
Grain soybean	9.39	0.87	4.12	5.51	1.91
Vegetable soybean	11.10	1.07	4.56	4.57	1.83
Sig.	*	*	*	*	ns
CV%	8.68	14.18	8.13	9.08	13.07

*Means within the same column are significantly different at *=P<0.05 and ns=not significant.*

Sugarcane biomass

The dry matter (biomass) yield of the sugarcane varieties CP72-2086 and N14 at different sampling dates after planting are shown in Figures 1 and 2.

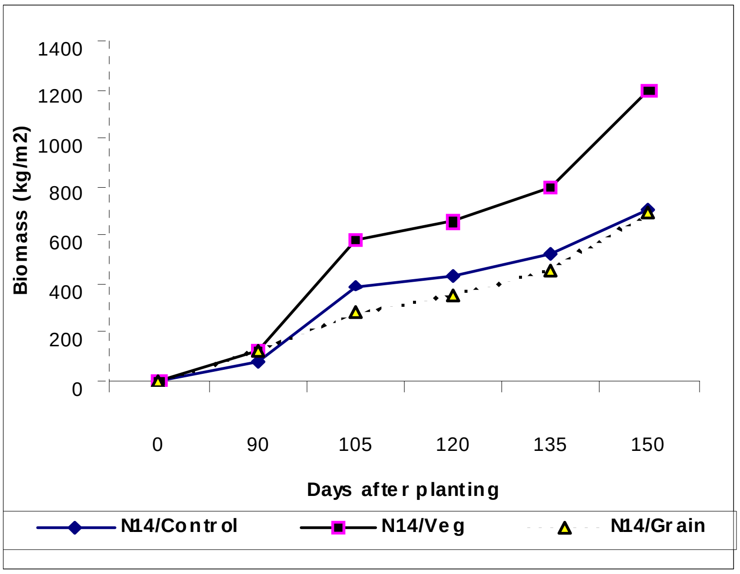

Figure 1. Biomass (kg/m^2) of sugarcane variety N14 planted in control, grain soybean and vegetable soybean plots.

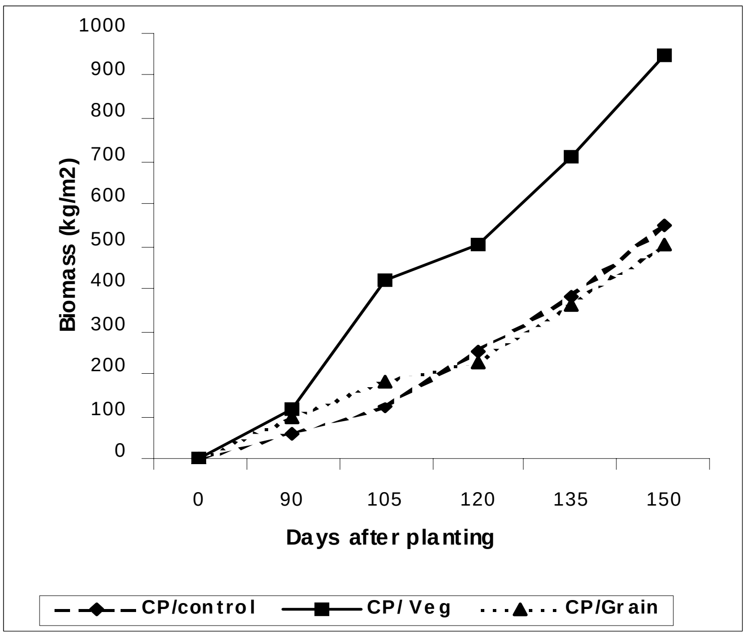

Figure 2. Biomass (kg/m^2) of sugarcane variety CP72-2086 planted in control, grain soybean and vegetable soybean plots.

Biomass of N14

There was no significant difference in biomass between treatments on the first sampling date at 90 days after planting (Figure 1). However at 105, 120, 135 and 150 days after planting, N14 on vegetable soybean plots had the greatest biomass of 581.75, 656.20, 765.20 and 1200 kg/m^2 respectively. N14 planted in control plots and grain soybean plots did not show any significant differences as from 120 days after planting. High biomass in vegetable soybean plots could be attributed to the contributions of nutrients and OM from ploughed-under biomass (Shoko, 2005).

Biomass of CP72-2086

There were significant differences in biomass between the three treatments. Cane planted on vegetable soybean plots had the largest biomass. As in N14, this could be because of the ploughing-under of the vegetable biomass and the high nitrogen fixed by vegetable soybean. However there were no significant differences in biomass of cane planted on grain soybean and control plots.

Tiller populations

N14 planted in vegetable soybean plots had the most tiller numbers at all the sampled ages of the cane (Figure 3). However, at 135 days after planting N14 in grain and vegetable soybean plots had the same number of tillers. N14 in control plots had the least tiller numbers at all the sampled dates. Peak tillering was reached at 120 days after planting in all the three treatments. After 120 days there was a decline in tiller numbers in all three treatments.

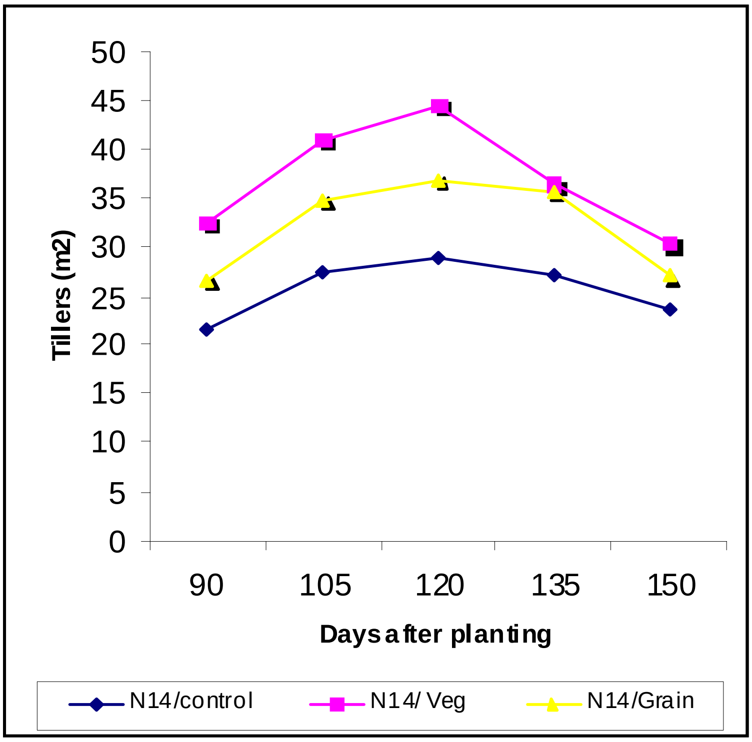

Figure 3. Tiller population trends of N14 planted in control, grain soybean and vegetable soybean plots.

At 90 days after planting, CP72-2086 in the grain soybean plots had the most tillers (Figure 4). However, from 105 to 150 days CP72-2086 planted in vegetable soybean plots had the most tiller numbers. CP72-2086 in control and grain soybean plots reached peak tillering at 105 days after planting, and in vegetable soybean plots peak tillering was reached 120 days after planting, and thereafter there was a decline in tiller numbers.

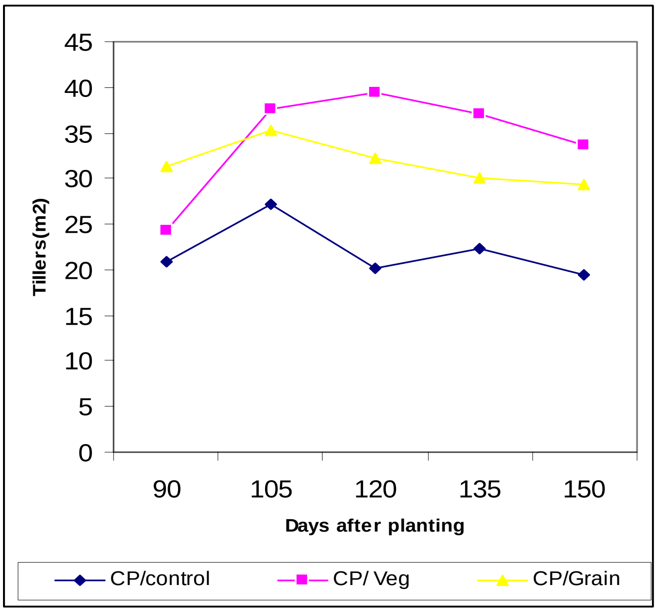

Figure 4. Tiller population trends of variety CP72-2086 planted in control, grain soyabean and vegetable soybean plots.

N14 showed a higher tiller population in the first four months than CP72-2086 (Figures 3 and 4). N14 had a higher tiller population in vegetable soybean plots than CP72-2086. In the vegetable soybean plots, peak tillering was achieved at around 120 days after planting in both varieties and thereafter there was a general decline in tillers (Figures 3 and 4).

Economic benefits

Green pods of vegetable soybean and mature grain of grain soybean constituted the yield. The yields, gross income, variable costs, net profit and total savings for each soybean treatment are given in Table 4. Grain soybeans had a higher yield and profit margin. The vegetable soybean can make N fertiliser savings of about 75 kg N/ha and grain soybean can contribute 15 kg/ha (Shoko, 2005). Considering the savings from N fertilisers and crop sales, vegetable soybean produced more economic benefits than grain soybean (Table 4).

Table 4. Mean yield (t/ha), gross income (ZW$ million/ha) from sales of pods (vegetable soybean), total variable costs and net profit (ZW$ million/ha).

Treatment	Yield	Gross income	Variable costs	Nett profit	Savings
Vegetable soybean	2.84	2.84	1.74	1.10	2.36
Grain soybean	1.14	3.31	1.63	1.68	0.34

Conclusions

Vegetable soybean added more N to the soil than grain soybean. Vegetable soybean produced more economic benefits for the resource-poor sugarcane grower than grain soybean, when used as a breakcrop during RSD fallows. Apart from the monetary reward to the farmer through the sale of green pods, vegetable soybean has the potential to improve the N, K, Ca and OM status of the soil. Soybean mined P from the soil, so there is need for the sugarcane grower to analyse the phosphorus status of the land after growing soybean. Soybean helped to maintain the ideal soil pH for sugarcane production. The incorporation of above-ground biomass of vegetable soybean helped to raise the OM by 5.6%. Improved OM can help the subsequent sugarcane crop to grow better.

The significant differences in tiller and biomass populations in the two cane varieties showed that the three treatments affected soil conditions differently. Results showed that cane following vegetable soybean had more tillers and biomass. This indicates the potential of vegetable soybean to improve cane growth and development. Other nutrients may also have influenced the growth pattern of the cane. Future research needs to study the benefits of incorporating the leaves and stems of grain soybean.

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