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Benefits of Soyabeans as a Breakcrop in Sugarcane Production Systems in the South Eastern Lowveld of Zimbabwe

Abstract

Nitrogen fertilizer is a substantial cost component of the sugarcane cropping system. Soybean was chosen as a break crop during fallow periods in sugarcane production systems because it has nutrient benefits like fixation of nitrogen. The overall objective of the study was to determine the nutrient benefits of using soyabean as breakcrop during fallow periods in sugarcane production systems in Zimbabwe. This research was conducted at Zimbabwe Sugar Association Experiment Station in the South Eastern Lowveld of Zimbabwe. The study was divided into two experiments. Experiment one was the soyabean production phase and the sugarcane production phase was in experiment two. Two soybean varieties, a vegetable and grain were studied. Sugarcane variety N14 was used in this study. 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 vegetable soyabean variety produced more biomass and tillers than after grain soyabean plots. It can be concluded that vegetable soybeans improved soil N more than grain soybeans. Soil chemical properties were significantly improved especially in plots which had vegetable soyabeans. Vegetable soybeans had a sale profit margin of Z$1.1million /ha and grain soybeans had Z$1.56 million /ha. However considering the total economic benefits from N fertilizer savings and sales, vegetable soybeans had Z$1.85 million/ha and grain soybeans had Z$1.48 million/ha.

Key words: benefits, breakcrops, grain soybeans, vegetable soyabeans

Introduction

Sugarcane is a giant crop producing large quantities of biomass and therefore removing large quantities of nutrients (Sundara, 1982; Shoko, 2005). Nitrogen requirements of sugarcane normally exceed the inherent capacity of soils to supply N through mineralisation of organic matter (Shoko, 2005; Shoko & Tagwira, 2005). On the other hand, provision of N through fertilization increases acidity (Tisdale et.al, 1999). A tonne of dry matter of sugarcane removes 1.6kgN, 0.6kgP and 2.25kgK (Viator and Griffin, 2001).

According to Clowes and Breakwell (1998), sugarcane generally requires 110-160kg N /ha if planted and 130-180kg N/ha if ratooned. This translates to 9 by 50kg of ammonium nitrate (A.N) if planted and 11 by 50 kg A.N if rationed (Shoko & Tagwira, 2005). Nitrogen deficiency generally leads to thin stalks, stunted growth and poor tillering (Sundara, 1982).N deficiency can reduce the sucrose concentration by about 9.3%. (Clowes and Breakwell, 1998; Zhou, 2004). This therefore means a lot of fertilizer is needed to produce a good sugarcane crop.

According to Alaban, et.al., (1990) research done in the Philippines and Australia shows that available P and K declined very drastically over a ten year period from 1979 to 1989 due to the monoculture system of sugarcane production. P declined from 27 mg/kg to 17 mg/kg and K from 145 mg/kg to 134 mg/kg. Hartermink and Wood (1998) working in Papua New Guinea found that a yield of 100 t.cane/ha removed 120 kg N/ha, 1.33 kg P/ ha and 125 kg K/ha. In South Africa continuous sugarcane production led to decreased pH, loss of soil organic matter and changes in soil biota (Meyer and Antwerpen 2001; Magarey, 1998). Hartermink and Wood (1998) working in Papua Guinea found that yield of 100 t.cane/ha removed 120 kg N/ha and 133 kg P/ha and 125 kg K/ ha.

So as to break the monoculture practice sugarcane farmers leave the land fallow for at least 90 days. However fallowing the land for 90 days is unattractive and considered uneconomic by sugarcane growers in Zimbabwe (Shoko & Tagwira, 2005). Both the small scale and the estates in Zimbabwe consider fallowing as wasteful on land and a great loss in cane growth for 90 days and hence loss of revenue. In Zimbabwe the rate of plough out in the estates is 10% to 12% per year (Clowes and Breakwell, 1998). About 4300 ha of land is left fallow in any one season in these estates (Shoko and Tagwira, 2005). Hence the need to come up with breakcrop that fits well in the 90 day fallow period.

Of all the several break crops 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 can fix large amounts of nitrogen of up to 300kg N/ha (Mills and Elphinstone, 2000; Viator and Griffin, 2001). Nitrogen fertilizer is a substantial cost component of the sugarcane cropping system, so any strategy that can maximize the availability of legume nitrogen and reduce the need for nitrogen fertilizer should be encouraged (Garside and Berthelsen, 2004).

The monoculture system of sugarcane production also affects other nutrients like phosphorus, potassium, exchangeable bases, pH and organic matter levels of the soil (Alaban et.al., 1990; Meyer and Antwerpen 2001; Magarey, 1998). The overall objective of this study was to determine the nutrient benefits of using soybeans as breakcrop during fallow periods in sugarcane production systems in Zimbabwe.

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, 430 m altitude 21001˚S latitude and 280 38˚E longitude. The research was conducted under irrigation farming system. The station is located on sandy clay loam soils (Clowes and Blackwell, 1998). In the top 0 to 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 260 C in summer to 160C in winter (Shoko & Tagwira, 2005). Before the initiation of this research the whole experimental area was under sugarcane (variety NCo 376) for six years.

Experimental Design

The experimental plots were arranged in a Completely Randomized Block Design (RCBD) with three treatments in the first experiment, namely vegetable soyabeans, grain soyabeans and fallow. The treatments were replicated four times. The second experiment had sugarcane variety N14 planted after soyabeans. Cane planted on fallow plots was used as control crop. They were randomly planted. Plot sizes were 22m x 10 m. The nett plot area was 25m2.

Soil sampling

Soil samples were collected at 0 to 30 cm and 30 to 90 cm, using a 50mm augur, before the planting and after incorporating soyabeans. The soil samples were analysed for total nitrogen using the Micro Kjeldahl method, phosphate using Resin method, exchangeable bases using ammonium acetate method, pH using 0.01M Cacl2 (1:5 soil: suspension) and organic matter using the Walkley Black Method.

Soybean Production Phase

Treatments used in this phase were vegetable soybeans, variety S114 and grain soybeans, variety storm. Soyabeans were planted using an interow spacing of 0.75 m and inrow spacing of 0.05 m at a seed rate of 80 kg/ha on 19 February 2004. Dual Gold and Gesaprim at 1.45L ha-1 and 3kg ha-1, respectively were used as pre-emergence herbicide mode of weed control. Phosphorus was applied at 100 kg P2O5/ha using single super phosphate fertilizer before planting.

Determination of Biomass and Nutrients in Soyabean Plant

All plants in the nett plot area of 5m2 were cut at ground level for the determination of total biomass.The plant samples were oven dried to a constant weight at 600 C and then dry weight was determined. From the positions that were marked for the collection of soybeans for biomass determination, five plants were selected per plot for nutrient analysis.

Estimation of N2 Fixation

The proportion of nitrogen fixed was estimated using N difference method (Ankomah, 1998). 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 soyabean and weed samples were oven dried to constant weight at 600 C and then nitrogen was determined using the Micro- Kjeldahl method. Nitrogen fixed by vegetable and grain soyabeans was determined at 80 and 120 days after planting respectively.

Harvesting of Soyabeans

Vegetable soyabean pods were harvested mature green after 80 days. Then the above ground biomass was ploughed into the soil after harvesting the mature green pods. The grain soyabeans 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

The subsequent sugarcane crop (variety N14) was planted after the soyabeans and on fallow plots. 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. The seedcane setts were dipped in bayfidan to reduce the transmission of disease pathogens. Phosphorus was applied at 100 kg P/ha before planting and potassium was applied at 60 kg K/ha. Nitrogen was applied at 120 kg N/ha.

Sampling for dry matter and tiller population started when the cane was three months old and thereafter was done monthly up to when the sugarcane crop was five months old. Destructive sampling was done on 1.5 m2. All the sugarcane plants in the sampling area were cut at ground level and oven dried at 70˚ C to constant dry weight for biomass determination.

Economic Benefits

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

Statistical Analyses

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

Results

Soil Characterization

Table 1 shows the chemical characterization of the soils from the experimental site on fallow and soybean plots after incorporating vegetable soybeans plant parts as well as the underground biomass of grain soyabeans.

The inherent soil nutrients were below the critical levels required by sugarcane as cited in the literature. After incorporating green vegetable soyabean plant parts there was an improvement on the levels of nutrients in the soil. The vegetable soyabeans which was ploughed in green had highest N and organic matter levels but lowest pH level. Soyabean plots had less Ca, K and pH than fallow plots. All in all vegetable soyabean plots had higher nutrient levels than grain soyabean plots.

Soyabean Biomass and Nitrogen Fixed

Above ground dry biomass, plant populations and estimates of nitrogen fixed by vegetable and grain soybeans are

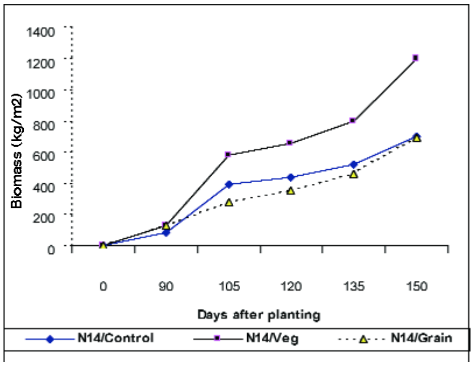

Figure 1. Biomass (kg / m2) of N14 planted in control, grain and vegetable soyabean plots (pp17).

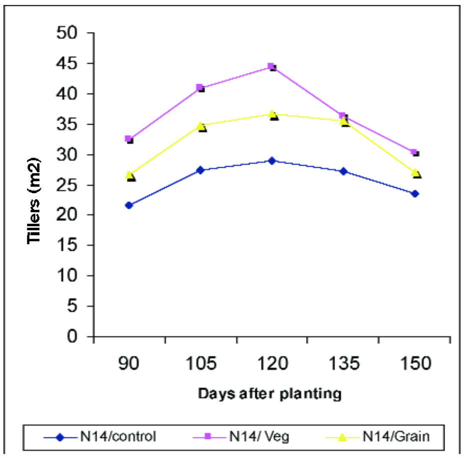

Figure 2. Tiller population trends of N14 planted in control, grain and vegetable soybean plots (pp18).

shown on Table 2. Vegetable soyabeans had the higher biomass and fixed more N than grain soyabeans. Vegetable soyabeans fixed 234 kg N/ha and grain soyabeans fixed 58 kg N/ ha.

To tal Nutrients Per Plant

Total nutrient contents of vegetable and grain soyabeans are shown on 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 soyabeans. Vegetable soyabean had 18%, 23% and 11%, more nitrogen, phosphorus and potassium respectively than grain soybean. Grain soyabean on the other hand had 21% and 4% more calcium and magnesium respectively than vegetable soyabeans.

Biomass of the Subsequent Sugarcane [Variety N14] Crop

There was no significant difference of the biomass among treatments on the first sampling date at 90 days after planting (Figure 1). However at 105, 120, 135 and 150 days after planting, N14 planted on vegetable soyabean plots had the greatest biomass of 581.75, 656.20, 765.20 and 1200 kg/ m2 respectively. N14 planted in control plots and grain soyabean plots did not show any significant differences as from 120 days after planting.

Tiller Populations of the Subsequent Sugarcane [Variety N 14] Crop

Figure 2 shows that N14 planted in vegetable soyabean plots had the most tiller numbers on all the sampled ages of the cane. However at 135 days after planting N14 in grain and vegetable soyabeans 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, with vegetable soyabean plots having the highest number which was 45 tillers. After 120 days there was a decline in tiller numbers in all the three treatments.

Economic Benefits:

Green pods of vegetable soyabean and mature grain of grain soybeans constituted the yield. The yields, gross income, variable costs, net profit and total savings for each soybean treatment are shown on Table 4. Grain soybeans had a higher yield and profit margin. The vegetable soybeans can make N fertilizer savings of about 75 kg N/ha and grain soybeans contributed 15 kg/ha (Shoko, 2005). Bank loan savings was calculated at 155% per annum. So considering the savings from N fertilizers and crop sales, vegetable had more economic benefits than grain soybeans (Table 4).

Discussion

There were no significant differences in mineral N among the fallow, vegetable and grain soybean (Table 1). Due to land preparation problems at the station the vegetable soyabean 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 out that lately incorporated legume biomass tend to decompose slowly and releasing less nutrients in the early stages of plant growth.

Studies by Garside and Berthelsen (2004) indicated that 30% of the total mineral nitrogen fixed by soybean crop is added to the soil in the first season. Chikowo, et.al.,(2003) observed that only 34% of the N fixed by soybeans was returned to the soil for the subsequent crop. From the above we can say vegetable soybean probably added 75 to 79 kg N/ha and grain soybeans 15 to 19 kg N/ha.

Phosphorus and calcium were significantly different (P<0.05). Fallow plots had the most P (Table 1). Since there was no crop on fallow plots, probably P was not mined from the soil. The low levels of the nutrient in soyabean plots could be that the crop used the available P already in soil for its growth. However the incorporation of vegetable soyabean biomass can help to return P to the soil in the long run (Shoko and Tagwira, 2005). This is valuable for the incoming cane crop (Sundara, 1982). The high biomass in cane from vegetable soybeans plots can be due to an extensive root development due to incorporation of plant material in addition to the P already in the soils (Shoko, 2005)

There were non-significant differences in Mg and K content of the soil. Significant differences (P<0.05) were noted on Ca (Tables 1). However Cafrom fallow and vegetable soyabeans was non-significantly different. Grain soyabean plots had the least Ca. This may be attributed to the quantity of Ca mined from the soil by the grain soyabeans (Table 1). Therefore, the incorporation of vegetable soyabean biomass can restore Ca in the soil for the subsequent sugarcane crop.

Organic matter (OM) was significantly different (P < 0.05) among the treatments. Vegetable soyabean plots had 13.5% more OM than fallow plots while grain soyabean plots only had 0.05% more OM than fallow plots (Table 1). Maybe the incorporation of above ground vegetable soyabean biomass improved the soil OM

Table 1. Chemical characteristics of soil on fallow and after incorporation of soybeans from the experimental site

Treatment	N (ppm)	P (ppm)	K	Ca	Mg	OM (%)	pH (Cacl2)
			-----------m.e%--------------				
Fallow	20a	36.96a	0.38a	10.98a	2.23a	0.96a	6.09a
Grain	18.94a	21.50b	0.41a	6.93b	2.27a	0.84b	5.99a
Vegetable	21.13a	29.53c	0.40a	9.96a	2.25a	1.01c	5.92a
Sig	ns	*	ns	*	ns	*	ns
c.v(%)	13.87	13.46	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 5% level and means followed by the different letters are significantly different at 5% level.*

Table 2. Plant population, above ground dry biomass and nitrogen fixed by the soyabeans from the experimental site.

Treatment	Plant population	Biomass (t /ha)	N fixed kg /ha)
Vegetable soybeans	142725	5.92	234
Grain soybean	156575	4.43	58
s.e	1.44	1.44	
c.v (%)	15.74	15.74	

Table 3. Nutrient composition of soyabeans from the experimental site.

Treatment	N	P	K	Ca	Mg
Grain	9.39	0.87	4.12	5.51	1.91
Vegetable	11.10	1.07	4.56	4.57	1.83
Sig	*	*	*	*	ns
c.v (%)	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.*

Table 4. Mean yield, gross income and production costs of soyabeans as a break crop.

Treatment	Yield (t/ha)	Income (Z$ / ha)	Costs (Z$ / ha)
Vegetable	2.84	2,840,000	1,740,000
Grain	1.14	3,310,000	1,630,000

more as the plant material decomposes. Improvement of OM can lead to improved cane yield due to good aeration, improved water holding capacity and high water infiltration rate (Sullivan, 2000). There were no significant differences in pH levels of the three treatments (Table1).This may mean that the incorporation of the vegetable soyabean biomass did not affect the soil pH.

High biomass of N14 in vegetable soyabean plots could be attributed to the contributions of nutrients and OM from ploughed under biomass (Shoko et.al.,). This trend is consistent with literature from work done by Zhou (2004) which showed that N14 can do better with the incorporation of green manuring crops. The tiller numbers are an indication of the number of stalks to be harvested at cane maturity. The more the tiller at early cane growth the higher the stalks at maturity (Zhou, 2004).

Conclusions

Vegetable soyabeans added more N to the soil than grain soybeans. Vegetable soyabeans also greatly improved the K, Ca and OM status of the soil. Soyabean mined P from the soil. So there is need for the sugarcane grower to analyse the phosphorus status of the land after planting soyabeans. Soyabeans helped to maintain the ideal soil pH for sugarcane production. The incorporation of above ground biomass of vegetable soybeans helped to raise the OM by 5.6%. The advantages of OM can help the incoming sugarcane crop in terms of growth.

The significant differences in tiller population biomass accumulation in sugarcane showed that the three treatments affected soil conditions differently. Results show that vegetable soyabean plots had more tillers and biomass. This indicates the potential of vegetable soybeans in improving cane growth and development. Other nutrients also may have influenced the growth pattern of the cane. Future research need to study the benefits of incorporating leaves and stems of grain soyabean.

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