International Journal of Manures and Fertilizers Vol. 3 (2), pp. 474-478, February, 2014. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

The prospective of reducing the rate of nitrogen fertilizer using a soya bean sugarcane production method in the South Eastern Lowveld of Zimbabwe

Sabau D. , Derren Matarauka and Masawi Samaz

Department of Soil Science, Faculty of Agriculture, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe.

Accepted 26 January, 2014

Monoculture is common in sugarcane production throughout the world and leads to decline in yields and soil fertility and build up of pests and diseases. Legumes have been shown as potential crops that break the monoculture cycles in several crops. Farmers can reduce nitrogen fertilizer requirements to the subsequent sugarcane crop when soyabean (*Glysine max* (L.) Merr) is used as a fallow crop. Field studies were conducted from 2004 to 2005 on nitrogen depleted sandy loam soils at the Zimbabwe Sugar Experiment Station in the South East Lowveld of Zimbabwe. The objectives of the study were to determine nitrogen fixed by soyabeans at various growth stages, determine nitrogen in the foliar of subsequent cane and estimate the artificial nitrogen fertilizer reduction. The treatments used were (i) vegetable soyabeans followed by cane topdressed with 80 and 120 kg nitrogen ha^{-1}, (ii) grain soyabean followed by cane topdressed with 80 and 120 kg nitrogen ha^{-1}, (iii) monoculture cane topdressed with 120 kg nitrogen ha^{-1}. Both grain and vegetable soyabeans fixed more nitrogen at flowering stage, 128 and 118 kg nitrogen ha^{-1}, respectively. The results showed that farmers can save nitrogen fertilizer by using vegetable soyabeans. The nitrogen saved was estimated at 80 kg nitrogen ha^{-1} as shown by the number of tillers, biomass and nitrogen in leaves of cane.

Key words: Nitrogen fertilizer, vegetable, grain soyabeans, tillers, CP72-2086.

INTRODUCTION

The monoculture approach to sugarcane production is a common phenomenon among sugarcane growers worldwide (Hartermink and Wood, 1998). This production system is necessitated by the fact that the crop is ratooned for several years. Therefore a sugarcane crop can be on the same land for up to 10 years as long as the crop is producing economic yields. Monoculture leads to a decline in sugarcane yields and depletion of soil fertility (Hartermink and Wood, 1998). Findings from Papua New Guinea indicated that a cane yield of 100 tons ha^{-1} removed 120 kg N ha^{-1} (Hartermink and Wood, 1998). The replenishment of nitrogen using nitrogen-fertilizer may be expensive particularly in developing countries where fertilizers are in short supply and are imported (Shoko and Tagwira, 2005). Nitrogen fertilizers are also vulnerable to leaching (Tisdale et al., 1999). Therefore, use of organic nitrogen sources can help to improve the organic and nutrient content of the soil (Giller et al., 1994). In Zimbabwe the plant cane crop requires about 100 kg N ha^{-1} nitrogen and subsequent ratoons require 120 kg ha^{-1} of nitrogen (Shoko and Tagwira, 2005).

Ratoon stunting disease (RSD) increases in sugarcane with monoculture. To reduce the incidence of ratoon stunting disease farmers leave the land fallow for at least 90 days (Shoko and Tagwira, 2005). Leaving the land fallow for at least 90 days is considered uneconomic by the sugarcane growers in Zimbabwe (Shoko, 2005). Farmers perceive fallowing as a great loss in cane growth for the 90 days and hence loss of revenue from the potential crop. Thus, the use of a break crop is a more economical approach in such circumstances as the crop can be sold for income. Therefore, the use of soyabean as a break

*Corresponding author. E-mail: Sabau86@gmail.com

Table 1. Treatment coding for the experiment.

Treatment	Pre- sugarcane phase	Subsequent sugarcane variety	N rates (kg ha^{-1})
T_1	Fallow	CP72-2086 (Monoculture cane)	120
T_2	Fallow	CP72-2086 (Monoculture cane)	120
T_3	Vegetable soyabeans	CP72-2086	120
T_4	Vegetable soyabeans	CP72-2086	80
T_5	Grain soyabeans	CP72-2086	120
T_6	Grain soyabeans	CP72-2086	80

crop has a potential for nitrogen replacement and improvement of soil organic matter (Giller et al., 1994; Shoko and Tagwira, 2005). Such soil nitrogen recapitalisation potential by soyabean may help to reduce the farmer's nitrogen fertilizer costs.

Research at Lousiana State University, USA (Viator and Griffin, 2001), Australia (Garside and Berthelsen, 2004), Stanger region of Kwazulu-Natal (Meyer and Van Antwerpen, 2001), and Zimbabwe (Giller et al., 1994; Mpepereki et al., 2003) demonstrated that the soyabean break crop had the potential to reduce nitrogen fertilizer needs by 100 $kgha^{-1}$ when ploughed under.

This study aimed to determine the most economical level of nitrogen fertilizer that can be applied to the sugarcane plant crop when soyabean is used as a breakcrop in sugarcane production systems in Zimbabwe. The most economical level was measured by nitrogen fixed in the soil, nitrogen in the foliar of cane, and the biomass accumulation and tiller populations produced by the subsequent sugarcane crop. The objectives of the study were to determine nitrogen fixed by soyabeans at various growth stages, determine nitrogen in the foliar of subsequent cane and estimate the artificial nitrogen fertilizer required to meet adequate crop nutrition.

MATERIALS AND METHODS

Site and its climate

In Zimbabwe, the commercial sugarcane industry is located in the south-eastern lowveld under irrigation (Clowes and Breakwell, 1998). This area lies around 21^{o}01′S latitude and 28^{o} 38′E longitude and at an altitude of 430 m above sea level (Clowes and Breakwell, 1998). Data was collected from the experiment at the Zimbabwe Sugar Association Experiment Station (ZSAES). The experiment station is situated in the south eastern lowveld of Zimbabwe and it is located on sandy clay loam soils (Clowes and Blackwell, 1998). At this site the average annual rainfall is 625 mm per annum, falling predominantly in the hot summer months (October to March).

Experimental design

The experimental plots were arranged in a Completely Randomized Block Design (RCBD) with six treatments in the first experiment (pre-sugarcane phase) comprising fallow, vegetable soyabeans and grain soyabeans (Table 1). The treatments were replicated four times. The second experiment was planted to sugarcane variety CP72-2086. The nitrogen rates were applied on the plant crop. Cane planted on fallow plots was used as control crop. Plot sizes were 22 x 10 m. The net plot area was 25 m^2.

Soil sampling and analyses

Soil samples were collected at 0 to 30 cm depth before the planting and after harvesting soyabeans. A sub- sample of 500 g was weighed from each composite sample and taken to the laboratory for analyses. The soil samples were analyzed for nitrogen, phosphorrus, potassium, calcium, magnesium, pH and organic matter. For the analyses of the nutrients the following methods were used: total nitrogen the Micro-Kjeldahl method (Quickfit, Bard and Tatlock, USA), available phosphorus, resin extract method was used (TM Ray Co, IBM Corp, USA) calcium, magnesium, potassium, 1 M ammonium acetate method was used, soil pH, 0.01 M CaCl (Hanna Ph 211, Dupond de Nemours and Co, USA) solution was used and for the determination of soil organic matter, redox method was used.

Soyabean production phase

Both grain (variety Storm) and vegetable soyabeans (variety S114) were planted using a seed rate of 80 kg ha^{-1}. The planting date was 19 February 2004. The seed was planted to a depth of 5 cm using the hand planting method. This method involves the dropping of seed using hands and covering the seed with soil using a hand held hoe. A combination of Dual Gold and Gesaprim at 1.45 Lha^{-1} and 3 $kgha^{-1}$ respectively were used as pre-emergence herbicide mode of weed control. The herbicide was applied on 19 February 2004 using a knapsack sprayer.

Soyabean biomass and plant nitrogen analyses

All the soyabean plants in the net plot of 5 m^2 (length of 5 m and wid- th of 1 m) were cut at ground level. The plants were partitioned into pods, leaves and stems. These were oven dried to constant weight at 80^{o}C. Five plants were collected from the net plot for biomass determination and nutrient analyses. These were analysed using the wet digestion method.

Determination of nitrogen fixed by soyabean

Nitrogen fixed was determined at flowering stages in both grain and Vegetable soyabeans. The proportion of nitrogen fixed was estimated using the nitrogen difference method (Shoko and Tagwira, 2005). Weeds from the unfertilised plots were used as non-fixing reference crop. The nitrogen-difference method uses the nitrogen for nitrogen fixing crop and nitrogen from non fixing crop. The difference between the nitrogen from the fixing crop and that of the non-fixing crop will be the estimate of the nitrogen fixed by the fixing crop.

Table 2. Chemical characteristics of soil on fallow and after incorporation of soyabeans from the experimental site. 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 not significantly different at 5% level and means followed by the different letters are significantly different at 5% level.

Treatmen	N(ppm)	OM(%)	pH(*$CaCl_2$*)
Fallow	20 a	0.86 a	6.09 a
Grain	18.94 a	0.64b	5.99 a
Vegetable	21.13 a	1.01c	5.92 a
Sig	ns	*	ns
c.v(%)	13.87	18.86	12.36

Table 3. Estimated N_2 fixed by soyabeans and available soil N

Soyabeans	Est. N_2 fixed (*kg /ha)*
At flowering (vegetable)	118
At flowering (grain)	128
At maturity (vegetable)	86
At maturity (grain)	42

Incorporation of soyabean material into the soil

Vegetable soyabean pods were harvested mature green and the other above ground part ploughed into the soil during land preparation. The grain soyabeans were harvested when the pods were dry and the above ground biomass was taken from the fields and only the roots were ploughed in during land preparation.

Subsequent sugarcane crop

The whole experimental site was uniformly prepared using a disc harrow to plant sugarcane (variety CP72-2086) . The crop was planted using three eyed cane setts. Double sett planting method, where two cane setts are laid side by side at the bottom of the planting furrow was used. The planting was done on 19 February 2004 (fallow plots) and 9 and 10 July 2004 (soyabean plots). Seedcane rate of 8 tons ha^{-1} was used. Fertilizer was applied at rates of 100 and 60 ha^{-1} phosphorus (P_2O_5) and potassium (K_2O) respectively. Potassium was applied when the crop was 4 weeks old. Nitrogen was split- applied at 120 ha^{-1} with 40 kg ha^{-1} applied on 31 March 2004, 2 April 2004 and 9 June 2004 (fallow plots). For sugarcane planted in soyabean plots, nitrogen was applied at two rates of 80 kg ha^{-1} and 120 kg ha^{-1} . The 80 kg ha^{-1} was split applied twice in splits of 40 kg ha^{-1} on 25 August 2004 and 22 September 2004. The 120 kg ha^{-1} was split applied in 3 splits at the rate of 40 kg ha^{-1} on 23 August 2004, 23 September 2004 and 27 October 2004. The crop was uniformly irrigated using furrow irrigation. Dis-ease inspection for smut was done once every month.

Sugarcane foliar analyses

Foliar samples were collected when the crop was 3 months old and thereafter every month up to when the sugarcane crop was 5 months old. Fully expanded leaves arising from the topmost visible dewlap (TVD) were cut off at the base. Forty leaf samples were collected randomly in the morning from actively growing cane in each plot. The leaves were placed in polythene bags and then sub sampled and dried immediately. The leaves were cut midway into 20 cm pieces using a guillotine. The laminae were separated from the midrib. The bundles were then oven dried to constant weight at 95^{O}C. Analysis for nitrogen was done following the soyabean protocol.

Sugarcane biomass and tiller measurement

Biomass determination was done when cane was three months old and up to five months old on a fortnight basis. The leaves and the stems were dried at 95^{O}C to constant dry weight. The leaves comprised senesced leaves, leaf blade and the sheath. Number of tillers was counted during the sampling for biomass determination.

Statistical analyses

The plant and soil nutrient data were subjected to analyses of variance (ANOVA) using MSTAT version 4 and mean separation was done using the least significant difference (LSD). Observed significant differences have been expressed in the text according to the level of probability. Standard errors of the mean were calculated.

RESULTS

Soil chemical characteristics

There were no significant differences in mineral nitrogen among the fallow vegetable and grain soyabean (Table 2). However vegetable soyabean plots had highest nitrogen. Due to land preparation problems at the station the vegetable soyabean biomass was incorporated later than scheduled (14 days later).

Organic matter was significantly different (P<0.05) among the treatments. Vegetable soyabeans produced 15.5 % more organic matter than fallow plots while grain soyabeans plots produced 0.5 % more organic matter than fallow plots (Table 2). The incorporation of above ground vegetable soyabean biomass may have improved the soil organic matter more as the plant material decomposed.

There were no significant differences in pH levels of the three treatments (Table 2). This therefore may mean that the incorporation of the vegetable soyabean biomass did not affect the soil pH.

Grain soyabean variety fixed more nitrogen than vegetable soyabean at flowering stage (Table 3). From the Table 3 grain soyabean fixed the least nitrogen at maturity. This can be attributable to nitrogen mobilization by the mature pod. The mature pod has a high harvest index. Since mature vegetable soyabeans were harvested while the pods were green not much of the nitrogen had been mobilized by the pods. The results also showed that soyabeans can add some nitrogen to the soil for the incoming crop.

Sugarcane biomass

Biomass determined at 90 days after planting showed no

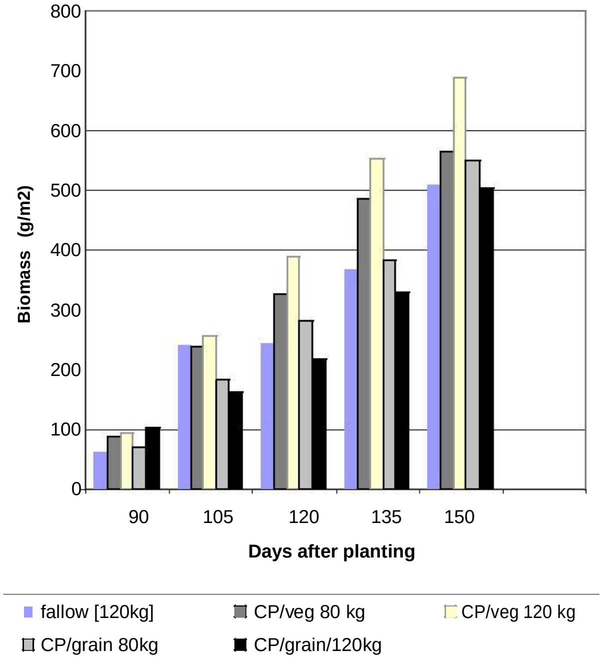

Figure 1. Biomass for CP72-2086 planted on fallow and soya-bean plots under different N rates

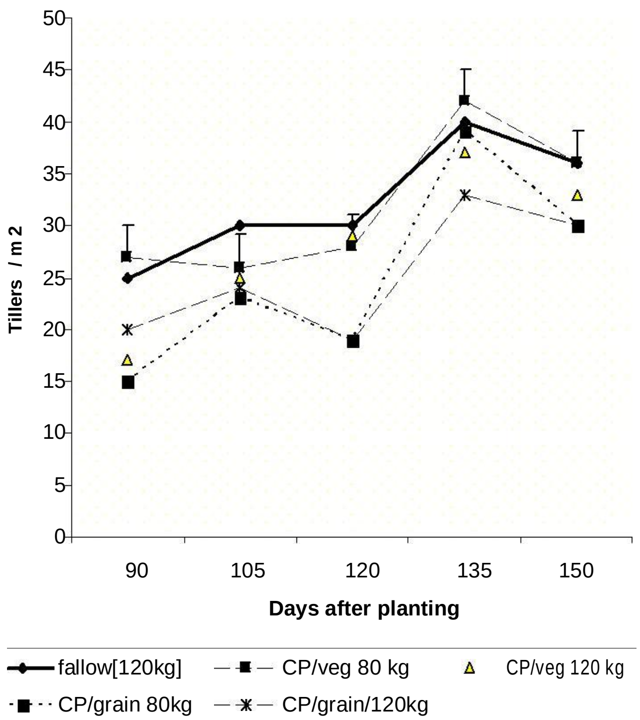

Figure 2. Tiller numbers for CP72-2086 planted on fallow and soyabean plots under different N rates.

significant difference among treatments (Figure 1). However cane planted on grain soyabean plots and fertilized with 120 kg nitrogen ha^{-1} had the largest biomass of 100 gm^{-1}. The other five treatments yielded the same at this age of the cane. At 105 days after planting the biomass showed significant differences ($p < 0.05$). However cane planted after vegetable soyabeans and fallow (monoculture cane) yielded the same biomass of 250 gm^{-2}. Cane planted after grain soyabeans and fertilized with 120 kg nitrogen ha^{-1} had the lowest biomass of 150 gm^{-2}.

Biomass at 120 days after planting of cane showed significant differences ($p < 0.05$). Cane planted on vegetable soyabeans and fertilized with 120 kg nitrogen ha^{-1} had the largest biomass of 390 gm^{-2} followed by cane on vegetable soyabeans and fertilized with 80 kg nitrogen ha^{-1}. Monoculture cane and cane planted on grain soyabean plots and fertilized with 120gm^{-2}, significant differen-ces ($p < 0.05$) were noted on cane that was 135 days old. Cane planted on vegetable soyabeans plots and fertilized with 120 kg ha^{-1} had the largest biomass of 550 gm^{-2} followed by cane on vegetable soyabeans and fertilized with 80 kg nitrogen ha^{-1}. There were no significant differ-ences between monoculture cane and cane planted after grain soyabean treatments.

At 150 days after planting CP72-2086 performed differently to the five treatments. Cane fertilized with 120 kgN ha^{-1} on vegetable soyabeans treatment had the highest biomass of 690 gm^{-2}. Cane planted on the treatment of grain and vegetable soyabeans with 80 kg nitrogen ha^{-1} performed were similar in performance to monoculture cane and fallow treatments performed the same way and yielded the lowest biomass of 500 gm^{-2}.

Tiller populations

All treatments showed a linear increase in the number of tillers on each sampling date (Figure 2). Monoculture cane had the highest number of tillers (30) at 120 days after planting. However all the treatments reached peak tillering and 135 days after planting and thereafter some tillers senesced and died. At peak tillering cane that was planted after vegetable soyabeans and fertilized with 80 kg nitrogen ha^{-1} produced 40 tillers ha^{-1} which was the highest. Monoculture cane produced 35 tillers. The least number of tillers were from cane on grain soyabean plots that were fertilized with 120 kg nitrogen ha^{-1}.

Senescence of tillers was gradual and the tiller num-bers somehow stabilized at 150 days after planting. Cane on vegetable soyabeans fertilized with 80 kg nitrogen ha^{-1}

Table 4. N in leaves of 5 months old sugarcane

Treatment	N (%)
Recommended	1.70
Monoculture cane	2.20
After vegetable soyas+80kg N	2.40
After vegetable soyas+120kg N	2.35
After grain soyas+80kg N	2.32
After grain soyas+120kg N	2.27

and fallow plots showed no significant differences and produced 35 tillers. Grain soyabean treatments performed similar to fallow treatments. Cane from these two treatments had 25 tillers at 150 days after planting.

Sugarcane foliar N concentration

All the five treatments were above the recommended nitrogen % in the foliar of cane (Table 4). Cane planted on vegetable soyabean treatment with 80 kg nitrogen ha^{-1} had 9.1% more nitrogen than the recommended and monoculture cane respectively. There were significant differences ($p<0.05$) between monoculture and the soybean treatments. However there were no significant differences between the treatments of each soyabean variety. However there were significant differences ($p<0.05$) between the treatments of the two varieties. The other vegetable soyabean treatment produced 38.2 and 6.8% more nitrogen than the recommended treatment and monoculture cane respectively.

DISCUSSIONS

The non significant levels on nitrogen in the various treatments (Table 4) can be attributed to poor land preparation and late incorporation of soyabean biomass at the experiment site. Late incorporation of plant material led to high lignin and polyphenolic contents, which release nutrients slowly (Giller et al., 1997). Kuntashula et al. (2003) also found out that late incorporated legume biomass tend to decompose slowly and release less nutrients in the early stages of plant growth.

Improvement of organic matter can lead to improved cane yield due to good aeration, improved water holding capacity and high water infiltration rate (Sullivan, 2000; Tisdale et al., 1999). There were no significant differentces in pH levels of the three treatments (Table 2).

This therefore may mean that the incorporation of the vegetable soyabean biomass did not affect the soil pH.

Estimated nitrogen fixed was highest in grain soyabean followed by vegetable soyabeans both at flowering (Table 2) . The results are in line with work done by Mpepereki et al (2003), Giller et al. (1994) and Shoko and Tagwira (2005). According to Chikowo et al. (2003) a legume crop contributes about 30% of the fixed nitrogen to the incoming crop per season. This implies that the sugarcane farmers can save N fertilizer requirements in the order of 38, 35, 26 and 13 kg ha^{-1} for grain at flowering, vegetable at flowering, vegetable at maturity and grain at maturity respectively. This is substantial saving on fertilizer taking into account that in Zimbabwe cane requires 120 kg nitro-gen ha^{-1} (Shoko and Tagwira (2005) and Clowes and Breakwell (1998).

Biomass is an important physiological growth parameter of cane. Work done by Zhou (2004) in the south Eastern Lowveld of Zimbabwe showed that biomass has a contribution to the final yield of cane. Figure 1 showed that farmers can reduce the nitrogen fertilizer application by one quarter when they plant vegetable soyabeans and then top dress subsequent cane using 80 kg nitrogen ha^{-1}. The biomass from this treatment was above that of the monoculture cane at 150 days after planting.

High biomass in vegetable soyabeans plots could be attributed to the contributions of nutrients and organic matter from ploughed under biomass (Shoko, 2005). In a more recent study conducted in Australia, Garside and Bell (2001) and Garside and Berthelsen (2004) found that subsequent sugarcane growth and development were 15 to 25% more in cane after soyabeans than monoculture cane. From our study cane tillers and biomass were higher in vegetable soyabean plots (Figure 1 and 2). This is also consistent with the findings of Nixon and Simmonds (2004) in their work done in Swaziland.

Tillers give the farmers the final stalk. The more the tiller numbers the higher the yield (Zhou, 2004). From Figure 2 it was shown that farmers can cut down on N fertilizer requirements on subsequent cane if they planted vegetable soyabeans and top- dress with 80 kg ha^{-1} instead of 120 kg ha^{-1}. Cane on the vegetable soyabeans and 80 kg N had more tillers than monoculture cane. Grain soyabean treatment of 80 and 120 kg nitrogen produced less tillers than monoculture cane. It may not be economical for farmers to use these treatments.

Conclusion

There was more nitrogen in the foliar of cane that followed soyabean. This is very important for sucrose formation and cane growth. Farmers can benefit from using soybeans in their production system. Nitrogen fixed by soybeans at various stages can make farmers reduce nitrogen fertilizer rates. The use of reduced fertilizer requirements by one quarter in conjunction with vegetable soybeans ploughed under green resulted in subsequent cane crop performing better than monoculture cane dur-ing early growth.

ACKNOWLEDGEMENT

The authors would like to thank the Zimbabwe Sugar Association Experiment station for facilitating and providing the site for this research.

REFERENCES

Chikowo, R Mapfumo, P Nyamugafata P, KE Giller (2003). Maize productivity and mineral N dynamics following different soil fertility management practices on a depleted sandy soil in Zimbabwe. Agric. Ecosyst. Environ. pp. 69-81.

Clowes MJ, Breakwell WL (1998). Zimbabwe Sugarcane Production Manual. ZSAES. Chiredzi.

Garside AL, Bell MJ (2001). Fallow legumes in the Australian sugar industry. Review of recent research findings and implications for the sugarcane cropping system. Proceedings of the 23rd conference of the Australian Society of Sugar Cane Technologists, pp. 230-235.

Garside AL, JE Berthelsen (2004). Management of legume biomass to maximize benefits to the following sugarcane crop. Proc. Aust. Soc. Sugar Cane Technol. p. 26.

Giller KE, McDonagh JF, Cadish G (1994). Can biological nitrogen fixation sustain agriculture in the tropics? CABI publishing. WallingfordGiller KE, Cadish G, Ehaliotis, G,Adams E, Sakala WD, Mafongoya PC (1997).Building soil nitrogen capital in Afri ca. Soil Sci .Soc .Am 51:151-192

Hartermink AE, AW Wood (1998) .Sustainable land management in the tropics. The case of sugarcane plantations. University of Technology. Papua New Guinea,

Kuntashula E , Mafongoya PC, Sileshi G, Lungu S (2003).Potential biomass transfer technologies in sustaining vegetable production in the wetlands (dambos) of eastern Zambia. Exp. Agricul 40: 37-51

Meyer JW, Antwerpen V (2001). Soil degradation as a factor in yield decline in the South African Sugar Industry. International Society of Sugarcane Technologists Proceedings XX1V Congress 21, September, p. 2

Mpepereki, S Kasasa P, Giller KE (2003) Biological nitrogen fixation by promiscuous soyabean varieties and their residual fertility contributions to the subsequent crops in communal soils of Zimbabwe. UZ. Hara-re.

Nixon DJ, Simmonds LP (2004). The impact of fallowing and green manuring on soil conditions and the growth of sugarcane. Exp. Agric. 40 (1): 127-138.

Shoko M (2005). Soyabean [glycine max (l) merr.] in sugarcane [saccharum officinarum (l)] breakcrop systems. An assessment of potential nutrient and economic benefits. MSc thesis, Africa University, Zimbabwe

Shoko M, F Tagwira (2005). Assessment of the potential of vegetable and grain soyabeans as breakcrops in sugarcane production systems in Zimbabwe. Proceedings of African Crop Science Society 7: 59- 65

Sullivan P (2000). Overview of cover crops and green manures. Am. Soc. Sugarcane Technol 20: 67-72

Tisdale SL, Havlin JL, Beaton DB, Werner LN (1999). Soil fertility and fertilizers. An introduction to nutrient management.6th ed. Prentice Hall New Jersey

Viator HP, Griffin JL (2001). Fallow period cropping to soyabeans provide benefits-Louisiana Agriculture 44(4): p.15

Zhou M (2004). Performance of varieties N14 and NCo376 in the south eastern lowveld of Zimbabwe. Proc S Afr Sug Technol Ass 78:137-147.