The Use of Soybean (Glycine max) as a Break Crop Affect the Cane and Sugar Yield of Sugarcane (Saccharum officinarum) Variety CP 72-2086 in Zimbabwe

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Abstract: The highest nitrogen requirement of sugarcane is problematic for small scale farmers in Zimbabwe due to the highest cost and scarcity of fertilizer. Producing legume crops in rotation with sugarcane during the fallow period may alleviate the problem. The study was to explore the best nitrogen and soybean combination for yield maximization in sugarcane. Two soybean varieties and three N rates (0, 80 and 120 kg N ha⁻¹) were used in this study. Cane planted in vegetable soybean plots and topdressed with 80 kg N ha⁻¹ produced significantly higher cane and sugar yields compared to cane grown on fallow plots that received 120 kg N ha⁻¹. Incorporating vegetable soybeans in the system can therefore save about 40 kg N ha⁻¹, while increasing cane yield resulting in a more profitable cane production cycle.

Key words: Fallowing • N Fertilizer • Soybeans • Sugarcane • Zimbabwe

INTRODUCTION

Monoculture is a common system in sugarcane (Saccharum officinarum) production world wide [1]. This production system leads to a decline in sugarcane fields and depletion of soil fertility [2]. Findings from Papua New Guinea indicated that a cane yield of 100 tons ha⁻¹ removed 120 kg nitrogen (N) ha⁻¹ [2]. The replenishment of nitrogen using nitrogen fertilizer may be expensive particularly in developing countries where fertilizers are in short supply and are imported [3]. Nitrogen fertilizers are also vulnerable to leaching [4]. Therefore, use of organic nitrogen sources can help to improve the organic and nutrient content of the soil [5]. In Zimbabwe the plant cane crop requires about 100 kg N ha⁻¹ and subsequent rations require 120 kg N ha⁻¹ [3].

Sugarcane is a C₄ plant and its photosynthetic rate is among the highest [6-8]. There are very large differences in photosynthetic rates of individual leaves related to age and nutritional levels in the soil [9,1]. The decline in photosynthetic rate is associated with a marked decrease in leaf N [10]. This suggests that N is a fundamental factor in determining leaf area indices and tiller populations among other sugarcane growth and development parameters.

The increase in total biomass helps much to increase sugar and cane yield [11, 3]. Biomass can be increased through increased interception of solar radiation [12]. Radiation interception is a function of LAI. This therefore means that an increase in leaf area can improve interception of solar radiation. LAI can be increased through application of optimum N levels to the cane crop [13]. A leaf area of 4-4.5 is viewed as where net productivity is maximum [14, 8]. Low nutrient levels in the soil lead to a decrease in leaf area.

Cane biomass can be increased by increasing interception of solar radiation and more efficient use of the solar radiation in photosynthesis [14, 3, 1]. Sigel and Donaldson, [15] showed that higher radiation interception which is due to a high LAI resulted in greater biomass production. As biomass accumulation increases the tiller number increases exponentially in the early growth of cane [16, 17, 8]. Sucrose yields in cane could be increased by increasing the efficiency of producing biomass per unit of intercepted radiation [16].

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The use of soybean as a break crop has a potential for N recapitalization and improvement of organic matter [5]. Such soil N recapitalization potential by soybean may help to improve cane growth, development and yield [18]. Soybean was chosen as the fallow crop because it grows and matures within the fallow period and fixes nitrogen which will be available to the incoming sugarcane crop [19, 20]. Research at Louisiana State University in the USA, in Australia, in the Stanger region of KwaZulu-Natal and in Zimbabwe demonstrated that the soybean break crop had the potential to reduce nitrogen fertilizer needs by 100 kg ha⁻¹ when ploughed under [5, 20, 9, 3].

This study aimed to determine the most economical level of nitrogen fertilizer that can be applied to the sugarcane crop when soybean is used as a break crop in sugarcane production systems in Zimbabwe.

MATERIALS AND METHODS

Site Description: In Zimbabwe, the commercial sugarcane industry is located mainly in the South Eastern Lowveld under irrigation [21]. 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 loam soils classified as lithosols [21]. ZSAES is 430m above sea level at latitude 21°01′S and longitude 28°38′N [8]. At this site the average annual rainfall is 625 mm per annum (20-year mean), falling predominantly in the hot summer months (October to March). The winters are relatively cool and dry. Mean air temperatures vary from about 26°C (October to January) to 16°C (June and July).

Experimental Design: The treatments were arranged in a split-plot design with vegetable and grain soybean and fallow treatments as main plot factors and different N rates applied to the subsequent sugarcane (variety CP72-2086) as subplot factors. The plot sizes were 22 m long × 10.5 m wide.

Soybean Production Phase: Both grain (var. Storm) and vegetable (var. S114) soybeans were planted on 19 February 2004. A seeding rate of 80 kg ha⁻¹ was used. The seed was planted by hand to a depth of 5 cm. A combination of flumioxazin-M-isopropyl (63 ml) and alachlor (286 ml) in 15 L of water was used as pre-emergence herbicide mode of weed control. The herbicide was applied on 19 February 2004 using a knapsack sprayer.

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fallow treatment (Main plot)</th>
<th>Cane fertilizer treatment (kg N ha⁻¹) (Split plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fallow</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Fallow</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>Vegetable soybean</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Vegetable soybean</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>Grain soybean</td>
<td>80</td>
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<tr>
<td>6</td>
<td>Grain soybean</td>
<td>120</td>
</tr>
</tbody>
</table>

Sugarcane Production Phase: The crop was planted using three-eyed two-cane sets (double planting) laid side by side in the bottom of the furrows on 9 and 10 July 2004 in former fallow and soybean plots. A seeding rate of 8 tonnes per hectare was used. Straight cane knives were dipped in a disinfectant called Jeyes fluid to prevent ratoon stunting disease (RSD). The pre-emergence herbicides were applied following the soybean protocol. Single super phosphate fertilizer was applied in the furrow before planting at 100 kg P ha⁻¹. Potassium was applied 4 weeks after planting at a rate of 60 kg K ha⁻¹. Nitrogen was applied at two rates of 80 kg N ha⁻¹ and 120 kg N ha⁻¹ as shown in Table 1. The N fertilizer was split applied with 80 kg being split into 2 tranches of 40 kg at 4 and 8 weeks after planting (WAP) and 120 kg into 3 tranches of 40 kg each AT 4, 8 and 12 WAP.

Disease inspection was done once every month. Irrigation was scheduled using evaporation data from a US Weather Bureau Class A (a-pan) located at the Automated Weather Station at ZSAES. Water was applied at 50% depletion of total available moisture (TAM).

Sugarcane Leaf Area Measurement: This was done when the sugarcane was 2 months old and thereafter fortnightly up to when the sugarcane crop was 5 months old. Destructive sampling was done on the bottom half of all the plots with odd numbers and on the top half of all the plots with even numbers. At each sampling date one linear meter was measured. All the sugarcane plants were cut at ground level. The plants were then partitioned and the leaves were taken for area measurement using a Delta-T leaf area meter (Sunscan devices, Pullman, WA, USA).

Sugarcane Foliar Analysis Samples: The foliar samples were collected when the crop was 2 months old and thereafter monthly up to when the sugarcane crop was 12 months old. Forty leaf samples were taken randomly from actively growing cane in each plot. The samples were taken in the morning. Fully expanded leaves arising from the topmost visible dewlap (TVD) were cut off at the base.
The leaves were placed in polythene tubes according to plots. The leaves were then sub-sampled and processed whilst fresh. The laminae were separated from the midrib. The laminae were bundled together and guillotined at the center. The bundles were then oven dried at 95 °C to constant weight and then crushed and taken for the analyses of N in the laboratory.

**Cane Yield Measurement**: Raw cane was taken to the mill for weighing and the yield was expressed as t cane ha⁻¹.

**Sugar Yield**: The total sugar (crystal) produced was expressed as ERC t ha⁻¹. The following model was used to calculate it:

\[ \text{ERC} \times \text{t cane ha}^{-1} \]

Statistical Analyses: Data was subjected to analyses of variance using GenStat version 4. Mean comparisons was done using LSD values at p = 0.05.

**RESULTS AND DISCUSSIONS**

**Sugarcane Leaf Area Indices [LAI]**: The results are shown in Figure 1. At 90 days after emergence fallow cane planted on fallow plots and topdressed with 80 kg N ha⁻¹ and 120 kg N ha⁻¹ had the lowest LAI (Fig. 1).

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Fig. 1: Leaf area indices at (a) 90 (b) 105 (c) 120 (d) 135 (e) 150 days after emergence. F' 80 is Fallow plots followed by cane topdressed with 80 kg N/ha. G is grain soybeans and V is vegetable soybeans
Fig. 2: %N in foliar of cane at 5 months old. Recom is recommended N in foliar, mono is monoculture cane. G is grain soybeans and V is vegetable soybeans. 80 kg and 120 kg are N rates for sugarcane crop planted on the soybean plots.

Fig. 3: Cane and corresponding sugar yields for each of the six treatments.

At 150 days after emergence cane grown on vegetable plots had the highest LAI. However, there were no significant differences between the two treatments, that is cane grown on vegetable soybean plots topdressed with 80 kg N ha$^{-1}$ and 120 kg N ha$^{-1}$, respectively (Figure 1). Cane grown on the two vegetable soybean plots had a LAI of greater than 4. This cane with an LAI of 4 has the maximum net productivity in terms of radial interception [8]. This cane can have the maximum growth and development and farmers can realize high sugar yields which lead to a high income. This LAI leads to luxurious biomass as shown in Figure 2. The results are in line with the findings by [1] who showed that vegetable soybeans can fix more N than grain soybeans. The supply of N from inorganic sources ensures continuous mineralization of N and such N is not easily leached [5, 3].

**Sugarcane Foliar N Concentration:** All five treatments were above the recommended nitrogen % in the foliage of cane (Figure 2). Foliage of cane planted on vegetable soybean treatment with 80 kg N ha$^{-1}$ had the highest N content. It had 90 and 30% more N than the recommended and monoculture cane, respectively. There were significant differences ($p < 0.05$) between monoculture and the soybeans treatments. However, there were no significant differences between the treatments of each soybean variety (Figure 2), but significant differences ($p < 0.05$) were noted between the treatments of the two varieties.

**Cane and Sugar Yields:** The cane and sugar yields are shown in Figure 3. The subsequent cane crop planted on vegetable soybean treatments showed the highest cane and sugar yield (Figure 3). In terms of sugar yield cane planted on vegetable soybean plots and topdressed with 80 kg N ha$^{-1}$ had the highest yield of 16.8 kg ha$^{-1}$. The control of fallow with 120 kg N ha$^{-1}$ produced 101 kg cane ha$^{-1}$ and 9.62 kg sugar ha$^{-1}$. Therefore farmers can get the highest sugar yield using 80 kg N ha$^{-1}$ when vegetable soybeans have been used as a break crop. There is a saving of 40 kg N ha$^{-1}$ when using this treatment.
CONCLUSION

The use of vegetable soybeans can help the sugarcane farmers to realize better income. LAl, foliar N and sugarcane and sugar yields were the highest in cane that was planted on vegetable soybean plots. Cane that followed vegetable soybeans and topdressed with 80 kg N ha⁻¹ performed similar to cane that followed soybeans and topdressed with 120 kg N ha⁻¹. Therefore, farmers can save on N fertilizer by 40 kg ha⁻¹ in their crops and still realize the same yield as when applying 120 kg N ha⁻¹.

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REFERENCES


