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Article

# Impact of Plant Population and Weed Control Methods on the Growth, Yield and Economic Potential of Sugarcane (*Saccharum officinarum* L.) Cultivation

*Impacto da População de Plantas e Métodos de Controle de Plantas Daninhas sobre o Crescimento, a Produção e o Potencial Econômico do Cultivo de Cana-de-Açúcar (**Saccharum officinarum** L.)*

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ABSTRACT - Sugarcane industries are faced with the challenges of reduced cane yield due to inability to ascertain an appropriate sugarcane planting density. Field trials were conducted at Bacita, southern Guinea savanna of Nigeria to examine appropriate planting density and weed control method that can minimize weed infestation in sugarcane field and give an optimum cane yield to improve the economic status of the sugarcane farming community. The experiment was established as a randomized complete block design in a split-plot arrangement with three replications. The main plot constituted four planting populations (43,200, 64,800, 86,400 and 108,800) plants ha$^{-1}$ while the sub-plot consisted of six weed control practices (weedy check, pre-emergence application of terbuthylazine at 2.0 kg a.i. ha$^{-1}$ + three supplementary hoe weeding (SHW), post emergence application of ametryn at 3.0 kg a.i. ha$^{-1}$ + two SHW., post emergence application of dicamba at 0.5 kg a.i. ha$^{-1}$ + two SHW., pre emergence application of terbuthylazine at 2.0 kg a.i. ha$^{-1}$ + post emergence application of 2.4-D at 3.0 kg a.e. ha$^{-1}$ and monthly hoe weeding). The study revealed that fifteen weed species were encountered as the most prevalent weed species in sugarcane ecology. Plant population of 108,800 plants ha$^{-1}$ had the lowest weed seedlings population with highest cane yield (216.03 tons ha$^{-1}$), production efficiency of 9.20% and benefit cost ratio of US$ 9.86 on every US$ 1 spent. This study concludes that, the adoption of 86,400-108,800 plants ha$^{-1}$ of sugarcane and pre emergence application of terbuthylazine at 2.0 kg a.i. ha$^{-1}$ + three SHW (for small scale growers) or pre emergence application of Terbuthylazine at 2.0 kg a.i. ha$^{-1}$ + post emergence application of 2.4-D at 3.0 kg a.e. ha$^{-1}$ for the commercial estates will minimize weed infestation and make sugarcane cultivation a profitable venture.

**Keywords:** terbuthylazine, dicamba, ametryn, weeds.

*RESUMO - As indústrias de cana-de-açúcar enfrentam os desafios da redução do rendimento de cana devido à incapacidade de determinar uma densidade apropriada de plantio dessa cultura. Ensaios de campo foram realizados em Bacita, na savana guineense ao sul da Nigéria, para examinar a densidade apropriada de plantio e o método de controle de plantas daninhas que minimizam a infestação destas no campo da cana-de-açúcar e proporcionam rendimento ideal de cana para melhorar o status econômico da comunidade de canaviais. O experimento foi estabelecido como um delineamento em blocos aleatórios, em um esquema de parcelas subdivididas, com três repetições. A parcela principal constituiu-se de*

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*quatro populações de plantio (43.200, 64.800, 86.400 e 108.800) de plantas ha$^{-1}$, enquanto a subparcela consistiu de seis práticas de controle de plantas daninhas (verificação das plantas daninhas, aplicação em pré-emergência de terbutilazina a 2,0 kg i.a. ha$^{-1}$ + três capinas com enxada complementares (CEC), aplicação em pós-emergência de ametryn a 3.0 kg i.a. ha$^{-1}$ + duas CEC, aplicação em pós-emergência de dicamba a 0,5 kg i.a. ha$^{-1}$ + duas CEC, aplicação em pré-emergência de terbutilazina a 2,0 kg i.a. ha$^{-1}$ + aplicação em pós-emergência de 2,4-D a 3,0 kg e.a. ha$^{-1}$ e capina mensal com enxada). O estudo revelou que 15 espécies de plantas daninhas foram encontradas como as mais prevalentes na ecologia da cana-de-açúcar. A população de 108.800 plantas ha$^{-1}$ apresentou a menor população de mudas de plantas daninhas com maior produção de cana (216,03 toneladas ha$^{-1}$), eficiência de produção de 9,20% e relação custo-benefício de US$ 9,86 em cada US$ 1 gasto. Este estudo conclui que a adoção de 86.400 a 108.800 plantas ha$^{-1}$ de cana-de-açúcar e a aplicação em pré-emergência de terbutilazina a 2,0 kg i.a. ha$^{-1}$ + três CEC (para pequenos produtores) ou aplicação em pré-emergência de terbutilazina a 2,0 kg i.a. ha$^{-1}$ + aplicação em pós-emergência de 2,4-D a 3,0 kg e.a. ha$^{-1}$ para as propriedades comerciais irão minimizar a infestação de plantas daninhas e tornar o cultivo da cana um empreendimento lucrativo.*

**Palavras-chave:** terbutilazina, dicamba, ametrina, plantas daninhas.

## INTRODUCTION

Yield decline is an issue that has plagued sugarcane (*Saccharum officinarum* L.) production systems in Nigeria despite the cultivable land potentials capable of producing over 3.0 million metric tons of sugarcane annually (NSDC, 2003). Many factors are responsible for the declining sugarcane yield (Azhar et al., 2007). Weed infestation and poor management practices (Sugarcane..., 2013) are some of the important factors taken into cognizant in this study.

Weeds are considered major constraints to higher yields in sugarcane production because they can reduce potential sugar yield by 24 to 93% as well as a loss of significant quantities of nutrients (Sugarcane..., 2013). In sugarcane, crop loss has ranged between 40-60%, the highest found in areas where farmers are not familiar with improved weed management technologies (Chauhan and Strivastava, 2002; Singh et al., 2011).

The long maturity period of cane has made weed infestation a critical factor during the crop growth period. Wider inter row spacing in sugarcane cultivation is an important factor that encourages weeds to establish faster before canopy closure. According to Singh and Kumar (2013), the wider spacing in between sugarcane rows allows a wide range of weed floral to grow profusely. Weeds are self-grown and establish faster than sugarcane, especially during the early stage of crop growth and subsequently cause reduction in yield. The kind of weed species and the duration of its infestation have an impact on stalk number and size, number of millable cane and yield (Singh and Kumar, 2013). Therefore, the main objective of this study is to determine the appropriate planting density and weed control method that can minimize weed infestation in sugarcane field and give an optimum cane yield to improve the economic statue of the sugarcane farming community in the southern Guinea savanna ecology of Nigeria.

## MATERIALS AND METHODS

### Description of study area

The study was carried out during the 2014 and 2015 growing season at Josepdam Sugar Company Bacita Nigeria. The region is located on longitude 9°05' N; latitude 4°57' E and 93.5 m above sea level. The rainfall recorded during the study year was 1029.4 mm and the temperature range between minimum of 28 °C and maximum of 34 °C. The experimental fields were fallowed for 3 years before the commencement of this study. The area is characterized by a well drained sandy loam soil with good soil nutritional status; bimodal rainfall distribution with peaks in June and September. The study was conducted at two different locations within a Josepdam sugar field.

**Experimental layout**

In each of the locations, the experiment was laid out in a randomized complete block design (RCBD) with a split plot arrangement and replicated three times. The main plot consisted of 4 different plant densities (10, 15, 20 and 25 three-eye budded setts established on a 5 m row) to give approximate planting densities of 43,200 plants $ha^{-1}$, 64,800 plants $ha^{-1}$, 86,400 plants $ha^{-1}$, 108,800 plants $ha^{-1}$, respectively, while the sub-plot had weed control practices as follows: weedy check; pre-emergence application of Terbutylazine at 2.0 kg a.i. $ha^{-1}$ + supplementary hand hoeing at 4, 10 and 16 weeks after planting (WAP); postemergence application of Ametryn at 3.0 kg a.i. $ha^{-1}$ + supplementary hand hoeing at 10 and 16 WAP; postemergence application of dicamba at 0.5 kg a.i. $ha^{-1}$ + supplementary hand hoeing at 10 and 16 WAP; preemergence application of Terbutylazine at 2.0 kg a.i. $ha^{-1}$ + 2, 4-D at 3.0 kg a.e. $ha^{-1}$ as directed sprayed; and monthly hand hoeing.

**Establishment**

Field clearing was carried out before ploughing, harrowing and ridging at the two different locations. Each sub-plot consisted of 4 rows measuring 5 m long and inter-row spacing of 1.6 m making a sub-plot size of 32 $m^2$. Three-eyed budded setts were laid at different density on the ridges horizontally end to end. NPK fertilizer was applied at an application rate of 180 kg $ha^{-1}$ N for basic and 92 kg $ha^{-1}$ of urea fertilizer application at 3 months after planting (MAP). Cultural practice such as molding, irrigation and other maintenance operations were carried during the growing period of the crop.

**Weed survey**

The survey was carried out to assess the weed composition with the aid of a quadrat measuring 0.25 x 0.25 m, placed at four random locations within the net plot during the sampling period of 1, 2, 4, 8 and 12 MAP. The weed seedlings emerged were observed, counted and pulled for identification with the aid of relevant weed handbooks like West African weeds by Akobundu and Agyakwa (1998). The weeds were separated into broadleaves, grasses and sedges. Weed fresh biomass was determined using a weigh balance and the dry biomass was obtained by subjecting the sampled weeds to oven drying.

**Sucrose analysis**

Using a hand held extractor, cane juice was extracted from randomly selected stalks from the net plot and placed on a hand held refractormeter for Brix determination. Randomly selected cane stalks samples were crushed using a JEFFCO cane grinder. 5.2 g of thejuice sample extracted was diluted with distilled water into a 100 mL Kohrash volumetric flask. The dissolved sample was made up to the mark of 100 mL with distilled water. Sufficient clarifying agent (lead subacetate) was added and filtered through Whatman #91 filter paper with Celite filter aid. The filtered sample was measured and placed in a polarimeter, % polarity was determined by multiplying the recorded value by five. Purity was determined by a simple equation.

$$Purity = \frac{\%\,Polarity}{\%\,Brix} \times 100$$

**Weed species composition**

The composition of the weed flora was analyzed by calculating the relative abundance (RA) of each species within each experimental field as follows: RA = (RD + RF)/2, where RD (relative density) = number of a weed species per unit area (within a quadrat) in the plot divided by the total number of weed species within the same unit area (quadrat); and RF (relative frequency) proportion of quadrat in which the species was present per experimental unit divided by the total frequency of all species in the experimental unit (Fadayomi and Takim, 2009).

### Data collection

Data on sugarcane emergence and number of tillers were collected at different sampling periods. Total canes emerged from each plot were counted at 21 DAP, 42 DAP and 2 MAP. Tillers from the net plot (16 $m^2$) were counted and recorded at 3, 6, 9 and 12 MAP. Data on cane yield and yield component were collected at 12 MAP.

### Analysis of variance

Data collected were subjected to analysis of variance (ANOVA) using Gen-stat Statistical Package (Discovery Edition 3) and where F-ratios were significant ($P \leq 0.05$), means were separated using the least significance difference (LSD).

### Economic analysis

The data obtained on the cost of farm inputs and revenues from the output of sugarcane were analyzed using addition, mean and percentages. Profit was used to determine the profitability of the sugarcane production. Profit was obtained by deducting total cost from total revenue. Efficiency of sugarcane enterprise was calculated by dividing total cost by total revenue and multiplying by 100. The benefit-cost ratio (BCR) was obtained by dividing benefit by cost.

## RESULTS AND DISCUSSION

### Weed emergence and composition

A total of forty-three (43) weed species belonging to 34 genera within 15 families was encountered across the trial sites (Table 1). About 56% of the genera were broadleaves species, 35% grasses and 9% sedge weed species. Annual weed species were 63%, 28% perennials and about 9% were either annuals or perennials depending on the environmental variation. Based on the level of importance, the most prevalent weed species included *Dactyloctenium aegyptium* (9.61%), *Digitaria horizontalis* (9.36%), *Echinochloa stagnina* (6.87), *Cynodon dactylon* (6.12%), *Chroris pilosa* (5.74%), *Ludwigia decurrens* (5.62%), *Paspalum scrobiculatum* (5.24%), *Cyperus iria* (4.87%), *Tridax procumbens* (4.39%), *Cyperus haspan* (3.62%), *Sida acuta* (3.62%), *Andropogon gayanus* (3.49%) *Senna occidentalis* (3.37%), *Rottbeollia cochinchinensis* (2.76%), and *Sorghum arundinaceum* (2.62%).

Plant density and weed control significantly influenced weed seedling population at 4, 6 and 8 MAP (Table 2). The pattern of weed emergence indicates that weed seedlings emerged throughout the trial period. The peak of weed seedlings emergence was at 4 MAP and declined gradually to the lowest emergence at 8 MAP and then there was a sudden increased. Terbuthylazine applied at preemergence and postemergence had the lowest weed seedlings population, followed by the plot treated with preemergence of Terbuthylazine + 3SHW, and weedy check plots had the highest weed seedlings.

Plant density significantly affects dry weed weight at 4, 6 and 12 MAP. At all these periods where significant difference was obtained, plots with 108,800 plants $ha^{-1}$ had significantly lower weed dry weight, while plots with 43,200 plants $ha^{-1}$ had significantly higher weed dry weight. Generally, weed control treatment significantly influences dry weed weight except at 2 and 8 MAP. The monthly hoe weeded plots had significantly lower weed dry weight, while all other weed control treatments had either relatively similar to manual hoe weeded plots or to each other. The unweeded plots had significantly higher dry weed weight during the assessment periods.

***Table 1*** **-** Weed species encountered in sugarcane ecologies during the study period at Bacita, Nigeria

| Family | Weed species | MG | LC | Weeds population dynamics(n° m$^{-2}$) | | | | | | Total | Rel. Abd (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1MAP | 2MAP | 4MAP | 6MAP | 8MAP | 12MAP | | |
| Asteraceae | *Tridax procumbens* L. | B | A | 8 | 5 | 8 | 5 | 3 | 5 | 35 | 4.39 |
| | *Vernonia cinerea* L Less. | B | A | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0.25 |
| | *Vernonia perrottetti* Sch. Bip. | B | A | 0 | 0 | 0 | 2 | 0 | 2 | 4 | 0.49 |
| | *Eclipta alba* (L.) Hassk. | B | A | 4 | 0 | 2 | 2 | 2 | 3 | 12 | 1.49 |
| | *Malenthera scandens* Roberty. | B | P | 0 | 0 | 0 | 4 | 0 | 0 | 4 | 0.49 |
| Combretaceae | *Combretum zenkeri* Engl. & Diels. | B | P | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 0.37 |
| Commelinaceae | *Commelina diffusa* Burm. F. | B | P | 0 | 2 | 1 | 1 | 0 | 1 | 5 | 0.62 |
| Convolvulaceae | *Evolvulus alsinoides* L. | B | A | 5 | 3 | 4 | 1 | 1 | 2 | 17 | 2.12 |
| Cleomaceae | *Cloeme viscose* L. | B | A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| Cyperaceae | *Cyperus haspan.* L. | S | P | 19 | 1 | 5 | 1 | 1 | 2 | 29 | 3.62 |
| | *Cyperus iria.* L. | S | A | 9 | 5 | 11 | 4 | 4 | 6 | 39 | 4.87 |
| | *Cyperus rotundus* L. | S | P | 11 | 0 | 2 | 0 | 0 | 1 | 14 | 1.75 |
| | *Fimbristylis littorilis* Gaudet. | S | A | 1 | 1 | 0 | 4 | 1 | 4 | 10 | 1.25 |
| Euphorbiaceae | *Euphorbia hyssopifolia* L. | B | A | 7 | 0 | 1 | 0 | 1 | 0 | 10 | 1.25 |
| Fabaceae | *Anthonotha macrophylla* L. | B | P | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.12 |
| | *Indigofera hirsute* Beauv. | B | A | 2 | 0 | 1 | 1 | 0 | 2 | 5 | 0.62 |
| | *Chamaecrista minosolides* L. | B | A/P | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0.25 |
| | *Senna occidentalis* L. | B | P | 13 | 5 | 2 | 4 | 2 | 1 | 27 | 3.37 |
| | *Tephrosia linearis* Willd. Pers. | B | A | 5 | 0 | 3 | 2 | 2 | 2 | 14 | 1.75 |
| Lamiaceae | *Salenostemon monostrochyus* Pers. Beauv. | B | A | 2 | 0 | 0 | 4 | 2 | 3 | 11 | 1.37 |
| Malvaceae | *Corchorus aestuans* L. | B | A | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0.25 |
| | *Malvastrum coromandelianum* (L) Garcke. | B | A/P | 0 | 0 | 0 | 2 | 2 | 1 | 5 | 0.62 |
| | *Sida acuta* Burm. F. | B | P | 4 | 4 | 8 | 4 | 2 | 7 | 29 | 3.62 |
| Onagraceae | *Ludwigia decurrens* Walt. | B | A | 15 | 9 | 7 | 3 | 3 | 8 | 45 | 5.62 |
| | *Lugwigia abyssinica* A. Rich. | B | A/P | 1 | 2 | 2 | 3 | 2 | 1 | 11 | 1.37 |
| Poaceae | *Andropogon tectorum* Schumach & Thonn. | G | P | 2 | 0 | 0 | 2 | 0 | 1 | 6 | 0.75 |
| | *Andropogon gayanus* Kunth. Var. | G | P | 12 | 4 | 8 | 3 | 0 | 1 | 28 | 3.49 |
| | *Brachiaria falcifera* (Trin) Stapf. | G | A | 0 | 3 | 3 | 1 | 2 | 4 | 15 | 1.87 |
| | *Chroris pilosa* Schumach. | G | A | 18 | 8 | 8 | 2 | 4 | 6 | 46 | 5.74 |
| | *Cynodon dactylon* L. Pers. Var. | G | P | 13 | 9 | 7 | 5 | 4 | 11 | 49 | 6.12 |
| | *Dactyloctenium aegyptium* (L) Willd. | G | A | 23 | 18 | 15 | 9 | 5 | 8 | 77 | 9.61 |
| | *Digitaria horizontalis* Willd. | G | A | 20 | 11 | 10 | 12 | 7 | 15 | 75 | 9.36 |
| | *Echinochloa obstusiflora* Stapf. | G | A | 4 | 2 | 1 | 2 | 1 | 1 | 13 | 1.62 |
| | *Echinochloa stagnina* Beauv. | G | A/P | 20 | 12 | 5 | 4 | 3 | 4 | 47 | 5.87 |
| | *Oryza barthii* A. Chev. | G | A | 3 | 5 | 1 | 1 | 0 | 1 | 10 | 1.25 |
| | *Rottbeollia cochinchinensis* (Lour.) Clayton. | G | A | 0 | 5 | 12 | 2 | 1 | 2 | 22 | 2.76 |
| | *Setaria pumila (Poir.)* Roem. & Bergius. | G | A | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0.25 |
| | *Paspalum conjugatum* Berg. | G | P | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0.37 |
| | *Paspalum scrobiculatum* L. | G | A | 14 | 6 | 9 | 3 | 6 | 4 | 42 | 5.24 |
| | *Sorghum arundinaceum* (Desv.) Stapf. | G | A | 2 | 9 | 6 | 3 | 0 | 1 | 21 | 2.62 |
| Rubiaceae | *Mitracorpus villosus*(Sw.) Cham & Schtol. | B | A | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2.62 |
| Solanaceae | *Physalis angulate* L. | B | A | 1 | 2 | 1 | 0 | 0 | 0 | 4 | 0.49 |
| Sterculiaceae | *Melochia corchorifolia* L. | B | A | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0.25 |

MAP = Months after planting, Rel. Abd = relative abundance, Morphological group, LC = life cycle, G = grass, B = broadleaf, S = sedge, A = annual, P = perennial, A/P = annual/perennial.

## Sugarcane performance

Sugarcane emergence and tillering were significantly influenced by trial site, except for cane emergence at 2 MAP. Similarly, plant density and weed control treatment had a significant effect on cane emergence except plant density on germination at 14 DAP and tillering at 6 MAP, which were not influenced by plant density (Table 3). The preemergence application of Terbuthylazine + three SHW and no weeding plots had relatively high germination seedlings across the period of assessment. Generally, the germination of seedlings increased with days after planting. Tillering was higher in preemergence application of Terbuthylazine + three SHW plots, which was similar to preemergence application of Terbuthylazine + postemergence application of 2.4-D plots at 3 MAP and MHW at 12 MAP. The unweeded plots had significantly lower tiller numbers and these plots had relatively similar numbers of tillers with postemergence application of Ametryn + two SHW except at 12 MAP.

***Table 2*** - Effect of planting population and weed control on weed seedling population and dry matter production

| Treatment | Weed dry matter (g $m^{-2}$) | | | | | | Weed density (seedling $m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 MAP | 2 MAP | 4 MAP | 6 MAP | 8 MAP | 12 MAP | 1 MAP | 2 MAP | 4 MAP | 6 MAP | 8 MAP | 12 MAP |
| Site (S) | | | | | | | | | | | | |
| North Field | 21 | 39 | 23 | 17 | 66 | 34 | 43 | 24 | 26 | 20 | 11 | 19 |
| South Field | 14 | 26 | 33 | 21 | 21 | 25 | 13 | 11 | 22 | 20 | 23 | 27 |
| Sed | 3.76 | 8.86 | 6.99 | 5.05 | 3.08* | 1.26* | 6.09* | 3.55 | 1.94 | 3.13 | 1.38 | 2.34 |
| Plant density (P) | | | | | | | | | | | | |
| 43,200 plants $ha^{-1}$ | 18 | 38 | 43 | 36 | 38 | 40 | 32 | 17 | 30 | 28 | 18 | 25 |
| 64,800 plants $ha^{-1}$ | 18 | 31 | 30 | 19 | 54 | 29 | 23 | 15 | 26 | 19 | 18 | 24 |
| 86,400 plants $ha^{-1}$ | 20 | 34 | 23 | 19 | 45 | 29 | 37 | 21 | 22 | 17 | 16 | 24 |
| 108,800 plants $ha^{-1}$ | 14 | 27 | 16 | 14 | 35 | 20 | 21 | 16 | 19 | 15 | 16 | 20 |
| Sed | 4.19 | 7.51 | 4.45** | 4.53* | 7.07 | 3.70* | 9.61 | 4.36 | 1.66** | 0.94** | 1.34* | 2.30 |
| Weed control (W) | | | | | | | | | | | | |
| No weeding | 22 | 46 | 38 | 39 | 50 | 30 | 46 | 21 | 29 | 26 | 19 | 26 |
| Pre-T + 3SHW | 11 | 28 | 29 | 20 | 35 | 30 | 16 | 16 | 23 | 19 | 18 | 22 |
| Post-A+ 2SHW | 17 | 32 | 27 | 20 | 41 | 27 | 28 | 16 | 26 | 21 | 13 | 21 |
| Post-D+ 2SHW | 25 | 26 | 25 | 22 | 43 | 28 | 41 | 15 | 24 | 20 | 18 | 23 |
| Pre-T + Post 2,4-D | 19 | 36 | 31 | 17 | 45 | 35 | 19 | 15 | 26 | 19 | 18 | 22 |
| MHW | 12 | 26 | 17 | 13 | 44 | 25 | 19 | 15 | 18 | 15 | 14 | 25 |
| Sed | 3.52** | 10.41 | 6.99** | 3.92** | 7.31 | 2.79* | 8.17** | 4.47 | 1.59** | 1.59** | 1.74* | 1.95 |
| Interaction | | | | | | | | | | | | |
| S x P | NS | NS | NS | NS | * | NS | NS | NS | NS | NS | * | NS |
| S x W | NS | NS | NS | NS | * | NS | NS | NS | NS | NS | * | NS |
| P x W | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| S x P x W | NS | NS | NS | NS | NS | * | NS | NS | NS | NS | NS | NS |

MAP = months after planting, Pre-T+ 3SHW = preemergence of terbutylazine at 2.0 kg a.i. $ha^{-1}$ + supplementary hoe weeding at 4, 10 and 16 weeks after planting of canes; Post-A + 2SHW = postemergence of ametryn at 3.0 kg a.i. $ha^{-1}$ + supplementary hoe weeding at 10 and 16 weeks after planting of cane; Post-D + 2SHW = postemergence of dicamba at 0.5 kg a.i. $ha^{-1}$ + supplementary hoe weeding at 10 and 16 weeks after planting of cane; Pre-T + Post 2.4-D = preemergence of terbutylazine at 2.0 kg a.i. $ha^{-1}$ + postemergence of 2.4-D at 3.0 kg a.e. $ha^{-1}$ and MHW = monthly hoe weeding.

***Table 3*** - Effect of plant density and weed control on sugarcane establishment

| Treatment | Germination count per plot | | | Tiller count per plot | | | |
|---|---|---|---|---|---|---|---|
| | 14DAP | 42DAP | 2MAP | 3MAP | 6MAP | 9MAP | 12MAP |
| Site (S) | | | | | | | |
| North Field | 51 | 75 | 88 | 98 | 112 | 121 | 144 |
| South Field | 53 | 56 | 55 | 67 | 78 | 87 | 98 |
| Sed | 1.41* | 1.93* | 7.25 | 6.89* | 6.66* | 7.30* | 8.56* |
| Plant density (P) | | | | | | | |
| 43,200 plants $ha^{-1}$ | 58 | 63 | 70 | 68 | 80 | 89 | 99 |
| 64,800 plants $ha^{-1}$ | 55 | 61 | 69 | 75 | 87 | 98 | 127 |
| 86,400 plants $ha^{-1}$ | 57 | 68 | 82 | 87 | 99 | 106 | 120 |
| 108,800 plants $ha^{-1}$ | 57 | 70 | 86 | 99 | 113 | 124 | 186 |
| Sed | 1.96 | 3.63* | 6.28* | 10.60* | 11.18 | 10.26* | 8.81* |
| Weed control (W) | | | | | | | |
| No weeding | 62 | 71 | 83 | 74 | 83 | 90 | 103 |
| Pre-T + 3SHW | 58 | 70 | 94 | 98 | 112 | 123 | 137 |
| Post-A + 2SHW | 55 | 61 | 67 | 73 | 88 | 97 | 116 |
| Post-D + 2SHW | 54 | 61 | 66 | 77 | 90 | 102 | 122 |
| Pre-T + Post 2,4-D | 57 | 64 | 74 | 90 | 101 | 108 | 122 |
| MHW | 57 | 65 | 77 | 81 | 96 | 107 | 127 |
| Sed | 1.52** | 2.66* | 6.00** | 4.49** | 4.95** | 5.20** | 6.75** |
| Interaction | | | | | | | |
| S x P | NS | NS | NS | NS | NS | NS | NS |
| S x W | ** | NS | NS | NS | NS | NS | NS |
| P x W | * | NS | NS | ** | ** | ** | NS |
| S x W x P | * | NS | NS | NS | NS | NS | NS |

DAP = days after planting, MAP = months after planting, T = terbutylazine A = ametryn, D = dicamba, SHW = supplementary hoe weeding, MHW = monthly hoe weeding.

The brix values across the assessment period were not significantly affected by all the factors under evaluation except sites at 11 and 12 MAP (Table 4), where northern field had significantly higher brix value than southern field. The percent polarity was influenced by location (site) of the trial. The north field had 19% compared to 18% recorded from southern field. The highest % polarity was 19.78% at plot where 43,200 plants $ha^{-1}$ were planted and treated with preemergence application of Terbuthylazine + 2.4-D while the lowest % polarity was 12.02% obtained at a similar plant population but a weedy check plot. Similarly, the lowest sucrose purity was 57.5%, obtained at 43,200 plants $ha^{-1}$ per plot with no weed control, while 90.9% sucrose purity were recorded in the plot with the lowest plant population treated with postemergence application of Ametryn + two SHW. No significant interaction was obtained.

The southern field had significantly higher internodes per stalk and stalk girth and low number of stalk per stool. Plant density did not significantly influence yield components of sugarcane. Similarly, weed control did not statistically influence yield component except stalk girth, where weedy check had the least stalk girth (0.85 mm) (Table 5). Millable cane increased with plant population while the lowest plant population plot had the least cane yield, 76 tons $ha^{-1}$, followed by 86,400 plants $ha^{-1}$ with 81 tons $ha^{-1}$; 95 tons $ha^{-1}$ were the highest cane yield obtained and recorded at the plot with 108,800 plants $ha^{-1}$. Plots treated with preemergence of Terbuthylazine + three SHW and preemergence of Terbuthylazine and postemergence of 2.4-D had a significantly higher millable cane yield, followed by monthly hoe weeding, although monthly hoe weeding had a similar cane yield with postemergence application of Ametryn + two SHW and postemergence application of Dicamba + two SHW plots, while the lowest cane yield was obtained from the unweeding plots, 22 tons $ha^{-1}$.

***Table 4*** - Effect of plant density and weed control practice on sugarcane sucrose polarity and purity

| Treatment | Brix percent per plot | | | | | % pol | Purity |
|---|---|---|---|---|---|---|---|
| | 8 MAP | 9 MAP | 10 MAP | 11 MAP | 12 MAP | | |
| Site (S) | | | | | | | |
| North Field | 18 | 19 | 20 | 21 | 22 | 19 | 86 |
| South Field | 18 | 19 | 19 | 20 | 21 | 18 | 82 |
| Sed | 0.10 | 0.20 | 0.56 | 0.30* | 0.21* | 0.35* | 1.91 |
| Plant density (P) | | | | | | | |
| 43,200 plants $ha^{-1}$ | 18 | 19 | 19 | 20 | 20 | 18 | 84 |
| 64,800 plants $ha^{-1}$ | 18 | 19 | 20 | 21 | 21 | 18 | 84 |
| 86,400 plants $ha^{-1}$ | 18 | 19 | 20 | 21 | 21 | 18 | 82 |
| 108,800 plants $ha^{-1}$ | 18 | 19 | 20 | 22 | 22 | 19 | 86 |
| Sed | 0.22 | 0.51 | 0.87 | 0.94 | 1.00 | 0.78 | 3.16 |
| Weed control (W) | | | | | | | |
| No weeding | 18 | 19 | 20 | 19 | 21 | 17 | 78 |
| Pre-T + 3SHW | 18 | 19 | 20 | 21 | 22 | 19 | 87 |
| Post-A+ 2SHW | 18 | 19 | 20 | 20 | 22 | 18 | 84 |
| Post-D+ 2SHW | 18 | 19 | 21 | 21 | 22 | 19 | 86 |
| Pre-T + Post 2,4-D | 18 | 19 | 20 | 21 | 22 | 18 | 83 |
| MHW | 18 | 19 | 20 | 22 | 23 | 19 | 85 |
| Sed | 0.20 | 0.51 | 0.83 | 1.03 | 1.04 | 0.90 | 4.47 |
| Interaction | | | | | | | |
| S x P | NS | NS | NS | NS | NS | NS | NS |
| S x W | NS | NS | NS | NS | NS | NS | NS |
| P x W | NS | NS | NS | NS | NS | * | * |
| S x P X W | NS | NS | NS | NS | NS | NS | NS |

MAP = months after planting, T = terbutylazine A = ametryn, D = dicamba, SHW = supplementary hoe weeding, MHW = monthly hoe weeding, pol = polarity.

***Table 5*** - Effect of plant density and weed control on sugarcane yield components

| Treatment | Yield and yield components | | | | | | |
|---|---|---|---|---|---|---|---|
| | Plant height (m) | Stalk per stool | Internodes/ stalk | Stalk girth (mm) | Single stalk weight (kg) | Millable cane plot$^{-1}$ | Cane yield (ton ha$^{-1}$) |
| Site (S) | | | | | | | |
| North Field | 1.19 | 9 | 9 | 0.03 | 0.54 | 101 | 79 |
| South Field | 1.30 | 6 | 11 | 0.96 | 1.15 | 79 | 89 |
| Sed | 0.035 | 0.284* | 0.407* | 0.010* | 0.163 | 8.91 | 14.6 |
| Plant density (P) | | | | | | | |
| 43,200 plants ha$^{-1}$ | 1.31 | 6 | 10 | 1.02 | 0.89 | 78 | 76 |
| 64,800 plants ha$^{-1}$ | 1.31 | 9 | 10 | 1.06 | 0.86 | 84 | 87 |
| 86,400 plants ha$^{-1}$ | 1.24 | 7 | 9 | 1.00 | 0.79 | 93 | 81 |
| 108,800 plants ha$^{-1}$ | 1.14 | 8 | 11 | 0.91 | 0.84 | 104 | 95 |
| Sed | 0.092 | 1.200 | 0.707 | 0.053 | 0.121 | 4.74** | 2.71 |
| Weed control (W) | | | | | | | |
| No weeding | 1.15 | 7 | 9 | 0.85 | 0.71 | 24 | 22 |
| Pre-T + 3SHW | 1.35 | 8 | 11 | 1.06 | 0.91 | 113 | 112 |
| Post-A+ 2SHW | 1.19 | 7 | 10 | 1.03 | 0.91 | 80 | 86 |
| Post-D+ 2SHW | 1.23 | 8 | 10 | 1.05 | 0.87 | 85 | 84 |
| Pre-T + Post 2,4-D | 1.29 | 7 | 10 | 0.98 | 0.77 | 106 | 104 |
| MHW | 1.28 | 7 | 10 | 1.00 | 0.89 | 97 | 98 |
| Sed | 0.133 | 0.743 | 0.872 | 0.067* | 0.112 | 7.23** | 5.89* |
| Interaction | | | | | | | |
| S x P | NS | NS | NS | NS | NS | NS | NS |
| S x W | NS | NS | NS | NS | * | NS | NS |
| P x W | NS | NS | NS | NS | NS | NS | NS |
| S x P X W | NS | NS | NS | NS | NS | NS | NS |

T = terbutylazine A = ametryn, D = dicamba, SHW = supplementary hoe weeding, MHW = monthly hoe weeding.

## Economic benefit

The economic estimate based on sugarcane sole cropping (Table 4) indicated that the variable production cost of sugarcane per hectare ranged from US$ 201.48 - US$ 386.93 depending on the plant population and weed control option. The profit per hectare increase increased in sugarcane plant density and differed across weed control options. The benefit-cost ratio was influenced by the weed control options across plant population. Plots treated with preemergence application of Terbuthyalzine + postemergence application of 2.4-D had better benefitcost ratio with 43,200 and 108,800 plants ha$^{-1}$ while postemergence of application of dicamba + two SHW and postemergence application of Ametryn + two SHW had BCR of 7.73 and 7.28 across 64,800 and 86,400 plants ha$^{-1}$, respectively. The production efficiency shows that weedy check plot had 88.83% and above while the least was 9.20% obtained where preemergence of Terbuthylazine + postemergence of 2.4-D was applied at plots with 108,800 plants ha$^{-1}$.

Weed seedlings emerged throughout the life cycle of sugarcane during the study period. Fifteen weed species were prevalent in the sugarcane ecology and grass weed species that were dominant with high relative abundance include: *Dactyloctenium aegyptium* had 9.61% followed by *Digitaria horizontalis* (9.36%), *Echinochloa stagnina* (6.87), *Cynodon dactylon* (6.12%), and *Chroris pilosa* (5.74%) in that sequence. This result agreeds with the one by Takim and Amodu (2013), who have reported that Poaceae family dominated sugarcane ecology in Ilorin, Southern Guinea savanna of Nigeria. Takim et al. (2014) have listed *Rottboellia cochinchinensis*, *Panicum maximum*, *Imperata cylindrica. Pannicum repens*, and *Cynodon dactylon* as the most dominant and problematic weed species in Ilorin while Singh et al. (2011) in India have reported *Dactyloctenium aegyptium*

***Table 6*** - Economic analysis of cultivating Sugarcane in SGS of Nigeria

| Treatment | Cane yield(1) (ton ha$^{-1}$) | (2) United States Dollar ($) | | | | Benefit-cost ratio | Production Efficiency (%) |
|---|---|---|---|---|---|---|---|
| | | Cane Price | TC | TR | Profit | | |
| 43,200 plant ha$^{-1}$ | | | | | | | |
| No weeding | 7.75 | 16.80 | 201.48 | 130.24 | -71.25 | -0.35 | 154.70 |
| Pre-T + 3SHW | 44.06 | 16.80 | 311.50 | 740.41 | 428.91 | 1.37 | 42.07 |
| Post-A+ 2SHW | 39 | 16.80 | 298.36 | 655.38 | 357.02 | 1.19 | 45.52 |
| Post-D+ 2SHW | 59.66 | 16.80 | 270.78 | 1002.56 | 731.79 | 2.70 | 27.00 |
| Pre-T + Post 2,4-D | 61.30 | 16.80 | 252.38 | 1042.20 | 789.82 | 3.12 | 24.21 |
| MHW | 63.81 | 16.80 | 319.71 | 1072.30 | 752.59 | 2.35 | 29.81 |
| 64,800 plant ha$^{-1}$ | | | | | | | |
| No weeding | 11.81 | 16.80 | 218.29 | 198.46 | -19.82 | -0.09 | 109.98 |
| Pre-T + 3SHW | 146.25 | 16.80 | 328.30 | 2457.67 | 2129.37 | 6.48 | 13.35 |
| Post-A+ 2SHW | 106.38 | 16.80 | 315.17 | 1787.67 | 1472.51 | 4.67 | 17.62 |
| Post-D+ 2SHW | 149.50 | 16.80 | 287.58 | 2512.29 | 2224.71 | 7.73 | 11.44 |
| Pre-T + Post 2,4-D | 119 | 16.80 | 269.19 | 1999.75 | 1730.56 | 6.42 | 13.46 |
| MHW | 121.94 | 16.80 | 336.51 | 2049.15 | 1712.64 | 5.08 | 16.42 |
| 86,400 plant ha$^{-1}$ | | | | | | | |
| No weeding | 12.81 | 16.80 | 251.89 | 215.27 | -36.63 | -0.14 | 117.01 |
| Pre-T + 3SHW | 85.13 | 16.80 | 361.91 | 1430.58 | 1068.66 | 2.95 | 25.29 |
| Post-A+ 2SHW | 171.88 | 16.80 | 348.78 | 2888.37 | 2539.60 | 7.28 | 12.07 |
| Post-D+ 2SHW | 90 | 16.80 | 321.19 | 1512.41 | 1191.22 | 3.70 | 21.23 |
| Pre-T + Post 2,4-D | 108.63 | 16.80 | 302.80 | 1825.48 | 1522.69 | 5.02 | 16.58 |
| MHW | 136.25 | 16.80 | 370.12 | 2289.63 | 1919.50 | 5.18 | 16.16 |
| 108,800 plant ha$^{-1}$ | | | | | | | |
| No weeding | 18 | 16.80 | 268.70 | 302.48 | 33.78 | 0.12 | 88.83 |
| Pre-T + 3SHW | 133.88 | 16.80 | 378.72 | 2249.80 | 1871.08 | 4.94 | 16.83 |
| Post-A+ 2SHW | 179.31 | 16.80 | 365.58 | 3013.23 | 2647.65 | 7.24 | 12.13 |
| Post-D+ 2SHW | 189.50 | 16.80 | 337.99 | 3184.47 | 2846.48 | 8.42 | 10.61 |
| Pre-T + Post 2,4-D | 206.69 | 16.80 | 319.60 | 3473.34 | 3153.74 | 9.86 | 9.20 |
| MHW | 216.03 | 16.80 | 386.93 | 3630.30 | 3243.37 | 8.38 | 10.65 |

MAP = months after planting, T = terbutylazine A = ametryn, D = dicamba, SHW = supplementary hoe weeding, MHW = monthly hoe weeding, TC = total cost, TR = total revenue. (1) 70% of cane yield were used in the computation, (2) US$ 1 = ₦ 304.50.

as the one among the major weeds species dominant in sugarcane ecologies. The dominance of grasses is the result of the continuous sole cropping of sugarcane (Derksen et al., 1993). The peak of the weed seedlings emergence in this study was at 4 MAP and the weed seedling emergence declined gradually from 8 MAP (October), which coincided with the end of the rainy season. This affirms Takim (2012), who has concluded that the emergence of weed seedlings in the southern Guinea savanna of Nigeria is usually preceded by or coinciding with a period of high rainfall, which highlights the importance of soil moisture to seed germination and emergence.

There was a decrease in the weed seedlings population with increase in planting density. Thus, weed control options where Terbuthylazine was applied as preemergence in herbicide + three SHW or preemergence application of Terbuthylazine + 2.4-D applied postemergence were the most effective weed control strategies that suppressed weed growth. It was observed that the wider spacing in between sugarcane rows allows a wide range of weed florals to grow profusely. Singh and Kumar (2013) have had a similar observation in the subtropical region of India where they reported that the inter row spacing with reduced canopy closure facilitated weeds to establish and dominate the area. In this study, 64,800 and 86,400 plants ha$^{-1}$ had relatively lower weed seedlings population than the lowest population of 43,200 plants ha$^{-1}$, probably due to early canopy closure where the shading effect might limit the availability of resources required for weed germination (Takim, 2012) although Forcella et al. (2000) have concluded that it is difficult to identify the major factor that determines the emergence and population of different weed species in relatively short-term studies.

It was observed in this study that prapplication of Terbuthylazine at 2.0 kg a.i. $ha^{-1}$ + postapplication of 2.4-D at 3.0 kg a.e. $ha^{-1}$ resulted in relatively low weed seedling population. The pre-emergence application substantially reduced the emergence potentials of weed seedlings while subsequently emerged and/or unaffected weeds were control by the postemergence herbicide. This shows that application of two weed control strategies during the growing stage (early developmental stage) is very effective in weed control. Khan and Hashmi (1987) have reported that early approach to weed control in crop fields reduce weed infestation while Singh et al. (2011) have concluded that lower weed seedlings and weed dry biomass is achieved when hoe weeding was carried out in a transplanted cane 30 days after planting alongside herbicide combination with 2.4-D. Nayak et al. (2014) have reported that sequential application of preemergence followed by postemergence herbicide proved to be a better result for a prolonged period of controlling weeds to realize higher yields.

A higher number of sugarcane emergences which subsequently translated to a higher number of millable canes was observed on plots with plant population of 108,800 plants $ha^{-1}$ which could be as a result of a high number of viable setts planted. Singh et al. (2011) have observed an increase in cane stalk number and yield as a result of adjusted cane row spacing of 1.2 m to 0.72 m while Cheema et al. (2002) have concluded that, despite overcrowding of tillers due to limited space and competition for limited resources yet reasonable number of tillers survived to maturity. The high number of millable cane and yield (ton $ha^{-1}$) recorded in pre-application of Terbuthylazine at 2.0 kg a.i. $ha^{-1}$ with three supplementary hoe weedings and Terbuthylazine applied preemergence herbicide + post application of 2.4-D might be due to minimum weed population, thereby enabling the crop to utilize the available resources for its growth and development. Similar report was presented earlier by Singh et al. (2011), yield component was significantly higher when triazine (atrazine) herbicide was applied alongside hoe weeding at 30 days after transplanting of sugarcane.

Wegener (1997) has reported that despite high production cost most farmers still realized a satisfactory profit. Sugarcane cultivation was found to be profitable in this study. The production cost ranged between US$ 201.48 - US$ 386.93 to produce one hectare of sugarcane in Bacita, Nigeria. Daniel (2014) reported an average of US$ 689.64 as cost of producing one hectare of sugarcane in Numan, Sudan savanna region of Nigeria. The profit increased with increase in plant population per hectare. High numbers of tillers were able to reach maturity and attract profit which opposed Bull (2000), who reported that few tillers reach maturity in high density planting.

This study concludes that the adoption of 86,400-108,800 plants $ha^{-1}$ of sugarcane and preemergence application of Terbuthylazine at 2.0 kg a.i. $ha^{-1}$ + supplementary hoe weeding at 4, 10 and 16 weeks after planting (for the small-scale growers) or preemergence application of Terbutylazine at 2.0 kg a.i. $ha^{-1}$ + postemergence application of 2.4-D at 3.0 kg a.e. $ha^{-1}$ for the commercial sugarcane estate will minimize sugarcane field weed infestation and make sugarcane production a profitable venture.

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