CLIMATE SMART AGRICULTURE, FOOD SECURITY AND SUSTAINABLE DEVELOPMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES volume One

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SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-8-8 @ SAEREM World

Society for Agriculture, Environmental Resources & Management (SAEREM)

First published 2025

SAEREM World

Nigeria

Typeset in Times New Roman

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SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-8-8

Printed at: SAEREM World

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SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-8-8 @ SAEREM World

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate Smart Agriculture, Food Security and Sustainable Development** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate smart agriculture (CSA) food security, Sustainable Development issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate smart agriculture, food security, and sustainable development necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Smart Agriculture, Food Security and Sustainable Development: *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of **Climate Smart Agriculture**, Part Two is concerned with The Concept of **Food Security And** and Part Three deals with the Concept of **Sustainable Development**

Eteyen Nyong; October 2025

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Chapter Nineteen

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1.0 Introduction

1.1 Importance of Sugarcane and Emerging Production Challenges

Sugarcane (*Saccharum officinarum* L.) is one of the world's most economically and industrially significant crops, cultivated for sugar, ethanol, molasses, bagasse, and bioenergy. In 2016, over 26.7 million hectares of sugarcane were harvested globally, producing approximately 1.89 billion tons, representing 21.1% of total global crop production (Iqbal et al., 2020). Brazil (41%), India (16%), China (6%), and Thailand (6%) dominate global production, while over 100 other countries contribute the remainder (FAOSTAT, 2019; Cherubin et al., 2021; Statista, 2023).

In tropical Africa, major producers include Mauritius, Kenya, Sudan, Ethiopia, Malawi, Nigeria, and others (Katia et al., 2019). In Nigeria, sugarcane occupies over 500,000 hectares, producing about 3 million metric tons annually, primarily in the North-Central and Kano regions (Bassey et al., 2024). Two main types of sugarcane are cultivated: industrial cane, used for sugar production, and chewing cane, consumed fresh or processed into traditional products such as *Mazarkwaila* and *Alewa* (Bassey et al., 2021).

However, sugarcane productivity in Nigeria and globally faces mounting challenges from climate change and biotic stressors. Rising temperatures, erratic rainfall, and prolonged droughts disrupt germination, tillering, and sucrose accumulation. Conversely, flooding leads to soil erosion, nutrient leaching, and lodging (Cheesman et al., 2024). High temperatures induce physiological stress, reducing photosynthetic efficiency and sugar content by accelerating maturity (Dutta & Dutta, 2024; Mehdi et al., 2024). Elevated CO_2 levels can enhance photosynthesis but increase fiber accumulation, thereby reducing juice extraction efficiency (Squizzato et al., 2021).

1.2 Problem Statement

Despite sugarcane's strategic importance to Nigeria's agro-industrial development, production efficiency remains low due to weed competition, climatic stress, and limited varietal adaptation. The reliance on imported cultivars, poor agronomic integration, and inadequate weed management result in unstable yields and declining sugar recovery. Moreover, the interactive effects of weed pressure and climate variability on sugarcane productivity are not well understood in the Nigerian context, leading to inconsistent management recommendations.

1.3 Objectives of the Chapter

This chapter aims to:

i. Examine the impacts of weed pressure on sugarcane growth, yield, and quality under changing climatic conditions.
ii. Assess the adaptability, weed-suppressive potential, and productivity of selected sugarcane hybrid clones.
iii. Identify climate-resilient and high-yielding sugarcane genotypes suitable for sustainable production in Nigeria.

1.4 Climate Change and Its Impact on Sugarcane Production

Sugarcane is highly sensitive to climatic variations, especially temperature, rainfall, and humidity. Global warming, altered precipitation, and increased extreme weather events significantly affect sugarcane growth, development, and yield (Shahzad et al., 2021; Shivanna, 2022; Shafiq et al., 2024).

1.4.1 Temperature Stress

Optimal sugarcane growth occurs between 28–32 °C. Temperatures exceeding 35 °C disrupt enzymatic and photosynthetic processes, accelerate maturity, and reduce sugar accumulation (Dutta & Dutta, 2024; Mehdi et al., 2024). Prolonged exposure to high temperatures damages chlorophyll, reduces stomatal conductance, and lowers overall productivity (Cheesman et al., 2024).

1.4.2 Water Stress and Drought

Water scarcity reduces leaf expansion, root elongation, and tiller formation. In regions with erratic rainfall, cane yield losses of 25-50% and sucrose reductions up to 35% have been reported (Cheesman et al., 2024; Ramesh et al., 2024). Conversely, flooding leads to waterlogging, root suffocation, and nutrient leaching.

1.4.3 Carbon Dioxide Enrichment

Elevated CO_2 (>450 ppm) enhances carboxylation and photosynthetic efficiency, increasing biomass and water-use efficiency (Squizzato et al., 2021). However, excessive vegetative growth may dilute sucrose concentration and raise fiber content (Shafiq et al., 2024).

1.4.4 Pest, Disease, and Weed Interactions

Climate change exacerbates pest and disease incidences, alters their distribution, and extends their active periods (Skendžić et al., 2021; Dutta & Phani, 2023; Singh et al., 2023). Similarly, increased temperature and moisture fluctuations modify weed ecology, boosting weed germination, altering species composition, and accelerating herbicide resistance (Haring, 2022; Chaki et al., 2023; Rao et al., 2023).

1.5 Weed Pressure in Sugarcane Systems

Weeds are among the most significant biotic constraints in sugarcane cultivation, competing for essential growth resources and reducing yield and sugar recovery (Bassey et al., 2023; Yuan et al., 2025). Under severe infestation, yield losses between 30-67% have been documented, depending on weed composition and management history (Mehdi et al., 2024; Shittu & Bassey, 2023; Shittu et al.., 2025).

In Nigeria, wide spacing, slow early growth, and frequent irrigation promote weed proliferation. The critical weed interference period (30–60 days after planting or ratooning) is particularly detrimental to stalk population and sucrose recovery (Zhou et al., 2025). Prolonged infestation shortens ratoon lifespan and may result in near-total crop failure (Kubiak et al., 2022).

Dominant weeds such as *Cyperus rotundus*, *Echinochloa colona*, *Amaranthus spinosus*, and *Sorghum halepense* display high adaptability to climate variability (Mahima & Bijnan, 2016; Ramesh et al., 2024). Climate-induced shifts, such as elevated CO_2 and increased rainfall variability, further enhance their persistence and competitiveness (Rao et al., 2023).

1.6 Climate-Smart and Integrated Weed Management Approaches

1.6.1 Weed Dynamics under Climate Change

Elevated CO_2 and temperature favor C_3 weeds with greater photosynthetic flexibility, increasing biomass accumulation and competitiveness (Haring, 2022; Ramesh et al., 2024). Rainfall fluctuations support aggressive perennials capable of rapid regrowth under intermittent moisture stress (Nayak et al., 2023). These dynamics necessitate adaptive weed control frameworks.

1.6.2 Cultural and Mechanical Approaches

Cultural practices such as legume rotation, high-density planting, and intercropping improve soil fertility while suppressing weed emergence. Organic mulches, green manures, and cover crops (*Crotalaria juncea*, *Mucuna pruriens*) significantly reduce weed biomass and conserve soil moisture (Mehdi et al., 2024). Mechanical weeding remains vital during the early growth stages (30–90 days post-planting) (Singh et al., 2023).

1.6.3 Biological and Allelopathic Control

Biological agents (*Trichoderma harzianum*, *Pseudomonas fluorescens*) and allelopathic compounds from sugarcane residues are promising eco-friendly tools for weed suppression (Rao et al., 2023; Chaki et al., 2023; Shittu et al., 2025a, 2025b). These strategies improve soil microbial activity and reduce herbicide dependence.

1.6.4 Chemical and Precision Weed Management

Pre- and post-emergence herbicide integration (e.g., metribuzin, atrazine, glyphosate, ametryn) under rotational schemes enhances control spectrum and delays resistance (Haring, 2022). Precision technologies such as site-specific application and drone-assisted spraying optimize efficacy and minimize environmental impact (Nayak et al., 2023).

1.6.5 Climate-Smart Integration Framework

A holistic climate-smart IWM framework includes:

- Adoption of weed-suppressive sugarcane varieties with dense canopies (Kumar et al., 2024; Dlamini et al., 2024);
- Residue retention and minimal tillage to limit weed germination;
- Decision-support systems (DSS) for real-time monitoring using remote sensing; and
- Farmer training and policy incentives for adaptive management (Ramesh et al., 2024).

2.0 MATERIALS AND METHODS

2.1 Experiment sites

A field trial was conducted at the upland sugarcane experimental field of the National Cereals Research Institute, Badeggi (Lat. 9° 45'N, Long. 06° 07 E and 89 m above sea level) in the southern Guinea savanna of Nigeria during the 2017/2018 cropping season. The site used in each year had been under continuous sugarcane cropping for over a decade. The total rainfall during the experimental period was 1504.1 mm in 2017 and 1045.4 mm in 2018, while the mean air temperature was 36 to 38° C in 2017 and 34 to 36° C in 2018. Before cultivation, the vegetative cover of the experimental site was manually cleared, ploughed and harrowed with a tractor in the first week of February 2017 and 2018. The land was fully irrigated before planting by pumping water from a stream using a 3.5 HP water pump with a 12.5 cm diameter hose. Thereafter, the land was marked out into plots with bunds at the edges for water retention.

2.2 Treatment and Experimental design

Fourteen promising clones (BD 140-02m, BD 140-011m, BD 140-014m, BD 1098-001m, BD 1098-003m, BD 1098-005m, BD 1098-014m, BD 441-004m, BD 441-007m, BD 575-007m, BD 1354-20m, BD 1576-31m, BD 1576-07m, BD 1576-14m) obtained from fuzz raising were advanced from the progeny testing II series to the preliminary yield trial. The fourteen clones with two commercial varieties (B 47419 and N 27) were planted in a randomized complete block design (RCBD).

2.3 Crop husbandry

Each plot size was 5 m x 6 m (30 m²), consisting of 6 sugarcane rows and replicated three times. Each row was spaced 1 m apart. Tender, healthy, young stalks of six-month-old sugarcane were used as planting material. The stalks were cut into setts, each containing three eye buds, and planted continuously end-to-end without intra-row spacing in a shallow sunken bed. Sixty cane sets were planted per plot. Basal application of 120 kg ha^{-1} N fertilizer as urea, 60 kg P_2O_5 ha^{-1} as single superphosphate, and 90 kg K_2O ha^{-1} as muriate of potash was split-applied. Half of N, P, and K were applied at planting before mulching, while the remnant was applied at 10 weeks after planting (WAP) during the earthing up as a strip by the sugarcane stand in the form of band placement. Fertilizers were applied by side-banding at about 5 cm away from the seedlings and at about 5 cm deep along the row.

Irrigation water was applied once per week from February to April. Rainfall was supplemented with irrigation in May, which was the establishment of the rainy season.

2.4 Agronomic data collection

Weed species samples in each plot were collected from a 1 m² quadrat at 3, 6, and 9 months after planting (MAP). Weed species seedlings in each quadrat were clipped at the soil level and identified according to Akobundu et al. (2016). The composition of the weed flora was analyzed by calculating the relative abundance (RA) of each species as follows:

$$\mathrm{R.A} = \frac{Total\ number\ of\ individual\ of\ a\ species\ in\ all\ the\ quadrats}{Total\ number\ of\ quadrats\ in\ which\ the\ species\ occurred}$$

$$= \sum \frac{WI}{n}$$

Where Wi is the sum of individuals of a species occurring in all the quadrats, “n” is the number of quadrats in which the species occurred (Das, 2011). The weed species were counted to determine the weed density on a plot basis and expressed in number per m². The weed samples were oven dried at 80 °C to a constant weight and weighed to determine the dry matter in g per m².

Data was collected on germination and establishment (%) at 21 and 42 days after planting (DAP), respectively, and tiller count at 3 months after planting (MAP). Sugarcane stalk height (cm) at 9 MAP was taken from the soil level to the tip of the last unfolded leaf using a graduated ruler. Stalk girth (cm) at 10 MAP was taken using a Vernier caliper. Per cent Brix at harvest (12 MAP) was taken using a hand refractometer to determine the level of soluble sugar. Millable cane and yield (t ha $^{-1}$) were taken at harvest from the harvested stalks and weighed. Cane juice was analyzed for purity, polarity, sucrose, glucose, fiber, and estimated recoverable sucrose percent (ERS). The estimated recoverable sucrose percent (ERS) and smut incidence were analyzed as follows:

Recoverable Sucrose percent (RS)

$$RS\ (\%) = \frac{Pol\% - (Brix - Pol) \times JF}{2}$$

Juice Factor = 0.65, Pol = Polarity (Islam *et al.*, 2011).

$$\text{Sugar yield (t ha}^{-1}\text{)} = \frac{Cane\ Yield\ t\ ha{-}1 \times Recovery\ Sucrose}{100}$$

2.5 Data analysis

All data collected were subjected to analysis of variance (ANOVA). The treatment means were separated using the Least Significant Difference (LSD) at a 5% level of probability using the SAS version 9.0 statistical package.

3.0 RESULTS

3.1 Weed dynamics and Relative Abundance

In the 2017 cropping seasons, the most abundant weed species across the experimental field was *Paspalum scrobiculatum* (Linn.) (Table 1). However, across the treatments in 2017, the most consistent and abundant weed species were *Paspalum scrobiculatum* (Linn.), *Kyllinga squamulata* (Thorn ex. Vahl.), *Setaria pumila* (Poit.), *Imperata cylindrical* (Linn.), *Cenchrus biflorus* (L.), and *Cynadon dactylon* (Linn.). Furthermore, as the season advanced from 6 to 9 MAP, the most consistent and abundant weed species were *Schwenckia americana* (L.), *Hyptis suaveolens* (Poit.), *Imperata cylindrical* (Linn.), *Paspalum scrobiculatum* (Linn.), *Digitaria milanjiana* (Wild.), and *Kyllinga squamulata* (Thorn. ex Vahl) only. The following weeds were early emergents but are not seen at the end of the season: *Cynodon dactylon* (L), *Cenchrus biflorus* (L), *Dactyloctenium aegyptium* (L), *Euphorbia hirta* (L), *Cleome viscose* (L), *Trichodesma zeylanium* (L), *Cyperus rotundus* (L), and *Phyllanthus pentandrus* (Schum & Thonn), *Eragrostis tenella* (Linn.) P. Beauv.

In 2018, the most abundant weed species observed were *Paspalum scrobiculatum* (Linn.), *Cenchrus biflorus* (L.), *Dactylactenum aegyptium* (Linn.), *Kyllinga squamulata* (Thorn. ex Vahl), *Eleusine indica* (L.), and *Setaria babarta* (L.) (Table 1). At 6 to 9 MAP across the season, the abundant weed species identified were *Cyperus esculentus* (Linn.), *Hytis suaveolens* (Poit.), *Phyllanthus leucanthus* (Schum & Thonn), *Boerhovia diffusa* (L.), *Digitaria horizontalis* (Wild.), and *Brachiaria deflexa* (Schumach). *Digitaria milanjiana* (Wild.), *Cenchrus biflorus* (L), *Setaria pumila* (Poit), *Panicum maxicum* (Jacq.), *Pennisetum pedicellatum* (Trin), *Eleusine indica* (L.), *Andropogon gayanus* (Schum & Thonn), *Setaria verticillata* (Lam.) Kunth, *Brachiaria jubata* (Fig. & De Not), *Euphorbia heterophylla* (L), and *Kyllinga squamulata* (Thorn.) were early emergents but are not seen at the end of the season.

3.2 Weed dry matter production

Weed dry matter (DM) in the plant crop differed significantly between sugarcane hybrid clones (Table 2). Least weed dry matter (0.41 g/cm²) was observed in BD 1576-07m, which did not differ significantly with weed dry matter obtained in BD 1098-005m (0.43 g/cm²), BD 1576-14m (0.43 g/cm²), B 47419 (0.45 g/cm²), N 27 (0.47 g/cm²), and BD 1098-003m (0.47 g/cm²) genotypes at 3 MAP compared with others. However, at 9 MAP, sugarcane genotype BD-1098-003 m had significantly ($P > 0.05$) lower weed dry matter, which differed from weed dry matter in other genotypes except in values obtained in BD 1354-20 m (0.51 g/cm²), BD 1576-31 m (0.36 g/cm²), BD 140-014 m (0.35 g/cm²), and BD 1098-014 m (0.33 g/cm²) genotypes. In general, weed dry weight decreased across all genotypes from 3 to 9 MAP. This suggests that sugarcane canopy development may have gradually suppressed weed growth over time.

3.3 Growth performance

The percentage of germination varied considerably ($P < 0.05$) across the sugarcane hybrid clones during the research year (Table 3). Other than BD 1098-014m, BD 441-007m, and N 27, the sugarcane genotype BD 140-014m yielded a greater germination percentage. Additionally, BD 140-014m had a greater percentage of developed plants (70.3%), comparable to BD 1098-014m and BD 441-007m. This was much higher than the other sugarcane clones that were examined, with the exception of BD 1098-005m, BD 575-007m, BD 1354-20m, BD 1576-31m, BD 1576-07m, and BD 1576-14m. Likewise, among all the clones that were examined, BD 441-007m had the most tillers (127.67), which was substantially the same as BD 1098-014m, while BD 1576-31m had the fewest tillers (19). The height of the sugarcane plants did not vary significantly ($P > 0.05$) among the genotypes under investigation.

3.4 Yield and yield related characters

In comparison to the other sugarcane hybrid clones evaluated, BD 140-014m had significantly ($P < 0.05$) more sugarcane stalks per stool, with the exception of BD 1098-014m, BD 1354-20m, and BD 1576-31m (Table 4). Comparable in size to the BD 1098-005m, the BD 140-014m hybrid also possessed larger stalks; both hybrids outperformed other hybrid clones in terms of stalk size (Table 4). Additionally, BD 140-011m had 113 millable stalks per plot, which was comparable to the BD 1098-001m hybrid clone. The cane yield of BD 1098-003m was the greatest at 136.8 t/ha, well above the cane yield of all other hybrid clones examined, with the exception of BD 1098-001m, BD 1098-014m, and N 27 (Table 4).

3.5 Brix content

As expected, Brix content generally increased across all genotypes from 8 to 12 months after planting (MAP). This indicates that sugar accumulation is a progressive process in sugarcane. Higher brix content was obtained in BD 1098-001m hybrid clone compared with that from other clones (Table 5). The trend of brix accumulation for hybrid clones like BD 140-02m, BD 140-011m, BD 140-014m, BD 1098-001m, BD 1098-003m, BD 1098-005m, BD 575-007m, BD 1576-31m, BD 1576-07m, BD 1576-14m and B 47419, increase with increase in age of the crop. Some genotypes, such as BD 1098-001m and BD 1576-31m, exhibited consistently higher Brix values throughout the observation period, suggesting their potential for higher sugar yield.

3.5 Juice quality traits

There was a significant difference in juice quality among the varied genotypes (Table 6). BD 1098-003m had the highest moisture percent (73.03) while BD 1098-005m had the lowest (57.90). Maximum fibre content was found in hybrid BD 1098-005m and lowest in BD 1098-003m. Genotypes such as BD 1098-001m, BD 441-004m, and BD 1354-20m consistently showed higher Brix values, indicating higher sugar content. Genotypes like BD 1098-005m and BD 1354-20m exhibited higher sucrose content, which is crucial for sugar production.

Furthermore, Significant differences were observed among the genotypes for all juice quality parameters. The glucose percentage were significantly ($P < 0.05$) higher in BD 1354-20m than other hybrid clones tested (Table 7). The polarity of BD 1576-14m (22.47) and BD 1354-20m (22.25) were significantly higher than other clones studied except N 27. Maximum purity percent of 93.6 was obtained from BD 1576-14m compared with that from other clones. Maximum recoverable sucrose was found in BD 1576-14m compared with that from other clones. Sugar yield differs among the diver's hybrid clones, BD 1098-003m and BD 1098-001m, gave higher yield than the other hybrids and the checks varieties (N 27 and B 47419).

4.0 Discussion

4.1 Weed Flora Composition and Dynamics

In the experimental fields under study, *Cyperus esculentus* (Linn.) emerged as the most prevalent weed species, while *Paspalum scrobiculatum* (Linn.) was dominant in 2017. These two species, being rhizomatous and perennial, exhibit remarkable adaptability and persistence in sugarcane fields. Such persistence reinforces previous findings that sedges are among the most problematic weed types in sugarcane systems, as highlighted by Zingsheim and Döring (2024) and Rathika et al. (2023).

Across both cropping seasons, the most common weed species identified were *P. scrobiculatum* (Linn.), *Sporobolus pumila* (Poir.), *Panicum leucanthus* (Schum. & Thonn.), *Boerhavia diffusa* (L.), *Hyptis suaveolens* (Poit.), *C. esculentus* (Linn.), and *Kyllinga squamulata* (Thorn. ex Vahl). The greater abundance of grass weed species during the 2017 wet season was likely driven by high soil moisture due to rainfall, which favored their proliferation. These grass species share phenological and physiological similarities with sugarcane, particularly during the vegetative phase, allowing them to thrive under similar environmental conditions (Bassey et al., 2024).
Broadleaved species such as *Commelina diffusa* Burm. and *C. benghalensis* L. were more abundant in 2017, while *Phyllanthus niruri* Schum. & Thorn., *H. suaveolens* Poit., and *B. diffusa* L. became more dominant in 2018. These species pose significant competition for nutrients and light, indicating the need for targeted weed management strategies. The observed trends align with the results of Khaliq et al. (2018) and Mehdi et al. (2024), who reported that weed species composition and duration of infestation are critical determinants of sugarcane yield reduction.
Overall, weed species were more prevalent in 2017 than in 2018, likely due to variations in rainfall, temperature, soil management, and prior cropping history factors influenced by climate variability. Similar findings were reported by Jabran & Doğan (2020); Keerthi et al. (2023) and Tursun et al. (2025), who separately noted that climatic fluctuations strongly influence weed population dynamics and diversity in tropical cropping systems.

4.2 Growth and Yield Variability Among Genotypes

The superior performance of hybrid clones BD-1098-003 m and BD-575-007 m in suppressing weed growth can be attributed to their higher tillering capacity, rapid canopy closure, and dense stooling habit. These morphological traits reduce light penetration to the soil surface, thereby limiting weed seed germination and growth. Similar conclusions were drawn by Budeguer et al. (2021) and Islam et al. (2023), who reported that improved sugarcane cultivars exhibit stronger weed-suppressive ability due to rapid canopy formation and vigorous early growth.
Dense canopy cover alters soil microclimate particularly temperature and moisture affecting weed seed dormancy and germination (Travlos et al., 2020; Song et al., 2024). This shading effect induces etiolation and stem weakening in emerging weeds, increasing their susceptibility to mechanical or environmental stress (Bassey et al., 2020; Bassey et al., 2023). Selecting sugarcane genotypes with such competitive traits can substantially enhance yield by minimizing resource competition and reducing the need for herbicide use.
Differences in growth parameters among hybrid clones may also reflect inherent genetic potential and resource-use efficiency. Traits such as high tiller density, superior canopy formation, and drought tolerance contribute to better establishment and sustained productivity. Similar genotype-dependent variation in establishment and tillering was reported by Ahmad et al. (2019), and Hatt and Döring (2023).

Significant differences in plant height observed among genotypes corroborate findings by Khan et al. (2018) and Desalegn et al. (2023), who evaluated diverse sugarcane clones under varying agro-climatic conditions. Azam et al. (2023) further associated these differences with genotypic expression and efficient input utilization. Comparable trends were observed by Bassey et al. (2020), who reported considerable variation in growth traits among fifteen sugarcane genotypes. Variability in stalk number and length across genotypes could be linked to morphological differences and genetic heterogeneity. Katia et al. (2019) reported similar results, attributing productivity variation to genetic divergence between parent lines. Consistent with findings by Alam et al. (2022); Bassey et al. (2019), and Rasheed et al. (2023), this study confirms that genotypic potential strongly influences cane yield per hectare.

4.3 Juice Quality and Sugar Recovery

Variation in juice quality among sugarcane genotypes reflects differences in genetic potential, maturity rate, and physiological efficiency. The observed improvement in juice quality as the crop aged (10-12 months) suggests that maturity duration influences sucrose accumulation. Afolayan & Abdusalam (2022) reported similar patterns in Nigerian genotypes, with brix values ranging from 17.8 to 25.0%.

Differences in brix, polarity, and purity across genotypes may be attributed to the consistent expression of sugar-related genes and the efficiency of assimilate partitioning. Li et al. (2023) noted that minimal variation in brix content among certain varieties was due to uniform genetic control of these traits. Zhi et al. (2023) and Umar et al. (2025), observed significant differences in fiber, moisture, sucrose, and purity levels among genotypes, emphasizing that varieties with higher juice purity (>85%) achieve earlier maturity and higher sugar yields.

Parihar (2020) similarly recorded purity values ranging from 75.9% to 89.3% and pol percentages from 12.0% to 13.4% across six clones. These results align with those of Bassey et al. (2020), who found an inverse relationship between cane yield and sugar recovery within the same genotype. The higher sugar yield observed in BD-1098m and related clones can thus be attributed to their superior genetic composition, as also supported by Adilakshmi et al. (2024) and Bassey et al. (2020).

4.4 Implications for Climate-Smart Sugarcane Breeding

The findings of this study underscore the importance of incorporating weed-suppressive and climate-resilient traits into sugarcane breeding programs. Genotypes exhibiting early vigor, dense canopy cover, and allelopathic potential are valuable in reducing herbicide dependence and maintaining productivity under variable climatic conditions.

The allelopathic potential observed in certain genotypes may also influence weed suppression through biochemical pathways that alter soil microbial interactions and nutrient dynamics

(Concenco et al., 2016; Khamare et al., 2022). Integrating such traits into breeding frameworks can yield varieties better adapted to climate-induced weed pressures.

Furthermore, the identification of genotypes with superior juice quality and higher recoverable sucrose supports sustainable sugar production, enhancing both farmer income and industrial efficiency. The combined improvement of agronomic performance, weed tolerance, and sugar yield should therefore be prioritized in future climate-smart breeding strategies.

5.0 Conclusion

Weed pressure remains one of the most critical biotic constraints limiting sugarcane productivity, with specific weed biotypes and their duration of infestation significantly influencing crop growth and yield attributes. The study demonstrated that certain hybrid genotypes, particularly BD 1098-001, BD 1098-003, BD 1098-005, and BD 1098-014 exhibited superior agronomic performance, characterized by high cane yield and elevated estimated recoverable sucrose (ERS). These genotypes show strong potential for advancement and multi-locational testing across diverse ecologies to assess yield stability and juice quality consistency.

Clones exhibiting high fiber content alongside good sugar yield may serve dual purposes for both sugar and ethanol production, an avenue yet to be fully explored in Nigerian sugarcane breeding programs. Identifying genotypes suited for such dual-purpose use could significantly enhance the efficiency and profitability of the sugar industry.

The timing of the highest Brix percentage in non-flowering sugarcane genotypes provides a practical indicator for determining physiological maturity and optimizing harvest schedules. This physiological insight is critical for improving sugar recovery and reducing post-harvest losses. The advancement of promising hybrid clones for broader adaptability trials is therefore imperative. Future breeding efforts should focus on integrating high-yield potential with traits conferring weed-suppressive ability, stress tolerance, and improved juice quality. Furthermore, sustained investment in genetic improvement, adaptive breeding, and climate-smart agronomic management is essential for developing resilient sugarcane varieties capable of maintaining productivity under increasing climatic variability.

In addition, complementary research on integrated pest, disease, and weed management will be indispensable for ensuring sustainable cane production and achieving national self-sufficiency in sugar and bioethanol production.

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Table 1. Mean relative abundance (%) of weed species encountered in sugarcane field in 2017 and 2018

	Relative abundance (%)					
	Months after planting (MAP)					
	2017			2018		
Treatment	3	6	9	3	6	9

Grassess						
Andropogon gayanus (Schum & Thonn)	-	-	-	29.0	-	-
Brachiaria jubata (Fig. & De Not)	-	-	-	22.86	-	-
Brachiaria deflexa (Schumach) C.E	-	-	-	30.35	-	14.29
Cenchrus biflorus (L.)	10.29	5.27	-	27.33	24.0	-
Cynodon dactylon (Linn.)	13.86	2.0	-	9.33	8.12	19.57
Dactyloctenium aegyptium (Linn.)	8.0	2.40	-	25.75	8.18	9.81
Digitaria horizontalis (Wild.)	-	-	-	22.53	6.17	16.50
Digitaria milanjiana (Wild.)	1.0	7.13	2.8	16.5	-	-
Eleusine indica (L.)	1.0	-	-	25.13	5.56	-
Imperata cylindrica (Linn.)	16.79	9.0	8.80	15.60	-	10.67
Panicum maxicum (Jacq.)	2.0	1.60	2.5	25.67	-	-
Paspalum scrobiculatum (Linn.)	34.37	8.68	5.52	29.02	6.83	6.86
Pennisetum pedicellatum (Trin)	-	3.0	-	13.0	-	-
Setaria barba (Lam)Kunth	-	-	-	28.0	21.41	-
Setaria pumila (Poit)	18.47	1.50	5.33	38.80	-	-
Setaria verticilillata (Lam) Kunth	-	-	-	8.67	-	-
Broadleaves						
Acalypha segetalis (Schum & Thonn)	-	3.38	1.0	-	-	-
Ageratum coryzoides (Linn.)	1.0	-	-	11.0	-	-
Boerhovia diffusa (L.)	2.25	1.0	3.29	-	11.75	38.33
		1.33	1.0	-	-	4.0
Calopogonium mucunoides (Desv.)	-					
Cleome viscosa (L.)	1.67	2.11	-	7.0	2.0	-
Commelina benghalensis (L.)	2.25	4.18	2.0	10.40	3.0	7.76
Corchorus olitorius (L.)	-	2.50	1.8	3.0	2.0	6.14
Daniella oliveru (Rolfe) Hutch & Dalz	-	1.0	-	-	2.0	-
Desmodium tortuosum (Sw.) DC	-	4.0	1.13	6.0	-	-
Euphorbia heterophylla (Linn.)	1.0	2.50	2.13	5.0	2.0	-
Euphorbia hirta (Linn.)	3.0	1.0	-	4.67	-	-
Eragrostis tenella (Linn.) P.Beauv.	8.0	-	-	22.0	-	-
Gomphrena celosiodes (Mart.)	-	5.0	-	-	-	6.0
Hyptis suaveolens (Poit)	4.22	6.25	2.27	3.33	21.89	16.63
Indigofera hirsute (Linn.)	1.67	3.42	1.75	-	2.46	-
Ipomoea asarifolia (Desr.) Roem	-	2.77	1.25	4.0	3.33	-
Mitracarpus villosus (Sw.) DC	2.0	-	1.0	-	2.0	-
Oldenlandia herbacea (Linn.)		-	-	-	2.67	-

Phyllanthus leucanthus (Schum & Thonn)	1.50	3.08	2.0	-	20.0	11.09
Phyllanthus pentandrus (Schum & Thonn)	3.0	5.44	-	-	-	-
Physalis angulata (Linn.)	-	1.0	-	4.0	8.67	2.0
Rottboellia cochinchinensis (Lour.)	3.33	4.33	2.73	-	2.0	2.67
Schwenckia americana (L.)	9.80	9.73	5.69	8.80	2.0	5.20
Sebestina chamaelea (L) Muell.Arg	-	1.60	4.0	18.33	-	4.0
Senna obtusifolia (L.)	-	1.0	1.56	-	2.0	-
Sesamum alatum (Thonning)	-	1.0	-	-	16.0	4.0
Spernacea semensis (L.)	2.0	-	-	-	-	-
Stylosanthus hamata (L.) Taub.	-	1.33	1.0	-	2.50	-
Tephrosia pedicelata (Bak.)	-	3.24	2.33	2.50	-	5.0
Trichodesma zeylanium ( )	2.0	2.71	-	-	3.33	-
Tridax procumbens (Linn.)	3.11	4.72	5.47	4.67	2.0	2.0
Sedges						
Cyperus esculentus (Linn.)	2.67	5.93	3.0	16.40	26.75	10.59
Cyperus rotundus (Linn.)	3.0	2.0	-	5.0	8.75	-
Kyllinga squamulata (Thorn.ex Vahl)	25.50	6.26	2.80	36.0	4.0	-

Source: Weed Field Survey (2017 and 2018)

Table 2. Mean values on weed dry weight (g m^{-2}) of varied sugar cane genotypes at 3, 6 and 9 months after planting (Two years pooled data)

Genotypes	Months after planting (MAP)		
	3	6	9
BD 140-02m	0.55	0.42	0.26
BD 140-011m	0.54	0.44	0.27
BD 140-014m	0.67	0.54	0.35
BD 1098-001m	0.59	0.46	0.26
BD 1098-003m	0.47	0.35	0.18
BD 1098-005m	0.43	0.37	0.22
BD 1098-014m	0.60	0.49	0.33
BD 441-004m	0.55	0.44	0.26
BD 441-007m	0.53	0.41	0.26
BD 575-007m	0.43	0.37	0.22
BD 1354-20m	0.82	0.68	0.51
BD 1576-31m	0.73	0.53	0.36
BD 1576-07m	0.41	0.39	0.24
BD 1576-14m	0.43	0.36	0.23

N 27	0.47	0.38	0.24
B 47419	0.45	0.36	0.27
CV %	4.5	18.7	15.2
LSD (0.05)	0.06	0.05	0.12

Table 3: Mean values for growth performance of selected hybrid sugarcane genotypes (Two years pooled data)

Genotypes	Germination (%)	Establishment (%)	Number of Tiller (#)	Plant height (cm)
BD 140-02m	49.33	49.30	71.33	156.53
BD 140-011m	37.67	50.33	68.33	189.80
BD 140-014m	64.00	70.33	106.00	187.80
BD 1098-001m	37.00	51.00	56.00	184.33
BD 1098-003m	46.00	59.67	76.33	194.07
BD 1098-005m	29.67	34.33	19.00	167.53
BD 1098-014m	58.00	68.33	124.00	143.27
BD 441-004m	38.33	39.33	64.67	186.33
BD 441-007m	50.67	66.33	127.67	158.87
BD 575-007m	18.33	31.33	61.67	151.00
BD 1354-20m	17.67	17.67	41.67	168.07
BD 1576-31m	9.33	15.00	20.00	157.60
BD 1576-07m	20.00	16.33	55.67	144.40
BD 1576-14m	24.33	32.67	50.67	167.80
N 27	51.33	55.67	92.00	191.467
B 47419	46.33	51.67	57.33	187.60
CV %	28.5	47.10	81.00	24.00
LSD (0.05)	17.78	34.80	92.17	NS

CV - coefficient of variation, LSD - least significant difference, NS- Not significant

Table 4: Mean values for Cane yield and yield related characters of selected hybrid sugarcane genotypes (Two years pooled data)

Genotypes	Stalk stool^{-1}	Stool plot^{-1}	Stalk girth (cm)	Millable cane (#)	Cane yield (t ha^{-1})
BD 140-02m	4.67	19.67	2.10	92.33	81.7
BD 140-011m	9.87	15.00	2.33	113.33	101.0
BD 140-014m	5.00	25.67	2.83	81.33	100.3
BD 1098-001m	6.13	15.00	2.23	110.00	116.7
BD 1098-003m	5.87	20.67	1.97	106.00	136.8
BD 1098-005m	5.57	12.00	2.80	54.00	85.7
BD 1098-014m	7.40	13.33	2.03	101.33	118.0
BD 441-004m	6.80	13.33	1.97	104.67	81.3
BD 441-007m	6.00	19.33	2.03	102.67	102.7

BD 575-007m	6.67	14.00	2.23	81.00	84.3
BD 1354-20m	7.63	14.00	2.43	74.33	83.7
BD 1576-31m	7.33	12.33	2.10	63.33	77.3
BD 1576-07m	7.03	8.33	2.37	62.00	85.0
BD 1576-14m	4.67	13.00	2.10	88.33	78.7
N 27	6.87	15.33	2.37	97.33	119.3
B 47419	5.13	8.67	1.93	103.33	71.7
CV (%)	26.50	62.70	12.30	57.50	15.70
LSD (0.05)	2.78	NS	0.46	NS	31.60

CV - coefficient of variation, LSD - least significant difference

Table 5: Trend of brix (%) accumulation of hybrid sugarcane genotypes (Two years pooled data)

Genotypes	Brix content (%)		
	Months after planting (MAP)		
	8	10	12
BD 140-02m	15.27	18.43	19.30
BD 140-011m	15.13	15.63	17.50
BD 140-014m	14.53	17.03	17.63
BD 1098-001m	17.13	20.67	21.40
BD 1098-003m	17.88	18.10	18.87
BD 1098-005m	14.33	18.43	20.60
BD 1098-014m	16.53	19.00	19.43
BD 441-004m	15.13	19.27	19.47
BD 441-007m	15.07	18.83	17.30
BD 575-007m	15.00	18.83	19.90
BD 1354-20m	9.87	16.73	16.27
BD 1576-31m	12.40	17.07	21.13
BD 1576-07m	14.07	18.23	18.70
BD 1576-14m	14.33	15.77	17.83
N 27	16.73	19.07	18.57
B 47419	14.30	16.73	17.33
CV (%)	19.80	9.10	10.10
LSD (0.05)	4.91	2.72	3.18

CV - coefficient of variation, LSD - least significant difference, MAP- months after planting

Table 6a: Juice quality of varied hybrid sugarcane genotypes (Two years pooled data)

Genotypes	Moisture (%)	Fibre (%)	Brix (%)	Sucrose (%)
BD 140-02m	67.87	10.93	21.20	20.82
BD 140-011m	67.16	12.74	20.10	19.85
BD 140-014m	68.33	11.55	20.12	18.87
BD 1098-001m	63.01	13.99	23.00	20.39
BD 1098-003m	73.03	5.37	21.60	18.40
BD 1098-005m	57.90	16.90	25.20	22.76
BD 1098-014m	65.41	10.59	24.00	19.19
BD 441-004m	64.00	11.40	24.60	23.12
BD 441-007m	64.10	14.90	21.00	19.70
BD 575-007m	65.30	11.70	23.00	21.32
BD 1354-20m	60.45	13.05	26.50	24.79
BD 1576-31m	62.85	14.15	23.00	21.66
BD 1576-07m	66.17	12.83	21.00	18.64
BD 1576-14m	64.64	11.36	24.00	24.75
N 27	69.79	9.21	21.00	17.09
B 47419	63.59	15.21	21.20	18.37
CV (%)	8.6	4.5	4.3	4.8
LSD (0.05)	7.9	3.2	1.4	1.9

CV - coefficient of variation, LSD - least significant difference

Table 6b: Juice quality of varied hybrid sugarcane genotypes (Combined year effect)

Genotypes	Glucose (%)	Polarity (%)	Purity (%)	Recoverable Sucrose	Sugar Yield (t ha^{-1})
BD 140-02m	26.03	19.15	89.50	11.78	9.62
BD 140-011m	24.82	18.29	87.9	11.13	10.06
BD 140-014m	23.60	17.44	86.30	10.47	10.50
BD 1098-001m	25.50	18.59	80.80	10.65	12.43
BD 1098-003m	23.02	16.89	78.40	9.45	12.93
BD 1098-005m	28.46	21.64	85.70	12.91	11.06
BD 1098-014m	23.93	17.48	72.60	9.24	10.90
BD 441-004m	28.91	20.99	85.30	12.47	10.14
BD 441-007m	24.63	18.13	86.40	10.85	11.14
BD 575-007m	26.64	19.46	84.60	11.49	9.69
BD 1354-20m	31.04	22.25	85.40	13.08	10.95
BD 1576-31m	27.08	19.80	86.10	11.83	9.14
BD 1576-07m	23.33	17.21	81.90	9.95	8.46
BD 1576-14m	30.94	22.47	93.60	14.11	11.10

N 27	21.43	16.09	76.40	8.86	10.57
B 47419	22.98	16.91	79.70	9.59	6.88
CV (%)	2.1	5.2	4.9	4.6	4.2
LSD (0.05)	12.2	5.8	9.8	1.4	1.2

CV – coefficient of variation, LSD – least significant difference