International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 27, Issue: 6, p. 91-101, 2025

RESEARCH PAPER OPEN ACCESS

Twin-row planting practice in village sugarcane (*Saccharum officinarum* L.) plantations during first ratoon under rainfed conditions in northern Côte d'Ivoire

Allé Yamoussou Joseph[1], Sawadogo Fatima[2], Traoré Mohamed Sahabane*[2], Fondio Lassina[3]

[1]*National Center of Agronomic Research (CNRA), Ferkéssédougou Research Station, Sugar Cane Program, Ferkessédougou, Côte d'Ivoire*

[2]*Peleforo Gon Coulibaly University (UPGC), Formation and Research Unit of Biological Sciences, Department of Vegetable Biology, Laboratory of Vegetable Physiology and Pathology, Korhogo, Côte d'Ivoire*

[3]*National Center of Agronomic Research (CNRA), Regional Directorate of Korhogo, Korhogo, Côte d'Ivoire*

Key words: Twin rows, Rainfed conditions, Immature phase, Weed infestation, Sugarcane, Côte d'Ivoire

DOI: https://dx.doi.org/10.12692/ijb/27.6.91-101 Published: December 13, 2025

ABSTRACT

This study aimed to determine an appropriate planting density for twin-row sugarcane cultivation during the immature phase under rainfed conditions, with the goal of improving agronomic performance. A randomized complete block design was employed, consisting of six treatments and three replications. The evaluated planting densities included twin rows spaced at 0.4 m and 0.5 m, combined with inter-row distances of 1.1 m, 1.3 m, 1.4 m, and 1.5 m. Observations focused primarily on growth parameters, weed infestation, and ground cover. Results indicated that planting density had no statistically significant effect on growth parameters across treatments. However, treatments T3 (twin-row spacing of 0.4 m; inter-row spacing of 1.4 m; middle inter-row spacing of 1.8 m) and T6 (twin-row spacing of 0.5 m; inter-row spacing of 1.3 m; middle inter-row spacing of 1.8 m) enhanced several agronomic traits, including the number of stalks, stools, and ratoons, as well as the soil ground cover.

***Corresponding author:** Traoré Mohamed Sahabane ✉ desahabane@gmail.com

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.; Poaceae), is a grass species native to New Guinea and nearby islands (Meslien, 2009). Cultivated throughout Asia as early as 300 J.C. and introduced to the Lesser Antilles by the Spanish in 1493, it is primarily valued for its crystallizable stalks containing sucrose (Fauconnier, 1991).

In Côte d'Ivoire, sugarcane is a major cash crop in the northern and central-western regions, providing an important source of income through its derived products (Archimède *et al.*, 2011). National production is estimated at approximately 200,000 tons of sugar per year, while projected consumption needs by 2025 are expected to reach 320,000 tons annually (Zadi *et al.*, 2017). Production is largely driven by the irrigated industrial subsector managed by sugar companies (Péné and Kéhé, 2005), covering 28,600 ha within a landholding of 61,400 ha (Kouamé *et al.*, 2009). In contrast, the rainfed or village subsector, practiced by smallholders around industrial complexes, accounts for about 5,000 ha (CNRA, 2021).

Yields remain relatively low in both systems: approximately 80 t/ha in industrial plantations and 40 t/ha in village plantations (Kouamé, 2010). Yet, under comparable natural conditions, countries such as Malawi achieve yields exceeding 70 t/ha in rainfed systems and up to 160 t/ha in irrigated systems. This discrepancy highlights the urgent need to improve sugarcane productivity in Côte d'Ivoire. Previous efforts have focused on selecting cultivars adapted to rainfed conditions (Péné and Kéhé, 2019) and exploring intercropping systems (Ouattara, 2020). Despite these advances, rainfed yields remain unsatisfactory in both industrial and village plantations.

Several factors may explain this underperformance, including low rainfall, shallow soils, varietal susceptibility to pests (Péné and Kéhé, 2005), soil infertility, limited technical support for farmers, inadequate production resources, high production costs, land pressure restricting plantation expansion, and weed infestation. Addressing these challenges requires revitalizing agronomic research through the development of innovative technologies.

One such innovation is the twin-row planting system, which has gained traction in certain sugarcane-producing countries as a response to rising input costs, reduced subsidies, and the need to lower planting expenses. This practice is expected to enhance field productivity and, consequently, farmers' income. The present study, as the first phase of our research, aims to identify at least one planting density suitable for twin-row sugarcane cultivation during the immature phase under rainfed conditions, with the objective of improving agronomic performance.

MATERIALS AND METHODS

Study site description

The study was conducted at the CNRA experimental station, located southwest of the town of Ferkessédougou (09°35′ N latitude, 05°12′ W longitude, and 323 m altitude), in northern Côte d'Ivoire. The site is characterized by a transitional sub-humid or sub-Sudanian climate, with a dry season from November to April and a rainy season from May to October (Péné and Kéhe, 2005). Rainfall follows a unimodal pattern, concentrated in August and September, which together account for nearly half of the mean annual precipitation of approximately 1200 mm.

Ferralitic soils are the most representative, with a shallow arable layer (40–60 cm) limited by indurations (Bigot *et al.*, 2005). They are predominantly hydromorphic, nutrient-poor, and have a pH ranging between 4.5 and 6.5.

Plant material and technical equipment

The plant material used in the experiment consisted of the sugarcane variety N21, developed by CIRAD-Visacane. This variety originates from a cross between R570 and R57.

The technical equipment employed for the study included:

1. a measuring tape for stalk length,
2. a caliper for stalk diameter,
3. pencils and recording sheets,
4. labels for plant identification,
5. machetes and hoes for plot maintenance.

Experimental design

The experimental design was a randomized complete block design with six treatments and three replications. The treatments were as follows:

T1: E 0.4 m / DL 1.1 m / Im 1.5 m (Twin-row spacing 0.4 m; inter-row spacing 1.1 m; middle inter-row spacing 1.5 m)

T2: E 0.4 m / DL1.3 m / Im 1.7 m (Twin-row spacing 0.4 m; inter-row spacing 1.3 m; middle inter-row spacing 1.7 m)

T3: E 0.4 m / DL 1.4 m / Im 1.8 m (Twin-row spacing 0.4 m; inter-row spacing 1.4 m; middle inter-row spacing 1.8 m)

T4: E 0.4 m / DL 1.5 m / Im 1.9 m (Twin-row spacing 0.4 m; inter-row spacing 1.5 m; middle inter-row spacing 1.9 m)

T5: E 0.5 m / DL 1.1 m / Im 1.6 m (Twin-row spacing 0.5 m; inter-row spacing 1.1 m; middle inter-row spacing 1.6 m)

T6: E 0.5 m / DL 1.3 m / Im 1.8 m (Twin-row spacing 0.5 m; inter-row spacing 1.3 m; middle inter-row spacing 1.8 m)

Each elementary plot consisted of four twin rows of 5 m length, including two border twin rows and two central twin rows forming the effective plot. The plot area (S) was calculated using the following formula:

S = [(Inter-row × 3) + (Twin-row spacing × 4)] × row length

The surface areas of the elementary plots (T1, T2, T3, T4, T5 and T6) were respectively 24.5; 27.5; 29; 30.5;26.5; 29.5 m^2, i.e., a total of 167.5 m^2.

The surface areas of the useful elementary plots (T1, T2, T3, T4, T5 and T6) were respectively 9.5; 10.5; 11; 11.5; 10.5;11.5 m^2, i.e., a total of 64.5 m^2.

Parameters evaluated

Number of sugarcane ratoons

The number of ratoons was determined at 21 days and 42 days after harvest (DAH). This involved counting the number of ratoons in the useful plot, consisting of the two central twin rows of sugarcane within each elementary plot. The number of ratoons was calculated using the following formula:

Number of ratoons=(Number of ratoons in the useful plot) × of 1 ha of planting / Length of the useful plot

with: Length per hectare =10,000 m^2/Length of the middle row

Number of sugarcane stems

The number of stems per hectare was assessed for each treatment every two weeks, starting from the second month after planting. The number of millable stalks was obtained by counting, using the following formula:

Number of stems/ha= (Number of stems in the useful plot × Length of 1 ha of planting) / Length of the useful plot

with: Length per hectare = 10,000 m^2 / Length of the middle row

Sugarcane height

Plant elongation was evaluated through measurements of stalk height taken every 14 days, from 3.5 months after harvest (MAH) until 9 MAH. Height was measured using a measuring tape, from the soil surface at the base of the stalk to the last leaf or ochrea. Ten plants were identified and marked, corresponding to 3–4 plants per effective row, selected according to stalk development in each treatment.

Number of visible internodes and stalk diameter

For each micro-plot, the number of internodes was counted on ten identified and marked plants within the effective plot, corresponding to the two central twin rows. Stalk diameter was measured at the collar using a caliper, six months after planting, on ten identified and marked plants within the effective plot (two central twin rows).

Number of stools

The number of stools was assessed three months after harvest. The number of stools per hectare was calculated using the following formula:

Number of stools = (Number of stools in the useful plot) × (Length per hectare) / Length of the useful plot

with: Length per hectare = 10,000 m^2 / Length of the middle row

Weed infestation rate and ground cover

Weed infestation was evaluated by observing the coverage provided by weeds within each elementary plot or treatment. Depending on the level or degree of coverage, a score corresponding to a percentage was assigned according to the 1-9 rating scale established by the Biological Trials Commission, revised by Mamotte (1984) (Table 1).

Table 1. Weed infestation rating scale

Score	%	Cover description
1	1	Espèce présente mais rare
2	7	Moins d'un individu par m²
3	15	Au moins un individu par m²
4	30	30 % de recouvrement
5	50	50 % de recouvrement
6	70	70 % de recouvrement
7	85	Recouvrement fort
8	93	Très peu de sol apparent
9	100	Recouvrement total

Source : Mamotte, 1984

A visual estimation was also conducted to assess the sugarcane ground cover rate in each plot. To ensure agronomic relevance, the Londo scale (1976), which distinguishes ten precise classes of ground cover, was adopted (Table 2).

Table 2. Ground cover assessment scale

Scale	Cover (%)	Corresponding rate
1	< 1 %	0.1 %
2	1 - 3 %	2 %
3	3 - 5 %	4 %
4	5 - 10 %	7.5 %
5	5 - 15 %	10 %
6	0 - 15 %	12.5 %
7	15 - 25 %	20 %
8	25 - 35 %	30 %
9	35 - 45 %	40 %
10	45 - 50 %	47.5 %
11	45 - 55 %	50 %
12	50 - 55 %	52.5 %
13	55 - 65 %	60 %
14	65 - 75 %	70 %
15	75 - 85 %	80 %
16	85 - 95 %	90 %
17	95 - 100 %	100 %

Statistical analyses

The data collected for the various measured parameters were processed using Excel 2010 to construct matrices for statistical analyses. An analysis of variance (ANOVA) was performed with XLSTAT software, version 2014.03, to determine the mean values of the different parameters. When significant differences were observed, the level of significance between means was estimated using the Newman–Keuls test at the 5 % threshold**.** Additionally, a principal component analysis (PCA) was conducted to establish relationships among the measured parameters and, in parallel, to assess correlations between the studied planting densities and the measured parameters, thereby allowing the formation of distinct groups.

RESULTS

Effect of twin-row planting on growth parameters

Number of ratoons per hectare

Table 3, presents the number of sugarcane ratoons per hectare at 21 days and 42 days after harvest (DAH) under rainfed conditions. The results showed no significant differences ($p>0.05$) among treatments during the ratooning periods. The mean number of ratoons was 43,558 ratoons/ha at 21 DAH**,** with values ranging from 35,834 to 54,283 ratoons/ha.

Table 3. Mean number of sugarcane ratoons per hectare at 21 and 42 days after harvest (DAH)

Treatments	R/ha 21 DAH	R/ha 42 DAH
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	39,649 ± 25,556[a]	24,092 ± 15,771[a]
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	41,102 ± 11,482[a]	34,738 ± 737[a]
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	35,834 ± 18,260[a]	34,803 ± 24,539[a]
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	54,283 ± 25,290[a]	40,397 ± 8,572[a]
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	44,353 ± 13,622[a]	37,642 ± 18,023[a]
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	46,125 ± 10,362[a]	34,321 ± 8,611[a]
Mean	44,285	34,943
Standard deviation	14,618	13,531
Coefficient of variation (%)	33	39
Probability (*p*-value)	0.8428	0.9078
Significance	ns	ns

Values followed by the same letter within a column do not differ significantly at the 5 % level (Fisher's LSD test). DAH: days after harvest; ns : not significant. Treatments: T1–T6 correspond to twin-row spacing and inter-row arrangements as described in the methodology.

Table 4. Mean number of sugarcane stalks per hectare at 3 and 9 months after harvest (mah) under rainfed conditions

Treatments	NT/ha 3 MAH	NT/ha 9 MAH
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	19,107 ± 19,525[a]	93,647 ± 39,136[a]
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	27,377 ± 14,108[a]	107,662 ± 17,264[a]
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	31,367 ± 27,868[a]	108,006 ± 40,334[a]
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	36,565 ± 37,348[a]	89,860 ± 37,574[a]
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	44,071 ± 22,265[a]	124,817 ± 27,099[a]
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	45,642 ± 7,912[a]	114,971 ± 12,859[a]
Mean	34,022	106,494
Standard deviation	21,920	28,795
Coefficient of variation (%)	64	27
Probability (p-value)	0.7280	0.7481
Significance	ns	ns

Values followed by the same letter within a column do not differ significantly at the 5 % level (Fisher's LSD test). ns: not significant; MAH: months after harvest; NT/ha: number of stalks per hectare.

Table 5. Mean stalk heights of sugarcane at 3.5 and 9 months after harvest under rainfed conditions

Treatments	H. (cm) 3.5 MAR	H. (cm) 9 MAR	Growth rate (mm/day)
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	22 ± 8.7[a]	165 ± 22[a]	9.2
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	22 ± 6.4[a]	168 ± 26[a]	9.5
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	18 ± 4.7[a]	163 ± 28[a]	9.4
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	19 ± 6.2[a]	167 ± 26[a]	9.6
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	22 ± 10.9[a]	177 ± 24[a]	10.1
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	22 ± 6.0[a]	162 ± 32[a]	9.2
Mean	21	167	9.5
Standard deviation	7.5	27	—
Coefficient of variation (%)	35.9	16	—
Probability (*p*-value)	0.1706	0.3096	—
Significance	ns	ns	

Values followed by the same letter within a column do not differ significantly at the 5% level (Fisher's LSD test). H: Height; MAH: months after harvest; Growth rate: stalk growth rate in mm/day; ns: not significant

Similarly, at 42 DAH, no significant treatment effects were observed, with mean values ranging from 24,092 to 40,397 ratoons/ha, and an overall average of 34,332 ratoons/ha across treatments. However, a decline in the number of ratoons was noted between the two observation periods.

Table 6. Mean number of sugarcane stools per hectare at 9 months after harvest (mah) under rainfed conditions

Treatments	NS/ha 9 MAH
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	10,801[a]
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	10,338[a]
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	11,511[a]
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	10,209[a]
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	11,766[a]
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	11,575[a]
Mean	11,033
Standard deviation	1,485
Coefficient of variation (%)	13
Probability (*p*-value)	0.7466
Significance	ns

Values followed by the same letter within a column do not differ significantly at the 5% level (Fisher's LSD test). NS: number of stools; MAH: months after harvest; ns: not significant.

Number of stalks per hectare, mean stalk elongation and number of sugarcane stools

The results showed no significant effect ($p>0.05$) of the different planting densities on number of stalks (Table 4) and stalk elongation (Table 5). However, the mean number of stalks increased from 34,022 at 3 months to 106,494 stalks at 9 months after harvest, representing a 32 % increase. Similarly, stalk elongation was observed between 3.5 months after harvest (MAH) and 9 MAH, increasing from 21 cm to 167 cm, with an average growth rate of 0.95 cm/day (Table 5).

Table 7. Evolution of the mean number of internodes in sugarcane stalks from 8 to 9 months after harvest (MAH) under rainfed conditions

Treatments	Internodes 8 MAH	Internodes 8.5 MAH	Internodes 9 MAH
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	13.97 ± 2.35[a]	17.3 ± 2.69[a]	18.23 ± 2.96[a]
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	14.18 ± 1.93[a]	15.37 ± 2.2[a]	16.37 ± 2.46[a]
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	14.37± 2.16[a]	17.53 ± 2.5[a]	17.9 ± 2.59[a]
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	14.13 ± 2.24[a]	16.6 ± 2.11[a]	17.17 ± 2.4[a]
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	14.36 ± 2.48[a]	15.75 ± 2.3[a]	16.2 ± 2.62[a]
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	14.41 ±2.68[a]	16.37± 3.08[a]	17.97 ± 3.0[a]
Mean	14.2	16.0	16.8
Standard deviation	2.3	2.8	2.6
Coefficient of variation (%)	16.1	16.4	15.7
Probability (*p*-value)	0.9759	0.0746	0.0850
Significance	ns	ns	ns

Values followed by the same letter within a column do not differ significantly at the 5% level (Fisher's LSD test). E.N: internodes; MAH: months after harvest; ns: not significant.

Table 8. Evolution of mean sugarcane stalk diameter from 8 to 9 months after harvest (MAH) under rainfed conditions

Treatments	D.M (cm) 8 MAH	D.M (cm) 8.5 MAH	D.M (cm) 9 MAH
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	1.29[b]	1.30[a]	1.36[a]
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	1.33[a]	1.35[a]	1.36[a]
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	1.31[a]	1.32[a]	1.37[a]
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	1.36[a]	1.39[a]	1.53[a]
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	1.28[b]	1.31[a]	1.32[a]
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	1.32[a]	1.35[a]	1.38[a]
Mean	1.31	1.34	1.39
Standard deviation	0.23	0.21	0.21
Coefficient of variation (%)	17	15	15
Probability (*p*-value)	0.0098	0.602	0.639
Significance	hs	ns	ns

Values followed by the same letter within a column do not differ significantly at the 5% level (Fisher's LSD test). D.M: diameter; MAH: months after harvest; ns: not significant; hs: highly significant.

Regarding the mean number of sugarcane stools per hectare (NS/ha) during the first ratoon under rainfed conditions at 9 MAH, no significant differences ($p>0.05$) were detected among planting densities (Table 6). The number of stools ranged from 10,209 to 11,766, with an overall mean of 11,033 stools/ha.

Table 9. Weed infestation and ground cover status of the plot at 8 months after harvest (MAH)

Treatments	Score	Ground cover (%)	Weed infestation (%)
T1 : E 0.4 m / Int 1.1 m / Im 1.5 m	5	40	50
T2 : E 0.4 m / Int 1.3 m / Im 1.7 m	7	30	85
T3 : E 0.4 m / Int 1.4 m / Im 1.8 m	4	60	30
T4 : E 0.4 m / Int 1.5 m / Im 1.9 m	6	52.5	70
T5 : E 0.5 m / Int 1.1 m / Im 1.6 m	2	80	7
T6 : E 0.5 m / Int 1.3 m / Im 1.8 m	3	70	15

Table 10. Correlations between variables and factors

Variables	F1	F2
Diameter (Diam)	-0,645	-0,187
Stalks/ha (NT/ha)	0,947	0,043
Elongation (Elg)	0,630	-0,716
Internodes/stalk (N-EN/stalk)	-0,461	0,858
Stools/ha (NS/ha)	0,835	0,536
Growth rate (Vc)	0,636	-0,695
Ratoons/ha (R/ha)	0,947	0,043
Weed infestation (%)	-0,798	-0,531
Ground cover (%)	0,790	0,273

Table 11. Pearson correlation matrix between studied parameters

Variables	Diam	NT/ha	Elg	N-EN/ stalk	NS/ha	VC	R/ha	Weed infestation (%)	Ground cover (%)
Diam	1	-0.717	-0.265	0.186	-0.634	-0.114	-0.707	0.474	-0.168
NT/ha		1	0.484	-0.471	0.786	0.480	1.000	-0.696	0.657
Elg			1	-0.844	0.156	0.949	0.484	-0.189	0.351
N-EN/stalk				1	0.094	-0.829	-0.471	-0.145	-0.065
NS/ha					1	0.192	0.786	-0,966	0.825
Vc						1	0.480	-0.218	0.458
R/ha							1	0.480	-0.218
Weed infestation %)								1	-0.906
Ground cover (%)									1

Number of internodes and stalk diameter of sugarcane

The mean number of visible internodes (Table 7) at 8, 8.5, and 9 months after harvest (MAH) was not significantly influenced ($p>0.05$) under rainfed conditions. On average, the number of internodes was 14 at 8 MAH, 16 at 8.5 MAH, and 16.8 at 9 MAH.

For the mean stalk diameter at the collar (Table 8), a highly significant difference ($p<0.05$) was observed among treatments at 8 MAH. Plants from treatments T2 (1.33 cm), T3 (1.31 cm), T4 (1.36 cm), and T6 (1.32 cm) recorded higher mean diameters compared to those from T1 (1.29 cm) and T5 (1.28 cm). However, at 8.5 and 9 MAH, no significant differences ($p>0.05$) were observed among treatments. The mean diameters were 1.34 cm at 8.5 MAH and 1.39 cm at 9 MAH.

Effect of twin-row planting on weed infestation and ground cover

Table 9 shows the visual evaluation of weed infestation and ground cover across treatments. Treatment T1 obtained a score of 5, corresponding to 50 % weed cover. Treatment T2 was rated 7, equivalent to 85 % weed cover. Treatment T3, with a score of 4, showed 30 % weed cover. Treatments T4, T5, and T6 recorded weed cover rates of 70%, 7%, and 15%, respectively, with scores of 6, 2, and 3. Regarding sugarcane ground cover, T1 displayed 40 %, T2 30 %, T3 60 %, T4 52.5 %, T5 80 %, and T6 70 %.

Relationships between agronomic parameters and studied treatments

Principal component analysis (PCA) highlighted correlations among parameters, treatments, and projection axis F1 and F2. Thus, the biplot projection plan (Fig. 1) expressed 84.41 % of the total variance, with a contribution of 57.58 % for axis F1 and 26.83 % for axis F2.

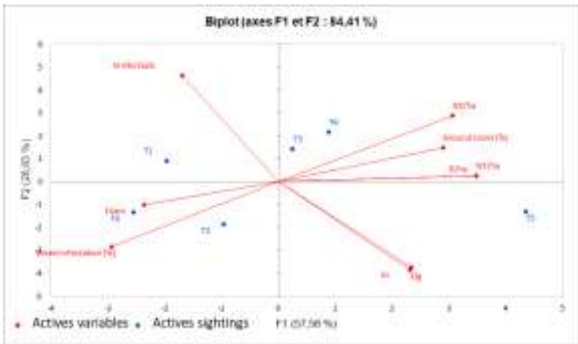

Fig. 1. Projection of treatments on the factorial plane of principal component analysis (PCA)

The parameters such as number of stalks/ha, number of stools/ha, number of ratoons/ha and ground cover, were positively correlated with axis F1. Stalk diameter was negatively correlated with axis F1. Positive and negative correlation were established respectively between axis F1 and F2 for the parameters elongation and growth rate. Weed infestation was negatively correlated with both axis F1 and F2 (Table 10).

The correlation matrix (Table 11) showed that stalk diameter at the collar was negatively correlated with the number of stalks, stools, and ratoons. A strong positive correlation was established between the number of stalks and ratoons. Positive and negative correlation were established respectively between number of stalks and weed infestation and ground cover rates. Ground cover rates was respectively positively correlated with the number of stalks and stools. Stalk elongation evolved inversely with the number of internodes and was positively linked to growth rate. Weed infestation and ground cover rates were strongly negatively correlated.

Based on these relationships, four sets were distinguished (Fig. 1).

1. Set 1 (T1), associated with a higher number of internodes.
2. Set 2 (T3 and T6), linked to higher stalk numbers, stools, ratoons, and ground cover.
3. Set 3 (T5), favored stalk elongation.
4. Set 4 (T2 and T4), characterized by larger stalk diameters and higher weed infestation.

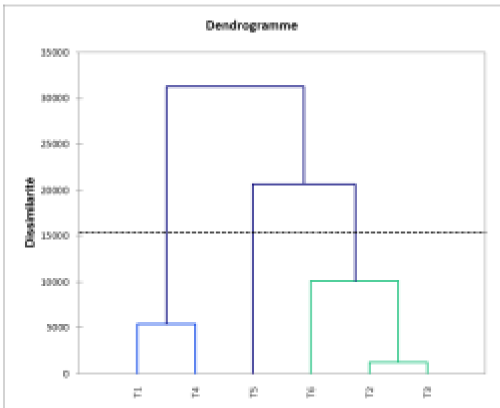

Fig. 2. Dendogram structuring the classes of planting density based on euclidean distances

However, hieralchical clustering from dendogram (Fig. 2) indicated that the four sets of densities determined can be separated into three groups:

1. Group 1, consists of treatments (planting density) T1 and T4.
2. Group 2, has gathered the treatments T2, T3 and T6.
3. Group 3, was formed by the treatment T5.

DISCUSSION

The present study evaluated the effect of twin-row planting densities on sugarcane growth parameters, weed infestation, and ground cover under rainfed conditions in northern Côte d'Ivoire. Overall, the results revealed no statistically significant differences among treatments for most growth parameters, including ratoon number, tillering, stalk elongation, and stool density. However, certain treatments (notably T3 and T6) showed agronomic advantages, particularly in terms of stalk number, stool density, ratoon number, and ground cover.

The absence of significant differences across treatments suggests that planting density alone may not be the primary determinant of sugarcane performance under rainfed conditions.

Similar findings have been reported in other studies, where environmental factors such as rainfall distribution, soil fertility, and pest pressure exerted stronger influences on yield than row spacing arrangements (Muli and Mgeni, 2020). In Malawi, for example, rainfed sugarcane yields exceeding 70 t/ha have been achieved despite variable planting densities, largely due to favorable rainfall and soil conditions. This highlights the importance of integrating planting techniques with broader agronomic management strategies (CNRA, 2021).

The observed decline in ratoon numbers between 21 and 42 days after harvest reflects the natural adjustment of plant populations during early regrowth. Treatments T3 and T6, which maintained higher stalk and stool densities, may offer practical advantages by ensuring better ground cover, thereby reducing weed infestation and improving soil moisture conservation.

This aligns with previous reports emphasizing the role of canopy closure in suppressing weeds and enhancing resource use efficiency (Konaté *et al.*, 2025). Also, this reduction may be explained by the dry season prevailing during this period (early growth stage), which favored termite attacks that damaged the sugarcane stalks (Amoukou, 2009). Conversely, the number of stalks increased between 3 and 9 months after harvest (MAH). This variability could be attributed to narrower leaves, which are better suited to twin-row planting densities (Widdicombe and Thelem, 2002), thereby enhancing soil cover. Such effects allow the canopy to develop more rapidly, maximizing light interception and suppressing weed growth.

It is important to recall that stalk number is influenced by cultural and edaphic conditions (Sabatier, 2012; Pémé, 2004), as well as fertilizer application, which promotes stalk development and sucrose accumulation (Zadi *et al.*, 2017). According to Cheavegatti-Gianotto *et al.* (2011), tillering is a multiplication process that increases yield and can last up to 120 days (four months). Given the positive correlation established between stalk number and stool density, similar observations apply to stool number.

Results related to stalk elongation and diameter showed no significant treatment effects, except at 8 MAH for stalk diameter. Nevertheless, increases in stalk height and diameter were observed between 3.5 and 9 MAH and between 8.5 and 9 MAH, respectively. Comparable findings were reported by Pouzet and Martiné (2000), who noted similar effects of row spacing on growth. The observed increases may reflect varietal responses to planting distance, as sugarcane reaches its maximum growth phase around 270 days, influenced by photoperiod and temperature conditions (Cheavegatti-Gianotto *et al.*, 2011).

The stalk samples analyzed in this study presented a high number of internodes (up to 18), with an average of 16 internodes. This observation is consistent with the tall stature of the plants (188 cm). Similar results were reported by Ekpelikpézé *et al.* (2016) and Babalakoum *et al.* (2022), who noted that longer stalks possess more internodes, while shorter stalks have fewer internodes with wider spacing.

Regarding ground cover, it functions as an indicator of the plant's ability to prevent soil erosion and runoff (Browman *et al.*, 2000). Vegetative cover plays a crucial role in weed control (Fahad *et al.*, 2015; Lefèvre, 2018). Adequate water availability enhances canopy development, increasing stalk numbers and reducing weed pressure, thereby improving stool growth. Our findings corroborated these observations, showing a significant negative correlation between weed infestation and ground cover.

The PCA analysis further clarified the relationships among parameters and treatments. Stalk number, stool density, ratoon number, elongation, growth rate, and ground cover were positively correlated with axis F1, while internode number was associated with axis F2.

Conversely, stalk diameter and weed infestation were negatively correlated with both axes. These findings suggest that treatments promoting higher stalk populations and ground cover (T3 and T6) are agronomically more favorable, whereas treatments associated with larger stalk diameters (T2 and T4) may be more vulnerable to weed competition.

CONCLUSION

This study assessed twin-row planting densities for improving sugarcane growth under rainfed conditions in Ferkéssédougou. Although no significant treatment effects were found on major growth parameters, clear trends emerged over time, including increases in stalk height, stalk number, internode formation, and diameter. Strong negative correlations were observed between weed infestation and ground cover, while stool and ratoon numbers were positively linked to ground cover. These relationships allowed grouping of density treatments based on their agronomic behavior. Overall, twin-row planting shows potential to enhance sugarcane performance, but its effectiveness depends on factors such as soil fertility, weed management, and rainfall.

RECOMMENDATIONS

1. Include yield measurements in future studies to identify the most productive twin-row density.
2. Validate the observed trends across seasons and locations to support farmer adoption.
3. Develop practical guidelines for rainfed sugarcane farmers on optimal twin-row spacing and management practices.

REFERNCES

Amoukou I. 2009. Un village nigérien face au changement climatique: stratégies locales d'adaptation au changement climatique dans une zone rurale du bassin du Niger. Université Abou Moumouni de Niamey, Niger, 95p.

Archimède H, Xande X, Gourdine JL, Fanchone A, Alexandre G. 2011. La canne à sucre et ses co-produits dans l'alimentation animale. Innovations Agronomiques **16**, 165–179.

Bigot S, Yao TB, Oswald J, Diedhiou A. 2005. Facteur de variabilité pluviométrique en Côte d'Ivoire et relations avec certaines modifications environnementales. Sécheresse **16**(1), 5–13.

Bowman G, Shirley C, Cramer C. 2000. Benefits of cover crops. In: Managing cover crops profitably, Sustainable Agriculture Network, 9–11.

Cheavegatti-Gianotto A, Abreu H, Arruda P, Bespalhok FJ, Burnquist W, Creste S, Ciero L, Ferro J, Oliveira FA, Sousa FT, Grossi-de-Sá M, Guzzo E, Hoffmann H, Andrade LM, Macedo N, Matsuoka S, Castro RF, Romano E, Silva W, Castro SFM, Ulian EC. 2011. Sugarcane (*Saccharum × officinarum*): a reference study for the regulation of genetically modified cultivars in Brazil. Tropical Plant Biology **4**(1), 62–89.

CNRA. 2021. Programme canne à sucre. https://cnra.ci/wp-content/uploads/2021/12/05-Progr-canne-a-sucre-2020-2023-VF.pdf

Ekpélikpézé OS, Loko YL, Adjatin A. 2016. Évolution de la production de canne à sucre (*Saccharum officinarum* L.) et gestion paysanne de sa diversité variétale au Bénin. International Journal of Innovation and Scientific Research **20**(2), 349–361.

Fahad S, Hussain S, Chauhan B, Saud S, Wu C, Hassan S, Tanveer M, Jan A, Huang J. 2015. Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times. Crop Protection **71**, 101–108.

Fauconnier R. 1991. La canne à sucre. Paris: Maisonneuve et Larousse, 165p.

Konaté ML, Mangara A, Diomandé S, Kouamé NF. 2025. Adventices majeurs des plantations villageoises de la canne à sucre dans le département de Ferkessédougou (Côte d'Ivoire). Journal of Animal & Plant Sciences **65**(1), 12300–12309.

Kouamé KD. 2010. Évaluation agronomique de variétés de canne à sucre (*Saccharum officinarum* L., Poaceae) introduites au complexe sucrier de Ferké 2 au nord de la Côte d'Ivoire: proposition d'allègement du schéma de sélection. Doctoral thesis, Université de Cocody, Abidjan, Côte d'Ivoire, 260p.

Lefèvre A. 2018. Influence de la composition spécifique de couverts végétaux sur les paramètres physiques, chimiques et biologiques du système sol-plante: étude de la biologie du sol. Université catholique de Louvain. http://hdl.handle.net/2078.1/thesis:17267

Meslien S. 2009. La canne à sucre et ses enjeux aux Antilles françaises, des origines au début du XXe siècle. Fort-de-France: Centre Régional de Documentation Pédagogique de la Martinique, 160p.

Muli B, Mgeni A. 2020. Rainfed sugarcane production and yield variability in smallholder systems of Malawi. African Journal of Agricultural Research **15**(12), 1456–1465.

Ouattara O. 2020. Effet de l'association canne à sucre–cultures vivrières sur la croissance de la canne à sucre en condition pluviale dans la région du Tchologo. Master thesis, Université Jean Lorougnon Guédé, 49p.

Pémé H. 2004. Étude des aspects de la maturation de la canne à sucre à SUCAF Gabon. Mémoire de fin de cycle, Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou (Mali), 48p.

Péné CB, Boua MB, Coulibaly-Ouattara Y. 2019. Nouvelles variétés de canne à sucre (*Saccharum officinarum* L.) adaptées aux conditions pluviales dans les périmètres sucriers de Ferké au Nord Côte d'Ivoire. Journal of Applied Biosciences **134**, 13702–13710.

Péné CB, Kéhé M. 2005. Performance de trois variétés de canne à sucre soumises au rationnement hydrique en pré-maturation au Nord de la Côte d'Ivoire. Agronomie Africaine **17**(1), 7–18.

Pouzet D, Martiné JF. 2000. Distribution spatiale des conseils en fertilisation de la canne à sucre. Saint-Denis: CIRAD–CA, 18p.

Zadi M, Turquin L, Péné CP. 2017. Évaluations agronomiques et technologiques des clones de canne à sucre présélectionnés au stade ligne à Ferkessédougou, Nord Côte d'Ivoire. Journal of Applied Biosciences **115**, 11502–11512.