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Enhancing Cassava Productivity Through Optimal Sowing Density In Central-Western Côte D'Ivoire

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Abstract

Cassava is a crucial food crop with significant economic and nutritional importance, particularly in tropical regions. Despite its potential, cassava yields remain insufficient in Côte d'Ivoire, largely due to poor cultivation practices such as inappropriate planting densities. This study investigates the impact of sowing density, location, and variety on cassava production in the Vavoua department of central-western Côte d'Ivoire. The research focused on two cassava varieties, Yavo and Bonoua, grown under three planting densities (1m x 80 cm, 1m x 1m, and 80 cm x 80 cm) at two locations, N'Guessankro and Sanpedro2. Results indicate that the Yavo variety achieved the highest yield when planted at a low density (1m x 1m) in N'Guessankro, benefiting from favorable environmental and soil conditions. Optimal spacing facilitated efficient resource use and enhanced photochemical activity, boosting cassava growth and yield. Conversely, close planting led to increased competition for nutrients, limiting productivity. The findings underscore the importance of selecting appropriate planting density, variety, and location to maximize cassava productivity. Further studies are recommended to explore the impact of organic fertilizers and their optimal application rates on cassava yields in this region.

Keywords: Cassava, Yavo variety, sowing density, yield

Introduction

Since its independence, the agricultural sector has remained a major driver of economic development in Côte d'Ivoire. Although public policies have largely prioritized export crops such as coffee and cocoa, food crops essential to national food security have received comparatively limited institutional support (Boni et al., 2015). Among these crops, cassava occupies an important place due to its adaptability, high carbohydrate content, and multiple uses in human nutrition and agro-industry. Globally, cassava is one of the most widely cultivated staple crops and ranks after rice and maize in terms of production, with an estimated global output of 302.7 million tons in 2020 (Bilong et al., 2022). Cassava roots are rich in carbohydrates, starch, and dietary fiber, making them an important source of calories for populations in tropical regions (Montagnac et al., 2009; Wang et al., 2011, Borku, 2025). In addition, cassava plays a strategic role during periods of food shortage because of its tolerance to harsh environmental conditions and its capacity to remain in the soil until needed for consumption (Ceballos et al., 2006). In Côte d'Ivoire, cassava is consumed in several traditional forms, both fresh and processed, and represents a major component of household food security. However, national production remains insufficient to satisfy the increasing demand of a rapidly growing population (Kintché et al., 2017; Hillocks, 2002). Low cassava productivity in Côte d'Ivoire is associated with several constraints, including declining soil fertility, inappropriate use of fertilizers, poor crop management practices, limited access to improved varieties, and unsuitable planting densities (Adjei-Nsiah et al., 2007). Among these factors, planting density is considered one of the most important agronomic practices influencing cassava growth and yield. Plant spacing determines the level of competition among plants for essential resources such as light, water, nutrients, and space, thereby directly affecting biomass accumulation and root production (Gnamien et al., 2024). Appropriate planting density can improve resource-use efficiency and maximize yield, whereas excessive density may increase interplant competition and reduce productivity. In addition to planting density, varietal characteristics and environmental conditions strongly influence cassava performance. Improved cassava varieties may respond differently depending on local soil and climatic conditions, making it necessary to identify the most suitable combinations of variety and planting density for specific production areas. The main objective of the study was to determine the optimal planting density for improving cassava yield under the agroecological conditions of the study area. Specifically, the study aimed to: (1) evaluate the effect of different planting densities on cassava yield; (2) compare the agronomic performance of the Yavo and Bonoua cassava varieties; (3) assess the influence of location on cassava productivity; and (4) identify the best combination of variety and planting density for maximizing cassava production in the Vavoua region.

2. Material and methods

2.1. Experimental site

The study was conducted from April to July 2022 in the central-western part of Côte d'Ivoire, in the department of Vavoua. It was carried out in the village of Pelezi, specifically in the Sanpedro2 and N'Guessankro areas. The study site is 91 km far from the town of Daloa and is located at 7°16'50" north latitude and 6°49'35" west longitude. This area experiences four seasons: a major rainy season from April to mid-July, a minor dry season from mid-July to mid-September, a minor rainy season from mid-September to November, and a major dry season from December to March.

2.2. Plant material, treatments, and experimental design

The plant material used in this study consists of two varieties of cassava (Yavo and Bonoua). Cassava tubers used were obtained from farmers who had previously cultivated these varieties. The experiment was laid out in a split-plot design with three replicates (blocks), implemented across two sites: Sanpedro 2 and N'Guessankro, which served as the main plot factor (environmental condition). The sub-plot factor was a combination of two cassava varieties (Yavo and Bonoua) and three planting densities (1 m × 80 cm, 1 m × 1 m, and 80 cm × 80 cm), resulting in six treatment combinations. Each block was divided into six sub-plots, randomly assigned one of the six treatments, for a total of 18 plots across the experiment, covering a total surface area of 1200 m². A two-meter buffer was maintained between plots to reduce inter-plot interference. Randomization of treatments within each block was conducted using a computer-generated random sequence to ensure unbiased allocation. Blocking was used to control for spatial variability across the field.

The treatments applied in both sites (Sanpedro 2 and N'Guessankro) are combinations of density and cultivar. These treatments are as follows:

YD1: Yavo planted at a medium density (1 m x 80 cm),

YD2: Yavo planted at a low density (1 m x 1 m),

YD3: Yavo planted at a high density (80 cm x 80 cm),

BD1: Bonoua planted at a medium density (1m x 80 cm),

BD2: Bonoua planted at a low density (1m x 1m),

BD3: Bonoua planted at a high density (80 cm x 80 cm)

Land preparation was done manually by ploughing using a hoe. Preparation began with clearing. This was followed by burning and stump removal at each site. The elementary plots were marked out with ropes to indicate the planting points according to the different densities of the plants. In order to ensure good germination conditions, the cuttings were planted after a rain and at three spacings: 80 cm x 80 cm; 1 m x 80 m and 1 m x 1 m. Manual weeding of individual plots was carried out as part of plot maintenance. A total of three weeding operations were carried out, the first of which was for weed control two weeks after sowing. The second was done 1 month after sowing and the third 2 months after planting. There were no phytosanitary treatments applied to the plots. In this study, data were collected from 20 plants per variety at different densities. Parameters such as plant height, stem diameter, number of tubers, number of branches, tuber length, tuber diameter, tuber weight and yield were recorded.

2.3. Statistical analysis of data

Standard errors (SE) are provided for all treatment means in the data tables to reflect variability. Before conducting ANOVA, assumptions of normality and homogeneity of variances were tested using the Shapiro-Wilk and Levene's tests, respectively. Data that did not meet these assumptions were transformed as needed to meet the requirements of the analysis. Analysis of variance (ANOVA) was performed on the data collected. For each variable studied, the means were compared using a 3-factor analysis of variance (ANOVA 3), factoring in locality, density, and cultivar. Test significance was determined by comparing the probability (p) associated with the statistic at the threshold of $\alpha = 0.05$. Maps were generated using QGIS version 2.8 software. All data were processed using the statistical software STATISTICA version 7.1.

3. Results and discussion

3.1. Results

3.1.1. Effect of locality on cassava agronomic parameters

The impact of locality on cassava agronomic parameters is illustrated in Table 1. The data reveals that locality significantly influenced all recorded parameters ($p < 0.05$). Among the localities assessed, N'Guessankro demonstrated the most favorable conditions for cassava growth and yield, with production exceeding 26020 kg/ha, compared to 14016.13 kg/ha observed in San pedro 2.

3.1.2. Variety response on agronomic parameters

Table 2 indicates that variety significantly influenced 75% of the agronomic parameters of cassava ($p < 0.05$), including plant height, collar circumference, number of branches, tuber length, tuber weight, and overall yield. The variety Bonoua demonstrated the highest values for vegetative parameters, while Yavo exhibited the highest mean tuber weight and yield. Notably, a discrepancy of approximately 2 kilograms in mean tuber weight and 2 kg/ha in mean yield was observed when comparing Yavo with the Bonoua variety.

3.1.3. Effect of planting density on cassava agronomic parameters

The impact of cassava planting density on agronomic parameters is summarized in Table 3. The results indicate that the applied densities significantly affected cassava production ($p < 0.05$). The highest values across all recorded parameters were achieved at the low density (1 cm x 1 cm), while the high density (80 cm x 80 cm) produced the lowest values. Meanwhile, the medium density (80 cm x 1 m) exhibited intermediate averages. Notably, the yield at the low density surpassed the high density by over 13 kg/ha and exceeded the medium density by 3 kg/ha.

3.1.4. Effect of location * density interaction on cassava agronomic parameters

The results presented in Table 4 demonstrate that location, variety, and planting density significantly influence cassava productivity ($p < 0.05$). These factors impacted over 87.5% of the measured parameters, including yield. Optimal cassava production was observed in the N'Guessankro locality with the Yavo variety planted at a low density (1 m x 1 m). Conversely, high-density planting in Sanpedro2 markedly reduced cassava productivity.

3.2. Discussion

3.2.1. Effect of locality on cassava agronomic parameters

The results demonstrate that cassava agronomic traits varied significantly between the two study sites, with superior performance observed in N'Guessankro. Two key factors may account for this disparity. First, the soil fertility in N'Guessankro is likely more favorable for cassava growth. Cassava is highly responsive to soil nutrient availability, particularly nitrogen, phosphorus, and potassium, which influence root and shoot development (Howeler, 2017; Trung et al., 2022). Soil analyses in similar Ivorian regions have shown that even moderate differences in organic matter or pH can significantly affect cassava yield potential (Gnahoua et al., 2016). Second, climatic conditions in N'Guessankro, such as rainfall distribution and solar radiation, may have been more conducive to plant development. Hounzinme et al. (2020) emphasized that cassava growth is sensitive to environmental stressors, especially water availability during the early growth phase. Therefore, N'Guessankro's edaphic and climatic profile likely allowed for more effective biomass accumulation and root bulking, resulting in higher productivity.

3.2.2. Variety response on agronomic parameters

Significant varietal differences were observed, indicating strong genotype × environment interactions. The Bonoua variety generally exhibited higher vegetative growth, but the Yavo variety achieved better root yields in N'Guessankro under wider spacing. This divergence suggests that genotypic plasticity plays a critical role in varietal performance under varying environmental and management conditions. Yavo's superior performance under wider spacing may be due to its root system architecture and photosynthetic efficiency, which are enhanced when interplant competition is reduced. Studies by Punyasu et al. (2025) and Ceballos et al. (2006, 2020, 2021) support this, noting that modern cassava genotypes with deep or spreading root systems can better exploit soil resources when provided sufficient space, particularly in marginal or transitional agroecological zones.

3.2.3. Effect of sowing density on cassava production and yield

Sowing density significantly influenced yield-related traits. Wider spacings (1 m × 80 cm and 1 m × 1 m) led to better performance compared to closer spacing (80 cm × 80 cm). This is likely due to enhanced light interception, reduced canopy competition, and improved nutrient and water availability per plant, which are critical for root development (Gnamien et al., 2024; Sultana et al., 2023). Dense planting creates shading that hampers lower leaf photosynthesis and increases competition for belowground resources. These results confirm previous findings (Fondio et al., 2000; Assefa et al., 2022), emphasizing the importance of spacing as a management lever to optimize cassava productivity.

3.2.4. Effect of the interaction between location and density on cassava agronomic parameters

The interaction between location and density was significant, particularly for the Yavo variety in N'Guessankro at the 1 m × 1 m spacing, which yielded the best results. This suggests a synergistic effect between genotype adaptability, environmental suitability, and reduced interplant competition. Yavo may possess traits such as drought avoidance, efficient water use, or deeper rooting, which make it better suited to wider spacing in low-competition environments like those found in N'Guessankro. Hussain et al. (2023) reported that organic matter-rich soils amplify such genotype-specific advantages by improving nutrient uptake and soil structure, which could further explain Yavo's superior performance. These findings underscore the importance of location-specific agronomic recommendations, taking into account the combined effects of environment, variety, and management practices.

4. Conclusion and recommandations

This study highlights the complex interplay between planting density, varietal performance, and agroecological conditions in determining cassava productivity in the Vavoua region. The Yavo variety achieved the highest yield when planted at a 1 m × 1 m spacing in N'Guessankro, suggesting that both genotype-specific spacing and site conditions must be considered in optimizing cassava production.

Implications

• For farmers: Adoption of Yavo with a 1 m × 1 m spacing in agroecological zones similar to N'Guessankro could significantly boost yields.

• For extension Services: Development of variety-specific planting guides and site-based recommendations should be integrated into farmer training and rural advisory programs.

• For policymakers: These findings can inform regional cassava development strategies, especially in national programs targeting food security and agricultural productivity.

Recommendations

• Incorporate optimized spacing for specific varieties into national cassava production guidelines.

• Support soil fertility mapping and varietal zoning to tailor interventions based on local conditions.

• Promote participatory trials with farmers to validate and refine these recommendations under real-world conditions.

Future research directions

• Evaluate the impact of different organic and inorganic fertilization regimes on varietal performance in N'Guessankro.

• Investigate the long-term soil health effects of varied planting densities.

• Explore genotype-specific root traits and their relationship to spacing efficiency under different stress environments.

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Table 1: Influence of locality on cassava agronomic parameters

Locality	H	Circ	NB	NT	TL	TD	TW	Y
Sp	2.88±21.28a	22±6.18a	1.52±0.66a	3.78±1.61a	23.77±6.27a	48.3±8.33a	1.69±1.23a	14016.13±10314.44a
NG	5.99±0.37b	34.44±8.73b	2.152±0.12b	4.85±2.64b	26.86±5.87b	62.48±11.26b	3.21±2.46b	26020±21112.09b
F	0.473	81.675	0.006	7.118	0.008	61.412	0.005	15.659
p	0.029	0.013	0.032	0.049	0.010	0.035	0.000	0.000

For each trait, values with the same letters in the column are statistically similar

H : plant height (cm) ; **Circ :** collar circumference (cm) ; **NB**: number of branches; **NT**: Number of tubers; **TL**: Tuber length; **TD**: Tuber diameter; **TW:** Tuber weight**;** **Y**: yield (kg/ha); **Sp :** Sanpedro2; **NG**: N'Guessankro; $p < 0.05$

Table 2: Variety response on agronomic parameters

Variety	H	Circ	NB	NT	TL	TD	TW	Y
Bonoua	5.21±21.24b	26.13±9.48a	1.96±1.42b	4.31±2.65a	24.25±6.55a	55.46±12.33a	2.29±1.96a	18665.33±15296.98a
Yavo	2.65±0.569a	30.35±9.730b	1.7±1.08a	4.31±1.76a	26.37±5.74a	55.32±12.09a	4.60±2.20b	21370.8±19688.99b
F	0.869	5.77	0.805	0.234	3.544	0.004	0.654	0.706
p	0.035	0.018	0.037	1.246	0.042	0.95	0.020	0.040

For each trait, values with the same letters in the column are statistically similar

H : plant height (cm) ; **Circ :** collar circumference (cm) ; **NB**: number of branches; **NT**: Number of tubers; **TL**: Tuber length; **TD**: Tuber diameter; **TW:** Tuber weight**;** **Y**: yield (kg/ha); $p < 0.05$

Table 3. Influence of density on agronomic parameters

Density	H	Circ	NB	NT	TL	TD	TW	Y
Low	2.62±0.50a	29.46±10.02b	1.6±1.21a	4.93±2.49ab	29.33±5.55a	57.94±11.54a	3.1325±2.33b	25060±18656.75c
Medium	2.55±0.43a	27.27±8.09a	1.95±2.08ab	4.15±1.88ab	25.021±6.77a	55.771±10.17a	2.2175±1.94a	22175±19411.72b
High	4.64±0.34b	28±5.34a	1.95±1.45ab	3.87±2.23a	25.59±6.43a	52.45±14.11a	2.003±1.83a	12819.2±1113.03a
F	0.972	0.510	0.614	2.408	0.083	2.104	3.439	5.699
p	0.038	0.041	0.043	0.044	0.032	0.026	0.0354	0.004

For each trait, values with the same letters in the column are statistically similar

H : plant height (cm) ; **Circ :** collar circumference (cm) ; **NB**: number of branches; **NT**: Number of tubers; **TL**: Tuber length; **TD**: Tuber diameter; **TW:** Tuber weight**; Y**: yield (kg/ha); $p < 0.05$

Table 4: Influence of the interaction of location * density on the agronomic parameters of cassava

Locality	Variety	Density	H	Circ	NB	NT	TL	TD	TW	Y
Sp	**Bonoua**	**Medium**	1.94±0.35a	21.99±8.71b	1.8±0.7b	3.8±1.54ab	25.198±4.62c	47.083±5.29ab	1.89±0.97ab	15120±7760.41ab
Sp	**Bonoua**	**Low**	2.24±0.328b	20.06±3.33b	1.3±0.67ab	3.7±1.49ab	29.598±8.62cd	51.911±8.007b	1.58±0.88ab	15800±8854.38ab
Sp	**Bonoua**	**High**	1.81±2.29a	17.52±1.67a	2.5±0.97bc	2.2±1.31a	26.06±6.94c	42.897±3.46a	0.66±0.42a	4224±251.92a
Sp	**Yavo**	**Medium**	2.79±0.17b	29.72±3.87c	1±0.34a	5.1±1.28bc	30.026±4.8cd	55.361±7.34b	3.33±1.44d	26640±11562.7bc
Sp	**Yavo**	**Low**	2.254±0.4b	21.65±3.94ab	1.1±0.316a	3.5±1.17a	24.432±5.2ab	52.821±6.41b	1.43±0.71ab	14300±7196.45ab
Sp	**Yavo**	**High**	1.914±0.43a	21.08±6.02ab	1.4±0.52ab	4.4±1.57ab	25.307±5.6b	39.754±6.96a	1.25±0.95a	8012.8±6092.29ab
NG	**Bonoua**	**Medium**	2.965±0.29b	29.25±7.13c	1.8±1.87b	5.9±4.04c	21.97±6.53ab	64.43±11.33	3.76±3.01e	30080±24127.66
NG	**Bonoua**	**Low**	2.904±0.317b	31.59±4.74cd	1.5±0.52ab	5.2±2.09bc	19.66±3.23a	58.056±9.80bc	2.52±1.07bc	25200±10768.27bc
NG	**Bonoua**	**High**	3.101±0.404c	36.42±11.09d	2.9±2.33bc	5.1±3.03bc	23.064±4.13b	68.404±10.87e	3.37±2.38e	21568±15273.98ab
NG	**Yavo**	**Low**	2.79±0.37b	36.88±13.03d	1.8±1.31b	4.9±2.02bc	24.16±2.84b	64.923±11.33d	3.55±3.00d	28400±24068.79c
NG	**Yavo**	**Medium**	2.802±0.208b	35.81±6.32d	3.9±3.51bc	4.2±2.34b	26.39±5.41c	60.298±13.85c	3.34±3.35d	33400±33503d
NG	**Yavo**	**High**	3.398±0.30c	36.98±5.87d	1±3.8a	3.8±1.75ab	27.94±8.29d	58.78±8.75bc	2.73±1.55bc	17472±11234bc
		F	0.889	11.047	3.556	2.189	2.699	9.644	3.01221	3.159
		p	0.554	0.004	0.001	0.020	0.004	0.002	0.001548	0.001

For each trait, values with the same letters in the column are statistically similar

H : plant height (cm) ; **Circ :** collar circumference (cm) ; **NB**: number of branches; **NT**: Number of tubers; **TL**: Tuber length; **TD**: Tuber diameter; **TW:** Tuber weight**;** **Y**: yield (kg/ha); Sp : Sanpedro2 ; NG: N'Guessankro; $p < 0.05$