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Optimizing Maize Productivity through Variety Selection, Moisture Conservation and Plant Density Management in the Southern Guinea Savanna.

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Abstract: Understanding varietal responses to varying plant population densities under high moisture and drought conditions of sub-humid West Africa is crucial to developing stress-tolerant, high-yielding maize hybrids steering sustainable development in the Nigerian grain industry. This study evaluated the independent and combined effects of maize varieties, plant population density, and in-situ moisture conservation on growth attributes, yield components, and final grain yield in the Southern Guinea Savanna Zone of Nigeria. A factorial Randomized Complete Block experiment (2 × 2 × 3) comprising two varieties (SAMMAZ 52 and Oba 6), two moisture conservation approaches (mulched with dry maize stover at ~4 t ha^{-1}, and un-mulched control), and three plant densities (22,222; 53,333; 88,888 plants ha^{-1}) was conducted in three replicates over 36 plots. The hybrid (Oba 6) consistently outperformed the open-pollinated (SAMMAZ 52) variety for most growth traits, yield components and final grain yield (5.17 t ha^{-1}), conferring a 35.4 % yield advantage. Medium density (53,333 plants ha^{-1}) enhanced leaf number, stem girth, ear size and kernel number, while mulched plots improved stem thickness, yield components giving a yield advantage of 27.0% relative to un-mulched treatments. Significant variety × density and variety × moisture interactions revealed Oba 6 as more responsive to medium density and mulching, producing optimal performance under mulched, medium density conditions. Positive correlations between grain yield and tasseling time, kernel number, ear length and grain weight further highlight important selection traits for breeding. The study recommends medium plant density combined with organic mulching and hybrid selection as a viable strategy for improving maize productivity under rain-fed Savanna conditions.

Keywords: grain yield, in-situ moisture conservation, maize, population density, and varieties.

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1. Introduction

Maize is a key staple and industrial crop grown across all Agro-ecological zones, particularly in the middle belt and northern regions in Nigeria. It belongs to the *Poaceae* family ranking third after wheat and rice and globally accepted for various economic purposes due to its high starch content (Verheye

2010). It's a major source of livelihood for 300 million people in the Sub-Saharan Africa (Macauley, 2015), and considered a primary constituent of livestock feed, palatable to ruminants and poultry (Enujeke 2013). According to FAOSTAT (2024), average maize yield in Africa falls between 2.22 and 2.50 t ha−1 in 2021 which is by far below global average of 5.88 t ha−1. Nigeria produces over 12 million MT of maize as of 2023 qualifying her as the largest producer in Africa (NAERLS, 2023). Growing global population continues to exert pressure on maize production demand (Hou et al., 2020). In the face of increasing global maize production, grain yield and overall productivity is continuously dwindling owing to increasing moisture stress posed by erratic rainfall (Husen and Shalemew 2021; Laskari, et al., 2022), reduced agricultural lands due to rapid industrialization (Ranjan et al., 2017; Wainwright et al., 2022) especially in the Sub-Saharan Africa which relies basically on rainfed agriculture contributing 97% to food security (Beyer et al., 2015). The use of obsolete variety has also been described as one major constrain to increasing maize yield and productivity (Yusuf et al., 2019). Outstanding performance of new hybrids under increased population density creates a basis for genetical improvement on high plant density tolerance (Ygzaw et al., 2025). Rapid climate change exacerbates global drought situation as water resources for agricultural expeditions are entirely insufficient and this impact negatively on maize production (Li et al., 2017; 2018) as rainfed agriculture account for 60-70% of global food supply therefore, adopting varieties with enhanced drought tolerance is of great importance in maize production (Cooper et al., 2014). Similarly, technologies that helps conserve water for plant use are essential for mitigating drought stress in dry lands. The role of organic mulch in mitigation carbon sequestration, reducing evapo-transpiration, increasing soil organic matter, carbon and enhancing soil nutrients and micro-climate environment has been emphasized by several authors (Qiu et al., 2020; Larkin, 2020; Chen et al., 2018; Jain et al., 2017). Tefera et al. (2024) reported a 91% yield increase using organic straw mulch (crop residues), demonstrating its importance for soil moisture retention and temperature regulation in sub-humid regions. Corroborating evidence from other cropping systems further supports mulching benefits: Luo et al. (2022), Hashim et al. (2013) respectively reported 89.7 and 47.68 % yield increase in wheat and maize. Together, these findings underscore the broad applicability of mulching as a soil moisture conservation strategy across different crops and environments.

Advances in plant genetics and selection with respect to competition resulting from increased population densities are consequential to varietal resilience in hybrid maize genotypes. Breeding efforts have reportedly increased grain yield per unit area by 168.5 to 311.8% globally over several decades of selection (Duvick, 2005). Over the years, higher population densities have been regarded as a key technique for yield improvement in maize (Assefa et al., 2016; Shi et al., 2022). Recent literatures have demonstrated that higher plant population densities have significant and direct positive effect on maize yield when compared with other agronomic practices targeted at yield improvement (Wang et al., 2023). Liu et al. (2023) reported 50% yield increase from improved varieties and agronomic practices. Maize farmers across the world now knows that increasing maize population per unit area could be the sure way to improving global food security (Jaikumar et al., 2021). Several authors have reported that sustainable development could stem from hybrids bred for improved tolerance to crowding-stress which possess higher yield potential (Lee and Tollenaar, 2007; Gonzalez et al., 2018). Other authors (Van-Oosterom et al., 2016; Hammer et al., 2009) admitted that maize hybrids are also bred for increased capacity to access stored soil water under water-deficit conditions by developing longer root penetration to cope under crowded population (Messina et al., 2020 and 2021). Report from China indicated regional yield increases ranging from 2.75 to 10.5% when planting density reaches 15,000 plants ha-1 without extra N fertilization (Hou et al., 2020).

Itakpe environment being in the Southern Guinea Savanna zone of Nigeria is heavily characterized by erratic rainfall, this posed serious threat to maize productivity, additionally, yield response to variation in plant population density under field condition has remained less understood as farmers loose bulk of their yields to drought. This creates a research gap for bother farmers and breeders in developing innovative planting technologies. Genetic improvement in hybrids is necessary to understand how variety-specific responses to moisture conservation and population densities impact on growth, yield characters and yield of maize crop. Therefore, the site-specific objectives of this research, conducted under the conditions of the Itakpe environment during the 2025 growing season, were to determine the;

i. effect of variety, varying in-situ moisture conservation and population density on growth, yield and yield characters of maize;
ii. possible interaction(s) of variety, in-situ moisture conservation and population density (V×MC, V×P, P×MC, V×MC×P) on growth, yield and yield-related characters of maize crop in Itakpe environment.
iii. relationship between yield-related characters and grain yield.
iv. best responsive, high-yielding variety and optimum plant population density for Itakpe environment.

2. Materials and Methods

2.1. Study Area Description

This research was carried out at Kogi State Polytechnic, Student Research Farm Itakpe Campus (Lat 7°38' N, Long. 6°19' E) on elevation of 150 – 196 m above sea-level. Itakpe is located within the Southern Guinea Savannah Ecological Zone of Nigeria and it is characterized by annual total rainfall of 1032 mm; average rainfall of about 138.5 mm mostly distributed between the months of April and October. Annual average temperature of 25.1°C, mean monthly minimum and maximum temperature of about 22.78°C and 28.05°C respectively (Mustapha et al., 2021). Itakpe soil belongs to the textural class of sand-clay-loam and has been characterized with the following constituent; sand 698.17 mg kg^{-1}, silt 109.30 mg kg^{-1}, clay 192.53 mg kg^{-1}, pH (H_2O) 5.93, pH (KCl) 5.33, Organic Carbon 1.08 %, Organic matter 1.85 mg kg^{-1}, total nitrogen 0.05 %, available phosphorus 3.69 mg kg^{-1}, electrical conductivity 0.47 mS/cm, Exchangeable Cation (meq/100gmSoil) such as Na^+, K^+, Mg^{2+} and Ca^{2+} were 0.46, 1.64, 1.8, 3.67 respectively. Total exchangeable bases 7.57, exchangeable acidity 1.31 and effective cation exchange capacity 8.88.

2.2 Experimental Design and Agronomic Practices

This study used two typical maize varieties; SAMMAZ 52 (open pollinated), Oba 6 (hybrid) obtained from Institute of Agricultural Research (IAR) Zaria; two moisture conservation methods; mulched (crop residues), un-mulched (check); three population densities; high (88,888 plants/ha), medium (53,333 plants/ha), low (22,222 plants/ha). These treatments were merged in a factorial combination (2×2×3) as listed in Table 1, a total of twelve treatments were obtained, assigned to every block using a random number system and replicated three times. A Randomized Complete Block Design was used. The experiment consisted of thirty-six plots, each plot measured 12m2 separated by 0.5m apart. Each replicate was separated with a discard row of 1.0m to narrow inter block variation. Both varieties were planted at different spacing; 75×15 cm, 75×25 cm, and 75×60 cm that corresponds to a population of 88,888, 53,333 and 22,222 plants per hectare.

Sowing was conducted in late June 2025 and harvested in October 2025.Total seasonal rainfall recorded during the experiment was 847 mm, with monthly distribution ranging from 112 mm in June to 168 mm in August, and a mean monthly temperature of 25.3°C. Plots designated for mulching received a uniform application of dry maize stover at approximately 4 t ha^{-1} (equivalent to ~480 g per 12 m^2 plot), spread evenly on the soil surface immediately after planting. Un-mulched plots served as the control (check) with no surface cover. Fertilizer was applied in two split doses at a rate of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, and 60 kg K_2O ha^{-1}. 400 kg ha^{-1} of NPK 15:15:15 was applied as first as basal fertilization (first dose) at two weeks after sowing (2 WAS), while 130 kg ha^{-1} urea was applied as top-dress at six weeks after sowing (6 WAS), corresponding approximately to the early vegetative and pre-tasseling growth stages, respectively. To prevent weeds from competing with the maize, atrazine and metolachlor was applied prior to emergence. At the 11–12th leaf stage, abamectin benzoate was sprayed at the rate of 30ml/16L using a knapsack sprayer in order to protect the maize against pests and diseases.

Table 1. Treatment Combination

Population Densities	Moisture Conservation: Mulched (M)	Un-mulched (U) [check]	Treatments	Variety: V_1 (OP)	V_2 (hybrid)
High density (P_1)	P_1 M	P_1 U	P_1 M	V_1P_1 M	V_2P_1 M
Medium density (P_2)	P_2 M	P_2 U	P_2 M	V_1P_2 M	V_2P_2 M
Low density (P_3)	P_3 M	P_3 U	P_3 M	V_1P_3 M	V_2P_3 M
			P_1 U	V_1P_1 U	V_2P_1 U
			P_2 U	V_1P_2 U	V_2P_2 U
			P_3 U	V_1P_3 U	V_2P_3 U

Sampling and Measurement

Ten plants were tagged in each plot for measurement of growth data at emergence, 3, 5, 7 and 9 weeks after sowing. Growth data measured include; plant height, number of leaves, stem girth, leaf area, number of days to tasseling. Leaf area was estimated using the formula: Leaf Area = Leaf length × Leaf width × 0.75, applied to the three fully expanded leaves per tagged plant. Yield data such as number of ears/plants, kernel/ear, ear length, were measured at physiological maturity. grain weight/plot, 100-grain weight and final grain yield was measured after harvest. 100-grain weight, rather than the 1000-kernel weight more commonly reported internationally, was adopted in this study because the smaller sample size allowed replicate sub-samples to be weighed with higher precision on the analytical balance available on-site; values are directly comparable to the 1000-kernel weight by multiplying by a factor of ten. Grain yield per plot was determined by harvesting all ears from each 12 m² plot, shelling, and weighing the grain. Final grain yield (t ha⁻¹) was calculated as:

$$\text{Grain yield (t ha}^{-1}) = \frac{[\text{Grain weight per plot (kg)} \div \text{Plot area (m}^2)] \times 10{,}000}{1{,}000}$$

Grain weight was adjusted to 12.5% moisture content before yield calculation.

2.4 *Statistical Analysis*

Statistical analysis was conducted using CropStat7.2.2007.3 software (IRRI, Metro Manila, Philippines). Variety, population density and in-situ moisture conservation as well as their interactions were subjected to Analysis of variance to determine their effect on growth and yield characters. Means of significantly different treatment effects were subjected to Post Hoc test using New Duncan Multiple Range Test at 0.05 level of probability. Correlation analysis was used to determine the relationship between various yield characters and grain yield using STAR v.2.0.1 (IRRI, 2013-2020).

3. Results and Discussion

3.1 *Effect of Variety, Population density and In-situ moisture conservation on maize growth characters*

Table 2 shows the effect of variety, population density and moisture conservation on the growth characters of maize in Itakpe environment. Variety significantly influenced all the growth characters measured ($p<0.05$) except the leaf area where both varieties were statistically at par. Oba 6 consistently had the highest germination (80.58 %), mean number of leaves (10.99), mean height (113.08 cm), mean girth (6.09 cm) and longer days to tasseling (66.80) as against SAMMAZ 52. This result may be due to varietal differences in genetic make-up which enhanced nutrient absorption, photosynthetic area radiation, crop architecture, water use efficiency as evident in high number on leaves, thicker stems, taller plants among others observed with Oba 6. This is in tandem with Yusuf et al. (2019). Similarly, other authors emphasized the impact of hybrid varieties on improving growth characteristics in maize (Udoh 2005; Enujeke 2013).

Population density did not significantly affect (p>0.05) number of days to tasseling. However, plots established with population of 88,888 plants/ha produced the highest germination (88.62%) and tallest plants (123.03 cm). Germination rate observed in plots established with 88,888 and 53,333 plants/ha were significantly indifferent (p>0.05). Plots established with 53,333 plants/ha produced the highest mean number of leaves (11.59), thickest stem girth (7.28 cm) and widest leaf area (309.51 cm^2), followed by plots planted with 88,888 plants/ha while plots established with 22,222 plants/ha had the lowest growth performance throughout with an exception to leaf area expansion. This result coincides with the reports of Tollenaar and Lee (2006) whose results underpins the fact that genetic improvement and good agronomic practice improved growth characteristics in maize under higher population densities. Hammer et al. (2009) also confirms that genetic modification targeted at improving crop physiology often result in improved growth characteristics such as crop canopy and root architecture, higher photosynthetic rate at most critical growth stage of maize (grain filling period).

Our result on mean height shows that plots established with higher population density (i.e., 88,888 plants/ha) had the tallest plants (123.03 cm) and this differ significantly from those of 53,333 (108.81 cm) and 22,222 plants/ha (96.13 cm) respectively. This is an indication that in crowded situation, plants compete fiercely to intercept solar radiation. This is reflected in the works of Djaman et al. (2022) who stressed that higher plant densities often reduce light penetration to the lower part of plant during vegetative growth stages thus raising indole acetic acid concentration which stimulate cell elongation that transform into development of taller plants. In another report by Zsubori et al. (2002), maize architecture enhances light penetration under normal distribution that improves vegetative canopy which result to oxidation of plant hormone (i.e., auxin) that result to decrease height and growth (Urge 2022). Moisture conservation did not affect most of the growth characters measured (p>0.05). mulched and un-mulched plots were statistically at par for all characters except mean stem girth where mulched plot consistently produced thicker stems with mean of 6.14 cm. this conforms with the report of Puka-Beals and Gramig (2021).

3.2. Effect of Variety, Population Density and In-situ moisture conservation on maize yield characters and yield.

Yield characters were significantly influenced (p<0.05) by variety, population density and in-situ moisture conservation (Table 3). Oba 6 variety produced the highest number of kernel/ear (391.98), longest ear (16.77 cm), maximum grain weight/plot (4.14 kg), 100-grain weight (244.40 g) and final mean yield per hectare (5.17 t/ha) against the SAMMAZ 52 variety. Sun et al. (2023) found significant differences in grain yield of different hybrid maize varieties under different plant densities in different locations of high latitude of China. Similarly, Pearl (2012) reported higher yield advantage in hybrid maize over the open pollinated in Ghana.

Alternatively, for number of ears/plants, both varieties did not differ significantly in performance. Oba 6 had 35.4 % yield advantage over SAMMAZ 52 variety. Similarly, same variety exhibited 24.3 %, 35.5 %, 16.5 % and 17.9 % yield advantage over the latter on 100-grain weight, grain weight/plot, ear length and number of kernels/ears respectively. Hao et al. (2024) also reported improved biomass yield, harvest index, kernel weight and kernel number among different hybrid varieties. Increase in yield and yield characters in maize hybrids has been attributed to genetic improvement according to Ci et al. (2012), improved hybrids are more resilient to environmental stress. This is confirmed in the report of Ci et al. (2011).

No significant differences were observed with the three population densities examined for number of ears/plants, grain weight per plot, 100-grain weight and total grain yield per hectare. However, population density of 53,333 plants/ha produced the highest number of kernels/ear (404.42) and longest ear (16.63 cm). followed by 88,888 plants/ha and 22,222 plants/ha in that order. This follows that kernel number and ear length have direct positive relationship with grain yield, this conforms with the report of Gonzalez et al. (2018) who stressed physiological increase maize yield implies more kernels per plant or heavier kernels at constant plant population or vice versa.

In-situ moisture conservation shows that mulched plots exhibited 6.53, 11.11, 16.15, 26.9 and 26.83 % yield advantage over un-mulched plots for number of kernels/ears, ear length, number of ears/plants, grain weight/plot and final grain yield/ha respectively. Mulched and un-mulched plots were statistically at par for 100-grain weight. This result could be attached to improved dry matter accumulation, improved light interception and better crop canopy development (Di et al., 2016) under high moisture availability. Solar radiation and plant population has been reported to have direct impact on yield increase (Ye et al., 2020). A drop in solar radiation has reportedly led to 3–6% yield reduction in maize in China (Gao et al., 2017). Our results show that the accumulated solar radiation was significantly associated with high soil moisture level based on previous research. Solomon (2015) reported higher grain yield in early maturing maize varieties from improved moisture conservation. In a related study on in-situ moisture conservation, Husen and Shalemew (2021) obtained the maximum yield from tied ridges in Ethiopia, consistent with our finding that moisture-conserving practices significantly improve maize yield under rain-fed conditions. Consistent with reports in the literature (Khan et al., 2022; Kaur et al., 2024; Ahmad et al., 2015), the use of organic mulch in our experiment is expected to have served as a barrier to light penetration at the soil surface during early crop development, thereby reducing weed seed germination and evapotranspiration while maintaining a favorable soil micro-climate. Although soil moisture was not directly measured in this study, the significantly higher yield in mulched plots supports the interpretation that mulch improved moisture retention.

Table 2. Effect of Variety, Plant Population and Moisture Conservation on the Growth Characters of Maize crop in Itakpe, Kogi State.

Growth characters	Variety		Population Density (Plants/ha)			In-situ Moisture Conservation		CV (%)
	SAMMAZ 52 (OPV)	Oba 6 (hybrid)	88,888	53,333	22,222	Mulched	Un-mulched	
Percent germination (%)	69.25±0.35$_{b}$	80.58±4.83$_{a}$	88.62±0.53$_{a}$	85.37±1.24$_{a}$	50.75±6.01$_{b}$	74.91±0.58$_{a}$	74.91±3.88$_{a}$	12.30
Mean Number of Leaves	10.18±0.36$_{b}$	10.99±0.12$_{a}$	10.41±0.39$_{b}$	11.59±0.14$_{a}$	9.76±0.11$_{b}$	10.86±0.07$_{a}$	10.32±0.15$_{a}$	7.90
Mean Girth (cm)	5.67±0.36$_{b}$	6.09±0.32$_{a}$	5.80±0.35$_{b}$	7.28±0.24$_{a}$	4.56±0.42$_{c}$	6.14±0.36$_{a}$	5.63±0.30$_{b}$	7.60
Mean Leaf Area (cm^2)	269.39±4.77$_{a}$	279.05±5.03$_{a}$	204.79±1.75$_{b}$	309.51±1.42$_{a}$	308.37±3.57$_{a}$	278.21±18.28$_{a}$	270.24±18.54$_{a}$	8.30
Mean Height (cm)	105.58±3.36$_{b}$	113.08±6.26$_{a}$	123.03±7.62$_{a}$	108.81±4.95$_{b}$	96.13±1.86$_{c}$	111.09±4.02$_{a}$	107.57±5.59$_{a}$	5.80
Days to tasseling	60.42±2.02$_{b}$	66.80±4.00$_{a}$	61.50±2.47$_{a}$	65.41±4.90$_{a}$	63.90±1.64$_{a}$	65.44±1.75$_{a}$	61.79±4.25$_{a}$	10.10

Mean(s) followed by the same letter(s) within rows, are not statistically significant a 0.05 level of probability.

Table 3. Effect of Variety, Plant Population and Moisture Conservation on the Yield Characters of Maize crop in Itakpe, Kogi State.

Yield characters	Variety		Population Density (Plants/ha)			In-situ Moisture Conservation		CV (%)
	SAMMAZ 52 (OPV)	Oba 6 (hybrid)	88,888	53,333	22,222	Mulched	Un-mulched	
Number of ears/plants	1.14±0.06$_{a}$	1.25±0.09$_{a}$	1.22±0.14$_{a}$	1.25±0.04$_{a}$	1.11±0.12$_{a}$	1.30±0.14$_{a}$	1.09±0.01$_{b}$	19.60
Number of kernel/ears	321.45±27.88$_{b}$	391.98±39.48$_{a}$	347.56±23.74$_{ab}$	404.42±72.62$_{a}$	318.16±4.68$_{b}$	368.75±39.07$_{a}$	344.67±28.30$_{b}$	17.40
Ear length (cm)	14.00±0.92$_{b}$	16.77±0.01$_{a}$	15.03±0.16$_{b}$	16.63±0.19$_{a}$	14.48±1.43$_{b}$	16.29±0.60$_{a}$	14.48±0.33$_{b}$	7.80
Grain weight/plot (kg/plot)	2.67±0.05$_{b}$	4.14±0.01$_{a}$	3.39±0.11$_{a}$	3.74±0.01$_{a}$	3.08±0.02$_{a}$	3.93±0.05$_{a}$	2.87±0.02$_{b}$	25.70
100-grain weight (g)	184.82±31.41$_{b}$	244.40±29.27$_{a}$	218.26±5.21$_{a}$	209.50±12.34$_{a}$	216.07±14.35$_{a}$	216.96±7.19$_{a}$	212.25±5.06$_{a}$	20.70
Yield (t ha^{-1})	3.34±0.66$_{b}$	5.17±0.13$_{a}$	4.23±1.34$_{a}$	4.68±0.17$_{a}$	3.86±0.31$_{a}$	4.92±0.60$_{a}$	3.60±0.20$_{b}$	25.70

Mean(s) followed by the same letter(s) within rows, are not statistically significant a 0.05 level of probability.

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3.3 *Interaction of Variety, Population Density and In-situ moisture conservation on maize growth characters*

Oba 6 responded better to population density than SAMMAZ 52 on plant height (figure 1). The variety attained it maximum height (130.09 cm) in plots established with 88,888 plants/ha whereas SAMMAZ 52 only attained a height of 115.98 cm under the same population density. Similarly, at 53,333 plants/ha, Oba 6 also appeared taller than SAMMAZ 52 while at lower densities, both varieties were at par. Increase in plant height observed amongst plots treated with higher population density is an evident that plants fiercely compete for solar radiation and other growth resource, therefore growing taller to intercept sunlight. This differences among both varieties could be due to genetic superiority of the hybrid over the OP variety. Hybrid varieties have stronger affinity for competition than the open pollinated. This result is in line with those of Gou et al. (2017) who implied that intercepted solar radiation during maize vegetative stage have positive implication on optimum plant density (Testa et al., 2016).

The relationship between moisture conservation and population density (figure 2), indicate that although, mulched plots were more responsive to higher population density (i.e., produced taller plants) but did not differ significantly (p>0.05) from the un-mulched plots. Similarly, population density of 53,333 plans/ha (mulched) produced the highest germination percent as against the un-mulched plots subjected to the same planting density. Percentage emergence at 88,888 plants/ha did for both moisture conservation method under examination did not differ significantly. Poor emergence rate was observed with lower plant population (figure 3). This result in tandem with Demo and Bogale (2024) and Larkin (2020).

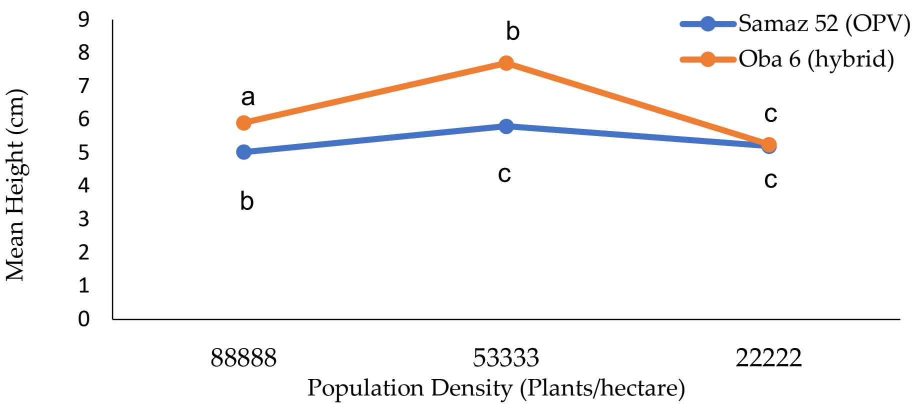
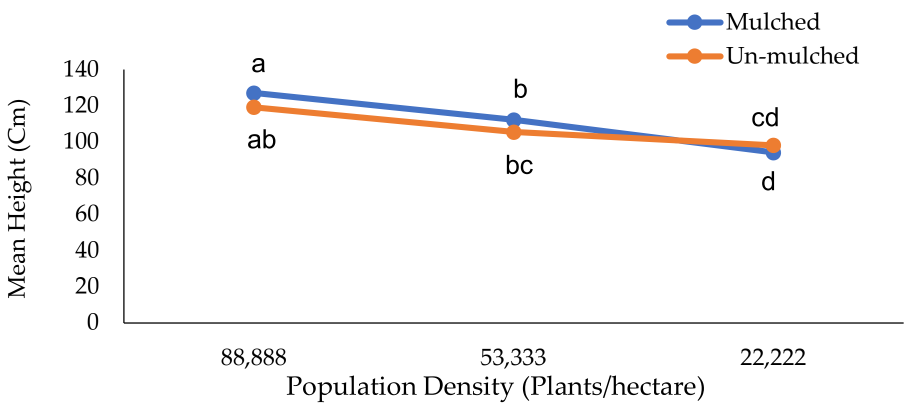


Figure 1. Interaction of Variety and Population Density (V×P) on mean height



DOI: 10.7160/sab.2026.570350

Figure 2. Interaction of Population Density and Moisture conservation (P×MC) on mean height

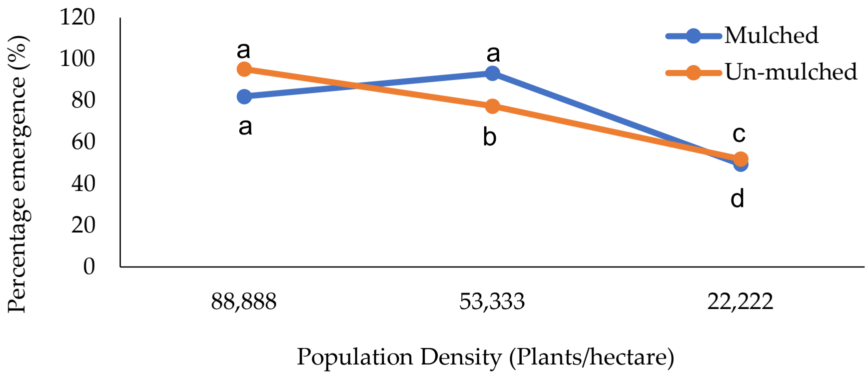


Figure 3. Interaction of population density and moisture conservation (P×MC) on percentage emergence

3.4 *Interaction of Variety, Population Density and In-situ moisture conservation on maize yield and yield characters.*

Oba 6 responded better to population density on number of kernels/ear and moisture conservation on final grain yield (t/ha). At 53,333 plants/ha, Oba 6 produced the highest number of kernels/ears, and this differed significantly from SAMMAZ 52 at the same density. Hao et al. (2024), reported increased yield characters and reduced kernel number as plants population increased. Kernels/ear reduced as plant population increased (figure 4). Similarly, Oba 6 produced higher grain yields in mulched plots and this differ significantly from obtained with SAMMAZ 52. Yield from un-mulched plots were statistically indifferent for both varieties (figure 7). Our results are in tandem with Gaffney et al. (2015) who reported that hybrid maize has higher yield advantage over OP varieties under drought condition when population density is increased up to 6.9 plants m-2. The recommended medium density of 53,333 plants/ha compares favorably with the conventional farmer practice of approximately 22,222–53,333 plants/ha commonly used in the Southern Guinea Savanna of Nigeria, suggesting a modest but practically feasible increase in plant stand. In the report of Cooper et al. (2014), hybrid varieties bred for drought tolerance are superior to OP varieties that are drought-sensitive when subjected to water stress and crowdedness. This aligns with our result on yield (figure 5), where Oba 6 had the best response to plant densities with the highest grain weight obtained in plots established with 53,333 plants/ha. This response differs significantly from those of SAMMAZ 52 also at higher (88,888 plants/ha) and lower densities (22,222 plants/ha). Yigzaw et al. (2025) also confirmed significant genotype × plant density interaction for some yield-related characters in maize.

Mulched plots responded to population density than the un-mulched plots for number of kernels/ears, though did not differ significantly. Highest kernel/ear was obtained in un-mulched plots established with 53,333 plants/ha and this was at par with mulched plot of the same plant density. Significant P × MC interaction on yield characters is an indication that organic mulch minimized evaporation, increased organic matter, enhanced soil structure and fertility (Puka-Beals and Gramig 2021) thus suppressing the negative effects of high population. This is in tandem with report of several other authors (Qin et al., 2015; Yang et al., 2015; Kader et al., 2017).

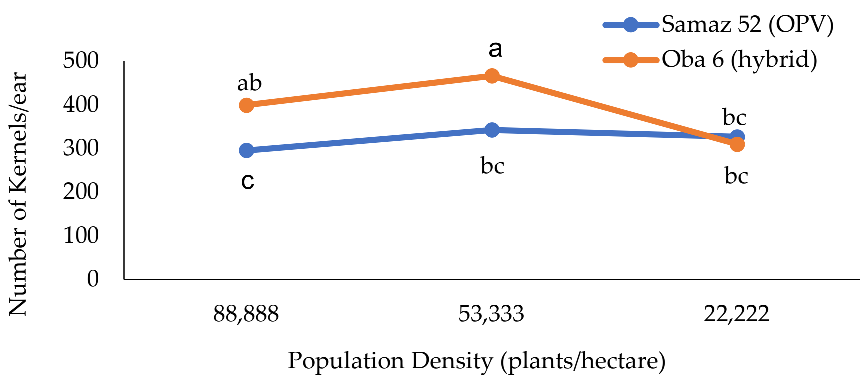


Figure 4. Interaction of variety and population density (V×P) on number of kernels ear^{-1}

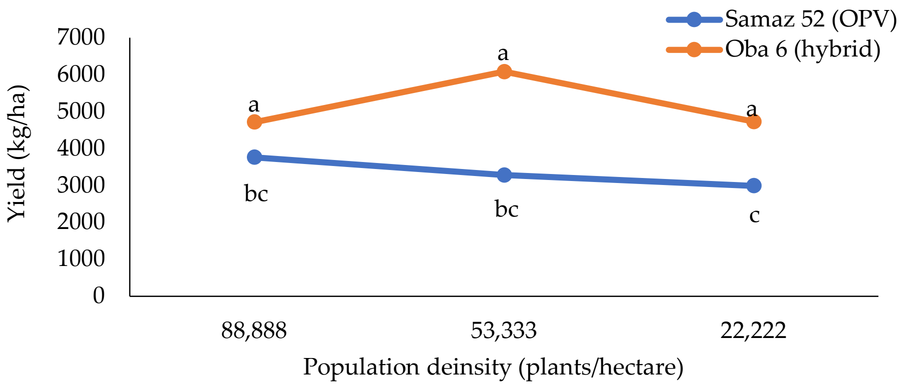


Figure 5. Interaction of variety and population density (V×P) on Yield per hectare

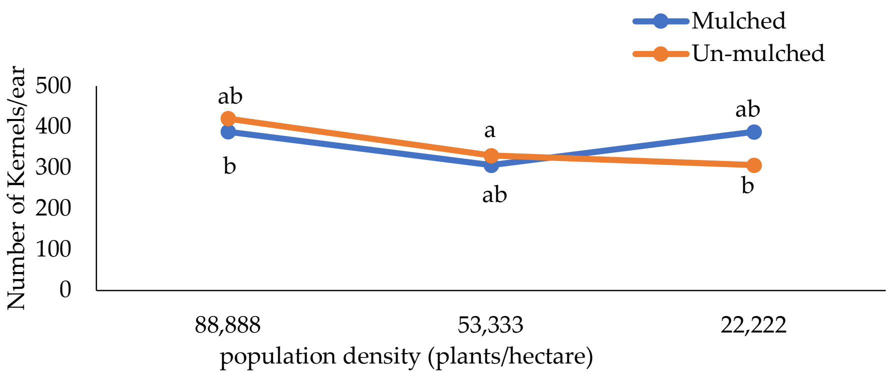


Figure 6. Interaction of Population density and Moisture conservation (P×MC) on number of kernels/ears.

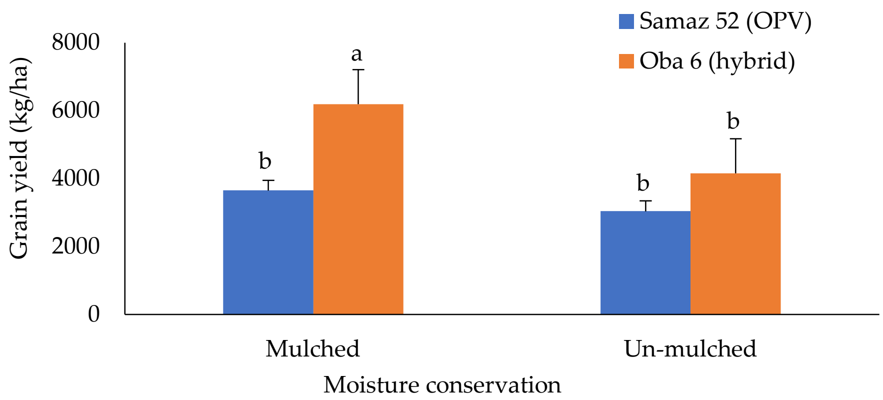


Figure 7. Interaction of Variety and Moisture Conservation (V×MC) on Yield per hectare.

3.5 Relationship between different pairs of yield characters and yield of maize planted under different plant population density and in-situ moisture conservation at Itakpe.

Pearson correlation result of yield and yield-related traits (Table 4) shows that yield had positive and significant correlation with days to tasseling, number of ear/plants, kernel/ear, ear length, grain weight/plot, and 100-grain weight at 0.05 level of probability, indicating 13.17, 11.49, 11.97, 45.56, 99.8, 6.30% contribution to yield respectively. Among the other yield characters examined, all showed positive and significant correlations. Leaf area was the exception as it exhibited positive but non-significant correlations with days to tasseling, number of kernels/ears, ear length, grain weight/plot, and grain yield. Leaf area showed negative non-significant correlations with number of ears/plant and 100-grain weight. Our result aligns with Hao et al. (2024) who found significant and positive correlation between grain yield and kernel weight. Sun et al. (2023) also found positive and significant correlation between yield and pairs of yield-related components in maize in high latitude of China.

Table 4. Estimate of Phenotypic Correlation Coefficient between different pairs of characters in maize

	LA	DTT	E/PL	K/EAR	EL	GW (kg/plot)	100-GW	Yield (tha^{-1})
LA	1							
DTT	0.301	1						
E/PL	-0.025	0.465*	1					
K/EAR	0.098	0.585*	0.387*	1				
EL	0.221	0.594*	0.458*	0.541*	1			
GW (kg/plot)	0.179	0.363*	0.340*	0.346*	0.675*	1		
100-GW	-0.071	0.445*	0.259*	0.298*	0.464*	0.251*	1	
Yield (tha^{-1})	0.179	0.363*	0.339*	0.346*	0.675*	0.999*	0.251*	1

LA=Leaf Area, DTT=days to tasseling, E/PL=number of ears/plants, K/EAR=number of kernel/ears, EL=ear length, GW (kg/plot) =grain weight/plot, 100-GW=100-grain weight and Yield (tha^{-1}) =final yield/ha

* Significant at 0.05 level of probability.

4. Conclusions

This study demonstrates that maize productivity in the Southern Guinea Savanna is strongly influenced by plant density, soil moisture conservation and variety selection. The hybrid variety (Oba 6) exhibited superior agronomic performance with 35 % yield advantage over the Open pollinated (SAMMAZ 52) variety, particularly under mulched conditions at medium plant density (53,333 plants ha^{-1}). Grain yield was significantly associated with kernel number, ear length and grain weight, indicating useful selection traits for breeding. These findings, based on a single-season, single-location experiment in Itakpe, suggest that integrating hybrid maize with medium plant density and in-situ moisture conservation has potential to enhance yield under rain-fed Savanna conditions.

However, given the inherent year-to-year variability in rainfall distribution that strongly influences density and mulch responses in this ecology, these results should be interpreted with caution and validated across multiple seasons and locations before broad agronomic recommendations are extended. It should be noted that final grain yield per hectare did not differ significantly among the three plant densities tested; the recommendation of medium density (53,333 plants ha^{-1}) is therefore based on its consistently superior performance in yield components (kernel number/ear, ear length and grain weight/plot) rather than on a statistically significant yield advantage. Adoption of hybrid maize cultivars such as Oba 6 is recommended for enhanced yield performance; while mulching with organic crop residue should be incorporated into maize production systems to reduce moisture loss and improve yield stability, medium density planting (53,333 plants ha^{-1}) should be adopted as it optimizes physiological efficiency and productivity. Further evaluation across seasons and nutrient regimes may be necessary to strengthen density-stress tolerance.

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This research data and datasets is available on request.

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