RESPONSE OF TWO OPEN POLLINATED AND TWO HYBRID VARIETIES OF MAIZE TO VARYING NITROGEN LEVELS AND INTRA-ROW SPACING IN SAMARU

[1]A. J. Sulaiman., [2]Usman. A., [1]A. A. Muhammad., [1]H. Dauda., [1]A.D. Hinjari and [3]Ibrahim. S

[1]*Department of Agronomy, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.*

[2]*Samaru College of Agriculture, Division of Agricultural Colleges, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.*

[3]*Department of Agronomy, Faculty of Agriculture, Federal University Gashua, Yobe State*

Corresponding author`s email: sulaimanaisha2017@gmail.com
Phone Number +2348036971399

DOI No. 10.528 / zenodo 10558777

Abstract

Three trials were conducted during the 2020, 2021 and 2022 rainy season at the Institute for Agricultural Research (IAR) farm, Samaru in the Northern Guinea Savannah zone of Nigeria to evaluate the growth response of two open pollinated and two hybrid varieties to varying nitrogen levels and plant spacing in Kaduna. The treatment consisted of four maize varieties (SAMMAZ 15, SAMMAZ 51, OBASUPER 13 and SC 651) three Nitrogen rates (90, 120 and 150)kg ha-^{1} and three plant spacing (75 X 30, 75 X 40 and 75 X 50).The experiment was laid out in a split plot design with a combination of nitrogen and population density in the main plot and variety in the subplot with three replications. Based on the results obtained it was indicated that among the four maize varieties evaluated OBASUPER 13, SC 651, SAMMAZ 15, and SAMMAZ 51thehybrid varieties (OBASUPER 13 and SC 651)generally exhibited superior vegetative growth, characterized by greater plant height and higher leaf numbers, particularly during the early and mid-growing stages. This superiority highlights the inherent heterotic advantage and enhanced resource-use efficiency of hybrid maize compared to open-pollinated varieties (OPVs). However, varietal performance varied across years, indicating strong genotype × environment (G×E) interactions, with OBASUPER 13 and SC 651 performing best in most seasons, while SAMMAZ 15 showed competitive yield potential under favorable conditions. Nitrogen application had a consistent and positive influence on maize growth and yield. The application of 150 kg N ha^{-1} produced the tallest plants, greatest leaf numbers, and highest grain yield across most seasons and in the combined analysis. This confirms that adequate nitrogen availability is crucial for promoting vigorous vegetative development, optimizing photosynthesis, and enhancing kernel formation. Conversely, the lowest nitrogen rate (90 kg N ha^{-1}) consistently resulted in reduced growth and yield, emphasizing the importance of appropriate N fertilization for maximizing maize productivity. Nevertheless, the absence of significant nitrogen effects in some seasons (notably 2022) suggests that environmental variability, particularly rainfall distribution and soil nutrient status, can moderate nitrogen response. Plant spacing also influenced maize performance, though its effects were less consistent than variety and nitrogen. Wider spacing (50 cm) generally enhanced grain yield per hectare, likely due to reduced inter-plant competition for nutrients, light, and water, whereas closer spacing (30 cm) limited resource availability and suppressed growth. The findings highlight that optimal spacing should balance plant population density and resource accessibility, particularly under rainfed tropical conditions.

Keywords: Maize; Leaf number; Plant height; Open pollinated; Hybrid.

Introduction

Maize (*Zea mays* L.) is one of the most significant cereal crops globally, especially in sub-Saharan Africa, where it is a staple food and a major contributor to both food security and the livelihoods of millions. In Nigeria, maize is cultivated across various agro-climatic zones, playing a crucial role in local economies (FAO, 2021). Despite its importance, maximizing maize productivity remains a challenge due to factors such as suboptimal agronomic practices, poor nutrient management, and inadequate knowledge of the varieties used. Key agronomic practices, such as nitrogen fertilization and plant spacing, have been shown to significantly affect maize growth and yield potential (Shrestha *et al*., 2020; Zhang *et al*., 2022).

Maize varieties are broadly classified into two categories: open-pollinated varieties (OPVs) and hybrid varieties. OPVs, such as SAMMAZ 15 and SAMMAZ 51, are widely adopted by small holder farmers because of their increased resistance to environmental stress, lower seed cost and the ability to recycle seeds across seasons. Despite these advantages, OPVs often exhibit lower yields when compared to hybrid maize. Hybrid varieties, such as Obasuper 13 and SC 651, are specifically bred for superior yield potential and overall higher productivity (Badu-Apraku *et al*., 2019; Fakorede *et al*., 2021). However, their cultivation requires greater investment, including the purchase of new seeds each season and higher input use, particularly fertilizers (Ouma and Mwangangi, 2020).

While hybrids are widely recognized for their yield superiority, OPVs remain valuable for their affordability, seed security, and adaptability under resource-limited conditions. These contrasting attributes underscore the importance of directly comparing the growth performance of OPVs and hybrids under varying agronomic conditions, particularly in the context of smallholder farming systems in Nigeria.

The morphological characteristics of maize are critical indicators of overall plant health and growth. These parameters are especially important in evaluating the comparative growth performance between OPVs and hybrid varieties, as they provide direct insights into their vegetative growth and potential yield under varying agronomic conditions. While hybrids typically show faster growth and larger plants, OPVs may exhibit greater adaptability to diverse environmental conditions (Zhang *et al*., 2022). This study, therefore, aims to compare the growth responses of two OPVs (SAMMAZ 15 and SAMMAZ 51) and two hybrid varieties (Obasuper 13 and SC 651) commonly used in the Northern Guinea Savannah with a particular focus on the morphological aspects of plant height and leaf number.

Nitrogen is one of the most important macronutrients for maize growth, influencing key growth parameters such as plant height and leaf number. Adequate nitrogen fertilization promotes robust vegetative growth by enhancing chlorophyll production, which is vital for photosynthesis (Mueller *et al*., 2017). However, the nitrogen needs of maize vary by variety and environmental conditions, and excessive nitrogen application can lead to negative environmental impacts, such as nitrate leaching (Roth *et al*., 2018). For this study, nitrogen levels of 90 kg/ha, 120 kg/ha, and 150 kg/ha were selected based on local agronomic recommendations for maize cultivation in Northern Guinea Savannah of Nigeria (Adewumi *et al*., 2022).

Plant spacing is critical factor that influences maize morphology and growth. Proper spacing reduces inter-plant competition for light, water, and nutrients, allowing plants to grow to their full potential (Kihara *et al*., 2021). Wider spacing often results in larger plants with more developed leaves, which can positively affect plant height and leaf number (Paponov *et al*., 2021). However, overly wide spacing may reduce plant density, leading to a lower yield per unit area (Tesfaye *et al*., 2020). This study employed spacing intervals of 75x30 cm, 75x40 cm, and 75x50 cm, based on previous research that identified these spacings as optimal for maize growth in the region (Amujoyegbe *et al*., 2022).

MATERIALS AND METHODS

Trials were conducted during the wet season of 2020, 2021, and 2022 at the experimental site of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, located at Samaru (11° 01' N, 70° 38' E and 686 m above sea level) in the Northern Guinea Savannah zone of Nigeria.The treatments for the study consisted of three population densities (53,333, 66,666, and 88,888 plants ha^-1), achieved using spacings of 50 x 75, 40 x 75, and 30 x 75 cm; three nitrogen rates (90, 120, and 150 kg N ha^{-1}); and four maize varieties (SAMMAZ 15, SAMMAZ 51, OBASUPER 13, and SC 651). The experimental layout was arranged in a split plot design, with nitrogen and population density in the main plot and variety in the subplot, replicated three times. Each gross plot measured 6 m x 4.5 m (27 m^2) and consisted of 6 ridges spaced 75 cm apart. The net plot was made up of the 2 inner ridges (9.0 m^2).The field was harrowed using a tractor, ridged at 75 cm apart, and marked into plots and replications. A boundary of 1.0 m between the plots and 2 m between the replicates was maintained. Seeds of the open-pollinated varieties were obtained from the Maize Breeding Unit at IAR. The seeds were dressed with Apron plus 50DS at a rate of 10 g per 4 kg of seeds before sowing. Seeds of OBASUPER 13 and SC 651 were purchased from Premier Seed Nigeria Ltd and Seed-co, respectively. Sowing occurred on the 5th, 7th, and 8th of July at a depth of approximately 2 cm, at a rate of 4 seeds per hole and intra-row spacing of 30, 40, and 50 cm as per the treatment. The seedlings were later thinned to 2 plants per stand two weeks after sowing. Half of the nitrogen was applied in the form of urea based on treatment, along with 60 kg P_2O_5 and 60 kg K_2O as single superphosphate and muriate of potash, respectively, at 2 weeks after sowing (WAS). The remaining half of the nitrogen fertilizer was applied as urea at 7 WAS, also based on treatment. Atrazine and pendimethalin were applied pre-emergence at a rate of 300 ml in 20 L of water (4 L/ha) after sowing. During the growing period, two hoe weeding were conducted to control emerged weeds at 3 and 6 WAS. Ridge molding was carried out at 8 WAS. For insect pest control (specifically stem borers), Caterpillar Force, a non-systemic insecticide with the active ingredient Emamectin Benzoate (5% WDG), was used at a rate of 10 g to 15 L of water. It was applied using a knapsack sprayer in the early morning to prevent wind drift. Harvesting was done manually by removing the ears once physiological maturity was reached, indicated by the formation of a black layer at the placental region of the ear and the visible loss of all milk from the kernel when broken. Observations were taken on plant height which was determined by measuring the height from the ground to the tip of the four tagged plants using a graduated meter rule and the average was recorded for each of the plots at all the sampling periods. All leaves on each of the tagged plants were counted and the average value was recorded for each of the plots at all the sampling periods and also grain yield of each plot was taken and converted to per hectare. The data collected was subjected to Analysis of Variance (ANOVA) using F-test and the significant differences among the treatment means were compared using Duncan Multiple Range Test (DMRT) as described by Duncan (1955).

RESULTS AND DISCUSSION

Plant Height

Table 2 illustrates the effects of nitrogen application and spacing on the plant height of maize varieties during the 2020, 2021, and 2022 rainy seasons, as well as their combined years. The results indicate that maize varieties had significant effects on plant height across most measurement periods, except at 4 and 10 weeks after sowing (WAS) in 2022. In 2020, the hybrid OBASUPER 13 was consistently the tallest at 4, 6, and 8 WAS, demonstrating a clear advantage over the open-pollinated varieties. At 4 WAS, the hybrid OBASUPER 13 was significantly taller than SAMMAZ 15, the shortest variety. At 6 and 8 WAS, OBASUPER 13 outperformed all other varieties, while SAMMAZ 51 had the shortest plants across both intervals. At 10 WAS, the two hybrids, OBASUPER 13 and SC 651 had similar heights, but SAMMAZ 15 was again the shortest. The hybrid varieties (OBASUPER 13 and SC 651) maintained a height advantage over the open-pollinated varieties (SAMMAZ 15 and SAMMAZ 51) throughout most of the season. In 2021, the hybrid OBASUPER 13 was again the tallest at 4, 6, and 8 WAS, showing superior growth compared to the open-pollinated varieties. SAMMAZ 15 and SAMMAZ 51 had the lowest heights at 4 WAS. SAMMAZ 15 and SC 651 were the shortest at 6 WAS, but at 10 WAS, OBASUPER 13 remained the tallest, while SAMMAZ 51 again had the shortest plants. At 4 WAS in 2022, all varieties had statistically similar heights, showing less variation between the hybrids and open-pollinated varieties early in the season. However, by 6 WAS, OBASUPER 13 regained its advantage, being the tallest among all varieties. At 8 WAS, OBASUPER 13 was the shortest, while the other varieties, including the open-pollinated SAMMAZ 15 and SAMMAZ 51, had statistically similar heights. At 10 WAS, all varieties were statistically similar in height, which again showed less clear differentiation between the hybrids and open-pollinated varieties. For the combined years, OBASUPER 13 consistently had the tallest plants at 4, 6, and 10 WAS, reinforcing its superiority over the open-pollinated varieties. The two hybrids were statistically similar at 4 WAS, but SAMMAZ 51 had the shortest height at 4 and 8 WAS, consistently trailing behind the hybrid varieties. Overall, the hybrid varieties (OBASUPER 13 and SC 651) showed superior plant height at most stages, particularly at the early and mid-growing periods, while the open-pollinated varieties (SAMMAZ 15 and SAMMAZ 51) tended to have shorter plants, especially at key stages like 4, 6, and 8 WAS. This finding agrees with Menkir *et al*. (2020)**,** who reported that maize hybrids exhibit greater vegetative growth and adaptability under varying nutrient conditions than open-pollinated varieties (OPVs). Similarly, Badu-Apraku *et al.* (2022) observed that hybrid maize typically expresses heterosis in plant height due to enhanced photosynthetic capacity and superior nutrient uptake efficiency. The reduced differences among varieties in 2022 may indicate a strong environmental influence possibly reduced rainfall or soil nutrient limitation—on varietal expression. Asim *et al.* (2021) and Bello *et al.* (2019**)** noted that environmental stress can suppress the genetic potential of hybrids, leading to non-significant differences among genotypes.

In 2020, 2021 and the combined years, application of 150 kg ha^{-1} nitrogen produced the tallest plants followed by 120 kg ha^{-1}N and then 90 kg ha^{-1} N application which produced the shortest plants at all the sampling periods except at 8WAS for the combined years where 120 kg ha N application produced highest and the same plant height as 150 kg ha^{-1} while 90 kg ha^{-1} resulted in the shortest plants. In 2022, no significant differences were observed at all the sampling periods when nitrogen was varied. The positive response of plant height to increasing N levels agrees with previous findings that N promotes vegetative growth, leaf area expansion, and stem elongation (Usman *et al*., 2024). According to Egharevba *et al*. (2019)**,** N deficiency reduces chlorophyll synthesis and photosynthetic activity, thereby limiting plant height and biomass accumulation. The non-responsiveness observed in 2022 could be attributed to external constraints such as water stress or soil nutrient saturation, where even the lowest N rate met the crop's requirements. Oluwasemire *et al*. (2023) reported similar trends, suggesting that environmental variability often dictates the degree of N responsiveness in maize.

At 4 WAS, the closest spacing (30 cm) produced the tallest plants, while the widest spacing (50 cm) produced the shortest plant in 2020. No significant differences were observed at 6 WAS. At 8 and 10 WAS, 50 cm and 40 cm spacing produced the tallest plants, while 30 cm spacing resulted in the shortest plants. In 2021, the widest spacing (50 cm) produced the tallest plants at all measurement periods while the closest spacing (30 cm) produced the shortest plants. At 6 WAS, 40 cm spacing had a height that was statistically similar to 30 cm spacing. In 2022, there was no significant difference observed at 4 and 10 WAS. At 6 WAS, 30 and 40 cm spacing produced the tallest plants. At 8 WAS, 40 cm spacing produced the tallest plants, while 30 cm and 50 cm spacing resulted in the shortest plant. This variation aligns with findings by Zhai *et al*. (2022) and Ngairangbam *et al*. (2024), who reported that wider spacing enhances individual plant growth by minimizing competition, though at the cost of reduced stand density and potentially lower yield per hectare. Conversely, closer spacing can limit height due to resource competition, as observed by Nwosu *et al*. (2021). The alternating significance of spacing effects across years reflects strong environment × management interactions, a phenomenon also observed by Maku *et al*. (2022) in multi-year maize trials.

In 2020, the interactions between variety and spacing and then nitrogen and spacing were significant at 10WAS. In 2021, the interaction between nitrogen and spacing was significant at 4WAS while variety and nitrogen was significant at 10WAS. The interactions for between nitrogen with spacing were significant in 2022 and the combined years while the interactions between variety with spacing and variety with nitrogen was significant only for the combined years.

Number of Leaves

Table 2 presents the result of the effects of nitrogen application at various regimes and spacing intervals on the number of leaves of maize varieties. The findings revealed that variety significantly affected the number of maize leaves across all measurement periods in 2020 and at 4 and 10 WAS in 2022. However, there was no significant effect among the four varieties in 2021. In 2020, OBASUPER 13 consistently had the highest number of leaves at 4, 6, 8 and 10 WAS. SC651 recorded the lowest number of leaves at 4 WAS, while SAMMAZ 15 and SC651 had the lowest number of leaves at 6, 8 and 10 WAS. This highlights OBASUPER 13's superior performance in leaf production compared to the open-pollinated varieties, especially at later stages. In 2022, SC651 had the lowest number of leaves at 4 WAS, while OBASUPER 13 had the lowest number of leaves at 10 WAS. The hybrid varieties (OBASUPER 13 and SC651) showed variability at different stages, with SC651 performing poorly at early stages (4 WAS), but OBASUPER 13 exhibiting consistent higher leaf counts at other stages. Over the combined years, OBASUPER 13 had the highest number of leaves at 4 and 6 WAS, outperforming both SAMMAZ 15 and SAMMAZ 51, the open-pollinated varieties, which recorded the lowest number of leaves at 4 and 6 WAS. At 8 WAS, there was no significant difference between OBASUPER 13, SC651, and SAMMAZ 15, compared to SAMMAZ 51, which had the lowest. At 10WAS, no significant difference was observed within the varieties. These findings suggest that OBASUPER 13 possesses superior vegetative vigor and leaf production potential compared to the open-pollinated varieties (OPVs).

Leaf number is an important determinant of canopy development, light interception, and photosynthetic efficiency in maize (Li *et al*., 2020). Differences among varieties may therefore reflect genotypic variation in growth rate, leaf initiation, and partitioning of assimilates to leaf development (Azeez *et al*., 2020; Badu-Apraku *et al*., 2022). The superior leaf production in OBASUPER 13 is consistent with earlier studies by Menkir *et al*. (2020)and Fakorede *et al*. (2021), who reported that hybrids often exhibit greater leaf area index and leaf number due to enhanced nutrient-use efficiency and heterosis. The absence of varietal differences in 2021 may be attributed to more uniform growing conditions or climatic moderation that reduced genotypic differentiation, as noted by Asim *et al*. (2021). Similarly, the irregular varietal response in 2022 (SC 651 with the lowest leaf number at 4 WAS and OBASUPER 13 with the lowest at 10 WAS) might reflect environmental stress or delayed nutrient uptake that affected leaf initiation. Environmental variability—especially temperature, rainfall distribution, and soil fertility has been shown to alter leaf development dynamics in maize (Oluwasemire *et al*., 2023).

Nitrogen application at different regimes (90 kg ha^{-1} N, 120 kg ha^{-1} N, and 150 kg ha^{-1} N) significantly affected the number of leaves of maize varieties across all sampling periods in 2020 and 2021. In 2020, the application of 150 kg ha^{-1} N resulted in the highest number of leaves at 4 and 10 WAS, while 90 kg ha^{-1} N recorded the highest number at 6 and 8 WAS but had the lowest leaf number at 4 and 10 WAS. Interestingly, 150 kg ha^{-1} N also recorded the lowest number of leaves at 6 and 8 WAS during the same year. In 2021, 150 kg ha^{-1} N consistently produced the highest number of leaves across all sampling periods, while 90 kg ha^{-1} N resulted in the lowest number at 4 and 6 WAS. However, in 2022, nitrogen application did not have any significant effect on the number of leaves across the sampling periods. Over the combined years, variety had a significant effect on the number of leaves across all measurement periods except at 10 WAS. OBASUPER 13 had the highest number of leaves at 4 and 6 WAS, while SAMMAZ 51 had the lowest number of leaves at the same sampling periods. At 8 WAS, there was no significant difference between OBASUPER 13, SC651, and SAMMAZ 15, while SAMMAZ 51 had the lowest number of leaves. Nitrogen plays a critical role in chlorophyll formation, cell division, and leaf expansion; thus, adequate N enhances leaf production and sustains canopy growth (Zhai *et al*., 2022). The fluctuation observed in 2020 might have been influenced by transient soil N availability, leaching, or moisture stress during critical vegetative stages. The consistency of response in 2021 reflects a more stable growing environment conducive to N uptake. Egharevba *et al*. (2019) and Usman *et al*. (2024) similarly reported that maize leaf number and leaf area increased proportionally with N rate up to 150–180 kg ha^{-1} in Nigeria's Guinea savanna.

The lack of N response in 2022 implies either a non-limiting soil N status or environmental stress (such as erratic rainfall) that constrained nutrient uptake and utilization. Oluwasemire *et al*. (2023) emphasized that under water-limited conditions, N fertilizer efficiency declines sharply, leading to non-significant differences in vegetative traits like leaf number.

The interactions were generally not significant across all the sampling periods in all years, except for Variety with Spacing at 6 WAS in 2020, Variety with Nitrogen and Nitrogen with Spacing at 8 and 10 WAS in 2021, which were significant. In 2022, Nitrogen with Spacing interaction was significant at 8WAS. Over the combined years, interactions were not significant across all sampling period.

Grain Yield per Hectare

Table 3 examines the influence of maize variety, nitrogen levels, and spacing on grain yield per hectare across the rainy seasons of 2020, 2021, 2022, and the combined years. Variety showed significant impact throughout all observation periods. In 2020, the hybrid OBASUPER 13 achieved the highest grain yield per hectare among the varieties, followed by SC651, while SAMMAZ 51 yielded the lowest. In 2021, SAMMAZ 15 led with the highest grain yield per hectare, followed by SC651 and OBASUPER 13, with SAMMAZ 51 again yielding the lowest. In 2022, OBASUPER 13 topped the yield, followed by SC651 and SAMMAZ 51, while SAMMAZ 15 recorded the lowest grain yield per hectare. Across the combined years, SC651 produced the highest grain yield per hectare, followed by SAMMAZ 15, with OBASUPER 13 and SAMMAZ 51 yielding the lowest and statistically similar results.

The study revealed that maize variety significantly influenced grain yield per hectare across all seasons and in the combined years. In 2020, the hybrid OBASUPER 13 produced the highest grain yield, followed by SC 651, while SAMMAZ 51 consistently yielded the lowest. This result underscores the superior yield potential of hybrid maize varieties compared to open-pollinated varieties (OPVs). Similar findings have been reported by Badu-Apraku *et al*. (2022) and Menkir *et al*. (2020)**,** who noted that hybrids often outperform OPVs due to heterosis, improved nutrient-use efficiency, and enhanced resilience under varied environmental conditions.

In 2021, however, the yield trend shifted, with SAMMAZ 15, an open-pollinated variety, achieving the highest grain yield per hectare, followed by SC 651 and OBASUPER 13, while SAMMAZ 51 again performed poorest. The improved performance of SAMMAZ 15 in that year could be attributed to favorable climatic conditions that supported the adaptability of OPVs, as observed by Bello *et al*. (2019). The performance variability among varieties across years supports the concept of genotype × environment interaction (G×E)**,** where seasonal fluctuations in rainfall, temperature, and soil conditions can alter yield outcomes (Asim *et al.*, 2021).

In 2022, OBASUPER 13 regained its superiority, recording the highest grain yield, followed by SC 651 and SAMMAZ 51, while SAMMAZ 15 yielded the least. The hybrid's dominance underlines its stable performance in variable field conditions a trend consistent with Usman *et al*. (2024)**,** who observed that hybrid maize exhibits, enhanced photosynthetic efficiency and nitrogen-use efficiency under higher nutrient availability.

Over the combined years, SC 651 had the highest mean grain yield, followed by SAMMAZ 15, while OBASUPER 13 and SAMMAZ 51 yielded the lowest and was statistically similar. The superior performance of SC 651 across years highlights its adaptability and yield stability, aligning with findings by Azeez *et al*. (2020) and Badu-Apraku *et al*. (2022) that certain hybrids maintain high productivity across multiple seasons due to stable physiological efficiency and tolerance to stress. Conversely, OBASUPER 13's lower mean yield despite strong single-year performances suggests that its productivity may be more environment-dependent.

Overall, the varietal differences emphasize that genetic potential and environmental compatibility jointly determine maize yield, confirming the importance of breeding for both yield potential and stability (Menkir *et al*., 2020).

Nitrogen application significantly influenced maize grain yield per hectare. In 2020, the highest grain yield per hectare was observed with 150 kg ha-1 N, followed by 120 kg ha-1 N, while 90 kg ha-1 N resulted in the lowest yield. Across the combined years, 150 kg ha-1 N also led to the highest yield, while 120 kg ha-1 N and 90 kg ha-1 N yielded statistically similar, lower results. The yield response to increased N levels observed here aligns with reports by Egharevba *et al*. (2019) and Zhai *et al*. (2022)**,** who demonstrated that maize yield rises linearly up to an optimal nitrogen threshold (typically between 120–180 kg N ha^{-1}), beyond which returns diminish due to possible nutrient imbalance or lodging. The higher yield at 150 kg N ha^{-1} suggests that this level met the crop's physiological N demand without inducing excessive vegetative growth, corroborating findings by Oluwasemire *et al*. (2023) and Usman *et al*. (2024) in similar agro-ecological zones of Nigeria.

Spacing had a notable impact as well, with the widest spacing (50 cm) resulting in the highest grain yield per hectare in 2022 and across the combined years. The 40 cm spacing followed with the second highest yield in these periods, while 30 cm spacing recorded the lowest yield.

Similar results were reported by Ngairangbam *et al*. (2024) and Nwosu *et al*. (2021)**,** who found that excessively close spacing restricts root growth and limits assimilate partitioning to the ears, thus reducing yield. Conversely, moderate to wide spacing improves ear size and grain weight despite fewer plants per unit area. However, the optimal spacing for maximum productivity depends on hybrid architecture, canopy structure, and environmental conditions (Fosu-Mensah *et al*., 2021).

Interaction effects between Variety, Nitrogen and spacing was highly significant in 2020, Variety and Nitrogen interaction was significant in 2020 and across the combined years, Variety and Spacing interaction was highly significant in 2020 while Nitrogen and Spacing interaction was significant in 2021 and 2022.

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Table 1: Effects of Nitrogen and spacing on the Plant Height of Maize Varieties in

	2020				2021				2022		
Treatment	4 WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS
Variety											
SAMMAZ 15	32.90b	60.24b	130.10b	188.20a	36.66c	65.24ab	130.25b	189.61 b	23.96	53.82bc	106.23b
SAMMAZ 51	30.05c	54.85c	119.07c	180.89b	35.48c	61.87b	119.81c	174.58c	24.58	56.50ab	105.50b
OBASUFER 13	36.88a	67.41a	140.27a	195.08a	41.50a	69.29a	141.75a	194.88a	25.91	58.77a	114.00a
SC 651	33.35b	60.48b	133.54ab	188.70a	38.77b	63.90b	133.54b	188.42b	24.01	52.43c	101.62b
SE±	0.962	1.848	3.641	3.508	0.756	2.311	2.097	2.586	1.087	1.880	3.709
Nitrogen levels (k_g ha)											
90	29.37c	54.20c	123.13c	179.04c	32.20c	58.81c	121.97c	172.12c	25.13	55.13	107.33
120	33.19b	60.85b	129.54b	186.10b	37.77b	64.05b	130.90b	187.61b	24.89	55.69	109.75
150	37.33a	67.18a	139.56a	199.50a	44.17a	72.37a	141.15a	189.00a	23.81	54.33	103.43
SE ±	1.110	2.134	4.204	4.050	0.239	2.669	2.422	2.986	1.255	2.171	4.282
Population density (P ha^{-1})											
50cm (53,333)	32.35b	59.31	132.25	189.19	40.77a	69.04a	138.60a	195.77a	23.83	53.10b	101.07b
40cm (66,666)	33.48ab	60.59	130.52	188.29	37.92b	64.63b	130.67b	188.80b	25.16	56.77a	109.53a
30cm (88,888)	34.05a	62.33	126.36b	185.03b	35.45c	61.55b	124.75c	176.05c	24.85	56.26a	95.65b
SE ±	1.110	2.134	4.204	4.050	0.239	2.669	2.422	2.986	1.255	2.171	4.282
Interaction											
V×N	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
V×S	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
N×S	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	**
V×N×S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability. V = Variety, M = Poultry manure, D = Stand density, NS = Not significant at 5% level , WAS = Week after sowing

Table 2: Effects of Nitrogen and spacing on the number of leaves of Maize Varieties in 2020, 2021 and 2022 wet seasons and combined years in Samaru

	2020				2021				2022				Combined			
Treatment	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS	4WAS	6WAS	8WAS	10WAS
Variety																
SAMMAZ 15	5.33b	8.96b	9.59b	11.70b	4.88	7.44	10.51	11.62	6.40ab	7.51	9.03	10.66ab	5.54b	7.97bc	9.71a	11.33
SAMMAZ 51	4.51d	8.44c	9.03c	11.85ab	4.88	7.59	10.48	11.55	6.48ab	7.51	9.03	10.96a	5.29c	7.85c	9.51b	11.45
OBASUFER																
13	5.70a	9.59a	10.18a	12.14a	4.81	7.77	10.37	11.62	6.59a	7.66	9.07	10.55b	5.70a	8.34a	9.87a	11.44
SC 651	5.00c	9.18b	9.66b	11.66b	4.88	7.66	10.62	11.40	6.25b	7.40	8.81	10.77ab	5.38c	8.08b	9.70a	11.28
SE±	0.157	0.177	0.174	0.179	0.112	0.187	0.161	0.174	0.141	0.151	0.173	0.155	0.079	0.100	0.098	0.098
Nitrogen levels (k_g ha)																
90	4.58c	9.77a	10.33a	11.44c	4.58c	7.05c	10.02a	10.88c	6.33	7.44	9.05	10.80	5.16c	7.63c	9.31c	11.04c
120	5.13b	8.94b	9.55b	11.83b	4.91b	7.58b	10.55b	11.58b	6.50	7.66	9.05	10.69	5.51b	8.06b	9.72b	11.37b
150	5.69a	8.41c	8.97c	12.25a	5.11a	8.22a	11.02a	12.19a	6.47	7.47	8.86	10.72	5.75a	7.63c	10.07a	11.72a
SE ±	0.181	0.205	0.201	0.207	0.129	0.22	0.186	0.201	0.163	0.175	0.200	0.179	0.092	0.115	0.113	0.113
Population density (P ha^{-1})																
50cm (53,333)	5.19	5.97ab	9.58	11.83	4.86	7.52	10.66a	11.83a	6.30	7.33b	8.69b	10.77	5.49	7.94	9.64	11.40
40cm (66,666)	5.22	8.91b	9.69	11.86	4.91	7.80	10.47ab	11.61a	6.52	7.52ab	9.02a	10.75	8.08	8.13	9.73	11.27
30cm (88,888)	5.00	9.25a	9.58	11.83	4.83	7.52	10.36b	11.22b	6.41	7.72a	9.25a	10.69	8.16	7.98	9.73	11.45
SE ±	0.181	0.205	0.201	0.207	0.129	0.22	0.186	0.201	0.163	0.175	0.200	0.179	0.092	0.115	0.113	0.113
Interaction																
V×N		NS	NS	NS		NS	NS	NS		*	NS	NS		NS	NS	NS
V×S		NS	*	NS		NS	NS	NS		NS	NS	NS		NS	NS	NS
N×S		NS	NS	NS		NS	NS	NS		*	*	NS		NS	*	NS
V×N×S		NS	NS	NS		NS	NS	NS		NS	NS	NS		NS	NS	NS

Ieans followed by the same letter within a treatment group are not significantly different at 0.05 level of probability. V = /ariety, M = Poultry manure, D = Stand density,
NS = Not significant at 5% level, WAS = Week after sowing

Table 3: Effects of Nitrogen and Population on grain yield per hectare of Maize Varieties during the 2020, 2021 and 2022 rainy seasons and the combined years in Samaru

Treatment	2020	2021	2022	Combined
Variety				
SAMMAZ 15	2559.67c	2906.85b	2129.01b	2528.8b
SAMMAZ 51	2134.87d	2832.64b	2125.87b	2358.5b
OBASUFER 13	3211.78a	4194.40a	2950.07a	3448.1a
SC 651	2923.45b	4378.69a	2991.35a	3429.2a
SE±	36.034	13.170	25.470	24.890
Nitrogen levels (k_g ha)				
90	2170.98c	3059.96c	2283.97b	2616.78b
120	2673.57b	3633.22b	2584.79a	2963.86b
150	3277.77a	4041.26a	2778.46a	3365.83a
SE ±	47.410	12.660	59.520	38.764
Population density (P ha $^{-1}$)				
50cm (53,333)	2373.48c	3302.16b	2730.11a	3450.64a
40cm (66,666)	2704.60b	3452.10b	2632.84a	2531.84ab
30cm (88,888)	3044.24a	3980.17a	2284.27b	2364.46b
SE ±	47.410	12.660	59.520	104.466
Interaction				
V×N	**	*	*	*
V×S	NS	NS	NS	NS
N×S	**	*	NS	**
V×N×S	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability. V = Variety, M = Poultry manure, D = Stand density, NS = Not significant at 5% level.