EFFECTS OF NITROGEN FERTILIZER RATES AND POPULATION ON THE NITROGEN CONTENT OF FLAG LEAF OF MAIZE (*Zea mays* L) VARIETIES IN SAMARU

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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. The study indicated that maize variety exerted a stronger influence on nitrogen flag leaf content than nitrogen rate or plant spacing across the three years of study. SAMMAZ 15 and SAMMAZ 51 consistently recorded superior nitrogen flag leaf content in most seasons and in the combined analysis, indicating their better efficiency in nitrogen uptake. Nitrogen application levels did not significantly enhance nitrogen flag leaf content, suggesting that moderate fertilization may suffice under the prevailing conditions. Similarly, plant spacing had inconsistent effects across years, implying limited influence on nitrogen accumulation in maize flag leaves. The significant interactions between variety, nitrogen, and spacing in certain years suggest that varietal adaptation and environmental factors jointly affect nitrogen utilization efficiency. Overall, open-pollinated varieties demonstrated stable nitrogen flag leaf content across environments, underscoring their potential for sustainable maize production under variable nitrogen regimes.

Keywords : Nitrogen, Population, Flag leaf, Varieties, Samaru and Adaptation

Introduction

Maize (*Zea mays* L.) is one of the world's most important cereal crops, serving as a staple food, industrial raw material, and livestock feed. Globally, it ranks alongside wheat and rice as a major contributor to caloric intake for millions of people (Shiferaw *et al.*, 2011). Its adaptability to diverse environments ranging from tropical to temperate regions has contributed to its widespread cultivation. Maize is cultivated on more than 190 million hectares worldwide and contributes significantly to food security, income generation, and agro-industrial development (FAO, 2020). In sub-Saharan Africa, maize provides over 30% of caloric intake in many countries and is deeply integrated into farming systems (IITA, 2019).

In Africa, maize is predominantly produced under rain-fed conditions, often by smallholder farmers using low external inputs. Consequently, yields remain below global averages due to constraints such as low soil fertility, suboptimal fertilizer use, pest pressure, and climate variability (Badu-Apraku and Fakorede, 2017). Nigeria is the largest maize producer in West Africa, where the crop plays a vital socio-economic role. Improvements in seed varieties, fertilizer use, and agronomic practices have contributed to rising production in recent decades (IITA, 2019). Despite these gains, productivity is still limited by nutrient deficiencies particularly nitrogen as well as drought, poor soil management, and the use of unimproved varieties.

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 and Njoroge, 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 a fundamental agronomic practice that plays a crucial role in determining crop productivity, plant health, and overall field performance. It refers to the deliberate arrangement of plants within a field, specifically the distance between individual plants within a row (intra-row spacing) and the distance between rows (inter-row spacing). The primary purpose of plant spacing is to regulate plant population, ensuring that each plant has sufficient access to essential growth resources such as light, nutrients, water, and physical space (FAO, 2015). Proper spacing allows plants to grow optimally without excessive competition, while improper spacing either too narrow or too wide—can negatively influence crop morphology, physiology, and yield outcomes.

The importance of plant spacing arises from its strong influence on crop canopy structure, root development, light interception, and microclimatic conditions within the crop stand. For many crops, especially cereals like maize, plant spacing determines the balance between individual plant performance and total crop productivity (Sangoi, 2001). When plants are spaced too closely, competition for resources intensifies, leading to elongated stems, reduced leaf area, smaller reproductive structures, and greater susceptibility to diseases due to humid canopies (Tollenaar and Lee, 2006). On the other hand, overly wide spacing results in underutilization of growth resources, reduced ground cover, and increased weed pressure (Nafziger, 1994).

Plant spacing also affects the architecture and biomass distribution of crop plants. In dense plantings, plants typically exhibit shade-avoidance traits such as taller stems, narrow leaves, and reduced root branching due to limited light penetration and intense inter-plant competition (Maddonni and Otegui, 2004). Conversely, with optimal spacing, crops achieve a more balanced architecture, improved photosynthetic efficiency, and better nutrient uptake. Furthermore, spacing must be tailored to specific factors such as crop species, variety or hybrid, soil fertility, climatic conditions, and management practices, as different crops and cultivars vary in their tolerance to population density (Farnham, 2001).

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 50 DS 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. The fresh flag leaves were harvested per bed, dried and taken to the lab for tissue analysis (Agronomy Departmental Laboratory). The Stoichiometric conversion formula (nitrogen content = nitrite content x molar mass of nitrate content/molar mass of nitrite) and (nitrite content = nitrate content x 0.05) were used to estimate the nitrogen content. All data collected were 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

Nitrogen Content of Maize Flag Leaf

Table 1 examines the influence of maize variety, nitrogen levels, and spacing on nitrogen flag leaf content across the rainy seasons of 2020, 2021, 2022, and the combined years. In 2020, SAMMAZ 15 recorded the highest nitrogen flag leaf content while SAMMAZ 51 and the other two hybrids recorded equal but statistically lower nitrogen flag leaf content. For the year 2021, no significant difference was detected. SAMMAZ 51 was observed to have significantly higher nitrogen flag leaf content for the year 2022 and the combined years. OBASUPER 13 showed significantly lower nitrogen flag leaf content although statistically comparable to SAMMAZ 15 and SC651 in 2022. Across the combined years, the two open pollinated varieties gave statistically higher nitrogen flag leaf content. While OBASUPER 13 gave statistically lower nitrogen flag leaf content, SC651 was observed to have values that were statistically comparable to all the other varieties. Increase in nitrogen application did not significantly increase nitrogen flag leaf content for all three years and the combined.

The highest spacing in 2020 gave the lowest nitrogen flag leaf while the spacing of 40 and 30 cm produced the highest but statistically equal nitrogen flag leaf content. No significant difference was observed for subsequent years and the combined.

Significant interaction was observed for variety and nitrogen and then variety and spacing in 2020 while nitrogen and spacing was significant for 2021 and the combined years.

DISCUSSION

These varietal differences may be attributed to inherent genetic variations in nitrogen uptake and partitioning efficiency among maize genotypes (Abdulai *et al*., 2021; Jaliya *et al*., 2012). Differences in nitrogen assimilation and leaf N concentration are well-documented among maize cultivars, reflecting variation in root architecture, nitrogen use efficiency, and photosynthetic capacity (Muoni *et al*., 2020; Amanullah and Almas, 2022). The observation that SAMMAZ 15 and SAMMAZ 51 alternated in their superiority across seasons suggests genotype × environment interaction effects, as environmental conditions such as rainfall and temperature strongly influence nitrogen uptake and assimilation (Olaiya *et al*., 2023). The higher nitrogen flag leaf content observed in open-pollinated varieties over the combined years supports reports that some open-pollinated cultivars maintain more stable nutrient accumulation under fluctuating environmental conditions compared to hybrids (Ajala *et al*., 2019).

Increasing nitrogen application did not significantly enhance flag leaf nitrogen content in any of the years studied. Similar findings were reported by Gungula *et al*. (2020), who found that beyond moderate N application rates, further increases did not significantly raise leaf N concentration, possibly due to luxury consumption and nutrient dilution effects. This result implies that the baseline nitrogen level used may have been sufficient to meet plant needs, with additional N inputs contributing little to leaf nitrogen concentration. Nitrogen saturation, coupled with environmental factors that limit N uptake efficiency such as rainfall distribution and soil microbial activity could also explain the lack of response (Amanullah and Almas, 2022).

Spacing significantly affected flag leaf nitrogen content in 2020 but not in subsequent years. The widest spacing gave the lowest nitrogen content, whereas the 40 cm and 30 cm spacings resulted in the highest but statistically similar values. This agrees with reports by Rashid *et al*. (2021), who found that closer spacing increases canopy density and enhances nitrogen assimilation due to improved light interception and leaf area index. However, inconsistent spacing effects across years suggest that environmental variability moderated the influence of plant population on leaf nitrogen dynamics, as also observed by Worku *et al*. (2020).

Significant interactions were observed between variety × nitrogen and variety × spacing in 2020, while nitrogen × spacing interactions were significant in 2021 and in the combined data. Such interactions indicate that varietal performance in terms of leaf nitrogen accumulation depends on both nutrient supply and plant density (Muoni *et al*., 2020). Similar interactive effects have been reported by Olaiya *et al*. (2023), who demonstrated that genotype, nitrogen level, and spacing jointly influence nutrient uptake efficiency and yield attributes in tropical maize. These findings underscore the importance of integrated management strategies that consider genotype-specific responses to agronomic factors.

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Table 1: Effects of Nitrogen FertilizerRate and Populationon the Nitrogen Contentof Flag Leaf of Maize Varieties in Samaruduring2020, 2021, 2022 rainyseasons and the combinedyears

Treatment	2020	2021	2022	Combined
Variety (V)				
SAMMAZ 15	2.17a	1.17	1.53ab	1.62a
SAMMAZ 51	1.95b	1.23	1.68a	1.62a
OBASUFER 13	1.90b	1.17	1.27b	1.45b
SC 651	1.90b	1.20	1.48ab	1.52ab
SE±	0.077	0.136	0.080	0.076
Nitrogen levels k_g ha (N)				
90	1.97	1.27	1.43	1.56
120	1.96	1.12	1.55	1.55
150	2.00	1.18	1.49	1.56
SE ±	0.089	0.157	0.144	0.088
Population density ha (P)				
50cm (53,333)	1.77b	1.27	1.53	1.56
40cm (66,666)	2.12a	1.09	1.50	1.57
30cm (88,888)	2.05a	1.21	1.43	1.52
SE ±	0.089	0.157	0.144	0.088
Interaction				
V×N	*	NS	NS	NS
V×S	*	NS	NS	NS
N×S	NS	*	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.