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PERFORMANCE EVALUATION OF PROVITAMIN A MAIZE (*ZEA MAYS* L.) HYBRIDS FOR YIELD AND OTHER AGRONOMIC TRAITS IN SOUTHWESTERN NIGERIA

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Abstract: Maize is a vital dietary staple in Nigeria, offering crucial nutrients such as carbohydrates, proteins, fats, and micronutrients. However, conventional maize lacks enough of the nutritional precursor for vitamins, necessitating the cultivation of stable, high-yielding provitamin A maize hybrids. This is crucial for combating malnutrition, particularly in rural populations vulnerable to “hidden hunger”. This study aimed to assess the agronomic performance and yield of newly developed maize hybrids over a two-year period in Ikorodu and Osogbo, Nigeria. Twenty-two improved maize hybrids, two commercial hybrids, and a reference check were evaluated. Hybrid grain yields ranged from 3.33 t/ha (Ife-hybrid 3) to 5.69 t/ha (LY1409-61) over the two years, averaging 4.03 t/ha. All hybrids, except Ife-hybrid 3 (3.33 t/ha), outperformed the reference check (3.92 t/ha), with four hybrids achieving yields exceeding 5 t/ha across the two years. The distribution of precipitation in 2019, with higher and well-distributed rainfall, significantly impacted grain yields compared to 2020. This effect was particularly notable during the flowering and grain filling stages from July to October. LY1409-61, AS1802-15, and LY1409-21 consistently performed well across varying weather conditions, indicating their adaptability to diverse agro-ecologies. Adopting these maize hybrids has the potential to enhance maize output and alleviate malnutrition in rural southwestern Nigeria. The study emphasises the vital role of promoting nutrient-enriched maize varieties to combat nutritional deficiencies, enhance food security, and benefit communities dependent on maize as a staple, which could notably contribute to sustainable agriculture and improved nutritional outcomes in the region.

Key words: adaptation, agronomic traits, grain yield, hidden hunger, malnutrition, food security.

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Introduction

Maize is a significant crop in sub-Saharan Africa, making up 40% of cereal production. It is mainly used as a food source, providing around 30% of the calorie intake in the region (Ekpa et al., 2019). Maize is a staple in Africa and Latin America, with varying daily consumption amounts. Additionally, maize is known for its health benefits, as it contains nutraceuticals that can enhance health and prevent diseases. These include phenolics, carotenoids, anthocyanins, phlobaphenes, dietary fibre, and lipids (Ekpa et al., 2019). Since maize constitutes a significant portion of the diet in tropical Africa and is a major feed ingredient in the livestock industry, the development of nutritionally balanced and vitamin-rich genotypes has become critical for its use by the African populace. Therefore, the development of high-yielding and well-adapted cultivars is the major goal of most maize breeding projects.

The interplay of genetic potential and environment determines grain yield. The variability of genetic potential among cultivars is a major factor in yield variation. Plant breeding uses multi-location trials to estimate and predict yield based on limited experimental data, yield stability, and genotype response patterns in different conditions. These provide trustworthy guidelines for selecting the optimum genotypes for planting at new places in future years (Crossa, 1990).

The extent of genetic variability for different traits among various maize hybrids is a key to crop improvement. The ability to develop high-yielding and stable cultivars is an ultimate goal of most breeding programmes. An ideal maize hybrid should have a high mean yield combined with a low degree of fluctuation under different conditions (Annicchiarico, 2002; Yousaf et al., 2021). However, drought stress influences the reduction of plant growth, development, and production (Mohammadai et al., 2012; Ansari et al., 2019). Therefore, understanding the environmental and agronomic responses of maize hybrids is fundamental to improving the efficiency of maize production. As a result, newly introduced hybrids must often be studied for several years before being approved for a specific site (Beiragi et al., 2011). Before making suggestions, the specificities of the hybrids and the growing conditions of the locations must be examined (Mitrovic et al., 2012).

Furthermore, the climatic conditions in these agro-ecologies fluctuate significantly across seasons and regions, which is a cause for concern. Inadequate crop management methods, diminishing soil fertility, the occurrence of unpredictable diseases and insect pests, and the escalation of climate variations are all issues of concern for maize production in Nigeria. The sensitivity of agro-ecosystems in which small-scale farmers in SSA grow maize to weather fluctuations is becoming increasingly worrisome as optimal production scenarios linked to uncertain climate change may become more widespread (Gaudin et al., 2015). As a result, the current study was designed to assess the adaptability of maize hybrids in southwestern Nigeria, with the goal of examining the adaptability and performance of new hybrid maize varieties as well as identifying high-yielding, disease resistant (tolerant) hybrid maize varieties.

Material and Methods

The experimental material for the present study comprises twenty-two single- and triple-crossed provitamin A hybrids, two commercial checks (Ife hybrid 3 and Ife hybrid 4), and one reference check (Table 1). The hybrids were evaluated along with checks in a randomized complete block design (RCBD) with three replications, having a plot length of 5 m and inter and intra row spacing of 75cm and 50cm, respectively, during the 2019 and 2020 growing seasons across two locations in different agro-ecological zones of Ikorodu (6.6194^{o}N, 3.5105^{o}E) in Ogun and Osogbo (7.7827^{o}N, 4.5418^{o}E) in Osun State.

Table 1. The list of genetic materials used in this study.

Entry	Hybrid	Origin
1	A1702-28	IITA
2	A1706-2	IITA
3	A1736-12	IITA
4	A1736-13	IITA
5	A1736-6	IITA
6	A1802-4	IITA
7	A1802-14	IITA
8	A1802-15	IITA
9	A1802-66	IITA
10	A1802-67	IITA
11	Ife Hybrid-3	IITA
12	Ife Hybrid-4	IITA
13	LY1001-18	IITA
14	LY1001-23	IITA
15	LY1409-14	IITA
16	LY1409-21	IITA
17	LY1409-61	IITA
18	LY1501-1	IITA
19	LY1501-5	IITA
20	LY1501-6	IITA
21	LY1501-7	IITA
22	LY1501-8	IITA
23	LY1501-9	IITA
24	Reference check	IITA
25	M1124-31	IITA

Three seeds were planted per hill and later thinned to two plants per hill to obtain a final plant density of about 53,333 plants/ha. Pre- and post-emergence herbicides were used to control weeds, followed by the application of a combination of the active ingredients, paraquat and atrazine, respectively, immediately after planting at a dosage rate of 2.5kg a.i./ha of atrazine and 0.75kg a.i./ha of paraquat. Supplementary hand weeding was carried out as needed to effectively control weeds during the growing period. NPK 20-10-10 fertiliser was applied at a rate of 80 kg N, 60 kg P_2O_5, and 60 kg K_2O ha^{-1} as a basal fertilizer at three (3) weeks after planting and later top-dressed with additional N (urea 46-0-0) at six (6) weeks after planting. The field perimeter surroundings were kept clean to minimise insect and rodent invasion. Other cultural and agronomic management practices were carried out according to the recommended package by Kamara et al. (2020).

Data collection

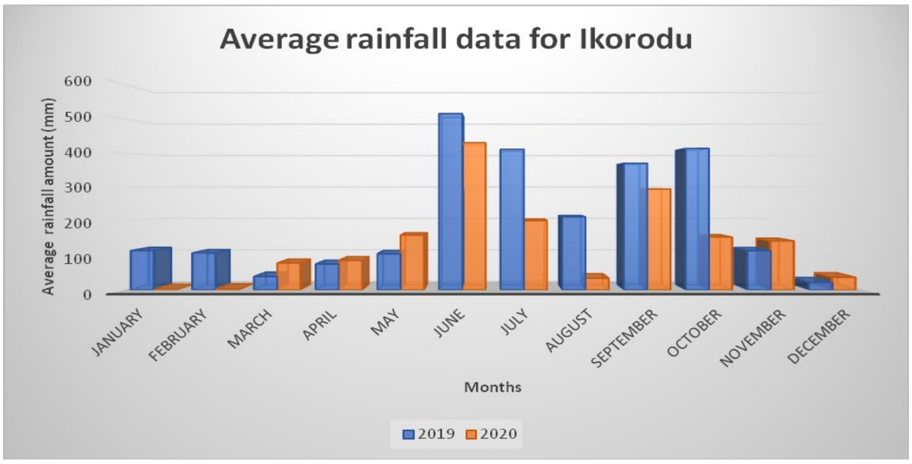
Data for grain yield and other agronomic traits were collected from the two inner rows. These traits included days to 50% anthesis, days to 50% silking, plant and ear heights (cm), root lodging (number of plants leaning more than 30^o from vertical), stalk lodging (stalks broken at or below the highest ear node), ear aspect, number of plants harvested, number of ears harvested and disease ratings using a scale of 1–5 (where 1=excellent, 2=very good, 3=good, 4=fair, and 5=very poor). All other data and ratings in this study were according to Badu-Apraku et al. (2012).

Statistical analysis

Data were analysed separately for each location and then combined across locations for grain yield (t/ha) and other measured traits using SAS (version 9.0) to determine the genotype × environment (G × E) interaction. In the combined analyses of variance, replications, year, location, and the year by location interaction were considered as random factors, while varieties were considered as fixed factors. The combined analysis of variance (ANOVA) was performed considering year-location combination as the environment to determine the effect of the environment (consisting of year [Y], location [L], and Y × L interaction), genotype, and all possible interactions among these sources of variation. Means were compared using New Duncan's Multiple Range Tests at the 0.05 and 0.01 probability levels when the F values were significant.

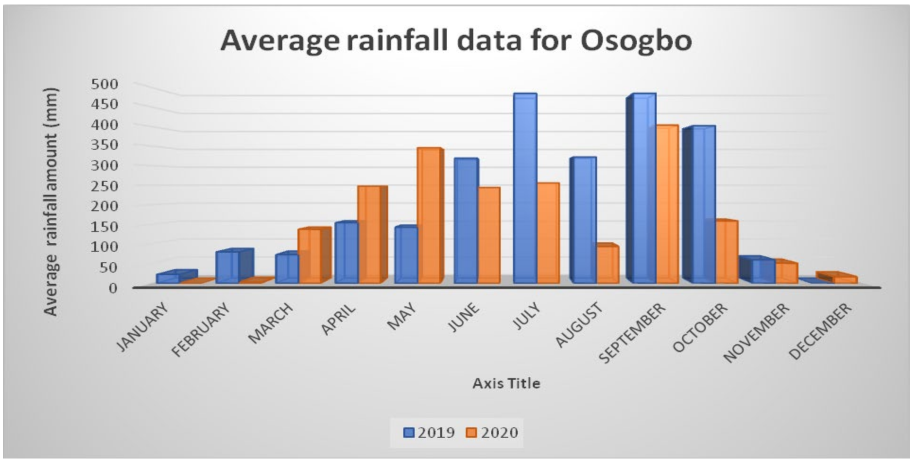
Results and Discussion

The amount and timing of rainfall during the flowering and grain-filling stages of the maize crop life cycle greatly affect plant growth and maturation. In this study, rainfall distribution and temperature were found to be the most influential factors on crop performance. The rainfall patterns in 2020 were not as favourable as in 2019, resulting in differences in agronomic and yield variables (Figures 1 and 2). Specifically, there was less rainfall during the critical flowering period in August 2020 compared to both 2019 and 2020 (Figures 1 and 2).



Source: www.worldweatheronline.com.

Figure 1. The monthly rainfall distribution pattern for Ikorodu in 2019 and 2020.



Source: www.worldweatheronline.com.

Figure 2. The monthly rainfall distribution pattern for Osogbo in 2019 and 2020.

The analysis of variance (ANOVA) showed that location and year had a significant effect on grain yield and other agronomic traits, except for ear aspect (Table 2). The interaction between genotype and year was significant for grain yield and ear height, while the interaction between genotype and location was significant for all traits except grain yield and ear height. The interaction between genotype, location, and year was significant for days to tasselling and silking, plant height, plant aspect, and ear height (Table 2). Genotype variations were highly significant for most traits, likely due to the different origins of the genotypes used. However, there was no significant interaction between genotype and environment for grain yield, ear height, and disease ratings, suggesting that these traits were consistent across the two research locations (Table 2). The findings highlight the importance of conducting multi-location trials to select genotypes with high yield and adaptability to different agro-ecological zones before releasing them as varieties (Badu-Apraku et al., 2010; Goa and Mohammed, 2013; Uba and Nwobi, 2022).

Table 2. Mean square of the agronomic characters of the provitamin A maize hybrids evaluated in 2019 and 2020 cropping seasons.

Source of var.	Df	Days to 50% tasselling	Days to 50% silking	Plant height	Ear height
Rep	2	10.44	1.84	157.43	350.94
Location	1	1434.45**	2766.40**	36278.00**	2151.60**
Genotype	24	17.83**	20.95**	380.67**	73.75
Year	1	1541.33**	552.16**	30947.36**	29333.74**
Genotype x loc.	24	19.41**	25.56**	173.92**	48.80
Loc. x year	1	2465.33**	3724.16**	660.08**	18825**
Gen. x year	24	6.47**	11.73**	380.82**	95.04*
Gen. x loc. x year	24	13.43**	17.56**	181.32**	48.24
Error	198	1.41	0.78	43.28	55.68
CV (%)		2.05	1.43	4.30	11.57
Means		57.89	62.04	153.07	64.48
Source of var.	Df	Plant asp.	Ear asp.	Husk cover	Grain yield (t/ha)
Rep	2	0.37	0.01	0.04	0.33
Location	1	42.56**	0.33	0.96**	85.47**
Genotype	24	0.52**	0.65**	0.31**	2.68*
Year	1	7.36**	12.81**	1.20**	131.14**
Genotype x loc.	24	0.42**	0.50**	0.17*	1.42
Loc. x year	1	19.76**	1.92**	0.56*	1.43
Gen. x year	24	0.46**	1.15**	0.13	2.78*
Gen. x loc. x year	24	0.37**	0.49**	0.12	1.31
Error	198	0.16	0.21	0.10	1.54
CV (%)		25.74	21.51	26.95	27.20
Means		1.54	2.11	1.16	4.56

*, ** significantly different at the 0.05 and 0.01 probability levels, respectively.

Table 3 displays the results of the ANOVA for disease scores across different locations and years. The location had a significant effect on the measured traits, except for root lodging. The interaction between location and year was significant for ear rot, curvularia, and rust, while root lodging was significant at a slightly lower significance level ($p<0.05$). The genotype did not have a significant effect on any of the measured traits. The year had a significant effect on ear rot, rust, and curvularia, and root lodging was also significant at a slightly lower significance level ($p<0.05$). Stalk lodging, streak, and blight did not have a significant effect on the different varieties. The genotype and its interactions with location and year were not significant for any of the disease ratings (Table 3).

Table 3. Mean square of disease/pest scores in provitamin A enriched maize hybrids.

Source of var.	Df	Root lodging	Stalk lodging	Ear rot	Streak	Rust	Blight	Curvularia
Rep	2	0.04	0.06	0.56	1.02	0.16	0.57	0.42
Location	1	0.56	0.65**	46.41**	17.76**	5.60**	9.01**	22.96**
Genotype	24	0.04	0.04	0.13	0.09	0.07	0.07	0.07
Year	1	0.16*	0.05	4.32**	0.16	5.60**	0.05	8.67**
Genotype x loc.	24	0.04	0.04	0.15	0.09	0.07	0.07	0.07
Loc. x year	1	0.16*	0.05	1.08**	0.16	5.60**	0.05	8.67**
Gen. x year	24	0.02	0.03	0.15	0.16	0.07	0.12	0.03
Gen. x loc. x year	24	0.02	0.03	0.12	0.16	0.07	0.12	0.03
Error	198	0.04	0.05	0.15	0.15	0.06	0.13	0.07
CV (%)		19.95	20.60	26.88	30.93	21.36	30.60	20.69
Means		1.04	1.05	1.45	1.24	1.14	1.17	1.28

*, ** significantly different at the 0.05 and 0.01 probability levels, respectively.

Table 4 displays the effects of genotype and location on days to tasselling and silking, as well as plant height. At Ikorodu, the days to tasselling ranged from 47 to 52 days in 2019 and 60 to 62 days in 2020, with an average of 55.71 days. At Osogbo, the range was 56 to 64 days in 2019 and 52 to 64 days in 2020, with an average of 60.08 days. The days to silking varied from 51 to 56 days in 2019 and 63 to 65 days in 2020, with an average of 59.00 days at Ikorodu and 61 to 73 days in 2019 and 57 to 66 days in 2020 at Osogbo. Plant heights ranged from 162.33 to 201.33cm in Ikorodu, with an average of 164.07cm. At Osogbo, the range was 126.67cm to 175.00cm in 2019 and 110.00cm to 150.00cm in 2020, with an average of 142.07cm.

Table 4. Interactive effects of location on the yellow hybrid variety for plant height and days to 50% tasselling and silking across two (2) years.

Varieties	Days to 50% tasselling				Days to 50% silking				Plant height (cm)			
	Ikorodu		Osogbo		Ikorodu		Osogbo		Ikorodu		Osogbo	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
A1702-28	50	62	63	58	54	65	71	62	178.50	153.33	150.00	130.00
A1706-2	51	61	61	61	54	64	65	64	183.83	156.67	156.00	110.00
A1736-12	52	60	64	58	55	63	72	61	178.33	156.33	170.00	135.00
A1736-13	51	61	53	57	54	64	63	60	162.33	147.67	140.00	135.00
A1736-6	50	61	62	58	54	64	68	61	168.50	149.33	140.00	140.00
A1802-4	51	61	59	58	55	64	64	61	186.67	152.00	150.00	140.00
A1802-14	50	61	65	64	55	63	73	67	173.33	149.33	126.67	110.00
A1802-15	51	60	63	60	53	64	68	63	172.00	149.00	152.00	130.00
A1802-66	51	61	58	59	55	64	63	62	177.50	153.33	160.00	125.00
A1802-67	51	60	56	58	53	63	63	63	168.17	151.00	165.00	120.00
Ife Hybrid-3	51	61	56	52	55	64	62	57	162.50	153.33	130.00	125.00
Ife Hybrid-4	51	61	62	58	55	63	71	62	201.33	151.67	161.33	140.00
LY1001-18	49	61	64	59	51	64	70	62	166.50	154.67	155.00	140.00
LY1001-23	50	61	58	59	54	64	62	62	180.00	150.00	153.00	130.00
LY1409-14	52	61	63	64	55	63	71	67	183.33	154.00	151.67	135.00
LY1409-21	49	61	61	58	55	64	70	61	172.00	156.67	135.00	150.00
LY1409-61	51	61	63	63	54	63	73	66	174.00	153.00	145.00	150.00
LY1501-1	51	62	64	59	55	65	72	63	174.67	154.33	155.00	120.00
LY1501-5	50	61	61	60	54	65	65	63	176.33	148.67	160.00	140.00
LY1501-6	52	62	63	60	56	65	68	63	183.67	155.67	160.00	125.00
LY1501-7	51	61	57	60	54	64	62	64	187.67	152.33	175.00	140.00
LY1501-8	52	60	57	61	54	63	62	65	174.00	147.00	155.00	135.00
LY1501-9	51	60	57	63	56	63	61	66	175.33	155.00	158.00	145.00
Reference check	49	61	63	62	54	64	73	65	168.17	150.00	131.67	135.00
M1124-31	47	61	64	58	51	63	72	63	164.00	156.33	133.33	150.00
Mean	55.71		60.08		59.00		65.07		164.07		142.07	
S.E (0.05)	0.21		0.24		0.41		0.33		1.26		1.20	

Table 5 illustrates the impact of location on plant aspect, ear aspect, and grain production for the yellow hybrid variety. Plant aspect varied from 1.00 to 2.67 and 1.67 to 2.67 in 2019 and 2020 at Ikorodu, respectively, whereas it ranged from 1.00 to 2.00 in both 2019 and 2020 at Osogbo. At Ikorodu, the ear aspect ranged from 1.00 to 3.00 in 2019 and 2020, with an average mean of 2.14 in both years. In the 2019 and 2020 cropping seasons, however, it varied from 1.00 to 2.00 and 2.00 to 3.00 in Osogbo. The grain yields in Ikorodu and Osogbo varied between 3.23 and 7.55 t/ha and 2.33 and 6.41 t/ha, respectively, in 2019. In the 2020 season, the grain yields ranged from 3.48 to 5.60 t/ha in Ikorodu and 2.75 to 3.87 t/ha in Osogbo. The average grain yield for the 2019 season was 5.09 t/ha, while for the 2020 season it was 4.03 t/ha. The hybrid LY1409-61 performed well in both seasons at Ikorodu, with yields of 7.55 t/ha in 2019 and 5.60 t/ha in 2020. AS1802-15 was the highest yielding variety in Osogbo in 2019 with a yield of 6.41 t/ha, while LY1409-21 was the top yielding variety in 2020 with a yield of 3.87 t/ha.

Table 5. Interactive effects of location on the yellow hybrid variety for plant aspect, ear aspect and grain yield across two (2) years.

Varieties	Plant aspect				Ear aspect				Grain yield (t/ha)			
	Ikorodu		Osogbo		Ikorodu		Osogbo		Ikorodu		Osogbo	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
A1702-28	1.00	1.67	1.00	1.00	1.33	2.67	2.00	2.33	6.71	3.49	4.24	3.39
A1706-2	1.67	2.33	1.00	2.00	2.00	2.33	2.00	2.00	4.76	4.41	5.37	3.25
A1736-12	1.67	2.33	2.00	1.00	1.67	2.33	3.00	2.00	5.40	4.20	4.63	3.06
A1736-13	1.67	2.33	1.00	1.00	1.67	2.33	2.00	2.00	5.35	4.61	3.21	3.35
A1736-6	2.67	2.67	1.33	1.00	3.00	2.67	2.33	2.33	4.23	4.03	4.12	3.75
A1802-4	1.00	2.33	1.00	1.00	1.33	2.33	1.00	2.33	6.17	3.80	4.07	3.17
A1802-14	1.00	2.33	2.00	1.67	1.33	2.00	2.33	2.00	6.61	5.43	4.27	2.89
A1802-15	1.00	2.00	1.00	1.00	1.67	2.00	2.00	2.00	5.71	5.47	6.41	3.40
A1802-66	1.67	2.00	1.00	1.00	2.67	2.00	2.00	2.00	5.72	5.52	3.19	3.01
A1802-67	1.67	2.33	1.00	1.00	2.67	2.33	1.00	2.00	5.14	3.82	6.36	2.75
Ife Hybrid-3	2.67	2.00	1.00	1.00	3.00	2.33	2.00	2.33	3.22	4.75	2.33	3.02
Ife Hybrid-4	1.33	2.33	1.00	1.00	1.67	2.33	2.00	2.33	5.78	4.47	5.34	2.97
LY1001-18	2.33	2.00	2.00	1.00	2.00	2.33	3.00	2.33	4.79	4.29	4.23	3.42
LY1001-23	1.00	2.67	1.00	1.00	1.00	3.00	1.00	2.67	7.06	3.71	6.40	3.18
LY1409-14	1.00	2.33	1.00	1.00	1.33	2.33	2.00	2.67	5.92	4.25	5.10	3.63
LY1409-21	1.33	2.33	2.00	1.00	1.67	2.33	2.00	2.00	6.06	4.33	4.72	3.87
LY1409-61	1.00	2.00	1.00	1.00	1.00	2.33	2.00	2.00	7.55	5.60	5.75	3.86
LY1501-1	1.33	2.33	2.00	1.00	2.00	2.33	2.00	2.00	5.82	5.00	4.21	3.3
LY1501-5	1.00	2.00	1.00	1.00	1.33	2.00	2.33	2.00	6.46	4.83	4.05	3.42
LY1501-6	1.33	2.33	1.00	1.00	2.00	2.33	2.00	2.33	6.27	3.48	4.28	3.44
LY1501-7	1.33	2.33	1.00	1.00	1.67	2.67	1.00	2.33	6.15	5.29	4.84	3.14
LY1501-8	1.67	2.67	1.00	1.00	1.67	2.67	1.00	3.00	5.40	4.00	5.33	3.69
LY1501-9	1.33	2.33	1.00	1.00	3.33	2.67	1.00	2.00	6.19	4.42	6.04	3.12
Reference check	2.67	2.67	1.33	1.00	1.33	2.67	3.00	2.00	3.23	5.01	4.28	3.16
M1124-31	1.33	2.67	2.00	1.00	1.67	2.67	2.67	2.00	6.43	4.30	6.20	3.13
Mean	1.92		1.67		2.14		2.07		5.09		4.03	
S.E (0.05)	0.06		0.03		0.06		0.05		0.12		0.12	

The weather conditions, specifically rainfall and temperature, have a notable influence on the yield of maize crops during important stages of their growth (Randjelovic et al., 2011; Petrović et al., 2023). In 2019, drought and high temperatures during the flowering stage resulted in less favourable rainfall, leading to a decrease in grain yield per hectare compared to 2020. Previous studies have shown that water deficiency stress at different stages of growth can significantly reduce grain yield (Naderi et al., 2009). Environmental factors also play a role in the genetic components of maize, as the location where the crops are grown can impact their yield. Other studies have shown that the interaction between genotype and location is influenced by environmental factors such as temperature and humidity (Butron et al., 2002; Adu et al., 2013).

The maize genotypes evaluated in this study had heterogeneous genetic compositions, which led to different results for the parameters examined. Plant height, days to tasselling, days to silking, and grain yield are all affected by varietal variances. The variance in the characteristics evaluated when compared to other locations, on the other hand, is due to environmental factors. Tahir et al. (2008) and Yang et al. (2021) have found that plant height is a genetically and environmentally determined factor; however, crop cultivar selection regulates the impact of the environment. Revilla et al. (2000) also discovered a difference in plant height across maize types owing to genotype by environment interactions.

The Duncan multiple range test was used in Table 6 to compare the means of the agronomic and yield-related characteristics and also to determine the variations between the genotypes for the characteristics examined. AS1804-14 exhibited the longest duration for both tasselling and silking, with values of 60.00 and 64.25, respectively. LY1409-14 followed closely behind with a tasselling duration of 59.29, while LY1409-61, LY1409-14, and reference check had a silking duration of 64.00. On the other hand, Ife Hybrid-3 (commercial control) had the shortest duration for both tasselling and silking, with values of 55.00 and 59.33, respectively. LY1409-61 was the highest-yielding variety with a grain yield of 5.69 t/ha. It was followed by AS1804-15 with an average yield of 5.35 metric t/ha across all environments in Table 6.

Table 7 shows that the varieties tested were generally resistant to streak, blight, rust, and curvularia leaf spot, with disease scores ranging from 1.17 to 1.33 for streak, 1.08 to 1.33 for blight, 1.08 to 1.25 for rust, and 1.17 to 1.42 for curvularia leaf spot. In contrast, M1124-31 and AS1802-4 received a higher rating of 1.33 (blight) and 1.42 (curvularia). There was no significant difference between the varieties in terms of streak resistance, blight and curvularia disease. Root and stalk lodging ranged from 1.00 to 1.17 among the genotypes, indicating that these factors played a role.

In plant breeding programmes, the genetic association between characteristics is critical for enhancing selection efficiency. Studies on the relationship between yield and associated characteristics might be a useful technique for crop development. The fact that grain yield and other yield components have a substantial positive correlation implies that any of the traits might be used for indirect selection for grain yield.

The correlation coefficient (r) for various characteristics of yellow hybrid maize is shown in Table 8. The study found that grain yield was positively and significantly (*p<0.001*) correlated with plant and ear heights. The flowering traits, specifically days to 50% anthesis and silking, were highly correlated with each other (*p<0.001*), suggesting that they were influenced by the same genes or a pleiotropic influence on one another, or that they have linkage genes in common (Brown and Caligari, 2008; Lobulu et al., 2021). However, these traits were negatively correlated with grain yield, plant height, and ear height, meaning that selecting for early flowering days may not be beneficial for these characteristics. Jayakumar et al. (2007) and Sabiel et al. (2014) also found a negative relationship between flowering time and grain yield.

Table 6. Mean performance of agronomic and yield related characters of the provitamin A enriched maize hybrids evaluated in 2019 and 2020.

Hybrids	Days to 50% asselling	Days to 50% silking	Plant height (cm)	Ear height	Plant aspect	Ear aspect	Husk cover	Grain yield (t/ha)
A1702-28	58.33defghi	63.00bc	152.96cde	66.88abc	1.42cde	2.08cd	1.00c	4.46bcd
A1706-2	58.50cdefgh	61.83efgh	151.63def	70.00a	1.75abc	2.08cd	1.25bc	4.45bcd
A1736-12	58.58cdefg	62.75cd	159.92ab	67.63ab	1.75abc	2.25bcd	1.25bc	4.32bcd
A1736-13	55.50mn	60.25l	146.25fg	61.71bc	1.50bcde	2.00cd	1.17bc	4.13bcd
A1736-6	57.58ghijk	61.67fghi	149.46ef	63.04abc	1.92a	2.58ab	1.25bc	4.03bcd
A1802-4	57.08jkl	60.83jkl	157.17bcd	66.71abc	1.33de	1.83d	1.08c	4.30bcd
A1804-14	60.00a	64.25a	139.83h	64.42abc	1.75abc	2.00cd	1.00c	4.80abc
A1804-15	58.67cdefg	62.50cde	150.75def	64.42abc	1.25e	1.92d	1.42ab	5.35ab
A1804-66	57.25ijkl	61.00ijkl	153.96bcde	62.00bc	1.42cde	2.17bcd	1.08c	4.36bcd
A1804-67	56.42lm	60.67kl	151.04def	60.71bc	1.50bcde	2.00cd	1.17bc	4.52abcd
Ife Hybrid-3	55.00n	59.33m	142.71gh	59.63c	1.67abcd	2.42abc	1.25bc	3.33d
Ife Hybrid-4	57.83efghijkl	62.00defg	163.58a	66.54abc	1.42cde	2.08cd	1.00c	4.64abc
LY1001-18	58.17defghi	61.83efgh	154.04bcde	64.00abc	1.83ab	2.42abc	1.17bc	4.18bcd
LY1001-23	57.00kl	60.50kl	153.25cde	64.46abc	1.42cde	1.92d	1.08c	5.09abc
LY1409-14	59.92ab	64.00a	156.00bcd	64.58abc	1.33de	2.08cd	1.17bc	4.71abc
LY1409-21	57.25ijkl	62.33cdef	153.42cde	65.33abc	1.67abcd	2.00cd	1.08c	4.75abc
LY1409-61	59.50abc	64.08a	155.50bcde	65.08abc	1.25e	1.83d	1.08c	5.69a
LY1501-1	58.92bcde	63.37ab	151.00edf	62.33bc	1.67abcd	2.08cd	1.00c	4.59abc
LY1501-5	57.92efghijk	61.67fghi	156.25bcd	65.38abc	1.25e	1.92d	1.17bc	4.69abc
LY1501-6	59.08abcd	62.92c	156.08bcd	64.46abc	1.42cde	2.17bcd	1.08c	4.37bcd
LY1501-7	57.17jkl	61.00ijkl	163.75a	66.08abc	1.42cde	1.92d	1.08c	4.86abc
LY1501-8	57.67ghijk	61.08hij	152.75cde	61.79bc	1.58abcde	2.08cd	1.00c	4.61abc
LY1501-9	57.75fghij	61.50ghij	158.33abc	64.83abc	1.42cde	1.83d	1.42ab	4.94abc
Reference check	58.83cdef	64.00a	146.21fg	61.67bc	1.92a	2.75a	1.67a	3.92cd
M1124-31	57.42hijkl	62.25cdefg	150.92def	68.21ab	1.75abc	2.25bcd	1.08c	5.02abc

Table 7. Mean disease score and lodging resistance of the provitamin A enriched maize hybrids evaluated in 2019 and 2020.

Hybrids	Stalk lodging	Root lodging	Ear rot	Streak	Blight	Rust	Curvularia
A1702-28	1.00a	1.08a	1.42ab	1.33a	1.17a	1.25a	1.17a
A1706-2	1.00a	1.17a	1.33ab	1.17a	1.17a	1.08ab	1.42a
A1736-12	1.00a	1.00a	1.50ab	1.33a	1.08a	1.17ab	1.33a
A1736-13	1.00a	1.08a	1.58ab	1.17a	1.25a	1.17ab	1.33a
A1736-6	1.00a	1.08a	1.50ab	1.33a	1.17a	1.00b	1.25a
A1802-4	1.00a	1.17a	1.50ab	1.17a	1.25a	1.17ab	1.42a
A1804-14	1.00a	1.00a	1.50ab	1.33a	1.08a	1.08ab	1.17a
A1804-15	1.08a	1.00a	1.33ab	1.17a	1.25a	1.25a	1.33a
A1804-66	1.00a	1.08a	1.50ab	1.17a	1.17a	1.08ab	1.33a
A1804-67	1.00a	1.08a	1.33ab	1.33a	1.08a	1.17ab	1.33a
Ife Hybrid-3	1.08a	1.00a	1.67a	1.33a	1.17a	1.08ab	1.33a
Ife Hybrid-4	1.08a	1.00a	1.50ab	1.33a	1.25a	1.08ab	1.33a
LY1001-18	1.17a	1.00a	1.50ab	1.33a	1.17a	1.25a	1.33a
LY1001-23	1.00a	1.00a	1.50ab	1.33a	1.17a	1.25a	1.17a
LY1409-14	1.08a	1.00a	1.50ab	1.33a	1.25a	1.17ab	1.25a
LY1409-21	1.00a	1.00a	1.33ab	1.33a	1.25a	1.17ab	1.25a
LY1409-61	1.00a	1.08a	1.58ab	1.33a	1.08a	1.08ab	1.17a
LY1501-1	1.08a	1.08a	1.50ab	1.17a	1.08a	1.17ab	1.17a
LY1501-5	1.08a	1.00a	1.33ab	1.33a	1.17a	1.08ab	1.33a
LY1501-6	1.17a	1.00a	1.33ab	1.33a	1.17a	1.00b	1.33a
LY1501-7	1.00a	1.08a	1.50ab	1.33a	1.17a	1.25a	1.33a
LY1501-8	1.08a	1.00a	1.50ab	1.33a	1.25a	1.08ab	1.25a
LY1501-9	1.08a	1.08a	1.58ab	1.33a	1.17a	1.17ab	1.17a
Reference check	1.08a	1.08a	1.50ab	1.17a	1.08a	1.08ab	1.25a
M1124-31	1.00a	1.00a	1.33ab	1.17a	1.33a	1.08ab	1.25a

The association between days to tasselling and ear height as well as days to tasselling and plant height, days to silking and plant height, days to silking and ear height, days to tasselling and curvularia, and days to silking and curvularia was negative and highly significant ($P<0.001$). Days to tasselling positively and significantly correlated with 50% silking (0.93**), plant aspect (0.16**), and ear aspect (0.60**), suggesting that there is a strong relationship between days to tasselling and yield attributes such as plant aspect and ear aspect. In addition, there was a positive and highly significant correlation between plant height and ear height (0.79**), as well as root lodging (0.20**), ear rot (0.25**), streak (0.28**), rust (0.51**), blight (0.26**), curvularia (0.62**), and grain yield (0.53**) (Table 8). Consequently, the result also showed that ear height correlated positively and significantly with the above-listed traits as well as plant height except for ear rot, which had a weak positive correlation ($p<0.005$), suggesting the usefulness of indirect selection (Kapoor et al., 2022). There was a negative and significant correlation between grain yield and plant aspect (-0.14**) and grain yield and ear aspect (-0.46**). The significant negative correlations show that these pairs of variables may not influence each other in any way and may not negatively affect grain yield.

Table 8. The Pearson correlation matrix of the provitamin A maize hybrids evaluated in 2019 and 2020 cropping seasons.

	50% tasse.	50% silking	Plant height	Ear height	Root lodg.	Stalk lodg.	Husk cover	Plant asp.	Ear asp.	Ear rot	Streak	Rust	Blight	Curv.	Grain yield
50% tassel.	-	0.93**	-0.58**	- 0.77**	- 0.20**	- 0.01	-0.21**	0.16**	0.60**	-0.13*	-0.29**	-0.58**	-0.25**	-0.69**	-0.31**
50% silking		-	- 0.55**	- 0.72**	- 0.20**	- 0.05**	-0.19**	0.08	0.27**	-0.26**	-0.34**	-0.57**	-0.29**	-0.69**	-0.27**
Plant height			-	0.79**	0.20**	0.10	0.14*	0.05	-0.25**	0.25**	0.28**	0.51**	0.26**	0.62**	0.53**
Ear height				-	0.20**	0.05	0.21**	-0.08	-0.27**	0.13*	0.27**	0.64**	0.29**	0.72**	0.44**
Root lodg.					-	- 0.05	0.09	0.05	-0.06	0.06	0.18**	0.30**	0.08	0.16**	0.06
Stalk lodg.						-	0.04	0.15**	0.06	0.24**	0.02	0.05	0.06	0.04	0.03
Husk cover							-	0.15**	0.10	0.06	0.15**	0.20**	0.02	0.20**	0.02
Plant asp.								-	0.57**	0.42**	0.27**	-0.09	0.17**	0.16**	-0.14**
Ear asp.									-	0.06	0.05	-0.25**	-0.07	-0.07	-0.46**
Ear rot										-	0.38**	0.18**	0.36**	0.29**	0.21**
Streak											-	0.22**	0.20**	0.34**	0.18**
Rust												-	0.25**	0.47**	0.34**
Blight													-	0.28**	0.24**
Curv.														-	0.34**
Grain yield															-

*, ** significant at $p<0.05$ and 0.01, respectively.

Conclusion

The differences in the provitamin A maize hybrids can be attributed to changes in the environment caused by varying amounts of rainfall in the years when the hybrids were evaluated. Additionally, the variations among the hybrids were influenced by factors such as grain yield, time taken for tasselling and silking, plant height, ear height, plant appearance, and ear appearance. In this study, it was found that the exceptional hybrids, namely LY1409-61, AS1802-15, and LY1409-21, possessed desirable agronomic traits and had the potential to increase maize yield and address malnutrition issues. Consequently, these outstanding hybrids, which displayed consistent performance over the course of two years, have the ability to withstand moisture stress and are therefore recommended for sustainable production in the agro-ecology of southwestern Nigeria.

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ZNAČAJ HIBRIDA KUKURUZA (*ZEA MAYS* L.) OBOGAĆENIH PROVITAMINOM A ZA PRINOS I AGRONOMSKE OSOBINE U JUGOZAPADNOJ NIGERIJI

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R e z i m e

Kukuruz je vitalna namirnica u ishrani u Nigeriji, kojom se u organizam unose ključne hranljive materije kao što su ugljeni hidrati, proteini, masti i mikronutrijenti. Međutim, standardnim hibidima kukuruza nedostaje dovoljno nutritivnog prekursora za vitamine, što zahteva gajenje stabilnih, visokoprinosnih hibrida kukuruza obogaćenih provitaminom A. Ovo je važno u ishrani, posebno kod ruralnih populacija koje su podložne „skrivenoj gladi" (engl. *„hidden hunger"*). Ovo istraživanje je imalo za cilj da proceni agronomski učinak i prinos novorazvijenih hibrida kukuruza tokom dvogodišnjeg perioda na lokalitetima Ikorodu i Osogbo u Nigeriji. Ocenjivana su 22 poboljšana hibrida kukuruza, dva komercijalna hibrida i jedna kontrolna varijanta. Prinosi zrna hibrida su se kretali od 3,33 t/ha (ife-hibrid 3) do 5,69 t/ha (LY1409-61) tokom dve godine, prosečno iznoseći 4,03 t/ha. Svi hibridi, osim ife-hibida 3 (3,33 t/ha), nadmašili su prinose na kontroli (3,92 t/ha), pri čemu su četiri hibrida ostvarila prinose preko 5 t/ha tokom dve godine. U 2019. godini, količine padavina su bile veće i dobro raspoređene, što je značajno uticalo na prinose zrna u odnosu na 2020. godinu. Ovaj uticaj je bio posebno primetan u fazama cvetanja i nalivanja zrna od jula do oktobra. LY1409-61, AS1802-15 i LY1409-21 najbolje su reagovali na lošije meteorološke uslove, što se može smatrati njihovom sortnom karakteristikom. Uvođenje ovih hibrida u proizvodnju ima potencijala da poveća proizvodnju kukuruza i ublaži neuhranjenost u ruralnoj jugozapadnoj Nigeriji. Ovim istraživanjem se naglašava uloga unapređenja u stvaranju i gajenju hibrida kukuruza obogaćenih hranljivim materijama u borbi protiv nedostataka u ishrani, poboljšanja prehrambene sigurnosti i koristi zajednicama koje zavise od kukuruza kao osnovne namirnice. To bi moglo značajno da doprinese održivoj poljoprivredi i poboljšanim ishodima ishrane u regionu.

Ključne reči: adaptacija, agronomske osobine, prinos zrna, skrivena glad, neuhranjenost, prehrambena sigurnost.

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