



Variability in Yield and Yield Components of Selected Pro-vitamin A Maize (*Zea mays* L.) Varieties in a Humid Environment of Port Harcourt, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OPT, AIN and BFI designed the study. Author OPT performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OPT, AIN and BFI managed the analyses of the study. Author OPT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed at assessing the magnitude and nature of genetic variation present in seventeen pro-vitamin A (PVA) maize varieties, investigate the extent of association among agronomic characters responsible for yield and its components in the maize varieties and evaluate the performance of the maize varieties. The field experiment was carried out at the Teaching and Research Farm of the Rivers State University, Nkpolu, Port Harcourt under rain fed conditions in May, 2018 and were laid out in a randomized complete block design with three replications. Data were collected on established plants per plot, days to 50% silking, days to 50% anthesis, anthesis-silking interval, plant height, ear height, final stand count, number of ears harvested, grain moisture content, field weight and grain yield. Results showed significant differences ($P < 0.01$) among varieties for all traits evaluated. PVASYN-13 had the highest grain yield per hectare among other varieties. High heritability estimates coupled with high genetic advance were observed in

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established plants per plot, anthesis-silking interval, final stand count, number of ears harvested, field weight and grain yield, an indication of the additive nature of their inheritance. Thus, the presence of variation could serve as basis for selection for yield improvement in maize.

Keywords: Grain yield; genetic advance; heritability; pro-vitamin A maize; variability.

1. INTRODUCTION

Maize is a very important crop which serve as a food security crop in emerging countries especially those in Sub-Saharan Africa (SSA) [1,2]. It is mainly consumed by humans and livestock and occasionally used in agro-allied industries [3,4]. Maize cultivation has spread in the world owing to its genetic diversity, adaptability and versatility [5,6]. It is the most-produced crop worldwide and is grown on more than 197 million hectares each year and has the highest average yield per hectare compared with other cereals [7]. Ever since the crop became popular in Nigeria, it has almost replaced traditionally grown cereals such as sorghum and millet because it grows well in all agro-ecological zones of the country [8,9].

As a result of the peculiarity of the numerous individuals depending on maize as food, efforts have been directed to increasing its nutritional quality and yield. It has been among the target crops for bio-fortification, particularly for protein quality and vitamin A content improvement [10]. Previous efforts at bio-fortification occasioned the high quality protein maize (QPM) which is crucial to meeting the protein demand in localities where it is consumed. Currently, energies are geared toward increasing the pro-vitamin A (PVA) content of maize as a food based approach to combat vitamin A deficiency (VAD) which is widespread in areas where maize is heavily consumed [11]. Efforts made so far to bio-fortify maize with PVA carotenoids have been considered productive [12,13,14].

In spite of the increased area of land dedicated to maize cultivation since the mid-2000s, as well as the exploitation of heterosis [15], maize production per hectare in Africa is low (2.07 t ha^{-1}) in relation to what is obtainable (11.10 t ha^{-1}) in countries like the United States of America [7]. The current low production level may further decline as a result of several other prevailing factors such as the geometric population growth, incidence of pests and diseases, urbanization, climate change, among others [16,17,18].

Numerous breeding programs have set out to significantly increase maize yield in recent years through the use of hybrid crops which usually have higher yields and often exhibit high resistance to weeds and other pests and diseases as well as early maturing [19]. However, the full expression of these characteristics might vary based on environments. Before a crop variety is to be adopted and selected, its growth and yield potential in the target environment is expected to be evaluated. Therefore, there is need to periodically search, identify and evaluate promising maize genotypes which practically help in selection and eventually bring about crop improvement [20]. Hence, this study was conducted with the following objectives, to:

- i. Assess the magnitude and nature of genetic variation present in the selected PVA maize varieties;
- ii. Investigate the extent of association among agronomic characters responsible for yield and its components in the PVA maize varieties; and
- iii. Evaluate the performance of the PVA maize varieties by determining the growth and yield potentials.

2. MATERIALS AND METHODS

The field study was conducted at the Teaching and Research Farm of the Rivers State University, Nkpolu, Port Harcourt, located in the humid tropical zone of Nigeria on latitude $4^{\circ}25'$ and $4^{\circ}28'$ and longitude $6^{\circ}15'$ and $7^{\circ}25'$. Fifteen PVA maize varieties and two checks sourced from the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria were used for this study. The list of the experimental materials is presented in Table 1. The trial was laid out in a well-prepared field in a randomized complete block design with three replications. Each variety was sown 2 seeds per hill on 2-rows of 5 m long ridge at the normal spacing of 75 cm by 25 cm (intra-row and inter-row, respectively). Hand weeding was done when necessary to keep the plots weed-free. Inorganic compound fertilizer, N.P.K (15:15:15)

was applied at two weeks after planting (WAP) and top-dressing with Urea at six WAP. Data were collected on parameters which include: established plants per plot - the total number of plants per plot obtained soon after thinning, days to 50% silking and days to 50% anthesis - the number of days from planting to the time when 50% of the plants in a plot have emerged silks and have tassels shedding pollens, respectively. Anthesis-silking interval - the difference between days to 50% silking and days to 50% anthesis, plant height - the average height in cm of 10 randomly selected maize plants per row from the base of the plant to where the tassel branching begins, using a meter rule, ear height - the average height in cm of 10 randomly selected maize plants per row from the base of the plant to the node bearing the upper ear, using a meter rule, final stand count - the total number of plants harvested per plot, number of ears harvested - the total number of ears harvested per plot, grain moisture content - taken in percentage by a moisture tester at harvest, field weight - it is the weight of cobs per plot measured in kilograms, grain yield - it was measured in tons per hectare and estimated as follows:

$$\text{Grain yield} = \frac{\text{FWT} \times (100 - \text{Grain MC}) \times 8 \times 10000}{(8 \times 5 \times 0.7 \times 100) \times 1000}$$

Table 1. List of experimental materials used in the study

S/N	Variety
1.	PVASYN-2
2.	PVASYN-5
3.	PVASYN-7
4.	PVASYN-8
5.	PVASYN-9
6.	PVASYN-10
7.	PVASYN-13
8.	PVASYN-21
9.	PVASYN-22
10.	STR SYN 2-Y
11.	TZL COM.4 C4
12.	TZL COMP.3 C4
13.	IWD C3 SYN
14.	DT SYN 15-W
15.	AFLA SYN 3-W
16.	Local Check 1
17.	Local Check 2

Data collected on the different characters on the basis of sampled plants were averaged and the mean values obtained were used for statistical analysis. The data obtained were subjected to

analysis of variance (ANOVA) using MINITAB, Version 17 statistical package. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at 5% level of significance. Genetic parameters were estimated from the mean squares of ANOVA to determine genetic variability among the varieties and the genetic effect of the different characters. Genotypic and phenotypic variances were determined according to the formula given by Singh and Chaudhary [21].

$$\text{Phenotypic variance } (\delta^2 p) = \delta^2 g + \delta^2 e$$

$$\text{Genotypic variance } (\delta^2 g) = \frac{MS_g - MSe}{r}$$

$$\text{Error variance } (\delta^2 e) = MSe$$

Where: MS_g = Mean square of genotype, MSe = mean square error, r = number of replication

Phenotypic and genotypic coefficients of variation were also computed as per the formula of Singh and Chaudhary [21].

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{\delta^2 p}}{\bar{x}} \times 100$$

$$\text{Genotypic Coefficient of variation (GCV)} = \frac{\sqrt{\delta^2 g}}{\bar{x}} \times 100$$

Where: \bar{x} = Sample mean of the character being evaluated

The PCV and GCV values were categorized as high = >20%, medium = 11-20% and low = 0-10% as suggested by Siva-Subramanian et al. [22].

Broad sense heritability (H^2) was estimated as: $\frac{\delta^2 g}{\delta^2 p} \times 100$. It was categorized as high = >50%, moderate= 21-50% and low = 0-20% according to the classification of Elrod and Stanfield [23].

Genetic advance (GA) was worked out according to the formula of Singh and Chaudhary [21]:

$$\text{Genetic advance (GA)} = \frac{\delta^2 g}{\sqrt{\delta^2 p}} \times K$$

Where, K = 2.06 (selection differential at 5%)

Expected genetic gain (EGG) was calculated according to the formula given by Robinson et al. [24].

$$\text{EGG} = \frac{GA \times 100}{\bar{x}}$$

Where: \bar{x} = Mean. EGG was categorized as high = >20%, medium = 11-20% and low = 0-10% based on the classification of Johnson et al. [25].

3. RESULTS

The mean squares obtained from the analysis of variance for the studied characters of the PVA maize varieties revealed that genotypic effect was significant ($P \leq 0.01$) for all characters evaluated (Table 2). However, the effect of replication was only significant ($P \leq 0.01$) for days to 50% anthesis and days to 50% silking. The values of coefficient of variation for the characters alternated from high to low; ranging from 2.47 (days to 50% silking) to 43.68 (anthesis-silking interval).

The mean performance of the PVA maize varieties evaluated for yield and yield components are presented in Table 3. The varieties were significantly different for all characters evaluated. PVASYN-9 had the highest plant height (117.01 cm) and ear height (48.91 cm), while IWD-C3-SYN and DTSYN-15-W had the lowest plant height (95.14 cm) and ear height (33.77 cm), respectively. In terms of grain yield, PVASYN-13 (4.90 t ha^{-1}) had the highest and was closely followed by IWD-C3-SYN (4.39 t ha^{-1}). Conversely, DTSYN-15-W had the lowest grain yield with 1.28 t ha^{-1} . The highest mean value for number of ears harvested was observed in PVASYN-8 (26.00), whereas the least value was observed in DTSYN-15-W (12.67).

Estimates of components of variance, coefficients of variation, broad sense heritability, genetic advance and expected genetic gain for the evaluated characters are presented in Table 4. The results showed that in all characters, a large portion of the phenotypic variance was accounted for by genetic components except days to 50% anthesis, days to 50% silking and grain moisture content, in which the contribution of genetic variance to phenotypic variance was less than 45%. PCV were generally higher than GCV for all characters. PCV ranged from 2.24 to 44.35% while GCV ranged from 1.32 to 34.51% for both days to 50% silking and anthesis-silking interval, respectively.

Heritability estimates were found to be high (>50%) in all characters, except days to 50% silking (34.97%), days to 50% anthesis (40.91%) and grain moisture content (35.47%), which showed moderate heritability values. Genetic

advance (at 5% selection intensity) was lowest for field weight (0.68) and highest for plant height (8.80). However, for comparison to be made easily among various characters which had different units of measurements, the values of genetic advance were expressed as percentage of the variety mean for each character and displayed as expected genetic gain (EGG). Based on the classification of EGG by Johnson et al. (1955), where values above 20% is regarded as high, between 11 and 20% as moderate and below 10% as low, EGG ranged from low to high. Anthesis-silking interval (55.33), field weight (50.10), grain yield (48.88), number of ears harvested (9.87), final stand count (25.84) and established plants per plot (24.15) all had high EGG. Conversely, low EGG was recorded for days to 50% silking (1.61), days to 50% anthesis (2.08), plant height (8.15) and grain moisture content (9.29). Only ear height (13.71) recorded a moderate EGG. High heritability estimates were accompanied by high EGG for established plants per plot, anthesis-silking interval, final stand count, number of ears harvested, field weight and grain yield while ear height had high heritability estimates and moderate EGG.

4. DISCUSSION

Genetic improvement in characters that are of economic importance along with maintaining sufficient amount of variability is often the desired objective in maize breeding programmes [26]. The presence of variability in any crop's base population has been adjudged key to such a crop's improvement [27]. In this study, genotypic effect was highly significant ($p \leq 0.01$) for all characters under study, showcasing significant differences among the maize varieties evaluated which revealed the presence of a wide range of genetic variation among the varieties thus, indicating the possibility of selection. The variation observed might be owing to the differences in the genetic makeup of the studied varieties. Many researchers including [28-33,20] had earlier observed and reported the presence of considerable genotypic variability among numerous maize genotypes for different characters.

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are useful for comparing the relative amount of phenotypic and genotypic variations among different characters and they are useful in selection [34]. The phenotypic coefficient of

Table 2. Mean squares from analysis of variance for different characters of seventeen maize varieties

SV	DF	Established plants per plot	Days to 50% silking	Days to 50% anthesis	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Number of plants at harvest	Number of ears at harvest	Field weight (kg)	Moisture content (%)	Grain yield (t ha ⁻¹)
Rep	2	5.55	15.08**	18.06**	0.14	11.18	2.5	3.59	1.49	0.06	1.26	0.33
Genotypes	16	39.68**	3.92**	4.80**	1.57**	96.17**	49.41**	38.13**	38.53**	0.49**	4.45**	2.31**
Error	32	5.82	1.5	1.56	0.28	13.81	9.21	4.82	3.28	0.05	1.68	0.25
Coefficient of Variation (%)		17.53	2.47	2.74	43.68	5.86	11.03	17.71	18.21	32.23	12.57	31.91

*, ** Significant at $p \leq 0.05$ and $p \leq 0.01$ probability levels, respectively. SV = source of variation; DF = degree of freedom; Rep = Replication

Table 3. Mean performance for different characters of 17 Pro-vitamin A (PVA) maize varieties

Variety	Established plants per plot	Days to 50% silking	Days to 50% anthesis	Anthesis-silking interval	Plant height (cm)	Ear height (cm)	Number of plants at harvest	Number of ears at harvest	Field weight (kg)	Moisture content (%)	Grain yield (t ha ⁻¹)
PVASYN-2	24.00a-e	68.33ab	66.00a-c	2.33ab	110.40a-d	42.34a-d	21.67b-d	21.00a-d	1.27c-e	13.08ab	2.76d-g
PVASYN-5	22.00b-e	67.00ab	64.67a-c	2.33ab	102.21de	43.19a-c	21.00b-d	21.00a-d	1.17c-e	12.68ab	2.55f-h
PVASYN-7	24.67a-c	67.00ab	65.00a-c	2.00b	103.28c-e	38.89b-d	22.00a-d	21.00a-d	1.20c-e	12.42ab	2.62e-h
PVASYN-8	28.00ab	66.33ab	64.00bc	2.33ab	108.75a-d	42.86a-d	27.33ab	26.00a	1.40b-d	14.08ab	3.02c-f
PVASYN-9	21.67b-e	69.33ab	67.33a-c	2.00b	117.01a	48.91a	21.33b-d	21.33a-d	1.66a-c	12.32ab	3.65bc
PVASYN-10	24.33a-d	66.00b	63.67c	2.33ab	115.72ab	47.17ab	24.00a-c	23.33a-d	1.42b-d	12.23ab	3.12c-f
PVASYN-13	22.67b-e	68.00ab	66.67a-c	1.33bc	114.47a-c	44.95a-c	22.33a-d	20.33b-e	2.27a	13.67ab	4.90a
PVASYN-21	19.67c-e	68.00ab	66.67a-c	1.33bc	107.12a-d	42.80a-d	18.33cd	17.67d-f	0.85de	12.82ab	1.86hi
PVASYN-22	21.00b-e	68.00ab	65.33a-c	2.67ab	107.32a-d	38.76b-d	20.67b-d	19.00c-e	1.36b-d	11.40ab	3.02c-f
STRSYN-2-Y	22.33b-e	68.33ab	66.33a-c	2.00b	110.03a-d	46.59ab	21.00b-d	19.00c-e	1.32b-d	11.32ab	2.93c-f
TZL.COMP.3.C4	23.33a-e	70.00a	66.33a-c	3.67a	105.17b-e	40.72a-d	23.00a-c	22.00a-d	1.55b-d	11.85ab	3.44c-e
TZL.COMP.4.C4	24.33a-d	68.33ab	68.00a	0.33c	111.33a-d	44.61a-c	22.00a-d	20.33b-e	1.44b-d	11.82ab	3.19c-f
IWD-C3-SYN	27.00a-c	66.33ab	65.00a-c	1.33bc	95.14e	35.75cd	26.00ab	25.67ab	2.01ab	12.75ab	4.39ab
DTSYN-15-W	16.67e	67.00ab	65.33a-c	1.67bc	101.87de	33.77d	15.67d	12.67f	0.59e	13.63ab	1.28i
AFLATOXIN-SYN-3-W	26.33a-c	69.33ab	67.67ab	1.67bc	106.18a-e	39.35b-d	26.00ab	24.00a-c	1.64a-c	14.90a	3.50cd
LocalCheck1	30.67a	67.33ab	65.67a-c	1.67bc	106.57a-d	43.58a-c	28.67a	25.67ab	1.12c-e	10.23b	2.53f-h
LocalCheck2	17.00de	68.67ab	67.33a-c	1.33bc	113.95a-c	45.69ab	16.00d	15.33ef	0.95c-e	14.53a	2.03g-i

Means with different alphabets in a column differed significantly at 5% level of probability according to Tukey's Honestly Significant Difference (HSD) test

Table 4. Genetic parameters of different characters of 17 Pro-vitamin A (PVA) maize varieties

Characters	Mean	Environ-mental variance (Ve)	Genotypic variance (Vg)	Phenotypic variance (Vp)	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability in broad-sense (%)	Genetic advance	Expected genetic gain (%)
Established plants per plot	23.28	5.82	11.29	17.11	17.77	14.43	65.98	5.62	24.15
Days to 50% Silking	67.84	1.50	0.81	2.31	2.24	1.32	34.97	1.09	1.61
Days to 50% Anthesis	65.94	1.56	1.08	2.64	2.46	1.58	40.91	1.37	2.08
Anthesis-Silking Interval	1.90	0.28	0.43	0.71	44.35	34.51	60.56	1.05	55.33
Plan Heights (cm)	108.03	13.81	27.45	41.26	5.95	4.85	66.53	8.80	8.15
Ear Height (cm)	42.35	9.21	13.40	22.61	11.23	8.64	59.27	5.81	13.71
Final Stand Counts	22.18	4.82	11.10	15.92	17.99	15.02	69.73	5.73	25.84
Number of Ears Harvested	20.90	3.28	11.75	15.03	18.55	16.40	78.18	6.24	29.87
Grain Moisture Content (%)	12.69	1.68	0.92	2.60	12.71	7.57	35.47	1.18	9.29
Field Weight (kg)	1.36	0.05	0.15	0.20	32.61	28.16	74.58	0.68	50.10
Grain Yield (t ha ⁻¹)	2.99	0.25	0.69	0.94	32.37	27.71	73.31	1.46	48.88

variation was higher than genotypic coefficients of variation for all corresponding characters in this study, indicating the contribution of the environment in the expression of these characters. Higher phenotypic coefficient of variation has been reported in maize [35,20] and other crops like soybean [36], fluted pumpkin [37], rice [38-40], barley [41] and African eggplant [42].

Heritability estimates helps to partition variability (into either heritable or non-heritable). The higher the heritability estimate for a character, the more likely it is for the characters to be easily passed on to the next generation. The heritability values ranged from medium to high for all characters under study indicating that the environment has little influence on them, but are rather largely under genetic control. Authors such as [43-47,32,20] have all earlier reported high heritability estimates for different yield controlling characters in maize. High heritability estimates for characters practically often denote the ease and efficiency of selection in any breeding program as it suggests that the characters are likely to be easily passed on to the next generation. Although, it is more reliable to consider heritability values along with those of genetic advance [30], as high heritability coupled with genetic advance reveals the presence of lesser environmental influence and prevalence of additive gene action in their expression [48]. Similarly, high values of genetic advance in percentage of the mean (EGG) are indicative of additive gene effect whereas low values are indicative of non-additive gene effect [49]. The characters with high heritability estimates accompanied with high EGG such as established plants per plot, anthesis-silking interval, final stand count, number of ears harvested, field weight and grain yield as observed in this study are indicative that they are under the control of additive gene action, suggesting that effective progress in improvement through selection could be achieved. Similar results of high heritability estimates accompanied by high EGG for similar characters were reported by several authors [50,20].

5. CONCLUSION

This study revealed the existence of considerable amount of genetic variability among the studied PVA maize varieties. The high broad sense heritability estimates obtained for characters such as established plants per plot, anthesis-silking interval, plant height, ear height,

final stand count, number of ears harvested, field weight and grain yield show that these characters are genetically controlled and the environment had less influence on them.

The high heritability estimates accompanied by high EGG for established plants per plot, anthesis-silking interval, final stand count, number of ears harvested, field weight and grain yield suggests that selection for these characters may be more promising because the variation observed is attributable to high degree of additive effect.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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