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Physiological Basis of Yield Differences in Quality Protein Maize Genotypes of Different Maturity Groups

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Authors' contributions

This work was carried out by the first author under the supervision of the second author. It was a PhD work of the first author. Authors OJO and ASA designed the study. Author OJO collected data, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript under the supervision of author ASA. Both authors read and approved the final manuscript.

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ABSTRACT

Yield performance of early maturing maize (*Zea mays* L.) varieties in the rainforest agroecology of southwest Nigeria, is lower than that of intermediate varieties and that there was no yield advantage in the late varieties over the intermediate maturing varieties. However, the physiological basis of yield differences is yet to be fully investigated. This study was carried out to investigate the physiological basis underlying yield differences in quality protein maize genotypes of different maturity groups. Field experiment was conducted as randomized complete block design (RCBD) with three replicates at Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan during 2013 and 2014 cropping seasons. The results indicated that season influenced days to 50% Anthesis (DTA), days to 50% silking (DTS), anthesis silking interval (ASI), plant height (PLHT), ear height (EHT), ear per plant (EPP), ear aspect (EASP), kernel width (KWDT) and grain yield (GYD). Maturity groups also influenced DTA, DTS, PASP, PLHT, EHT, and with no

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effect on GYD. The overall mean grain yields across seasons were 4.44, 4.16, 3.64 and 3.36 t/ha for season 1, 2, 3 and 4, respectively. It was concluded from this study that all the maturity groups used had similar grain yield.

Keywords: Maturity group; agronomic traits; Zea mays; genotypes; grain yield.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal in rain-fed production systems in West and Central Africa [1]. In most of the countries in this region, maize is grown in several agro-ecologies during different cropping seasons. For these reasons, different maturity groups of maize varieties are required to meet the needs of different end-users. Varietal maturity of maize is measured as the number of days from planting to physiological maturity of kernel [2]. Kumar [3] reported that early-maturing varieties required fewer corn heat units to reach flowering, while late-maturing cultivars exhibited extended vegetative period. Several workers have reported on the effect of maturity class on maize productivity. Kamara et al. [4] reported that maize plants that flowered early were smaller and had fewer leaves with low grain yield compared with late cultivars. Data from maize variety trials conducted in Ghana from 1982 to 1990 showed that the intermediate and late maturing varieties out-yielded the early maturing varieties by 27 to 40% [5]. The extra-early and early maturing maize varieties were lower yielding than the late varieties and there was no yield advantage in the late varieties over the intermediate types in the Guinea savanna zone [6,7]. Bello et al. [8] also reported that late-/intermediate-maturing varieties out-yielded early-maturing ones with yield advantage of 34.29% and taller by 17.04% compared to early ones. Agele [9] reported that late-maturing varieties of maize produced higher seed yield than the early-maturing varieties, and when both were sown in the rainy season, they produced larger seed yield than late season crop.

Capristo et al. [10] reported lowest grain yield for short-season hybrids and comparable yield between mid- and long-season hybrids. They highlighted further that the results indicated that grain yield of short-season hybrids would be more limited by the capacity of the reproductive sinks during grain fillings compared to their long-season counterparts. In contrast to the above reports, Bruns and Abass [11,12] reported that several short-season and mid-season hybrids grown in the Mississippi Delta produced grain yields comparable to full-season hybrids.

While it is generally believed that late-maturing or long-season varieties give higher grain yield than early- or extra-early varieties [9], there is ample evidence from tropical areas that the traditional system of classifying maturity flowering phenology is misleading [13]. In addition, even where yield differences were negligible, physiological strategy for achieving the yield differed in maize varieties belonging to different maturity classes. Olakojo and Iken [14] observed that maize genotypes that differed significantly in plant height had statistically similar grain yield. As a way of ensuring that maize is grown at all seasons and in all agro-ecological zones of Nigeria, different maize varieties have been developed with distinct phenological characteristics and ecological adaptations. Arising from the foregoing therefore, there are gaps in the current understanding of the physiological basis of the yield differences due to differences in maturity rating. The elucidation of the physiological pathways will provide insight into what traits could be used as direct selection criteria to provide higher genetic gain in maize varietal development.

This then necessitated further indepth investigation of the basis of yield differences in varieties belonging to different maturity classes.

2. MATERIALS AND METHODS

2.1 Planting Materials

The experimental materials comprised 12 quality protein maize (QPM) genotypes belonging to three different maturity groups namely, early, intermediate and late maturity groups (Table 1). The seeds of the genotypes were multiplied during the late season of 2012. After harvesting and processing, preliminary evaluation of seed quality were done and remaining seeds were sealed inside polyethene bag for storage in a cool room (Temperature range of 20oC- 30oC and Relative Humidity of 35% -65%) of the

Table 1. List of quality protein maize genotypes used for the study

S/N	Pedigree	Code	Maturity group	Source
1	EVDT.W99STRQPMC0	EVDT-W99	Early	IITA
2	DMR-ESR-WQPM	DMR-ESR-W	Early	IITA
3	TZE-YPOPDTSTRQPMC1	TZE-YPOPDT	Early	IITA
4	POOL-18SR	POOL-18R	Early	11TA
5	ART/98/SW5-OB	ART/98/SW5-OB	Intermediate	IAR&T
6	ART/98/SW6-OB	ART/98/SW6-OB	Intermediate	IAR&T
7	ART/98/ILE-1-OB	ILE-1-OB	Intermediate	IAR&T
8	POP66-SR/ACR.91SUWAN1-SRC1/ACR.91SUWAN1-SRC1	POP66-SR/ACR.91	Intermediate	11TA
9	SYNLDFO/OBATANPA/IWDC2SYN*2	SYNLDFO/OBANTAPA	Late	11TA
10	SYNLDFO/OBATANPA/TZLCOMP.4C3*2	SYNLDFO/OBAT	Late	11TA
11	SYNLDFO/OBATANPA/ TZLCOMP.3C3*2	SYNLDFO/OBAT/TZL	Late	11TA
12	OBANTANPA/TZLCOMP/SYN-W-1/TZL COMP./SYN-W-/F2		Late	11TA

Institute of Agricultural Research and Training (I.A.R.& T), Obafemi Awolowo University, Moor Plantation, Ibadan during the period of the study.

2.2 Experimental Layout and Cultural Practices

The study was carried out at the Research Farm of the I.A.R.&T., during the early and late cropping seasons of 2013 and 2014 in a randomized complete block design (RCBD) involving the 12 genotypes with 3 replications. The materials were planted in 4-row plots, each row being 5 m long, 0.75 m apart. Hills were spaced 0.25 m within row with 2 seeds sown per hill and this was later thinned to 1 plant/hill after emergence to give a total plant population of 53,333 plants/ha. A compound fertilizer (NPK 15:15:15) was applied at the rate of 60 kg N, 60 kg P and 60 kg Kha-1at three weeks after planting (WAP). An additional 60 kg N ha-1 was applied as top dressing at seven WAP using urea (46% N). Chemical weed control was done using a mixture of S-metolachlor as pre- and paraquat as post-emergence herbicides at 3 litres/ha, respectively applied immediately after planting. This was supplemented with manual weeding six weeks after planting in each planting season as was required to keep the field sufficiently clean to prevent weed-crop competition.

2.3 Data Collection

Data were collected from the two middle rows in each plot. The parameters measured include: Days to anthesis and silking as the number of days from planting to when 50% of the plants in each plot shed pollen and silks had emerged respectively. Anthesis-silking interval was computed as the difference between dates of silking and pollen shed. Plant and ear heights were measured as the distance (cm) from the base of the plant to the height of the first tassel branch and the node bearing upper ear respectively. Plant aspect was rated visually on a scale of 1 to 5 where 1=excellent overall phenotypic appeal and 5= poor overall phenotypic appeal of plants. Ear aspect was also rated on a scale of 1 to 5 where 1 = clear, uniform, large and well- filled cobs and5 = variable, small and partially filled cobs. The total number of plants and ears were counted in each plot at the time of harvest. The number of ears per plant was then calculated as the proportion of the total number of ears harvested divided by the total number of plants in a plot. All ears harvested from each plot were shelled and percentage moisture at harvest was determined. Grain yield (GYD) at 13% moisture was used to compute grain yield in tonnes per hectare (t/ha).

2.4 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) separately for each maturity group and combined across the different maturity groups. All analysis was done using General Linear Model (GLM) procedure of the statistical analysis system (SAS) software version 9.2. [15] to compute mean squares for each character. Mean separation was done using Duncan Multiple Range Test (DMRT) of same statistical package.

3. RESULTS

3.1 Mean Square Values of Agronomic Characters of 12 Maize Genotypes

The results of the mean squares from analysis of variance (ANOVA) were significant ($p<0.01$) different. Season effect on flowering traits were days to 50% Anthesis (DTA), days to 50% silking (DTS), anthesis silking interval (ASI), morphological traits (namely plant height (PLHT), ear height (EHT)), and productivity traits(ear per plant (EPP), ear aspect (EASP), kernel width (KWDT) and grain yield (GYD)) (Table 2). Maturity groups had significant ($p <0.05$) effect only on DTA, DTS, PASP, PLHT and EHT. Noticeably, the effect of maturity was negligible for all the productivity traits and consequently for grain yield. Similarly the effect of variety within each maturity group, VAR (MAT) was only significant ($P<0.05$) for DTA, DTS, PLHT, EPP and EASP. Interactive effect of S x MAT was significant ($p<0.05$) on ASI only.

From season to season, flowering and morphological traits were significantly more variable than productivity traits (Table 3). Of all the productivity traits, KWDT was the most variable. Unlike flowering and morphological traits, productivity traits like EPP, EASP and GYD showed a definite and consistent trend. While values for the two seasons (1 and 2) on the one hand and for the last 2 seasons (3 and 4) on the other were comparable, the former were consistently higher than the latter for EPP and GYD and vice versa for EASP.

The early-maturing varieties had a mean DTA of 51.5 days while intermediate and late had higher values of 54.7 days and 54.2 days and DTS of about 2.7-3.2 days earlier than intermediate and late-maturing varieties while the ASI values for the three groups were comparable (Table 4).The three maturity groups were significantly different for plant height in the order late (149.9 cm) > early (143.8 cm) > intermediate (135.8 cm). Early- and intermediate- maturing varieties had comparable ($p>0.05$) ear heights values of 61.1 and 55.5 cm, which were lower than; late-maturing varieties (64.4). The results obtained for productivity traits had no significant differences ($p>0.05$) irrespective of maturity group.

4. DISCUSSION

Precipitation pattern of rainfall has great impact in the expression of plant potentials during periods of flowering/ grain filling of the crop growth cycle, especially maize. Rainfall distribution was probably the single most important environmental factor that affected overall crop performance in this study. The rainfall patterns were favourable during the third growing season and this led to early planting which resulted to comparable values of agronomic parameters. The third growing season was characterized by optimum temperature, relatively high incident radiation and adequate rainfall which probably enhanced crop performance that led to earliness in the flowering traits and reduced anthesis silking interval. Plant height and ear height increased by 17.3% and 38.7%, respectively over the first growing season. This result is in conformity with the findings of [16] who reported that plant height can be increased by sowing date. Interesting to note in this study was that all these attributes (as a result of early planting) was not enough to compensate for yield. The yield and yield traits were lower during the third planting season. The longer flowering data recorded in this study by late and intermediate maturing genotypes was also reported by [3]. This could be due to the fact that flowering traits is a physiological processes and are mainly affected by genotype and environment. Similar results are also reported by [17]. These results were expected as the genotypes used were of different maturity groups. Number of days recorded for anthesis silking interval (ASI) among early, intermediate and late maturing groups during the planting seasons were similar ($p> 0.05$). This indicates an interval of 2 days between pollen shed and silk intrusion in the genotypes tested. Bello and Olaoye [18] described ASI as a measured of nicking (synchronization) of pollen shed with silking. The differential response of maize maturing groups regarding plant and ear heights may be attributed to difference in the genetic potential for these traits. Higher plant and ear heights associated with late maturing maize genotypes in this study are also reported by [19]. Plant and ear aspects are vital in determining varietal acceptability under farmer's condition. The result showed that among early, intermediate and late maturing groups, plant and ear aspects were fair in overall phenotypic appeal (< 3).

Comparison among the early, intermediate and late maturity showed no significant different among the maturity groups. Despite the fact that some genotypes were late to maturity, higher in plant and ear heights, there was no yield

Table 2. Mean square values of agronomic characters of 12 maize genotypes evaluated in 2013 and 2014

Source of variation	DF	DTA	DTS	ASI (day)	PASP	PLHT (cm)	EHT (cm)	EPP	EASP	KWDT	GYD (tons/ha)
Season (S)	3	74.8***	94.8***	7.4***	8.7***	3168.2***	2779.1***	0.16***	4.7***	0.190**	8.7***
Maturity(MAT)	2	141.4***	139.5***	1.0	2.2**	2387.5***	967.0***	0.03	0.7	0.001	0.2
VAR(MAT)	9	7.8***	8.3***	1.6	0.2	442.5*	125.9	0.05*	1.3*	0.060	0.8
Rep(Season)	8	0.9	2.9	1.3	4.4***	486.2*	276.1**	0.15***	1.9**	0.070	5.8***
S X MAT	6	2.8	4.0	2.2*	0.5	100.8	64.6	0.02	0.1	0.047	1.3
S X VAR(MAT)	27	3.2**	2.7	1.1	0.3	146.1	74.1	0.05**	0.3	0.040	0.9
Error	88	1.5	2.1	0.9	0.3	203.6	83.6	0.02	0.5	0.04	1.1
Total	143										

,,*** significant at P<0.05, 0.01 and 0.001 respectively; S- Season; MAT= Maturity Group; VAR(MAT)- Variety within Maturity Group; SXMAT- Interactive effect of Season and Maturity Group; DTA- Days to 50% Anthesis; DTS- Days to 50% Silking; ASI-Anthesis Silking Interval; PASP-Plant Aspect; PLHT- Plant Height (cm); EHT-Ear Height (cm); EPP- Ear Per Plant; EASP- Ear Aspect; KWDT- Kernel Width (cm); GYD- Grain Yield (tons/ha)*

Table 3. Effect of storage duration on agronomic characters of 12 maize genotypes evaluated in 2013 and 2014

Season	DTA	DTS	ASI (day)	PASP	PLHT (cm)	EHT (cm)	EPP	EASP	KWDT	GYD (tons/ha)
Season 1	53.46b	55.41b	1.95a	2.69c	131.52c	51.44c	1.00a	2.34a	1.35c	4.44a
Season 2	55.07a	56.45a	1.36b	1.98a	145.13b	63.04b	1.01a	2.64a	1.51a	4.16a
Season 3	51.61c	52.82c	1.21b	2.39b	154.25a	71.35a	0.86b	3.14b	1.37c	3.64b
Season 4	53.85b	56.00a	2.14a	3,15d	141.80b	55.59c	0.92b	3.00b	1.46b	3.36b
Mean	53.50	55.17	1.67	2.55	143.18	60.36	0.95	2.78	1.42	3.90

DTA- Days to 50% Anthesis; DTS- Days to 50% Silking; ASI-Anthesis Silking Interval; PASP-Plant Aspect; PLHT-Plant Height (cm); EHT-Ear Height (cm); EPP- Ear Per Plant; EASP-Ear Aspect; KWDT- Kernel Width (cm); GYD- Grain Yield (tons/ha)

Table 4. Effect of maturity group on agronomics traits of 12 maize genotypes evaluated in 2013 and 2014

Maturity Group	DTA	DTS	ASI (day)	PASP	PLHT(cm)	EHT (cm)	EPP	EASP	KWDT	GYD (tons/ha)
Early	51.5b	53.2b	1.66a	2.79b	143.8b	61.1b	1.11a	2.64a	1.56a	3.68a
Intermediate	54.7a	56.3a	1.52a	2.50a	135.8c	55.5b	1.10a	2.63a	1.56a	3.68a
Late	54.2a	56.1a	1.81a	2.37a	149.9a	64.4a	1.28a	2.87a	1.66a	3.69a

DTA- Days to 50% Anthesis; DTS- Days to 50% Silking; ASI-Anthesis Silking Interval; PASP-Plant Aspect; PLHT-Plant Height (cm); EHT-Ear Height (cm); EPP- Ear Per Plant; EASP- Ear Aspect; KWDT-Kernel Width (cm); GYD- Grain Yield (tons/ha) disparity among the maturity groups. It is generally recognized that longer maturing genotypes produced greater yield to enhance long duration in metabolic transformation into grain and stover yields as reported by [9] and [20]. The reports of these researchers were in contrast to the finding of this study. The comparable yield among the three maturity groups was in agreement with the earlier findings of [11,12] but in contrast with the findings of [10]. Comparable average yield among the maturity groups can be attributed, in part, to response of early genotypes to rainfed condition during planting because of the drought tolerant traits on some of the early genotypes and similar proportion of stay green at brown silk stage.

5. CONCLUSION

The results showed that all the physiological traits (DTA, DTS, ASI, PASP, PLHT, EHT, EPP, EASP, KWDT and GYD) measured were higher in late maturing genotype compare to other maturity groups but with no yield advantage. It was concluded from this study that all the maturity groups used had similar grain yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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