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Effects of maturity group and duration of seed storage on leaf shedding and yield of tropical maize genotypes

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Abstract
A field experiment was carried out at the Research Farm of the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria during the early and late cropping seasons of 2014 and 2015. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications to determine the effect of seed storage duration on number of leaves and yield of tropical maize genotypes of different maturity groups. Analysis of the data revealed that storage duration (SD) of 0 (initial), 3, 9 and 15 months and maturity group (MAT) (early, intermediate and late) effects were highly significant on above ear photosynthetically active leaf (AEPAL), below ear photosynthetically active leaf (BEPAL), number of lost leaf (NLL) and total number of leaf produced (TLN). Percent retained leaf (Percent RL) and grain yield (GYD) were also significantly influenced by storage duration. Varietal effect differed significantly for NLL and TLN. The interactive effect of SD and MAT was significant on the average number of AEPAL, BEPAL, NLL and percent RL only. Averaged over the storage duration of early, intermediate and late maturing genotypes produced 17, 18 and 20 leaves, respectively. The TLN was higher for late maturing genotypes but least for early maturing. Genotypes in late maturing group had 8.7 % of their leaves above ear compared to the varieties in early group. Percentage yield reduction at 9 and 15 months in storage were 18 and 24 %, respectively. Thus it is advisable not to store seeds for more than one year before sowing. It is recommended that maize seeds be stored not beyond six months before planting for commercial purpose.

Keywords: Genotypes; Grain yield; Maturity group; Photosynthetically active leaf, Storage,

Introduction
Leaf growth is one of the important determinants of plant productivity. Yield or dry matter production in crops is closely related to leaf area and the interception of photosynthetically active radiation (Norman *et al*., 1995), which itself is a direct function of leaf development. Leaf area and light distribution are important input parameters for determination of the efficiency of photosynthesis. Substantial differences in leaf production exist among crop cultivars (Birch *et al*., 2003). Rapid leaf appearance by early- maturing genotypes may help these types of genotypes achieve earlier canopy closure and better use of the light available during the growing season which is critical in a short growing season environment (Begna *et al*. 2001). Garcia *et al*. (2009) reported that short season hybrids had higher leaf and sheath growth rates than mid- and full-season hybrids, resulting in a higher stem growth rate in rainfed condition.

The quality of seeds reflects potential seed germination, field emergence and seedling establishment under different environmental conditions (Sun *et al*., 2007). Depending on storage condition, the rate of ageing will eventually determine the longevity. Germination rate, uniformity of seedlings, tolerance to environmental stresses, seedling emergence and post-emergence seedling growth decrease with ageing in maize seeds (Coolbear, 1995; Hampton and TeKrony, 1995; Khan *et al*., 2003). One of the main problems often observed in the field is poor seedling establishment, which is influenced by seed quality, climatic conditions and field management practices (Delouche, 2004; Zhu *et al*., 2010). It has been widely reported that the longer the period of seed storage, the lower the seed quality and consequently the yield (Ghassemi-Golezani *et al*, 2010). The critical period when significant yield loss occurs has not been ascertained in tropical maize germplasm. Seed quality greatly influences seedling emergence and growth. However, its effect on phenological stages in tropical maize of different maturity groups is yet to be investigated. This information is essential for planning proper management practices for maize of different maturity groups.

Materials and Methods

Planting materials

The experimental materials comprised of 12 quality protein maize (QPM) genotypes belonging to three different maturity groups; namely early, intermediate and late maturity groups. Nine of the QPM genotypes were developed at the Maize Improvement Programme of the International Institute of Tropical Agriculture (IITA), Ibadan. The other three genotypes were obtained from the Cereals Improvement Programme of the Institute of Agricultural Research and Training (IAR&T), Ibadan where they were developed. The seeds of the genotypes were multiplied during the late season of 2013. Harvesting was done in December of the same year and seed quality evaluation was carried out in February of 2014. After the preliminary evaluation of seed quality using germination test, seeds were stored for 0 (initial), 3, 9 and 15 months in envelops wrapped with polythene bags in the Institute cold room with temperature range of 20-30^{o}C and relative humidity of 35 - 65% during the period of the study.

Experimental layout and cultural practices

Seeds of the 12 maize genotypes were planted at the Research Farm of the IAR&T, Ibadan, during the early and late cropping seasons of 2014 and 2015 in a randomized complete block design (RCBD) with 3 replications. The materials were planted in 5 m long 4- rows plots, with 0.75 m apart. Intra-row spacing of 0.25 m was used and 2 seeds were sown per hill. The maize plants were later thinned ten days after emergence to 1 plant/hill to give a total plant population of 53,333 plants/ha. Chemical weed control was done using a mixture of S-metolachlor as pre-emergence and paraquat as post-emergence herbicides at 4 litres/ha applied immediately after planting maize. A compound fertilizer (NPK 15:15:15) was applied at the rate of 60 kg N, 60 kg P and 60 kg Kha^{-1} at 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 supplemented with manual weeding at 6 WAP in each planting season as may be required to keep the field sufficiently clean to prevent weed-crop competition.

Data collection

Data were collected from ten plants selected at random from the two middle rows in each plot. The parameters measured included: Number of leaves above the ear (AEPAL) was the the total number of leaves above the ear that were 25% at least green (photosynthetically active leaf). Below Ear

Leaf (BEPAL) was the total number of leaves below ear that were 25% or more green (photosynthetically active leaf). Lost Leaf (LL) was the total number of leaves that were no more part of the standing plant by leaf tagging during early vegetative growth. Total Leaf Number (TLN) was taken as the count of the total number of leaves produced from planting till the emergence of flag leaf. All these parameters were measured according to Binford and Blackmer (1993). All ears harvested from each plot were shelled and the percentage moisture at harvest was determined. Grain yield was adjusted to 13 % moisture content and used to compute grain yield per hectare of land. The data collected were subjected to analysis of variance (ANOVA) separately for each maturity group and combined across maturity. All analyses were done using General Linear Model (GLM) procedure of the statistical analysis system, SAS software version 9.2. (SAS Institute, 2002). Mean separation was done using Duncan Multiple Range Test (DMRT). Pearson's correlation analysis was also carried out to show the relationship between photosynthetically active leaf and maize yield.

Results

Mean squares values of phenological traits and grain yield of 12 maize genotypes are presented in Table 1. Effect of storage duration (SD) and maturity group (MAT) were highly significant ($p<0.01$-0.001) on AEPAL, BEPAL, NLL and TLN. Percent retained leaf (Percent RL) and grain yield (GYD) were significantly influenced by storage duration. Varietal effect differed significantly for NLL and TLN.

The interactive effect of SD x MAT was significant ($p < 0.05$-0.001) on the average number of AEPAL, BEPAL, NLL and percent RL but not significant on TLN and GYD. The other interactive effect of SD and VAR (MAT) was significant ($p < 0.05$-0.01) on NLL.

Table 2 showed that the more AEPAL were produced during month 3 and months 9 storage durations and lowest at the initial stage (month 0). BEPAL was highest at the beginning of the trial but reduced after 3 and 9 months in storage and later increased after 15 months in storage. The total NLL was higher after 9 months in storage and lowest

Table 1: Mean square values of phenological traits and grain yield of 12 maize genotypes evaluated in 2014 and 2015

Source of variation	DF	AEPAL	BEPAL	NLL	TLN	Percent RL	GYD (T/ha)
Storage Duration, SD	3	2.23***	6.10***	4.67***	2.05**	0.009***	8.7***
Maturity, MAT	2	2.52***	23.82***	5.44***	77.96***	0.002	0.2
VAR(MAT)	9	0.33	0.61	1.14***	2.27***	0.001	0.8
Rep (SD)	8	0.26	0.42	0.37	0.53	0.001	5.8***
SD x MAT	6	0.43*	1.24*	1.20***	0.29	0.003**	1.3
SD x VAR(MAT)	27	0.24	0.57	0.58**	0.45	0.001	0.9
Error	88	0.19	0.42	0.28	0.38	0.001	1.1

*, **, *** significant at $P<0.05$, 0.01 and 0. 001 respectively

DF- Degree of Freedom; AEPAL-Above Ear Photosynthetically Active Leaf ; BEPAL- Below Ear Photosynthetically Active Leaf ; NLL- Number of Lost Leaf; TLN- Total Leaf Number; Percent RL-Percent retained leaf; GYD-Grain Yield(T/ha).

after 3 months in storage. The percentage of NLL to TLN were; 30.42, 32.87, 34.41 and 33.28 %. Average TLN produced across duration of storage was highest after 9 months in storage and was not statistically different among other storage periods. The proportion of leaves retained at brown silk stage was highest at the initial stage of the trial and decreased over storage periods. Grain yield was the highest at the initial stage of the storage. The overall mean grain yields across duration of storage were 4.44, 4.16, 3.64 and 3.36 t/ha. There was no significant yield difference between initial and after 3 months in storage. Percentage yield reduction at 9 and 15 months in storage were 18 and 24 %, respectively.

Table 3 showed that early maturing varieties had the least number of AEPAL, BEPAL, NLL and TLN as compared to other 2 maturity groups. The BEPAL were also higher in late maturing group. Averaged over the duration of storage, early, intermediate and late maturing genotypes produced 17, 18 and 20 leaves, respectively. Grain yield were not influenced by maturity groups. Of all the genotypes, varietal influence was significant for NLL and TLN (Table 4). All the late maturing genotypes had much of the leaves produced below ear but not significantly different from one another and other maturity groups. Average PAL ranged from 11.34 in TZE-YPOPDT (early) to about 13.49 in SYNLDFO/OBAT (late). Average NLL were higher in the entire late

Table 2: Effect of storage duration on phenological traits of 12 maize genotypes of different maturity groups evaluated in 2014 and 2015

Storage Duration	AEPAL	BEPAL	NLL	TLN	Percent RL	GYD (T/ha)
Initial	5.20c	7.30a	5.50c	18.08b	69a	4.44a
3 Months	5.76a	6.40c	5.87b	17.86b	67b	4.16a
9 Months	5.66a	6.47c	6.37a	18.51a	65c	3.64b
15 Months	5.45b	6.82b	6.01b	18.06b	66bc	3.36b

Means with the same letter in each column are not significantly different at $P< 0.05$ using Duncan's multiple range test.
AEPAL=Above Ear Photosynthetically Active Leaf; BEPAL= Below Ear Photosynthetically Active Leaf; NLL= Number of Lost Leaf; TLN= Total Leaf Number; Percent RL=Percent retained leaf; GYD-Grain Yield (T/ha)

Table 3: Effect of maturity group on phenological traits of 12 maize genotypes in 2014 and 2015

Maturity Group	AEPAL	BEPAL	NLL	T LN	Percent RL	GYD (T/ha)
Early	5.29c	6.18c	5.58c	16.97c	67a	3.68a
Intermediate	5.52b	6.52b	6.00b	18.08b	66a	3.68a
Late	5.75a	7.54a	6.25a	19.52a	67a	3.69a

Means with the same letter in each column are not significantly different at $P< 0.05$ using Duncan's multiple range test.
AEPAL=Above Ear Photosynthetically Active Leaf; BEPAL= Below Ear Photosynthetically Active Leaf; AEP/BEP=Ratio of above and below ear Photosynthetically Active Leaf; PAL=Photosynthetically Active Leaf; NLL= Number of Lost Leaf; TLN= Total Leaf Number; Percent RL=Percent retained leaf; GYD- Grain Yield (T/ha).

maturing group and some intermediate maturing group and lower in the entire early maturing group. Average TLN recorded by each of the genotypes within the maturity groups are almost similar.

Among the genotypes in different maturity groups, highest yield of 4.13, 4.39 and 4.19 T/ha were recorded by DMR-ESR (early), ILE-01-OB (intermediate) and SYNLDFO/OBAT/TZL (late), respectively. Results in Table 5 show that AEPAL had significant and positive correlation with grain yield in early maturing genotypes. In intermediate genotypes, it was BEPAL and NLL that had positive and negative significant correlation respectively with grain yield

Discussion

Leaf growth is one of the most important determinants of plant productivity. Leaves are the principal organs of photosynthesis and there exist a positive relationship between photosynthetic efficiency, leaf area and relative growth rate in crop plants. Higher interception of light and net photosynthetic canopy results in increased dry matter production and yield due to higher leaf area of the plant. Yield or dry matter production for different crop is

Table 4: Mean values of agronomic traits of 12 maize genotypes with different maturity groups evaluated in 2014 and 2015

Variety	AEPAL	BEPAL	NLL	TLN	Percent RL	GYD (T/ha)
Early						
EVDT-W99	5.42a	6.33a	6.17a	16.00a	66a	3.53a
DMR-ESR-W	5.17a	6.33a	5.33bc	16.50a	68a	4.13a
TZE-YPOPDT	5.17a	6.17a	5.17c	16.50a	69a	3.89a
POOL-18SR	5.42a	5.92ab	5.66b	16.91a	67a	3.77a
Mean	**5.29**	**6.18**	**5.58**	16.47	67	3.83
Intermediate						
ART/98/SW5-OB	5.52a	6.53a	6.00a	18.08a	67a	3.96a
POP66-SR/ACR 91	5.42a	6.33a	6.17a	17.92a	66a	3.84a
ILE-1-OB	5.67a	6.58a	5.92a	18.25a	68a	4.39a
ART/98/SW6-OB	5.50a	6.67a	5.92a	18.08a	67a	3.63a
Mean	**5.52**	**6.52**	**6.00**	18.08	66	3.96
Late						
SYNLDFO/OBANTAPA	5.83a	7.33ab	6.17a	19.33a	68a	3.86a
SYNLDFO/OBAT	5.83a	7.66ab	6.07a	19.50a	69a	3.86a
SYNLDFO/OBAT/TZL	5.92a	7.25b	6.67a	19.83a	66a	4.19a
OBANTAPA/TZLCOMP	5.42b	7.92a	6.08a	19.42a	69a	3.77a
Mean	**5.75**	**7.54**	**6.25**	19.52	67	3.92

Means with the same letter in each column are not significantly different at P< 0.05 using Duncan's multiple range test.

AEPAL=Above Ear Photosynthetically Active Leaf; BEPAL= Below Ear Photosynthetically Active Leaf; AEP/BEP=Ratio of above and below ear Photosynthetically Active Leaf; PAL=Photosynthetically Active Leaf; NLL= Number of Lost Leaf; TLN= Total Leaf Number;
Percent RL=Percent retained leaf; GYD-Grain Yield (T/ha)

Table 5: Pearson's correlation coefficients (N=36) between phonological and yield in 12 maize genotypes of different maturity groups.

	Grain Yield		
	Early	Intermediate	Late
AEPAL	0.52*	0.27	0.02
BEPAL	0.27	0.49*	-0.24
PAL	-0.39	-0.16	-0.21
NLL	-0.41	-0.78**	0.06
TLN	-0.37	-0.21	-0.13

*, **and *** significant at P<0.05, 0.01 and 0.001 respectively.
AEPAL= Above ear photosynthetically active leaf; BEPAL=Below ear Photosynthetically active leaf; PAL= photosynthetically active leaf; NLL=Lost leaf; TLN= Total leaf number;
GYD= Grain Yield (T/ha).

closely related to the interception of photosynthetically active radiation (Monteith and Elston, 1983), which itself is a direct function of leaf development. From the result, storage duration affect the proportion of leaves above the ear. The above ear canopy was lighter during the first trial period with thicker below ear canopy. These brought lesser mutual shading of the leaves above the ear and ear leaf from the leaves on the upper layer of the canopy thereby exposing the leaves to where fluxes of photosynthesis photon and atmospheric CO_2 are highest and hence higher yield.

Higher percent retained leaves during the first trial connotes increased stay green, hence more assimilate deployed to the kernel and the resultant good yield. The crucial role of leaves above ear during the grain-filling stage in corn was established. It was interesting to note from this study that although the maize in late maturing group had more above ear leaf than those in other maturing groups, grain yield was not statistically different. This could possibly be as a result of sink limitation in late maturing genotypes which was evident by the result of laboratory seed quality assessment on one hundred seed weight which was lower in both intermediate and late maturing genotypes. This corroborates the results of Andrew *et al*. (2000) who reported that despite the greater amount of carbohydrates in the leafy hybrids, grain yields were not greatly increased. This indicates that the kernel component of maize provide a weak sink. Late maturing maize genotypes produced three and two leaves more than early and intermediate genotypes, respectively. This is in agreement with the earlier findings of Kamara *et al*. (2009).

These leaves were mainly below the ear in late maturing genotypes which contributes less to the overall grain yield as was noticed in this result. Rate of leaf senescence as measured by percent retained leaf during the grain-filling period were similar for all the maturity groups. This could result in similar light interception, rate and duration of grain filling by green leaf area which could have accounted for similar grain yield among the three maturity groups. The uniformity among the genotypes used in each of the maturity groups is an indication of genetic similarity among the different maturity groups as regard leaf number and placement. The significant and strong positive relationship that existed between photosynthetically active leaf traits indicates similarity in trend. The result clearly indicates that yield reduction over storage duration was as a result of seed ageing that influenced the rate of plant development according to the average value of seedling vigor index (data not shown) over storage durations observed in the laboratory seed quality assessment. This corroborates the findings of Ghassemi – Golezani and Dalil (2011).

The contribution of both the AEPAL and BEPAL were clearly spelt out by their r values. The r values of 0.52, p=0.05 between AEPAL and yield in early maturing genotypes and 0.49, p=0.05 for BEPAL in intermediate, respectively indicates that AEPAL contributes more to grain yield in early and the BEPAL in intermediate genotype. The leaves above the ear are crucial to maize grain yield due to their strategic position in the canopy, i.e. being in upper layer of the canopy where fluxes of photosynthetic photons and atmospheric CO_2 are highest. They are also generally younger than the leaves below. They are expected to be photosynthesizing at or near their maximum capacity, and are therefore able to produce more photo-assimilates during grain filling. This result is in contrast with previous works of Subedi and Ma (2005). They reported that the major contribution to ear development and final grain yield are made by the earleaf and all leaves below the ear leaf. Furthermore, it is consistent with the report of Edmeades *et al*. (2000). They reported that assimilates moved preferentially from a leaf to its nearest sink. This implies that leaves above and immediately below the primary ear supply most of the assimilates for grain filling, while assimilates from the lower leaves are more likely to be translocated into the root and lower stem

Conclusion

In this study, it was concluded that the seed sowing value at the beginning of storage and 3 months afterwards had comparable grain yield. There were yield loss of about 17% and 25% after 9 and 15 months in storage. This indicates that sowing of stored seed lots at about or after one year storage period might be of economic loss when planted. It is therefore suggested that maize seed be stored not beyond six months before planting.

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