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Performance of Half-Sib Progenies Developed from an Early Maturing Maize (*Zea mays* L.) Population in a Rain-Forest Location

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Authors' contributions

This work was done in collaboration among all the three authors. Author AOF managed the study and literature search and wrote the first draft of the manuscript. Authors AO and MABF designed and supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

Problem: Half-sib progenies were developed in a maize breeding program of the Department of Crop Production and Protection of Obafemi Awolowo University Ile-Ife, Nigeria but have not been evaluated for further improvements.
Aims: Therefore, this study was undertaken to evaluate the performances of the half-sib progenies, as well as estimate and determine the association among selected traits.
Study Design: 160 half-sib progenies each developed in the late planting seasons of 2013 and 2014 from an early maturing maize population were used for this study. Each of the field trials were laid out in a 16 x 10 incomplete block design and replicated twice.
Place and Duration of Study: The study was conducted during the early and late planting seasons of 2015 at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife (7º28'N 4º33'E and 244 m above sea level).
Methodology: All data collected were subjected to Analysis of Variance (ANOVA) and means were separated using Least Significant Difference (LSD) at 0.05 probability level. Genotypic and phenotypic variances were generated to calculate heritability estimates for all traits taken.
Results: The results observed showed highly significant differences ($P < 0.01$) between seasons

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and among half-sib progenies from both years of development for all traits. Half-sib progenies developed in 2014 were also observed to perform better than those developed in 2013 for all traits studied. Heritability was high (72%) for ear height for the 2013 developed half-sib progenies and moderate at 45% for the 2014 half-sib progenies and this trait had highly significant and positive correlations with yield.

Conclusion: It was concluded that sufficient genetic variability existed among the progenies that could be exploited to improve the population. However, it was recommended that these progenies could also be evaluated in multiple locations to ascertain their adaptability and performance.

Keywords: Half-sib progeny; maize; heritability; variability; evaluation.

1. INTRODUCTION

Two broad agro-ecologies; forest and savannah, with contrasting climatic conditions and differing vegetation distribution were identified in Nigeria [1,2]. The adaptability of maize to either agro-ecology has allowed for the crop to be one of the most cultivated in Nigeria. The rainforest once contributed 50% of the total maize grain output with the other agro-ecologies providing the rest. However, a dramatic shift has resulted in a production reversal with the Northern-guinea savannah now referred to as the maize belt of Nigeria. Despite the potential of a large maize grain output from the rainforest agro-ecology, where it is commonly believed that crops can be cultivated anytime due to favorable weather conditions for rain-fed agriculture, an inherently poor soil, the incidences and poor management of pest and diseases, and even more recently, the recurrent drought and increasing rates of false starts of the rains due to changes in climatic conditions, have been reported as being responsible for the reduced output of maize [3,4].

Continuous efforts are being made to increase the contribution of the rainforest agro-ecology to the overall maize grain output of Nigeria, with emphasis laid on breeding higher yielding varieties to meet local and international demand through the release of stress-tolerant, disease and pest resistant and drought tolerant maize varieties [5]. For developing high yielding varieties to increase yield per unit area, several methods of selection have been employed by maize breeders. These include mass-selection, full-sib selection, selfed-progeny selection and half-sib selection. These selection procedures are preceded by controlled pollination processes to develop the progenies that are used in the procedures [6].

Pollination is the transfer of pollen grains from the anther to the stigma of a flower. Maize is monoecious – having both male and female parts on the same plants and generally protrandrous, where the male spikelets mature earlier than the female spikelets. This protrandrous nature coupled with the small, barely visible and light wind-borne pollen produced by the plant facilitates a high cross pollination percentage, almost 95% with a 5% chance of self-pollination [7]. To minimize contamination by unwanted pollen, controlled pollination procedures are employed, where the objective is to apply the chosen pollen to the chosen silks. It involves identifying the parent plants, male (for plants that will supply the pollen) and female (for plants that will provide the stigma). Several pollination techniques have been identified.

In the production of S_1 or selfed progenies, the pollen from an identified, randomly selected parent is transferred to the stigma on that same plant. This form of pollination is called selfing [8].

Full-sib progenies are produced from a pollination procedure involving just a pair of parents where pollen from an identified male plant is transferred to the stigma of another randomly identified female plant and vice-versa in that same pair. The seeds harvested from these two plants are referred to as full sibs [9].

Bulk sibbing is a pollination procedure where pollen from several randomly selected male plants are collected and transferred to the stigma of several randomly selected female plants which may or may not include the male plants. The seeds harvested from this procedure are termed bulk or mass sibs [10].

Half-sib progenies are developed from a half-sibbing pollination procedure where pollen from an identified, randomly selected male plant is transferred to the stigma of several other randomly identified female plants. All the seeds produced from this pollination procedure are termed half-sibs. Half-sib progenies are most commonly used in breeding programs for the improvement of maize populations because of the large pool of genetic variability they provide for exploitation [11]. They also combine the advantages of having a reduced inbreeding depression (peculiar to the selfed progeny method), an increased number of seeds available for evaluations (a disadvantage of both the full-sib and selfed progeny development methods) and identification of parent material involved (a disadvantage of the mass/bulk sib pollination procedure) [12].

The dynamic nature of constraints facing maize production in the rain-forest location and the advantages of half-sib progenies in population improvement necessitated the development of half-sib progenies by the maize breeding program of the Department of Crop Production and Protection, Obafemi Awolowo University to meet future contingencies. Therefore, the study was conducted to evaluate the performances of the developed half-sib progenies, determine and estimate the association among some selected traits for further improvements of the maize lines.

2. MATERIALS AND METHODS

Field trials were conducted at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife (7º28'N 4º33'E and 244 m above sea level), a typical rainforest agro-ecology. The experimental materials used were 160 half-sib progenies each, which had been developed in the late planting seasons of both 2013 and 2014, from an early maturing, yellow endosperm maize population. The experiments were laid out in a 16 x 10 randomized incomplete block design, replicated twice in each planting season of 2015. Planting during the early season evaluation was done on May 4th, while the late season evaluation planting was done on September 15th. Seeds were treated prior to planting with Apron-plus and sown in 5 m long single row plots at a spacing of 0.75 m apart by 0.50 m within at the rate of 2 seeds per hill bringing total plant population to 53,333 plants per hectare. A pre-emergence herbicide was applied after planting, with subsequent hand weeding done as deemed necessary. Fertilizer was applied on the 3rd and 5th week after planting. Data were collected on emergence count at the 9th day after planting from which emergence percentage was derived, number of days to 50% tasseling, anthesis and silking, ASI (anthesis-silking interval), Plant and ear heights. At harvesting, the number and weight of ears per plot and moisture content were taken. Kernel Row Number, Ear Length, Ear Diameter were obtained from the averages of 5 randomly selected ears per plot.

2.1 Statistical Analysis

All data collected were subjected to Analysis of Variance (ANOVA).Genetic variances were computed from the respective mean squares of the analysis of variance and estimates of heritability were calculated from these variances. Pearson correlation analysis between all traits measured was also carried out.

Heritability (H) is then calculated as; $\frac{\sigma^2_g}{\sigma^2_p}$

$$= \frac{\sigma^2_g}{\frac{\sigma^2_e}{re} + \frac{\sigma^2_{(ps)}}{e} + \sigma^2_g}$$

and

$$\sigma^2_p = \frac{\sigma^2_e}{re} + \frac{\sigma^2_{(ps)}}{e} + \sigma^2_g$$

Heritability was categorized as low when less than 30%, medium when between 30 and 60%, and high when above 60% as suggested by Langade et al. [13].

3. RESULTS

Mean squares from analysis of variance showed highly significant differences ($P \leq 0.01$) between seasons and among half-sib progenies from both 2013 and 2014 developed progenies for all the traits studied (Table 1). The highest coefficient of variation values was obtained for Anthesis Silking Interval (ASI) and yield from the 2013 and 2014 half-sib progenies while the coefficient of determination (R^2) value was at least 70% for all traits and among half-sib progenies from both 2013 and 2014 developed progenies. It was observed that in the first planting season, the 2014 half-sib progenies had significantly higher means than half-sib progenies developed in 2013 for days to tasseling and ASI while there were no significant differences for the other studied traits (Table 2). In contrast, during the late season evaluation, means of days to 50% tasseling and ASI were not significantly different, while significantly higher means were observed for the 2014 half-sib progenies compared to the 2013 half-sib progenies for the other traits. Highest heritability estimate values were observed for ear height (72%) among the half-sib progenies that were developed in 2013 (Table 3).

Table 1. Mean squares from the analysis of variance for half-sib progenies developed in both 2013 and 2014 late planting seasons and evaluated in early and late planting seasons of 2015 at the Teaching and Research Farm, OAU, Ile-Ife

Source of variation	Df	E%	TS	ASI	EHT	EWT	KMOIST	ED	EL	KRN	SP	Yield
2013												
Block (Rep X Sea)	36	1448.33**	12.05**	19.19**	181.06**	0.18**	4.93**	0.85**	4.59**	3.15**	96.99	0.91**
Rep /Sea	2	140.92	399.53**	42.81**	859.70**	1.35**	44.08**	0.02	24.82**	6.07*	20.89	6.78**
Sea	1	2441.41**	1654.44**	1531.41**	217852.07**	174.45**	12644.25**	213.66**	2333.66**	746.03**	3478.75**	668.71**
Pro	159	530.64**	24.05**	8.08**	215.88**	0.19**	4.76**	0.64**	4.66**	6.23**	241.09**	0.86**
Sea X Pro	159	220.87	25.04**	4.11	60.72	0.14**	5.19**	0.53**	2.9**	5.11**	250.14**	0.60**
Error	282	213.89	3.43	4.16	56.89	0.09	2.38	0.31	1.17	1.84	97.52	0.43
CV		20.48	3.5	76.69	11.59	44.16	9.48	14.93	9.21	11.94	12.83	46.22
R^2		0.78	0.92	0.81	0.95	0.89	0.96	0.83	0.92	0.85	0.76	0.89
2014												
Block (Rep X Sea)	36	689.59**	24.87**	32.51**	564.74**	0.13**	3.45*	0.31**	7.27**	7.45**	113.91	0.56**
Rep/Sea	2	474.30*	9.16	31.10**	376.23**	0.002	12.82**	0.84**	9.71**	28.52**	124.16	0.08
Sea	1	91550.10**	305.26**	2095.26**	152578.30**	156.51**	10556.0**	230.81**	2099.02**	454.87**	24.15	570.48**
Pro	159	252.3**	7.22**	8.02**	153.44**	0.17**	3.01**	0.10**	2.32**	2.06**	108.29	0.72**
Sea X Pro	159	218.02**	3.70	6.26	83.22*	0.16**	2.51*	0.07*	1.66*	2.09**	131.84**	0.71**
Error	282	155.05	3.25	5.13	66.55	0.06	1.9	0.05	1.27	1.47	93.19	0.27
CV		15.8	3.42	77.09	11.57	30.71	8.54	6.13	9.26	10.27	12.34	32.97
R^2		0.81	0.77	0.79	0.91	0.92	0.95	0.94	0.89	0.76	0.59	0.91

**, ** Significant at 0.05 and 0.01 levels of probability respectively, E% - Emergence Percentage, TS – No of Days to 50% Tasseling, ASI – Anthesis – Silking Interval, EHT – Ear Height, KRN – Kernel Row Number, EWT – Fresh Ear Weight, KMOIST – Moisture Content, ED – Ear Diameter, EL – Ear Length*

The heritability estimates for other traits among half-sib progenies from both 2013 and 2014 ranged between low and moderate. Negative genotypic variances were observed for tasseling among the 2013 half-sib progenies and for KRN and shelling percentage for the 2014 half-sib progenies.

Correlation coefficients among all traits taken for the half sibs progenies developed in late seasons of 2013 and 2014 and evaluated during the early and late cropping seasons of 2015 are presented in Tables 4, 5, 6 and 7. Negative and highly significant correlation of emergence percent with all measured flowering traits, ear diameter, ear length and kernel row number were observed for half-sib progenies developed in the late planting season of 2013 and evaluated in the early cropping season of 2015 (Table 4). The relationship between emergence percent and ear Number were however positive and highly significant (Table 4). Negative correlations between days to flowering (Tasseling, Anthesis, Silkng) and ear number and weight, ear diameter and yield were also obtained from the early season planting for the progenies developed in the season of 2013 (Table 4). Highly significant positive correlations were observed between plant and ear heights, yield components (ear number and weights, ear diameter, ear length, shelling percentage) and yield except kernel moisture which had a significant negative correlation with yield (Table 4). On the other hand, highly significant positive correlations were observed between the emergence percent and the flowering traits (days to tasseling, anthesis and silking and anthesis silking interval), ear number and weights, shelling percentage and yield (Table 5). Significant negative correlation existed between ear number, ear weight, days to silking and anthesis silking interval while significant positive correlations existed between kernel moisture, ear diameter, ear length, kernel row number, shelling percentage and days to tasseling, anthesis and silking except for the anthesis silking interval which had negative correlations with these yield components (Table 5).

Table 2. Emergence, reproductive, vegetative, yield and yield components traits of both 2013 and 2014 developed half-sib progenies evaluated during the early and late cropping seasons of 2015 at the Teaching and Research Farm, OAU, Ile-Ife

		MEAN ± SEM	
Traits$^{\$}$		**Early**	**Late**
E%	**2013**	73.37±1.249	69.46±1.306
	2014	66.85±1.146	90.77±0.798
TS	**2013**	50.88±0.111	54.09±0.386
	2014	52.06±0.161	53.44±0.159
ASI	**2013**	1.11±0.114	4.21±0.194
	2014	1.13±0.112	4.75±0.219
EHT	**2013**	83.54±0.761	46.64±0.661
	2014	85.92±0.706	55.04±0.655
EWT	**2013**	1.23±0.032	0.18±0.008
	2014	1.28±0.033	0.29±0.011
KMOIST	**2013**	20.71±0.079	11.822±0.166
	2014	20.2±0.082	12.08±0.111
ED	**2013**	4.33±0.019	3.17±0.056
	2014	4.42±0.016	3.22±0.019
EL	**2013**	13.67±0.086	9.85±0.143
	2014	13.99±0.087	10.36±0.092
KRN	**2013**	12.45±0.067	10.29±0.187
	2014	12.64±0.064	10.94±0.100
SP	**2013**	79.31±0.416	74.64±1.195
	2014	78.42±0.450	78.26±0.780
YIELD	**2013**	2.44±0.066	0.39±0.019
	2014	2.53±0.069	0.64±0.028

$^{\$}$-Check Table 1 for meaning of abbreviations

Table 1. Estimates of genetic variability parameters and heritability for half-sib progenies from both 2013 and 2014 evaluated at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife in 2015

Traits$	E%	TS	ASI	EHT	EWT	KMOIST	ED	EL	KRN	SP	Yield
2013											
G*E Variance	3.49	10.81	-0.03	1.92	0.03	1.39	0.11	0.87	1.64	76.31	0.085
Genotypic Variance	77.44	-0.25	0.99	38.79	0.01	-0.11	0.03	0.44	0.28	-2.26	0.07
Phenotypic Variance	132.66	6.01	2.02	53.97	0.05	1.19	0.16	1.17	1.56	60.27	0.22
Heritability (%)	58	-4	49	72	26	9	17	38	18	-4	32
2014											
G * E Variance	31.49	0.23	0.57	8.34	0.05	0.31	0.01	0.19	0.31	0.12	0.22
Genotypic Variance	8.57	0.88	0.44	17.56	0.003	0.1	0.01	0.17	-0.01	-5.89	0.0025
Phenotypic Variance	63.08	1.81	2.01	38.36	0.04	0.75	0.03	0.58	0.52	17.47	0.18
Heritability(%)	14	49	22	46	6	17	3	28	-2	-34	1

Equate all negative variances and heritability estimates to zero (0) $-Check Table 1 for meaning of abbreviations

Table 2. Pearson correlation among all traits of 160 half-sib progenies developed in the late season of 2013 and evaluated in the early planting season of 2015 on the Teaching and Research Farm, OAU, Ile-Ife

	E%	TS	ANTH	SILK	ASI	EHT	PHT	ENO	EWT	KMOIST	EAR DIAM	EAR LENG	KRN	SH%
TS	-0.20**													
ANTH	-0.19**	0.92**												
SILK	-0.28**	0.71**	0.74**											
ASI	-0.21**	0.12*	0.07^{ns}	0.72**										
EHT	0.07^{ns}	-0.28**	-0.30**	-0.39**	-0.26**									
PHT	0.03^{ns}	-0.26**	-0.26**	-0.35**	-0.24**	0.83**								
ENO	0.20**	-0.29**	-0.31**	-0.28**	-0.09^{ns}	0.22**	0.22**							
EWT	0.10^{ns}	-0.30**	-0.32**	-0.36**	-0.21**	0.40**	0.40**	0.86**						
KMOIST	0.13*	0.13*	0.10^{ns}	0.15**	0.12*	-0.15**	-0.20**	-0.20**	-0.24**					
EAR DIAM	-0.13*	-0.14**	-0.17**	-0.27**	-0.23**	0.27**	0.29**	0.27**	0.47**	-0.11*				
EAR LENG	-0.18**	-0.07^{ns}	-0.04^{ns}	-0.12*	-0.14*	0.27**	0.40**	0.29**	0.50**	-0.15**	0.35**			
KRN	-0.11*	0.02^{ns}	-0.01^{ns}	0.002^{ns}	0.01^{ns}	0.19**	0.17**	-0.001^{ns}	0.10^{ns}	0.06^{ns}	0.38**	-0.01^{ns}		
SH%	-0.04^{ns}	-0.07^{ns}	-0.08^{ns}	0.01^{ns}	0.10^{ns}	0.07^{ns}	0.08^{ns}	0.16**	0.17**	-0.01^{ns}	0.04^{ns}	0.18**	0.10^{ns}	
YLD	0.08^{ns}	-0.30**	-0.31**	-0.34**	-0.19**	0.39**	0.39**	0.84**	0.98**	-0.27**	0.45**	0.49**	0.11*	0.34**

, Significant F-Test at 0.05 and 0.01 levels of probability respectively, ^{ns} – Not Significant, E% - Emergence Percentage, TS – No of Days to 50% Tasseling, ANTH – No of Days to 50% pollen shed/ Anthesis, SILK – No of Days to 50% silking, ASI – Anthesis – Silking Interval, EHT – Ear Height, PHT – Plant Height, ENO – Ear Number, EWT – Fresh Ear Weight, KMOIST Moisture Content, KRN – Kernel Row Number, SH% - Shelling Percentage*

Table 3. Pearson correlation among all traits of 160 half-sib progenies developed in the late season of 2013 and evaluated in the late planting season of 2015 on the Teaching and Research Farm, OAU, Ile-Ife

	E%	TS	ANTH	SILK	ASI	EHT	PHT	ENO	EWT	KMOIST	EAR DIAM	EAR LENG	KRN	SH%
TS	0.19**													
ANTH	0.19**	0.99**												
SILK	0.23**	0.86**	0.86**											
ASI	0.13**	0.03ns	0.02ns	0.52**										
EHT	0.19**	0.16**	0.18**	0.05ns	-0.20**									
PHT	0.10ns	0.23**	0.24**	0.11*	-0.17**	0.73**								
ENO	0.25**	-0.002ns	-0.002ns	-0.13*	-0.26**	0.50**	0.41**							
EWT	0.16**	-0.06ns	-0.06ns	-0.20**	-0.31**	0.56**	0.46**	0.82**						
KMOIST	0.04ns	0.45**	0.44**	0.34**	-0.06ns	0.28**	0.32**	0.18**	0.24**					
EAR DIAM	0.03ns	0.19**	0.19**	0.12*	-0.10ns	0.17**	0.17**	0.11*	0.20**	0.31**				
EAR LENG	0.003ns	0.22**	0.24**	0.13*	-0.13*	0.42**	0.43**	0.28**	0.49**	0.39**	0.40**			
KRN	-0.04ns	0.20**	0.21**	0.04ns	-0.27**	0.33**	0.31**	0.32**	0.43**	0.35**	0.45**	0.58**		
SH%	0.13*	0.22**	0.22**	0.12*	-0.13*	0.33**	0.32**	0.38**	0.37**	0.37**	0.29**	0.44**	0.64**	
YLD	0.16**	-0.09ns	-0.08ns	-0.22**	-0.31**	0.54**	0.45**	0.82**	0.98**	0.21**	0.19**	0.47**	0.44**	0.45**

$^{\$}$ *- Check Table 4 for meaning of abbreviations*

Table 6. Pearson correlation among all traits of 160 half-sib progenies developed in the late season of 2014 and evaluated in the early planting season of 2015 on the Teaching and Research Farm, OAU, Ile-Ife

	E%	TS	ANTH	SILK	ASI	EHT	PHT	ENO	EWT	KMOIST	EAR DIAM	EAR LENG	KRN	SH%
TS	-0.25**													
ANTH	-0.25**	0.95**												
SILK	-0.22**	0.84**	0.84**											
ASI	-0.07ns	0.24**	0.17**	0.68**										
EHT	0.04ns	-0.28**	-0.29**	-0.36**	-0.27**									
PHT	-0.07ns	-0.17**	-0.18**	-0.24**	-0.19**	0.82**								
ENO	0.21**	-0.11ns	-0.12*	-0.14**	-0.09ns	0.13*	0.11ns							
EWT	0.06ns	-0.18**	-0.18**	-0.21**	-0.14*	0.32**	0.31**	0.78**						
KMOIST	-0.11*	0.15**	0.15**	0.15**	0.06**	-0.13*	-0.14**	-0.15**	-0.11*					

	E%	TS	ANTH	SILK	ASI	EHT	PHT	ENO	EWT	KMOIST	EAR DIAM	EAR LENG	KRN	SH%
EAR DIAM	-0.04^{ns}	-0.25**	-0.25**	-0.26**	-0.13*	0.36**	0.35**	0.14*	0.35**	0.05^{ns}				
EAR LENG	-0.13**	-0.16**	-0.16**	-0.21**	-0.17**	0.40**	0.44**	0.20**	0.42**	-0.05^{ns}	0.35**			
KRN	-0.09^{ns}	-0.07^{ns}	-0.07^{ns}	-0.07^{ns}	-0.03^{ns}	0.20**	0.20**	0.06^{ns}	0.16**	0.05^{ns}	0.46**	0.10^{ns}		
SH%	-0.03^{ns}	-0.10^{ns}	-0.07^{ns}	-0.08^{ns}	-0.06^{ns}	0.18**	0.15**	0.02^{ns}	0.09^{ns}	-0.05^{ns}	0.09^{ns}	0.15**	0.11*	
YLD	0.05^{ns}	-0.20**	-0.20**	-0.22**	-0.14**	0.34**	0.33**	0.74**	0.97**	-0.16**	0.35**	0.43**	0.16**	0.32**

[$] - Check Table 4 for meaning of abbreviations

Table 4. Pearson correlation among all traits of 160 half-sib progenies developed in the late season of 2014 and evaluated in the late planting season of 2015 on the Teaching and Research Farm, OAU, Ile-Ife

	E%	TS	ANTH	SILK	ASI	EHT	PHT	ENO	EWT	KMOIST	EAR DIAM	EAR LENG	KRN	SH%
TS	0.02^{ns}													
ANTH	0.03^{ns}	0.93**												
SILK	0.01^{ns}	0.51**	0.55**											
ASI	-0.004^{ns}	0.006^{ns}	0.006^{ns}	0.84**										
EHT	-0.02^{ns}	-0.34**	-0.37**	-0.39**	-0.22**									
PHT	0.02^{ns}	-0.44**	-0.46**	-0.46**	-0.25**	0.82**								
ENO	-0.02^{ns}	-0.28**	-0.31**	-0.59**	-0.50**	0.38**	0.47**							
EWT	0.02^{ns}	-0.29**	-0.32**	-0.59**	-0.50**	0.44**	0.54**	0.78**						
KMOIST	0.10^{ns}	0.19**	0.19**	0.15**	0.06^{ns}	0.02^{ns}	0.03^{ns}	0.02^{ns}	0.06^{ns}					
EAR DIAM	0.04^{ns}	-0.23**	-0.21**	-0.44**	-0.39**	0.30**	0.38**	0.32**	0.53**	0.08^{ns}				
EAR LENG	-0.01^{ns}	-0.24**	-0.22**	-0.45**	-0.39**	0.29**	0.43**	0.34**	0.58**	0.03^{ns}	0.54**			
KRN	0.02^{ns}	-0.29**	-0.29**	-0.48**	-0.38**	0.29**	0.36**	0.33**	0.46**	-0.12*	0.64**	0.44**		
SH%	-0.01^{ns}	-0.02^{ns}	-0.01^{ns}	-0.11*	-0.13*	0.07^{ns}	0.12*	0.13*	0.11*	-0.13*	0.07^{ns}	0.09^{ns}	0.16**	
YLD	0.01^{ns}	-0.30**	-0.33**	-0.59**	-0.49**	0.43**	0.54**	0.77**	0.97**	0.01^{ns}	0.50**	0.56**	0.45**	0.32**

[$] - Check Table 4 for meaning of abbreviations

The trend of highly significant positive correlations between yield, plant height, ear height and yield components observed in the early season with progenies developed in 2013 were also observed with the progenies developed in 2014 and evaluated in the early season of 2015 (Table 5). Similar trends of results were also observed for the 2014 developed half sib progenies and evaluated in the early and late planting seasons of 2015 (Tables 6 and 7).

4. DISCUSSION

The significant differences observed between the seasons for all the traits studied, were due to the planting conditions that characterized the two seasons of evaluation in 2015. The early planting season evaluation was done when the rains had stabilized, while the evaluation in the late season was done towards the end of the late planting season of 2015 and at the onset of terminal drought. There had been just enough soil moisture to support plant growth. However, with the cessation of rainfall and increased temperatures, half-sib progenies from both 2013 and 2014 were exposed to terminal drought resulting in prolonged flowering, poor grain-filling and subsequent reduced yield. This is supported by reports from Hu and Buyanovsky [14], who had shown that crop germination, growth and yield were greatly determined by various rainfall conditions such as peak of rain, false start of rainfall and retreat of rainfall as well as temperature. Maize is a cross pollinator and exhibits heterozygosity at most of its loci. The method of development of progenies and the sizeable number of half-sib progenies that had been evaluated from each year significantly increased the gene pool. This explains the significant differences observed among the half-sib progenies for all the traits, within each year of development, an indication of the large variation among the progenies for the studied traits. Similar observations had been made by Hidayat et al. [15] and Noor et al. [16]. The high coefficient of determination (R^2) values for all the traits within each year of development indicates that the statistical model employed was adequate to explain the variations that had been observed. The high CV values that were observed for yield and ASI from both years of development suggests the considerable influence of unexplained factors on the expression of these traits during the conduct of the trial. The higher means observed for days to tasseling and ASI for the 2014 half-sib progenies compared to the lower means of 2013 during the early season evaluation in 2015 indicates a better seed set and a more efficient allocation of dry matter to the grains that is the result of lengthier flowering periods resulting in better quality grains corroborated by results from Oluwaranti et al. [17] who compared maize varieties from differing maturity groups under optimum planting conditions and reported better quality grains for late maturity group due to lengthier flowering periods compared to the varieties from other maturity groups. Yield of both the 2013 and 2014 half-sib progenies were not significantly different from each other as obtained by results from the 2015 early planting season. Adebo and Olaoye [18] reported similar results in their comparisons of maize hybrids from different breeding periods under optimum planting conditions and concluded that any differences observed in yield are due, more to the inherent potential of the seeds than the periods in which they were developed. By contrast, during the late planting evaluation in 2015, means for tasseling, ASI, moisture content and shelling percentage of both the 2013 and 2014 half-sib progenies were not significantly different from each other. These traits are maturity determinants as the base population from which the half-sib progenies were developed from, were of the early maturity group. This is corroborated by results from Rahman et al. [19] who reported that flowering traits, moisture content and shelling percentage could be used in the determination of the maturity groups of maize. However, since the half-sib progenies from both 2013 and 2014 may have been developed from the same base population, a greater tolerance for reduced soil moisture and water-availability must have been conferred on progenies developed in 2014 compared to progenies developed in 2013 as shown by the significantly higher means of all the other traits (emergence percentage, ear and plant heights, ENO, EWT, KRN, and Yield). Proponents of genetic variation postulate that genes within a population change as determined by the environment, where more favorable traits are passed on as a whole. While the better performance of the half-sib progenies developed in 2014 may be attributable to reduction in seed quality due to a lengthier storage of the 2013 half-sib progenies' seeds compared to those of 2014, higher temperature and reduced rainfall were recorded during the 2014 progeny development procedures compared to 2013. This may have resulted in a greater tolerance of the 2014 half-sib progenies to the reduced moisture that was characteristic of the late season evaluation. Contrasting results for all variance parameters and heritability estimates for the same traits for both the 2013 and 2014 half-sib progenies are a further indication of the differing degrees of genetic contribution to the expression of the traits. The low to moderate heritability estimate values obtained for most traits also suggest the considerable influence of the environment on the expression of these traits. Ear height seemed least influenced by the environment although its high heritability reduced from 72% observed among the 2013 half-sib progenies to the moderate heritability obtained among the 2014 half-sib progenies. Because of the negative genotypic variances that were obtained for days to tasseling and shelling percentage among half-sib progenies developed in 2013, it is assumed there is no genetic variation among progenies for these traits. The same is also assumed for KRN and SP among the 2014 half-sib progenies. The negative genotypic variances affected the values for the estimate of heritability that was obtained for these traits. ASI and yield had moderate heritability values among the 2013 half-sib progenies, while for these same traits, heritability values were low for half-sib progenies that had been developed in 2014. Similar results were reported by Rahman et al. [19] and Ullah et al. [20] for progenies developed in 2013 and 2014 respectively. They collectively opined that the high CVs and considerable influence of the environment on this trait indicates that ASI and yield are polygenically controlled traits.

Correlations help measure the association between traits as well as provide useful information on the nature, extent and direction of selection processes. A poor emergence translates to an eventual poor yield output and vice-versa, an indication of the significant and positive association between emergence and yield. This association was only observed for half-sib progenies developed in 2013. The negative correlation between ASI and yield indicates that lengthier anthesis-silking intervals would result in lower yield. Maize breeders have worked fastidiously in shortening ASI because shorter periods for ASI allow maize to escape stresses induced by drought as well as increase yield and ensure food availability. Higher placed ears resulted in better yield as shown by the positive correlations that exist between these two traits. Nzuve et al. [21] also reported similar results and attributes this to a high dry matter accumulation function carried out by the high number of leaves possessed in the case of tall plants. The positive and significant association that exists between all yield components and yield is an indication of the importance of the contributions of these components to yield output and determination. The lower the values obtained for these components, the more reduced the yield would be. Ear weight and ear number contribute immensely to yield as indicated by the consistently high and positive coefficients observed for these traits with yield compared to the other yield-related traits considered.

5. CONCLUSION

Sufficient genetic variability exists among half-sib progenies from either year of development that could be exploited to improve the population. The year of development of maize progenies from the same base population did not confer similar performances on the half-sib progenies as the 2014 half-sib progenies performed better than the 2013 half-sib progenies for all traits. The variations observed among the progenies were due more to the environment than the genotype. As such, improving the expression of the said traits in the rain-forest location would require that the planting conditions be improved. However, these progenies could also be evaluated in multiple locations to ascertain their adaptability and performance. Ear height, weight and anthesis silking interval had significant positive and negative correlations with yield respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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