Genetic gain in heterosis of maize reciprocal composites

A.O. Kolawole
A. Menkir
E. Blay
K. Ofori

Introduction

Hybrid maize can play an important role in productivity increases in the diverse production environments in sub-Saharan Africa. The development of hybrids requires improvement in breeding efficiency to accelerate the rate of genetic gain. To maximize expression of heterosis in hybrids, the International Institute of Tropical Agriculture (IITA) created two late maturing composites known as TZL COMP3 and TZL COMP4 for a long-term reciprocal recurrent selection (RRS) program. These composites have been subjected to four cycles of RRS to boost agronomic performance of hybrids formed from inbred lines derived from advanced selection cycles (Falconer and Mackay, 1996). The present study was thus conducted to evaluate the effect of selection on genetic gain in heterosis for grain yield and other agronomic traits.

Materials and methods

Two tropical maize composites, known as TZL COMP3 and TZL COMP4, were developed at IITA using the comprehensive breeding system of Eberhart et al. (1967) and was subjected to four cycles of RRS to improve their performance. Parental populations consisting of the original (C_0) and advanced (C_1, C_2, C_3 and C_4) selection cycles of TZL COMP3 and TZL COMP4 were increased using plant-to-plant crosses in a population of more than 1000 plants. Each population cross was generated by crossing 8 rows of one composite with 8 rows of the complementary composite for each of the selection cycles (TZL COMP3 C_0 x TZL COMP4 C_0, TZL COMP3 C_1 x TZL COMP4 C_1, TZL COMP3 C_2 x TZL COMP4 C_2, TZL COMP3 C_3 x TZL COMP4 C_3 and TZL COMP3 C_4 x TZL COMP4 C_4). This allows sampling of more than 100 plants in each composite. The parental populations (10), varietal crosses (5), were evaluated along with a check (IWD C_2 SYN) at four locations for two years in Nigeria for grain yield and other agronomic traits. The trial was arranged in a 4x4 alpha lattice design with three replicates. At each location a genotype was planted in a two rows plot, 5m long with 0.75m spacing between rows and 0.5m spacing between hills.

Fertilizer and field management practices recommended for optimum maize production were used in all the test locations. Grain yield, foliar diseases and other agronomic traits were recorded in this study. Combined analysis of variance across locations was computed in SAS version 9.3 to generate entry means adjusted for block effects. Response to selection was calculated by regression method and percent response per cycle of selection was estimated (Hallauer and Miranda, 1995). Mid-parent heterosis (MPH) was calculated for each trait as suggested by Falconer and Mackay (1996).

Table 1. Trait means and response to RRS of two reciprocal composites evaluated across eight environments in Nigeria.

Traits	Mean					Response cycle^{-1}	% Gain cycle^{-1}	R^2
	C_0 x C_0	C_1 x C_1	C_2 x C_2	C_3 x C_3	C_4 x C_4			
Yield (kg ha^{-1})	5616	6242	6112	6148	6545	176	3	0.69
Days to anthesis	59.39	60.19	60.06	59.67	58.54	-0.22	0	0.28
Days to silk	61.12	62.18	61.77	61.37	60.15	-0.27	0	0.32
Anthesis-silking interval	1.73	1.99	1.71	1.70	1.62	-0.05	-3	0.34
Plant height (cm)	221.17	220.79	217.45	217.49	213.01	-1.96**	-1	0.89
Ear height (cm)	113.30	118.91	113.44	109.37	116.66	-0.28	0	0.02
Husk cover (1-5)	2.46	2.41	2.32	2.26	2.39	-0.03	-1	0.33
Ear aspect (1-5)	2.88	2.64	2.69	2.44	2.45	-0.10*	-4	0.84
Ears/plant	0.95	0.95	1.03	0.97	0.97	0.01	1	0.06
Plant aspect (1-5)	2.74	2.53	2.42	2.25	2.51	-0.07	-3	0.44
Maize streak virus (1-5)	2.00	1.79	1.80	1.89	1.80	-0.03	-2	0.30
Southern corn leaf rust (1-5)	2.52	2.50	2.16	2.25	2.11	-0.11*	-4	0.79
Southern corn leaf blight (1–5)	1.94	1.63	2.07	1.37	1.61	-0.09	-5	0.27
Curvularia leaf spot (1-5)	2.00	2.03	1.90	2.16	1.85	-0.02	-1	0.04

*, ** Significantly different from zero at p < 0.05 and p < 0.01 levels respectively

Table 2. Means for grain yield and some agronomic traits for cycles (C_0 – C_4) of the TZL COMP3 and TZL COMP4 maize populations, their varietal crosses and a check evaluated across eight environments in Nigeria.

Populations and Crosses	Traits											
	Grain yield	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height	Ear height	Husk cover	Ear aspect	Plant aspect	Maize streak virus	Southern corn leaf rust	Southern corn leaf blight	*Curvularia* leaf spot
TZL COMP3													
TZL COMP3 C_0	5249	60	62	2	225.5	116.4	2.5	2.8	2.9	1.9	2.7	1.9	2.0
TZL COMP3 C_1	4815	61	62	2	216.4	113.3	2.4	3.1	2.7	2.2	2.5	1.6	1.9
TZL COMP3 C_2	5076	61	62	2	211.1	105.2	2.4	3.0	2.7	1.9	2.4	1.7	2.0
TZL COMP3 C_3	4375	60	62	2	206.3	108.4	2.6	2.8	2.7	1.9	2.4	2.2	2.0
TZL COMP3 C_4	5257	60	61	2	204.8	116.0	2.4	2.9	2.6	1.8	2.4	2.1	1.9
Gain per cycle	-42.32	-0.06	-0.15	-0.09	-5.16**	-0.57	-0.004	0.01	-0.06	-0.04*	-0.08*	0.10	-0.02
TZL COMP4													
TZL COMP4 C_0	5546	61	62	2	222.8	112.1	2.3	3.0	2.6	1.9	2.5	1.7	2.1
TZL COMP4 C_1	5092	61	63	2	228.2	116.1	2.3	2.9	2.7	1.8	2.6	1.9	2.1
TZL COMP4 C_2	5967	61	63	2	219.8	112.4	2.3	2.7	2.5	2.2	2.6	2.1	1.9
TZL COMP4 C_3	6056	60	62	1	223.6	110.6	2.3	2.7	2.5	1.8	2.1	1.9	2.1
TZL COMP4 C_4	5318	60	61	1	225.2	116.1	2.2	2.7	2.6	1.8	2.1	1.7	2.1
Gain per cycle	50.74	-0.24	-0.35	-0.11	0.02	0.25	-0.01	-0.06*	-0.01	-0.03	-0.12	-0.001	0.004
Grand mean	5275	61	62	2	218.4	112.6	2.4	2.8	2.6	1.9	2.4	1.9	2.0
LSD (0.05)	440	0.6	0.7	0.4	7.7	7.7	0.2	0.2	0.3	0.3	0.3	0.7	0.3
Varietal Crosses													
Grand mean	6132	60	61	2	218.0	114.3	2.4	2.6	2.5	1.9	2.3	1.7	2.0
Check variety													
IWD C2 SYN	5028	60	61	2	210.4	106.4	2.6	3.19	2.9	1.8	2.67	1.5	2.0

*,** significant at the 0.05 and 0.01 probability levels respectively.

Results and discussion

RRS was effective in making significant genetic gain of 3% cycle^{-1} for grain yield and 1% for number of ears per plant. These improvements in grain yield were associated with a significant reduction of -3% in anthesis-silking interval, -1% in plant height, -1% in husk cover, -4% in ear aspect, -3% in plant aspect, -2% in maize streak virus disease, -4% in southern leaf rust, -5% in southern leaf blight and -1% in *Curvularia* leaf spot. These results indicate that the frequency of favorable alleles for grain yield and other traits have been shifted in the desired directions (Table 1).

The effectiveness of RRS as a method of improving maize populations was shown from the performance of the parental populations. The productivity of parental populations and the varietal crosses as well as their agronomic performance improved considerably (Table 2). The average MPH across environments was 16 %. After four cycles of RRS, MPH increased from 4 % to 24 %. Grain yield, number of ears per plant and ear height accounted for positive average heterotic effects, suggesting the presence of nonadditive gene effects. However, average negative estimates for flowering traits, ear aspect, plant aspect and foliar diseases suggest that dominance is towards low value for these traits (Table 3). This results demonstrate that the breeding procedure was effective in improving the target traits and the advanced selection cycles can serve as sources of inbred lines to develop commercial hybrids.



Table 2. Estimates of mid-parent heterosis for yield and other agronomic traits of TZL COMP3 and TZL COMP4 varietal crosses evaluated across eight environments in Nigeria.

Varietal crosses	% MPH								
	Grain yield (kg ha^{-1})	Days to anthesis	Days to silking	Anthesis-silking interval	Ear Aspect (1-5)	Ears per plant	Plant Aspect (1-5)	Southern corn leaf rust (1-5)	Southern corn leaf blight (1-5)
C_0 x C_0	4.04	-1.63	-1.70	-4.04	0.72	4.42	-0.38	-2.64	5.83
C_1 x C_1	26.00	-1.50	-0.85	23.84	-10.97	2.02	-5.27	-1.52	-6.78
C_2 x C_2	10.68	-1.37	-1.59	-8.53	-5.10	8.51	-6.22	-13.94	10.08
C_3 x C_3	17.87	-0.90	-0.55	13.28	-12.13	4.89	-13.98	1.48	-32.58
C_4 x C_4	23.78	-2.57	-2.09	-25.47	-12.6	2.31	-3.79	-6.16	-16.31
Mean	16.47	-1.59	-1.36	-0.18	-8.02	4.43	-5.93	-4.56	-7.95
Gain cycle^{-1}	3.13	-0.13	-0.05	-5.34	-2.78	-0.14	-1.55	-0.40	-7.01
Coefficient of determination (r^2)	0.29	0.11	0.01	0.19	0.59	0.01	0.24	0.01	0.41

Conclusions

- Genetic gain in productivity and improved agronomic performance was observed for most traits in the varietal cross hybrids.
- There was positive heterosis for grain yield and negative heterosis for resistance to foliar diseases in varietal cross hybrids.
- Superior varietal cross hybrids were identified for further testing and eventual release.

Acknowledgement

The financial support of the West Africa Center for Crop Improvement (WACCI) and the International Institute of Tropical Agriculture (IITA) for this study is gratefully acknowledged. Special thanks are also due to the staff of the IITA Maize Improvement Program in Ibadan, Nigeria, for technical assistance.

References

Eberhart, S. A., Harrison, M. N., & Ogada, F. (1967). A comprehensive breeding system. *Theoretical and Applied Genetics*, *37*(4), 169-174.
Falconer, D. S., & Mackay, T. F. C. (1996). *Introduction to quantitative genetics* (4th ed.). Longman Science and Technology, Harlow, UK.
Hallauer, A. R., & Miranda, F. J. B. (1995). *Quantitative genetics in maize breeding* (2nd ed.). Iowa State University Press, Ames, IA, USA.
SAS Institute, (2010). Statistical Analysis Software (SAS) user's guide. Version 9.3. SAS Institute, Inc., Cary, NC.

*adesike@yahoo.com

Presented at InterDrought-V
Hyderabad International Convention Center (HICC)
Hyderabad, India
21-25 February, 2017