Effects of Three Cycles of S_1 Selection on Genetic Variances and Correlations of an Early Maize Population under Drought and Well-watered Environments

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Introduction

Drought is the most important factor limiting maize (*Zea mays* L.) production and productivity in savannas of West and Central Africa (WCA). Annual maize yield loss due to drought is about 15% in the West African savannas. Grain yield losses can even be greater if drought stress occur at the most drought-sensitive stages of crop growth, such as the flowering and grain filling periods (NeSmith and Ritchie, 1992). The drought tolerant and *Striga* resistant early maturing source population, TZE-W Pop DT STR developed by the International Insitutue of Tropical Agriculture (IITA) has undergone five cycles of S_1 family recurrent selection for improved grain yield and other agronomic traits under artificial *Striga* infestation, followed by three selection cycles under drought. The objectives of the present study were to examine (i) the relative changes in genetic variances and heritabilities for grain yield and its components in TZE-W Pop DT C_3 STR C_5 under drought and well-watered conditions; (ii) the genetic correlations among the traits under drought, and (iii) predicted direct and correlated responses to selection for drought-adaptive traits in the population.

Materials and Methods

Sixty S_1 families each were extracted from C_0, C_1, C_2, and C_3 of TZE-W Pop DT C_3 STR C_5. The 240 S_1 families were evaluated in 15 x 16 randomized incomplete block design with two replications under induced moisture stress and well-watered conditions at Ikenne for 2 yr and under terminal drought at Kadawa (a drought-prone environment) during the rainy season of 2011, all in Nigeria. The experimental units were one-row plots, each 3 m long with a row spacing of 0.75 m and intra row spacing of 0.4 m. The induced drought stress experiment was irrigated with 17 mm of water each week until 28 days after planting (DAP) after which irrigation was discontinued for the rest of the growth cycle so that the maize plants relied on stored water in the soil for growth and development. Standard agronomic practices were adopted. Data were recorded on grain yield and other agronomic traits.

Statistical analyses included ANOVA using the MIXED procedure (SAS, 2001), estimation of genetic variance and heritability for each cycle of selection using Restricted Maximum Likelihood (REML) method, with their standard errors calculated using the method of Hallauer and Miranda (1988), predicted gain from selection, based on C_3 alone estimated according to the method of Hallauer and Miranda (1988), realized gain per cycle which was obtained as linear regression coefficient (b-value), percent gain per cycle, which was obtained as 100 (b-value) divided by the intercept, and genotypic correlation coefficients with their standard errors computed with the REML method (Holland, 2006) using procedures MIXED and IML of the SAS system (SAS, 2001).

Results and Discussion

Analysis of variance revealed significant (P<0.01) differences in the cycles of selection for grain yield (Fig. 1) and all other traits except anthesis-silking interval (ASI), root and stalk lodging under drought and well-watered conditions (data not shown). Grain yield ranged from 1081 kg ha^{-1} for C_0 to 2018 kg ha^{-1} for C_3 under drought and 2280 kg ha^{-1} for C_0 to 3507 kg ha^{-1} for C_3 under well-watered environments. Realized gain from selection for yield was 955 kg ha^{-1}, corresponding to 30.5% cycle^{-1} under drought and 352 kg ha^{-1} with a corresponding gain of 16.7% cycle^{-1} under well-watered conditions. Predicted gain based on C_3 was 282 kg ha^{-1} and 583 kg ha^{-1} under drought and well-watered environments, respectively. The high realized gains from selection for grain yield under drought and well-watered conditions were associated with a decrease in days to anthesis and silking, improved plant aspect, ear aspect, delayed leaf senescence, and increased plant height, and ear per plant (EPP).

Genetic variances and heritability estimates generally decreased for grain yield and other traits in advanced cycles under drought and well-watered conditions except for grain yield and ear height under well-watered conditions (Tables 1 and 2). Genetic variances and heritability estimates were higher under drought than under well-watered conditions. Heritability for grain yield ranged from 0.40 for C_3 to 0.69 for C_0 under drought and 0.46 for C_0 to 0.65 for C_1 under well-watered conditions.

Under drought, grain yield was significantly correlated with days to silking, ASI, plant and ear aspects in C_0 to C_2 but not with any other trait in C_3 (Table 3). Under well-watered conditions, grain yield was significantly correlated with plant and ear aspects in all cycles except for ear aspect in C_1 and C_3. Yield was not correlated with plant height in C_0 and C_1 but was significantly correlated with plant height in the advanced cycles under well-watered conditions. Days to silking had positive and significant genetic correlation with plant and ear aspects in the advanced cycles under drought. Plant aspect had positive and significant genetic correlation with ear aspect under drought and well-watered conditions.

Table 1. Estimates of genetic variances and broad-sense heritability of grain yield and other traits of S_1 families derived from cycles of selection in an early white population tested under drought at Ikenne, Nigeria in 2011 and 2012.

	Genetic Variances				Broad-sense Heritability			
	C0	C1	C2	C3	C0	C1	C2	C3
Grain yield (kg ha^{-1})	256608±470**	127835±442**	162704±410**	100657±496**	0.69±0.031	0.54±0.025	0.65±0.029	0.40±0.021
Days to anthesis	1.80±1.22	1.85±1.06	2.11±1.25	0.00	0.22±0.064	0.72±0.033	0.00±0.032	0.00±0.088
Days to silk	3.96±1.73*	3.66±1.44*	4.69±1.83*	3.21±1.59*	0.34±0.051	0.76±0.034	0.97±0.033	0.12±0.075
ASI	0.86±1.22	0.71±1.20	1.35±1.26	0.66±1.08	0.53±0.024	0.50±0.023	0.83±0.028	0.53±0.024
Plant height (cm)	68.06±12.14**	82.52±10.61**	39.56±12.20**	14.92±14.23	0.33±0.032	0.54±0.026	0.99±0.017	0.05±0.055
Ear height, cm	45.78±8.29**	53.15±6.94**	31.89±7.67**	19.78±10.32	0.44±0.029	0.60±0.030	0.99±0.024	0.15±0.039
Husk cover	0.030±0.231	0.019±0.241	0.039±0.223	0.024±0.198	0.43±0.026	0.40±0.018	0.18±0.027	0.28±0.047
Plant aspect	0.053±0.251	0.042±0.211	0.038±0.233	0.022±0.246	0.49±0.030	0.65±0.030	0.16±0.026	0.25±0.039
Ear aspect	0.076±0.240	0.032±0.211	0.025±0.222	0.024±0.228	0.62±0.031	0.59±0.027	0.13±0.023	0.25±0.045
Stay green characteristic	0.038±0.415	0.124±0.378	0.012±0.427	0.063±0.391	0.17±0.041	0.57±0.027	0.59±0.034	0.23±0.045
EPP	0.008±0.096	0.007±0.102	0.008±0.090	0.003±0.089	0.58±0.028	0.57±0.026	0.02±0.030	0.26±0.041

*, ** Significantly different at 0.05 and 0.01 levels of probability.

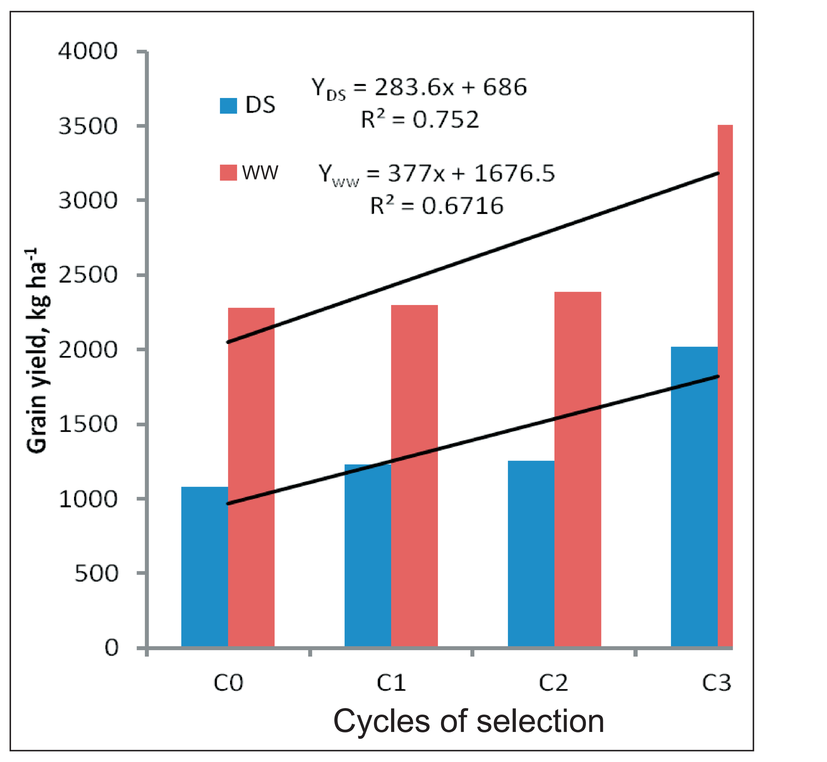

Fig. 1. Grain yield response to three cycles of S_1 selection in TZE-W Pop DT STR maize population

Drought tolerant

Drought susceptible

Table 2. Estimates of genetic variances and broad-sense heritability of grain yield and other traits of S_1 families derived from cycles of selection in an early white population tested under well-watered conditions at Ikenne, Nigeria in 2011 and 2012.

	Genetic Variances				Broad-sense heritability			
	C0	C1	C2	C3	C0	C1	C2	C3
Grain yield(kg ha^{-1})	86173±438**	154875±450**	120601±585**	300151**	0.46±0.035	0.65±0.031	0.51±0.023	0.58±0.035
Days to anthesis	1.23±1.25	1.73±1.02	1.55±1.31	0.00	0.59±0.035	0.71±0.038	0.68±0.032	0.00
Days to silk	1.81±1.33	2.26±1.16	1.86±1.42	0.06±1.48	0.63±0.037	0.76±0.036	0.68±0.032	0.01±0.121
ASI	0.10±0.64	0.12±0.62	0.06±0.62	0.03±0.60	0.33±0.031	0.46±0.021	0.26±0.021	0.21±0.012
Plant height (cm)	45.44±8.47**	13.66±8.88	68.42±8.94**	29.51±8.38**	0.55±0.033	0.29±0.025	0.68±0.032	0.21±0.086
Ear height, cm	17.23±7.04**	14.03±6.78*	0.00	22.37±6.86**	0.41±0.033	0.41±0.027	0.00	0.37±0.053
Root lodging, %	0.044±0.635	0.028±0.749	0.166±0.776	0.00	0.11±0.073	0.09±0.047	0.35±0.034	0.00
Stalk lodging, %	0.085±0.711	0.204±0.758	0.125±0.691	0.00	0.23±0.045	0.37±0.041	0.33±0.037	0.00
Husk cover	0.046±0.279	0.037±0.283	0.044±0.274	0.015±0.271	0.55±0.031	0.46±0.035	0.53±0.033	0.22±0.057
Plant aspect	0.030±0.296	0.054±0.269	0.028±0.294	0.023±0.309	0.45±0.025	0.58±0.034	0.45±0.023	0.29±0.044
Ear aspect	0.027±0.224	0.039±1.086	0.010±0.243	0.005±0.277	0.52±0.032	0.08±0.011	0.32±0.019	0.07±0.075
EPP	0.003±0.224	0.005±0.095	0.001±0.101	0.005±0.101	0.37±0.034	0.61±0.028	0.13±0.023	0.25±0.077

*, ** Significantly different at 0.05 and 0.01 levels of probability.

Table 3. Genetic correlation estimates between selected pair of traits of S_1 families derived from four cycles of selection in TZE-W DT C3 Pop STR C5 under drought at Ikenne and well-watered conditions at Ikenne and Kadawa, Nigeria in 2011 and 2012.

	Drought stress				Well-watered conditions			
Trait	C0	C1	C2	C3	C0	C1	C2	C3
Grian yield vs. days to silk	-0.39	-0.69**	-0.59**	-0.77	-0.20	-0.34	-0.18	0.90
Grian yield vs. ASI	-0.18	-1.00**	-0.63**	-0.61	-0.38	-0.01	-0.52	0.12
Grian yield vs. plant height	0.40	0.21	0.34	0.41	0.19	0.32	0.92**	1.00**
Grian yield vs. husk cover	-0.33	-0.51	-0.43	-0.41	-0.44	-0.02	0.30	0.47
Grian yield vs. Plant aspect	-0.99**	-1.00**	-0.63**	-0.61	-0.81**	-0.81**	-1.00**	-1.00**
Grian yield vs. ear aspect	-1.00**	-1.00**	-1.00**	-1.00	-0.89**	-1.00	-1.00**	-1.00
Days to silk vs. ASI	0.69**	0.71**	0.74**	1.00	0.34	0.35	0.35	1.00
Days to silk vs. plant height	0.61	0.10	1.00	1.00	0.43	0.41	0.14	0.14
Days to silk vs. husk cover	0.33	0.31	0.42	0.79*	0.32	-0.67**	-0.58	-1.00
Days to silk vs. plant aspect	-0.12	0.67**	0.40*	0.94**	0.07	0.32	-0.20	-1.00
Days to silk vs. ear aspect	0.27	0.79**	0.72**	0.42	0.07	-1.00	0.07	-1.00
ASI vs. plant height	0.65	0.01	0.28	0.22	-0.06	-0.48	-0.13	0.66
ASI vs. husk cover	0.88	0.37	0.59*	0.69	-0.13	0.27	0.13	-0.44
ASI vs. plant aspect	-0.24	0.57	0.55*	1.00**	0.94	0.10	0.86	0.32
ASI vs. ear aspect	0.46	0.98**	0.90**	1.00	0.45	-0.34	0.53	-0.58
Plant height vs. husk cover	-0.65*	-0.23	0.06	0.15	-0.60*	0.23	0.10	-0.41
Plant height vs. plant aspect	-0.63*	-0.28	-0.72	1.00	-0.74**	-0.31	-1.00**	-1.00
Plant aspect vs. ear aspect	-0.32	-0.42	0.66	-0.02	-0.34	-1.00	-0.86**	-1.00
Husk cover vs. plant aspect	0.70*	0.41	0.73**	0.53	0.58	0.36	0.11	-0.19
Husk cover vs. ear aspect	0.42	0.61	0.52	0.07	0.40	1.00	-0.03	-1.00
Plant aspect vs. ear aspect	0.99**	0.97**	0.58	0.75*	0.81**	1.00	1.00**	1.00

*, ** Significantly different at 0.05 and 0.01 levels of probability.

Conclusions

In conclusion, the high realized gains from selection for grain yield under drought and well-watered conditions indicated that the S_1 family selection method adopted in our breeding programme has been effective. However, the low genetic variances, heritabilities, and predicted gain cycle^{-1} for grain yield and other traits suggest that there is low genetic variability in the cycle 3 to allow significant gain from selection under the research conditions. Therefore, for significant progress from selection, there is a need to introgress drought tolerant genes into the population.

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