Journal of Plant Breeding and Crop Science Vol. 1(8). pp. 284-292, October, 2009
Available online http://www.academicjournals.org/jpbcs
ISSN 2006-9758 © 2009 Academic Journals

Full Length Research Paper

Comparison of predicted responses to three types of recurrent selection procedures for the improvement of a maize (*Zea mays* L.) population

S. O. Ajala[2], C. E. Ago[1] and G. Olaoye[3]*

[1]National Cereals Research Institute, P. M. B 5042, Ibadan, Nigeria.
[2]International Institute of Agriculture, P. M. B 5320, Ibadan, Nigeria.
[3]Department of Agronomy, University of Ilorin, P. M. B 1515, Ilorin, Nigeria.

Accepted 7 September, 2009

A maize population was subjected to three different selection procedures to determine the best method for its improvement in a study conducted at Ibadan, Nigeria. Considerable genetic variability existed within the population for effective selection for each of the traits considered, using any of the procedures namely full-sib, half-sib and S1 family selection. Heritability estimates were from moderate to large for most traits. Direct selection for grain yield is expected to result in favourable increases in other traits except that the selected materials will flower earlier. Since increases in plant height due to selection for grain yield is undesirable, it was concluded that the best selection method for yield improvement that will increase height, the least would be full-sib family selection.

Key words: Recurrent selection, predicted responses, maize.

INTRODUCTION

Several intrapopulation selection schemes have been proposed for the improvement of grain yield and other traits in maize breeding populations. However, reports from various workers (Burton et al., 1971; Genter, 1973) indicate that methods which are effective in improving one population may not be so for another. Furthermore, various selection procedures differ in effectiveness when applied for the improvement of the same population (Adeyemo, 1986).Information on the magnitude of various components of genetic variation is important in determining the best selection and breeding procedure for a particular set of materials under given circumstances (Obilana and Hallauer, 1974; Subandi and Compton, 1974). Relative efficiency of different selection procedures is dependent on the relative rate of improvement, time and cost of a procedure. Studies comparing effects of different selection procedures exist in the literature (Duclos and Crane, 1968; Moll and Stuber, 1971; Genter, 1973; Horner et al., 1973), however modifications to these procedures are still being investigated. For example, Dhi1lon and Khehra (1989) and Ajala et al. (2007) proposed modifications to the S_1 and full-sib recurrent selection procedures respectively which allow a cycle to be completed in two seasons instead of three. Therefore, estimating and comparing quantitative genetic information for several alternative procedures would aid in identifying the best selection method for improving a specific population. FARZ 23 (096EP6), a well liked and widely cultivated variety in southern Nigeria, is a medium maturing maize population developed by the National Cereals Research Institute (NCRI) in Nigeria from a yellow composite after six cycles of selection for ear prolificacy. Its tendency towards ear prolificacy makes it attractive especially in intercropping systems where this attribute is well expressed and in sole cropping where each stand carry at least a mature cob. This study was conducted to determine the amount of genetic variation present in a maize population, FARZ 23 (096EP6), by using full-sib, half-sib and S_1 families, and to use this information in determining the best selection method by predicting responses to selection for the three procedures.

---

*Corresponding author. E-mail debolaoye@yahoo.com. Tel: +234 8035850557.

MATERIALS AND METHODS

Full-sib (FS), half-sib (HS) and S_1 progenies were generated in the late season of 1987. In the production of S_1 lines, a random sample of about 140 individual plants were selfed and seeds from each plant was bulked at harvest to form a S_1 family; while for full-sibs, a sample of about 250 plants were paired to make controlled reciprocal crosses. At harvest, seeds from each pair was bulked to form a particular full-sib family. In the formation of half-sib families, pollen from an individual plant (male parent) was used to pollinate six other plants (female parents) and at the same time, used to pollinate itself to generate a half- sib family as well as the selfed version of the male parents. Seeds from the female parents of a particular half-sib family were bulked at harvest, while seeds from the male parents were harvested separately in a smaller bag, tied and kept in the bigger bag containing its half-sib progeny. One hundred and twenty half-sib families were generated this way. Finally, a total of 93, 100 and 84 full-sib, half-sib and S_1 families, respectively, were obtained with enough seeds for two plantings each with three replications. The evaluation trials were carried out at the Ibadan station of NCRI in the early and late seasons of 1988. For each planting (environment), single-row plots of 5m in length were used except for S_1 families where rows of 3m length were used due to fewer seed quantity. Replications of progeny types were planted intermixed to enable valid comparisons. Spacing was 0.25m within a row and 0.75m between rows giving a density of approximately 53,333 plants/ha. Hills were double planted but later thinned to one plant per hill after emergence counts but not later than four weeks after planting. A total of 160 kg N, 60 kg K_20 and 60 kg P_20_5 was applied as NPK top-dressed with CAN at anthesis. Weeding of the trials was done manually with hand hoes as necessary.

Data taken from each trial included emergence counts at 5, 7 and 9 days after planting (DAP) and used in estimating Emergence percentage and index. Emergence Index (EI) was calculated as: EI = Σ (Nx) (DAP)/Seedlings emerged 9DAP, Where, Nx is the number of seedlings emerged on a day x. Other agronomic and yield data obtained included days to 50% tasseling and silking, plant height, moisture content at harvest, number of ears per plot and grain yield. To determine grain yield, grain weight/plot was obtained and converted to t/ha at 15% moisture content.

Data from each progeny type were analyzed separately in a randomized complete block design. Ear number, moisture content and grain yield for the second environment (late season) were not included in the combined analysis because there was an abrupt cessation of rains after flowering resulting in severe moisture stress. Analyses of covariance were also performed for each pair of traits. Means were obtained on entry basis for each progeny type, while the expected mean squares (EMS) and mean cross product from analysis of variance and covariance respectively, for each progeny type were used to estimate components of genetic (δ^2g) genotype x environment interaction (δ^2g) environmental (δ^2), phenotypic (δ^2ph) variances and genetic correlations as appropriate. Standard error (SE) for each of the variance components (δ^2_i) except phenotypic variance was calculated as:

$$SE\delta^2_i = [2/C^2 [\Sigma MS_i^2/(df_i + 2)]]^{½}$$

While that for phenotypic variance ((δ^2ph) was computed as:

$$SE(\delta^2 ph) = [(1/re^2)\{2MS_g^2 / (df\, df_1 + 2)\}]^{½}$$

Where;
MS = mean squares for genotype;
df = degree of freedom;
C = coefficient of the component in the EMS for trait I;
r = number of replicates;
e = number of environments.

Heritability (h^2) on entry mean basis was calculated as proportion of the genetic variance (δ^2g) to phenotypic variance (δ^2ph) with its SE also calculated as a proportion of SEδ^2g to SEδ^2ph.

The genetic components of variances were obtained as outlined by Jan-Orn et al. (1976) to obtain by substitution from the following;

$$\delta^2 HS = ¼\,\delta^2_A$$

$$\delta^2 FS = ½\,\delta^2_A + ¼\,\delta^2_D$$

$$\delta^2 S1 = \delta^2_A + ¼\,\delta^2_D$$

$$\delta^2_A = \delta^2_{A*}$$

When p = q = 0.5 or when dominance is lacking (h = 0). δ^2_A, δ^2_D and δ^2_{A*} refer to estimates for additive, dominance and additive action due to average effect of gene substitution.

Predicted response or gain for each type of selection was determined using the formula:

$$\Delta_G = i.c.\delta_{ph}.h^2$$

Where;
i = standardized selection differential often referred to as k;
δ^2ph = phenotypic standard deviation (square root of the phenotypic variance);
c = parental control;
h^2 = the heritability for the trait under consideration. 20% selection intensity was used for all calculations.

For each of the conventional full-sib, half-sib and S_1 selections, parental control was one. In addition, parental control value of two was also used for half-sib and S_1 selection methods. Parental control value of two can be obtained for each of the two methods if the selfed male parent from each selected half-sib family or if corresponding S_2 seeds generated from selected S_1's respectively, were used for recombinations. For example, concurrent with the evaluation trials, S_2 seeds were generated from individual S_1 families Gains/season or generation were obtained by dividing gain/cycle by the number of seasons for each procedure. For each of the three methods, three seasons are normally required to complete a cycle. But for both full-sib and S_1 selection methods, two seasons/cycle are feasible based on recent modifications to the two procedures respectively, proposed by Compton and Lonnquist (1982) and Dhillon and Khehra (1989). However, with two seasons per cycle in S_1 selection, parental control value of 2 is not possible. Correlated responses to selection were calculated as:

$$CR_{y(x)} = i_x.h_x.h_y.r_{gx,y}.\ \delta_{phy}$$

Where;
i_x = selection intensity (standardized selection differential) applied to trait x;
h_x and h_v, are square roots of heritability estimates for traits x and y respectively;
$r_{gx,y}$ is the genetic correlation between trait x and y and δ_{phy} is square root of phenotypic variance for trait y.

RESULTS AND DISCUSSION

The range in means for all traits except emergence index

Table 1. Summary of traits measured for full-sib (FS), half-sib (HS) and S_1 families derived from FARZ 23 (096EP6) maize population.

		Range			
Traits		**Mean**	**Min**	**Max**	**CV %**
Emergence %	FS	83.3	46.8	95.2	11.96
	HS	80.7	55.9	94.1	11.76
	S1	84.6	51.3	96.2	12.99
Emergence index (days)	FS	5.9	5.3	6.6	10.00
	HS	5.9	5.2	6.8	8.97
	S1	5.7	5.3	6.3	10.32
Days to tesseling	FS	56.1	52.5	59.7	3.01
	HS	55.0	52.8	57.8	2.56
	S1	54.9	50.7	61.2	2.74
Days to silking	FS	61.6	58.2	65.8	3.37
	HS	60.7	58	64	3.05
	S1	61.3	55.3	67.2	3.59
Plants height (cm)	FS	196.5	167.5	226.7	9.33
	HS	197.3	168.8	220.3	8.89
	S1	179.8	150.5	212.1	11.64
Ear Number	FS	13.8	7.7	19.3	19.26
	HS	15.9	9.7	20.0	17.88
	S1	8.3	2.7	12.3	30.06
Moisture content (%)	FS	19.7	16.7	22.1	6.85
	HS	19.0	16.8	20.7	6.33
	S1	18.4	16.0	21.6	9.76
Grain yield (t/ha)	FS	3.6	1.8	5.3	22.01
	HS	4.2	2.5	6.6	18.37
	S1	2.6	0.8	3.9	29.74

was quite large. For example, days to silking for the three progeny types was between 55 and 67 while grain yield varied from 1 to 4 t/ha for the S_1 families and 2.5 to 6.6 t/ha for the half-sibs (Table 1). A look at the means showed that with S_1 selection, plant height and grain yield were greatly reduced when compared with the other two methods. Obviously, these traits were affected more by selfing which is the most severe form of inbreeding, than by the other two methods. Lothrop et al. (1985) also arrived at similar conclusions for a IAPIR sorghum population. The standard error (SE) of the mean for all the traits was small, while the coefficient of variability (CV) which is a relative measure of variation, was reasonable for all the traits except for grain yield of the S_1 families where it was relatively large. Large CV in this type of study was assumed by Obilana and Hallauer (1974) to be strictly a function of the mean yield, for example 2.6 t/ha for S_1 versus 3.6 and 4.2 t/ha for full-sib and half-sib families, respectively,

Comparisons of the variance components for the three families (Table 2) revealed that environmental or error variance (δ^2) was largest for all the traits. Estimated components of variance were at least twice their corresponding standard errors in most cases. Genetic variances (δ^2g) in all cases except for emergence percentage among the half-sib families revealed that considerable genetic variation existed in the maize population for the traits measured. Genetic variances for emergence percentage, plant height, days to tasseling and silking were in the order of S_1 > full-sib > half-sib. Also, estimates of genotype x environment component of variance (δ^2ge) for the traits were in most instances,

Table 2. Estimated of genetic (δ^2g), genotype x environment interaction (δ^2ge), error (δ^2), phenotypic (δ^2ph), variances and heritability (h^2), estimates obtained for full-sib (FS), half-sib (HS) and S_1 families from FARZ 23 (096EP6).

Traits	Type	δ^2g	Δ^2ge	δ^2	δ^{2ph}	h^2
Emergence %	FS	48.7±11.71	19.7±8.10	99.3±7.30	75.1±11.01	0.65±01.6
	HS	-7.9±10.60	83.1±16.09	90.2±6.38	48.7±6.89	-0.16±0.22
	S_1	57.9±11.89	3.0±7.31	120.9±9.40	79.6±12.31	0.73±0.15
Emergence index (days)	FS	0.0±0.00	0.0±0.00	0.4±0.03	0.1±0.00	-
	HS	0.0±.0.00	0.0±.0.00	0.3±0.09	0.1±0.00	-
	S_1	0.0±.0.00	0.0±.0.00	0.3±0.09	0.1±0.00	-
Days to tasseling	FS	1.7±0.40	0.7±0.3	2.9±0.21	2.5±0.42	0.68±0.16
	HS	0.8±0.19	0.3±0.11	2.0±0.10	1.3±0.21	0.62±0.15
	S_1	4.0±0.71	0.7±0.22	2.3±0.19	4.7±0.68	0.85±0.15
Days to silking	FS	1.7±0.39	0.4±0.30	4.3±0.32	2.6±0.42	0.65±0.15
	HS	0.7±0.31	0.8±0.31	3.4±0.21	1.7±0.21	0.41±0.18
	S_1	4.0±0.78	0.8±0.41	4.8±0.40	5.2±0.82	0.77±0.15
Plant height (cm)	FS	77.0±27.62	64.6±27.01	336.1±24.71	165.3±24.19	0.47±0.17
	HS	66.6±16.35	-22.7±13.42	307.6±21.82	129.2±15.10	0.52±0.12
	S_1	139.3±33.04	-20.2±22.40	438.6±33.89	22.5±31.11	0.63±0.15
Ear Number	FS	3.4±0.88	-	7.1±0.73	5.8±0.81	0.59±0.16
	HS	2.0±0.52	-	8.1±0.81	4.7±0.88	0.43±0.11
	S_1	2.0±0.68	-	6.4±0.70	4.1±0.63	0.49±0.17
Moisture content (%)	FS	0.5±0.17	-	1.8±0.19	1.1±0.21	0.46±0.09
	HS	0.3±0.10	-	1.5±0.19	0.8±0.22	0.38±0.13
	S_1	0.5±0.27	-	3.3±0.36	1.6±0.21	0.31±0.19
Grain yield (t/ha)	FS	0.4±0.11	-	0.6±0.10	0.6±0.10	0.67±0.17
	HS	0.3±0.10	-	0.6±0.10	0.5±0.10	0.60±0.20
	S_1	0.3±0.10	-	0.6±0.10	0.5±0.11	0.60±0.20

smallest for half-sib families and largest for S_1 families. These results which are comparable to those of Harris et al. (1972), tend to support the notion by Jan-Orn et al. (1976) that greater heterozygousity confers a buffering effect or stability over a wide range of environments whereas inbreeding leads to increased homozygousity and less buffering capacity. Results obtained for variance component estimates of yield traits (namely; ear number, moisture content and grain yield) were not consistent with those for other traits. However, error or environmental variances for these three traits were as large as or larger than other traits. This might be as a result of data from a single season being used in estimating components of variance for the traits and thus emphasizes the need for evaluating progenies in more than one environment.

Except for emergence percentage of the half-sib families, heritability (on entry mean basis) was moderate to high for all traits studied (Table 2). The negative heritability estimate of -16.2% obtained for emergence percentage among the half-sib families, though not unconnected with the very high dominance effect obtained for the trait is not clearly understood. Perhaps half-sib being the least affected by inbreeding was not an effective method of generating progenies that would be sufficiently variable to detect genetic differences among them. Emergence percentage is dependent on the number of seeds that emerged relative to the total number of seeds planted. Thus, the effect of the other two systems especially selfing, might be the aggregation of lethal genes leading to reduction in viability proportional to the genetic constitution of individual family, whereas in the half-sibs, greater heterozygousity would lead to the lethals being hidden in heterozygotes and the resultant effect would be greater viability of seeds and less variability of emergence percentage than those obtained from other systems. Opeke (1983) for example, obtained heritability

Table 3. Estimates of variances for additive ($\delta^2{}_A$), dominance ($\delta^2{}_A$), additive variance from S_1 ($\delta^2{}_{A*}$), their interaction with environment and also pertinent ratios from their comparisons in FARZ 23 (096EP6).

	Genetic variance			Interactions				Ratios	
Traits	$\delta^2{}_A$	$\delta^2{}_D$	$\Delta^2{}_{A*}$	$\delta^2{}_{AE}$	$\Delta^2{}_{DE}$	$\delta^2{}_{A*E}$	$\delta^2{}_{D/}{}^{\delta 2}{}_A$	$\delta^2{}_{A*/}{}^{\delta 2}{}_A$	δ^2AE/δ^2DE
Emergence %	-31.6	258.0	-6.6	332.4	-586.0	149.5	+	0.2	+
Emergence index (days)	0.0	0.0	0.0	0.4	-0.8	0.2	0.0	0.0	+
Days to tasseling	3.2	0.4	3.9	1.2	0.4	0.6	0.1	1.2	3.0
Days to silking	2.8	1.2	3.7	3.2	-4.8	2.0	0.4	1.3	+
Plant height (cm)	266.4	-224.8	195.5	-90.8	440.0	-130.2	+	0.7	+
Ear number	8.0	-2.4	2.6	-	-	-	+	0.3	-
Moisture content (%)	1.2	-0.4	0.6	-	-	-	+	0.5	-
Grain yield (t/ha)	1.2	-0.8	0.5			-	+	0.4	-

+ Negative values obtained and are assumed to be ≤ zero.

obtained heritability estimates for emergence percentage as high as 0.84 for three maize populations using S_1 selection, while a value of 0.73 was obtained for the S_1s in this study.

Estimates of additive gene action due to average effect of gene substitution ($\delta^2{}_{A*}$) were larger than those for additive effects ($\delta^2{}_A$) for emergence percentage and flowering data (Table 3), while the opposite was the case for the other traits that is; $\delta^2{}_A > \delta^2{}_{A*}$ for plant height, ear number, moisture content and grain yield. Since in the absence of dominance and epistasis, $\delta^2{}_{A*} = \delta^2{}_A$ except for sampling error (Jan-Orn et al., 1976; Sprague and Eberhart, 1977), the absence of dominance and/or epistasis cannot be ruled out in this study. However, the ratio of $\delta^2{}_D/\delta^2{}_A$ suggests that except for emergence percentage and days to silking, the amount of dominance genetic variance in this population is small. In effect, with nearly all variation present being additive, substantial progress is expected using any of the selection methods.

Phenotypic and genotypic correlations between tasseling and silking were very high for each of the three selection methods (Table 4) suggesting, as expected, that either of the two can be used as a measure of flowering. Also, correlations between ear number and grain yield were very high. Genetic correlations between emergence percentage and ear number or grain yield were very high, implying that family members within each of the selection methods with high emergence percentage produced more ears/plot and consequently gave high grain yield at harvest. Among the full-sib families, the genetic correlation between plant height and flowering was high. Other phenotypic correlations though significant in some instances, were lower than ±0.52 meaning that they account for less than one fourth of the observed variation and thus have no predictive value. Genetic correlations in such cases, except that between grain yield and emergence, were lower still.

Predicted responses to selection using different combinations of generations per cycle and parental control, are presented in Table 5. For the flowering traits and moisture content, a maximum gain of about 3% per generation is feasible. In all cases, predicted responses were expressed as a percentage of the mean for that trait for ease of comparison. S_1 selection with a parental control of two and three generations per cycle gave the largest predicted response for grain yield and ear number, whereas half-sib selection that takes three generations to complete a cycle and a parental control value of one gave the least response to both traits. A further look at the responses to selection for grain yield for the three selection methods without these modifications, reveal that comparable gains per generation of about 200 kg/ha will be obtained in each case, while the modification gave better gains in grain yield/generation (Table 5). The usefulness of these modifications would therefore, depend on how much time and resources each can save.

Correlated responses estimated as a percentage of estimated gains for each selection method for a given trait in this study (Table 6) showed that in nearly all instances, direct selection for each of the traits would be better. Indirect selection for grain yield through ear number will for example, only allow for a maximum of 90% of the gain possible if selection were to be for grain yield using any of the three methods. An example of the few instances where indirect selection might work is in selecting for ear number through emergence percentage among the half-sib families that would result in 112% of the gain possible with direct selection for the same trait.

Modifications that affect estimates of responses to selection are those that can change the number of generations to complete a cycle or the parental control. These include the reduction in the number of generations/cycle from three to two for full-sib (Compton and Lonnquist, 1982; Ajala et al., 2007) and S_1 (Dhillon & Khehra 1989) selection methods, and the use of the selfed male parents from each selected half-sib families or S_2 seeds from each selected S_1 progeny respectively, for recombination. A look at the gains in grain yield for each of the conventional methods (three generations/cycle and a parental control value of one) showed that about 200 kg/

Table 4. Phenotypic (above diagonals) and genotypic (below diagonals) correlations among some traits in FARZ 23 maize population.

S/N	Traits	Type	1	2	3	4	5	6	7
1.	Emergence %	FS		0.00	-0.01	0.04	0.67	0.10	0.51
		HS		-0.01	0.00	-0.04	0.41	-0.11	0.10
		S_1		-0.09	-0.14	0.10	0.44	0.12	0.33
2.	Days to 50% tasseling	FS	0.10		0.85	0.30	-0.11	0.25	-0.10
		HS	0.00		0.79	0.01	-0.08	0.26	-0.04
		S_1	-0.10		0.75	-0.02	-0.11	0.07	-0.17
3.	Days to 50% silking	FS	0.05	0.92		0.19	-0.22	0.28	-0.23
		HS	0.01	0.84		-0.12	-0.05	0.28	-0.21
		S_1	-0.14	0.75		-0.05	-0.26	0.03	-0.35
4.	Plant height (cm)	FS	0.01	0.73	0.70		0.03	0.17	0.25
		HS	0.00	0.21	0.08		-0.08	0.01	0.27
		S_1	-0.01	0.06	0.04		0.05	0.11	0.21
5.	Ear number	FS	0.81	-0.16	-0.28	-0.19		0.01	0.79
		HS	0.68	-0.14	-0.1	0.20		-0.25	0.64
		S_1	0.72	-0.19	-0.43	0.27		0.19	0.78
6.	Moisture content (%)	FS	0.15	0.27	0.32	0.25	-0.01		0.03
		HS	0.01	0.27	0.36	0.09	-0.21		-0.12
		S_1	0.02	0.13	0.06	0.21	0.31		0.20
7.	Grain yield (t/ha)	FS	0.67	-0.37	-0.25	0.28	0.83	0.07	
		HS	0.51	-0.30	-0.34	0.40	0.70	-0.06	
		S_1	0.57	-0.24	-0.47	0.45	0.77	0.44	

+ FS = Fullsib, HS = Halfsib.

showed that about 200 kg/ha of improvement in grain yield will be obtained in each case. This is in agreement with data reported by Paliwal and Sprague (1981) and Darrah (1986), but contrary to those reported by Adeyemo (1986) for TZSR-Y maize population using full-sib, half-sib, S_1 and S_1 testcross family selections. The question is whether the yield increases obtained by the modification to each of the conventional procedures are worthwhile given the extra workload and resources that may have to be committed. Except for the modifications to full-sib and S_1 selection that utilizes two seasons (generations)/cycle, modifications to the other methods require extra workload and resources to achieve. The conventional half-sib selection and its modification can be excluded as possible procedures for improving the population because the gains recorded in most cases for the traits were lower than for the other two methods. Besides, half-sib selection with c = 2 is operationally cumbersome. S_1 selection that can be completed in three generations and using S_2 seeds of selected lines for recombination, gave the highest predicted gain for each trait and thus offered a good option for improvement. But when this is considered with S_1 selection using two generations/cycle, the gains especially for grain yield seem not to be worthwhile considering the extra resources and time needed to achieve it. However, the usefulness of this modification to S_1 selection proposed by Dhillon and Khehra (1989) has not been generally validated by experimentation. Moreover, it seems that a poor correspondence between predicted and observed responses using S_1 selection, frequently occur (Burton et al., 1971; Muleba and Paulsen, 1983). Bradshaw (1983) suggested that the use of total genetic variance or its additive portion in predicting progress for S_1 selection is not appropriate and thus proposed that use of covariance between S_1 and S_1 testcross families would be more appropriate since it gave predicted gains that were generally smaller than using the other method. Therefore, the general lack of correspondence was attributed to the computational method used. Although Bradshaw's (1983) proposal offers perhaps the best method of obtaining a more realistic estimate of predicted response to S_1 selection, it has

Table 5. Predicted responses to each of full-sib (FS), half-sib (HS) and S1 progeny selection for some traits in FARZ 23 maize population at 20% (i = 1.40) selection intensity.

			Emergence height			**50% tasseling**			**50% silking**			**Plants**	
Family type	**(y)**	**(c)**	**Gain/ Cycle (%)**	**Gain/Generation (%)**		**Gain/ Cycle (days)**	**Gain/ Generation (Days)**	**Gain/ Generation (%)**	**Gain/ Cycle (Days)**	**Gain/ Generation (Days)**	**Gain/ Generation (%)**	**Gain/ Cycle (cm)**	**Gain/ Generation (cm)**	**Gain/ Generation (%)**
Full-sib	3	1	7.89	2.63	3.16	1.5	0.5	0.89	1.47	0.49	0.8	8.45	2.82	1.44
	2	1	7.89	3.95	4.74	1.5	0.75	1.34	1.47	0.74	1.2	8.45	4.23	2.15
Half-sib	3	1	-1.56	-0.52	-0.64	0.99	0.33	0.60	0.75	0.25	0.41	8.27	2.76	1.40
	3	2	-3.13	-1.04	-1.29	1.98	0.66	1.20	1.50	0.50	0.82	16.55	5.52	2.80
S_1	3	1	9.12	3.04	3.59	2.58	0.86	1.57	2.46	0.82	1.34	13.16	4.39	2.44
		2	18.24	6.08	7.19	5.16	1.72	3.13	4.92	1.64	2.68	26.32	8.77	4.88
	2	1	9.12	4.56	5.39	2.58	1.29	2.35	2.46	1.23	2.01	13.16	6.58	3.66

			Ear number (No.)		**Ear number (%)**	**Moisture content (%)**			**Grain yield (t/ha)**		**Grain yield (%)**
Full-sib	3	1	1.99	0.66	4.78	0.68	0.27	1.37	0.73	0.24	6.67
	2	1	1.99	1.00	7.25	0.68	0.34	1.73	0.73	0.37	10.28
Half-sib	3	1	1.31	0.44	2.77	0.48	0.16	0.84	0.59	0.20	4.76
	3	2	2.62	0.87	5.47	0.95	0.32	1.68	1.19	0.40	9.52
S_1	3	1	1.39	0.46	5.54	0.55	0.18	0.98	0.59	0.20	7.69
		2	2.78	0.93	11.20	1.10	0.37	2.01	1.19	0.40	15.38
	2	1	1.39	0.70	8.43	0.55	0.28	1.52	0.59	0.30	11.54

y = number of generations, c = parental control.

not been widely used probably because it requires the additional effort of generating S_1 testcrosses. This creates a rather laborious situation where two selection methods (S_1 selection *per se* and S_1 testcross selection) are combined in one. Full-sib selection thus seems to offer the best method for improving the population considering operational efficiency and gains from selection. Adeyemo (1986) also concluded that full-sib selection offers the best improvement procedure for TZSR-Y maize population because both the realized and predicted gains were comparable using the method. The positive correlations obtained between plant height and yield for the three methods is undesirable because tall plants tend to be highly susceptible to lodging in conditions of high rainfall and fertility, the condition prevalent in the early season in Southern Nigeria. Fortunately, full- sib selection offers the best opportunity for improving yield without greatly affecting plant height (r = 0.26).

In Southern Nigeria, there are two natural seasons in a year. Although the rainfall distribution in the late season is sometimes unreliable, availability and use of irrigation facilities can correct this. FARZ 23 maize population is a medium maturing variety that is best suited for the early season. Since the conventional practice is to evaluate families in the season or environmental conditions in which the product will eventually be

Table 6. Correlated responses (expressed a percentage of expected gain) to full sib (FS), half sib (HS) and S1 progeny selection for some traits in FARZ 23 maize population.

Trait	Type	1	2	3	4	5	6	7
Emergence %	FS	100	10.3	5.1	0.9	77.7	12.7	68.4
	HS	100	0.0	1.9	0.0	112.2	1.3	98.1
	S_1	100	-10.7	-14.4	-0.1	58.7	1.3	51.1
Days to 50% tasseling	FS	10.0	100	90.0	60.7	-14.7	22.0	-36.7
	HS	0.0	100	68.7	19.2	-12.1	21.2	-29.3
	S_1	-9.3	100	71.3	5.0	-14.3	7.8	-20.2
Days to 50% silking	FS	4.8	93.2	100	59.9	-26.5	26.5	-25.2
	HS	0.0	102.7	100	9.3	-10.7	34.7	-40.0
	S_1	-13.4	78.9	100	3.7	-36.2	3.7	-41.5
Plant height (cm)	FS	0.0	88.0	83.3	100	-21.5	25.0	33.7
	HS	0.0	23.0	7.1	100	1.8	7.7	42.7
	S_1	-1.1	6.9	4.4	100	23.7	14.7	43.5
Ear number	FS	85.4	-17.1	-29.6	-17.1	100	-1.0	88.9
	HS	-42.0	-16.8	-9.9	2.3	100	-19.8	82.4
	S_1	87.1	-25.2	-54.0	30.2	100.0	24.5	84.2
Moisture Content (%)	FS	17.6	32.4	38.2	25.0	-1.5	100	8.8
	HS	0.0	35.4	37.5	10.4	-22.9	100	8.3
	S_1	3.6	-21.8	9.1	29.1	38.2	100	60.0
Grain yield (t/ha)	FS	65.8	-37.0	-24.7	23.3	76.7	5.5	100
	HS	-27.1	-30.5	-28.8	37.3	59.3	-5.1	100
	S_1	62.7	-28.8	-54.2	45.8	69.5	32.2	100

utilized, evaluation should be done in the early season. With a late season, using supplementary irrigation when necessary, it is possible to complete a cycle of the modified full-sib selection in a year (two seasons), while the conventional full-sib selection takes three seasons per cycle, but can also be completed in a year when irrigation facilities are available to fully support the third season. Results obtained in this study especially for yield, are valid for the conditions prevalent in the early season. A point of interest would have been to compare variances obtained in the early season with that obtained in the late season. Both seasons can fully support maize crop in a good year. The late season further represents a realistic growing condition for maize in subsistence farming because of competition for space by other crops in the early season. Unfortunately, the comparison was not possible.

Some studies have reported on good correspondence between predicted and realized gains from selection (Silva, 1968; Moll and Stuber, 1971) while others reported on lack of correspondence (Moll and Robinson, 1966; Muleba and Paulsen, 1983) due to computational method, or large g x e interactions (Darrah et al., 1972, 1978). Nonetheless, the primary objective of the study was to determine the best selection method that can be used for the improvement of FARZ 23 maize population. An attempt to generate situations of c = 2 for both half-sib and S_1 family selection does not seem to have any apparent advantage for yield improvement. In both situations, three generations are required to complete a cycle thus reducing any apparent gains to comparable levels with full-sib selection with c = 1 when gains/generation is considered. Full-sib selection that utilizes two seasons or generation per cycle thus offers the best option for the improvement of the population.

ACKNOWLEDGEMENTS

The support of Dr. B. B. Wudiri, the late Director of National Cereals Research Institute, Nigeria is hereby gratefully acknowledged. A colleague at ICIPE - Kenya, Dr. Lane Smith (now at Auburn University, Alabama, USA) read through the manuscript at various times during preparation. We sincerely appreciate his contribution.

REFERENCES

Adeyemo MO (1986). Genetic variability and predicted responses to four types of progeny selection in a Nigerian maize population. Ph.D. Thesis. University of Ife, Nigeria p. 123.

Ajala SO, Menkir A, Kamara AY, Alabi SO, Abdullai MS (2007). Breeding strategies to improve maize for adaptation to low soil nitrogen in West and Central Africa in African Crop Science Proceedings, El-Minia, Egypt pp. 87-94.

Bradshaw JE (1983). Estimating the predicted response to S_1 family selection. Heredity 51: 415-418.

Burton JW, Penny LH, Hallauer AR, Eberhart SA (1971). Evaluation of synthetic populations developed from a maize variety (BSK) by two methods of recurrent selection. Crop Sci. 11: 658-661.

Compton WA, Lonnquist JW (1982). A multiplicative selection index applied to four cycles of full-sib recurrent selection in maize. Crop Sci. 22: 981-983.

Darrah LL, Eberhart SA, Penny LH (1972). A maize breeding methods study in Kenya. Crop Sci. 12: 605-608.

Darrah LL, Eberhart SA, Penny LH (1978). Six years of maize selection in 'Kitale Synthetic II' 'Ecuador 573' and 'Kitale Composite A' using methods of comprehensive breeding systems. Euphytica 27: 191-204.

Darrah LL (1986). Evaluation of population improvement in the Kenya maize breeding methods study. In: To feed ourselves. Proc of 1st Eastern, Central and Southern Africa Regional Maize Workshop (Ed. CIMMYT Mexico), Lusaka, Zambia pp. 160-175.

Dhillon BS, Khehra AS (1989). Modified S_1 recurrent selection in maize improvement. Crop Sci. 29: 226-228.

Duclos LA, Crane PL (1968). Comparative performance of top crosses and S_1 progeny for improving populations of corn (*Zea ways* L.). Crop Sci. 8: 191-194.

Genter CF (1973). Comparison of S_1 and testcross evaluation after two cycles of recurrent selection in maize. Crop Sci. 13: 524-527.

Harris RE, Gardner CO, Compton WA (1972). Effect of mass selection and irradiation in corn measured by random S_1 lines and their testcrosses. Crop Sci. 12: 594-598.

Horner ES, Lundy HW, Luttick MC, Chapman WH (1973). Comparisons of three methods of recurrent selection in maize. Crop Sci. 13: 485-489.

Jan-Orn J, Gardner CO, Ross WM (1976). Quantitative genetic studies of the NP3R random-mating sorghum population. Crop Sci. 16: 489-496.

Lothrop JE, Atkins RE, Smith OS (1985). Variability yield and yield components in IAPIR grain sorghum random-mating population. I. Means, Variance components and heritabilities. Crop Sci. 25: 235-244.

Moll RH, Robinson WD (1966). Observed and expected responses in four selection experiments in maize. Crop Sci. 6: 319-324.

Moll RH, Stuber CW (1971). Comparisons of response to alternative selection procedures initiated with two populations of maize (*Zea mays* L). Crop Sci. 11: 706-711.

Muleba N, Paulsen GM (1983). Effects of selection for yield versus yield efficiency on morphological and physiological traits of tropical maize. Euphytica 32: 659-667.

Obilana AT, Hallauer AR (1974). Estimation of variability of quantitative traits in BSSS by using unselected maize inbred lines. Crop Sci. 14: 99-103.

Opeke BO (1983). Genetic variability for seedling emergence and its relationship with mature plant characteristics in maize M. Sc Thesis, University of Ife, Nigeria p. 75.

Paliwal RL, Sprague EW (1981). Improving adaptation yield dependability in maize in the developing world. CIMMYT, El Batan Mexico p. 19.

Silva da WJ, Lonnquist JW (1969). Genetic variances in populations developed from full-sib and S_1 testcross progeny selection in an open-pollinated variety of maize. Crop Sci 8: 201- 204.

Sprague GF, Eberhart SA (1977). Corn Breeding. In Corn and Corn Improvement (Ed G. F. Sprague), ASA Monograph 18: 305-362.

Subandi, Compton WA (1974). Genetic studies in an exotic population of corn (Zea mays L) grown under two plant densities. 1. Estimates of genetic parameters. Theor. Appl. Gen. 44: 153-159.