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PROGRESS FROM HALF-SIB SELECTION IN KITALE STATION MAIZE

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A strain of Kenya flat-white maize (*Zea mays* L.) had been maintained on the Agricultural Research Station at Kitale, Kenya for several years by visual selection of the ears at harvest (mass selection) to provide seed the following year. Since the Kenya flat-white complex apparently traces back to varieties from South Africa that originally came from the southern U.S.A such as "Hickory King", "White Horsetooth", "White Pearl", and others [6], the late maturity and disease resistance of the Kenya strain suggests that mass selection has been effective in developing adapted varieties for Kenya conditions.

Theoretical studies [2, 8] and preliminary results [1] suggest that half-sib selection (recurrent selection for general combining ability) should produce even greater improvement than mass selection. Two cycles of half-sib selection were completed in the Kitale Station strain by Harrison [6]. In 1955 approximately 1,000 plants from the Kitale Station strain were grown and 300 plants were selected and selfed. Selection criteria were reduced ear height, stalk strength, disease resistance, and general vigour.

In 1956 300 S_1 lines were grown in a crossing block and detasselled. The Kitale Station strain was interplanted to provide pollen. One hundred lines having desirable agronomic characters were selected, and the topcross seed was harvested.

The 100 half-sib families were evaluated in six replications at two locations in 1957; the better 25 families were retested in 1958; and the highest yielding ten entries were selected for recombination. Remnant S_1 seed was planted for recombination in 1959. Selected plants within each S_1 line were used in making all possible crosses among the ten selected S_1 lines. The S_1 intercrosses were random mated to form the C1 and was released as "Kitale II". A second cycle of selection was conducted in a similar manner from 1960 to 1963, except that the yield trials were grown at three locations in 1962. The C2 improved population was released as "Kitale III".

To evaluate progress from selection, we increased the seed of each entry by sibbing (plant-to-plant crosses), made the necessary variety crosses in 1964, and grew the evaluation trials in 1965. This report summarizes the results of the evaluation trials.

Materials and Methods

We used a design suggested by Gardner and Eberhart [4] to evaluate progress from selections. The mating design included Kitale Station (C0), Kitale II (C1), Kitale III (C2), and three variety crosses, the variety crosses random mated, the varieties selfed, and the variety crosses selfed. One hundred plants from each variety were used in making the crosses, sibs, and selfs to obtain a representative genetic sample for each entry. Seed for all entries except the variety crosses random mated and the variety crosses selfed was produced in the February 1964 irrigation nursery, whereas seed for the latter entries was produced in the August 1964 irrigation nursery. A duplicate entry of Kitale Station maize was used as the 16th entry, and this study was grown as a triple 4 x 4 lattice at nine locations in 1965. Four-row plots were used with 91 cm. between rows and 30 cm. between plants in a row. Each row consisted of nine hills; and hills were over-planted and thinned to one plant except end hills and those adjacent missing hills, where two plants were retained. Data were recorded on only the two centre rows to minimize competition.

Data for nine characters were recorded. The number of days from planting to the day that 50 per cent or more of the anthers were extruded on half the plants in each plot was used as days to tassel. Ear height (cm.) was recorded as the height of the top ear node above ground level. At harvest, the number of lodged plants and number of ears per plot were used to compute percentage lodging and usable ears per 100 plants. Plants leaning more than 45° and those broken below the ear were considered lodged. A 1 to 6 scale was used for blight (*Helminthosporium turcicum* Pass.) and rust (*Puccinia sorghi* Schw.) scores with 1 as resistant and 6 as susceptible. Ten unselected top ears were used to determine ear length, ear

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diameter, and kernel weight. Fifty kernel samples were used to estimate kernel weight (cg). The shelled grain weight per plot was determined and converted to yield (q/ha) adjusted to 12.5 per cent moisture.

Results and Discussion

The analysis proposed by Gardner and Eberhart [4] was used, but the heterosis effects (h_{ij}) did not differ significantly from zero. This suggests that changes in gene frequencies were not great enough to cause detectable heterosis between the three substrains of Kitale maize. The modified model presented by Hammond and Gardner [5] was used and the coefficients of the parameters are shown for the entries in this experiment in Table I. Deviations from regression for this model were small and non-significant for all characters, indicating that the model was satisfactory for this experiment.

Table I—The List of Entries and Coefficients of the Genetic Parameters Used in the Model

Entry	Code	Genetic parameters				Duplicate parameter
		m	a_ℓ	d_o	d_ℓ	
Kitale Station	C0	1		1·00		1·00
Kitale Station	C0	1		1·00		−1·00
Kitale II	C1	1	1·00	1·00	1·00	
Kitale III	C2	1	2·00	1·00	2·00	
Kitale x Kitale II	C0 x C1	1	0·50	1·00	0·50	
Kitale x Kitale III	C0 x C2	1	1·00	1·00	1·00	
Kitale II x Kitale III	C1 x C2	1	1·50	1·00	1·50	
(Kitale x Kitale II)R	(C0 x C1)R	1	0·50	1·00	0·50	
(Kitale x Kitale III)R	(C0 x C2)R	1	1·00	1·00	1·00	
(Kitale II x Kitale III)R	(C1 x C2)R	1	1·50	1·00	1·50	
(Kitale)S	(C0)S	1		0·50		
(Kitale II)S	(C1)S	1	1·00	0·50	0·50	
(Kitale III)S	(C2)S	1	2·00	0·50	1·00	
(Kitale x Kitale II)S	(C0 x C1)S	1	0·50	0·50	0·25	
(Kitale x Kitale III)S	(C0 x C2)S	1	1·00	0·50	0·50	
(Kitale II x Kitale III)S	(C1 x C2)S	1	1·50	0·50	0·75	

The environmental response (b_ℓ) was computed for each entry as suggested by Eberhart and Russell [3]. The observed (Y) and predicted means ($\hat{Y}$) are shown in Table II for the 11 characters measured. The agreement between Y and $\hat{Y}$ is extremely good for all characters.

The least squares estimates of the genetic parameters are shown in Table III. The gain per cycle in the varieties (b_v) and the varieties selfed (b_s) can be estimated as:

$$b_v = a_\ell - d_\ell$$

$$b_s = a_\ell - (\tfrac{1}{2})d_\ell$$

The correlation between the coefficients of the a_ℓ and d_ℓ parameters (Table I) is 0·87. Consequently, the standard errors of the estimates of a_ℓ and d_ℓ are large even though the standard errors for b_v and b_s are relatively small. Because all entries in the trial are used to obtain the least squares estimate of b_v, twice b_v provides a better estimate of the superiority of Kitale III over Kitale Station than the difference in the observed means.

The mean yield of the varieties was improved 2.6 q/ha per cycle so that Kitale III is estimated to outyield Kitale Station by 5.2 q/ha (15 per cent) at a yield level of 34.6 q/ha. The response to environmental conditions also was improved so that Kitale III is expected to outyield Kitale Station by 9.4 q/ha (14 per cent) in environments where Kitale Station maize will yield 65 q/ha. In contrast, when the environment is so poor that Kitale Station maize only yields 15 q/ha, Kitale III is expected to give only a 2.4 q/ha (16 per cent) higher yield.

TABLE II—OBSERVED (Y) AND PREDICTED (Y) PERFORMANCE OF MAIZE VARIETIES AND VARIETY CROSSES FROM EVALUATION TRIALS GROWN AT NINE LOCATIONS NEAR KITALE, KENYA, IN 1965

Entry Code*	Yield, (q/ha) Mean		Yield, (q/ha) b		Kernel Weight, cg		Ears per 100 plants		Lodging per cent	
	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$
C0**	34·5	34·6	·94	·94	52	52	72	72	34	35
C0 x C1 ..	37·0	35·9	·91	·97	52	52	75	74	33	32
(C0 x C1)R ..	34·8	35·9	1·00	·97	50	52	73	74	34	32
C1	35·8	37·2	1·05	1·01	52	52	76	76	32	30
C0 x C2 ..	38·4	37·2	1·05	1·01	54	52	74	76	28	30
(C0 x C2)R ..	37·8	37·2	·96	1·01	51	52	77	76	33	30
C1 x C2 ..	39·5	38·6	·99	1·04	52	52	79	77	25	28
(C1 x C2)R ..	38·4	38·6	1·06	1·04	53	52	76	77	23	28
C2	39·3	39·9	1·09	1·08	52	52	78	79	30	26
(C0)S	11·7	13·3	·34	·35	47	47	46	50	32	35
(C0 x C1)S ..	15·0	14·1	·33	·37	49	48	51	51	34	34
(C1)S	16·5	14·9	·47	·40	48	48	58	52	35	33
(C0 x C2)S ..	14·9	14·9	·42	·40	48	49	52	33	35	33
(C1 x C2)S ..	15·9	15·7	·38	·42	47	49	55	53	33	31
(C2)S	15·2	16·5	·44	·45	51	50	51	55	26	30
LSD (·05) ..	6·7	—	·23	—	3	—	8	—	8	—

*R and S indicate random mating and selfing, respectively.

**Mean of duplicate entries.

TABLE II—(*Contd.*)

Ear diam., mm		Ear length, mm		Ear height, cm		Days to tassel		Blight score		Rust score	
Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$
47	47	168	166	181	179	106	105	1·2	1·1	2·2	2·2
47	47	160	164	176	178	103	105	1·0	1·1	2·1	2·1
48	47	163	164	172	178	104	105	1·1	1·1	2·1	2·1
46	48	161	163	173	176	105	105	·8	1·0	2·0	2·0
48	48	166	163	178	176	105	105	1·0	1·0	1·9	2·0
47	48	160	163	178	176	106	105	1·0	1·0	1·9	2·0
48	48	162	161	179	175	103	104	1·1	1·0	2·0	1·9
47	48	158	161	176	175	105	104	1·0	1·0	1·9	1·9
50	48	163	160	171	173	104	104	1·0	1·0	1·7	1·8
43	43	142	141	140	140	109	107	1·3	1·3	2·2	2·1
44	43	141	140	145	145	104	107	1·3	1·2	1·9	2·0
42	44	138	139	153	150	107	107	1·2	1·2	2·1	1·9
45	44	137	139	150	150	107	107	1·2	1·2	1·7	1·9
45	44	137	137	148	155	106	107	1·1	1·1	1·7	1·8
45	45	138	136	164	160	108	107	1·1	1·1	1·7	1·7
3	—	10	—	8	—	2	—	·2	—	·4	—

TABLE III—THE LEAST SQUARES ESTIMATES OF THE GENETIC PARAMETERS FROM EVALUATION TRIALS GROWN AT NINE LOCATIONS NEAR KITALE, KENYA, IN 1965

Character	m	a_ℓ	d_o	d_ℓ	*b_v	†b_s
Yield						
Mean (q/ha)	−8·1±1·9	·55±1·60	42·68±2·20	2·10±1·91	2·64± ·60	1·60± ·81
b_ℓ	−·24± ·07	·03± ·06	1·17± ·08	·04± ·07	·07± ·02	·05± ·03
Kernel wt. (cg)	43·2±1·8	1·70±1·55	8·56±2·13	−1·35±1·84	·35± ·58	1·03± ·72
Usable ears per 100 plants	27·2±4·2	1·59±3·59	44·88±4·93	1·82±4·27	3·47±1·33	2·50±1·67
Lodging	35·4±5·2	−·48±4·39	−·72±6·03	−4·08±5·22	−4·56±1·63	−2·52±2·04
Ear diameter (mm)	39·2±1·6	1·06±1·35	7·62±1·85	−·28±1·60	·78± ·50	·92± ·62
Ear length (mm)	116·1±4·4	−1·49±3·70	49·67±5·08	−1·65±4·40	−3·14±1·37	−2·31±1·72
Ear height (cm)	101·0±6·2	23·08±5·30	78·02±7·07	−25·94±6·30	−2·86±1·97	10·10±2·46
Days to tassel	109·1±2·5	·30±2·08	−3·95±2·85	−·83±2·47	−·53± ·77	−·12± ·96
Blight score (1 to 6)	1·46± ·15	−·12± ·12	−·36± ·17	·06± ·14	−·06± ·05	−·09± ·06
Rust score (1 to 6)	2·06± ·18	−·25± ·15	·13± ·21	·04± ·18	−·21± ·06	−·23± ·07

*$b_v = a_\ell + d_\ell$ and is gain per cycle for the varieties.

†$b_s = a_\ell + \frac{1}{2}d_\ell$ and is gain per cycle for the varieties selfed.

The number of usable ears per 100 plants increased 3.4 per cycle which resulted in a decrease of 3.1 mm. per cycle in ear length of the top ear. Ear diameter and kernel weight of the top ear did not change. Lodging was reduced 4.5 per cent per cycle and ear height was reduced 2.9 cm. per cycle. The change in the rust score also indicates that a slight improvement in the rust resistance was obtained.

Changes in the varieties when selfed were in the same direction as for the varieties *per se* (except for ear height), but the magnitude was less. The inbreeding depression (d_0) for yield was large but it was relatively small for lodging, days to tassel, rust score, kernel weight and ear width.

Two cycles of selection were very effective in improving the Kitale Station maize. The improvement in the lodging and disease resistance and the reduction in ear height suggests that the mass selection and the S_1 selection (single replication at one environment) in the nursery generations was very effective. Correlated responses from the selection in the yield evaluation trials could have caused some change, but a positive correlation of ear height with yield was reported by Robinson, Comstock and Harvey [7]. The nursery selection (especially the S_1 selection) also may have increased the rate of yield improvement.

Improvement per year was not high, however, because of the excessive cycle length. An irrigation nursery with simultaneous selfing and top-crossing will reduce the cycle length from four to two years for this long season maize at Kitale, but this will eliminate the opportunity to select among S_1 lines in the top-cross nursery. Since the growing season is March to October, two seasons per year are impossible; but three crops can be grown in two years. An irrigation nursery has been established and used in subsequent recurrent selection programmes [1].

Summary

Two cycles of half-sib family selection (recurrent selection for general combining ability) for yield with mass selection and S_1 selection for agronomic traits in the nursery generations improved Kitale Station maize by 5.2 q/ha (15 per cent) for yield and 6.8 ears per 100 plants while reducing ear height by 5.8 cm., rust score by 0.4, and lodging by 9.0 per cent. The environmental response (b_ℓ) was increased from 0.93 to 1.07.

Gain per year was small because of the excessive cycle length, but use of an irrigation nursery can reduce the cycle length from four to two years at Kitale. The S_1 selection among lines when crossing to the tester will be eliminated, however, since selfing and crossing will be done the same season.

Changes in gene frequencies were not enough to produce significant heterosis for yield in the variety crosses among the original and selected substrains suggesting that a large number of loci with small effects may have been involved in the yield improvement.

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References

[1] Darrah, L. L., S. A. Eberhart and L. H. Penny (1972). Preliminary results from a maize breeding study in Kenya. *Crop Sci., 12*, 605-608.

[2] Eberhart, S. A., M. N. Harrison and F. Ogada (1967). A comprehensive breeding system. *Der Zuchter, 37*, 169-174.

[3] ——— and —W. A. Russell (1966). Stability parameters for comparing varieties. *Crop Sci., 6*, 36-40.

[4] Gardner, C. O., and S. A. Eberhart (1966). Analysis and Interpretations of the variety cross diallel and related populations. *Biometrics, 22*, 439-452.

[5] Hammond, J. J. and C. O. Gardner (1973). A modification of the variety cross diallel model for evaluating cycles of selection. (Submitted to *Crop Science*).

[6] Harrison, M. N. (1970). Maize improvement in East Africa. In Crop improvement in East Africa. (Edit. C. L. A. Leakey). Common. Agr. But, Farnham Royal.

[7] Robinson, H. F., R. E. Comstock, and P. H. Harvey (1951). Genotypic and phenotypic correlations in corn and their implication in selection. *Agrn. J., 43*, 282-287.

[8] Sprague, G. F. (1966). Quantitative genetics in plant breeding. In K. J. Frey (ed.) *Plant Breeding*. Iowa State University Press, Ames, Iowa, pp. 315-347.