Indian J. Genet., **66**(3): 203-206 (2006)

Selection index and selection criteria for green ear maize (*Zea mays* L.) over environments

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(Received: July 2005; Revised: May 2006; Accepted: May 2006)

Abstract

Selection indices were constructed for green ear of normal field maize (*Zea mays* L.) utilizing fifteen important characters in three different environments separately and over environments. Comparison of three different methods of assigning weight to generate selection criteria indicated that inbred parents differed in performance in each environment. While single cross hybrid 1 × 3 was observed to be consistent over all the three environments, among other crosses 5 × 7 at Pantnagar and Almora; 3 × 7, 4 × 5 at Almora and Gorakhpur; and 3 × 4 at Pantnagar and Gorakhpur were consistent in index value for green ear characters. The behaviour of inbred parent and single cross hybrids was influenced by genotype by environment interaction as evidenced from alteration of ranking according to specific environment.

Key word: Green ear maize, selection index, environment, inbred, single cross hybrid

Introduction

Maize (*Zea mays* L.) occupies an important place in Indian agriculture with an area of 6.59 million hectare and production of 13.30 million tonnes [1]. Diversified use of maize has been given priority in the national arena of agriculture research. Maize is a favorite snack food in the form of green ears roasted or boiled In India and other countries. In most tropical countries, normal flint maize ears are used for consumption in this way and are a source of food and energy [2].

As no effort has been made to improve the quality characteristics of normal field corn to be used as green ears, there is a need to pay attention to this aspect in tropical environment without sacrificing grain yield potential. The present study aimed at identification of parent and single cross maize hybrid suitable for consumption at green ear stage with the help of selection indices.

Materials and methods

Seven diverse inbred lines from both indigenous and exotic sources differing in green ear characters were crossed in all possible combinations at Hyderabad (2001 *rabi*) and Pantnagar during *kharif* 2002. All possible single crosses (excluding reciprocals), along with parents were grown in Randomized Complete Block Design with three replications in three environments, *viz.*, Pantnagar, Almora and Gorakhpur in *Kharif* 2003. All entries were grown in 2-row plot with row length of 5 m following spacing of 75 cm between rows and 25 cm between plants. Application of recommended dose of fertilizers and other normal cultural practices were followed in all the three environments.

Data were recorded for 15 different characters important for green ear *viz.*, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, kernels depth, kernel density, ear weight per plants, husk extension, shank length, ear tipfillness, pericarp thickness, husk weight without ear, reducing sugar (%), 100 kernel weight and green ear yield. Green ear yield was taken 21 days after pollination and measured on plot basis. Pericarp thickness was measured after Helm and Zuber [3] and reducing sugar was measured as per AACC [4].

Selection index was computed using 15 characters important for consumption at green ear stage using the methodology of Smith [5]. Selection index in separate environments was constructed in three different ways by giving different weights to various characters taking in to amount consumers preference for green ear maize, Some of the characters were measured in such a way that lower value are desirable *viz.*, kernel density, husk extension, ear tip illness, per carp thickness and husk weight. For shank length preferable values are medium to low. Three selection indices were constructed referred to as SI 1, SI 2 and SI 3 in each environment. For generalization, general selection indices were calculated following Hanson and Johnson [6] method utilizing corrected bi values and selection criteria were obtained using overall mean values of green ear characters constituting selection index (Table 3). The same procedure of assigning weight as in classical selection index was followed for construction of general selection index (GSI).

Table 1. Classical selection indices for green ear maize in three different environment evaluated during *kharif* 2003

Environment	Selection index	Bi values for different characters														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pantnagar	SI 1	0.78	−0.89	1.07	1.13	0.27	1.15	0.90	−0.01	1.95	−0.61	0.95	−0.03	0.37	1.04	1.81
	SI 2	0.77	−1.21	1.09	1.19	0.34	0.52	0.90	0.36	1.72	−0.55	0.45	−0.20	0.23	1.02	1.63
	SI 3	0.76	−1.38	1.08	1.21	0.25	−0.19	0.90	−0.98	1.54	−0.53	−0.06	−0.36	0.35	0.98	1.46
Almora	SI 1	2.95	20.33	−2.79	1.95	−0.73	−9.14	−0.36	3.57	0.28	0.32	1.02	−1.13	−2.86	3.06	6.24
	SI 2	3.42	22.29	−2.65	1.94	−0.71	−9.86	−0.47	3.00	0.25	0.22	0.52	−1.37	−2.99	3.10	6.33
	SI 3	4.00	23.15	−2.29	1.90	−0.75	−10.82	−0.56	2.28	0.00	0.05	0.02	−1.63	−2.89	3.14	6.27
Gorakhpur	SI 1	5.33	−11.73	3.03	1.86	2.24	2.34	0.38	−2.53	−0.64	0.47	0.97	−2.39	−9.71	2.40	4.99
	SI 2	5.58	−8.39	3.30	1.77	2.41	0.80	0.35	−2.57	−0.25	0.28	0.50	−2.20	−7.90	2.36	5.01
	SI 3	6.28	2.11	3.74	1.57	2.59	−1.72	0.27	−1.98	0.85	−0.10	0.04	−1.45	−5.04	2.28	4.73
		Weights assigned for different characters														
	SI 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	SI 2	1	1	1	1	1	0.5	1	0.5	0.75	0.5	0.5	0.5	1	1	1
	SI 3	1	1	1	1	1	0	1	0	0	0	0	0	1	1	1

Note: Characters code - 1. Ear length (cm), 2. Ear diameter (cm), 3. Number of kernel rows/ear, 4. Number of Kernel row, 5. Kernel depth (mm), 6. kernel density (cm for 10 Kernels), 7. Single Ear wt (g), S. Husk extension (cm), 9. Shank length (cm), 10. Ear tipfillness (cm), 11. Pericarp thickness (μm), 12. Husk weight (kg), 13. Reducing sugar (mg/100mg), 14. 100 Kernel weight (g) 15. Green Ear Yield (kg/plot)

Results and discussions

Three selection indices were constructed altering relative weights for six of the fifteen characters (Table 1). Due to marked difference in phenotypic values between inbred parents and their crosses, ranking based on selection criterion was done separately for inbreds and single crosses. At Pantnagar environment when equal weights were considered (SI 1) inbred parent 3 ranked first and parent 2 ranked last (Table 2). But following SI 2 and SI 3, somewhat different ranking of parents were obtained. Line 6 ranked first and line 5 ranked last in both cases. Line 7 ranked 3rd and 2nd for SC 2 and SC 3 respectively. The hybrid 1 × 3 ranked first followed by 3 × 7, 1 × 5, 6 × 7, 5 × 7 among the 21 single cross hybrid based on SC 1. Crosses 2 × 4, 5 × 6, 1 × 4, 2 × 6, 4 × 6 were the last five in the aggregate value considering SI. Based on SC 2 and SC 3, cross 2 × 3 ranked first and other good aggregate crosses for green ear characters were 5 × 7, 6 × 7, 1 × 3, 3 × 4 and 3 × 6.

At Almora considering SI, parent 2 ranked first and parents 1 ranked last and reverse was true for SC 2. Parents 4 ranked first for SC 3. Parent 2 and parent 5 showed values in selection criterion based in SI 2and SC 3. When selection criterion SC 1 was applied cross 4 × 6 ranked first followed by 2 × 6, 2 × 7, 1 × 7 and 6 × 7 in respect of top index values. Cross 3 × 7 ranked first when selection criterion SC 2 and SC 3 were followed. Other crosses acquiring top position in index values are 1 × 3, 5 × 6, 4 × 5 and 5 × 7 based on selection criterion SC 2 and SC 3.

At Gorakhpur parent 1 ranked first and parent 2 ranked last according to SC 1, whereas parent 7 ranked 1st and 2nd following SC 2 and SC 3. Parent 2 and 3 ranked 5th and 6th based on SC 2 and SC 3. The performance of parents 1 was 7th in the SC 2 and in contrast, it was 1st on bases SC 3. Cross 1 × 3 ranked first based on SC I and SC 2, 2nd based on SC 3 in the index value of aggregate genotype. Cross 3 × 7 ranked first based on SC 3. Other good performing single crosses for green ear characters were 1 × 5, 3 × 7, 3 × 4, 4 × 5, 1 × 6 based on SC 2 and SC 3.

In classical selection indices, we used genotypic and phenotypic variance and covariance estimates for each environment separately. Thus selection index derived form such estimate is valid for that specific environment only. The selection index of Pantnagar environment cannot be used for Almora or Gorakhpur environments. For generalization, general selection indices were obtained using overall mean values of green ear characters (Table 3). For all three general selection indices, parents 1 ranked 1st and parent 2 ranked last in the index value for green ear traits. Other good parent obtaining high index values were parent 3, parent 4 and parent 7. Among 21 single cross hybrid cross 1 × 3 ranked 1st based on GSI 1 and GSI 2, 2nd based on GSI 3. According to GSI 3 cross 3 × 7 ranked first in the index value. Other crosses with better index values were 4 × 5, 3 × 7, 3 × 5 and 1 × 5 considering all the GSI's values.

Index selection is a procedure that combines all information available for an individual or family to aid in the selection of those with the highest aggregate breeding value. For green ear characters of maize it is worthwhile to construct selection index for particular environment and also for drawing general conclusion based on data collected over environment. One general

Table 2. Selection criterion and ranking of inbreds and their crosses for green ear maize using 15 characters

Parents/ crosses	Pantnagar						Almora						Gorakhpur					
	SCI	Rank	SC2	Rank	SC3	Rank	SCI	Rank	SC2	Rank	SC3	Rank	SCI	Rank	SC2	Rank	SC3	Rank
1	265.86	3	207.69	5	145.71	6	246.30	7	199.50	1	150.50	3	305.87	1	273.28	7	270.61	1
2	237.53	7	200.29	6	160.12	5	175.47	1	148.00	7	118.60	6	229.86	7	215.63	6	230.11	6
3	276.85	1	224.09	2	167.62	4	228.86	6	185.70	2	140.10	5	270.16	2	241.19	5	241.13	5
4	242.72	6	210.26	4	173.79	3	207.74	5	183.60	3	156.60	1	244.18	4	236.08	4	256.89	3
5	243.27	5	193.73	7	140.94	7	201.65	3	160.50	6	117.50	7	232.75	6	205.40	3	206.06	7
6	274.09	2	240.58	1	203.72	1	194.27	2	168.90	5	141.50	4	236.55	5	224.85	2	241.70	4
7	247.98	4	217.20	3	182.64	2	204.20	4	180.80	4	155.30	2	255.77	3	247.26	1	267.04	2
1 × 2	309.36	16	269.89	17	226.63	16	253.82	14	221.90	8	186.70	9	186.70	8	349.56	9	332.79	9
1 × 3	361.47	1	308.50	2	251.51	7	279.31	21	236.90	2	192.30	4	192.30	1	297.26	1	367.65	2
1 × 4	295.84	19	262.96	19	226.33	17	237.75	9	210.70	14	181.40	15	181.40	9	347.45	8	333.76	8
1 × 5	347.07	3	297.29	5	243.14	11	265.73	18	227.40	7	186.90	8	186.90	2	379.37	2	354.51	4
1 × 6	326.56	9	289.20	8	247.61	10	237.61	8	211.70	13	182.60	13	182.60	7	250.19	7	338.36	5
1 × 7	315.63	13	283.78	11	248.10	9	232.88	4	209.00	16	182.90	12	182.90	16	320.46	16	311.23	16
2 × 3	314.73	14	274.60	15	230.36	13	241.88	11	208.70	18	172.40	21	172.40	17	320.21	17	304.01	17
2 × 4	281.21	21	248.37	21	211.58	21	235.13	6	208.80	17	180.10	17	180.10	13	333.76	12	321.89	14
2 × 5	311.72	15	271.19	16	226.75	14	247.43	13	218.90	9	187.40	7	187.40	10	344.32	10	328.67	11
2 × 6	301.53	18	265.92	18	226.65	15	229.01	2	203.80	20	176.50	20	176.50	19	299.16	19	287.92	20
2 × 7	318.29	12	286.05	10	249.79	8	230.70	3	205.90	19	178.90	18	178.90	14	328.79	14	318.96	13
3 × 4	321.91	10	289.80	7	253.72	5	240.04	10	216.10	10	189.90	6	189.90	6	353.75	6	344.63	3
3 × 5	333.36	6	281.65	12	225.55	19	276.99	20	232.90	5	186.10	10	186.10	3	376.64	5	348.19	7
3 × 6	332.72	7	295.43	6	253.95	4	248.98	12	214.10	11	182.10	14	182.10	12	334.65	13	319.07	15
3 × 7	356.63	2	323.07	1	285.24	1	264.35	17	237.80	1	209.50	1	209.50	5	365.16	3	353.21	1
4 × 5	332.37	8	281.26	13	226.18	18	275.26	19	234.60	4	191.60	5	191.60	4	374.56	4	349.47	6
4 × 6	307.39	17	275.43	14	239.78	12	227.66	1	203.50	21	176.70	19	176.70	21	282.96	21	273.93	21
4 × 7	319.56	11	287.72	9	252.16	6	237.13	7	212.70	12	185.90	11	185.90	20	295.78	20	287.79	19
5 × 6	289.61	20	254.09	20	214.70	20	260.72	16	235.60	3	208.10	2	208.10	11	340.21	11	328.38	10
5 × 7	334.50	5	303.52	3	268.34	2	254.63	15	231.90	6	207.10	3	207.10	15	326.76	15	318.63	12
6 × 7	335.11	4	302.30	4	265.49	3	234.77	5	209.20	15	181.20	16	181.20	18	307.04	18	297.41	18

problem for selection index is to assign weight for a particular character either based on economic value and quality consideration. Economic values of the various traits breeders wish to select are rarely known, as only for few studies deal with this issue. To overcome this problem different relative weights were assigned to generate three different selection indices in each environment.

Among the inbred parents at Pantnagar environment line 6 and 7 may be considered to have good combination of green ear characters based on SI 2 and SI 3. Ranking based on SI 1 where equal importance to all characters was assigned is somewhat misleading. The performance of parents for green ear characters varied with environments, as depicted in the change in ranks for each selection criterion. At Almora environment, parents 1, 2 differed of based on SI 1 and SI 3, but common poor parent were identified (parent 2 and 5) based on SI 2 and SI 3. At Gorakhpur, the low performers for aggregate green ear traits were line 5 and line 6. Thus breeder can choose specific parent, which shows high aggregate genotypic values at each location and can follow a method to give more weights to green ear characters. This suggest that genotype by environment interaction plays an important role in the performance of the inbred lines for green ear characters.

Among 21 single crosses, at Pantnagar environment some crosses having good aggregate value in the selection criterion were 2 × 2, 5 × 7, 6 × 7, 1 × 3, 3 × 4 and 3 × 6. At Almora best crosses based on selection criterion SC 2 and SC 3 were 3 × 7, 1 × 3, 5 × 6, 4 × 5 and 5 × 7. Crosses 1 × 3, 3 × 7, 1 × 5, 3 × 4, 4 × 5, 1 × 6 were good for green ear characters at Gorakhpur based on SC 2 and SC 3. Cross 1 × 3 was observed to be consistent over the entire three environments for aggregate index value for green ear characters. Among other crosses, 5 × 7 at Pantnagar and Almora; 3 × 7, 4 × 5 at Almora and Gorakhpur; and 3 × 4 at Pantnagar and Gorakhpur were consistent in index value for green ear characters. The performance of single cross hybrids was also influenced by genotype-environment interaction as evidenced from alteration of ranking according to specific environment.

This problem can be partially solved by taking into consideration data from all the environments and by constructing generalized selection indices, which can predict the behaviour irrespective, of environments. The

Table 3. Selection criterion and ranking of 28 genotypes for green ear maize using general selection index

Genotypes	Selection criterion and rank					
	GSI 1	Rank	GSI 2	Rank	GSI 3	Rank
Parents						
1	301.08	1	378.83	1	79.93	1
2	220.27	7	268.09	7	34.52	7
3	277.55	2	341.02	2	68.48	2
4	252.09	3	313.04	3	45.88	4
5	238.79	6	300.83	4	42.57	6
6	242.06	5	296.84	6	43.61	5
7	245.65	4	299.43	5	51.98	3
Single crosses						
1 × 2	345.10	7	436.48	8	97.49	12
1 × 3	398.46	1	506.02	1	144.29	2
1 × 4	326.16	16	407.11	17	102.71	8
1 × 5	374.13	3	468.88	4	131.76	3
1 × 6	348.34	6	441.12	6	94.79	13
1 × 7	330.43	14	417.08	14	89.52	16
2 × 3	325.91	17	407.54	16	82.66	19
2 × 4	318.68	18	400.18	18	94.56	.14
2 × 5	342.23	10	430.89	9	97.84	11
2 × 6	306.97	20	382.85	20	87.00	18
2 × 7	328.80	15	410.77	15	94.54	15
3 × 4	342.66	9	426.85	12	114.94	6
3 × 5	372.80	4	471.18	3	126.52	4
3 × 6	341.01	11	427.38	11	101.36	10
3 × 7	367.52	5	450.84	5	145.44	1
4 × 5	385.93	2	487.65	2	122.43	5
4 × 6	299.97	21	378.43	21	74.56	21
4 × 7	312.42	19	394.42	19	75.88	20
5 × 6	331.89	13	420.74	13	102.55	9
5 × 7	344.67	8	437.2	7	106.73	7
6 × 7	335.12	12	428.36	10	88.35	17

Codes of the inbred parent are: 1. $P_{45}C_6H_2O_2$-2-B-B-B/ $P33C_2$CSTE7⊗13-162-1-1-2-4-1, 2. Pop31⊗23-1-1-1-1-12/ 3Z⊗4-2 to 3, 3. Comp A_6⊗1-90-37-5-1-2-1-2-1, 4. Lineas prometadorous process⊗6-7-2-3-5-4-1-1, 5. Comp A_6⊗ 1-90-37-5-1-1-2-5-1, 6. Lineas prometadorous process ⊗6-3-1-1-1-4-1-1, 7. YHP Alm⊗217-2-1-13-2-1.

general selection index indicated that parent 1, parent 3, parent 4, parent 7 showed higher index value for green ear characters among the 7 parent studied. The single crosses 1 × 3, 4 × 5, 3 × 7, 3 × 5 and 1 × 5 had higher index value based on general selection indices. For more precise estimates the number of environment should be increased restricting the number of characters to those, very pertinent to usage at green ear stage.

Acknowledgement

First author acknowledges financial support form CSIR in the form of Junior Research Fellowship. He is also thankful to The Director, V.P.K.A.S. (ICAR), Almora, for granting study leave during the course of study.

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