emergent
Life Sciences Research

Research Article

Use of different selection indices for improving the genetic gain in maize (*Zea mays* L.)

B. J. Antony, R. M. Kachapur, G. K. Naidu, S. C. Talekar, S. I. Haralpur, S. R. Salakinkop

Received: 16 January 2023
Accepted: 01 May 2023
Online: 09 May 2023

Authors:
B. J. Antony, R. M. Kachapur ✉, G. K. Naidu, S. C. Talekar, S. T. Haralpur, S. R. Salakinkop

✉ kachapurr@uasd.in

Emer Life Sci Res (2023) 9(1): 126-134

E-ISSN: 2395-6658
P-ISSN: 2395-664X

DOI: https://doi.org/10.31783/elsr.2023.91126134

Abstract

Plant breeding relies heavily on artificial selection for improving grain yield through various yield contributing traits. The selection of complex quantitative traits like maize grain yield is difficult due to less heritability and a greater influence of the environment. The present study was made using 25 maize inbred lines aimed at identifying yield-attributing traits and identifying simultaneous selection models based on discriminant functions. The expected genetic gain for grain yield when all the studied traits were included in simultaneous selection was higher (51.86) than that of selecting grain yield alone (33.96). There were four traits that made up the ideal discriminant function: grain yield, kernels per row, 100-grain weight and cob length which had 49.57 percent relative efficiency and 155.29 percent genetic advance. The relative efficiency of selection considering grain yield alone was at 106.38%, but when five (X_1, X_2, X_3, X_5, and X_6) and six traits were simultaneously considered the efficiency increased to 160.37 and 162.47%. Based on the ideal discriminant function among the genotypes G17 was selected as the best inbred line with the highest selection score of 66.57 followed by G20 (65.19) and G22 (65.01). Whereas, G23 was the last with 17.05 selection score.

Keywords discriminant function, genetic gain, maize, selection efficiency, selection index

Introduction

Maize (*Zea mays* L.) is an extensively grown cereal crop in the world and in India after rice and wheat. Maize along with other two staple cereals viz, wheat and rice forms a major component of the human diet, accounting for an estimated 42 percent of the world's food calories and 37 percent of protein intake [1]. Maize is cultivated under varied agro climatic situations from tropical to temperate regions. It has various uses as a source of raw material for the poultry industry and animal feed and off late industrial uses for extraction of starch, fructose and maltose syrup and oil etc. Because of all these uses, maize has been identified as a pro-industry-oriented crop that drives economic development and farmers income. The importance of maize is also evident from the fact that it is being cultivated in 165 countries around the world in 197 M. ha area, with a production of 1137 m.t and productivity of 5.8 tons/hectare [2]. Currently, USA ranks first in maize production and contributes about 40 % to global maize production. In terms of area and production, India ranks 4^{th}, occupying 4 % of the area and contributing 2 % to the global maize crop. In India maize is grown on an area of 9.5 million hectares during 2019-20 with production of 26.09 million tons and productivity of 3 t/ha [3].

The compound annual growth rate (CAGR) of consumption of maize by the feed industry is around 6 % globally. Whereas, it is 9.0 % in India [2] which provides a huge opportunity for farmers cultivate maize in India. India's productivity (3 t/ha) is extremely low when compared to the global average maize productivity (5.8 t/ha). In India, the maize area increase is very minimal, which is evident from the growth of maize area from 8.26 M. ha (2009-10) to 9.57 M. ha (2019-20) [4]. 70% of the maize growing area in India is under rainfed conditions (www.iimr.icar.gov.in) coupled with the emergence of many biotic and abiotic factors affecting the production and productivity of maize (www.ficci.in).

Therefore, the major target trait for crop improvement is grain yield in any of the maize breeding programs. But grain yield is a complex and variable trait determined by several component traits. Thus, the simultaneous selection of component traits may be an effective strategy for improving maize grain yield [5-6]. The selection index aids the selection of several traits simultaneously to improve the highly complex traits like yield by giving appropriate weightage to each trait [7]. Selecting yield-attributing traits based on the selection index is more efficient and effective than practicing direct selection for yield [8-9]. Besides that, lines selected using secondary traits show higher adaptability and good yield in maize [10-11]. Padjung et al., [11] suggested that secondary characters in corn keep potential lines yield more in any environmental conditions. Where, the discriminant function analysis concept helps to select lines with high grain yield and yield attributing traits, which was initially put forward by Fisher [12] and different researchers [12-13] to identify the combination of important components to formulate an effective selection strategy. This study discusses the use of the selection index to improve grain yield and examine their efficiency in the selection of maize.

Methodology

A set of 25 maize inbred lines (Table-1) collected from IMIC nursery CIMMYT and AICRP-Maize, Dharwad center were raised at All India Co-ordinated Maize Improvement Project, MARS, Dharwad during *Kharif*, 2020-21. Each entry was raised in randomized block design with three replications in two rows of 4 m length with a spacing of 60 x 20 cm and all recommended package of practices was followed. For each genotype, data was recorded on five randomly selected plants in each replication. The average values were subjected to statistical analysis for 11 traits viz., days to 50 percent tasseling, days to 50 percent silking, days to 75 percent dry husk, plant height (cm), ear height (cm), kernel row number, number of kernels per row, cob girth (cm), cob length (cm), 100-grain weight (g) and grain yield (q/ha). Six traits viz., grain yield (X_1), kernel row number(X_2), number of kernels per row (X_3), cob girth (X_4), cob length(X_5) and100-grain weight (X_6)were used to construct the selection index using discriminant function [14]. The grain yield is assumed to be the dependent character with 100 % relative efficiency while constructing the selection index. The method proposed by Robinson [15] was used to construct selection indices and to develop the discriminant function. Based on six characters, a total of 63 selection indices were developed. In addition, the genetic advance through selection was estimated using the formula [15]. The expected genetic advance from direct selection and from the selection indices were calculated as follows:

$$\text{Geneticadvance from direct selection} = \frac{z}{p}\frac{g_{yy}}{\sqrt{t_{yy}}}$$

$$\text{Genetic advance from selection indices} = \frac{z}{p}\sqrt{b_1 g_{1y} + b_2 g_{2y} + \cdots + b_n g_{ny}}$$

here, $\frac{z}{p}$ is the selection differential in standard units, for the present study it was 2.06 for 5 percent selected [16]. The g_{yy} and t_{yy} denote genotypic and phenotypic variances of trait y.b_1, b_2, b_n represent the relative weights of each character and g_{1y}, g_{2y}, …, g_{ny} represent genotypic covariances of independent characters.

The percent relative efficiency from the selection indices was calculated for all the functions studied as below,

$$\text{Percent relative efficiency} = \frac{\text{Geneticadvance from direct selection}}{\text{Genetic advance from selection indices}} - 1 \times 100$$

An individual genotype selection score was calculated using the most effective discriminant function that has a high percentage of relative efficiency and genetic advancement. The analysis was carried out using R Studio software with a selection index package.

Table 1. Description and source of maize inbred lines used for the investigation

Genotype number	Inbreds	Pedigree	Source
G1	IMIC-02	VL 162291 (AMDROUT)	CIMMYT
G2	IMIC-40	VL 18780 (CML45/G9AC6RC)	CIMMYT
G3	IMIC-68	VL 18797 (CML 161 x CML 451/ CML 161)	CIMMYT
G4	IMIC-69	VL 175118 (MARSSYN-155 -5-2-1-BB)	CIMMYT
G5	IMIC-73	VL 18935 ((CML 161 x CML 451)-B-18-1-BBB/CML 161-B)	CIMMYT
G6	IMIC-87	VL 18297 (Pop 351 Co-H S274-1-1-B-4-2-B*6/composite 14-BBB)	CIMMYT
G7	CTLB-01	VL 18718	CIMMYT
G8	CTLB-02	VL 175029	CIMMYT
G9	CML-451	[(NPH28-1* G25)* NPH28]-1-2-1-1-3-1-b*6	CIMMYT
G10	CI-4	Pop27-C5-HS-29-1-1-#	AICRP on maize, MARS, UAS Dharwad
G11	CM-202	C121E (US inbred line)	AICRP on maize, MARS, UAS Dharwad
G12	CM-111	Cuba 342-2-f ###	AICRP on maize, MARS, UAS Dharwad
G13	VL 109126	VL 109126	CIMMYT
G14	ZL 153493	ZL 153493	CIMMYT
G15	VL 105554	SW3-17-BB2-BBB-2BB	CIMMYT
G16	VL 143906	(CML 444/VL 111354)-42-B-1-BBB-1-BBB	CIMMYT
G17	VL 18448	CML 563	CIMMYT
G18	ZL 14501	ZL 14501	CIMMYT
G19	VL 18321	(CA 34505 x CA 00302)-B-2-1-B-1-BB(S)-B2-B*7	CIMMYT
G20	ZL 153493	ZL 153493	CIMMYT
G21	VL 18329	CML 582 (CA34505/CA0302)	CIMMYT
G22	VL 1110195	(POOL 16 BNSEQC3 F2 8 x 15-3-1-2-1-BB/ (CML 161 x CML 451)-B-23-1	CIMMYT
G23	KL 154690	(CML 468/ CML 444// CML 444-1-BBB)-BBB-1-B(DMR)-B	CIMMYT
G24	VL 19190	(CML 466/ CML 165-B// CML 466)-BB-9-B*4/ (CML 465/ CML 165-B// CML 465)	CIMMYT
G25	VL 162563	AMDROUT 1 (DT-Tester) c1 F2-36-8-B(DM) -BB-B1-B	CIMMYT

Results

Discriminant function analysis was used to find out suitable selection indices for improving complex traits like grain yield by finding out the relative role of component traits. Inbred lines under the study showed a high level of significance in multivariate analysis of variance (MANOVA) as shown in Table 2. The average selection efficiency of the trait and combinations is displayed in Table 3. The results of

Table 2. Multivariate analysis of variance (MANOVA) for 25 inbred lines ofmaize

Source of variation	df	Approx. F	p value
Genotypes	24	9.42	<2e-16 **
Replication	1	1.35	0.25
Error	49		

**- Significance at 1% level of probability

Table 3. Average selection efficiency of various combinations of traits in maize

No. of traits in the index	Percent Relative efficiency
One	29.970
Two	57.502
Three	84.162
Four	110.447
Five	136.527
Six	162.472

the selection index revealed that selection efficiency was higher when the selection was based on the combinations of components compared with selection based on yield alone (Table 3). It is possible to achieve the greatest selection efficiency if all the six traits are considered while selecting. In the case of selecting a single trait, grain yield (q/ha) showed a genetic advance of 33.96% (Table 4), and it was much smaller when compared with the combinations of traits. Using simultaneous selection with two discriminants, the highest genetic advance (41.59%) would result from combining grain yield (X_1) and 100-grain weight (X_6), followed by grain yield (X_1) and a number of kernels per row (X_3) (40.09%). The genetic advance further increased to 47.71% and 49.57% when three traits were considered together (grain yield (X_1), number of kernels per row (X_3)

Table 4. Highest relative efficiency and genetic advance of trait combinations in maize

Trait combinations	Genetic Advance	Percent Relative Efficiency
Grain yield q/ha	33.960	106.383
Grain yield (q/ha) + 100- grain weight (g)	41.588	130.278
Grain yield (q/ha) + Number of kernels per row	40.087	125.578
Grain yield (q/ha) + Number of kernels per row + 100-grain weight (g)	47.714	149.471
Grain yield (q/ha) + cob length + 100-grain weight (g)	43.155	135.188
Grain yield (q/ha) + Number of kernels per row+ cob length + 100-grain weight (g)	49.572	155.291
Grain yield (q/ha) + Kernel row number+ Number of kernels per row + 100-grain weight (g)	49.290	154.406
Grain yield (q/ha) + Kernel row number+ Number of kernels per row + cob length + 100-grain weight (g)	51.198	160.383
Grain yield (q/ha) + Number of kernels per row + cob girth + cob length + 100-grain weight (g)	50.219	157.318
Grain yield (q/ha) + Kernel row number+ Number of kernels per row + cob girth + cob length + 100-grain weight (g)	51.865	162.472

and 100-grain weight (X_6))and four traits(grain yield (X_1), number of kernels per row (X_3) and 100-grain weight (X_6) and cob length (X_5)), respectively. It was found that the combination of six traits had a high expected genetic advance of 51.87%, which is nearly equal to the estimated genetic advance of the five traits, including grain yield (X_1), kernel row number (X_2), number of kernels per row (X_3), cob length (X_5), and 100-grain weight (X_6), which demonstrated 51.19% expected genetic advance (Table 4). The average selection efficiency varies from 29.97 (when one trait is taken into consideration) to 162.47 (when all traits are considered) (Table 3). The relative selection efficiency was observed to increase with an increasing number of traits along with grain yield, as shown in Table 4. The relative efficiency of selection based on grain yield alone is 106.38%, but when selection is made using five (X_1, X_2, X_3, X_5, and X_6) and six traits simultaneously it increases to 160.37 and 162.47 percent respectively. Breeding programs aim to maximize genetic gain through selection, but it is also recommended to select fewer traits to reduce the labour involved and time and make a better selection strategy. Accordingly, the selection index consisting of four traits: grain yield (X_1), number of kernels per row (X_3), 100-grain weight (X_6), and cob length (X_5) that exhibited 49.57 percent genetic advance and 155.29 percent relative efficiency is identified as optimum selection indices. By calculating the selection score for each inbred line using the ideal selection index the genotypes were ranked (Table 5). As a result, G17 had the highest selection score of 66.57 followed by G20 (65.19) and G22 (65.01) which are easily selected. Whereas, G23 ranked last with a 17.05 selection score.

Table 5. Selection score and genotype ranking based on scores for 25 inbred lines of maize

SN.	Genotype	Selection Score	Rank
1	G1	50.61	11
2	G2	51.59	10
3	G3	62.71	5
4	G4	42.91	13
5	G5	23.00	23
6	G6	45.53	12
7	G7	39.14	14
8	G8	34.64	16
9	G9	31.92	18
10	G10	33.67	17
11	G11	28.33	20
12	G12	23.77	22
13	G13	63.31	4
14	G14	57.59	7
15	G15	23.89	21
16	G16	54.12	8
17	G17	66.57	1
18	G18	38.86	15
19	G19	53.47	9
20	G20	65.19	2
21	G21	17.82	24
22	G22	65.01	3
23	G23	17.05	25
24	G24	58.06	6
25	G25	30.88	19

Discussion

Selection is a common technique used in crop improvement programs and is mainly aimed at increasing grain yield [17]. The selection efficiency increases by concurrently selecting important yield-attributing traits based on the index that gives appropriate weight to each trait as compared to choosing a single character [13]. Robinson et al., [15] proposed a method that is a well-known model of selection indices and the use of selection indices for improving the selection efficiency was reported in rice [18]. Similarly, it was planned to use different selection indices in this study to evaluate 25 maize inbred lines for six traits to identify a superior lines among them. MANOVA showed significant differences among the inbred lines, which indicated the existence of genetic divergence among the inbred lines under evaluation which is sufficient for the traits examined. The results demonstrated that the selection index, which comprises more than one trait, can provide significantly higher genetic advance compared to the selection of a single trait, pointing to the practicality of using selection indices for the simultaneous improvement of several traits [19]. The highest estimated genetic gain was achieved when selection was based on all six traits. Nevertheless, the results suggest that the selection of kernel row number (X_2), number of kernels per row (X_3), cob length (X_5), and 100-grain weight (X_6) along with grain yield (X_1) can be practiced to achieve similar results, given that both had the same genetic gains. These results are in accordance with [20], who suggested that selection based on the index using kernel rows and kernel weight was almost as efficient as selection for yield itself. Similarly, Khavari and Poor [21], identified, kernel row number and the number of kernels per row were as important traits. Whereas, Asghar and Mehdi [22], suggested 100-grain weight as an important trait to be considered while selecting for grain yield. Additionally, the results showed that when any attribute was considered in combination with grain yield, it resulted in higher relative genetic advance and selection efficiency (Table 6) the findings in the present study are in concurrence with the other similar results in maize [23].

Table 6. Selection indices, discriminant function, expected genetic advance and percent relative efficiency for different selection indices in maize

SN.	Selection Indices	Discriminant Function	Genetic Advance	Percent Relative Efficiency
1	Grain yield X_1	$0.9439\ X_1$	33.960	106.383
2	Kernel row number X_2	$0.7731\ X_2$	2.201	6.894
3	Number of kernels per row X_3	$0.9018\ X_3$	8.572	26.853
4	Cob girth X_4	$0.8978\ X_4$	0.797	2.496
5	Cob length X_5	$0.8836\ X_5$	3.536	11.077
6	100-grain weight X_6	$0.9202\ X_6$	8.338	26.119
7	X_1, X_2	$0.9545\ X_1 + 0.6744\ X_2$	35.351	110.742
8	X_1, X_3	$0.9466\ X_1 + 0.9522\ X_3$	40.087	125.578
9	X_1, X_4	$0.9339\ X_1 + 1.6861\ X_4$	34.469	107.978
10	X_1, X_5	$0.947\ X_1 + 0.8653\ X_5$	35.488	111.171
11	X_1, X_6	$0.8996\ X_1 + 1.2235\ X_6$	41.588	130.278
12	X_2, X_3	$0.4691\ X_2 + 1.0032\ X_3$	10.639	33.327
13	X_2, X_4	$0.636X_2 + 1.5107\ X_4$	2.928	9.173
14	X_2, X_5	$0.6975\ X_2 + 0.9536\ X_5$	5.246	16.432
15	X_2, X_6	$0.7295\ X_2 + 0.9462\ X_6$	9.678	30.316
16	X_3, X_4	$0.8157\ X_3 + 2.0053\ X_4$	9.332	29.232
17	X_3, X_5	$0.9034\ X_3 + 0.9182\ X_5$	11.552	36.187
18	X_3, X_6	$0.9042\ X_3 + 0.9532\ X_6$	15.365	48.132
19	X_4, X_5	$1.4696\ X_4 + 0.7896\ X_5$	4.285	13.423
20	X_4, X_6	$1.5111\ X_4 + 0.8886\ X_6$	8.939	28.002
21	X_5, X_6	$0.8319\ X_5 + 0.9302\ X_6$	10.393	32.556
22	X_1, X_2, X_3	$0.953\ X_1 + -0.0553\ X_2 + 1.1653\ X_3$	41.715	130.679
23	X_1, X_2, X_4	$0.9428\ X_1 + 0.3132\ X_2 + 2.8409\ X_4$	35.895	112.446
24	X_1, X_2, X_5	$0.958\ X_1 + 0.5809\ X_2 + 0.9486\ X_5$	36.961	115.785
25	X_1, X_2, X_6	$0.9164\ X_1 + 0.4666\ X_2 + 1.2342\ X_6$	42.965	134.592
26	X_1, X_3, X_4	$0.9447\ X_1 + 0.8588\ X_3 + 2.1465\ X_4$	40.676	127.423
27	X_1, X_3, X_5	$0.9451\ X_1 + 1.027\ X_3 + 0.6916\ X_5$	41.964	131.457
28	X_1, X_3, X_6	$0.9118\ X_1 + 0.8719\ X_3 + 1.2386\ X_6$	47.714	149.471
29	X_1, X_4, X_5	$0.9258\ X_1 + 3.7498\ X_4 + 0.4318\ X_5$	36.065	112.979
30	X_1, X_4, X_6	$0.899\ X_1 + 0.9837\ X_4 + 1.2256\ X_6$	42.116	131.934
31	X_1, X_5, X_6	$0.9065\ X_1 + 0.6042\ X_5 + 1.2586\ X_6$	43.155	135.188
32	X_2, X_3, X_4	$0.4145\ X_2 + 0.9089\ X_3 + 2.2696\ X_4$	11.398	35.706
33	X_2, X_3, X_5	$0.3275\ X_2 + 1.0448\ X_3 + 0.8988\ X_5$	13.551	42.449

Continued Table 6.

34	X_2, X_3, X_6	$0.2987 X_2 + 1.0483 X_3 + 0.9502 X_6$	17.191	53.853
35	X_2, X_4, X_5	$0.4975 X_2 + 2.5407 X_4 + 0.7519 X_5$	6.066	19.004
36	X_2, X_4, X_6	$0.428 X_2 + 2.583 X_4 + 0.8921 X_6$	10.376	32.505
37	X_2, X_5, X_6	$0.7158 X_2 + 0.874 X_5 + 0.9495 X_6$	11.927	37.361
38	X_3, X_4, X_5	$0.7986 X_3 + 2.8447 X_4 + 0.7596 X_5$	12.349	38.685
39	X_3, X_4, X_6	$0.7657 X_3 + 2.8358 X_4 + 0.9274 X_6$	16.116	50.486
40	X_3, X_5, X_6	$0.964 X_3 + 0.7473 X_5 + 0.9434 X_6$	17.948	56.225
41	X_4, X_5, X_6	$3.5886 X_4 + 0.4373 X_5 + 0.8537 X_6$	11.175	35.007
42	X_1, X_2, X_3, X_4	$0.9505 X_1 + -0.114 X_2 + 1.0556 X_3 + 2.5431 X_4$	42.321	132.575
43	X_1, X_2, X_3, X_5	$0.9519 X_1 + -0.1909 X_2 + 1.2737 X_3 + 0.6857 X_5$	43.647	136.731
44	X_1, X_2, X_3, X_6	$0.9265 X_1 + -0.1335 X_2 + 1.1122 X_3 + 1.1913 X_6$	49.290	154.406
45	X_1, X_2, X_4, X_5	$0.9359 X_1 + 0.2023 X_2 + 5.1606 X_4 + 0.4247 X_5$	37.575	117.709
46	X_1, X_2, X_4, X_6	$0.9167 X_1 + 0.17 X_2 + 2.5507 X_4 + 1.1804 X_6$	43.520	136.332
47	X_1, X_2, X_5, X_6	$0.92 X_1 + 0.5635 X_2 + 0.6988 X_5 + 1.2467 X_6$	44.592	139.689
48	X_1, X_3, X_4, X_5	$0.9356 X_1 + 0.8752 X_3 + 4.1717 X_4 + 0.4075 X_5$	42.601	133.452
49	X_1, X_3, X_4, X_5	$0.9128 X_1 + 0.7925 X_3 + 2.00 X_4 + 1.2239 X_5$	48.310	151.336
50	X_1, X_3, X_4, X_6	$0.9047 X_1 + 1.0334 X_3 + 0.4236 X_4 + 1.2541 X_6$	49.572	155.291
51	X_1, X_4, X_5, X_6	$0.8876 X_1 + 4.5107 X_4 + 0.0746 X_5 + 1.2125 X_6$	43.752	137.059
52	X_1, X_3, X_4, X_5	0.2507 X1 + 0.9302 X3 + 3.3637 X4 + 0.6966 X5	14.354	44.964
53	X_2, X_3, X_4, X_5	0.2122 X2 + 0.9043 X3 + 3.2138 X4 + 0.9172 X5	17.958	56.257
54	X_2, X_3, X_4, X_6	0.1579 X2 + 1.1482 X3 + 0.7301 X4 + 0.9387 X6	19.805	62.042
55	X_2, X_4, X_5, X_6	0.3003 X2 + 5.0807 X4 + 0.4045 X5 + 0.8565 X6	12.786	40.054
56	X_3, X_4, X_5, X_6	0.7753 X3 + 4.89 X4 + 0.4218 X5 + 0.8912 X6	18.772	58.805
57	X_1, X_2, X_3, X_4, X_5	0.9408 X1 + -0.2886 X2 + 1.1137 X3 + 4.8354 X4 + 0.3437 X5	44.302	138.783
58	X_1, X_2, X_3, X_4, X_6	0.9287 X1 + -0.2063 X2 + 1.0069 + 2.6004 X4 + 1.1624 X6	49.900	156.319
59	X_1, X_2, X_3, X_5, X_6	0.921 X1 + -0.2564 X2 + 1.2986 + 0.4382 X5 + 1.2003 X6	51.198	160.383
60	X_1, X_2, X_4, X_5, X_6	0.9074 X1 + 0.0759 X2 + 6.2576 X4 + 0.0813 X5 + 1.162 X6	45.227	141.679
61	X_1, X_3, X_4, X_5, X_6	0.8992 X1 + 0.8373 X3 + 5.1962 X4 + 0.0633 X5 + 1.212 X6	50.219	157.318
62	X_2, X_3, X_4, X_5, X_6	0.0134 X2 + 0.9618 X3 + 5.60 X4 + 0.347 X5 + 0.8743 X6	20.648	64.682
63	X_1,X_2, X_3, X_4, X_5, X_6	0.9161 X1 + -0.4044 X2 + 1.0974 X3 + 6.0662 X4 + 0.0082 X5 + 1.142 X6	51.865	162.472

The results identified by the selection index consist of four traits: grain yield (X_1), number of kernels per row (X_3), 100-grain weight (X_6), and cob length (X_5) as the best model. This combination of traits showed the highest relative efficiency on par with the combination of all six traits. It also gives added advantage to breeders by reducing phenotyping costs. Using the same model, the genotypes are ranked and the genotype G17 with the highest value followed by G20 and G22 were identified as the best genotypes. They can be selected and advanced for further breeding programs. In addition, the present study demonstrated that the method of discriminant function selection in plants was more effective than the method of straight selection based only on grain yield. Using a selection index to simultaneously select yield attributing traits by providing appropriate weightage to all the components could efficiently improve grain yield [24-25]. Consequently, when selecting maize grain yield, it is crucial to pay attention to all important attributing traits with appropriate selection factors.

Acknowledgments

The authors acknowledge the support of AICRP-Maize, University of Agricultural Sciences, Dharwad for providing all the logistic support in the conduct of the experiment and data collection and CIMMYT for the genetic material. The authors also wish to thank the Department of Genetics and Plant Breeding, AC, Dharwad for providing facilities. Additionally, the first author would also like to thank the

Indian Council of Agricultural Research (ICAR) for providing financial assistance for carrying out the PG research.

References

[1] O. Erenstein, M. Jaleta, K. Sonder, K. Mottaleb and B. M. Prasanna **(2022)**. Global maize production, consumption and trade: trends and R & D implications. Food Sec., **14:** 1295-1319.
[2] Anonymous **(2022)**. Maize vision: a knowledge report. https://ficci.in/spdocument/22966/India-Maize-Summit.
[3] Anonymous **(2020)**. Area, production and productivity of maize in India. https://iimr.icar.gov.in/india-maze-scenario.
[4] Anonymous **(2021)**. Agriculture statistics at a glance-2021, Department of Agriculture and Farmers welfare and Department of Economics and Statistics, Governement of India, https://eands.dacnet.nic.in
[5] S. J. Dao, E. V. S. Traore, V. Gracen and Y. D. Eric **(2017)** Selection of drought tolerant maize hybrids using path coefficient analysis and selection index. Pakistan J. Biol. Sci., **20:** 132-139.
[6] N. M. Htwe, M. Aye and C. N. Thu **(2020)**. Selection index for yield and yield contributing traits in improved rice genotypes. Int. J. Environ. Rural Develop., **11:** 86-91.
[7] L. N. Hazel **(1943)**. The genetic basis for constructing selection indexes. Genetics, **28:** 476-490.
[8] M. R. Islam, M. O. Kayess, M. Hasanuzzaman, W. M. Rahman, M. J. Uddin and M. R. Zaman **(2017)**. Selection index for genetic improvement of wheat (*Triticum aestivum* L.). J. Chem. Biol. Phys. Sci., **7:** 1-8.
[9] M. F. Anshori, B. S. Purwoko, I. S. Dewi, S. W. Ardie and W. B. Suwarno **(2019)**. Selection index based on multivariate analysis for selecting doubled-haploid rice lines in lowland saline prone area. SABRAO J. Breed. Genet., **51:** 161-174.
[10] N. Fadhli, M. Farid, Rafiuddin, R. Effendi, M. Azrai and M. F. Anshori **(2020)**. Multivariate analysis to determine secondary trait in selecting adaptive hybrid maize lines under drought stress. Biodiversitas J. Biol. Divers., **21:** 3617-3624.
[11] R. Padjung, M. Farid, Y. Musa, M. F. Anshori, A. Nur and A. Masnenong **(2021)**. Drought-adapted maize line based on morphophysiological selection index. Biodiversitas J. Biol. Divers., **22:** 4028-4035.
[12] R. A. Fisher **(1936)**. The use of multiple measurements in taxonomic problems. Ann. Eugen., **7:** 179-188.
[13] H. F. Smith **(1936)**. A discriminant function for plant selection. Ann. Eugen., **7:** 240- 250.
[14] A. R. Dhabolkar **(1999)**. Elements of biometrical genetics. Concept publishing company, New Delhi, India.
[15] H. F. Robinson, R. E. Comstock and P. H. Harvey **(1951)**. Genotypic and phenotypic correlations in corn and their implications in selection. Agron. J., **43:** 282-287.
[16] J. L. Lush (1949). Heritability of quantitiave characters in farm animals. Heriditas, **35(S1):** 356-375.
[17] I. Bos and P. D. Caligari **(2007)**. Selection methods in plant breeding (2nd edition). Springer Germany.
[18] R. Venmuhil, D. Sassikumar, C. Vanniarajan and R. Indirani **(2020)**. Selection indices for improving the selection efficiency of rice genotypes using grain quality traits. Electron. J. Plant Breed., **11:** 543-549.
[19] A. D. Kalola, D. J. Parmar, G. N. Motka and P. R. Vaishnav **(2018)**. Comparison of selection indices using different weights for biometrical characters in bajra crop. Electron. J. Plant Breed., **9:** 124-134.
[20] M. Yousaf **(1977)**. The use of selection indices in maize (*Zea mays* L.). *In* A. Muhammed, R. Aksel, R. C. Borstel (Eds) Genetic Diversity in Plants, Springer publication. pp259-367. doi: 10.1007/978-1-4684-2886-5_24.
[21] S. K. Khavari and A. M. Poor **(2018)**. Genetic improvement of grain yield by determination of selection index in single cross hybrids of maize (*Zea mays* L.). Plant Genet. Res., **5:** 1-18.
[22] M. J. Asghar and S. S. Mehdi **(2010)**. Selection indices for yield and quality traits in sweet corn. Pak. J. Bot., **42:** 775-789.

[23] D. S. M. Al-Obeydy, J. M. Al-Juboory and A. H. Al-Juboory **(2015)**. Estimating of genetic parameters and construction of selection indices for exotic and endogenous maize genotypes. J. Tikrit Univ. Agri. Sci., **15:** 8-17.
[24] D. S. Falconer and T. F. C. Mackay **(1996)**. Introduction to Quantitative Genetics, 4th edition, New York, Longman Inc.
[25] Q. O. Oloyede-Kamiyo **(2019)**. Efficiency of index-based selection methods for stem borer resistance in maize (*Zea mays* L.). J. Crop Sci. Biotechnol., **22:** 205-211.