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Utilizing Selection Indices and Discriminant Function Analysis to Enhance Seed Yield in Sesame (*Sesamum indicum* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The current study focuses on harnessing genetic variation and employing selection indices for evaluating thirty-four advanced sesame breeding lines, alongside four checks (DS-5, DSS-9, JTS-8, and TKG-22). The evaluation encompassed the assessment of fifteen quantitative traits during the summer of 2022 at the AICRP on Sesame and Niger, MARS, UAS, Dharwad. Particularly noteworthy was the high genotypic and phenotypic coefficient variation observed for traits such as the number of secondary branches per plant, yield per plant (g) and seed yield (Kg/ha). The highest heritability coupled with the greatest genetic advance over the mean was detected for the number of primary branches per plant, suggesting a predominant role of additive genetic components in their expression and indicating a promising avenue for

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direct selection. The study involved the construction of thirty-one selection indices using the discriminant function technique, which incorporated five key traits: seed yield per plant (g) (X1), days to maturity (X2), number of productive capsules per plant (X3), thousand seed weight (g) (X4), and oil content (%) (X5). Among these various selection indices, the one comprising all component characters (X1, X2, X3, X4, and X5) exhibited the highest expected genetic advance and relative efficiency.

Keywords: Sesame; relative efficiency; selection index; discriminant function; expected genetic advance and genetic variation.

1. INTRODUCTION

"Sesame (*Sesamum indicum* L.) is an ancient oilseed crop with a historical origin dating back to 1600 B.C in the Tigris and Euphrates valleys" [1]. "This highly nutritious oilseed boasts a composition comprising protein (18-25%), carbohydrates (13.5%), oil (44-58%) and an array of essential minerals, including calcium, phosphorous, zinc, manganese, copper and iron. Notably, sesame is rich in polyunsaturated fatty acids with significant proportions of oleic acid (43%), linoleic acid (35%), palmitic acid (11%) and stearic acids (7%)" [2]. "Its health benefits encompass a wide range including antioxidant, antiaging, antihypertensive, anticancer, cholesterol-lowering and antimutagenic properties" [3]. "Sesame oil is renowned for its exceptional shelf life, attributed to its resistance to oxidative rancidity even after prolonged exposure to air" [4]. The demand for sesame is steadily increasing in India, driven by the rising consumption of edible oils. Despite being one of the earliest known oilseed crops with a long history, sesame often remains a neglected or "orphan crop" in India, primarily due to the limited research efforts devoted to it [5].

The foundation of crop improvement programs and the achievement of breeding objectives hinge on the assessment of variability within breeding lines. In their work from, Hazel and Lush [6] demonstrated that utilizing a selection index for a specific trait proves to be a more effective approach compared to the selection of individual traits. Fisher's discriminant function analysis, developed in [7], provides valuable insights into the appropriate weighting assigned to various yield components. An exhaustive examination involving 31 selection indices, constructed from all conceivable combinations of five distinct traits revealed that when selection is predicated on individual components, it outperforms straight selection, resulting in enhanced selection efficiency.

2. MATERIALS AND METHODS

The experiment was conducted during summer 2022 at AICRP on Sesame and Niger, MARS, UAS, Dharwad. Thirty-four advanced breeding lines derived from cross DS-5 × RMT-496 along with four checks *viz.,* DS-5, DSS-9, JTS-8 and TKG-22 (Table 1) were evaluated in Randomized Complete Block Design (RCBD) with two replications for fifteen quantitative traits *viz.,* days to 50% flowering, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of productive branches per plant, number of productive capsules per plant, number of capsules on main stem, capsule length (cm), number of seed per capsule, internodal length (cm), thousand seed weight (g), oil content (%), yield per plant (g) and seed yield (Kg/ha). Genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) as per Burton [8] and heritability (h^2) and genetic advance over mean (GAM) according to Allard [9] were estimated. Discriminant function analysis described by Dabholkar [10] was used to construct the selection indices involving five characters *viz*., seed yield per plant (X_1) along with four components *viz.,* days to maturity (X_2), number of productive capsules per plant (X_3), 1000 seed weight (X_4) and oil content (X_5).

3. RESULTS AND DISCUSSION

Analysis of variance for fifteen productivity traits was carried out (Table 2). The mean sum of squares for genotypes were highly significant for all traits except for two traits *viz.,* days to 50 percent flowering and days to maturity suggesting that the material under investigation possessed considerable amount of genetic variability. These results indicated that significant variations exist across advanced breeding lines for all traits examined, which may give breeders an excellent opportunity to recognize high-performing lines for desirable characteristics to improve crop yield. Notably, the estimation of both Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) indicated higher values for traits such as the number of secondary branches per plant (49.05% &46.37%), yield per plant (g) (29.19% & 27.84%), and seed yield (Kg/ha) (31.79% & 29.19%), signifying the presence of considerable variability in these specific attributes (Table 3). These results are in consonance with Kehie et al. [11] and Saravanan et al. [12]. This points to a substantial reservoir of variation within the studied genotypes for these traits. Additionally, heritability, in conjunction with the genetic advance as a percentage of the mean, exhibited high values across all traits, including the number of primary branches per plant (91.33& 32.16), number of secondary branches per plant (89.36% & 80.29%), number of productive branches per plant (90.57% & 34.29%), number of productive capsules per plant (90.72% & 37.73%), number of seeds per capsule (83.47% & 35.16%), seed yield per plant (g) (90.91% & 54.67%) and seed yield (Kg/ha) (84.33% & 55.22%). Similar result was observed by Kiruthika et al. [13]. These findings highlight the significant role of additive gene action in the inheritance of these traits suggesting that they can be effectively improved through straightforward and direct selection methods.

Selection indices were formulated and evaluated for their relative efficiency (RI) in selecting superior genotypes, particularly concerning seed yield per plant and other traits. The data pertaining to selection indices, discriminant functions, expected genetic gains, and RI are summarized in Table 4 and Table 5. When seed yield per plant was included in the selection function, the RI reached 119.04%. This percentage increased to 121.53% when two traits (seed yield per plant + number of productive capsules per plant) were simultaneously considered. Among the combinations involving the consideration of three traits simultaneously (Seed yield per plant + Number of productive capsules per plant + thousand seed weight), the highest RI observed was 123.72%, which further improved to 124.52% when four traits (seed yield per plant + number of productive capsules per plant +1000 seed weight - oil content) were simultaneously accounted for. The highest RI of 125.26% was achieved when all five characters (Seed yield per plant - Days to maturity + Number of productive capsules per plant +1000 seed weight - Oil content) were considered simultaneously. Remarkably, it's worth noting that whenever seed yield per plant was combined with any other trait, it led to an enhancement in the expected genetic gain [14].

Table 1. List of advanced breeding lines of sesame of cross DS-5 × RMT-496

SL. No	Genotypes	SL. No	Genotypes
1	(DS-5 × RMT-496)-1-1-1-1	20	(DS-5 × RMT-496)-3-2-1-2
2	(DS-5 × RMT-496)-1-1-1-2	21	(DS-5 × RMT-496)-3-2-3-1
3	(DS-5 × RMT-496)-1-1-1-3	22	(DS-5 × RMT-496)-3-2-3-2
4	(DS-5 × RMT-496)-1-2-1-1	23	(DS-5 × RMT-496)-3-2-3-3
5	(DS-5 × RMT-496)-1-2-1-2	24	(DS-5 × RMT-496)-3-3-1-1
6	(DS-5 × RMT-496)-1-3-1-1	25	(DS-5 × RMT-496)-3-3-1-2
7	(DS-5 × RMT-496)-1-3-1-2	26	(DS-5 × RMT-496)-3-3-1-3
8	(DS-5 × RMT-496)-1-3-1-3	27	(DS-5 × RMT-496)-3-3-2-1
9	(DS-5 × RMT-496)-1-3-3-1	28	(DS-5 × RMT-496)-3-3-2-2
10	(DS-5 × RMT-496)-1-3-3-2	29	(DS-5 × RMT-496)-3-3-3-1
11	(DS-5 × RMT-496)-1-3-3-3	30	(DS-5 × RMT-496)-3-3-3-2
12	(DS-5 × RMT-496)-3-1-1-1	31	(DS-5 × RMT-496)-3-3-3-3
13	(DS-5 × RMT-496)-3-1-1-2	32	(DS-5 × RMT-496)-3-3-4-1
14	(DS-5 × RMT-496)-3-1-1-3	33	(DS-5 × RMT-496)-3-3-4-2
15	(DS-5 × RMT-496)-3-1-2-1	34	(DS-5 × RMT-496)-3-3-4-3
16	(DS-5 × RMT-496)-3-1-2-2	35	DS-5(local check)
17	(DS-5 × RMT-496)-3-1-3-1	36	DSS-9(local check)
18	(DS-5 × RMT-496)-3-1-3-2	37	JTS-8(zonal check)
19	(DS-5 × RMT-496)-3-2-1-1	38	TKG-22(national check)

Table 2. Analysis of variance for fifteen quantitative characters in advanced breeding lines of sesame cross DS-5 × RMT-496

Source of variation	d. f	DFF	DM	PH (cm)	NPB	NSB	NPBP	NPCP	NCMS	CL (cm)	NSPC	INL (cm)	TSW (g)	OC (%)	YPP (g)	SY (Kg/ha)
Replication	1	11.07	7.58	5.09	0.11	0.28	0.02	361.18	0.01	0.07	112.92	0.04	0.21	28.67	4.53	852.76
Genotypes	37	1.69	4.47	101.24**	1.77**	0.80**	1.42**	950.26**	20.06**	0.08**	126.64**	0.11**	0.16**	36.50**	9.58**	57711.65**
Error	37	0.69	1.80	7.68	0.08	0.05	0.07	46.21	5.90	0.04	11.41	0.04	0.06	9.63	0.46	4905.18
CV (%)		1.51	1.28	2.57	13.80	16.00	16.51	6.15	8.65	6.22	8.31	5.91	7.91	7.96	8.80	12.58

**- Significant at 5% probability level   **- Significant at 1% probability level*

DFF-Days to 50% flowering; DM- Days to maturity; PH: Plant height (cm); NPB- Number of primary branches; NSB- Number of secondary branches; NPBP- Number of productive branches per plant; NPCP- Number of productive Capsules per plant; NCMS- Number of capsules on main stem; CL- Capsule length (cm); NSPC- Number of seed per capsule; INL- Internodal length (cm); TSW-Thousand seed weight (g); OC-Oil content (%); YPP- Yield per plant (g); SY- Seed yield (Kg/ha).

Table 3. Genetic variability parameters for yield and yield related characters in advanced breeding lines of sesame cross DS-5 × RMT-496

Character	Range		Mean	Coefficient of variation		h^2 (%)	GAM (%)
	Min.	Max.		PCV (%)	GCV (%)		
DFF	53.00	57.00	54.78	1.99	1.30	42.28	1.74
DM	101.50	107.50	104.92	1.69	1.10	42.73	1.49
PH (cm)	95.17	126.50	107.81	6.85	6.34	85.89	12.11
NPB	3.50	7.50	5.63	17.09	16.33	91.33	32.16
NSB	0.22	2.50	1.33	49.05	46.37	89.36	80.29
NPBP	3.00	6.35	4.69	18.38	17.49	90.57	34.29
NPCP	63.33	168.67	110.58	20.19	19.23	90.72	37.73
NCMS	21.33	34.50	28.07	12.83	9.48	54.54	14.42
CL (cm)	2.62	3.45	3.04	7.87	4.82	37.56	6.09
NSPC	28.67	57.67	40.63	20.45	18.68	83.47	35.16
INL (cm)	3.05	3.97	3.58	7.77	5.04	42.14	6.75
TSW (g)	2.46	3.99	3.20	10.50	6.91	43.23	9.35
OC (%)	27.68	45.48	38.99	12.32	9.40	58.26	14.78
YPP (g)	3.92	13.45	7.67	29.19	27.84	90.91	54.67
SY (Kg/ha)	274.00	972.29	556.67	31.79	29.19	84.33	55.22

Table 4. Average selection efficiency of different combination of characters in sesame

No. of characters in the index	Relative Efficiency (%)
One	27.55
Two	53.47
Three	78.11
Four	101.68
Five	125.26

Table 5. Highest Relative efficiency with character combinations in sesame

SL. No.	Character	Relative efficiency (%)
1	Seed yield per plant	119.04
2	Seed yield per plant + Number of productive capsules per plant	121.53
3	Seed yield per plant - 1000 seed weight	121.19
4	Seed yield per plant + Number of productive capsules per plant +1000 seed weight	123.72
5	Seed yield per plant + Number of productive capsules per plant - Oil content	122.23
6	Seed yield per plant +1000 seed weight - Oil content	122.03
7	Seed yield per plant + Number of productive capsules per plant +1000 seed weight - Oil content	124.52
8	Seed yield per plant - Days to maturity +Number of productive capsules per plant -1000 seed weight	123.43
9	Seed yield per plant - Days to maturity + Number of productive capsules per plant +1000 seed weight - Oil content	125.26

Table 6. Selection index, discriminant function, expected genetic advance in yield and relative efficiency from the use of different selection indices in sesame

SL. No.	Selection index	Discriminant function	Expected genetic advance	Relative efficiency (%)
1	X_1 Seed yield per plant	$0.84 X_1$	318.03	119.04
2	X_2 Days to maturity	$0.40 X_2$	1.49	0.56
3	X_3 Number of productive capsules per plant	$0.90 X_3$	44.05	16.49
4	X_4 1000 seed weight	$0.42 X_4$	0.30	0.11
5	X_5 Oil content	$0.48 X_5$	4.221	1.58
6	$X_1.X_2$	$0.84 X_1 - 0.57 X_2$	317.13	118.71
7	$X_1.X_3$	$0.84 X_1 + 1.04 X_3$	324.68	121.53
8	$X_1.X_4$	$0.84 X_1 - 83.11 X_4$	323.77	121.19
9	$X_1.X_5$	$0.85 X_1 - 0.48 X_5$	319.91	119.75
10	$X_2.X_3$	$0.30 X_2 + 0.90 X_3$	43.94	16.45
11	$X_2.X_4$	$0.40 X_2 - 0.81 X_4$	1.69	0.63
12	$X_2.X_5$	$0.42 X_2 + 0.47 X_5$	4.03	1.51
13	$X_3.X_4$	$0.90 X_3 - 0.33 X_4$	43.94	16.45
14	$X_3.X_5$	$0.919 X_3 + 0.86 X_5$	45.01	16.84
15	$X_4.X_5$	$1.19 X_4 + 0.47 X_5$	4.39	1.64
16	$X_1.X_2.X_3$	$0.84 X_1 - 0.57 X_2 + 1.04 X_3$	323.78	121.19
17	$X_1.X_2.X_4$	$0.83 X_1 - 1.53 X_2 + 84.72 X_4$	323.02	120.91
18	$X_1.X_2.X_5$	$0.85 X_1 + 0.13 X_2 - 0.49 X_5$	319.01	119.41
19	$X_1.X_3.X_4$	$0.84 X_1 + 1.24 X_3 + 85.85 X_4$	330.51	123.72
20	$X_1.X_3.X_5$	$0.85 X_1 + 1.05 X_3 - 0.04 X_5$	326.55	122.23
21	$X_1.X_4.X_5$	$0.85 X_1 + 86.59 X_4 - 1.39 X_5$	326.00	122.03
22	$X_2.X_3.X_4$	$0.32 X_2 + 0.90 X_3 + 0.09 X_4$	43.84	16.41
23	$X_2.X_3.X_5$	$0.61 X_2 + 0.91 X_3 + 0.88 X_5$	44.86	16.79
24	$X_2.X_4.X_5$	$0.40 X_2 + 1.61 X_4 + 0.46 X_5$	4.32	1.61
25	$X_3.X_4.X_5$	$0.91 X_3 - 0.04 X_4 + 0.87 X_5$	44.91	16.81
26	$X_1.X_2.X_3.X_4$	$0.83 X_1 - 1.55 X_2 + 1.24 X_3 - 87.47 X_4$	329.76	123.43
27	$X_1.X_2.X_3.X_5$	$0.85 X_1 + 0.37 X_2 + 1.05 X_3 -0.04 X_5$	325.64	121.89
28	$X_1.X_2.X_4.X_5$	$0.84 X_1 - 2.73 X_2 + 89.41 X_4 -1.71 X_5$	325.35	121.78
29	$X_1.X_3.X_4.X_5$	$0.85 X_1 + 1.24 X_3 + 88.68 X_4 -0.92 X_5$	332.65	124.52
30	$X_2.X_3.X_4.X_5$	$0.63 X_2 + 0.916 X_3 + 0.18 X_4 + 0.89 X_5$	44.77	16.76
31	$X_1.X_2.X_3.X_4.X_5$	$0.84 X_1 - 2.47 X_2 + 1.24 X_3 + 91.27 X_4 - 1.21 X_5$	334.96	125.26

Within two-component combinations, the pairing of seed yield per plant and the number of productive capsules per plant (X1 + X3) demonstrated a genetic advance of 324.68g and an RI of 121.53%. Moving on to three-component combinations, a selection index incorporating seed yield per plant, number of productive capsules per plant, and 1000 seed weight (X1 + X3 + X4) exhibited a genetic advance of 323.780g and an RI of 123.72%. When considering four-character combinations, the selection index comprising seed yield per plant, number of productive capsules per plant, 1000 seed weight, and oil content (X1 + X3 + X4 - X5) yielded a genetic advance of 332.65g and an RI of 124.52%. However, for optimal seed yield selection efficiency, the discriminant function encompassing seed yield per plant, days to maturity, number of productive capsules per plant, thousand seed weight, and oil content (X1 - X2 + X3 + X4 - X5) outperformed others, boasting a genetic advance and RI of 334.96g and 125.26%. Nevertheless, in practical sesame breeding programs, breeders might seek maximum gains while efficiently utilizing the minimum number of traits.

4. CONCLUSION

The current study has uncovered a substantial level of genetic variability within sesame genotypes concerning seed yield and its associated traits highest heritability and genetic advance exhibited by number of primary branches per plant. Notably, the selection index built around key traits, including seed yield per plant, days to maturity, number of productive capsules per plant, thousand seed weight, and oil content, has demonstrated a high genetic gain with a remarkable RI. Consequently, when conducting selections, it is advisable to assign maximum weightage to these specific traits. Furthermore, the study has highlighted the superiority of the discriminant function method for plant selection compared to straightforward selection solely based on seed yield. Therefore, it is recommended to prioritize the utilization of important selection indices when aiming to advance seed yield in sesame crop breeding programs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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