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Genetic Divergence in Safflower (*Carthamus tinctorius* L.)

R. K. AGRAWAL[1], H. KUMAR[2], R. B. SINGH[3] and R. M. SINGH[4]

Fifty lines of safflower germ plasm were subjected to D^2 analysis for quantifying degree of divergence and to assess the relative contribution of yield and yield components towards total variability. The lines on the basis of D^2 estimates were catalogued into 12 clusters of which each of the three clusters had single line.

Days to 50 per cent flowering, plant height, number of primary branches, number of capitula per plant, number of seeds per capitulum, seed yield per plant and oil content contributed more towards total divergence. The first two canonical roots accounted for 69 per cent and the first five for 92 per cent of the variability. The clustering obtained through group constellation made in two diamensional space using first two roots showed close agreement with that obtained by D^2 analysis. Number of seeds per capitulum, oil content, plant height and size of capitulum were important in vector I and plant height, days to 50 per cent flowering and seed yield in vector II.

India is one of the centres of origin of safflower and has tremendous variability with preponderance of indegenous biotypes (Ashri, 1973; and Karve, 1976). The exotic biotypes too contained some lines of Indian origin. A survey of existing germ plasm showed that owing to an export, reimport and exchange of materials, there was a lot of duplications (Karve, 1976). Since ecogeographical divergence is not necessarily related with the genetic diversity (Mahndiratta *et al.*, 1971; Murty and Quadri, 1966; Singh and Bains, 1968 and others), the phenotypic variability could not be taken as an index of selection of diverse lines for productive heterosis breeding. Mahalonobis (1936) D^2-statistics which is based on multivariate analysis of quantitative traits, is a powerful tool for measuring divergence among a set of population, using the concept of statistical distance utilizing multivariate measurements.

Safflower, a potential oilseed crop of dryland agriculture, has not yet been subjected to detailed genetic study for the characterization of its variability. In the present study fifty lines of safflower were put to D^2-analysis for quantifying degree of divergence and to assess the relative contribution of different characters to total divergence.

MATERIAL AND METHODS

Fifty lines of safflower were grown in randomized block design with two

1, 2, 4. Department of Genetics and Plant Breeding, Banaras Hindu University, Varanasi 221005.
3. IBPGR Officer, FAO, Bangkok, Thailand.

replications in *Rabi* season, 1977-78 at the Agriculture Research Farm of Banaras Hindu University, Varanasi. Each plot consisted of 3 rows with 22 plants in each. Plants were spaced at 20 cm within and 45 cm between rows. Observations were recorded on ten randomly selected plants for the ten characters, namely, days to 50 per cent flowering, days to maturity, plant height (cm), number of primary branches, size of capitulum (cm), number of capitula per plant, number of seeds per capitulum, 100-seed weight (g), seed yield per plant (g) and o.l content (%).

Plot means were used for the statistical analysis. The differences among the lines were tested by the analysis of variance. The diversity was measured by Wilk's criterion, Mahalanobsis D^2-statistics and canonical analysis as described by Rao (1952). The divergence among the lines was plotted in scatter diagram using first and second canonical vectors as co-ordinates and clustering obtained through D^2-analysis were superimposed on this.

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant varietal differences for all the traits. The aggregate effects of all the characters as tested by Wilk's criterion also exhibited significant differences between lines (V-statistics for 490 d.f. = 1010.47).

The D^2 values obtained for all the possible 1225 pairs of lines ranged from 2.65 (S 12 to S 14) to 26.89 (between S 26 and S 29). The fifty lines, on the basis of D^2 values were catalogued into 12 clusters (Table 1). The clustering pattern indicated that lines S 11, S 26 and S 27 were genetically distinct among themselves and from the rest of the lines and formed most divergent single line cluster *viz.*, L J and K. The characteristic feactures of these lines contributing towards diversity were extra tallness (S 11), dwarfness, early flowering and lower oil content (S 26), larger number of seeds and heads and seed yield (S 27).

The intra cluster variations ranged from 11.25 (cluster 'E') to 26.83 (cluster 'H'). Inter-cluster distance was maximum between clusters 'C' and 'L' ($D^2 = 178.39$) and lowest between clusters 'B' and 'F' ($D^2 = 28.41$). The inter-cluster distance between clusters 'A' and 'H' ($D^2 = 28.49$) was similar to that of clusters 'B' and 'F' (Table 2).

Among the single line clusters, cluster 'L' exhibited overall highest inter-cluster distance with cluster 'C' and was closer to cluster 'D' 'E' and 'H' Cluster 'J' was more distant from cluster 'L', 'E', 'K' and 'A' while cluster 'K' was relatively less distant from clusters 'E', 'H', 'D' and 'A' as compared to the remaining clusters (Table 2).

The distribution of 50 lines in as much as 12 clusters and with three single line clusters indicated the presence of wide genetic diversity (Table 1)

which could probably be attributed to isolation and selection of new types as suggested by Ashri (1972). The primitive methods of cultivation of safflower in India, in small populations as a mixed and/or garden crop for its dried florets and oil satisfied well, among others, the requirements for isolation and selection. Thus, the gene pools were fragmented into many small groups and both environmental and human selections probably led to divergence of the safflower germ plasm pools for plant height, length of period from planting to flowering, number of heads per plant, seeds per capitulum and seed yield.

The cluster 'H' which showed highest intra-cluster variation included two lines S 17 and S 18, both of which had highest number of seeds per capitulum (36.66) and capitulum size (2.20) (Table 3). The next higher intra-cluster distances were observed for clusters 'A' and 'D' each with II lines and for clusters 'C' and 'B' with three and eight lines, respectively The high intra-cluster value (D^2 = 25.95) of cluster 'G' as compared to others might be attributed to the lines S 4 which showed greater divergence with the other two lines S 36 and S 32 (Plate 1). The cluster 'E' having intra-cluster divergence included three lines of similar expression (Plate 1) for all the ten characters with highest intra-cluster means for oil content (37.22 per cent) (Table 3).

The clusters 'A' and 'H' were similar in expression for all the characters, except oil content while clusters 'B' and 'F' differed mainly in 100-seed weight (Table 3). Both the lines S1 and S 41 of cluster 'F' (Table 3) were on an average lowest yielder (5.01 g) and had the minimum number of seeds per capitulum (12.94). The overlapping between two clusters 'B' and 'I' for line S 15 was attributed mainly to differences in number of primary branches and number of capitula per plant; the cluster 'I' had the highest intra-cluster mean for number of primary branches (9.03) and number of capitula per plant (21.96).

A comparison of the intra-cluster means (Table 3) and the D^2-estimates for the different characters in relation with the inter-cluster distances (Table 2) revealed that all the traits recorded here, except days to maturity, size of capitulum and 100-seed weight attributed maximum to the divergence in the present materials.

The first two canonical roots accounted for about 69 percent of the variability (Table 4). The number of seeds per capitulum, oil content, plant height and size of capitulum were important sources of variation in the vector I as judged from the magnitude of coefficients for these characters. Whereas in Vector II, plant height, days to 50 per cent flowering and seed yield per plant were important. Although the contribution of the Vector III (11.32 percent) was not much different from the Vector II (14.46 percent), the former exhibited the importance of oil content, number of primary branches and number of capitula per plant towards total divergence. The group constellation made in two diamensional space using first two roots as coordinates confirmed the major grouping as obtained by D^2

analysis and also the inter-cluster distances were in accordance with the graphical representation of canoncical graph

The study suggested that the selection of lines associated with diverse clusters and differing in characters contributing maximum towards total genetic divergence such as plant height, number of seeds per capitulum and oil content would be more effective in the present materials of safflower for recombination breeding.

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TABLE 1 Distribution of 50 lines in different clusters

Clusters

Clusters	Lines number	Number of lines included
A	S12, S14, S8, S8, S5, S13 S10, S7, S28, S37, S2	11
B	S49, S43, S34, S29, S44, S35, S40, S48	8
C	S26, S21, S31, S23	4
D	S16, S42, S3, S47, S22, S50, S33, S25, S30, S45, S46	11
E	S39, S19, S38	3
F	S41, S9	2
G	S36, S32, S4	3
H	S18, S17	2
I	S15, S6, S24	3
J	S20	1
K	S27	1
L	S11	1

Table 2. The inter-and intra-cluster average values of D^2 and D. (in parenthesis) for twelve clusters of fifty safflower lines

Clusters	A	B	C	D	E	F	G	H	I	J	K	L
A	22.81 (4.77)	132.42 (11.51)	128.05 (11.31)	66.24 (8.14)	43.51 (6.59)	142.08 (11.92)	65.73 (8.11)	28.49 (5.33)	134.87 (11.61)	100.89 (10.04)	54.79 (7.40)	87.49 (9.35)
B		22.73 (4.77)	33.88 (5.82)	46.07 (6.79)	100.89 (10.04)	28.41 (5.33)	47.51 (6.89)	110.64 (10.51)	29.51 (5.43)	51.86 (7.20)	117.45 (10.84)	135.41 (11.63)
C			16.54 (4.06)	58.41 (7.64)	111.68 (10.57)	50.04 (7.07)	45.29 (6.73)	126.34 (11.24)	52.80 (5.73)	49.96 (7.07)	134.27 (11.59)	178.39 (13.35
D				22.28 (4.72)	44.25 (6.65)	40.39 (6.35)	34.32 (5.86)	54.78 (7.40)	54.11 (7.35)	66.55 (8.16)	50.06 (7.06)	65.24 (8.08)
E					11.25 (3.35)	101.32 (10.06)	57.99 (7.61)	56.29 (7.50)	103.45 (10.17)	137.88 (11.74)	41.13 (6.41)	69.14 (8.31)
F						12.61 (3.55)	59.78 (7.73)	118.92 (10.90)	33.72 (5.80)	77.49 (8.80)	125.73 (11.21)	99.75 (9.98)
G							25.95 (5.09)	68.64 (8.28)	60.99 (7.81)	75.48 (8.69)	68.60 (8.28)	103.70 (10.18)
H								26.63 (5.17)	116.15 (10.77)	75.24 (8.67)	42.29 (6.50)	71.30 (8.44)
I									18.12 (4.25)	75.22 (8.67)	130.26 (11.41)	158.14 (12.57)
J										0.00 (0.00)	123.95 (11.13)	146.17 (12.09)
K											0.00 (0.00)	86.62 (9.31)
L												0.00 (0.00)

Table 3. Intra-cluster group means for ten characters in safflower

Clusters	Days to 50% flowering	Days to maturity	Plant hight [cm]	No of primary branches per plant	No of capitula per plant	Size of capitulum [cm]	No of seeds per capitulum	Test weight 100 seed weight [gm]	Seed yield per plant [gm]	Oil content
A	127.18	168.59	131.83	5.49	10.29	2.12	35 92	3 65	10.65	36.24
B	123.75	167.69	109.59	6.68	15 30	1.74	15.68	3.57	5.68	25.10
C	119.50	166.87	96.97	5.75	13.67	1.64	13.87	4.05	7.27	28 98
D	128.45	168 90	126.30	6.63	14.70	1.87	22.19	4.11	10.90	29 23
E	136.16	168.00	130.43	7.10	15.96	1.85	21.46	3.33	10.59	37.32
F	129.45	169.75	118.65	6.85	13.05	1.64	12.94	4.61	5.01	23.98
G	125.83	167.00	114.13	6.46	13.13	1.72	18.23	3.53	7.39	34.76
H	126.75	168.50	135.50	6.15	11 30	2 20	36.66	3.61	12.14	30.24
I	124.00	166.66	110.46	9.03	21.96	1.66	17.62	3.53	7.39	24.15
J	117.00	166.00	109.00	4.40	7.70	2.15	26.22	4.42	7.08	23.73
K	129.50	169.00	133.70	7.90	19.30	2.09	30.72	3.90	21.99	32.84
L	136.50	169.50	164.00	4.80	7.20	2.10	27.17	4.67	6.47	29.42

TABLE 4 Canonical roots, vectors and the percentage sum of squares accounted by first five roots

Canonical Vector i										Root λ i	% sum of square to i
Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of capitula per plant	Size of capitulum (cm)	No of seeds per capitulum	Test weight (100-seed weight (gm)	Seed yield per plant (gm)	Oil content (%)		
0.114	0.026	0.416	−0.107	−0.103	0.306	0.578	−0.112	0.210	0.852	912.28	54.63
0.408	0.109	0.678	0.193	−0.084	−0.249	−0.452	0.089	0.204	−0.027	241.45	14.46
0.155	0.077	−0.287	0.280	0.205	−0.513	−0.049	0.052	−0.157	0.688	188.99	11.32
−0.145	0.071	−0.155	−0.434	0.034	0.354	−0.546	0.357	0.258	0.408	112.24	6.72
0.001	−0.053	−0.239	0.232	0.282	0.203	−0.052	−0.256	0.718	−0.055	80.28	4.80
									Σ λ i	1670.04	
									Σ Ri	134.8	8.07