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SELF INCOMPATIBILITY AND GENETIC DIVERGENCE IN BRASSICA CAMPESTRIS VAR. BROWN SARSON

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SUMMARY. The degree of genetic divergence as measured by Mahalanobis's generalized distance (D^2-statistic), between twenty three populations of *Brassica Campestris* var. brown *sarson*, was examined in relation to their geographical distribution of six characters related to fitness, namely, days to first flower, number of siliqua on main axis, height, number of primary branches, number of fruit-bearing branches and the number of seeds per siliqua, and the divergence between populations was assessed. The populations could be grouped into eight clusters, three belonging to self-compatible (SC) and the rest to the self-incompatible (SI) and confirmed by canonical analysis. Intra-and inter-cluster divergence were parallel with flowering time and height contributing maximum to the divergence. The possible role of disruptive selection in nature and human selection for yield was discussed for the appearance of SC forms in the otherwise self-incompatible brown *sarson*.

1. Introduction

Among the known measures of divergence between populations, statistical distance has been successfully used for classification in anthropometry and psychometry [Hotelling (1931); Rao (1952); Anderson (1958)] and recently in biology [Nair and Mukherjee (1960); Murty *et al*, (1962)], utilizing multivariate analysis. Although extensive data are available where changes in the breeding system have accelerated genetic divergence in natural populations (Stebbins, 1957), a quantitative assessment of the divergence is not made. Reports of spontaneous occurrence of self-compatible forms in the otherwise self-incompatible *Brassica campestris* var. brown *sarson*, which is closely related to rape seed, have prompted our study to assess the effect of change in breeding system on the nature and degree of genetic divergence as measured by the D^2-statistic of Mahalanobis (1936) between populations belonging to these two groups. The relative contributions of some of the factors influencing yield to the divergence between these populations are also examined.

2. Material

Twenty four populations of brown *sarson* including five self-compatible forms were selected at random from a large collection, representing the material cultivated in North India from Punjab to Assam, for studying six characters related to fitness namely, days to flower, height, number of primary branches, number of fruit-bearing branches, number of siliqua on the main axis and number of seeds per siliqua. However, one of them (Culture No. 7) could not be included due to limited quantity of seeds and defective germination leaving only 23 varieties for analysis. Sample size was sixty plants per population grown in a randomized complete block design with four replications. Individual plant data were collected for each of the characters.

3. Results and discussion

Significant differences were found among the means of the populations for each of the six characters studied. The means of the populations and the variance-covariance matrices for error and varieties +error are given in Table 1 and Table 2 respectively. The differences between the populations on the aggregate of the six characters tested by Wilks' Λ criterion using the experimental error for testing significance (Rao, *loc. cit*) were highly significant (χ^2 for 132 d.f. being 481.60). Based on the procedure described by Rao (*loc. cit*) after transforming the means to uncorrelated variables using the method of pivotal condensation (Table 3), the populations could be grouped into eight clusters using Mahalanobis' D^2-statistic, three clusters, viz., V, VI and VII belonging to the self-compatible group (SC). (Fig. 1). The inter-and intra-group D^2 values are presented in Table 4. Clusters VI, VII and VIII are far removed from the rest. The other clusters contain varieties from diverse geographic areas, but are close to each other indicating that their divergence may not be directly related to their geographical distribution. However, cluster V has only self-compatible forms while cluster I to IV have only self-incompatible forms. Cluster VIII appears to be uniquely different from the other self-incompatible types. An examination of its vegetative and reproductive parts has indicated that it is a hybrid derivative of *Brassica juncea* and *Brassica campestris* var. brown *sarson.*

It is interesting that two of the three self-compatible clusters are in different directions away from the rest of the clusters. The lines in cluster V are earlier and shorter than those of cluster VI indicating divergence for flowering time. They did not substantially differ in the number of primary branches, although the lines of cluster V have more number of fruit-bearing branches, less number of siliquae on main axis and seeds per siliqua (Table 5). This is suggestive that self-compatibility could arise in any of the two directions of divergent selection for flowering time. Cluster VII consists of only one variety (variety No. 20) which is also self-compatible. However, this population is a complex combination of some features of the varieties of clusters V and VI. This variety is the earliest among the self-compatible types but tall. It resembles those of cluster V in the number of fruit-bearing branches and number of seeds per siliqua and resembles cluster VI in height and number of siliquae on main axis.

Intra-cluster divergence is low in clusters I, V and VI. Either limited gene exchange between the populations or selection for diverse characters depending on local consumer preference could be responsible for the observed high intra-group variation in the clusters III and IV. Among the six characters, flowering time (53.4% of the total pairwise comparisons) have contributed the maximum to inter-cluster divergence followed by height (17.4%), number of fruit-bearing branches (11.1%) and number of siliquae on main axis (8.3%).

Inter-group divergence among clusters I, II and III is limited. On the basis of D^2 between members within each cluster, relative importance of the characters contributing substantially to intra-group divergence are height followed by flowering time, the rest having similar contributions. Thus, flowering time and height are found to be of importance in intra- and inter-cluster levels.

4. Canonical analysis

Group constellations were also independently derived using canonical analysis (Rao, 1952), to verify the grouping obtained using D^2-statistic. The first two canonical roots have accounted for 67.3 per cent and 15.5 per cent respectively of the total variation. Since 82.8 per cent of the variation is explained by the first two roots, a two-dimensional representation of the relative positions of the varieties is considered to be adequate in this case. (Fig. 2). The sum of the six canonical roots is 393.9 of which $\lambda_1 = 264.9$, $\lambda_2 = 61.0$, $\lambda_3 = 35.3$ and $\lambda_4+\lambda_5+\lambda_6 = 32.7$

Grouping by canonical analysis has confirmed the distinctive nature of the self-compatible populations as seen from the $\lambda_1-\lambda_2$ chart (Fig. 2) which have formed three different constellations. The uniqueness of the population 24 (Cluster VIII) and the closeness of the clusters I, II and III are also established.

The first two canonical vectors Z_1 and Z_2 supplying the best two linear functions are given below :

canonical vectors	flowering time	number of primary branches	number of secondary branches	height	number of siliquae on main axis	number of seeds per siliqua
Z_1	0.7593	0.2984	0.1866	0.5399	−0.0800	0.0422
Z_2	0.1429	0.3615	0.6803	−0.2092	−0.1410	−0.5681

The importance of flowering time and height in the divergence between populations is reflected in the corresponding coefficients in the first canonical vector.

Self-compatible types are placed in a taxonomical group different from SI types by some workers (Singh, 1958). This does not appear to be correct since cluster V(SC) is closer to the SI clusters than to the other SC clusters VI and VII. (Table 4). Therefore, clusters V and VI may represent divergence in opposite directions for some characters such as flowering time similar to that observed in the selection experiments in *Drosophila* by Millicent and Thoday (1961). The parentage of population 20 (cluster VII) is not available to relate its position with the other SC types. Evidence of disruptive selection for flowering time, as a major cause for the appearance of SC forms in brown *sarson* is also available from the restricted distribution of SC types and selection results over the past three years.* The diverse ecological conditions under which brown *sarson* is grown in India are reflected in the high variability among the cultivated types. However, geographical distance alone could not account for

*Murty and Mathur (unpublished)

the observed divergence between the clusters in this study. Degree of variability could not be a cause since the SC forms are found to be as variable as the SI forms. Moreover, contribution of each of the characters in intra-and inter-cluster D^2 is parallel indicating the influence of similar factors at both the levels of differentiation. It is likely that disruptive selection for flowering time in nature and selection for stabilizing yield by man are responsible for the observed differentiation which is enhanced by the changes in the breeding systems of the populations. The utility of multivariate analysis in classificatory problems at intra-specific level is evident from the clear separation of SC and SI forms and non-overlapping of clusters. Studies are underway to find out whether further artificial disruptive selection for flowering time among the populations would lead to greater divergence.

TABLE 1. MEANS FOR SIX CHARACTERS OF 24 POPULATIONS OF BROWN *SARSON*

varieties	flowering time (days)		height (inches)		number of primary branches		number of fruit-bearing branches		number of siliquae of main axis		number of seeds per siliqua	
	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	x_5	y_5	x_6	y_6
1	47.19	15.11	46.60	11.85	5.50	-3.19	24.03	5.57	39.37	3.65	16.70	6.37
2	48.48	15.52	52.60	12.93	7.34	-2.03	24.22	4.77	38.53	3.41	19.15	7.09
3	57.93	18.55	59.65	14.94	8.20	-2.68	27.48	5.73	43.45	3.84	19.63	6.97
4	51.08	16.36	42.55	11.56	6.55	-2.02	24.33	5.66	34.18	3.19	16.73	6.00
5	59.38	19.01	41.35	12.14	7.61	-1.52	32.79	7.76	20.80	1.09	15.05	4.53
6	59.85	19.16	42.70	12.40	7.75	-1.55	30.86	7.30	21.07	1.13	14.11	4.04
8	75.53	24.18	63.85	17.25	7.69	-5.15	19.91	5.85	36.52	2.77	21.68	8.21
9	54.38	17.41	45.10	12.28	7.69	-1.40	25.98	5.75	38.20	3.75	18.75	6.66
10	72.40	23.18	58.30	16.07	7.18	-4.83	18.80	5.72	31.95	2.33	21.31	8.20
11	60.21	19.28	50.10	13.62	7.60	-2.51	31.43	7.30	38.32	3.36	17.10	5.69
12	51.73	16.56	48.10	12.51	6.87	-2.32	29.60	6.51	37.80	3.34	16.70	5.80
13	46.78	14.98	43.95	11.39	6.05	-2.32	26.27	5.84	31.60	2.59	16.13	5.84
14	47.71	15.28	49.65	12.39	6.22	-2.81	23.93	5.20	37.36	3.27	18.20	6.94
15	41.13	13.17	39.45	10.14	6.26	-1.15	26.47	5.42	34.38	3.25	17.97	6.76
16	48.78	15.62	43.45	11.49	6.79	-1.67	28.73	6.24	36.28	3.35	15.80	5.38
17	59.25	18.97	53.30	14.04	6.86	-3.52	25.95	6.29	51.51	5.29	15.87	5.44
18	55.31	17.71	55.15	13.97	8.17	-2.02	34.07	7.01	47.61	4.50	17.52	5.75
19	57.63	18.45	42.70	12.20	7.58	-1.54	32.18	7.45	35.43	3.27	19.88	7.11
20	51.31	16.43	70.47	16.05	6.23	-5.26	28.27	5.80	31.62	1.20	17.56	6.54
21	56.10	17.96	47.40	12.81	7.35	-2.13	28.63	6.53	31.07	2.44	17.01	5.78
22	55.70	17.84	51.40	13.41	7.93	-1.91	46.95	9.93	40.20	3.14	16.06	4.76
23	61.99	19.85	60.35	15.43	9.85	-1.40	39.08	7.79	45.03	3.89	16.98	4.81
24	71.38	22.86	71.30	18.05	7.05	-6.22	43.85	10.49	37.73	1.77	16.49	5.26

x's—Actual means y's—Transformed uncorrelated means

TABLE 2. VARIANCE-COVARIANCE MATRIX FOR 'ERROR' AND VARIETIES AND ERROR FOR SIX CHARACTER IN BROWN *SARSON*

	x_1	x_2	x_3	x_4	x_5	x_6
			error			
x_1	643.73	–373.42	15.99	–303.71	–208.81	9.66
x_2		2791.52	249.67	1071.85	973.80	161.89
x_3			88.24	208.83	58.88	58.73
x_4				2245.79	651.40	200.96
x_5					3236.71	37.67
x_6						285.94
			varieties and error			
x_1	7097.27	3701.99	361.47	385.42	–129.06	479.02
x_2		8091.71	525.93	2385.62	3640.68	559.17
x_3			162.50	460.36	171.79	75.52
x_4				6323.21	1259.82	–339.13
x_5					8746.38	234.72
x_6						596.98

x_1=flowering time
x_2=height
x_3=number of primary branches
x_4=number of fruit bearing branches
x_5=number of siliquae on main axis
x_6=number of seeds per siliqua

TABLE 3. UNCORRELATED VARIABLES (y's) AFTER TRANSFORMING ORIGINAL VARIABLES (x's)

$y_1=0.3202x_1$
$y_2=0.0930x_1+0.1601x_2$
$y_3=-0.0857x_1-0.1034x_2+1.0309x_3$
$y_4=0.0909x_1-0.0298x_2-0.4212x_3+0.2074x_4$
$y_5=0.0026x_1-0.0516x_2+0.1146x_3-0.0300x_4+0.1530x_5$
$y_6=-0.0079x_1+0.0036x_2-0.3046x_3-0.0216x_4+0.0022x_5+0.5200x_6$

TABLE 4. INTER- AND INTRA-CLUSTER AVERAGE D^2 IN SOME POPULATIONS OF BROWN *SARSON*

(Figures in brackets denote distance $D=\sqrt{D^2}$)

	I	II	III	IV	V	VI	VII	VIII
I	3.22	14.75	8.17	37.37	37.72	101.20	30.47	135.88
	(1.80)	(3.84)	(2.86)	(6.11)	(6.14)	(10.06)	(5.52)	(11.66)
II		7.68	23.27	14.99	17.02	57.71	28.87	79.74
		(2.77)	(4.82)	(3.87)	(4.13)	(7.60)	(5.37)	(8.93)
III			14.26	41.37	31.37	120.72	49.75	155.98
			(3.78)	(6.43)	(5.60)	(10.98)	(7.05)	(12.49)
IV				13.53	16.01	65.66	42.67	40.63
				(3.68)	(4.00)	(8.10)	(6.53)	(6.37)
V					0.54	73.62	43.43	79.89
					(0.73)	(8.58)	(6.59)	(8.94)
VI						2.71	58.28	36.21
						(1.64)	(7.64)	(6.02)
VII							—	70.23
								(8.38)
VIII								—

TABLE 5. MEANS FOR SIX CHARACTERS FOR THE EIGHT CLUSTERS FORMED IN 24 POPULATIONS OF BROWN *SARSON*

cluster	x_1	x_2	x_3	x_4	x_5	x_6
I	48.25	47.07	6.33	24.56	36.21	17.38
II	56.88	50.91	7.52	29.91	40.74	17.67
III	48.10	42.67	6.91	27.06	36.29	17.51
IV	58.84	55.87	8.89	43.01	42.61	16.52
V	59.61	42.02	7.68	31.82	20.93	14.58
VI	73.96	61.07	7.44	19.35	34.23	21.49
VII	51.31	70.47	6.23	28.27	31.62	17.56
VIII	71.38	71.30	7.05	43.85	37.73	16.49

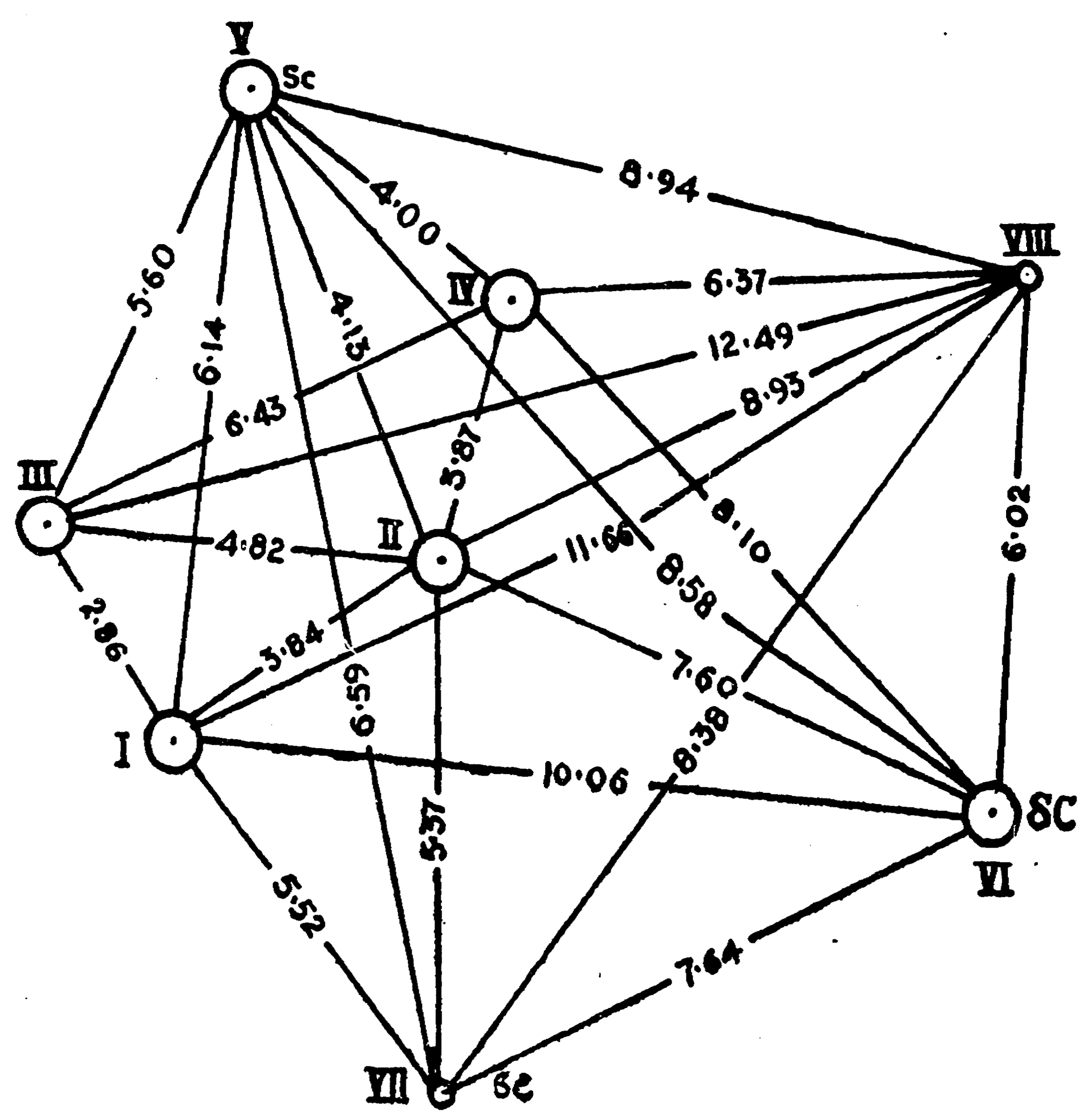

Fig. 1. Statistical distances among some populations of *Brassica* campestris

Groups

I. 1 Kanpur Lotni 15
2 Kanpur Lotni 17
4 Kanpur Lotni 27
13 I. A. R. I. 124
14 I. A. R. I. 125

II 3 Kanpur Lotni 26
11 I. A. R. I. 122
12 I. A. R. I. 123
17 PUSA BST 1
18 LGLG
19 PC 54 G
21 GBS II

III. 9 I. A. R. I. 119
15 Assam Local
16 PUSA BST 2

IV. 22 GBS 203
23 GBS 206

V. 5 K. Tora 5905
6 K. Tora 5907

VI. 8 I. A. R. I. 117
10 I. A. R. I. 120

VII. 20 GBS-I

VIII. 24 GBS-817

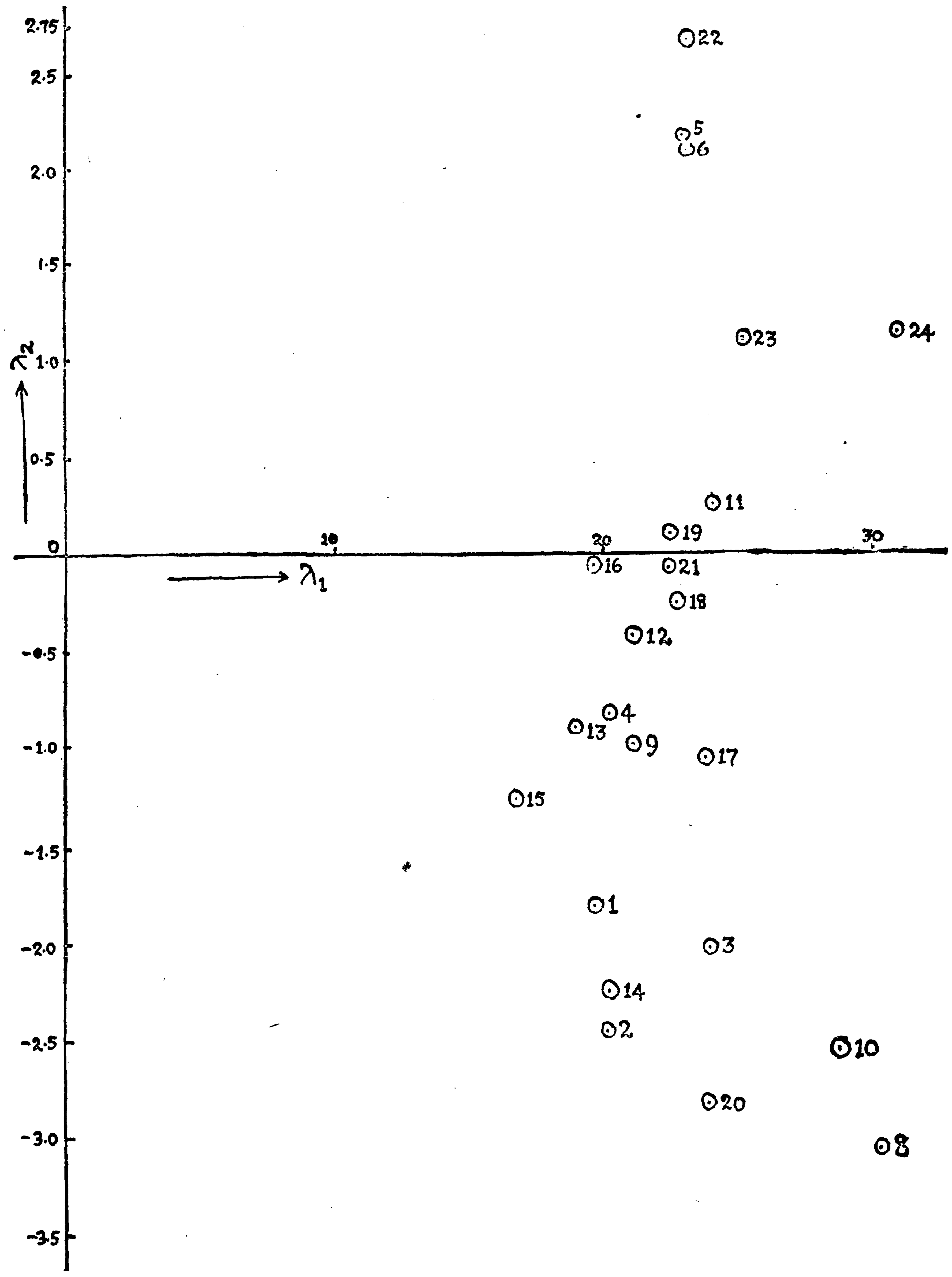

Fig. 2. Group constellations of populations of brown *Sarson* in $\lambda_1 - \lambda_2$ chart.

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