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Genetic Basis of Seed Setting in Alfalfa

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Summary. The genetic basis of seed setting was evaluated in seven clones of alfalfa selected under predominantly self-pollinating conditions. They were hand crossed in all possible combinations. Their compatibility was studied by the percentage of flowers forming pods and number of seeds per pod during crossing. The variances for GCA, SCA and reciprocal effects were significant for percentage of pod set with a narrow sense heritability of 64%. This suggested maternal influence of clones on percent pod set, controlled primarily by additive genetic components. GCA was the only significant component for number of seeds per pod with a narrow sense heritability of 71%. There were wide differences between the clones in their relative magnitude of GCA, SCA and reciprocal effects for both traits used as compatibility indexes. Performance of the diallel crosses was judged by studying seed yield and its related characters, namely seeds per pod, dry matter per plant, frost resistance, plant vigor and plant height. Although GCA and SCA variances were significant for all characters, reciprocal differences in general were absent. The SCA values were very high as compared to GCA. Narrow sense heritability values were very low while broad sense heritability were much higher. This suggested that almost none of the variation was due to additive genetic components and all the variability is controlled by interactions of a digenic, trigenic and quadrigenic nature and heterzozygosity. Heterosis was evaluated by comparing the seed yield of single crosses with their mid-parent and high-parent, and very high values were observed. Thus selection of better genes may not be feasible and further improvement in selected clones may have to be brought about by utilization of various interactions and heterosis. An attempt was made to find combinations of characters that may be used for the selection of seed yield but none were found to be satisfactory.

Key words: *Medicago sativa* - Self-compatibility - Autogamous - Heterosis - Heritability

Introduction

Seed yield is a complex character in any crop, and is even more so in alfalfa. In the northern Canadian climate, alfalfa has gained popularity as a forage crop, but low seed yield does not ensure adequate supplies of seed at reasonable prices. This is generally attributed to a scarcity of cross-pollinating bees. These serve the function of tripping (release of the Staminal Column), considered necessary for successful fertilization (Armstrong and White, 1935) as it causes stigmatal rupturing allowing the pollen tube to grow. Autogamous (self-fertilizing) plants avoid this problem. Heterozygosity and combination of better genes are recognized as the two genetic components of vigor. Self fertilization may therefore reduce vigor and yield by reducing heterozygosity. This report deals with the study of genetic basis of seed setting in clones that were selected for high seed yield under predominantly self-pollinating conditions.

Materials and Methods

The plant material originated from crosses between variety 'Ferax' and artificially produced tetraploid 'Alaskan Falcata'. The resulting progeny were selected for seed setting and vegetative growth for a number of generations. The selected plants were intercrossed and the progeny were subjected to several cycles of selection for high seed and forage yield. Percent cross pollination in the field was checked in each of these years by the use of two male-sterile lines, 20-DRC and MST-1 by taking the percent of flowers that set pod. Open pollinated seeds of 140 selected lines were tested in a field trial. Seeds from forty-one lines that produced high seed and forage yields were again field tested with variety 'Grimm' as a check. Seven high seed and forage yielders were selected from this test. They were used in complete diallel crossing after emasculation. Percent pod set and number of seeds per pod set during crossing was recorded on each female parent. Raising of the diallel cross progenies and the field plan has been described in Singh and Lesins (1971b). Measures of seed setting on single plants were obtained in the following ways:

1. Number of seeds per pod - obtained from one hundred pods randomly collected from each plant at the time of harvesting.
2. Seed yield per plant (gm) in the second year of establishment (1969).

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Table 1. Percent pod set in the fields of Edmonton, Alberta, Canada

	% pod Set in different years						
Material	1958	1962	1963	1964	1967	1969	Average
20-DRC (male-sterile)	2.1	2.1	4.1	7.5	0.7	1.2	2.9
Grimm (variety)	-	9.5	17.2	16.6	6.8	9.2	12.3
Selected lines	23.0	24.2	25.5	29.5	21.2	35.2	26.4

3. Seed yield per plant (gm) in the third year of establishment (1970).

Individual plants were also scored for vigor and frost resistance in the second year on a scale of 1 - 9, 9 being most vigorous and frost resistant. Plant height (cm) was taken at maturity. Individual plants were harvested and placed in bags for drying and the dry weight was taken when they were free of moisture.

Mean values of the plants for each character were used for analysis of variance as randomized block design to test the differences among the genotypes. Correlations were established between seed yield and other characters studied using the formulae suggested by Fisher (1954) and Al-Jibouri, Miller and Robinson (1958) and a path of causal relationships was developed. Sums of squares were partitioned into general (GCA), specific (SCA) combining ability and reciprocal effects, following the method suggested by Griffing (1956). An attempt was made to assess the broad and narrow sense heritabilities and performance of single crosses were compared with mid-parent and high-parent for seed yield and dry matter per plant. This comparison was taken as an indicator of the heterotic effect (Falconer, 1960).

Results and Discussion

Pollination

The flowers of alfalfa are suited to insect pollination. In areas of its origin, cross pollination by bees may be considered prevalent. Its spread in new areas, especially where bees are not all that common, causes a problem with adequate pollination. A survey of cross pollination in Edmonton, Alberta, Canada, from 1957 to 1969 gave the results presented in Table 1. Percent cross-pollination is checked by growing male-sterile plants randomly in the field. Inflorescences were visited at the time of flowering and tagged with their number of flowers. They were harvested at maturity and percent of flowers forming pods were calculated. Percent pod set on male-sterile lines was taken as an indicator of cross pollination, as they will not form pods without cross pollination. The average percent cross pollination in the Edmonton area, although varied from year to year (7.5 % for 1964 to 0.7 % for 1967) was found to be only 2.9 %. Significantly higher pod set in the selected clones (Table 1) indicated their high self-compatibility seeds per flower may be used as another indicator of self-compatibility which was found to be only 0.058 for the male-sterile as compared to 0.764 to 0.586 for the selected clones and 0.142 to 0.234 for 'Grimm'. This would suggest that there is a low percentage of cross-pollination in the Edmonton region and selection for high seed yield will select plants with high self-compatibility as indicated by Lesins (1961).

Compatibility

Compatibility of the selected clones was further studied by crossing them in all possible combinations. The two indexes of compatibility used were percentage of flowers producing pod (CI-1) and seeds per pod set (CI-2) (Singh and Lesins 1971a). The analysis of variance produced a genotypic variance of 54.535 with an F-value of 5.093 for percent pod set and 5.011 with an F-value of 5.219 for number of seeds per pod. Both F-values were significant at the 1 % level of probability, and this suggests significant genetic variation in the parental clones for the two traits. The diallel analysis for the variances due to general combining ability (GCA), specific combining ability (SCA) and reciprocal effects (RE) for the two indexes of compatibility are given in Table 2. It indicates that although the GCA variances are significant for both percent pod set and number of seeds per pod, the variances due to SCA and reciprocal effects are significant for the percent pod set only.

Estimates of general and specific combining ability effects and reciprocal effect were calculated for the significant components of Table 2 and are given in Table 3. The significant differences in general combining ability for percent pod set of clones 242, 201

Table 2. Mean squares due to GCA, SCA and reciprocal effects (RE) for the two indexes of compatibility

Compatibility index	V(GCA)	V(SCA)	V(RE)	Residual
% Pod Set - [CI-1]	468.400**	91.580**	90.200**	10.706
No. of seeds/pod - [CI-2]	3.986**	0.557	0.745	0.960
D.F.	6	14	21	41

** significant at 1 % level of probability

Table 3. Estimates of GCA effects ($\hat{g}$i(C-I)), SCA effects ($\hat{S}$ij, upper diagonal) and reciprocal effects ($\hat{r}$ij, lower diagonal) for percentage of pod set (Cl-1) and GCA ($\hat{g}$i(Cl-2)) for number of seeds per pod of seven parental clones and their crosses

Clone No.	5	16	34	63	67	201	242	$\hat{g}$i(CI-1)	$\hat{g}$i(CI-2)
5	-	6.791	8.154	-2.538	-0.058	-2.171	-10.180	-6.298	0.295
16	6.320	-	-6.892	10.114	-0.780	-0.493	1.452	5.598	0.283
34	-0.465	11.595	-	-2.707	0.427	1.699	-0.682	-7.969	-0.513
63	6.560	-4.550	-4.690	-	-7.435	-7.423	9.989	2.018	-0.081
67	-0.045	-7.860	-5.590	-4.285	-	3.311	4.534	-7.066	-0.349
201	-2.290	-12.390	-4.230	-4.615	-6.700	-	5.076	6.531	0.302
242	4.175	-8.660	-1.390	11.160	-14.430	0.340	-	7.183	0.265

0.412 = standard error of SCA effects of CI-1
0.504 = standard error of reciprocal effects of CI-1
1.145 = standard error of GCA effects of CI-1
0.343 = standard error of GCA effects of CI-2

and 16 are positive and quite high. Clones 5, 34 and 67 have negative and low GCA values and are thus expected to produce a low percentage of pod set. Differences in the specific combining ability of single crosses are also very pronounced for this character. Crosses 16 × 63 and 63 × 242 with a high SCA value should produce more pods per 100 flowers than expected on the basis of GCA estimates of the clones. The opposite is true for crosses 5 × 242, 63 × 67 and 63 × 201. It could be noted that clones with the lowest GCA, when used in crosses, do not produce crosses with the lowest SCA; also, clones with the highest GCA do not produce crosses with the highest SCA. One could, therefore, conclude that single crosses showing a high SCA did not necessarily have parental clones with a high GCA and vice versa. This would be expected if there are appreciable amounts of additive and non-additive genetic components determining the expression of the trait. The significant reciprocal differences for percent pod set should be evaluated as the deviation from zero. Some of the combinations giving the higher values for reciprocal effects are 242 × 67, 201 × 16, 34 × 16 and 262 × 63. Reciprocal cross differences for parental clones produced a significant *t* value for clone 34 (*t* = 3,519, table value of *t* = 2.571). The *t* value for other clones was not significant. The percent pod set, therefore, may be expected to be influenced by the female parent.

The GCA effects of the parental clones for number of seeds per pod (CI-2) are also given in Table 3. The magnitude of the difference between the highest (0.302 for clone 201) and the lowest (-0.513 for clone 34) is only 0.815 suggesting that these clones are fairly homogenous, although the GCA variance for this index was significant. It was also found that the clones of higher GCA value did not necessarily produce crosses with high SCA and vice versa. It could be pointed out that the variances for SCA and reciprocal effects of this trait were not significant (Table 2).

In conclusion, the two indexes of compatibility seem to have a high additive genetic variance on the basis of combining ability estimates. This is confirmed by the high estimates of their narrow sense heritabilities (67.8 % for percent pod set and 71.1 % seeds per

Table 4. The combining ability analysis of the characters studied in the diallel crosses

Characters	Sources of variation			
	GCA (σ^2g)	SCA (σ^2s)	RE (σ^2r)	Redidual
Seed yield (gm) 1969	178.850**	1936.890**	22.650	43.990
Seed yield (gm) 1970	12.440	4158.120**	8.250	24.770
Seeds per pod	0.610**	48.080**	0.020	0.130
Dry matter per plant (kg)	0.005**	0.708**	0.002	0.002
Frost resistance (1-9)	0.286**	295.140**	0.019	0.043
Plant vigor (1-9)	0.191**	256.970**	0.312**	0.047
Plant height (cm)	416.489**	54534.500**	12.280	30.743
D.F.	6	21	21	144

** significant at 1 % level of probability

pod). They represented 84.4 % and 88 % of their broad sense heritability values respectively. The two indexes studied here are quite heritable with an appreciable amount of additive genetic components. In studying the compatibility of the clones, one may prefer to use percent pod set, as its SCA and reciprocal effects were significant and this index is expected to be sensitive in distinguishing differences in compatibility relationships of the clones.

Genetic Analysis and Performance of Diallel Crosses

Preliminary analysis of variance estimated the genotype and replication effects. It was found that the genotypic differences were highly significant (P = 0.01) for all the characters and accounted for a major portion of the total phenotypic variation. Further analysis, therefore, was performed to evaluate combining ability, heritability and heterosis for seed yield. An attempt was also made to evaluate association and causal paths of seeds per pod, dry matter per plant, frost resistance, plant vigor and plant height as contributors to seed yield.

a. Combining Ability

Table 4 contains variances for GCA, SCA and reciprocal effects (RE) and suggests that the GCA and SCA variances are highly significant for all the characters considered in this study. The reciprocal effect, however, is significant for one character only, namely, plant vigor. There are two generalities that could be drawn from this table: 1. Reciprocal effects are not common. 2. The value of SCA variance for each character is higher than the value for GCA. The latter may provide an indication of the preponderance of genetic factors contributing to the specific combining ability of each of these characters. It may be pointed out that there was very little cross pollination in our field conditions and the clones tested here were selected for high seed and forage yield under predominantly self-pollinating conditions. Increased seed yield in the process of selection may, therefore, be assumed to be due to the merger of the most favorable alleles rather than the temporary effect of heterozygosity. Under these circumstances, high SCA values would be expected, as selection would fix the additive genetic components of GCA for characters influenced by selection. All the characters studied here show the same pattern. It is expected that because the earlier selection was based on seed yield and other characters are correlated to it (see Correlations), all the characters may be expected to produce similar results. The general absence of reciprocal effects are in agreement with other reports (Bolton (1948), Davis and Paton (1962) and Davis and Gartner (1966)).

Estimates of GCA ($\hat{g}i$) and SCA ($\hat{s}ij$) for seed yield in 1969 and 1970 of the clones studied are given in Table 5. It shows that clone 242 had the highest value of GCA in 1969 (6.87) and clone 34 the lowest value (-4.29), but the differences between the GCA 's of different clones in 1970 were much less (range, 1.25

Table 5. Estimates of GCA (ĝi) and SCA (Ŝij) for seed yield of seven clones and their diallel crosses

Clone Year	Ŝij for clone no.						
	16	34	63	67	210	242	ĝi
5 a	0.84	0.53	-0.37	-3.52	1.25	9.87	-1.10
b	-1.76	1.36	1.49	0.19	2.71	9.98	0.56
c	-0.46	0.95	0.56	-1.66	1.98	9.93	-0.27
16 a		-2.49	-1.21	8.07	3.19	5.97	0.43
b		2.25	0.09	5.60	1.49	1.12	-0.44
c		-0.12	-0.56	6.84	2.34	3.55	0.01
34 a			9.19	1.27	-3.11	1.31	-4.29
b			8.84	-0.47	2.14	-3.49	1.25
c			9.02	0.40	-0.49	-1.09	-1.52
63 a				3.50	5.55	-0.49	-0.04
b				3.27	1.22	0.45	-0.14
c				3.34	3.39	-0.02	-0.09
67 a					0.67	1.70	-2.93
b					2.58	3.15	0.61
c					1.63	2.43	-1.16
201 a						5.20	1.05
b						-0.87	-1.69
c						2.16	-0.32
242 a							6.87
b							-0.13
c							3.37

(a - 1969 b - 1970 c - average)

to -1.69). It may be pointed out that the planting was done in eight replications. Four replications were studied for the seed yield in 1969 and the other four in 1970. The discrepancy between the two years, therefore, may be attributed to the differences between the second and third year of growth and seasonal differences between the two years. The SCA value for 5 × 242 is 9.87 (1969) and 9.98 (1970); for 16 × 67, 8.07 (1969) and 5.60 (1970); for 34 × 63, 9.19 (1969) and 8.84 (1970); 63 × 67, 3.40 (1969) and 3.27 (1970) and 63 × 242, -0.49 (1969) and 0.45 (1970). The exception from this pattern is the cross 201 × 242 where SCA in 1969 is 5.20 as compared to -0.87 for 1970. The estimates of SCA, in general, are higher than the GCA values. Such results are expected if the clones have been previously selected, and corroborate the findings of Evans et al. (1969), Kehr (1961), Singh and Lesins (1971) in alfalfa, and Sprague and Tatum (1942) in maize. It is also evident from the table that single crosses having higher values for SCA do not necessarily have parents of higher GCA and vice versa.

It may be pointed out that in diploid organisms, general combining ability is regulated by the genetic components that are additive and fixable while specific combining ability is due to the genes' dominance and epistatic interactions. The explanation in autotetraploids like alfalfa, however, is not so simple. Levings and Dudley (1963) presented a detailed account of the genetic nature associated with general and specific combining ability in autotetraploids. Here the GCA includes $1/4\ \sigma^2$ additive (A), $1/36\ \sigma^2$ digenic (D), $1/16\ \sigma^2$ due to A × A, $1/44\ \sigma^2$ due to A × D and $1/1296\ \sigma^2$ due to D × D. Similarly the SCA includes $1/6\ \sigma^2 D$, $1/12\ \sigma^2$ trigenic (T), $1/36\ \sigma^2$ quadrigenic (F), $1/8\ \sigma^2$ A × A, $7/72\ \sigma^2$ A × D and $31/648\ \sigma^2$ D × D. It may be pointed out that not all the components of GCA are fixable and therefore, even after selection, significant GCA may be observed. It is suspected that in the clones studied here, further improvement by selection may not be feasible and all the fixable components of GCA have already responded to earlier selections resulting in an increase in seed yield.

b. Heritability

The estimates of heritability were made to further assess the genetic components involved in the expres-

Table 6. Heritability estimates of various characters

Characters	% heritability		Expected genetic gain
	Broad sense ($\sigma^2 G/\sigma^2 P$)	Narrow sense ($\sigma^2 A/\sigma^2 P$)	
Seed yield (gm)	86.05	8.20	0.168
Seeds per pod	75.37	1.23	0.026
Dry matter per plant (kg)	71.90	0.61	0.013
Frost resistance (1-9)	84.49	0.09	0.002
Plant vigor (1-9)	81.89	0.07	0.002
Plant height (cm)	88.08	0.70	0.014

sion of phenotypic variability of seed yield and other characters contributing to it as shown in Table 6. In general, the broad sense heritability is high (71.9 % for dry matter per plant to 88.08 % for plant height). In contrast, the narrow sense heritability is very low. Its value for most characters ranges from 0.07 to 1.23 with the exception of seed yield, which has a narrow sense heritability of 8.20. The narrow sense values, therefore, account for an almost negligible amount of phenotypic variation for all characters and 9.53 % for seed yield. Therefore, the expected genetic gains, as shown in the table, are also very low. These findings complement the conclusions drawn from combining ability studies and suggest that most of the variability observed here is of the non-additive genetic nature.

c. Heterosis

Seed yield of the single crosses was compared with their mid-parent and high-parent values as shown in Table 7. This comparison was taken as heterosis (Falconer, 1960). As evident from the table, all crosses showed heterosis over the mid-parent and high-parent. The heterotic effect over mid-parent ranged from 198.5 % for 34 × 201 to 858.5 % for 63 × 67. Other crosses had values that ranged between 200 % and 400 %. On the average, single crosses were 372 % better than their mid-parents. Comparison of the seed yield of crosses with their high-parent also gave similar results and the yields of single crosses were higher than their high-parent (range = 137 % for 5 × 67 to 577 % for 63 × 67). On the average, crosses were 287 × 5x better than their high-parent for seed yield. The degree of heterosis observed in this study is relatively higher than that in other reports dealing with inbreeding depression and heterosis in this species, which may be attributed to the selection of clones for several generations. It may be pointed out that all the parental clones were low in seed yield. Clones 67, 63 and 34 were among the low yielders, but they showed the highest heterosis. On the other hand, clone 242 has the highest seed yield of all the clones and crosses involving 242 as one of the parents, were also among

Table 7. Seed yield per plant for self parents and single cross progenies and as % of mid-parent and high-parent

Line/Progeny	Seed yield (gm)	p Mid-parent	p High-parent
5	8.815	-	-
16	6.132	-	-
34	4.372	-	-
63	3.475	-	-
67	2.200	-	-
201	9.007	-	-
242	9.797	-	-
5 × 16	19.796	264.90	224.57
5 × 34	14.770	224.02	167.55
5 × 63	18.115	294.79	205.50
5 × 67	12.076	219.28	136.99
5 × 201	20.822	233.66	231.17
5 × 242	35.267	378.97	359.97
16 × 34	13.281	252.87	216.58
16 × 63	18.811	391.67	306.76
16 × 67	25.200	604.89	410.95
16 × 201	24.298	321.01	269.76
16 × 242	32.900	413.10	335.81
34 × 63	24.492	624.31	560.20
34 × 67	13.679	416.28	313.28
34 × 201	13.277	198.49	147.40
34 × 242	23.517	331.97	240.04
63 × 67	20.063	858.49	577.35
63 × 201	24.605	394.24	273.17
63 × 242	25.973	391.39	265.11
67 × 201	18.381	328.05	204.07
67 × 242	25.267	421.25	257.90
201 × 242	32.749	348.32	334.27
Mean (crosses)	21.778	371.99	287.54

Table 8. Correlations involving seed yield and other characters

Combinations		Simple Correlations	Partial Correlations (contants)			
			T_2	T_3	T_4	T_5
T_1 vs T_2	r	*		-	-	-
	rg	*		-	*	**
	rph	*		*	-	**
T_1 vs T_3	r	*	*		*	**
	rg	**	**		**	**
	rph	**	**		**	-
T_1 vs T_4	r	-	-	-		-
	rg	*	**	*		**
	rph	*	*	**		**
T_1 vs T_5	r	*	-	-	-	
	rg	**	**	**	**	
	rph	**	**	**	**	

\- not significant
* significant at 5 % level of probability
** significant at 1 % level of prabability
T_1 = seed yield; T_2 = seeds per pod; T_3 = dry matter per plant; T_4 = frost resistance; T_5 = plant height

the high yielders. Heterotic effects were also observed for dry matter per plant when single crosses were compared to the mid-parent and high-parent values, but it never exceeded 145%.

The heterotic effects observed in this study may be explained as follows. All the clones of this study were previously selected for several generations under predominantly self-pollinating conditions. This would lead to some degree of homozygosity. The high degree of heterosis in such situations, therefore, would result from the interaction of better genes fixed in the selected clones and the effect of heterozygosity. The nature of interactions are, of course, expected to be of digenic, trigenic and quadrigenic nature because of the autotetraploid nature of the species. Furthermore, it may be suggested that interactions resulting from heterozygosity and better genes are the two essential components of yield in alfalfa. However, improvement, by selection of better genes, will not be feasible and further improvement in selected clones has to be derived from the utilization of interactions and heterosis.

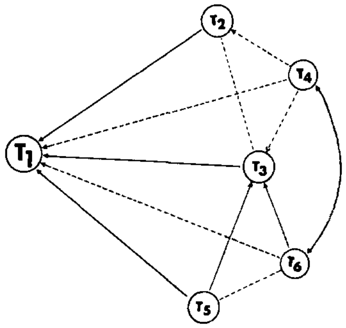

Fig. 1. Interrelationship between seed yield and its contributors.
—— Correlations significant at simple, genotypic and phenotypic levels
---- Correlations significant at genotypic and phenotypic levels only
T_1 = seed yield, T_2 = seeds per pod, T_3 = Dry matter per plant, T_4 = Frost resistance, T_5 = plant height, T_6 = vigor

d. Correlations

Simple, genotypic, and phenotypic correlations were calculated between seed yield and the other characters studied. It was found (Table 8) that the estimates of simple, genotypic, and phenotypic correlations are significant for seed yield with seeds per pod, dry matter per plant and plant height. Although frost resistance showed genotpyic and phenotypic association with seed yield, their simple correlation value was not significant. The correlations between seed yield and plant vigor were significant at the phenotypic level only. A set of partial correlations were tried (Table 8) to establish the importance of one contributing trait over another but did not show differential results. The pattern exhibited by the simple correlations, therefore, was taken as the relationship between seed yield and its contributors. It is realized, however, that more traits should be studied in order to establish the contribution of various traits to seed yield. On the basis of this study, using correlations of seed yield with all other characters, a cause and effect diagram was developed (Fig. 1), which indicated that the direct contributors to seed yield are dry matter per plant, resistance to frost and seeds per pod. In this diagram, frost resistance also contributes to seeds per pod, plant vigor and dry matter per plant. Similarly, plant vigor contributes to plant height and dry matter. Some of the other traits, such as number of pods per plant (or an indirect measure of it), should, if possible, be included in studying the characters influencing seed yield, which was not done in the present study. Most of the associations observed in this study are biologically obvious and may not need further explanation.

Table 9. Discriminant function and expected genetic advance in seed yield from the use of different selection indices

Selection indices	Discriminant function	Genetic gain
T_1, T_2	$y = 16.7334T_1 + 12.3340T_2$	138.95 (100)*
T_1, T_3	$y = 16.7445T_1 + 51.4877T_3$	138.92 (99.99)
T_1, T_4	$y = 15.3291T_1 + 85.8856T_4$	133.24 (96.37)
T_1, T_2, T_3	$y = 16.6598T_1 + 11.3535T_2 + 32.0699T_3$	138.64 (99.77)
T_1, T_2, T_4	$y = 15.2044T_1 + 10.7748T_2 + 85.5809T_4$	132.77 (95.55)
T_1, T_3, T_4	$y = 15.3413T_1 - 5.0762T_3 + 86.0083T_4$	133.29 (95.92)
T_1, T_2, T_3, T_4	$y = 13.6929T_1 + 14.5161T_2$ $831.3423T_3 + 64.4054T_4$	136.06 (97.92)

where T_1 = seed yield, T_2 = seeds per pod, T_3 = dry matter per plant and T_4 = frost resistance

* Value in brackets indicate relative efficiency of selection

The method of discriminant function was used to construct the selection indices involving various characters showing strong correlation with seed yield. Table 9 shows the selection indices, their discriminant functions and genetic gains along with the relative efficiency of selection. It suggests that none of the character combinations studied here could replace seed yield for the efficiency of selection for seed yield. However, characters related to pod set in such an analysis may be a better indicator of seed yield than the characters discussed here.

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