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Genetic Architecture of Yield and Components of Yield in Mustard (*Brassica juncea* (L.) Czern & Coss.)

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Summary. Seed yield and some of its primary components, viz. primary and secondary branches, siliquae per plant, seeds per siliqua and seed size, were studied in the F_1 and F_2 populations of five intervarietal crosses of mustard. The parental cultivars represented a fairly wide range of variation for all the characters. Both additive and dominance components were important for these traits and the gene actions were dependent upon the particular cross combination involved. Degrees of dominance were variable within each trait and inconsistent over the generations. The estimates of broad sense heritability and genetic advance were moderate to high, indicating that direct selection on the basis of primary branches and seeds per siliqua would be successful in the early segregating generations. Only one group of genes was detected in these traits. None of the F_1 hybrids were higher than the highest yielding cultivar 'Laha 101'. The production of hybrids higher than this cultivar is not possible without the introduction of genes from other sources.

Key words: Mustard – Degree of dominance – Heritability – Genetic coefficient of variation – Genetic advance

Introduction

Mustard (*Brassica juncea* (L.) Czern & Coss.) is one of the major edible oil yielding crops of the Indo-Pak-Bangladesh subcontinent. The limited number of publications available indicates that little genetical work has been done on this crop compared to other crops. With the initiation of breeding programmes, especially with diverse germplasm, it becomes necessary to measure the nature and relative magnitude of different gene actions governing the various quantitative traits. This information would be helpful to the plant breeders for two reasons: types of genetic variation in the traits for which selection is intended, and rapid evaluation of the yielding capacity by identifying crosses which will produce superior genotypes. The present experiment was, therefore, designed to study the genetic architecture of seed yield and some of its primary components in mustard.

Materials and Methods

The experiment was carried out using the parental, F_1 and F_2 populations of five intervarietal crosses, namely, 'Varuna' × 'KB2', 'Laha 101' × 'Rai Monipuri', 'KB 2' × 'Rai Monipuri', 'Varuna' × 'Rai Monipuri' and 'Rai7' × 'Rai5'. 'Varuna', 'Laha 101' and 'KB 2' are Indian cultivars and the remaining three are indigenous. All the six parents used in the crosses were pure lines and selected from the genetic stock maintained at the Department of Botany, Rajshahi University, Bangladesh. The F_1 and F_2 populations, along with the parents of each of the five crosses, were grown at the experimental garden of Rajshahi University (Bangladesh) in the winter season of 1975-76. The experiment had three replications, and in each replication the experimental plots allotted to each of the P_1, P_2, F_1 and F_2 populations of the five crosses were 3, 3, 3 and 8, respectively. Each plot consisted of a 4.5 m row and the space between and within rows was 30 cm. Non-experimental border rows were planted around the experimental field to avoid border effects. The six traits recorded were: primary and secondary branches per plant, siliquae per plant, seeds per siliqua (mean of three randomly selected siliqua from the main inflorescence), seed size (Wt. of 1000 seeds in gm) and seed yield per plant (gm). The data from the three replications were pooled to calculate the means and variances of each population. The arithmetic means for F_1 and F_2 were calculated as $(\bar{P}_1 + \bar{P}_2)/2$ and $(\bar{P}_1 + 2\bar{F}_1 + \bar{P}_2)/4$, respectively. The geometric mean of F_2 was calculated as antilogarithm of $(\log \bar{P}_1 + 2 \log \bar{F}_1 + \log \bar{P}_2)/4$. The minimum number of genes controlling the expression of the traits was estimated using two formulae. According to the Castle-Wright formula (1921), N(no. of gene pairs) $= (\bar{P}_1 - \bar{P}_2)^2/8(VF_2 - VF_1)$. According to the other formula (Burton 1951) $n = 0.25\,(0.75 - h + h^2)\,D^2/(VF_2 - VF_1)$, where $h = (\bar{F}_1 - \bar{P}_1)/(\bar{P}_2 - \bar{P}_1)$, and $D = \bar{P}_2 - \bar{P}_1$. In the above expressions, $\bar{P}_1$, $\bar{P}_2$, $\bar{F}_1$ and $\bar{F}_2$ indicate means of the smaller parent, of the larger parent, of the F_1 and F_2 populations, respectively. The degrees of dominance, h_1 and h_2, displayed for the traits in the F_1 and F_2 populations, respectively, were calcu-

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lated using the potence-ratio method (Romero & Frey 1973) as $h_1 = (\bar{F}_1 - MP)/D$ and $h_2 = 2\ (\bar{F}_2 - MP)/D$. Here D denotes the mean of the larger parent minus mid-parent (MP). Heritability in the broad sense and genetic coefficient of variation (GCV) were computed by the method of Burton (1951). The genetic advance (GA) to be expected from the selection of the top 5% of the plants was calculated as follows (Allard 1960): $GA = (\delta_g^2/\delta_{ph}^2)\ K\delta ph$, where $K\delta ph$ is the selection differential; in this case K has a value of 2.06. Genetic advance was also calculated as a % of the F_2 mean, and is the advance expected from one cycle of selection. Bartlett's X^2 test was applied to test the extent of variation among the F_1 variances within each trait.

Results and Discussion

The mean performance of the six parental cultivars for the six traits are given in Table 1. The results indicate that a fairly wide range of variation existed among the parental populations.

The observed, theoretical arithmetic and geometric means and variances of F_1 and F_2 populations are presented in Table 2. In each cross the observed F_1 means were greater than the observed F_2 means, except for seed yield in the crosses V × K and V × RM. To reveal the nature and degree of dominance, the observed F_1 means were compared with the parental means and with the theoretical arithmetic F_1 means. Agreement between the observed and arithmetic F_1 means suggests absence of dominance; partial dominance exists when the observed F_1 stands between the arithmetic F_1 mean and the mean of either parent and overdominance is encountered when the observed F_1 mean exceeds that of the higher parent or is lower than the lower parent. In the results obtained, the observed F_1 mean and the calculated arithmetic F_1 mean of the crosses L × RM and V × RM for primary and secondary branches, V × K, L × RM and V × RM for siliquae per plant, L × RM and R7 × R5 for seeds per siliqua, V × K, L × RM and R7 × R5 for seed size and seed yield were in close agreement, indicating additive gene action. Significant differences between the observed and calculated F_1 means were found in the remaining crosses and traits, suggesting non-additive gene action.

The extent of agreement between the observed and calculated F_2 means furnishes an indication of the nature of gene action in the inheritance of the particular trait. Arithmetic gene action assumes that the effects of the individual gene upon the genotype are additive, whereas geometric gene action considers that they are multiplicative. The observed F_2 means of each cross for all the traits were in close agreement with both the calculated arithmetic and geometric F_2 means (Table 2), which made it impossible to determine the type of gene action in the F_2 generation.

The considerable range of F_1 variation observed between the crosses within each character and Bartlett's X^2 test indicated heterogeneity between the variances for all traits except seed size. This heterogeneity between the variances within each trait was also reflected in the F_2, though the F_2 variances were, as expected, greater in magnitude (Table 2).

The estimates of the broad sense heritability, genetic coefficient of variation (GCV), genetic advance (GA), GA % of F_2 mean, degrees of dominance of F_1 (h_1) and F_2 (h_2) and minimum number of genes (n and N) for various traits are shown in Table 3. The heritability estimates ranged from 0.46 to 0.76 (mean 0.67) for primary branches, 0.58 to 0.77 (mean 0.72) for secondary branches, 0.68 to 0.89 (mean 0.82) for siliquae per plant, 0.77 to 0.89 (mean 0.83) for seeds per siliqua, 0.78 to 0.88 (mean 0.83) for seed size and 0.18 to 0.81 (mean 0.50) for seed yield. The magnitude of heritability estimates was directly related to the level of genetic diversity in a population. It may be mentioned that broad sense heritability estimates include dominance and epistasis as well as additive genetic variances, and the estimates so obtained should be considered as maximum heritabilities. These heritability values were in conformity with the findings of Paul et al. (1976a, b) and Wahhab & Bechyne (1977). Singh & Singh (1972) got inconsistent estimates

Table 1. Mean performances of six parental populations of mustard involved in the crosses

Parent	Abbreviations[a]	Primary branches	Secondary branches	Siliquae per plant	Seeds per siliqua	Seed size (gm)	Seed yield per plant (gm)
'Varuna'	V	7.48	15.48	358	10.70	3.40	9.54
'KB 2'	K	11.38	24.20	438	13.98	2.38	7.25
'Laha 101'	L	9.50	20.85	460	15.68	2.48	13.20
'Rai 5'	R5	7.80	13.48	342	14.85	2.18	9.48
'Rai 7'	R7	9.80	17.28	462	16.25	2.08	10.28
'Rai Monipuri'	RM	8.35	15.26	368	12.72	1.70	9.70

[a] These abbreviations will be used while referring to crosses

of heritability in two years. In the first year they obtained 70, 58, 80 and 47% heritability for primary and secondary branches, seeds per siliqua and seed yield, respectively. In the second year the corresponding values were 52, 26, 16 and 42%. Their narrow sense heritability was more or less consistent over two years. Thus, environmental differences affected the dominance component considerably, whereas the additive effect remained consistent for all traits over both years. This suggests that the experimental materials in the breeding programmes need to be evaluated in different environments for dependable information. The present experiment has limitations in that it was carried out in only one year and one location.

The mean genotypic coefficient of variation (GCV) ranged from 13.82% (siliquae per plant) to 92.78% (seed size). Seed size, primary branches and seeds per siliqua showed higher GCV, which offered scope for their improvement as they were less affected by the environment. The degree of success in a selection programme also depends upon the magnitude of heritability; high heritability

Table 2. Observed (O), theoretical arithmetic (A) and geometric (G) means and variances (V) of yield and yield components of mustard in F_1 and F_2 populations

Cross	F_1			F_2			
	O	A	V	O	A	G	V
Primary branches							
V × K	10.26[b]	9.43	7.50	10.20	9.85	9.73	22.50
L × RM	8.92	8.93	9.45	8.72	8.92	8.91	17.45
K × RM	10.42[b]	9.87	6.72	9.88	10.10	10.08	24.32
V × RM	7.67	7.92	7.54	7.28	7.79	7.79	30.85
R7 × R5	8.52[a]	8.80	4.65	8.20	8.66	8.63	18.92
Secondary branches							
V × K	21.38[b]	19.84	7.63	20.32	20.61	20.34	30.52
L × RM	18.32	18.06	8.64	17.42	18.19	18.08	20.40
K × RM	21.25[b]	19.73	6.72	20.48	20.49	20.21	26.42
V × RM	15.29	15.37	7.64	14.78	15.33	15.07	32.45
R7 × R5	18.45[b]	15.38	6.92	17.80	16.92	16.78	30.56
Siliquae per plant							
V × K	398	398	610	370	398	397	1925
L × RM	425	414	462	418	420	418	4042
K × RM	420[a]	403	488	412	412	411	4352
V × RM	362	363	542	353	363	362	3462
R7 × R5	338[b]	402	478	325	370	367	2720
Seeds per siliqua							
V × K	14.33[b]	12.34	7.62	14.20	13.34	13.24	46.25
L × RM	14.21	14.20	4.63	14.17	14.21	14.17	40.18
K × RM	12.92[a]	13.35	5.32	12.90	13.14	13.13	50.45
V × RM	12.23[b]	11.71	7.68	11.92	11.97	11.95	34.62
R7 × R5	15.28	15.55	10.45	15.20	15.42	15.41	20.28
Seed size							
V × K	2.85	2.89	0.98	2.70	2.87	2.85	4.48
L × RM	2.18	2.09	0.65	2.10	2.14	2.12	5.50
K × RM	2.40[b]	2.04	0.92	2.32	2.22	2.20	4.36
V × RM	2.30[a]	2.55	0.78	2.15	2.43	2.35	6.25
R7 × R5	2.25	2.13	0.92	2.10	2.19	2.19	5.42
Seed yield per plant							
V × K	8.49	8.40	2.40	8.72	8.44	8.40	7.45
L × RM	11.25	11.45	3.42	10.82	11.35	11.28	5.48
K × RM	8.12[b]	8.48	3.68	6.75	8.30	8.25	6.45
V × RM	8.89[b]	9.62	1.80	9.10	9.62	9.25	9.85
R7 × R5	10.35	9.88	3.82	10.20	10.12	10.11	4.65

[a,b] Significant at 5 and 1%levels respectively

values for seed size, seeds per siliqua and primary branches further emphasise the possible scope of genetic improvement of these traits.

The maximum genetic advance expressed as the percentage of the F_2 mean was expected in seed size and lowest in siliquae per plant. An expected advance of 174.91%, 81.31% and 76.93% for seed size, seeds per siliqua and primary branches, respectively, was encouraging, but due to the negative association between seed yield and seed size (Paul et al., 1976 a), direct selection on the basis of seed size may not be successful in the early segregating generations.

The estimated degrees of dominance in the F_1 and F_2 populations (Table 3) varied in different crosses of each trait. Moreover, some showed overdominance in the F_2 and partial dominance in the F_1 population. The correla-

Table 3. Estimates of broad sense heritability (H), genetic coefficient of variation (GCV), genetic advance (GA), GA % of F_2 mean, degrees of dominance of F_1 (h_1) and F_2 (h_2), and minimum number of genes (n and N) for various traits of mustard

Cross	H	GCV	GA	GA%	h_1	h_2	n	N
Primary branches								
V × K	0.67	37.97	6.51	63.87	0.43	0.79	0.14	0.13
L × RM	0.46	32.43	3.95	45.21	−0.02	−0.74	0.02	0.02
K × RM	0.72	42.46	7.35	74.41	0.36	0.01	0.07	0.07
V × RM	0.76	66.32	8.65	118.75	−0.58	−2.98	0.005	0.004
R7 × R5	0.75	46.06	6.79	82.42	−0.28	−1.20	0.04	0.04
Mean	0.67	44.93	6.65	76.93	−0.02	−0.82	0.06	0.05
Secondary branches								
V × K	0.75	23.55	8.54	42.02	0.35	0.22	0.44	0.42
L × RM	0.58	19.69	5.36	30.79	0.09	−0.23	0.33	0.53
K × RM	0.75	21.67	7.90	38.55	0.34	0.17	0.54	0.51
V × RM	0.76	33.70	8.97	60.70	−0.73	−10.73	0.003	0.003
R7 × R5	0.77	27.31	8.81	49.49	1.62	2.55	0.18	0.08
Mean	0.72	25.18	7.92	44.31	0.33	−1.60	0.30	0.31
Siliquae per plant								
V × K	0.68	9.80	61.74	16.69	---	0.70	0.61	0.61
L × RM	0.89	14.31	115.99	27.75	0.24	0.17	0.30	0.30
K × RM	0.89	15.09	120.66	29.29	0.49	0.51	0.18	0.16
V × RM	0.83	15.31	102.23	28.96	−0.20	−2.00	0.004	0.004
R7 × R5	0.82	14.57	88.56	27.25	−1.07	2.57	---	0.80
Mean	0.82	13.82	97.84	25.99	−0.14	−0.32	0.27	0.37
Seeds per siliqua								
V × K	0.84	46.58	11.70	82.40	1.21	2.27	0.06	0.03
L × RM	0.88	42.05	11.55	81.48	0.0007	---	0.03	0.03
K × RM	0.89	52.08	13.09	101.46	−0.68	−1.43	0.005	0.004
V × RM	0.78	43.54	9.43	79.13	0.51	0.42	0.03	0.02
R7 × R5	0.77	34.41	8.98	62.01	---	0.82	0.03	0.02
Mean	0.83	43.73	10.95	81.30	0.26	0.11	0.03	0.02
Seed size								
V × K	0.78	69.29	3.41	126.16	−0.08	−0.75	0.04	0.04
L × RM	0.88	104.87	4.26	202.86	0.23	0.05	0.02	0.02
K × RM	0.79	79.94	3.39	146.28	1.06	1.65	0.03	0.02
V × RM	0.88	108.78	4.51	209.64	−0.29	−0.94	0.07	0.07
R7 × R5	0.83	101.02	3.98	189.61	2.41	−1.20	0.001	0.001
Mean	0.83	92.78	3.91	174.91	0.67	0.04	0.03	0.03
Seed yield per plant								
V × K	0.68	25.77	3.81	43.71	0.08	0.55	0.13	0.13
L × RM	0.38	13.26	1.81	16.75	−0.11	−0.72	0.75	0.74
K × RM	0.43	24.66	2.25	33.29	−0.30	−2.84	0.28	0.27
V × RM	0.81	31.18	5.28	58.06	−9.13	−13.02	---	---
R7 × R5	0.18	8.93	0.79	7.77	1.18	1.60	0.16	0.10
Mean	0.50	20.76	2.79	31.92	−1.66	−2.89	0.33	0.31

tion coefficients between h_1 and h_2 were 0.97**, 0.53, 0.83, 0.73, -0.13 and 0.98**, respectively for primary and secondary branches, siliquae per plant, seeds per siliqua, seed size and seed yield. A significant positive correlation suggested that the degrees of dominance for various crosses were relatively similar in F_1 and F_2 for primary branches and seed yield, whereas on the other hand, non-significant, as well as a negative correlation, indicated that the degrees of dominance were relatively dissimilar in the F_1 and F_2 populations for the remaining traits.

Only one group of genes was detected for each trait in both formulae. It may be mentioned that these estimates furnish an unbiased estimate of gene number if the assumptions listed by Sewall Wright (Burton 1951) apply to the situation. Paul et al. (1976 b) reported 1-6 gene groups for some of these traits. Singh & Singh (1972) reported 5-7 genes for seed yield and 1-4 for yield components.

This study indicates that the genetic control of seed yield and its components in mustard depends upon the particular cross combination involved, and that both additive and dominance gene actions are important. None of the F_1 hybrids yielded higher than the highest yielding cultivar 'Laha 101', so their potentialities as outstanding F_1 hybrids are not encouraging and the production of hybrids yielding higher than this cultivar is not feasible without the introduction of genes from other sources. In contrast, however, Singh & Singh (1972) got sufficient hybrid vigour for seed yield in mustard, not only over their superior parents but also over the best available cultivars. Such discrepancy can be expected because dominance and overdominance gene actions responsible for heterotic effect are greatly affected by environments, and further, different parental genotypes were used.

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Literature

Allard, R.W.: Principles of plant breeding. New York: Wiley & Sons 1960

Burton, G.W.: Quantitative inheritance in pearl millet (*Pennisetum glaucum*). Agron. J. **43**, 409-417 (1951)

Castle, W.E.: An improved method of estimating the number of genetic factors concerned in case of blending inheritance. Science **54**, 223 (1921)

Paul, N.K.; Joarder, O.I.; Eunus, A.M.: Genotypic and phenotypic variability and correlation studies in *Brassica juncea* L. Z. Pflanzenzücht. 77, 145-154 (1976a)

Paul, N.K.; Joarder, O.I.; Eunus, A.M.: Analysis of yield and some of its components in mustard. Ind. J. agric. Sci. **46**, 517-524 (1976b)

Romero, G.E.; Frey, K.J.: Inheritance of semidwarfness in several wheat crosses. Crop Sci. **13**, 334-337 (1973)

Singh, S.P.; Singh, D.: Inheritance of yield and other agronomic characters in Indian mustard (*Brassica juncea*). Can. J. Gen. Cytol. **14**, 227-233 (1972)

Wahhab, M.A.; Bechyne, M.: Heritability estimates for some yield-contributing characters in Indian mustard. Ind. J. agric. Sci. **47**, 556-559 (1977)

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