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Variability Comparison of Mustard Crosses in Advanced Segregating Generations

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ABSTRACT

In advanced segregating generations, variability was studied and compared in 14 mustard crosses, for yield and its attributing traits. The fourteen crosses in the F_4 generation in the first year and F_5 generation in the second year differed significantly for all characters except total chlorophyll content, 100 seed weight and secondary branches per plant and seed yield per plant in F_4 and total chlorophyll content and 100 seed weight in F_5 generation. In F_4 generation Pusa Bold × Pusa Bahar was the highest yielder (10.62 g/plant) but in F_5 generation Pusa Bahar × Varuna (10.25 g/plant) was the highest yielder. At both genotypic and phenotypic level, seed yield per plant was positively associated with plant height, height upto first fruiting branch and siliquae per plant only in F_5 generation whereas, in F_4 generation no such positive association on seed yield component with seed yield per plant was found. In F_5 generation, seed yield was positively associated with plant height, height upto first fruiting branch and siliquae per plant. On the basis of the mean performance of the crosses F_5, three of them namely Pusa Bahar × Varuna, Pusa Bold × Kranti and Pusa Barani × Pusa Jaikissan were identified as high yielding and can be used for further selection of superior high yielding genotypes of mustard.

Key words: *Mustard, Correlation, Heritability, Genetic advance*

INTRODUCTION

The genus *Brassica* is an important member of the *cruciferae* family. It comprises of several economically important species which yield edible roots, stems, leaves, buds, flowers and seeds condiment. Most of the species are used as oilseed crop and some as forage. The important rapeseed and mustard growing countries in the world are India, Canada, China, Pakistan, Holland, Bangladesh and Sweden. India ranks first in the world in respect of acreage and second in the production next to Canada.

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In India, rapeseed-mustard cultivation is mainly confined to the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, Assam, Bihar, Gujarat, and West Bengal in India. Among the different states, Rajasthan alone produces more than 50% of the total rapeseed and mustard produced in India. Among the edible oil bearing seed crop of the world, oil seed *Brassica* occupies a predominant third place ranking next only to soybean and groundnut and in respect of acreage occupies 20.7 millions hectares of the area as against 57.7 and 25 million hectares of soybean and groundnut, respectively.

Indian mustard (*B. juncea* 2n=4x=36) and yellow sarson (*B. campestris*) are the important species largely grown as oilseed crop in subtropical and tropical countries. In Asia mustard and rapeseed are chiefly grown in China, India and Pakistan and also grown in countries other than Asia *i.e*. countries in Europe, Canada and Russia. In trade, sarson, toria and taramira are known as rapeseed and rai as mustard. Banarasi rai (*B. nigra* Koch.) which does not fall under any of the four groups is a garden crop used as spice. The cultivation of white mustard (*Brassica alba*, *Sinapis alba*) is no longer found in India. Rai and yellow sarson is self fertile and rest of the cruciferous oilseeds, viz. brown sarson, toria, taramira, Banarasi rai and white mustard are self incompatible. The acreage under yellow sarson in India is scanty (mainly in Bihar, Central Uttar Pradesh, West Bengal) and constantly on the decrease. In the recent past, the acreage under brown mustard (*B. juncea*) is steadily on the increase (over 90%), at the expense of other *Brassicas* due to its higher production, greater resistance to pest and diseases and moisture stress.

The success of a crop improvement program depends mainly on the extent of genetic variability, heritability, genetic advance and association of characters. Genetic variability provides useful information for selection of parents with transgressive segregation[9]. Heritability helps to measure the level of possible genetic progress as it provides information on the proportion of phenotypic variance that is attributable to genetic factors controlling different traits. Successful selection can be made when heritability estimate is considered along with genetic advance[6]. Information on the magnitude and direction of association between yield and its attributing traits is very important for progress in any selection and genetic improvement of a crop[3]. Many times yield itself has low heritability and in such cases indirect selection for yield using its attributing traits is very important.

The present study was envisaged with the objective to study the character association in advanced segregating generations of mustard crosses in order to search traits and promising mustard crosses for further selection of superior high yielding genotypes.

MATERIALS AND METHODS

Plant Materials

The materials used were developed and maintained by Regional Research Station Programme on Mustard, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. The materials represented the seeds of segregating generations of 14 mustard crosses in their F_4 and F_5 generations and the crosses were advanced from F_4 to F_5 by bulk method. The details of the experimental materials for the experiment are presented in Table 1.

Site and Soil

The field experiments were conducted at Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, during rabi seasons of two consecutive years (2010-11 and 2011-12). The soil at the experimental site is sandy loam in texture, a true representative of the terai region of West Bengal, India. The experimental site belongs to the sub-tropical humid climate, being situated just south of the tropic of cancer. The seasons can be broadly classified into: (i) Hot and dry (March-May), (ii) Hot and humid (June and September), (iii) Cool and dry (November-February) seasons. The crop was sown on 30th November 2010-11 in the first year and 29th November 2011-12 in the second year, for experimental trials. The details of the climatic conditions during the period of standing crop are presented in Table 2.

Field Experiment

The following sub-headings describe the methods and practices followed during the two years 2010-11 and 2011-12, to carry out the field experiments.

Design and Layout

Randomized Block Design was followed for the experiment, where the 14 crosses of mustard were sown in 2010-11 (F_4 generation) and 2011-12 (F_5 generation), with a spacing of 10 cm for plant to plant and 30 cm row to row in 20 m^2 plots, in three replications.

Observations and Recording of Experimental Data

Except for days to 50% flowering where data was recorded plot wise, ten randomly selected but competitive plants per entry per replication were scored to get mean phenotypic value for each of the other 10 characters considered. Same observations were recorded for the following characters for both the experimental trials in 2010-11 and 2011-12. The details of the observations recorded for the different characters are given as below:

Plant height: Plant height (cm) was measured from base to apex of the main shoot after harvesting the plants.

Height upto first branching: Length (cm) of the portion of the main stem from the ground level upto the first capsule bearing branch was recorded.

Days to 50% flowering: It was measured as days from the date of sowing to the date when 50% of the plants has flowered.

Days to Physiological maturity: It was measured as days from the date of sowing to when physiological maturity of the siliqua occurred on the plant.

Primary branches per plant: Siliqua bearing primary branches of a plant were counted and recorded for each sample plant.

Secondary branches per plant: Total number of sub-branches on the primary branches of the main shoot of the plant was recorded at the time of harvest.

Siliquae per plant: Average number of siliquae obtained from 10 plants was recorded.

Seeds per siliqua: To record the number of seeds per siliqua, a siliqua from middle portion of the main raceme was pinched off from each of the 10 plants. Seeds of each siliqua were counted and the mean value of seeds from the 10 siliquae was recorded.

Total Chlorophyll Content: It was measured by using SPAD meter having spad 502 as unit.

100-seed weight: 100 seeds were counted from bulk harvested seed yield of 10 plants and their weight was recorded in grams by using a digital electronic balance.

Seed yield per plant: After recording majority of the observations the bundled harvest of 10 sample plants was trampled to yield seed in bulk. Bulk seed was weighed using a digital electronic balance and recorded in grams. Ultimately single plant yield was calculated by taking the average.

Agronomic Practices

The land was brought to a fine tilth before sowing. The fertilizer dose of N: P: K @ 60: 40: 40 Kg/ha was applied where half of N along with whole of P and K as a basal dose and remaining half of N was applied later as top dressing. Irrigation was given as and when required. Intercultural operation like thinning and weeding were done as and when necessary.

Statistical analysis

The method suggested by Al. Jibouri *et al*.[2] was used to evaluate the genetic parameters. The genotypic and phenotypic correlations were calculated by the method suggested by Johnson *et al*.[7]. The path analysis was carried out by the method proposed by Dewey and Lu[5]. The entire statistical analysis was done using the software "Windostat".

RESULTS

The fourteen crosses in F_4 population in the first year and F_5 population in the second year, differed significantly for all characters except total chlorophyll content, 100 seed weight and secondary branches per plant and seed yield per plant in F_4 and total chlorophyll content and 100 seed weight in F_5 population.

Description of yield and its attributing traits

The mean value of yield and its attributing traits are presented in Table 3.

Plant height (cm): The cross Pusa Bold × Pusa Bahar was the best performer (155.87) in F_4 generation and Pusa Bold × Varuna (167.27) in F_5 generation.

Height upto first fruiting branch (cm): The cross Kranti × Pusa Jaikissan (17.33) showed minimum height up to first fruiting branch in case of F_4 generation and Varuna × Pusa Bahar (5.70) in F_5 generation.

Days to 50% flowering: The minimum days to 50% flowering was recorded by Pusa Barani × Kranti (46) for F_4 generation and Pusa Bold × Pusa Jaikissan (49) for F_5 generation.

Days to physiological maturity: The minimum days to physiological maturity was observed in Varuna × Pusa Bahar (92.33) in F_4 generation and Pusa Bold × Kranti (108.67) in F_5 generation.

Primary branches per plant: The maximum primary branches per plant was exhibited by Pusa Barani × Kranti (7.43) and Pusa Bold × Pusa Jaikissan (5.83) in F_4 and F_5 generations, respectively.

Secondary branches per plant: The cross Pusa Jaikissan × Kranti (7.27) and Pusa Bold × Pusa Bahar (9.43) recorded the highest value for this character in F_4 and F_5 generations, respectively.

Siliquae per plant: The cross Kranti × Pusa Jaikissan (202.94) showed highest mean value for this character in F_4 generation and Kranti × Pusa Bahar (299.17) in F_5 generation.

Seeds per siliqua: Highest score for this character was shown by Varuna × Pusa Bahar in both F_4 (15.23) and F_5 (16.03) generations.

Total chlorophyll content: Maximum chlorophyll content was observed in Pusa Barani × Pusa Jaikissan (49.13) and Pusa Jaikissan × Pusa Barani (50.33) in F_4 and F_5 generations, respectively.

100 seed weight (g): The Maximum test weight was recorded in Pusa Bold × Pusa Jaikissan (0.54) in F_4 population and Kranti × Pusa Jaikissan (0.55) in F_5 generation.

Seed yield per plant (g): In F_4 generation Pusa Bold × Pusa Bahar was the highest yielder (10.62). However, the fourteen crosses did not differ significantly for this character. In F_5 generation Pusa Bahar × Varuna (10.25) was the highest yielder, which did not differ significantly from two other crosses namely Pusa Bold × Kranti (9.62) and Pusa Barani × Pusa Jaikissan (9.55).

Genetic parameters for different characters

Estimates of genetic parameters exhibited wide range of variability for all the characters (Table 4). The degree of variability exhibited by the different characters can be judged by the value of Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV). The estimates of both GCV and PCV were comparatively high for only height up to first fruiting branch in both F_4 and F_5 generations, which indicated the presence of high amount of both genotypic and phenotypic variability for this trait in the genetic material. The variability estimates, in general revealed that the estimates of PCV were greater than GCV for primary branches per plant, secondary branches per plant, seeds per siliqua, total chlorophyll content, 100 seed weight and seed yield per plant in both F_4 and F_5 generations but for height up to first fruiting branch and siliquae per plant only in F_4 generation, which suggested role of environment in the expression of these characters.

The least difference between PCV and GCV was observed for plant height, days to 50% flowering, and days to physiological maturity were in both F_4 and F_5 generations and height up to first fruiting branch and siliquae per plant in F_5 generation, which suggested that these characters are least affected by the environment. In such a situation selection can be effective on the basis of phenotype alone with equal probability of success. On the basis of GCV, it is possible to comment on heritable variation but it can be found out with greater degree of accuracy when heritability in broad sense (h^2_b) in conjunction with genetic advance (GA) is studied. The h^2_b estimates ranged from 34% for total chlorophyll content to 97.80% for plant height and siliquae per plant in F_4

generation. High estimates of h^2_b were observed for plant height, height up to first fruiting branch, days to 50% flowering, days to physiological maturity, siliquae per plant, and seed yield per plant and moderate for seeds per siliqua in both F_4 and F_5 generations.

Correlation studies

Genotypic correlation**:** At the genotypic level in F_4 generation, none of the component characters was positively associated with seed yield (Table 5). Secondary branches per plant was negatively associated with seed yield (-0.782). In F_5 generation, seed yield was positively associated with plant height (0.558), height up to first fruiting branch (0.514) and siliquae per plant (0.646). In F_5, plant height was positively associated with height up to first fruiting branch (0.821), secondary branches per plant (0.464), siliquae per plant (0.480) and negatively associated with primary branches per plant (-0.487) and seeds per siliqua (-0.856). Height up to first fruiting branch in F_5, was positively associated with days to 50% flowering (0.499) and negatively associated with seeds per siliqua (-0.519) and 100 seed weight (-0.468). Siliquae per plant was negatively associated with seeds per siliqua in both F_4 (-0.741) and F_5 (-0.798).

Phenotypic correlation: At the phenotypic level in F_4 generation, none of the component characters were positively associated with seed yield (Table 6). In F_5 generation seed yield per plant was positively associated with plant height (0.532), height up to first fruiting branch (0.488) and siliquae per plant (0.615). Plant height was positively associated with height up to first fruiting branch (0.811) and siliquae per plant (0.479) and negatively associated with seeds per siliqua (-0.536) in F_5. Height up to first fruiting branch was positively associated with only days to 50% flowering in both F_4 (0.576) and F_5 (0.486). Siliquae per plant was negatively associated with seeds per siliqua in both F_4 (-0.533) and F_5 (-0.493).

Path analysis

In F_4 generation, high direct effect on seed yield per plant was exhibited by 100 seed weight followed by total chlorophyll content and days to physiological maturity but however, none of these three component characters were positively associated with seed yield (Table 7). Also seed yield per plant was not positively associated with any of the other component characters. In F_5 generation highest positive direct effect on seed yield per plant was exhibited by siliquae per plant which was also positively associated with seed yield per plant. Plant height was positively associated with seed yield even though its direct effect was quite low, due to its better performance through siliquae per plant and seeds per siliqua. Height up to first fruiting branch had a low direct effect but positive association with seed yield per plant, due to its better performance through siliquae per plant, seeds per siliqua and total chlorophyll content.

Table 1: List of 14 mustard crosses evaluated over two years (F_4 during 2010-11 and F_5 during 2011-12)

Cross No.	Parents involved in the cross
1	Varuna × Pusabahar
2	Pusabahar × Varuna
3	Pusabahar × Kranti
4	Kranti × Pusa jaikissan
5	Pusa jaikissan × Kranti
6	Pusa Bold × Pusa Jaikissan
7	Pusa Jaikissan × Pusa Barani
8	Pusa Barani × Pusa Jaikissan
9	Pusa Bold × Varuna
10	Pusa Bold × Pusa Bahar
11	Kranti × Pusa Bahar
12	Pusa Bold × Pusa Barani
13	Pusa Bold × Kranti
14	Pusa Barani × Kranti

Table 2: Average monthly records of meteorological parameters at Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Village-Pundibari, District-Cooch Behar, West Bengal, India, during rabi (Winter) season of 2010-11 and 2011-12

Year	Months	Temperature (°C)		Total rainfall (mm)	Relative humidity (%)	
		Max.	Min.		Max.	Min.
	November	31.75	22.41	0.027	79.87	76.57
2010	December	26.45	15.54	1.07	79.16	76.55
	January	24.48	10.65	0.05	90.29	70.71
2011	February	28.18	12.29	0.031	82.04	58.89
	November	29.03	14.73	0.017	80.43	79.57
2011	December	26.88	12.21	0.01	90.71	82.42
	January	22.39	9.32	0.11	89.06	68.90
2012	February	26.41	11.48	0.52	86.59	50.86

Source: Department of Agronomy, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India

Table 3: Mean table for different characters of segregating generation of 14 mustard crosses

Crosses \ Characters		Plant height (cm)	Height upto first fruiting branch (cm)	Days to 50% flowering	Days to physiological maturity	Primary Branches per plant	Secondary Branches per plant	Siliquae per plant	Seeds per siliqua	Total Chlorophyll content (spad 502)	100 seed weight (g)	Seed Yield per plant (g)
Varuna × Pusa Bahar	F_4 (2010-11)	132.33	21.43	47.33	92.33	5.80	4.27	86.23	15.23	48.17	0.38	7.12
	F_5 (2011-12)	86.53	5.70	53.33	113.67	5.57	6.23	116.07	16.03	47.27	0.48	4.06
Pusa Bahar × Varuna	F_4 (2010-11)	147.13	32.87	49.00	92.67	4.27	6.50	153.43	12.00	46.40	0.47	7.30
	F_5 (2011-12)	158.43	40.73	56.00	116.33	4.70	8.47	213.50	12.67	39.62	0.51	10.25
Pusa Bahar × Kranti	F_4 (2010-11)	133.67	28..93	49.00	97.33	4.67	7.20	201.30	12.10	45.43	0.50	8.56
	F_5 (2011-12)	144.63	23.37	54.33	116.00	4.80	8.20	237.60	14.07	43.80	0.52	6.00
Kranti × Pusa Jaikissan	F_4 (2010-11)	108.77	17.33	50.33	114.67	4.67	7.17	202.94	12.40	45.40	0.50	7.13
	F_5 (2011-12)	116.90	7.50	52.33	110.00	5.37	8.63	246.40	12.90	40.59	0.55	5.87
Pusa Jaikissan × Kranti	F_4 (2010-11)	106.20	29.17	50.00	114.00	4.63	7.27	196.80	12.07	39.30	0.47	7.42
	F_5 (2011-12)	131.73	25.03	52.33	111.00	5.03	9.35	205.23	13.63	43.00	0.48	7.87
Pusa Bold × Pusa Jaikissan	F_4 (2010-11)	133.53	34.27	47.33	95.33	3.73	5.67	178.83	12.20	48.83	0.54	7.85
	F_5 (2011-12)	150.03	26.53	49.00	114.00	5.83	7.00	262.70	13.33	50.17	0.46	8.67
Pusa Jaikissan × Pusa Barani	F_4 (2010-11)	117.77	25.67	47.00	99.67	4.20	5.80	186.33	12.37	43.43	0.50	8.34
	F_5 (2011-12)	142.30	23.03	52.67	114.00	5.50	7.20	232.87	13.00	50.33	0.47	7.82
Pusa Barani × Pusa Jaikissan	F_4 (2010-11)	144.93	34.87	50.00	115.33	3.87	5.87	178.20	12.87	49.13	0.53	8.36
	F_5 (2011-12)	102.60	17.00	52.67	114.67	5.63	6.47	256.67	14.60	43.93	0.52	9.55
Pusa Bold × Varuna	F_4 (2010-11)	148.07	42.67	55.00	99.00	3.70	5.13	166.00	13.07	44.93	0.51	7.37
	F_5 (2011-12)	167.27	51.13	63.33	115.67	5.27	8.10	244.00	13.57	43.43	0.48	7.97
Pusa Bold × Pusa Bahar	F_4 (2010-11)	155.87	40.33	53.00	112.67	4.03	4.20	117.33	12.57	44.77	0.49	10.62
	F_5 (2011-12)	144.17	18.30	60.00	116.00	5.00	9.43	286.67	12.93	44.28	0.50	9.17
Kranti × Pusa Bahar	F_4 (2010-11)	143.53	18.70	47.00	120.00	4.50	6.07	175.17	11.80	45.70	0.52	8.36
	F_5 (2011-12)	131.30	19.47	54.67	114.00	5.23	9.10	299.17	13.30	45.95	0.47	8.25
Pusa Bold × Pusa Barani	F_4 (2010-11)	135.00	25.67	53.33	94.67	3.93	5.77	175.57	12.30	44.73	0.50	8.21
	F_5 (2011-12)	141.20	33.93	53.67	110.00	5.20	7.10	239.27	12.90	41.10	0.44	8.10
Pusa Bold × Kranti	F_4 (2010-11)	147.00	29.33	49.00	119.00	4.10	6.03	145.87	11.63	44.67	0.39	7.27
	F_5 (2011-12)	152.03	24.50	54.33	108.67	5.07	8.67	297.50	13.33	44.80	0.50	9.62
Pusa Barani ×Kranti	F_4 (2010-11)	125.63	19.53	46.00	109.33	7.43	6.83	166.57	12.53	44.95	0.50	7.41
	F_5 (2011-12)	129.03	21.13	57.00	116.00	4.60	9.05	264.17	13.03	39.90	0.48	8.11
Mean (F_4)		134.24	28.60	49.52	105.43	4.52	5.98	166.47	12.51	45.42	0.49	7.95
Mean (F_5)		135.58	24.10	54.69	133.57	5.20	8.07	242.99	13.52	44.15	0.49	7.95
CD of F_4 (P= 0.05)		3.83	4.53	1.41	2.49	1.64	-	8.19	1.23	-	-	-
CD of F_5 (P= 0.05)		2.62	2.60	1.69	1.03	0.72	1.60	2.66	1.52	-	-	1.00

Table 4: Genetic parameters for different characters of segregating generations of 14 mustard crosses

Characters		Plant height (cm)	Height upto first fruiting branch (cm)	Days to 50% flowering	Days to physiological maturity	Primary Branches per plant	Secondary Branches per plant	Siliquae per plant	Seeds per siliqua	Total Chlorophyll content (spad502)	100 seed weight (g)	Seed Yield per plant (g)
Mean	F_4 (2010-11)	134.24	28.61	49.52	105.43	4.54	5.98	166.47	12.51	45.42	0.49	7.95
	F_5 (2011-12)	135.58	24.10	54.69	113.57	5.20	8.07	242.99	13.52	44.15	0.49	7.95
Range	F_4 (2010-11)	104.00 -158.80	15.20-44.50	46.00- 55.00	90.00- 120.00	3.20- 9.40	2.20- 9.80	84.0- 208.00	9.60- 16.40	37.20- 63.20	0.35- 0.59	6.33-11.28
	F_5 (2011-12)	85.40-169.80	5.00- 52.00	48.00- 64.00	108.00- 117.00	4.30- 6.60	5.00-9.80	115.00- 300.00	11.30- 17.10	35.16- 55.60	0.40-0.55	3.35- 11.00
CV (%)	F_4 (2010-11)	1.70	9.43	1.70	1.41	21.55	25.07	2.93	5.88	11.67	6.91	5.73
	F_5 (2011-12)	1.15	6.42	1.84	5.54	8.25	11.80	0.65	6.70	9.24	6.71	7.48
PCV	F_4 (2010-11)	11.35	28.50	5.58	9.96	28.08	26.25	19.69	8.48	10.93	11.26	12.60
	F_5 (2011-12)	16.08	49.66	6.68	2.33	9.68	16.47	18.98	8.51	10.78	7.84	21.82
GCV	F_4 (2010-11)	11.22	26.90	5.32	9.86	18.00	7.79	16.47	6.11	4.06	8.90	11.22
	F_5 (2011-12)	16.04	49.25	6.42	2.26	5.07	11.50	18.97	5.31	5.55	4.06	20.49
h^2_b	F_4 (2010-11)	97.8	89.1	90.7	98.0	41.1	8.8	97.8	51.9	34.0	62.4	79.3
	F_5 (2011-12)	99.5	98.3	92.4	94.6	27.5	48.7	99.9	38.6	26.5	26.8	88.2
GAMP	F_4 (2010-11)	22.86	52.29	10.43	20.10	23.77	4.76	39.65	9.06	3.11	14.48	20.57
	F_5 (2011-12)	32.95	100.60	12.72	4.54	5.48	16.53	39.05	6.80	5.89	4.33	39.66

CV = Coefficient of variance, PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, h^2_b = heritability in broad sense, GAMP = genetic advance as percent of mean

Table 5: Genotypic correlation between yield and its attributing traits in segregating generations of 14 mustard crosses

Sl. No.	Characters		Height upto first fruiting branch (cm)	Days to 50% flowering	Days to physiological maturity	Primary Branches per plant	Secondary Branches per plant	Siliquae per plant	Seeds per siliqua	Total Chlorophyll content (spad 502)	100 seed weight (g)	Seed Yield per plant (g)
1	Plant height (cm)	F_4 (2010-11)	0.582*	0.320	-0.333	-0.425	-0.216	-0.520*	-0.003	-0.648**	-0.117	0.426
		F_5 (2011-12)	0.821**	0.414	0.135	-0.487*	0.464*	0.480*	-0.856**	-0.087	-0.299	0.558*
2	Height upto first fruiting branch (cm)	F_4 (2010-11)		0.623**	-0.186	-0.726**	-0.853**	-0.156	-0.043	-0.044	0.152	0.383
		F_5 (2011-12)		0.499*	0.219	-0.359	0.133	0.162	-0.519*	-0.282	-0.468*	0.514*
3	Days to 50% flowering	F_4 (2010-11)			-0.042	-0.696**	-0.758**	-0.013	-0.017	0.262	0.160	0.285
		F_5 (2011-12)			0.455	-0.663**	0.476*	0.176	-0.228	-0.504*	0.070	0.173
4	Days to physiological maturity	F_4 (2010-11)				0.061	0.522*	0.183	-0.446	0.372	0.019	0.166
		F_5 (2011-12)				-0.284	-0.003	-0.048	0.106	0.086	0.042	0.094
5	Primary Branches per plant	F_4 (2010-11)					0.019	-0.226	0.403	0.013	-0.209	-0.320
		F_5 (2011-12)					-0.144	-0.214	0.870**	0.152	-0.071	-0.254
6	Secondary Branches per plant	F_4 (2010-11)						0.700**	-0.683**	0.940**	0.479*	-0.782**
		F_5 (2011-12)						0.565*	-0.717**	-0.582*	0.227	0.326
7	Siliquae per plant	F_4 (2010-11)							-0.741**	0.362	0.727**	-0.142
		F_5 (2011-12)							-0.798**	-0.082	0.132	0.646**
8	Seeds per siliqua	F_4 (2010-11)								-0.702**	-0.457	-0.175
		F_5 (2011-12)								0.298	0.201	-0.739**
9	Total Chlorophyll content (spad 502)	F_4 (2010-11)									0.126	-0.155
		F_5 (2011-12)									-0.435	-0.218
10	100 seed weight (g)	F_4 (2010-11)										0.330
		F_5 (2011-12)										-0.112

, * = Significant at 5% and 1% probability levels, respectively

Table 6: Phenotypic correlation between yield and its attributing traits in segregating generations of 14 mustard crosses

Sl. No.	Characters		Height upto first fruiting branch (cm)	Days to 50% flowering	Days to physiological maturity	Primary Branches per plant	Secondary Branches per plant	Siliquae per plant	Seeds per siliqua	Total Chlorophyll content (spad 502)	100 seed weight (g)	Seed Yield per plant (g)
1	Plant height (cm)	F_4 (2010-11)	0.565*	0.306	-0.034	-0.256	-0.360	-0.495*	0.017	0.211	-0.078	0.406
		F_5 (2011-12)	0.811**	0.395	0.134	-0.261	0.329	0.479*	-0.536*	-0.046	-0.142	0.532*
2	Height upto first fruiting branch (cm)	F_4 (2010-11)		0.576*	-0.157	-0.484*	-0.251	-0.129	-0.061	0.073	0.154	0.374
		F_5 (2011-12)		0.486*	0.222	-0.202	0.073	0.162	-0.312	-0.158	-0.242	0.488*
3	Days to 50% flowering	F_4 (2010-11)			-0.049	-0.380	-0.070	-0.010	0.027	-0.089	0.122	0.237
		F_5 (2011-12)			0.429	-0.325	0.321	0.168	-0.095	-0.267	0.024	0.172
4	Days to physiological maturity	F_4 (2010-11)				-0.002	0.130	0.182	-0.322	-0.123	0.052	0.145
		F_5 (2011-12)				-0.186	0.011	-0.045	0.064	-0.002	0.067	0.115
5	Primary Branches per plant	F_4 (2010-11)					0.304	0.164	0.248	-0.061	-0.260	-0.278
		F_5 (2011-12)					-0.396	-0.115	0.080	0.453	-0.271	-0.165
6	Secondary Branches per plant	F_4 (2010-11)						0.493*	-0.205	0.076	0.170	-0.276
		F_5 (2011-12)						0.395	-0.455	-0.361	0.250	0.205
7	Siliquae per plant	F_4 (2010-11)							-0.533*	-0.200	0.567*	-0.099
		F_5 (2011-12)							-0.493*	-0.036	0.070	0.615**
8	Seeds per siliqua	F_4 (2010-11)								0.086	-0.272	-0.135
		F_5 (2011-12)								0.328	-0.046	-0.418
9	Total Chlorophyll content (spad	F_4 (2010-11)									0.189	-0.101
		F_5 (2011-12)									-0.359	-0.086
10	100 seed weight (g)	F_4 (2010-11)										0.276
		F_5 (2011-12)										-0.008

, * = Significant at 5% and 1% probability levels, respectively

Table 7: Genotypic direct (diagonal) and indirect (off-diagonal) effects of different attributing traits on seed yield in segregating generations of 14 mustard crosses

Sl. No.	Characters		Plant height (cm)	Height upto first fruiting branch (cm)	Days to 50% flowering	Days to physiological maturity	Primary Branches per plant	Secondary Branches per plant	Siliquae per plant	Seeds per siliqua	Total Chlorophyll content (spad 502)	100 seed weight (g)	Genotypic Correlation with Seed Yield per plant (g)
1	Plant height (cm)	F_4 (2010-11)	**-1.47**	-0.65	-0.27	-0.01	1.05	-0.08	2.47	0.00	-0.27	-0.34	0.43
		F_5 (2011-12)	**0.10**	0.11	-0.08	0.02	0.08	-0.27	0.35	0.19	0.03	0.03	0.56*
2	Height upto first fruiting branch (cm)	F_4 (2010-11)	-0.85	**-1.12**	-0.53	-0.04	1.79	-0.06	0.74	0.04	-0.02	0.44	0.38
		F_5 (2011-12)	0.08	**0.13**	-0.10	0.04	0.06	-0.08	0.12	0.11	0.10	0.04	0.51*
3	Days to 50% flowering	F_4 (2010-11)	-0.47	-0.70	**-0.85**	-0.01	1.71	-0.05	0.06	0.02	0.11	0.46	0.29
		F_5 (2011-12)	0.04	0.07	**-0.20**	0.08	0.12	-0.28	0.13	0.05	0.17	-0.01	0.17
4	Days to physiological maturity	F_4 (2010-11)	0.05	0.21	0.04	**0.23**	-0.15	0.04	-0.87	0.42	0.16	0.06	0.17
		F_5 (2011-12)	0.01	0.03	-0.09	**0.18**	0.05	0.00	-0.04	-0.02	-0.03	0.00	0.09
5	Primary Branches per plant	F_4 (2010-11)	0.62	0.82	0.59	0.01	**-2.46**	0.00	1.08	-0.38	0.01	-0.60	-0.32
		F_5 (2011-12)	-0.05	-0.05	0.13	-0.05	**-0.17**	0.67	-0.16	-0.19	-0.40	0.01	-0.25
6	Secondary Branches per plant	F_4 (2010-11)	1.78	0.96	0.64	0.12	-0.05	**0.07**	-8.09	1.59	0.81	1.38	-0.78**
		F_5 (2011-12)	0.05	0.02	-0.09	-0.01	0.20	**-0.59**	0.41	0.16	0.20	-0.02	0.33
7	Siliquae per plant	F_4 (2010-11)	0.76	0.18	0.01	0.04	0.56	0.12	**-4.76**	0.70	0.15	2.10	-0.14
		F_5 (2011-12)	0.05	0.02	-0.03	-0.01	0.03	-0.33	**0.72**	0.18	0.03	-0.01	0.65**
8	Seeds per siliqua	F_4 (2010-11)	0.00	0.05	0.02	-0.10	-0.99	-0.12	3.53	**-0.94**	-0.29	-1.32	-0.18
		F_5 (2011-12)	-0.09	-0.07	0.04	0.02	-0.15	0.42	-0.58	**-0.22**	-0.10	-0.02	-0.74**
9	Total Chlorophyll content (spad 502)	F_4 (2010-11)	-0.95	-0.05	0.22	-0.08	0.03	-0.13	1.72	-0.66	**0.42**	0.36	-0.16
		F_5 (2011-12)	-0.01	-0.04	0.10	0.02	-0.20	0.34	-0.06	-0.07	**-0.34**	0.04	-0.22
10	100 seed weight (g)	F_4 (2010-11)	0.17	-0.17	-0.14	0.00	0.52	0.03	-3.46	0.43	0.05	**2.89**	0.33
		F_5 (2011-12)	-0.03	-0.06	-0.01	0.01	0.01	-0.13	0.10	-0.04	0.15	**-0.09**	-0.11

DISCUSSION

In F_4 generation, Pusa Bold × Pusa Bahar was the highest yielder. However in F_5 generation Pusa Bahar × Varuna (10.25) was the highest yielder. At both genotypic and phenotypic levels seed yield per plant was positively associated with plant height, height upto first fruiting branch and siliquae per plant only in F_5 generation. This is in agreement with the findings of Vijay Kumar *et al*.[14] and Verma *et al*.[13].

In F_4 generation no such positive association of seed yield component with seed yield per plant was found. In F_5 generation although seed yield was positively associated with plant height, height upto first fruiting branch and siliquae per plant, but only direct selection through siliquae per plant would increase seed yield because both plant height and height upto first fruiting branch and siliquae per plant had low direct effect on seed yield per plant. The low direct effect of plant height and height upto first fruiting branch on seed yield was compensated by their better performance through siliquae per plant which itself was positively associated with seed yield, along with high direct effect which also exhibited high GA and h^2_b and therefore, direct selection for siliquae per plant would be most effective for improving seed yield. This is in conformation with the findings of Patel *et al.*[8], Badsra and Chaudhary[4] and Singh *et al*.[11].

The type and magnitude of association between the yield attributing traits differed from one generation to another. This shift in association from one generation to another could be attributed to difference in gene complementation of linkage blocks and an indication of unstable nature of breeding population, which is in confirmation with the findings of previous workers[1,10]. Taking into consideration the PCV, GCV, high heritability along with GA, traits can be selected for selecting suitable promising high yielding genotypes[12]. Moderate estimates of heritability for these characters indicated that environmental effect constitutes a sufficient portion of the total phenotypic variation and hence, selection for these characters is less effective. Expected GA for height up to first fruiting branch was high and this character exhibited high GCV, h^2_b, along with high GA, which indicated the predominance of additive gene effect in controlling this character. Therefore the character height up to first fruiting branch possessing high GCV, heritability, and genetic advance (as percentage of mean) could be effectively used in selection, as it has been suggested that the characters with high heritability coupled with high genetic advance would response to selection better than those with high heritability and low genetic advance.

The three traits in the present study which qualify these criteria are plant height,

height upto first fruiting branch and siliquae per plant and they can be used to select high yielding genotypes from the promising crosses under study. Based on the mean performance of the crosses under study in F_5, three of them namely Pusa Bahar × Varuna, Pusa Bold × Kranti and Pusa Barani × Pusa Jaikissan were identified as high yielding and can be used for further selection of superior high yielding genotypes of mustard.

CONCLUSIONS

The type and extent of association between different yield attributing traits were different from one generation to another for the 14 mustard crosses under study. This could be due to certain linkage blocks resulting in instability even in such advanced segregating generations of mustard when actually stability is expected, due to fixation of most of the genes. Hence care must be taken even in the advanced segregating generations so that proper selection for superior and high yielding mustard genotypes is done successfully. One way to overcome this bottleneck of linkage block is to extend the selection of genotypes to a few further generations.

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