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ASSESSMENT OF GENETIC VARIATION AMONG ADVANCED LINES OF *BRASSICA NAPUS* L.

PROCJENA GENETSKOG ODSTUPANJA MEĐU NAPREDNIM LINIJAMA *BRASSICAE NAPUS* L.

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ABSTRACT

A field experiment was conducted with 22 *Brassica napus* L. advanced lines at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka to study the genetic variation among advanced lines of *Brassica napus* L. during November 2008 to March 2009. The genotypes were significantly different for all the characters studied except for days to 80% maturity. The characters days to 80% maturity, plant height, number of primary branches per plant, number of seeds per siliqua, number of siliqua per plant and seed yield per plant showed higher influence of environment whereas, siliqua length and 1000-seed weight showed the least. Moreover, the number of primary branches per plant, number of secondary branches per plant, siliqua length, number of seeds per siliqua, number of siliqua per plant, 1000-seed weight and seed yield per plant showed moderate broad base heritability while plant height exhibited the highest heritability. The significant positive correlation with seed yield per plant was found in plant height, number of primary branches per plant and number of siliqua per plant. However, the highest significant positive correlation was found between days to 50% flowering and plant height. Path coefficient analysis showed that the plant height had maximum positive direct effect on seed yield followed by number of siliqua per plant and siliqua length. Plant height, number of primary branches per plant and number of siliqua per plant were the most important contributors to seed yield per plant which could be taken into consideration in future hybridization program.

Key words: genetic variability, *Brassica napus*, correlation coefficient, path coefficient

SAŽETAK

Od studenog 2008. do ožujka 2009. obavljeni su poljski pokusi s 22 napredne linije *Brassicae napus* L. na pokusnoj farmi Sher-e-Bangla Poljoprivrednog fakulteta u Dhaki, radi istraživanja genetskog odstupanja među naprednim linijama *Brassicae napus* L. Genetski su se značajno razlikovale u svim istraživanim značajkama osim dana do 80% zrelosti. Značajke dana do 80% zrelosti, visina biljke, broj primarnih grančica po biljci, broj sjemenki po komušci, broj komušaka po biljci i prinos sjemena po biljci pokazale su veći utjecaj okoline dok su duljina komuške i težina 1000-sjemenki pokazali najmanji. Osim toga, broj primarnih grančica po biljci, broj sekundarnih grančica po biljci, duljina komuške, broj sjemenki po komušci, broj komušaka po biljci, težina 1000-sjemenki i prinos sjemena po biljci pokazali su umjereno široku osnovnu nasljednost, dok je visina biljke pokazala najveću nasljednost. Značajna pozitivna korelacija s prinosom sjemena po biljci nađena je u visini biljke, broju primarnih grančica po biljci i broju komušaka po biljci. Međutim, najviša značajna pozitivna korelacija nađena je između dana do 50% cvjetanja i visine biljke. Analiza koeficijenta kretanja pokazala je da je visina biljke maksimalno pozitivno direktno djelovala na prinos sjemena i zatim na broj komušaka po biljci i duljinu komušaka. Visina biljke, broj primarnih grančica po biljci i broj komušaka po biljci bili su najvažniji pomagači za prinos sjemena po biljci, što treba uzeti u obzir u budućem programu hibridizacije.

Ključne riječi: genetsko odstupanje, *Brassica napus* L., koeficijent korelacije, koeficijent kretanja

INTRODUCTION

Brassica napus L. is the most important oilseed crop in Bangladesh and about 240000 ha of land was under rapeseed cultivation during 2009 which produced about 220000 tons of rapeseed and the average yield was 0.9166 ton/ha (Anonymous, 2010). It is ranked as the third most important oilseed crop after soybean and palm. Mustard and rapeseed seeds contain 42% oil, 25% protein (Khaleque, 1985). The oil is mainly used as edible product. Oil and fat are not only the source of energy (9-k.cal.g $^{-1}$) but also contain fat-soluble vitamins A, D, E and K. According to Mondal *et al.*, 2001, oil crops produce 0.16 million tons of edible oil every year as against the total requirements of 0.5

million tons for a population of 130 million in Bangladesh. The shortage of edible oil has become a chronic problem for the nation. To fulfill the requirement, the country has to import edible oils at the cost of huge amount of foreign exchange. In general, the *B. napus* varieties have high seed and oil productivity with bold seeds. They are more tolerant against *Alternaria* leaf blight and aphid attack than the varieties of *B. campestries* and *B. juncea*. High yield potential of *B. napus* is mainly due to elongate flower raceme with moderate number of large siliqua accommodating a greater number of bold seeds and also due to a higher number of plants that can be accommodated per unit area. The major activities of plant breeding are building up a gene pool of variable germplasm, selection of individual from the gene pool and utilization of selected individual to evolve a superior variety (Kempthorne, 1957). The knowledge of genetic variability present in the population, heritability of economically important characters and correlation coefficients of those characters is very important before launching an effective breeding program. If a plant breeding program is to advance most rapidly and efficiently, knowledge of the phenotypic and particularly of the genotypic interrelationships among and between yield contributing characters is necessary. Thus determination of correlation between the characters are a matter of considerable importance in selection practices since it helps in the construction of selection indices and also permit the prediction of correlated response. Following correlation analysis, the path coefficient analysis would provide a true picture of genetic association between different traits (Bhatt, 1973). Path coefficient analysis specifies the cause and effect and measures their relative importance. Therefore, correlation in combination with the path coefficient analysis quantifies the direct and indirect contribution of one character upon another (Dewey and Lu, 1959).

MATERIAL AND METHODS

The seeds of the experimental material were collected from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University (SAU) and three released varieties collected from Bangladesh Agricultural Research Institute (BARI). The experiment was laid out in Randomized Complete Block Design (RCBD). The field was divided into three blocks; the blocks were sub-divided into 22 plots where genotypes were randomly assigned. The plot size was 3m lengths with 2 rows where row to row and plant to plant distances were

25cm and 15cm, respectively. Seeds were sown in lines in the experimental plots on 12 November, 2008. Adequate soil fertility was censured by applying of Urea, TSP, MP, Gypsum and Borax @ 250-170-85-150-5 kg/ha, respectively. Urea was applied by two installments. Total amount of TSP, MP, gypsum and borax along with half of the urea were applied at the time of final land preparation as a basal dose during final land preparation. The second half of the urea was top-dressed at the time of flower initiation. Standard Intercultural operations (such as weeding, thinning, irrigation, pest management, etc.) were done uniformly in all the plots to ensure proper growth condition for the crop. Harvesting was started from February 20, 2009 depending upon the maturity. Observations were recorded on 10 randomly chosen plants from each plot. Data were collected on days to 50% flowering, days to 80% maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, siliqua length (cm), number of siliqua per plant, number of seeds per siliqua, 1000 seeds weight (g) and seed yield per plant (g). Data were subjected to analysis and genotypic and phenotypic coefficient of variations; heritability and genetic advance were estimated as per Singh and Chowdhury (1986) and Johnson *et al.* (1955). Genotypic and phenotypic correlation coefficients were calculated as according to Miller *et al.* (1958) and path coefficient analysis was done according to method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSIONS

Genetic variability

Days to 50% flowering

Significant differences were observed among the genotypes for days to 50 flowering which ranged from 36.00 days (Nap 2012) to 42.67 days (Nap 9908) whereas mean performance was 37.94 days (Table 1 and Figure 1). The estimated phenotypic and genotypic variances were 2.56 and 3.64, respectively. The phenotypic coefficient of variation (PCV) (5.03%) and genotypic coefficient of variation (GCV) (4.23%) were close to each other indicating less influence of environmental factors on expression of this character. Therefore, selection based upon phenotypic expression of this character would be effective

Table 1. Range, mean, mean sum of square and genotypic, phenotypic and environmental variances for 10 yield and its component characters in *Brassica napus* L.

Tablica 1. Raspon, srednja vrijednost, srednja vrijednost zbroja kvadrata i genotipske, fenotipske i okolišne varijance za 10 značajki prinosa i njegovih komponenata u *Brassica napus* L.

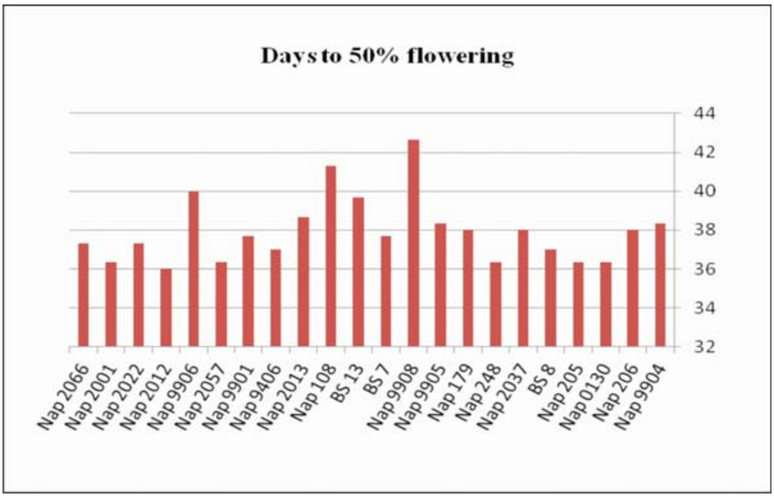
Characters Značajke	Range Raspon	Mean Srednja vrijednost	Mean Sum of Square (MS) Srednji zbroj kvadrata	Genotypic Variance (σ^2_g) Genotipska varijanca	Phenotypic Variance (σ^2_p) Fenotipska varijanca
Days to 50% flowering Dani do 50% cvjetanja	36.00-42.67	37.94	8.75**	2.56	3.64
Days to 80% maturity Dani do 80% zrelosti	99.67-106.00	102.92	7.12	0.98	5.22
Plant height (cm) Visina biljke	78.90-107.00	92.83	107.00**	53.80	71.41
Number of primary branches per plant Broj primarnih grančica po biljci	2.90-6.50	4.68	2.94**	0.62	1.7
Number of secondary branches per plant Broj sekundarnih gračica po biljci	7.30-22.10	13.97	45.35**	12.44	20.47
Siliquae length (cm) Duljina komuške	6.81-9.12	7.36	0.82**	0.22	0.38
Number of seeds per siliqua Broj sjemenki po komušci	16.68-29	23.39	58.19**	13.57	31.04
Number of siliqua per plant Broj komušaka po biljci	170.90-285.93	222.83	2576.58**	679.65	1217.28
1000-seed weight (g) Težina 1000 sjemenki	2.94-4.83	3.79	1.25**	0.34	0.57
Seed yield per plant (g) Prinos sjemena po biljci	2.68-10.98	6.46	9.73**	2.61	4.51

** Significant at 1% level of probability
** Značajno na 1% vjerojatnosti

for the improvement of this crop. Heritability estimates for this trait were high (70.33) with low genetic advance (2.77) and also low genetic advance in percentage of mean (7.30) (Table 3). Lekh *et al*. (1998) mentioned the high genotypic and phenotypic coefficient of variation for days to 50% flowering.

Figure 1. Mean performance of days to 50% flowering

Grafikon 1. Dani do 50% cvjetanja



Days to 80% maturity

The analysis of variance (ANOVA) showed that there were no significant differences among the genotypes for days to 80% maturity (Table 1). The highest and lowest values for this trait were observed in Nap 2037 (99.67 days) and Nap 108, (106 days), respectively. The mean for this trait was 102.92 days. This trait showed higher estimates of phenotypic coefficient of variation (5.22%) than the corresponding genotypic coefficient of variation (0.98%). The higher differences between PCV and GCV suggested that the expression of this character was mostly under the control of environment. The low heritability (18.69%) with low genetic advance (0.88) was found for days to 80% maturity indicating that selection based on phenotype for this character would not be effective.

Plant height

The maximum plant height was found in Nap 9908 (107.00 cm) and the minimum in Nap 2022 (78.9 cm) and the mean value was 92.83 cm (Table 1). The phenotypic variance (71.41) appeared to be higher than the genotypic variance (53.80), suggesting considerable influence of environment on the expression of the genes controlling this trait. High heritability (75.34%) with high genetic advance in percent age of mean (13.12) for this trait might be taken into consideration while selecting a suitable line (Table 2). Yadava, 1973 also found high heritability for plant height among the nine characters studied in 29 varieties. Katiyar *et al.* (1974) reported high heritability and genetic advance value for plant height.

Number of primary branches per plant

The highly significant differences were observed among the genotypes for number of primary branches per plant. The highest number of primary branches per plant was observed in Nap 206 (6.50) and the lowest in Nap 9905 (2.90) whereas the mean value was 4.68. The phenotypic variance (1.7) and phenotypic coefficient of variation (27.86) were much higher than the corresponding genotypic variance (0.62) and genotypic coefficient of variation (16.82), respectively (Table 2). The estimate of heritability (36.47%) was low with high genetic advance in percentage of mean (20.93) indicating selection based on this trait would not be judicious. Similar results were reported by Katiyar *et al.* (1974) for number of primary branches per plant.

Number of secondary branches per plant

Significant differences among the genotypes were observed for number of secondary branches per plant. The maximum number of secondary branches per plant was found in BS8 (22.10) and the minimum in Nap 9906 (7.30) and mean value was 13.97 (Figure 2). The least difference between phenotypic coefficient of variation (20.47) and genotypic coefficient of variation (12.44) indicates the genetic control of this trait (Table 2). The high heritability (60.77%) along with high genetic advance in percentage of mean (40.54) was found for this trait

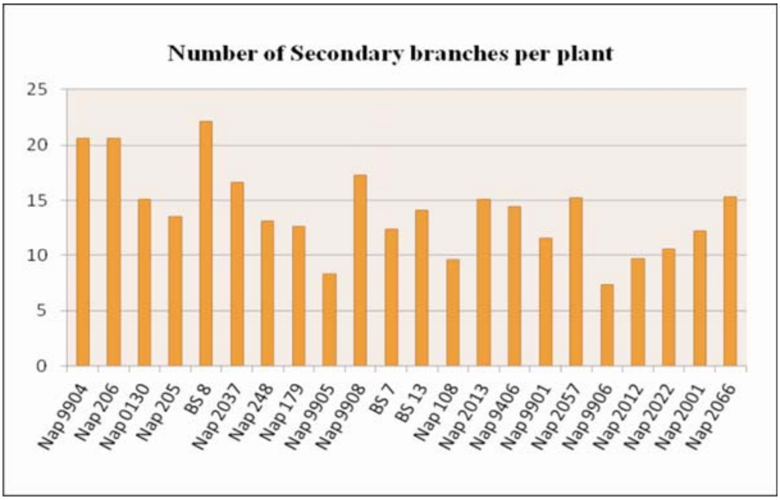
Table 2. Genotypic, phenotypic and environmental coefficient of variation, heritability, genetic advance and genetic advance in percentage of mean for 10 yield and its component characters in *Brassica napus* L.
Tablica 2. Genotipski, fenotipski i okolišni koeficijent varijance, nasljednost, genetski napredak i genetski napredak u postotku srednje vrijednosti za 10 značajki prinosa i njegovih komponenata kod *Brassica napus* L.

Characters Značajke	Genotypic Coefficient of Variation (GCV) Genotipski koeficijent varijace	Phenotypic Coefficient of Variation (PCV) Fenotipski koeficijent varijace	Broad Base Heritability (h^2_b) Nasljednost široke osnove	Genetic Advance (5%) Genetski napredak	Genetic Advance in % mean (5%) Genetski napredak	CV (%)
Days to 50% flowering Dani do 50% cvjetanja	4.23	5.03	70.33	2.77	7.30	2.74
Days to 80% maturity Dani do 80% zrelosti	0.96	2.22	18.69	0.88	0.85	2.00
Plant height (cm) Visina biljke	7.90	9.10	75.34	13.12	14.13	4.52
Number of primary branches per plant Broj primarnih grančica po biljci	16.82	27.86	36.47	0.98	20.93	22.17
Number of secondary branches per plant Broj sekundarnih grančica po biljci	25.25	32.39	60.77	5.66	40.54	20.29
Siliquae length (cm) Duljina komuške	6.38	8.36	58.27	0.74	10.04	5.40
Number of seeds per siliqua Broj sjemenki po komušci	15.75	23.82	43.72	5.02	21.45	17.86
Number of siliqua per plant Broj komušaka po biljci	11.70	15.66	55.83	40.13	18.01	10.41
1000-seed weight (g) Težina 1000 sjemenki	15.38	19.93	59.52	0.93	24.44	12.68
Seed yield per plant (g) Prinos sjemena po biljci	25.01	32.87	57.87	2.53	33.19	16.90

suggesting that there was a good scope for the phenotypic selection for this trait; this is in agreement with Choudhary *et al.,* 2003. Lekh *et al*. (1998) reported the highest genotypic coefficient of variation for the number of secondary branches per plant.

Figure 2. Mean performance of no. of secondary branches/plant

Grafikon 2. Broj sekundarnih grančica po biljci



Siliquae length (cm)

The genotypes varied significantly for siliqua length and ranged from 6.81 cm (Nap 2057) to 9.12 cm (Nap 9904) with a mean value of 7.36 cm. The phenotypic coefficient of variation (8.36) and genotypic coefficient of variation (6.38) were close to each other which indicated less environmental influence on this character. The estimated heritability (58.27%) was moderate with moderate genetic advance in percent age of mean (10.04) (Table 2) indicating that the character was mostly governed by additive genes. Therefore, selection based on siliqua length would be suitable for future breeding program.

Number of seeds per siliqua

The variance due to number of seeds per siliqua showed that the genotypes differed significantly. The number of seeds per siliqua ranged from 16.68 (Nap2037) to 29.00 (Nap 9904) with a mean value of 23.39 (Figure 3). The phenotypic variance (31.04) and phenotypic coefficient of variation (23.82) were much higher than their corresponding genotypic variance (13.57) and genotypic coefficient variance (15.75), indicating that the phenotypic expression of this trait is highly governed by the environment. The moderate heritability (43.72%) was very high with considerable genetic advance in percentage of mean (21.45) suggesting this trait provided a better opportunity for selecting high valued genotype for breeding program. Singh (1986) found a high heritability and genetic advance in the number of seeds per siliqua.

Figure 3. Mean performance of no. of siliqua/plant

Grafikon 3. Broj sjemenki po komušci

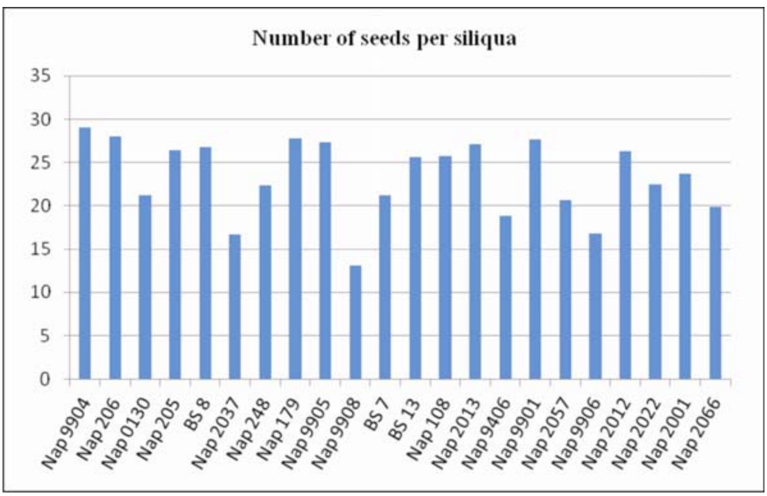


Table 3. Genotypic (G) and phenotypic (P) correlation coefficients among different pairs of morphological characters of different advanced lines of *Brassica napus* L.

Tablica 3. Genotipski i fenotipski koeficijenti korelacije među različitim parovima morfoloških značajki različitih naprednih linija *Brassicae napus* L.

Characters		DM	PH	NPB	NSB	SL	NSS	NSP	TSW	SYP
DFF	G	0.261	0.734**	0.080	-0.045	0.006	-0.250	0.475*	0.591**	-0.186
	P	0.132	0.648**	0.032	-0.052	0.010	-0.267	0.399	0.496*	-0.159
DM	G		0.139	-0.988**	-0.611**	-0.074	0.038	-0.437*	0.470*	0.129
	P		0.056	-0.424*	-0.626**	-0.001	0.046	-0.253	0.180	0.049
PH	G			0.467*	0.021	-0.013	-0.038	0.628**	0.301	0.463*
	P			0.371	0.016	-0.040	-0.030	0.601**	0.314	0.389
NPB	G				0.489*	0.517*	0.415	0.571**	0.024	0.645**
	P				0.451*	0.303	0.313	0.492*	0.023	0.413*
NSB	G					0.323	0.085	0.302	0.134	0.206
	P					0.183	0.064	0.349	0.076	0.185
SL	G						0.722**	-0.013	-0.257	0.342
	P						0.541**	-0.027	-0.187	0.291
NSS	G							-0.240	-0.541**	0.266
	P							-0.179	-0.438*	0.216
NSP	G								0.172	0.610**
	P								0.180	0.489*
TSW	G									-0.147
	P									-0.095

*Significant at 5% and ** Significant at 1% level of probability
DFF = Days to 50% flowering, DM = Days to 80% maturity, PH = Plant height (cm), NPB = Number of primary branches per plant, NSB = Number of secondary branches per plant, NSP = Number of siliqua per plant, SL = Siliqua length (cm), NSS = Number of seed per siliqua, TSW = 1000-seed weight and SYP = Seed yield per plant.

Number of siliqua per plant

Number of siliqua per plan showed significant differences among the genotypes. The maximum and minimum number of siliqua per plant was observed in genotypes Nap 206 (285.93) and Nap 9905 (170.90), respectively. The phenotype (1217.28) was much higher than the genotype (679.65) but phenotypic coefficient of variation (15.66) and genotypic coefficient of variation (11.70) were close to each other. Heritability was moderate (55.83%) with a high genetic advance (40.13). Besides GA percentage over mean (42.55%) was also high (Table 3). High heritability and high genetic advance indicated that selection based on this character would be judicious. Mahmood *et al.* (2003) reported that a number of siliqua per plant was highly heritable coupled with high genetic advance. Akbar *et al.* (2007) also found higher GCV, broad base heritability and genetic advance for this trait.

Number of seeds per siliqua

The variance due to number of seeds per siliqua showed that the genotypes differed significantly. The number of seeds per siliqua ranged from 16.68 (Nap2037) to 29.00 (Nap 9904) with a mean value of 23.39. The phenotypic variance (31.04) and phenotypic coefficient of variation (23.82) were much higher than their corresponding genotypic variance (13.57) and genotypic coefficient variance (15.75), indicating that the phenotypic expression of this trait is highly governed by the environment. The moderate heritability (43.72%) was very high with considerable genetic advance in percentage of mean (21.45) suggesting this trait provided a better opportunity for selecting high valued genotype for breeding program. Singh (1986) found a high heritability and genetic advance in the number of seeds per siliqua.

1000-seed weight (g)

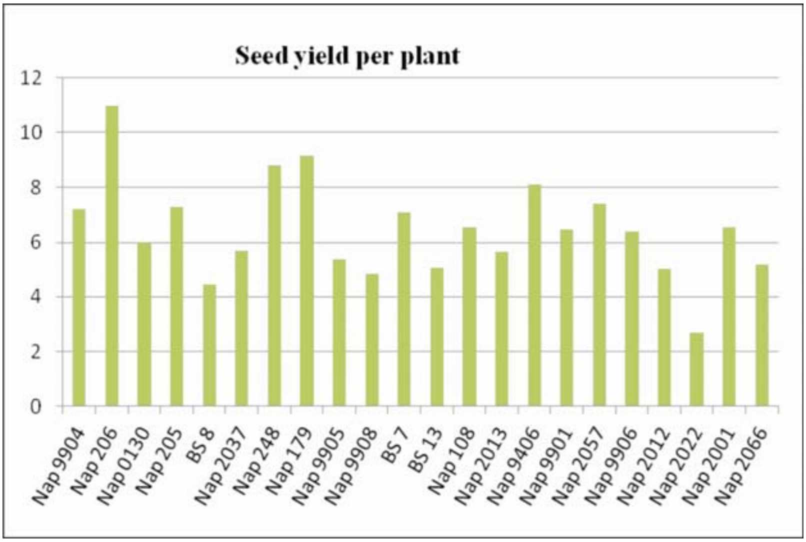
Significant differences were observed among the genotypes for 1000-seed weight which ranged from 2.94 g (Nap 205) to 4.83 g (Nap 9906) with a mean value of 3.79 g (Appendix I). The phenotypic (0.57) and genotypic (0.34) variances were very close to each other indicated less environmental influences on this trait. The phenotype coefficient of variation (19.93) and genotypic coefficient of variation (15.38) were also very close to each other (Table 2). The high heritability (59.52%) along with considerable genetic advance in percentage of mean (24.44) provided opportunity for selecting high valued genotypes for this trait. Singh (1986) and Singh *et al.* (2002) reported the high heritability and genetic advance 1000 in seed weight.

Seed yield per plant (g)

Seed yield per plant showed a highly significant mean sum of squares due to different genotypes that suggested considerable range of variation for this trait (Figure 4). The seed yield per plant ranged from 2.68 g (Nap 2022) to 10.98 g (Nap 206) with a mean value of 6.46 g. The phenotypic variance (4.51) and the genotypic variance (2.61) were close to each other. The phenotypic coefficient of variation (32.87) and genotypic coefficient of variation (25.01) were also very close to each other indicating less environmental influence on this trait governed by the additional gene action. The estimated heritability was moderate (57.87%) with a high genetic advance in percentage of mean (33.19) indicating that phenotypic selection for seed yield per plant would be effective. Katiyar *et al.* (1974), Singh (1986) and Aytaç and Kinaci (2009) mentioned the high heritability and genetic advance for seed yield. The analysis of variances showed significant mean squares for different characters indicated the presence of sufficient variation among the genotypes for all the characters except days to 80% maturity. The number of siliqua per plant showed highest range of variation (170.90-285.93) that means a wide range of variation present for this character. This character also showed the highest mean value (222.83). However, the phenotypic variance and phenotype coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient variation for all the characters under study. In case of days to 80% maturity, plant height, number of primary branches per plant, number of seeds per siliqua, number of siliqua per plant and seed yield per plant showed higher influence of environment for the expression of these characters. On the other hand, siliqua length and 1000-seed weight showed least difference in phenotypic and genotypic variance suggesting additional gene action for the expression of the characters. The plant height (75.34) exhibited the highest value of heritability while days to 80% maturity (18.69). Furthermore, the number of primary branches per plant, number of secondary branches per plant, siliqua length, number of seeds per siliqua, number of siliqua per plant, 1000-seed weight and seed yield per plant showed moderate broad base heritability.

Figure 4. Mean performance of seed yield/plant

Grafikon 4. Prinos sjemena po biljci



CORRELATION COEFFICIENT

Yield is a complex product being influenced by several inter-dependable quantitative characters. Thus selection for yield may not be effective unless the other yield components influencing it directly or indirectly are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. The results of correlation coefficient are presented in Table 3.

Days to 50% flowering

Days to 50% flowering showed significant positive association with plant height (G = 0.734, P = 0.648) and 1000-seed weight (G = 0.591, P = 0.496) at both genotypic and phenotypic level (Table 4). Similar results were reported by Shivahare *et al*., 1975 and Ali *et al.,* 2003. This character also showed positive association with days to maturity (G = 0.26, P = 0.132), number of primary branches per plant (G = 0.080, P = 0.032), siliquae length (G = 0.006, P = 0.010), and number of siliqua per plant (G = 0.475, P = 0.399) showed significant positive correlation at genotypic level but insignificant at phenotypic level. It had negative insignificant correlation with number of secondary branches per plant (G = -0.045, P =-0.052), number of seeds per siliquae (G =-0.250, P = -0.267) and seed yield per plant (G = -0.186, P =-0.159) at both genotypic and phenotypic level. These results suggested that if days to 50% flowering increased, then plant height also increased. Similar relation was found in case of days to maturity and 1000-seed weight, number of siliqua per plant, siliquae length. On the other hand, if days to 50% flowering increased, then number of secondary branches per plant, number of seeds per siliqua and seed yield per plant decreased. Similar result was found by Ghosh and Gulati (2001).

Days to 80% maturity

Days to maturity showed non-significant positive correlation with plant height (G = 0.139, P = 0.056), number of seeds per siliqua (G = 0.038, P = 0.046), 1000-seed weight (G = 0.470, P = 0.180) and seed yield per plant (G = 0.129, P = 0.049). This trait had significant negative correlation with number of primary branches per plant (G = -0.988, P = -0.424) and number of secondary branches per plant (G = -0.611, P = -0.626) at both genotypic and phenotypic level. It also had negative insignificant correlation with number of siliqua per plant (G = -0.437, P = -0.253) at both genotypic and phenotypic level. This indicated that if days to maturity increased then number of primary branches per plant and number of secondary branches per plant decreased. This trait had non-significant positive correlation with seed yield (G = 0.129, P = 0.049). This is in agreement with Malek *et al.,* 2000.

Plant height

Plant height showed highly significant positive correlation with number of siliqua per plant (G = 0.628, P = 0.601) at both genotypic and phenotypic level indicating yield could be improved by increasing plant height. This character also showed significant positive correlation with number of primary branches per plant (G = 0.467, P = 0.371) and seed yield per plant (G =0.463, P = 0.389) at genotypic level but positive insignificant correlation at phenotypic level. It had insignificant positive correlation with number of secondary branches per plant (G = 0.021, P = 0.016) and 1000-seed weight (G = 0.301, P = 0.314) at both levels. This trait also showed negative insignificant correlation with siliqua length (G = -0.013, P = -0.040) and number of seeds per siliquae (G = -0.038, P = -0.030) at the both level. This indicated that if plant height increased then number of siliqua per plant also increased. Similar result was reported by Srivastava *et al.* (1983). Significant positive correlation between plant height and seed yield per plant was found by Khan and Khan (2003). Chaudhury *et al*. (1990) found positive correlation of plant height with number of seeds per siliqua and number of siliqua per plant. Basalma (2008) reported opposite result for this trait.

Number of primary branches per plant

Number of primary branches per plant showed significant positive correlation with number of secondary branches per plant (G = 0.489, P = 0.451), number of siliqua per plant (G = 0.571, P = 0.492) and seed yield per plant (G = 0.645, P = 0.413) at both genotypic and phenotypic level but in case of siliqua length (G = 0.517, P = 0.303) significant positive correlation at genotypic level and insignificant at phenotypic level. Insignificant positive correlation was found with number of seeds per siliqua (G = 0.415, P = 0.313) and 1000-seed weight (G = 0.024, P = 0.023). This trait did not have a negative correlation with other traits. These suggesting if number of primary branches increases then yield per plant also increases. Malik *et al.* (2000) reported similar result for number of primary branches and seed yield both at genotypic and phenotypic level.

Number of secondary branches per plant

Number of secondary branches per plant showed insignificant positive correlation with siliqua length (G = 0.323, P = 0.183), number of seeds per siliqua (G = 0.085, P = 0.064), number of siliqua per plant (G = 0.302, P = 0.349), 1000-seed weight (G = 0.134, P = 0.076) and seed yield per plant (G = 0.206, P = 0.185). This indicated that branching was an important contributor to yield, independent of its association with plant size. This trait had no negative correlation with other traits. Similar results were found by Thurling and Das, (1980) for number of secondary branches with seed yield.

Siliqua length (cm)

Siliquae length showed highly significant positive correlation with number of seeds per siliqua (G = 0.722, P = 0.541) at both the genotypic and phenotypic level. It had significant positive correlation with seed yield per plant (G = 0.342, P = 0.291) at both genotypic and phenotypic level. It also had non-significant negative correlation with number of siliqua per plant (G = -0.013, P = -0.027) and 1000-seed weight (G = -0.257, P =-0.187). Labana *et al.* (1980) reported opposite result for siliquae length and plant height.

Number of seeds per siliqua

Number of seeds per siliqua showed significant negative correlation with 1000-seed weight (G = -0.541, P = -0.438) at both the genotypic and phenotypic level. It also had negative insignificant correlation with number of siliqua per plant (G = -0.240, P = -0.179) at both levels. Besides these, it had in significant positive correlation with seed yield per plant (G = 0.266, P = 0.216). Akbar *et al.* (2007) found that siliquae per plant had highly significant positive correlation with seed yield. Malek *et al.* (2000) reported similar results for number of siliqua per plant with number of seeds per siliquae.

Number of siliqua per plant

Number of siliqua per plant showed significant positive correlation with seed yield per plant (G = 0.610, P =0.489) at both genotypic and phenotypic level. It also had non-significant positive correlation with 1000-seed weight (G = 0.172, P = 0.180). Malik *et al.* (2000) reported positive correlation between siliqua per plant and seed yield per plant.

1000-seed weight (g)

Thousand seed weight showed in-significant negative correlation with seed yield per plant (G = -0.147, P = -0.095) at both genotypic and phenotypic level. Tuncturk and Ciftci (2007) reported positive correlation between seed yield with 1000-seed weight which does not support the present findings.

Seed yield per plant (g)

Seed yield per plant had highest significant positive correlation with number of primary branches per plant (G = 0.645, P = 0.413) followed by number of siliqua per plant (G = 0.610, P = 0.489) at both genotypic and phenotypic level suggesting, if the number of primary branches per plant number of siliqua per plant also increase then seed yield per plant also increase. Yield per plant also had insignificant positive correlation with days to maturity (G = 0.129, P = 0.049), number of secondary branches per plant (G = 0.206, P = 0.185), siliqua length (G = 0.342, P = 0.291) and number of seeds per siliqua (G = 0.266, P = 0.216) at both genotypic and phenotypic level and plant height (G = 0.463, P = 0.389) had significant positive correlation at genotypic level but negative insignificant at phenotypic level. This trait also had negative insignificant correlation with days to 50% flowering (G = -0.186, P = -0.159) and 1000-seed weight (G = -0.147, P = -0.095) at both genotypic and phenotypic level. Kumar *et al.* (1999) reported seed yield had positive correlation with plant height, number of siliqua per plant and 1000 seed weight. Jeromel *et al.* (2007) found complete positive correlation between plant height and yield.

PATH COEFFICIENT

The direct and indirect effects of yield contributing characters on seed yield were worked out by using path analysis. Here seed yield per plant was considered as effect (dependent variable) and days to 50% flowering, days to 80% maturity, plant height, siliqua length, number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua, number of siliqua per plant and 1000-seed weight were treated as causes or independent variables as given in Table 4.

Days to 50% flowering

Days to 50% flowering had negative direct effect on seed yield per plant (-2.011) at genotypic level; it also had negative correlation with seed yield per plant (-0.186). Days to 50% flowering contributed indirectly through days to 80% maturity (0.097), plant height (0.892), number of secondary branches per

Table 4. Partitioning of genotypic correlation coefficients into direct (bold faced) and indirect effects by path analysis in *Brassica napus* L.
Tablica 4. Podjela genotipskih koeficijenata korelacije na direktno i indirektno djelovanje analize kretanja kod *Brassicae napus* L.

Characters	DFF	DM	PH	NPB	NSB	SL	NSS	NSP	TSW	SYP (r_g)
DFF	**-2.011**	0.097	0.892	-0.026	0.009	0.005	0.044	0.520	0.284	-0.186
DM	-0.525	**0.373**	0.169	0.321	0.117	-0.066	-0.007	-0.479	0.226	0.129
PH	-1.476	0.053	**1.215**	-0.152	-0.004	-0.012	0.007	0.688	0.144	0.463*
NPB	-0.161	-0.369	0.568	**-0.324**	-0.093	0.460	-0.073	0.625	0.012	0.645**
NSB	0.090	-0.228	0.026	-0.159	**-0.191**	0.288	-0.015	0.331	0.064	0.206
SL	-0.012	-0.028	-0.016	-0.168	-0.062	**0.891**	-0.126	-0.014	-0.123	0.342
NSS	0.503	0.014	-0.046	-0.135	-0.016	0.643	**-0.174**	-0.263	-0.260	0.266
NSP	-0.955	-0.163	0.763	-0.185	-0.058	-0.012	0.042	**1.095**	0.083	0.610**
TSW	-1.188	0.175	0.366	-0.008	-0.026	-0.228	0.094	0.188	**0.480**	-0.147

Residual effect is the square root of: 0.350
DFF = Days to 50% flowering, DM = Days to 80% maturity, PH = Plant height (cm), NPB = Number of primary branches per plant, NSB = Number of secondary branches per plant, SL = Siliquae length (cm), NSS = Number of seed per siliqua, NSP = Number of siliqua per plant, TSW = 1000-seed weight and SYP = Seed yield per plant.

plant (0.009), siliqua length (0.005), number of seeds per siliqua (0.044), number of siliqua per plant (0.520) and 1000-seed weight (0.044) (Table 4). The highest indirect positive effect was found via plant height followed by number of siliqua per plant. This trait also had negative indirect effect via number of primary branches per plant (-0.026).

Days to 80% maturity

Days to 80% maturity had positive direct effect on seed yield per plant (0.373) and it also had positive correlation with seed yield per plant (0.129). Days to 80% maturity had positive direct effect on seed yield through plant height (0.169), number of primary branches per plant (0.321), number of secondary branches per plant (0.117) and 1000-sed weight (0.226). This trait also had negative indirect effect on seed yield via days to 50% flowering (-0.525), Siliquae length (-0.066) and number of seeds per siliquae (-0.007) at genotypic level.

Plant height

Plant height had direct positive effect (1.215) on seed yield per plant. It had positive indirect effect on seed yield via days to maturity (0.053), number of seeds per siliquae (0.007), number of siliqua per plant (0.688) and 1000-seed weight per plant (0.144). Aytac *et al*. (2008) reported plant height showed a considerable direct positive effect on seed yield per plant. It had negative indirect effect via days to 50% flowering (-1.476), number of primary branches per plant (-0.152), number of secondary branches per plant (-0.004) and siliqua length (-0.012). Plant height finally made significant positive correlation with seed yield (0.463). These results indicated if plant height increased then seed yield also increased mostly through the direct positive effect of plant height and positive indirect effect of other characters. Han (1990) and Singh (2004) also reported direct positive result for this character.

Number of primary branches per plant

Number of primary branches per plant had negative direct effect (-0.324) on seed yield per plant and also positive highly significant correlation with seed yield per plant at genotypic level (0.495). Mahak *et al.* (2003) and Singh *et al.* (2001) reported that number of primary branches per plant had direct positive effect on seed yield. So, selection for this trait will be judicious and more effective in future breeding program. It had positive indirect effects via plant height (0.568), siliquae length (0.460), number of siliquae per plant (0.625) and 1000-seed weight (0.012). It had negative indirect effects via days to 50% flowering (-0.161), days to 80% maturity (-0.369), number of primary branches per plant (-0.324), number of secondary branches per plant (-0.093) and number of seeds per siliqua (-0.073).

Number of secondary branches per plant

Number of secondary branch per plant showed negative direct effect (-0.191) on seed yield per plant. It had indirect positive effect via days to 50% flowering (0.090), plant height (0.026), siliqua length (0.288), number of siliqua per plant (0.331) and 1000-seed weight (0.064) on seed yield per plant. It had indirect negative effect via days to 80% maturity (-0.228), number of primary branches per plant (-0.159) and number of seeds per siliqua (-0.015). The genotypic correlation with seed yield was positive mainly due to negative direct effect of number of secondary branches per plant plus positive indirect effect of other characters.

Siliqua length (cm)

Siliqua length had positive direct effect (0.891) on seed yield per plant. The negative indirect effect via number of primary branches per plant (-0.168) followed by number of seeds per siliqua (-0.126) and 1000-seed weight (-0.123). The genotypic correlation with seed yield was positive (0.342). Hence, selection should be practiced for this trait which had longer siliqua in order to improve seed yield.

Number of seeds per siliqua

Number of seeds per siliqua had negative direct effect (-0.174) on seed yield per plant. The positive indirect effect was observed via days to 50% flowering (0.503), days to 80% maturity (0.014) and siliqua length (0.643). The direct effect was negative and the total effect was positive. The negative direct effect was mainly counter balanced by indirect positive effect of different characters. This indicated that selection for greater number of seeds per siliqua would give better response in the improvement of seed yield per plant. Singh *et al.* (2001) found that number of seeds per siliqua had direct positive effects on seed yield.

Number of siliquae per plant

Number of siliquae per plant had positive direct effect (1.095) on seed yield per plant and positive indirect effect via plant height (0.763), number of seeds per siliqua (0.042) and 1000-seed weight (0.083). Akbar *et al.* (2007) reported siliqua per plant had maximum direct contribution for improving seed yield. It also showed negative indirect effect through days to 50% flowering (-0.955), days to 80% maturity (-0.163), number of primary branches per plant (-0.185), number of secondary branches per plant (-0.058) and siliqua length (-0.012). The genotypic correlation of number of siliqua per plant with seed yield per plant was positive and considerably higher in magnitude. It is mainly due to high positive direct effect and positive indirect effects of other characters. Therefore, selection would be effective for this trait. The opposite result was found by Han (1990) whereas Khulbe and Pant (1999) reported this character as selection criterion for yield improvement.

1000-seed weight (g)

The direct effect of 1000-seed weight (0.480) on seed yield per plant was positive. The character showed high negative indirect effect via days to 50% flowering (-1.188) followed by siliqua length (0.228) on seed yield per plant. It also had high positive indirect effect via plant height (0.366) followed by number of siliqua per plant (0.1880 and days to 80% maturity (0.175). The genotypic correlation was negative (-0.147). Singh *et al.* (2001) found that 1000-seed weight had direct positive effects on seed yield.

CONCLUSIONS

The genotypic residual effect was 0.350, which indicated that there were other responsible traits for contribution to seed yield per plant that were not taken into consideration in the present study. The path coefficient studies indicated that plant height, number of primary branches per plant and number of siliqua per plant were the most important contributors to seed yield per plant which could be taken into consideration in future hybridization programs.

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