Journal of Applied Horticulture, 15(3): 211-214, 2013

Genetic variability and trait association in sprouting broccoli (*Brassica oleracea* var. *italica* Plenck) under temperate Kashmir valley conditions

K. Habib, N. Ahmad[1], P.A. Sofi[2]*, S.H. Khan and T. Shafi

Division of Vegetable Sciences, SKUAST-K, Shalimar, 191121, J&K. [1]Central Institute of Temperate Horticulture, Old Airport Road, Srinagar, J&K. [2]Regional Research Station, SKUAST-K, Wadura Sopore, 193201, J&K, India
**E-mail: parvazesofi@gmail.com*

Abstract

Ten diverse broccoli genotypes selected from germplasm collection maintained at SKUAST-K, Shalimar were crossed in all possible combinations excluding reciprocals. Forty five F_1 crosses (excluding reciprocals) were generated through a 10 x 10 diallel mating design. Each genotype was represented by two rows of ten plants each at spacing 60 x 45 cm in a Randomized Block Design with 3 replications in Rabi 2008 and 2009. Data was recorded on five randomly selected competitive plants from each replication for 16 metric traits. Phenotypic and genotypic coefficient of variation was moderate to high in lateral head yield, lateral head number, main head yield and total carotenoids and low for days to central head harvest, days to central head initiation, plant height and plant spread. Broad sense heritability was comparatively moderate to higher in plant height, head length, days to central head initiation, lateral head yield, main head yield,. total head yield and total carotenoids content but low for ascorbic acid content, plant spread and dry matter content. Genetic advance was high ($\geq$ 20.%) for lateral head yield and total carotenoids content while it was low (<5%) for ascorbic acid, peduncle length and dry matter content. Among various traits, the plant spread, head diameter, leaf number, leaf area, lateral head number, main head yield and lateral head yield possessed positive correlation with total yield at genotypic level while plant height, head length, ascorbic acid and total carotenoids had negative correlation with total yield at genotypic level. However, main head yield, lateral head yield, head diameter and lateral head number had highly significant positive correlation with total head yield.

Key words: Broccoli, genetic variability, genetic advance, diallel

Introduction

Sprouting broccoli (*Brassica oleracea* var. *italica* Plenck.) is one of the most important members of cole group belonging to family Brassicaceae. Broccoli is native of Italy, introduced to United States of America around 1925 by Italian immigrants. The name broccoli has been derived from the word "Brachium" meaning an arm or branch (Chaudhary, 1970). It is also known as Italian asparagus, sprout cauliflower and little sprouts. Broccoli is the most nutritious member of the cole group and contains many vitamins, iron and calcium. It is recommended for consumption as a measure to decrease the incidence of human cancer. Different types of broccoli's are available but green types are more popular. It is marketed as fresh, frozen and also used in salads (Pierce, 1987). It contains 3.3 percent protein along with appreciable quantities of thiamine, niacin and riboflavin and is recognized as excellent source of dietary carotenoids, which are reported to confer health-promoting effects on humans when consumed in the diet and is known to protect humans against certain specific chronic ailments including cancer, cardiovascular diseases, and age-related sight degeneration. Besides, it is also rich source of sulphorophane, a compound known to have anticancer properties.

USA is the largest producer of broccoli in the world followed by Italy, Northern Europe and cooler regions of Far East. In India, broccoli was hardly regarded as commercial crop till recently and that is why no authentic statistics pertaining its area and production is available. But now, the crop is becoming increasingly popular in cosmopolitan cities of India due to its rich nutritive value and versatile use. It is mostly cultivated in the hills of Himachal Pradesh, Uttarakhand, Nilgiri Hills and Northern Plains of India. In Kashmir, broccoli is a new introduction and is becoming popular among the growers because of its nutritional importance and export market demand. Till recently, only few varieties like Green Head were in cultivation which are low yielding and lack single compact head and produces multiple sprouts which is not suitable for export market. The farmers are demanding for high yielding compact single head varieties and hybrids rich in phytomins and minerals. Therefore, the expansion of broccoli production as a profitable crop in Kashmir region lies in giving more emphasis on identification and development of high yielding genotypes and hybrids with wide adaptation to the local production conditions.

Breeding approach for evolving high yielding and stable genotypes requires a detailed investigation on the genetic make-up of all the quantitative characters contributing to yield under specific agro-ecological conditions. For efficient utilization of available genetic variability, crop specific information on variability components such as PCV, GCV, heritability and genetic advance is important. Information on genetic variability coupled with the trait association is imperative to devise an efficient breeding strategy for utilization of available genetic variability. Sufficient variability has been reported for morphological and economic traits in broccoli that could be potentially used for seeking improvement in these traits

(Cervenski *et al.,* 2007). The present study was undertaken with an objective of elucidating the genetic architecture of economic traits in broccoli using a diallel mating design.

Materials and methods

Ten diverse broccoli genotypes selected from the germplasm collections maintained at Division of Vegetable Sciences, SKUAST-K, Shalimar were crossed in all possible combinations excluding reciprocals at Vegetable Research Farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar. Forty five F_1 crosses (excluding reciprocals) were generated through a 10 x 10 diallel mating design as per Method II and Model I of Griffing (1956). The parents along with their derived hybrids were evaluated in Rabi 2008 and 2009. Recommended agronomic practices were followed to ensure a good crop for optimal expression of traits in parents as well as crosses. Each genotype was represented by two rows of ten plants each at spacing 60 x 45 cm in a Randomized Block Design with 3 replications. Data was recorded on five randomly selected competitive plants from each replication for 16 traits namely: plant height (cm), plant spread (cm), days to central head initiation, days to central head harvesting, leaf number, leaf area (cm^2), central head diameter (cm), central head length (cm), number of lateral heads, peduncle length (cm), central head yield (g), yield of lateral heads (g), total head yield (g), dry matter content (%), total ascorbic acid (mg/100g) and total carotenoids (mg/100g). Analysis of variance for all the characters pooled over environments was carried out as per Verma *et al.* (1987) based on the following model:

$$Y_{ijk} = \mu + G_i + E_j + (G \times E)_{ij} + e_{ijk}$$

Where,

Y_{ijk} = mean of ith progeny in kth replicate of jth environment,

μ = general mean,

G_i = effect of ith genotype,

E_j = effect of jth environment,

$(G \times E)_{ij}$ = interaction, between ith progeny and jth environment,

e_{ijk} = residual error

Results

Analysis of variance for the traits studied, presented in the Tables 1 and 2, revealed the presence of significant variability in the material including both parents and crosses as depicted by significant mean squares due to genotypes, lines and crosses except for dry matter content where mean squares due to crosses and G x E was non-significant. The mean squares due to environment (years) was significant for all the traits except dry matter content indicating significant effect of environment on the expression of these traits.

The data pertaining to various variability parameters *viz.,* range, phenotypic and genotypic coefficient of variation (PCV and GCV), heritability (broad sense) and genetic advance (percent of mean) are presented in Table 3 and 4. The range was found higher for lateral head yield, lateral head number, main head yield, total head yield and leaf area than other parameters. The magnitude of variability for the traits revealed presence of substantial genetic variability in the genotypes studied. Phenotypic and genotypic coefficient of variation was moderate to high in lateral head yield, lateral head number, main head yield and total carotenoids. For days to central head harvest, days to central head initiation, plant height and plant spread, the PCV and GCV was low. GCV was generally lower than PCV for all the characters. Broad sense heritability was comparatively moderate to higher in plant height, head length, days to central head initiation, lateral head yield, main head yield, total head yield and total carotenoids content. It was comparatively low for ascorbic acid content, plant spread and dry matter content. Genetic advance calculated as percent of mean

Table 1. Pooled analysis of variance for plant height (cm), plant spread (cm), days to central head initiation, days to central head harvesting, peduncle length (cm), head diameter (cm), head length (cm) and leaf number

Source of variation	d.f	Plant height	Plant spread	Days to central head initiation	Days to central head harvest	Peduncle length	Head diameter	Head length	Leaf number
Environments	1	0.46**	2.30**	0.93**	0.71**	26.63**	11.21**	15.75**	19.84**
Replications	2	-	-	-	-	-	-	-	-
Replications within Environment	2	1.25	2.93	3.05	2.50	3.15	1.16	1.60	0.43
Genotypes	54	61.33**	100.20**	56.20**	60.87**	6.17**	10.89**	9.51**	32.02**
Parents	9	89.73**	101.23**	59.43**	82.98**	48.60**	10.28*	29.04**	23.58**
Crosses	44	16.19**	43.08**	22.28**	50.91**	32.38**	15.75*	20.87**	13.21*
Genotypes x Environments	54	2.98**	3.54**	4.94**	48.10**	0.13	0.75	4.60**	1.92*
Pooled error	216	0.42	1.41	0.75	0.62	1.47	0.22	0.54	0.59

*, ** Significant at 5 and 1 per cent levels, respectively

Table 2. Pooled analysis of variance for leaf area (cm^2), number of lateral heads, main head yield (g), lateral head yield (g), total head yield (g), dry matter content (%), total ascorbic acid (mg/100g) and total carotenoids (mg/100g)

Source of variation	d.f	Leaf area	Lateral head number	Main head yield	Lateral head yield	Total head yield	Dry matter content	Ascorbic acid	Total carotenoides
Environments	1	12.29**	3.98**	3.92**	9.64*	562.90**	1.00	10.10*	92.87**
Replications	2	-	-	-	-	-	-	-	-
Replications within Environment	2	0.20	3.36	1.67	1.71	6.04	0.74	1.20	0.96
Genotypes	54	114.02**	337.50**	14.03**	61.98**	214.6**	40.20**	12.16**	30.39**
Parents	9	139.48**	109.29**	82.40**	39.62**	436.90**	5.02*	39.41**	13.24**
Crosses	44	230.01**	80.39**	59.30**	28.48**	968.83**	1.92	25.69**	16.89**
Genotypes x Environments	54	36.28**	33.01**	9.63**	8.02**	29.64**	0.31	12.16**	1.68
Pooled error	216	1.35	0.56	1.09	0.44	0.81	0.96	0.43	1.36

*, ** Significant at 5 and 1 per cent levels, respectively

Table 3. Mean, range, coefficient of variation, heritability and genetic advance for yield and yield components in broccoli (pooled over environments)

Estimates	Plant height	Plant spread	Days to central head initiation	Days to central head harvest	Peduncle length	Head diameter	Head length	Leaf number
Mean	52.51 ±1.77	47.04 ±2.96	52.59 ±1.58	82.76 ±2.98	5.61 ±0.28	12.11 ±0.85	16.17 ±0.60	24.59 ±1.40
Range	47.64-60.97	39.77-54.94	45.04-57.46	68.90-89.37	4.84-6.45	9.59-14.37	14.48-20.04	20.76-28.50
GCV	5.93	6.03	5.24	3.80	4.29	8.71	6.89	7.31
PCV	7.94	12.69	7.58	8.85	10.56	15.34	9.37	11.87
h^2	55.80	22.60	47.70	18.40	16.50	32.30	54.10	37.90
Genetic advance (% of mean)	8.93	5.87	7.68	3.41	3.57	9.74	10.02	9.15

Table 4. Mean, range, coefficient of variation, heritability and genetic advance for yield and yield components in broccoli (pooled over environments)

Estimates	Leaf area	Lateral head number	Main head yield	Lateral head yield	Total head yield	Dry matter content	Ascorbic acid	Total carotenoids
Mean	345.94 ±29.49	9.81 ±0.33	344.65 ±25.11	122.07 ±17.45	466.72 ±32.88	12.75 ±0.77	80.82 ±2.72	43.09 ±2.19
Range	232.12-414.88	5.29-14.28	227.01-413.28	53.02-202.67	367.50-612.20	10.30-14.50	77.27-84.95	31.49-54.42
GCV	9.46	14.37	11.67	22.33	10.27	3.55	10.66	13.89
PCV	17.22	26.73	17.75	32.52	16.25	10.72	16.31	19.68
h^2	30.20	28.90	43.20	47.2	40.00	11.00	21.00	49.90
Genetic advance (% of mean)	10.60	15.49	15.35	30.68	13.00	2.51	0.84	20.47

was high ($\geq$ 20.%) for lateral head yield and total carotenoids content while it was low (<5%) for ascorbic acid, peduncle length and dry matter content. For plant height, plant spread, days to central head initiation, days to central head harvest, head diameter, head length, leaf number, leaf area, lateral head number and main head yield, it was 8.93, 5.87, 7.68, 3.41, 9.74, 10.02, 9.15, 10.60, 15.49 and 15.35, respectively.

Correlation coefficients of various characters with total head yield of broccoli are presented in the Table 5. Among various traits, the plant spread, head diameter, leaf number, leaf area, lateral head number, main head yield and lateral head yield possessed positive correlation with total yield at genotypic level while plant height, head length, ascorbic acid and total carotenoids had negative correlation with total yield at genotypic level. However among the traits, the main head yield, lateral head yield, head diameter and lateral head number had highly significant positive correlation with total head yield, than other traits.

Table 5. Genotypic correlation of different parameters with total head yield

Traits	R value
Plant height	-0.02
Plant spread	0.15**
Days to central head initiation	-0.03
Days to central head harvest	-0.17**
Head diameter	0.61**
Head length	-0.36**
Leaf number	0.06**
Leaf area	0.05**
Lateral head number	0.18**
Main head yield	0.86**
Lateral head yield	0.58**
Dry matter content	-0.07**
Ascorbic acid	-0.26**
Total carotenoids	-0.11**

*, ** Significant at 5 and 1 per cent levels, respectively

Discussion

In the present study, analysis of variance revealed presence of significant variability among the parents and the crosses for all the characters in both individual environments, indicating that the material selected were divergent and also resulted in creation of substantial genetic variability. The interaction resulting from genotype x environment was also significant for most of the traits. This indicated differential response of genotypes to changing environment. Since, the nature of genetic variability determines the most effective selection procedure to accumulate superior alleles in a cultivar, therefore, unbiased estimate of genetic components of variance is of primary concern to a breeder. The main aim of estimating the magnitude of variability was to partition the total variation into components attributable to different causes, because relative magnitude of the components determines the genetic composition of populations. The selection potential of any breeding material depends upon the amount of heritable variability present in it. The genetic gain depends on the magnitude of differences among genotypic values of individuals in the parent material. Heritability (broad sense) is a good measure to estimate the magnitude of genotypic variability. Burton (1952) reported that genotypic coefficient of variation together with heritability would give the best picture of the progress expected from selection, and it serves as a useful guide in understanding the proportion of total variation due to genotype.

The parameters of variability *viz*., mean, range, phenotypic and genotypic coefficients of variation, broad sense heritability and genetic gain revealed that the parents and their F_1's exhibited wide variability for most of the traits. The range was found moderate to high for characters like leaf area, main head yield, lateral head yield and total head yield. Similarly moderate to high coefficient of variation and heritability was observed for characters like lateral head yield, lateral head number, main head yield, total head yield, leaf area and total carotenoids. The moderate to high coefficient of variability and heritability for these traits indicated scope for making selection and realizing high genetic gain. This was evident as genetic gain for these above traits was moderate to high ranging from 10.60 to 30.68 percent. For rest of the characters the coefficient of variation and heritability in broad sense were low resulting in low expected genetic advance. Similar results were also reported by Sandhu and Singh (1977), Sun *et al.* (1995) and Rai and Singh (2000) in cauliflower, Chinese cabbage and cabbage, respectively for yield and yield attributing traits and Diksha and Awasti (2008) for total carotenoids in broccoli. For traits like plant height, days to central head initiation and head length although the heritability was high but the genetic advance was low owing to low coefficient of variation.

Knowledge of nature and magnitude of genetic association among components of economic worth can help in improving the efficiency of selection by making possible use of suitable combination of characters. The correlations mostly occur because of pleiotropic effects and/or linkages between the traits. In crop improvement, breeding value correlations are more useful, especially for indirect selection. Indirect selection can be advantageous over direct selection when the correlation between two traits is very high (Falconer, 1960). Compensation between yield components may lead to variation in correlation pattern and, therefore, he stressed the need for continual investigation of inter-relationship between yield components. Johnson *et al.* (1955) emphasized the importance of genotype–environment interaction and their contribution to genetic slippage in the selection of complex characters. Thus, studies under different environments might give a clear and reliable picture of association, which can effectively be utilized for selecting yield components. The correlated changes in yield and yield components may at times lead to physiologically efficient genotypes for expression of yield. In presence of substantial breeding value correlation between two traits, selection in one trait will cause a change in its mean through additive effects of genes of selected individuals and simultaneously cause an indirect change in the mean of the other traits.

Grafius (1964) pointed out that "there is no way in which yield can be changed without changing one or more of the yield components" and "while all changes in the yield must be accompanied by changes in one or more of the components, all changes in the components, need not be expressed in changes in yield". This is due to varying degree of positive and negative correlation between yield and its components on the one hand and within the components on the other, such that any gains that are made through selection in favour of one component may be offset by a relative reduction in other component (s). Thus, the knowledge of magnitude of genetic variability existing in the materials, type of gene action governing yield and its components and clear understanding of the related genetic parameters are essential for successful exploitation of existing genetic variability and formulation of efficient breeding strategies.

In the present study, the genotypic correlation between all the traits with total head yield was found positive except plant height, days to central head initiation, days to central head harvest, head length, ascorbic acid content, dry matter content and total carotenoids content where negative correlation was found. Pandey *et al.* (1986) found positive correlation between number of leaves and with net curd weight while Boos and Artemeva (1984) after making interline hybrids of white cabbage found a high negative correlation between earliness and yield as observed in the present study. Significant positive correlation of main head yield, lateral head yield, lateral head number and head diameter with total head yield indicate that selection for any or all the above yield contributing traits is expected to bring indirect improvement in yield of broccoli. However the quality attributed like dry matter content, ascorbic acid content, total carotenoids and maturity traits having significant negative correlation, shall have reverse impact on total head yield.

References

Boos, G.V. and Artemeva, A.M. 1984. Combining ability of varieties and lines of white cabbage. *Sbornik. Nauchnykh Trudov Prikladnoi Botanike Genetike-i-Selektsii.*, 86: 44-51.

Burton, G.W. 1952. Breeding methods for pearl millet (*Pennisetum glaucum*) indicated by genetic variance component studies. *Agronomy Journal,* 51: 479-481.

Cervenski, J., D. Gvozdenovic, D. Bugarski and M. Vasic, 2007. Combining abilities for head height and head width in cabbage (*Brassica oleracea* var. *capitata* L.). *Acta Hort.,* 729: 67-71.

Choudhary, B.1970. *Vegetables.* 2nd revised edition, National Book Trust, New Delhi. Pp.78-79.

Diksha, D. and C.P. Awasthi, 2003. Quality components in broccoli heads harvested at different stages of maturity. *Indian Journal Agricultural Biochemistry*, 22(1): 5-9.

Falconer, D.S. 1960. *An Introduction to Quantitative Genetics*. The Ronald Press. 384 pp.

Grafius, T.J. 1964. A geometry of plant breeding. *Crop Sci*., 4: 241-246.

Griffing, B. 1956. A generalized treatment of the use of diallel cross in quantitative inheritance. *Heredity,* 10: 31-50.

Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimation of genetic and environmental variability in soybeans. *Agronomy J*., 47: 314-318.

Pandey, B.C., S.N. Singh and G. Patil, 1986. Heterosis in cauliflower. *Indian Journal Agricultural Sciences,* 79(2): 102-105.

Peirce, L.C. 1987. *Vegetables: Characteristics Production and Marketing*, John Willey and Sons, New York. Pp. 217-219.

Rai, N. and A.K. Singh, 2000. Genetic variability, heritability and genetic advance studies in cabbage. *Journal Applied Biology,* 10(1): 8-11,

Sandhu, J.S. and A.K. Singh, 1977. Inheritance of maturity period and curd weight in cauliflower (*Brassica oleracea* var. *botrytis* L.). *Haryana Journal Horticultural Sciences,* 6(3-4): 161-165.

Sun, R.F., X. Niu and D. Zhu, 1995. Inheritance of head weight and other agronomic characters in Chinese cabbage (*Brassica campestris* ssp. *pekinensis*). International symposium on cultivar improvement of horticultural crops. Part I: vegetable crops, held at Beijing, China on September 6-10-1993. *Acta Hort.,* 402: 445-450.

Verma, M.M., K.S. Gill and D.S. Virk, 1987. Genotype-environment interaction, its measurement and significance in plant breeding communication centre. Punjab Agriculture University, Ludinana.

Received: July, 2013; Revised: September, 2013; Accepted: October, 2013