The Bioscan 11(1): 569-572, 2016 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

VARIABILITY STUDIES IN SPROUTING BROCCOLI HYBRIDS (*BRASSICA OLERACEA* L. VAR. *ITALICA* PLENCK) UNDER MID HILLS OF NORTH-WESTREN HIMALAYAS

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KEYWORDS
Genetic advance
Genetic diversity
Genetic variability
Heritability
Sprouting broccoli

Received on :
15.09.2015

Accepted on :
11.02.2016

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ABSTRACT

Significant differences were observed among genotypes in sprouting broccoli suggesting sufficient genetic variability for yield and other yield related characters. The highest estimates of phenotypic coefficient of variation and genotypic coefficient of variation were observed for number of spears per plant (42.85 % and 83.93 %) followed by weight of spears per plant (40.46 % and 35.31 %) and terminal head weight per pant (33.60 % and 31.96 %). High heritability coupled with high genetic advance was observed for characters viz., terminal head weight per plant (90.46 % and 62. 61 %), marketable yield per plant (89.44 % and 56.51 %), number of spears per plant (82.56% and 72.86 %), harvest index (77.03 % and 35.35 %) and weight of spears per plant (76.17 % and 63.50 %). These high estimates suggest substantial variability for the characters thereby ensuring ample scope for improvement of these characters through direct selection. On the basis of genetic divergence, sixteen genotypes were grouped into three clusters. Altar and Indica were found to be the most diverse genotypes and offer promise as a breeding stock to be used in hybridization for obtaining transgressive segregants for further exploitation in broccoli improvement programme.

INTRODUCTION

Broccoli (*Brassica oleracea* L. var. *italica* Plenck) a member of family Brassicacea is one of the nutritious cole crop. It is known for its taste, flavor, nutritive and medicinal properties (Tiwari, 2010). Broccoli and other cole crop like cauliflower contain the compound namely, glucoraphanin, which can be processed into an anti-cancer compound sulphoraphane (Aires *et al*., 2006 and Kushwaha *et al*., 2013). Broccoli is a cool season vegetable and its off season cultivation fetches lucrative remuneration to the growers during summer season in hills when it cannot be grown in plains due to prevailing high temperature. These days broccoli is highly preferred on an account of its nutrition and the crop is being sold at higher prices in comparison to other cole crops *viz.,* cabbage, cauliflower, knol-khol, kale and brussel sprouts. Furthermore, hill farmers with small land holdings are benefited with sprouting type of broccoli as two to three harvestings can be taken.The improvement in any crop is proportional to the magnitude of the genetic variability present in the germplasm (Dhankar and Dhankar, 2002 and Yadav *et al*., 2014). Information on the extent of genetic variability available for yield and its component characters along with heritability and genetic advance would be of immense importance to the breeders as the success of selection of any crop improvement programme is determined by these specific genetic parameters. D^2 analysis will help the breeders in grouping of genotypes in different clusters and to identify genotypically diverse and desirable genotypes. High yield, earliness, compact and medium size head with maximum number of lateral heads (spears) are the main criteria which are being taken into consideration for genetic improvement of broccoli. Hence, an attempt was made with specific objectives to examine the genetic parameters of variability to identify major characters for achieving higher yield.

MATERIALS AND METHODS

The present investigation was conducted at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK HPKV, Palampur, in two environments viz., environment I (*Rabi*, 2010-2011) and environment II (*Rabi*, 2011-2012). The experimental material comprised of 16 genotypes of sprouting broccoli. There were 16 plants in each plot having 4.5 m^2 area planted at 60 cm distance between and 45 cm with in row in a Randomized Complete Block Design, with three replications. Observation were recorded on five randomly selected competitive plants per replication for fourteen characters viz., days to first harvest, marketable yield per plant, terminal head weight per plant, gross weight per plant, number of spears per plant, head size index, plant frame, leaf size with leaf stalk, leaf size without leaf stalk, plant height up to longest leaf, plant height up to head, stalk length, weight of spears per plant and harvest index. The data regarding above mentioned characters were averaged and subjected to analysis of variance (Panse and Sukhatme, 1985). The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were calculated as per Burton and De Vane (1953). Heritability (broad sense) and genetic advance as per cent of mean were computed by following the methods of Burton and De Vane (1953) and Johnson *et al*. (1955), respectively. To determine the genetic diversity Mahalonobis' D^2 analysis was done and genotypes were grouped in various clusters following Tocher's method as suggested by Rao (1952).

RESULTS AND DISCUSSION

Analysis of variance indicated significant differences among all the genotypes for all characters in environment I and environment II (Table 1). This indicates sufficient genetic variability in the genetic stock under study. Pooled analysis of variance over the environment revealed the presence of g×e interactions for characters namely, days to first harvest, number of spears per plant, leaf size without leaf stalk, weight of spears per and harvest index (Table 2).The presence of g×e interactions has greatly influenced the variation due to genotypes to the extent that genotypic differences recorded in individual environment have vanished for these characters.

The knowledge of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) is helpful in predicting the amount of variation present in the given genetic stock which in turn helps in formulating an efficient breeding programme. The high estimates of phenotypic and genotypic coefficients of variation were observed for number of spears per plant followed by weight of spears per plant and terminal head weight per pant. Similar findings were also reported by Kalia and Shakuntla (2002). Marketable yield per plant recorded higher magnitude of phenotypic coefficient of variation. These high estimates suggest substantial variability for the characters thereby ensuring ample scope for improvement of these characters through selection.

Moderate PCV and GCV were recorded for leaf size without leaf stalk, harvest index, head size index, leaf size with leaf stalk, plant frame, gross weight per plant and plant height up to head. These moderate estimates suggested that direct selection for these characters should be considered cautiously, whereas days to first harvest showed low PCV and GCV suggesting thereby that the genotypes possessed less variability for this character. Similar findings were also reported by Kalia and Shakuntla (2002).

The information on heritability estimates is helpful in studying the inheritance of quantitative characters as well as for planning breeding programmes (Ulaganathan and Nirmalakumari, 2014). High heritability was noticed for terminal head weight per plant followed by marketable yield per plant, number of spears per plant, harvest index, weight of spears per plants, days to first harvest, leaf size with leaf stalk, stalk length and gross weight per plant. These findings are in agreement with Kalia and Shakuntla (2002), Khattra *et al*.,(1997), Kanwar and Korla (2002) and Jindal and Thakur (2004).

High heritability for these characters indicate that large proportion of phenotypic variance is attributed to genotypic variance and therefore, reliable selection could be made for these characters on the basis of phenotypic expression. Moderate heritability was shown by plant frame, plant height

Table 1 : Analysis of variance for different characters of broccoli in environment I (2010-11) and environment II (2011-12)

Sr. No.	Characters	Source	Mean Sum of Squares					
			Replication		Genotypes		Error	
			Environment I	Environment II	Environment I	Environment II	Environment I	Environment II
		d.f.	2		15		30	
1	Days to first harvest		27.9	299.01	158.80*	425.29*	13.23	26.88
2	Marketable yield/plant (g)		159.39	914.02	28177.00*	24685.72*	874.41	1016.73
3	Terminal head weight/plant (g)		370.08	820.89	31661.15*	24453.78*	704.17	941.22
4	Gross weight/plant (g)		10368.75	62659.39	38818.88*	66957.72*	7075.97	9876.19
5	Number of spears/plant		0.23	0.7	14.88*	13.59*	0.28	0.38
6	Head size index (cm^2)		1291.72	2069	3502.73*	3874.38*	908.68	1041.42
7	Plant frame (cm^2)		18396.72	2550174	950545.94*	1002219.17*	213727.3	216443.1
8	Leaf size with leaf stalk (cm^2)		985.86	8621.71	37588.85*	29117.77*	2969.44	4596.57
9	Leaf size without leaf stalk (cm^2)		293.9	15917.26	8535.83*	28594.18*	1340.35	1966.1
10	Plant height up to longest leaf (cm)		78.28	599.99	39.84*	52.70*	11.93	14.43
11	Plant height up to head (cm)		12.41	32.63	46.66*	41.75*	8.69	15.92
12	Stalk length (cm)		0.03	0.02	0.20*	0.15*	0.02	0.02
13	Weight of spears/plant (g)		347.41	260.94	4889.01*	4382.15*	200.34	271.55
14	Harvest index (%)		7.39	16.09	206.65*	123.44*	13.57	11.34

*Significant at $p \leq 0.05$

Table 2: Analysis of variance for different characters of broccoli in pooled over the environments

Sr. No.	Characters	Mean Sum of Squares Source	Genotypes	Environments	Genotype × (g×e) Environment	Pooled error
		d.f.	15	1	15	60
1	Days to first harvest		494.95*	743.70*	89.15*	20.05
2	Marketable yield/plant (g)		51660.71*	1971.09	1202.02	945.57
3	Terminal head weight/plant (g)		54682.17*	1759.59	1432.77	822.7
4	Gross weight/plant (g)		94587.86*	240500.26*	11188.74	8476.08
5	Number of spears/plant		25.48*	7.36	3.00*	0.33
6	Head size index (cm^2)		6085.89*	590.19	1291.18	975.05
7	Plant frame (cm^2)		1709313.49*	1847728.22*	243451.6	215085.2
8	Leaf size with leaf stalk(cm^2)		60778.59*	154496.50*	5928.03	3783
9	Leaf size without leaf stalk(cm^2)		22846.53	59946.51	14283.49*	1653.22
10	Plant height up to longest leaf (cm)		74.11*	537.65*	18.43	13.18
11	Plant height up to head (cm)		74.74*	484.38*	13.67	12.95
12	Stalk length (cm)		0.31	0.006	0.37	6.02
13	Weight of spears/plant (g)		8186.72*	6147.20*	1084.43*	235.94
14	Harvest index (%)		308.84*	106.70*	23.25*	12.46

*Significant at $p \leq 0.05$

Table 3: Estimates of different parameters of variability for various characters of broccoli

Sr. No.	Characters	Range	Mean	PCV (%)	GCV (%)	ECV (%)	h^2_{bs} (%)	GA (%)
1	Days to first harvest	93.46-129.00	109.32	9.62	8.01	5.32	69.4	13.76
2	Marketable yield/plant (g)	140.66-541.33	316.76	30.67	29.01	9.96	89.44	56.51
3	Terminal head weight/plant (g)	99.00-525.50	296.11	33.6	31.96	10.38	90.46	62.61
4	Gross weight/plant (g)	680.66-1121.16	858.05	17.23	13.49	10.73	61.26	21.75
5	Number of spears/plant	1.41-9.96	5.2	42.85	38.93	17.89	82.56	72.86
6	Head size index (cm^2)	131.17-257.38	225.56	19.22	12.85	14.28	44.76	17.72
7	Plant frame (cm^2)	2777.66-4837.22	3820.28	17.92	13.03	12.29	52.92	19.53
8	Leaf size with leaf stalk (cm^2)	476.67-798.39	624.19	18.71	15.55	10.39	69.12	26.64
9	Leaf size without leaf stalk (cm^2)	297.10-449.83	367.04	22.67	14.81	17.16	42.67	19.93
10	Plant height up to longest leaf (cm)	44.23-53.61	49.18	10	6.42	7.67	41.22	8.49
11	Plant height up to head (cm)	27.36-42.96	31.56	15.17	10.19	11.24	45.15	14.11
12	Stalk length (cm)	2.10-3.21	2.49	10.89	8.86	6.34	66.11	14.84
13	Weight of spears/plant (g)	20.83-156.66	101.96	40.46	35.31	19.75	76.17	63.5
14	Harvest index (%)	19.54-49.23	35.59	22.41	19.67	10.74	77.03	35.35

Table 4: Clustering pattern of 16 genotypes of broccoli

Cluster Number	Number of genotypes	Genotypes
I	14	Packman, PalamHaritika, CBH-1, BR-60, PalamSamridhi, Pluto, Supreme, BR-70, Green Magic, Kendi, Fiesta, Lucky, Tiltest, Green Beauty
II	1	Altar
III	1	Indica

up to head, head size index, leaf size without leaf stalk and plant height up to longest leaf. The genetic advance expressed as per cent of mean varied from 8.49% to 72.86% for plant height up to longest leaf and number of spears per plant, respectively.

High estimates of genetic advance were observed for number of spears per plant, weight of spears per plant, terminal head weight per plant, marketable yield per plant and harvest index. Moderate genetic advance was recorded by leaf size with leaf stalk, gross weight per plant, leaf size without leaf stalk, plant frame, head size index, stalk length, plant height up to head and days to first harvest, whereas expected genetic advance was found to be low for plant height up to longest leaf.

The estimates of heritability act as a predictive instrument in exercising the reliability of phenotypic values. Therefore, it helps the breeders to make selection for a particular character when heritability is high. The genetic advance is a useful indicator of the progress that can be expected as a result of exercising selection on the pertinent population. Heritability along with genetic advance is more useful than the heritability alone in predicting the resultant effect of selecting best genotype as it suggests the presence of additive gene effects. High heritability associated with high genetic advance were observed for terminal head weight per plant, marketable yield per plant, number of spears per plant, harvest index and weight of spears per plant. This view was also reported by Kalia and Shakuntla (2002). The results indicated that most likely the heritability is due to additive gene effects and direct selection could be effective for these characters. High heritability along

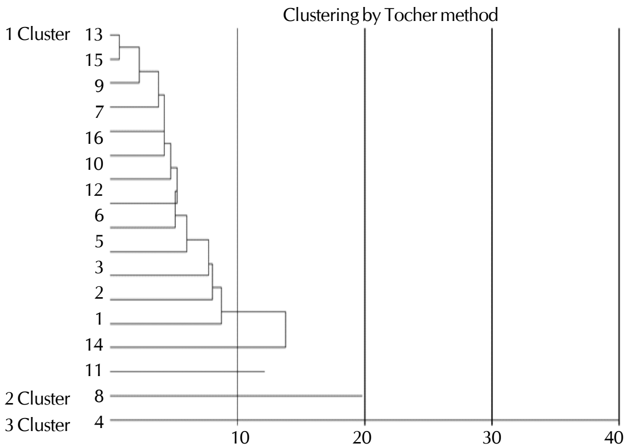

Figure 1: Dendrogram showing grouping of 16 broccoli genotypes generated using D[2] cluster analysis

with moderate genetic advance were observed for days to first harvest, stalk length and leaf size without leaf stalk. The results revealed the presence of additive and non-additive gene action, providing scope for improvement of these characters through hybridization and selection. Similar findings have also been reported by Dhatt and Garg (2008) and Kanwar and Korla (2002). In case of gross weight per plant, plant height up to head, plant frame and head size index moderate heritability was associated with moderate genetic advance. These estimates indicated the role of dominance and epistasis. Moderate heritability along with low genetic advance for plant height up to longest leaf may be attributed to non-additive gene action and epistasis.

The multivariate analysis revealed considerable genetic diversity present in all the genotypes. Sixteen genotypes of broccoli were grouped into three clusters when studied under Tocher's method of D^2 analysis (Table 4). Maximum genotypes were placed in cluster I, which comprised of 14 genotypes with 87.50% contribution and remaining two clusters namely, cluster II and cluster III were monogenotypic *i.e.* containing only one genotype. The cluster pattern revealed that the genotypes of same geographical distribution fall into different clusters which indicated that clustering pattern and geographical distribution were independent of each other. The maximum intra-cluster difference was recorded in cluster I (1.68). The maximum inter-cluster genetic divergence was recorded between cluster II and III (8.96) suggesting wide diversity among genotypes of the two clusters due to different genetic constitution. The results of cluster analysis can contribute directly for development of classification scheme and also for identification of diverse pattern of hybridization. On the basis of dendrogram (Figure 1), it is clear that the genotypes 'Altar' and 'Indica' were most diverse genotypes and offer promise as a breeding stock to be used in hybridization for obtaining transgressive segregants for further exploitation in broccoli improvement programme.

The results indicated the presence of adequate genetic variability within the germplasm evaluated for the improvement of marketable yield and other related characters. The genetic variation observed suggests that a positive response to direct selection is possible for all the characters studied. Multivariate analysis revealed considerable genetic diversity in all the sixteen genotypes studied.

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