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Genetic variability for antioxidants and horticultural traits in cabbage

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ABSTRACT

Significant differences for antioxidant content and horticultural traits among 36 diverse cabbage genotypes revealed the presence of sufficient variability which could be exploited for developing nutritionally and antioxidant rich cultivars. The phenotypic and genotypic coefficients of variation were high for carotenoids, stalk length, head compactness, gross plant weight, net head weight, dry matter, core length, plant height and equatorial diameter, and low for days to 50% maturity, number of non-wrapper leaves, frame spread and ascorbic acid. The expressions of all the studied traits except ascorbic acid, harvest index and head compactness were less influenced by environment, as evident from meagre differences between respective PCV and GCV. Moderate to high heritability was evident for all the traits and was accompanied with high genetic advance for carotenoids (138.25%), dry matter (62.74%), plant height (49.76%), gross plant weight (65.35%), net head weight (64.71%), stalk length (81.82%), core length (57.72%) and head compactness (76.0%) which show the presence of additive gene action. On the other hand, low genetic advance observed for ascorbic acid, number of non-wrapper leaves, head shape index, days to 50% maturity and harvest index reflected the predominance of non-additive gene action.

Key words: Carotenoids, ascorbic acid, dry matter, cabbage, quality breeding.

INTRODUCTION

Antioxidants are the phyto-chemicals that have the ability to protect body against oxidative stress, i.e. free radicals or reactive oxygen species (ROS) like singlet oxygen, superoxide radical, hydrogen peroxide, hydroxyl ion, and free hydroxyl radical ($^1O_2$, $^\bullet O^-_2$, H_2O_2, OH^- and $^\bullet OH$, respectively). These free radicals are invariably produced during normal metabolism and exposure to stresses. In human, un-neutralised free radicals damage various body cells causing many degenerate diseases associated with ageing, heart disease, cancer, loss of memory and paralysis (Adams and Best, 1; Peterson *et al.*, 12; Dorge, 4). Carotenoids are secondary plant compounds that form lipid soluble yellow, orange and red pigments. Lutein (an oxygenated xanthophyll) and β-carotene (a hydrocarbon carotene and precursor of vitamin-A) are two nutritionally important plant derived carotenoids (Zaripheh and Erdman Jr., 15). Diets containing carotenoid rich vegetables are associated with decreased risk of chronic diseases including cataract (Johnson *et al.*, 5). Humans have no enzymatic capability to synthesise ascorbic acid and its deficiency causes scurvy disease. Ascorbic acid is also a highly effective antioxidant and a substrate for ascorbate peroxidase as well as an enzyme cofactor for the biosynthesis of several other important biochemicals. Cole crops, in general, are good source of carotenoids and ascorbic acid (vitamin-C) which are well known antioxidants (Kurilich *et al.*, 9). Cabbage (*Brassica oleracea* var. *capitata* L.), a member of Brassicaceae family, is economically and nutritionally an important cole crop, grown in more than 90 countries across five continents of the world (Chiang *et al.*, 3). The increasing popularity of cabbage in meal and as an integral part of fast food has made it imperative to initiate efforts to improve the antioxidant concentration which are important from human health point of view along with yield of cabbage head.

The objective of the present study, therefore, was to examine the variability, transmissibility into the progeny, and extent of inheritance of antioxidant and horticultural traits among 36 available genetically diverse cultivars and germplasms of cabbage.

MATERIALS AND METHODS

The present investigation was carried out at Naggar Farm, IARI Regional Station, Katrain, Kullu Valley, Himachal Pradesh. Thirty-six diverse genotypes (Table 1) of cabbage were evaluated in a randomized block design with three replications during 2005-06 and 2006-07. The plot size was 2.7 m x 2.7 m. Row to row and plant to plant spacing was kept at 45 cm. All the recommended package of practices was followed throughout the crop growth period to have better phenotypic and morphological expression. Observations were recorded with respect to frame spread (cm), plant height (cm), gross plant weight (kg), net head weight (kg), number of non-wrapper leaves,

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Table 1. Details of cabbage genotypes.

S. No.	Genotype	Leaf colour	Leaf surface	Core length	Head shape	Maturity	S. No.	Genotype	Leaf colour	Leaf surface	Core length	Head shape	Maturity
1	CMS-GA	G	S	M	S	E	19	EC-490189	G	S	M	C	L
2	Golden Acre	G	S	L	S	E	20	C-6	G	B	M	S	E
3	83-1	G	S	S	S	L	21	C-8	G	B	M	F	E
4	83-2	G	S	L	S	M	22	Red Rock Mammoth	P	S	L	F	L
5	Pride of Asia	G	S	M	S	E	23	Sel-6	G	S	M	S	M
6	AC-204	G	S	L	S	M	24	83-5	G	S	L	S	E
7	EC-490174	G	S	L	C	L	25	KIRC-1A	G	S	S	C	M
8	Pusa Mukta	G	B	M	S	E	26	KIRC-8	G	S	L	S	E
9	C-4	G	B	L	S	E	27	KIRC-1-1	G	S	M	C	M
10	Red Cabbage	P	S	L	C	L	28	KIRC-2	G	S	M	S	M
11	C-2	G	B	L	S	L	29	KIRC-10	G	S	S	F	M
12	AC-1019	G	S	L	C	E	30	KIRC-9	G	S	L	C	L
13	EC-490192	G	S	M	S	L	31	EC-490162	G	S	M	S	M
14	MR-1	G	S	S	C	L	32	ARU Glory	G	S	L	S	L
15	AC-208	G	S	L	F	L	33	Fieldman-K	G	S	M	S	E
16	AC-1021	G	S	L	F	M	34	C-3	G	B	L	D	E
17	CMS-3	G	S	L	S	L	35	Kinner Red	P	S	L	C	M
18	Pusa Drum Head	G	S	L	F	L	36	Pride of India	G	S	M	S	E

Leaf colour: G: green P: purple
Leaf surface: B: bumpy S: smooth
Core length: S: short M: medium L: long
Head shape: S: spherical F: flat C: conical
Maturity: E: early M: mid L: late

stalk length (cm), polar diameter (cm), equatorial diameter (cm), core length (cm), harvest index (%), head shape index and head compactness on ten randomly selected plants for each genotype and replication. The head compactness was determined according to Pearson (11). Data on days to 50% maturity were, however, taken on the whole plot basis. Samples of heads of each genotype in replicated trials were taken at fresh marketable stage, frozen immediately in liquid nitrogen and stored at -80°C until estimation of carotenoid and ascorbic acid contents.

The analysis of carotenoid is based on the extraction of crude pigment mixture in lipid solvent as described by Ranganna (13). The pigment content was expressed as total carotenoids by measuring its optical density at 452 nm. Three grams of frozen sample was taken and ground with acetone in a pestle-mortar. The extract was decanted into a conical flask. The extraction was continued till the residue became colourless. All the extract were pooled and transferred into a separating funnel. Then 10 ml of petroleum ether (BP 60-80 °C) was added and stirred thoroughly. The pigments were transferred into petroleum ether phase by diluting the acetone with water containing 5% sodium sulphate to remove excess water. Finally, uniform volume was made up with petroleum ether and colour intensity was measured in a spectrophotometer using 3% acetone in petroleum ether as blank. The amount of carotenoid was calculated using the following formula and expressed as mg/ 100 g fresh weight:

$$\text{Total carotenoids (mg/ 100g)} = \frac{3.87 \times OD_{452} \times \text{Volume made up (ml)} \times 100}{\text{Weight of sample (g)} \times 1000}$$

Ascorbic acid was determined by the direct colorimetric method as mentioned by Ranganna (13).

The data were pooled and statistically calculated for analysis of variance (Panse and Sukhatme, 10), estimation of variability, heritability in broad sense and genetic advance as percentage of mean (Burton and De Vane, 2).

RESULTS AND DISCUSSION

The analysis of variance showed that the genotypes varied significantly among themselves for all the investigated antioxidants and horticultural parameters, thus indicating the presence of adequate amount of variability for to be harnessed in cabbage improvement programme. The extent of variability and inheritance pattern present in the germplasm was estimated in terms of range, phenotypic and genotypic coefficient of variation (PCV and GCV) and heritability (h^2) along with genetic advance as percentage of mean (Table 2). The carotenoid content varied greatly by 15-fold, however ascorbic acid content ranged from 25.47-57.60 mg/ 100 g fresh weight (2.3-fold). The variation for horticultural traits was minimum for days to 50% maturity (1.5-fold) and maximum for stalk length (6.8-fold). This result gets support from the finding of Joshi (6), and Thakur and Thakur (14) for horticultural traits. Kopsell *et al.* (8) found significant differences in carotenoid pigment accumulation among different species of *Brassica*, while Kurilich *et al.* (9) reported substantial variability both within and among subspecies of *Brassica* for ß-carotene and ascorbic acid content. Kobra *et al.* (7) observed 17-fold differences for ß-carotene among F_2 and F_3 family means in broccoli.

The magnitudes of PCV were slightly higher than their corresponding GCV. The lower differences between PCV and GCV for all the characters except ascorbic acid, harvest index and head compactness indicated lesser influence of the environment on the expression of these traits. The respective PCV and GCV was high for carotenoid content (68.22 & 67.66), stalk length (47.24 & 43.47), head compactness (37.94 & 33.07), gross plant weight (35.91 & 33.86), net head weight (35.77 & 33.55), dry matter (31.01 & 30.75), core length (29.70 & 28.83), plant height (25.60 & 24.87) and equatorial diameter (22.27 & 21.67), while it was low for days to 50% maturity (14.07 & 13.89), number of non-wrapper leaves (15.94 & 15.26), head shape index (16.28 & 15.16), polar diameter (18.76 & 17.76), frame spread (18.95 & 18.42), harvest index (20.90 & 15.96) and ascorbic acid content (20.87 & 16.65). The traits having high GCV possess a higher magnitude of variability and thus, present a better possibility of exploitation for improvement in cabbage through breeding approaches.

Heritable portion of variation can be deduced by computing the heritability and genetic advance as percentage of mean. High heritability (>80%) was estimated for carotenoid (98.4%), dry matter (98.4%), days to 50% maturity (97.4%), equatorial diameter (94.7%), frame spread (94.5%), plant height (94.3%), core length (94.2%), number of non-wrapper leaves (91.6%), polar diameter (89.6%), gross plant weight (88.9%), net head weight (88.0%), head shape index (86.7%) and stalk length (84.7%). A high heritability for a trait indicates that a large portion of phenotypic variance is contributed through genotypic variance and therefore, a reliable selection can be made for these traits. Moderate heritability (50-80%) was recorded for harvest index (58.3%), ascorbic acid (63.6%) and head compactness (76.0%) which indicates a considerable influence of environment on the expression of mentioned these three traits. This finding is getting support from estimates of coefficient of variation.

Table 2. Estimates of variability and heritability in cabbage genotypes.

Character	Range	Mean	GCV (%)	PCV (%)	h^2 (%)	GA as % of mean
Carotenoids (μg/ 100 g FW)	171.0-2559.7	671.30	67.66	68.22	98.4	138.25
Ascorbic acid (mg/ 100 g FW)	25.47-57.60	39.20	16.65	20.87	63.6	27.35
Days to 50% maturity	69.67-107.00	85.30	13.89	14.07	97.4	28.23
Frame spread (cm)	34.83-66.23	47.80	18.42	18.95	94.5	36.90
Plant height (cm)	12.43-31.97	18.63	24.87	25.60	94.3	49.76
Gross plant weight (kg)	0.66-2.33	1.27	33.86	35.91	88.9	65.35
Net head weight (kg)	0.28-1.26	0.68	33.55	35.77	88.0	64.71
No. of non-wrapper leaves	8.70-17.50	14.36	15.26	15.94	91.6	30.08
Stalk length (cm)	0.24-1.62	0.66	43.47	47.24	84.7	81.82
Polar diameter (cm)	8.63-16.83	11.67	17.76	18.76	89.6	34.62
Equatorial dia (cm)	7.73-21.57	12.83	21.67	22.27	94.7	43.41
Core length (cm)	2.24-7.72	4.73	28.83	29.70	94.2	57.72
Harvest index (%)	27.20-71.30	54.85	15.96	20.90	58.3	25.09
Head shape index	0.61-1.23	0.93	15.16	16.28	86.7	29.03
Head compactness	14.70-79.20	39.71	33.07	37.94	76.0	59.38
Dry matter (%)	4.17-14.47	7.89	30.75	31.01	98.4	62.74

GCV: genotypic coefficient of variation; PCV: phenotypic coefficient of variation; FW: fresh weight

h^2: heritability; GA: genetic advance

Effectiveness and potentiality of the traits under selection could be revealed by an assessment of genetic gain. Heritability values along with genetic advance as percentage of mean, together, are more useful tools for selection than either of them alone. Genetic advance as percentage of mean varied from 25.09-138.25% for harvest index and carotenoid content. It was highest for carotenoid content (138.25%) followed by stalk length (81.82%), gross plant weight (65.35%), net head weight (64.71%), dry matter (62.74%), head compactness (59.38%), core length (57.72%), plant height (49.76%) and equatorial diameter (43.41%); moderate for frame spread (36.90%) and polar diameter (34.62%); and low for number of non-wrapper leaves (30.08%), head shape index (29.03%), days to 50% maturity (28.23%), ascorbic acid content (27.35%) and harvest index (25.09%).

In the present study, high heritability accompanied with a high genetic advance for carotenoid content, dry matter, plant height, gross plant weight, net head weight, stalk length, equatorial diameter and core length clearly suggest the role of additive gene action and thus, a high genetic gain is expected from selection for these traits. Moderate heritability along with high genetic advance for head compactness suggests the involvement of both additive and non-additive gene actions. The traits, namely number of non-wrapper leaves, head shape index, days to 50% maturity, ascorbic acid and harvest index showed a low genetic advance along with moderate to high heritability and thus, reflected the regulation of the aforesaid traits through non-additive gene, which could be exploited for the development of synthetics and hybrids in cabbage.

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