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GENETIC VARIABILITY, INHERITANCE AND CORRELATION FOR MINERAL CONTENTS IN CABBAGE (*BRASSICA OLERACEA* VAR. *CAPITATA* L.)

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ABSTRACT

Brassica vegetables are important sources of dietary minerals. However, information on the inheritance and correlation for content of mineral elements such as iron, zinc, copper, manganese, potassium, and calcium in cabbage, which is essential if the quality of this vegetable is to be improved through breeding, is not available. Therefore, the experiment was set up with seventy-one cabbage genotypes including cultivars, germplasm and F_1 hybrids grown in field. Mineral composition of the genotypes tested differed highly significantly indicating the presence of adequate amount of variability. A high heritability (>80%) accompanied by high genetic advance as percentage of mean (>40%) for uptake and accumulation of Fe, Zn, Cu, Mn and Ca indicates the predominance of additive gene, which could be improved by hybridization followed by selection breeding approach. Nevertheless, heterosis breeding would be an imperative in increasing the K content in cabbage heads as indicated by non-additive gene action for K accumulation having high heritability (>80%) and low genetic advance as percentage of mean (<30%). Moreover, both additive and non-additive genes were responsible for individual head weight. A positive correlation for Fe, Zn and Mn contents with other minerals will help in simultaneous selection of mineral elements. Nevertheless, major yield contributing ‘head weight’ was negatively correlated with minerals content and emphasized the selection of smaller head size to maintain the higher minerals content in tissues of cabbage heads. Hence, assessing the heritability, inheritance and correlation for minerals would be useful in the developing mineral-rich and productive genotypes.

Key words: *Brassica*, cabbage, correlation, heritability, macronutrients, micronutrients

INTRODUCTION

Cabbage (*Brassica oleracea* var *capitata* L.) has a prime status among vegetables. It is an important cole crop grown under temperate to tropical climatic conditions throughout the globe. The vegetable *Brassicas* are consumed for their nutritional values, namely minerals, carotenoids and vitamins content (Farnham *et al*. 2000). Minerals such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), boron (B), chlorine (Cl) and sodium (Na) are elements required by living organisms, both animals and plants, to support various physio-biochemical processes. In human beings, plants and animals, Fe is incorporated into the heme complex, which mediates redox reactions and oxygen transport. Fe is also an integral part of many enzymes such as nitrogenases and hydro genases, and mediates electron transport during photosynthesis and terminal respiration, and

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reduction and assimilation of nitrate and sulphate. Zn is part of the structure of several enzymes such as carboxypeptidase, alcohol dehydrogenase and carbonic anhydrase, which also mediate leaf formation and auxin synthesis. Zn ions are now considered neurotransmitters. Its deficiency in humans causes hair loss, skin lesions, diarrhoea, loss of memory, weak eyesight, as well as taste and smell abnormalities. Cu is an integral part of cytochrome oxidase, plastocyanin, Cu/Zn-SOD (Superoxide dismutase), and many other enzymes and proteins. It also assists in carbohydrate metabolism and biological nitrogen fixation. Mn, another micronutrient, is a cofactor in many enzymes like Mn-SOD, oxydoreductases, transferases, hydrolases, lyases, isomerases, ligases, lectins, and integrins. It is also important in evolution of photosynthetic oxygen. Among the macronutrients, K ions are vital to keep cells alive through Na-K pump in human and animal systems whereas in plants K helps in maintaining the water status and turgor pressure, opening and closing of the stomata, and accumulation and translocation of carbohydrates. Ca is essential for the normal growth and maintenance of bones and teeth, and assists in the production of lymphatic fluids; while in plants, it plays an important role in maintaining cell integrity and membrane permeability.

Billions of people in developing countries suffer from micronutrient malnutrition, also known as 'hidden hunger' that is caused by insufficient availability and intake of micronutrients such as vitamin A, Zn, and Fe (Anonymous 2007). It is more conspicuous in developing and poor countries since the beginning of green revolution cropping systems, which replaced the nutritionally rich traditional crops. The consequences are affecting human health, well being, productivity, livelihood, and contributing towards stagnant national development in many developing nations including India (Welch and Graham 1999). Recent estimates indicate that nearly half of the world's population suffers from Zn deficiency (Cakmak 2007), while more than two billion people worldwide are anaemic and much of it is due to Fe deficiency (Anonymous 2001). It has been assumed that increase in yield has resulted in decrease in the content of mineral elements due to a "dilution effect" caused by both environmental and genetic factors (Jarrel and Beverly 1981, Davis *et al*. 2004, Davis 2005, White *et al*. 2009). Furthermore, the recent studies have indicated that high yielding genotypes have lower minerals content (Monasterio and Graham 2000, Davis *et al*. 2004, Garvin *et al*. 2006). In vegetables, the negative correlation between minerals content and yield was reported in broccoli (Farnham *et al*. 2000), kohlrabi, kale and savoy cabbage (Broadley *et al*. 2008). Significant variability was reported for Ca and Mg content among broccoli cultivars (Farnham *et al*. 2000), for Ca, Mg, K, Fe and Zn content among cultivars and selections of kale and collard (Kopsell *et al*. 2004), and for Fe, Zn, Cu, Mn, K and Ca content among 36 genotypes of cabbage (Singh *et al*. 2010).

To the best of our knowledge, only meagre information is available on the variability, heritability, inheritance, and correlation for minerals in field grown cabbage. Because of the increasing popularity of cabbage, health benefits of consuming mineral-rich foods and designing the nutrient management practices in crops, the objective of the present study was to examine the heritability, inheritance correlation and path coefficient for micronutrients and macronutrients in cabbage, which would ultimately be very useful in determining the breeding strategies to be followed for developing the mineral-rich and productive genotypes/cultivars.

MATERIALS AND METHODS

Seventy-one genotypes of cabbage including commercial cultivars, germplasm and F_1 hybrids (Table 1) were planted at Naggar Farm, Indian Agricultural Research Institute (IARI) Regional Station, Katrain, Kullu, Himachal Pradesh during 2006-2007. It is located at 32°12' N latitude and 77°13' E longitude with an altitude of 1690 m above the sea level. The Farm receives 1000-1100 mm rainfall and 1100-1300 mm snowfall annually. The plot size was 2.7 × 2.7 m and inter- and intra-row spacing was kept at 45 cm. Plots were replicated three times in complete randomized block design for estimation of mineral content. Crops were raised as per recommended package of practices followed for cabbage cultivation to get better phenotypic expression. One sample head of each genotype in replication was taken at fresh marketable stage. The head was chopped, mixed and 100 g of fresh tissues were kept in hot air oven at 60-65 ºC for drying. These dried samples were ground in pestle-mortar, passed through 1 mm sieve, and finally stored in airtight container for the analysis of minerals (Singh *et al*. 1999).

Table 1. List of 71 genotypes (16 cultivars, germplasm & their 55 F_1 hybrids) used as experimental material for the study

No.	Genotype	No.	Genotype
1	CMS(GA)	19	CMS(GA) × Pusa Mukta
2	Golden Acre	20	CMS(GA) × C-4
3	83-1	21	CMS(GA) × Red Cabbage
4	83-2	22	CMS(GA) × C-2
5	Pride of Asia	23	CMS(GA) × AC- 1019
6	AC-204	24	CMS(GA) × EC-490192
7	EC-490174	25	CMS(GA) × MR-1
8	Pusa Mukta	26	CMS(GA) × AC-208
9	C-4	27	CMS(GA) × AC-1021
10	Red Cabbage	28	Golden Acre × AC-204
11	C-2	29	Golden Acre × EC-490174
12	AC- 1019	30	Golden Acre × Pusa Mukta
13	EC-490192	31	Golden Acre × C-4
14	MR-1	32	Golden Acre × Red Cabbage
15	AC-208	33	Golden Acre × C-2
16	AC-1021	34	Golden Acre × AC- 1019
17	CMS(GA) × AC-204	35	Golden Acre × EC-490192
18	CMS(GA) × EC-490174	36	Golden Acre × MR-1
37	Golden Acre × AC-208	55	83-2 × C-2
38	Golden Acre × AC-1021	56	83-2 × AC- 1019
39	83-1 × AC-204	57	83-2 × EC-490192
40	83-1 × EC-490174	58	83-2 × MR-1
41	83-1 × Pusa Mukta	59	83-2 × AC-208
42	83-1 × C-4	60	83-2 × AC-1021
43	83-1 × Red Cabbage	61	Pride of Asia × AC-204
44	83-1 × C-2	62	Pride of Asia × EC-490174
45	83-1 × AC- 1019	63	Pride of Asia × Pusa Mukta
46	83-1 × EC-490192	64	Pride of Asia × C-4
47	83-1 × MR-1	65	Pride of Asia × Red Cabbage
48	83-1 × AC-208	66	Pride of Asia × C-2
49	83-1 × AC-1021	67	Pride of Asia × AC- 1019
50	83-2 × AC-204	68	Pride of Asia × EC-490192
51	83-2 × EC-490174	69	Pride of Asia × MR-1
52	83-2 × Pusa Mukta	70	Pride of Asia × AC-208
53	83-2 × C-4	71	Pride of Asia × AC-1021
54	83-2 × Red Cabbage	-	-

The dried tissues were digested with a mixture of perchloric acid and nitric acid (1:1, w/w). Dried tissues (100 mg) and 15 cm^3 of acid mixture were put in 100 cm^3 conical flask, allowed overnight for pre-digestion, and then heated at 100 ºC for an hour and 250 ºC until the solution turned colourless and volume was reduced to 2-3 cm^3. The digested plant material was made up to 50 cm^3 with double distilled water and filtered. The filtrate was used for determination of mineral concentration.

The concentrations of Zn, Fe, Cu and Mn were determined on atomic absorption spectrophotometer (AAS-4141) directly from the filtrate using an air-acetylene flame at respective wavelength of 213.9 nm, 248.3 nm, 324.8 nm and 279.8 nm and at the respective current of 5 mA, 5 mA, 3.5 mA and 5 mA. The contents of K and Ca were determined on flame photometer (ELICO CL-361) and measured at 766.5 nm and 422.7 nm wavelength, respectively. All the elemental concentrations were computed on 100 g fresh weight basis.

The data were analysed statistically by analysis of variance (Singh and Chaudhary 1977), heritability in a broad sense (Burton and De Vane 1953), genetic advance (Johnson *et al*. 1955), correlation coefficient (Searle 1961), and path coefficient (Dewey and Lu 1959).

RESULTS AND DISCUSSION

The mean squares (Table 2) showed that the genotypes varied highly significantly among themselves for the content of all the minerals such as Fe, Zn, Cu, Mn, K, and Ca as well as head weight. Highly significant mean squares for mineral contents indicate the presence of sufficient natural variation, which could be exploited through various breeding approaches. Singh *et al*. (2009) also reported sufficient amount of variability for minerals content in cultivars and hybrids of cabbage. The extent of variability for minerals present in cabbage (Table 3) was estimated in terms of phenotypic and genotypic variance (Vp and Vg), and phenotypic and genotypic coefficient of variation (PCV and GCV). The Vg was highest for Fe followed by Zn, Mn, Cu, and K content, and lowest for Ca content. Fe, Zn, Cu, Mn, K, and Ca have greater amount of Vg and GCV, and therefore,

Table 2. Analysis of variance (ANOVA) for minerals content and head weight in cabbage

Source of variation	d. f.	Mean square						
		Iron	Zinc	Copper	Manganese	Potassium	Calcium	Head weight
Replication	2	685	82	5	288	21	0.98	3281
Genotype	70	204727**	14782**	6772**	12934**	2132**	387.18**	22279**
Error	141	1553	232	40	180	19	16.43	2380

** significant at 1% level

Table 3. Variability, heritability, and genetic advance for mineral elements and head weight in cabbage

Mineral	Vg	Vp	GCV	PCV	h^2 (%)	GA	GA as percentage of mean (%)
Iron	67724.8	69277.5	46.1	46.6	97.8	530.1	93.8
Zinc	4849.9	5082.0	39.6	40.4	95.4	140.1	79.6
Copper	2244.1	2283.9	59.7	60.2	98.3	96.7	121.8
Manganese	4251.3	4430.8	31.2	31.9	95.9	131.6	63.0
Potassium	704.6	723.2	11.6	11.8	97.4	54.0	23.7
Calcium	123.6	140.0	32.7	34.8	88.3	21.5	63.2
Head weight	6633.0	9012.6	25.1	29.2	73.6	143.9	44.3

Vg - genotypic variance, Vp - phenotypic variance, GCV - genotypic coefficient of variation, PCV - phenotypic coefficient of variation, h^2 – heritability, GA - genetic advance

present a better possibility of improvement of minerals contents through breeding. The magnitude of PCV was slightly higher than the corresponding GCV for minerals contents indicating lesser influence of environment on accumulation of minerals in cabbage head. The result corroborates the findings of Hakala *et al*. (2003) and Singh *et al*. (2010).

Heritable portion of variation can be deduced by computing the heritability and genetic advance as percentage of mean. High heritability (>80%) was estimated for all minerals such as Cu followed by Fe, K, Mn, Zn and Ca (Table 4). A high heritability for the traits indicates that a large portion of phenotypic variance is contributed through genotypic variance and therefore a reliable selection can be made for these traits. The lowest but moderate heritability for head weight (73.6%) indicates a considerable influence of environment. Effectiveness and potentiality of the traits under selection could be revealed by an assessment of genetic gain. Genetic advance as percentage of mean varied from 23.7 to 121.8%. It was estimated high (>40%) for Cu followed by Fe, Zn, Ca and Mn, and low (<30%) for K content. Heritability estimates along with genetic advance as percentage of mean, together, are more useful in predicting the gain under selection than either of them alone (Singh and Chaudhary 1977). In the present study, a high heritability accompanied by a high genetic advance for Fe, Zn, Cu, Mn and Ca clearly suggest the role of additive gene action and thus a high genetic gain is expected from hybridization followed by selection for these minerals. However, K showed a low genetic advance along with high heritability and thus reflecting the regulation of the previously mentioned mineral through non-additive gene, which could be exploited for the development of synthetics and hybrids through heterosis breeding. Moderate heritability along with moderate to high genetic advance for head weight suggests the involvement of both additive and non-additive genes, which could be improved through reciprocal recurrent selection.

Correlation coefficients of various macro- and micronutrients were analysed to find out the direction and magnitude of associations at genotypic and phenotypic levels (Table 4).

Genotypic correlation coefficients for mineral contents were slightly higher in magnitude than

Table 4. Genotypic (G) and phenotypic (P) correlation coefficients for minerals in among cabbage

Mineral		Iron	Zinc	Copper	Manganese	Potassium	Calcium	Head weight
Iron	G	-	0.679**	0.640**	0.466**	0.238*	0.164	-0.356**
	P	-	0.659**	0.627**	0.450**	0.233*	0.159	-0.308**
Zinc	G		-	0.781**	0.723**	0.240*	0.122	-0.639**
	P		-	0.757**	0.690**	0.233*	0.109	-0.540**
Copper	G			-	0.595**	0.154	0.004	-0.556**
	P			-	0.578**	0.148	0.004	-0.472**
Manganese	G				-	0.287*	0.100	-0.602**
	P				-	0.278*	0.092	-0.497**
Potassium	G					-	-0.087	-0.463**
	P					-	-0.081	-0.392**
Calcium	G						-	-0.174
	P						-	-0.123

* and **: significant at 5% and 1% level, respectively.

Table 5. Genotypic path coefficient for minerals in cabbage

Mineral	Iron	Zinc	Copper	Manganese	Potassium	Calcium	'r' value with head weight
Iron	0.274	-0.252	-0.182	-0.079	-0.086	-0.031	-0.356**
Zinc	0.186	-0.371	-0.222	-0.122	-0.087	-0.023	-0.639**
Copper	0.175	-0.290	-0.283	-0.101	-0.056	-0.001	-0.556**
Manganese	0.128	-0.269	-0.169	-0.169	-0.104	-0.019	-0.602**
Potassium	0.065	-0.089	-0.044	-0.048	-0.363	0.016	-0.463**
Calcium	0.045	-0.045	-0.001	-0.017	0.032	-0.188	-0.174

Residual effect - 0.6328, the bold value indicates direct effect, while others indirect effect.
** significant at 1% level

phenotypic correlation coefficients indicating the lower influence of environment on minerals' accumulation. The result supported the finding of Singh *et al*. (2010) in strawberry fruits. Nevertheless, the difference between genotypic and phenotypic correlation coefficients for head weight is wider, which reveals that the apparent association is not only due to genes but also due to favourable influence of environment. The association of minerals and the magnitude of their relationship revealed that all minerals such as Fe, Zn, Mn, Cu and K had significant positive correlation among each other, except for Ca content. It may be inferred that the selection, either based on these minerals in combination or alone, would be beneficial to identify the genotypes having higher mineral contents. However, Fe, Zn, Cu, Mn and K showed negative correlation with head weight. The result suggests that cabbage breeding should emphasize the selection of smaller head size to maintain the higher minerals content in tissues of cabbage heads. The negative correlation between minerals content and yield was reported by Farnham *et al*. (2000) in broccoli, Monasterio and Graham (2000) in wheat, Garvin *et al*. (2006) in winter wheat, Broadley *et al*. (2008) in cole crops and White *et al*. (2009) in potato. There is no correlation for Ca content with other studied minerals.

In general, correlation coefficient indicates only the interrelationships between any two traits without tracing any possible causes of such interrelationships. In such situation, the path coefficient analysis at genotypic level (Table 5) is done to partition the correlation coefficient into direct and indirect effects. Head weight was taken as dependent variable while computing the path coefficient.

Negative direct effects on the head weight was the highest for Zn (-0.371) followed by K, Cu, Ca and Mn (-0.363, -0.283, -0.188 and -0.169, respectively), while positive direct effect was expressed only by Fe content (0.274). The K content showed negative direct effect (-0.363) on head weight which is quite close to its correlation coefficient (-0.463) indicating that a direct selection through K would be very effective.

CONCLUSIONS

The additive genes are responsible for the accumulation of Fe, Zn, Cu, Mn and Ca and it could be improved by hybridization followed by selection. A positive correlation for Fe, Zn, and Mn contents with other minerals will help in simultaneous selection of other mineral elements. However, the negative correlation between head weight and minerals content could be minimized to some extent by the selection of smaller heads. Hence, the knowledge of inheritance and interrelationships among minerals would be helpful in adopting the suitable breeding approaches and identification and selection of mineral-rich productive genotypes.

REFERENCES

Anonymous 2001. Iron deficiency anemia: assessment, prevention and control: A guide for programme managers. Geneva, World Health Organization (WHO/NHD/01.3).

Anonymous 2007. Harvest Plus. http://www.harvestplus.org/micronut.html.

Broadley M.R., Hammond J.P., King G.J., Astley D., Bowen H.C., Meacham M.C., Mead A., Pink D.A.C., Teakle G.R., Hayden R.M., Spracklen W.P., White P.J. 2008. Shoot calcium and magnesium concentrations differ between subtaxa, are highly heritable, and associate with potentially pleiotropic loci in *Brassica oleracea*. Plant Physiology 146: 1707-1720.

Burton G.W., De Vane D.H. 1953. Estimating heritability in fall fescue from replicated clonal material. Agronomy J. 4: 78-81.

Cakmak I. 2007. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil 302: 1-17.

Davis D.R. 2005. Trade-offs in agriculture and nutrition. Food Technol. 59: 120.

Davis D.R., Epp M.D., Riordan H.D. 2004. Changes in USDA food composition data for 43 garden crops, 1950 to 1999. J. Amer. Coll. Nutr. 23**:** 669-682.

Dewey D.R., Lu K.H. 1959. A correlation and path analysis of components of crested wheat grass seed production. Agronomy J. 51: 515-518.

Farnham M.W., Grusak M.A., Wang M. 2000. Calcium and magnesium concentration of inbred and hybrid broccoli heads. J. Amer. Soc. Hortic. Sci. 125 (3): 344-349.

Garvin D.F., Welch R.M., Finley J.W. 2006. Historical shifts in the seed mineral micronutrient concentration of US hard red winter wheat germplasm. J. Sci. Food Agric. 86: 2213-2220.

Hakala M., Lapvetelainen A., Huopalahti R., Kallio H., Tahvonen R. 2003. Effects of varieties and cultivation conditions on the composition of strawberries. J. Food Com. Anal. 16: 67-80.

Jarrell W.M., Beverly R.B. 1981. The dilution effect in plant nutrition studies. Adv. Agron. 34: 197-224.

Johnson H.W., Robinson H.F., Comstock R.E. 1955. Estimates of genetic and environmental variability in soybean. Agron. J. 47: 314-418.

Kopsell D.E., Kopsell D.A., Lefsrud M.G., Curran C.J. 2004. Variability in elemental accumulations among leafy *Brassica oleracea* cultivars and selections. J. Plant Nutr. 27 (10): 1813-1826.

Monasterio I., Graham R.D. 2000. Breeding for trace minerals in wheat. Food Nutr. Bull. 21: 392-396.

Searle S.R. 1961. Phenotypic, genotypic and environmental correlations. Biometrics 17: 474-480.

Singh R.K., Chaudhary B.D. 1977. Biometrical methods in quantitative genetic analysis. Kalyani Publishers, Ludhiana.

Singh D., Chhonkar P.K., Pandey R.N. 1999. Soil plant water analysis: A methods manual. IARI, New Delhi.

Singh B.K., Sharma S.R., Singh B. 2009. Heterosis for mineral elements in single cross-hybrids of cabbage (*Brassica oleracea* var. *capitata* L). Scientia Hortic. 122 (1): 32-36.

Singh B.K., Sharma S.R., Singh B. 2010. Variation in mineral concentrations among cultivars and germplasm of cabbage (*Brassica oleracea* var. *capitata* L.). J. Plant Nutr. 33: 95-104.

Singh A., Singh B.K., Brajendra, Nath A., Deka B.C. 2010. Studies on the variability, inheritance, and inter-relationships of mineral macro-nutrients and micro-nutrients in strawberry (*Fragaria* ×

ananassa Duch.). J. Hortic. Sci. Biotechnol 85: 551-555.

Welch R.M., Graham R.D. 1999. A new paradigm for world agriculture: Meeting human needs productive, sustainable and nutritious. Field Crop Res. 60: 1-10.

White P.J., Bradshaw J.E., Dale M.F.B., Ramsay G. 2009. Relationships between yield and mineral concentrations in potato tubers. HortScience 44: 6-11.