Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
Spanish Journal of Agricultural Research 2010 8(2), 371-376
ISSN: 1695-971-X

Short communication. Mineral composition in foliage of some cultivated and wild species of *Chenopodium*

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Abstract

Members of the genus *Chenopodium* are used as a foliage crop and fodder in many parts of the world. Forty accessions of *Chenopodium* spp. (*C. album*, *C. berlandieri*, *C. bushianum*, *C. giganteum*, *C. murale*, *C. quinoa*, and *C. ugandae*) were sown in a randomized block design with 3 replications. For determination of mineral composition, leaves of each accession from each replication were collected from lower, middle and upper regions of the plant, bulked together and transported to the laboratory. All the samples were analyzed in triplicate. The present study showed that *Chenopodium* spp. is a rich source of minerals like (means, in mg 100 mg^{-1}) potassium (6,329), sodium (8,350), calcium (1,154) and iron (83.92). The heritability estimates were high for all the minerals, with potassium and nickel showing the highest values (99.49 and 99.16% respectively). Sodium was positively correlated with calcium (0.483**) and copper (0.274*). Copper was negatively correlated with all heavy metals except iron and nickel. Leaf size was negatively correlated with potassium and chromium, and positively correlated with calcium and copper. This study would be of immense importance in enhancement of minerals in chenopod foliage as well as in mitigating nutritional deficiency prevalent among the poor populations in the developing countries.

Additional key words: correlation, foliage, genetic advance, heritability, mineral content, qualitative improvement.

Resumen

Comunicación corta. Composición en minerales de las hojas de algunas especies cultivadas y silvestres de *Chenopodium*

Los miembros del género *Chenopodium* son utilizados como cultivos forrajeros en muchas partes del mundo. Se sembraron 40 accesiones de *Chenopodium* spp. (*C. album*, *C. berlandieri*, *C. bushianum*, *C. giganteum*, *C. murale*, *C. quinoa* y *C. ugandae*) en un diseño de bloques al azar con tres réplicas. Para determinar la composición mineral, se recogieron hojas de cada accesión de cada replica, de las zonas baja, media y alta de la planta, que se unieron en una sola muestra y se analizaron en laboratorio por triplicado. El presente estudio muestra que *Chenopodium* spp. es una rica fuente de minerales como (de media, en mg 100 mg^{-1}) potasio (6.329), sodio (8.350), calcio (1.154) y hierro (83,92). Las estimaciones de la heredabilidad fueron altas para todos los minerales, mostrando los valores más altos para potasio y níquel (99,49 y 99,16%, respectivamente). El sodio se correlacionó positivamente con el calcio (0,483**) y el cobre (0,274*), mientras que el cobre se correlacionó negativamente con todos los metales pesados, excepto el hierro y el níquel. El tamaño de la hoja se correlacionó negativamente con el potasio y el cromo, y positivamente con el calcio y el cobre. Este estudio es de gran importancia para aumentar los minerales en el follaje de *Chenopodium*, así como en la mitigación de la deficiencia nutricional prevalente entre las poblaciones pobres de los países en desarrollo.

Palabras clave adicionales: avance genético, contenido de minerales, correlación, follaje, heredabilidad, mejora cualitativa.

* Corresponding author: atul_238@rediffmail.com
Received: 26-05-09; Accepted: 10-03-10.

Abbreviations used: GCV (genotypic coefficient of variation), PCV (phenotypic coefficient of variation), RDA (recommended dietary allowance).

A large portion of the population in the developing countries has little access to protein and mineral rich diet, since wheat and rice are the principal food crops. To mitigate this problem, recently attention has centered on the exploitation and utilization of unusual and underexploited plant material for food. However, much of these efforts have laid emphasis on grain while sources of leafy vegetables have been largely overlooked. Green vegetables have long been recognized as the cheapest and most abundant sources of protein, vitamins and minerals (Aletor *et al*., 2002; Shukla *et al*., 2006; Bhargava *et al*., 2007a). In recent years, leafy vegetables have evoked interest, especially as potential food crops for diversification of agriculture to newer areas, environmental sustainability and for combating the nutritional deficiency in many parts of the world (Shukla *et al*., 2006; Bhargava *et al*., 2007a).

The genus *Chenopodium* comprises about 250 species (Giusti, 1970) most of which are colonizing annuals (Wilson, 1990). *Chenopodium* spp. have been cultivated since centuries as a leafy vegetable and subsidiary grain crop in different parts of the world. Recently, the genus has been recognized to have antitumour, antifungal and antioxidant activity (Nascimento *et al*., 2006; Kumar *et al*., 2007). Although only three species are cultivated (Bhargava *et al*., 2006, 2007a), the leaves and tender stems of numerous others are consumed as food and fodder (Moerman, 1998; Partap *et al*., 1998). The foliage of *Chenopodium* constitutes an inexpensive and rich source of protein, carotenoid and vitamin C (Prakash *et al*., 1993). Although some reports have described the nutritional and antinutritional factors in the leaves of the some species of the genus (Prakash *et al*., 1993; Repo-Carrasco *et al*., 2003), the database of their mineral composition is far from exhaustive.

A number of different species of *Chenopodium* have been introduced and acclimatized in central mountain regions of North America, Europe and Africa (Mujica *et al*., 2001; Bhargava *et al*., 2006, 2007b), but systematic evaluation for different qualitative traits are rare leading to lack of information on many aspects. Genetic variability in the base population plays a very important role in any crop-breeding program (Bhargava *et al*., 2007b). The characters of economic importance are generally quantitative in nature and exhibit considerable degree of interaction with the environment. Thus, it becomes imperative to compute the variability present in the material and its partitioning into genotypic, phenotypic and environmental ones. Improvement of yield requires an in-depth knowledge of the magnitude of variation present in the available germplasm, interdependence of quantitative characters with yield, heritability and genetic gain of the material. Correlation coefficients show relationships among various traits along with the degree of linear relation between these characters. Although reports on variability and correlation analysis among different minerals are available in other crops (Seiler and Campbell, 2004), such studies on foliage yield in vegetable chenopods are rare (Bhargava *et al*., 2008) wherein the authors assessed the genetic diversity in the genus using the multivariate analysis. Apart from this study no study mentions the qualitative improvement in chenopods with reference to minerals. The existence of genetic variability in mineral element composition would indicate the potential for selecting for enhanced forage quality. Therefore, the objectives of this study were to: (i) determine the variability for different minerals in the foliage of various wild and cultivated species of *Chenopodium*, and (ii) examine relationships among mineral concentrations in the foliage and their direct impact on leaf size while exercising selection.

The experiment was conducted at the experimental field of National Botanical Research Institute, Lucknow (altitude = 120 m; 26.5°N latitude, 80.5°E longitude). This subtropical region is situated in the Indo-Gangetic Plains and has sharp differences in summer and winter temperatures. *Chenopodium* spp. occurs as a winter crop and is harvested before the arrival of summers. The experimental material comprised 40 accessions of *Chenopodium* spp. whose details have been provided in Table 1. The material was sown in November 2003 in a randomized block design with 3 replications. The plot size for each accession was 4 m^2, with row-to-row and plant-to-plant distance of 25 and 15 cm, respectively. The soil of the experimental site was sandy loam with a pH of 6.8 ± 0.04, electrical conductivity of 479 ± 1.26 µs cm^{-1} and organic matter content of 1.06 %. Twenty tons ha^{-1} of compost was added in the field prior to sowing and no chemical fertilizer or fungicide was used during the experiment. The leaves were collected when the plants had attained an aboveground height of 20 cm.

For determination of mineral composition, leaves of each accession from each replication were collected from lower, middle and upper regions of the plant, bulked together and transported to the laboratory. All the samples were analyzed in triplicate. The leaves were thoroughly washed with tap water and finally rinsed in deionized water (0.2% non-phosphate detergent

Table 1. Accessions of *Chenopodium* used in the present study

No.	Accessions	Source	2n
1	*C. quinoa* Willd. CHEN 33/84	IPK, Gatersleben, Germany	36
2	*C. quinoa* Willd. CHEN 92/91	IPK, Gatersleben, Germany	36
3	*C. quinoa* Willd. CHEN 67/78	IPK, Gatersleben, Germany	36
4	*C. quinoa* Willd. CHEN 84/79	IPK, Gatersleben, Germany	36
5	*C. quinoa* Willd. PI 510532	USDA	36
6	*C. quinoa* Willd. PI 510536	USDA	36
7	*C. quinoa* Willd. PI 510537	USDA	36
8	*C. quinoa* Willd. PI 510547	USDA	36
9	*C. quinoa* Willd. PI 587173	USDA	36
10	*C. quinoa* Willd. PI 614881	USDA	36
11	*C. quinoa* Willd. PI 614883	USDA	36
12	*C. quinoa* Willd. Ames 13719	USDA	36
13	*C. quinoa* Willd. Ames 13762	USDA	36
14	*C. quinoa* Willd. Ames 22156	USDA	36
15	*C. quinoa* Willd. Ames 22158	USDA	36
16	*C. quinoa* Willd. PI 584524	USDA	36
17	*C. quinoa* Willd. PI 433232	USDA	36
18	*C. quinoa* Willd. PI 478410	USDA	36
19	*C. berlandieri* subsp. *nuttalliae* PI 568155	USDA	36
20	C. *berlandieri* subsp. *nuttalliae* PI 568156	USDA	36
21	*C. bushianum* Ames 22376	USDA	54
22	*C. giganteum* CHEN 86/85	IPK, Gatersleben, Germany	54
23	*C. giganteum* Ames 86650	USDA	54
24	*C. giganteum* PI 596372	USDA	54
25	*C. giganteum* 'local'	India	54
26	*C. murale* 'local'	India	18
27	*C. album* 'local red'	India	18
28	*C. album* 'chandanbathua'	India	18
29	*C. album* 'Chandigarh'	India	36
30	*C. album* 'Mexico'	Mexico	36
31	*C. album* PRC 9801	India	54
32	*C. album* PRC 9802	India	54
33	*C. album* PRC 9803	India	54
34	*C. album* PRC 9804	India	54
35	*C. album* IC 107296	India	54
36	*C. albu*m IC 107297	India	54
37	*C. album* PI 605700	USDA	54
38	*C. album* 'local 6x'	India	54
39	*C. album* 'Iowa'	USDA	54
40	*C. ugandae* CHEN 77/78	IPK, Gatersleben,Germany	36

solution). The leaves were then oven dried for 72 h at 80°C and digested in a 1:4 mixture of $HClO_3$ and HNO_3. Calcium, sodium and potassium were determined by flame photometry, while iron, magnesium, zinc, copper, nickel, chromium and cadmium were determined using atomic absorption spectrophotometer (Perkin Elmer 5100). Leaf area (cm^2) was measured using the leaf area meter of Delta T Devices Ltd, when the plant was in full bloom. The raw data was compiled by taking the means of all the plants taken for each treatment and replication for different traits. Mean, phenotypic and genotypic coefficients of variation, heritability and genetic advance were analyzed according to Singh and Chaudhary (1985). Correlation analysis was performed according to Johnson *et al*. (1955a).

Minerals are important in human diet because they serve as cofactors for many physiologic and metabolic functions. Significant genotypic differences are known to exist in the metal uptake by plants (Hocking and McLaughlin, 2000). The analysis of variance revealed significant differences among the accessions for all the 10 variables as well as for leaf size (Table 2). The mean, range and other variability parameters for leaf

Table 2. Mean (mg/100 g dry weight), range and variability parameters for leaf size (cm²) and various minerals (mg/100 g dry weight) in *Chenopodium* spp.

	F value	Mean ±SE	Range	GCV[a]	PCV[b]	Heritability (%)	Genetic advance
K	586.71	6,329 ± 234	2,081-8,527	23.42	23.48	99.49	48.12
Ca	16.26	1,154 ± 20.15	1,005-1,625	10.69	11.69	83.57	20.13
Na	150.39	8,350 ± 544.70	1,065-15,640	41.09	41.50	98.03	83.81
Fe	7.05	83.92 ± 0.53	75.60-92.33	3.67	4.49	66.86	6.19
Mg	59.57	795.25 ± 16.26	396-856	12.80	13.13	95.13	25.72
Zn	7.57	14.88 ± 1.24	3.15-36.17	48.93	59.05	68.65	83.51
Cu	10.28	13.21 ± 0.19	10.39-14.66	8.79	10.11	75.57	15.74
Ni	354.21	6.61 ± 1.07	0.00-22.19	102.49	102.92	99.16	210.24
Cr	266.27	4.32 ± 0.60	1.03-18.80	88.26	88.76	98.88	180.80
Cd	169.81	2.40 ± 0.38	0.48-13.42	99.20	100.08	98.25	202.57
Leaf size	115.81	23.23 ± 1.15	3.43-46.51	53.27	53.96	97.45	108.34

[a] Genotypic coefficient of variation. [b] Phenotypic coefficient of variation.

size and different minerals are presented in Table 2. The potassium content among the accessions ranged from 2,081-8,527 mg 100 mg^{-1} with an average of 6,329 mg 100 mg^{-1}. The mean calcium content for 40 accessions was 1,154 ± 0.20 mg 100 mg^{-1}, while the sodium content of the leaves measured 8,350 ± 544.70 mg 100 mg^{-1}. The iron content ranged from 75.6-92.33 mg 100 mg^{-1}, with an arithmetic mean of 83.92 ± 0.53 mg 100 mg^{-1}. The mean values for zinc and copper content were 14.88+1.24 and 13.21 ± 0.19 mg 100 mg^{-1}, respectively. The nickel content among the accessions ranged from 0.00-22.19 mg 100 mg^{-1}, while chromium and copper averaged at 4.32 ± 0.60 and 2.40 ± 0.38 mg 100 mg^{-1}, respectively. An enormous amount of variation was found in leaf size for which the lowest and the highest values differed by over 13 times (lowest: 3.43 cm²; highest: 46.51 cm²) (Table 2). Our results show that potassium, calcium, sodium, iron and copper contents in *Chenopodium* were particularly high and moderate consumption of the foliage would satisfy the 'Recommended Dietary Allowance' (RDA), a standard developed in USA which specifies the amount of each nutrient that needs to be consumed daily in order to maintain good health (NRC, 1989). The mineral content of chenopod leaves compares favourably with those reported for other leafy vegetables by Aletor *et al.* (2002) and Kawashima and Soares (2003). The calcium and iron content in *Chenopodium* were much higher as compared to amaranth (Barminas *et al.*, 1998) and spinach (Singh *et al.*, 2001), but chenopod foliage is comparatively inferior in magnesium and zinc (Aletor and Adeogun, 1995; Odhav *et al.*, 2007). A comparison with many other uncultivated plant foods also shows that chenopod leaves are rich in calcium, iron, potassium, zinc and sodium (Cook *et al.*, 2000). Earlier studies have shown that the foliage of many species of *Chenopodium* is rich in protein, carotenoid and ascorbic acid (Prakash *et al.*, 1993; Bhargava *et al.*, 2007a). Thus, chenopod leaves should be included in the diet to overcome the nutritional problems prevalent in different regions of the world.

The values of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance are presented in Table 2. Highest coefficient of variation values were obtained for nickel, followed by cadmium and chromium. High GCV and PCV values recorded for these metals, as well as for leaf size, indicated good scope for improvement in these traits through selection for isolation of ideal plant types that can contribute in bioleaching of these metals from contaminated soils. Likewise, potassium, sodium and zinc also had moderate GCV and PCV values indicating considerable scope for improvement through selection for plants better suited for edible purposes. The heritability estimates were high for all the minerals as well as for leaf size, with potassium and nickel showing the highest values. Maximum genetic advance was observed for nickel, followed by cadmium and chromium. Low genetic advance values were obtained for iron and copper (Table 2).

The genotypic and phenotypic correlations among various minerals are presented in Table 3. The genotypic correlation coefficients were generally higher than the corresponding phenotypic values for most of the traits. Throughout the remainder of this section, reference will be made only to genotypic correlations. Sodium was significantly correlated: positively with calcium (0.483**) and copper (0.274*), and negatively

Table 3. Genotypic (G) and phenotypic (P) correlation coefficients between various minerals in *Chenopodium* spp.

Minerals		Ca	Na	Fe	Mg	Zn	Cu	Ni	Cr	Cd	Leaf size
K	G	–0.029	–0.118	0.095	0.036	0.112	–0.371**	0.040	0.032	0.109	–0.227*
	P	–0.026	–0.117	0.087	0.034	0.092	–0.325**	0.041	0.033	0.108	–0.224*
Ca	G		0.483**	–0.310**	0.148	–0.151	0.046	0.092	–0.071	0.003	0.285**
	P		0.440**	–0.205	0.143	–0.116	0.072	0.085	–0.065	0.009	0.254*
Na	G			–0.229*	–0.134	–0.470**	0.274*	–0.378**	–0.308**	0.125	0.079
	P			–0.183	–0.123	–0.388**	0.249*	–0.374**	–0.304**	0.128	0.081
Fe	G				0.239*	0.351**	–0.065	0.187	0.198	0.117	–0.173
	P				0.189	0.234	–0.065	0.155	0.161	0.107	–0.140
Mg	G					0.436**	–0.173	0.266*	0.251*	0.218*	0.039
	P					0.365**	–0.137	0.252*	0.233*	0.204	0.040
Zn	G						–0.589**	0.659**	0.743**	0.288**	–0.113
	P						–0.418**	0.538**	0.604**	0.237*	–0.080
Cu	G							–0.663**	–0.657**	–0.562**	0.330**
	P							–0.573**	–0.575**	–0.469**	0.283**
Ni	G								0.682**	0.461**	–0.197
	P								0.680**	0.458**	–0.192
Cr	G									0.382**	–0.218*
	P									0.376**	–0.214*
Cd	G										–0.047
	P										–0.046

*,** Significance at 5% and 1%, respectively.

with iron (–0.229*), zinc (–0.470**), nickel (–0.378**) and chromium (–0.308**). Zinc exhibited strong positive association with iron (0.351**) and magnesium (0.436**). Copper was negatively and significantly correlated with potassium and all heavy metals except iron and nickel. Nickel was positively correlated with zinc and magnesium, the values being significant in both the cases (0.659** and 0.266*, respectively). Chromium and cadmium showed strong positive association with magnesium, zinc and nickel, while cadmium and chromium were also strongly correlated with each other (Table 3). Leaf size was negatively correlated with potassium and chromium, and positively correlated with calcium and copper. Correlation studies show that attempts to increase leaf size for fodder use would lead to an increase in calcium and copper content, but a reduction in potassium and chromium levels in the leaves.

Improvement of nutritional quality must go hand in hand with improvement of agronomic characters. Knowledge of heritability of a character is important as it indicates the possibility and extent to which improvement is possible through selection. The heritability values for most of the traits were high suggesting that these traits are under genotypic control. Such high heritability values for various traits have also been reported earlier in vegetable chenopods (Bhargava *et al*., 2003). However, high heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by substantial genetic advance (Johnson *et al*., 1955b). In the present study, moderate to high genetic advance values for most of the minerals indicate that improvement can be made in the aforesaid characters. The genetic advance for some minerals were extremely high because of the extreme variation in the material investigated, and smaller values are expected in further selection cycles in a more improved material. The heritability and genetic advance values were high for sodium, potassium and heavy metals like zinc, nickel, cadmium and chromium, suggesting that these traits are under genetic control. The abovementioned heavy metals also share significant positive correlation among themselves, which suggests that selection for improvement in any one mineral would lead to a concomitant increase in the other three. Likewise, strong negative association of copper with all heavy metals shows that attempts to increase copper could result in decrease in the concentration of other heavy metals, which would be more desirable for edible purposes.

The genetic variation of the minerals in different chenopod species should allow for the selection of individuals for improving mineral elements in the forage. The selection program for enhancement of selected minerals should be carried out in different regions, taking into account local preferences and mineral deficiency prevalent among the populations. This would allow the inhabitants of different regions to utilize these species to supplement their diet so as to optimize the nutritional value of their diets.

Acknowledgements

The authors thank Director, NBRI and CSIR, New Delhi for facilities and financial support.

References

ALETOR V.A., ADEOGUN O.A., 1995. Nutrient and antinutrient components of some tropical leafy vegetables. Food Chem 53, 325-329.

ALETOR O., OSHODI A.A., IPINMOROTI K., 2002. Chemical composition of common leafy vegetables and functional properties of their leaf protein concentrates. Food Chem 78, 63-68.

BARMINAS J.T., CHARLES M., EMMANUEL D., 1998. Mineral composition of non conventional leafy vegetables. Plant Foods Hum Nutr 53, 29-36.

BHARGAVA A., SHUKLA S., OHRI D., 2003. Genetic variability and heritability of selected traits during different cuttings of vegetable *Chenopodium*. Ind J Genet Plant Breed 63, 359-360.

BHARGAVA A., SHUKLA S., OHRI D., 2006. *Chenopodium quinoa*- an Indian perspective. Industrial Crops Prod 23, 73-87.

BHARGAVA A., SHUKLA S., OHRI D., 2007a. Evaluation of foliage yield and leaf quality traits in *Chenopodium* spp. in multiyear trials. Euphytica 153, 199-213.

BHARGAVA A., SHUKLA S., OHRI D., 2007b. Genetic variability and interrelationship among various morphological and quality traits in quinoa (*Chenopodium quinoa* Willd.). Field Crops Res 101, 104-116.

BHARGAVA A., SHUKLA S., SRIVASTAVA J., SINGH N., OHRI D., 2008. Genetic diversity for mineral accumulation in *Chenopodium* spp. Scientia Hortic 118, 336-346.

COOK J.A., VANDERJAGT D.J., PASTUSZYN A., MOUNKAILA G., GLEW R.S., MILLSON M., GLEW R.H., 2000. Nutrient and chemical composition of 13 wild plant foods of Niger. J Food Comp Anal 13, 83-92.

GIUSTI L., 1970. El género *Chenopodium* en Argentina 1: Números de cromosomas. Darwiniana 16, 98-105. [In Spanish].

HOCKING P.J., MCLAUGHLIN M.J., 2000. Genotypic variation in cadmium accumulation by seed of linseed and comparison with seeds of some other crop species. Aust J Agric Res 51, 427-433.

JOHNSON H.W., ROBINSON H.F., COMSTOCK R.E., 1955a. Genotypic and phenotypic correlations in soybean and their implications in selection. Agron J 47, 477-483.

JOHNSON H.W., ROBINSON H.F., COMSTOCK R.E., 1955b. Estimates of genetic and environmental variability in soybean. Agron J 47, 314-318.

KAWASHIMA L.M., VALENTE-SOARES L.M., 2003. Mineral profile of raw and cooked leafy vegetables consumed in southern Brazil. J Food Comp Anal 16, 605-611.

KUMAR R., MISHRA A.K., DUBEY N.K., TRIPATHI Y.B., 2007. Evaluation of *Chenopodium ambrosioides* oil as a potential source of antifungal, antiaflatoxigenic and antioxidant activity. Inter J Food Microbiol 115, 159-164.

MOERMAN D., 1998. Native American Ethnobotany. Timber Press, Oregon, USA.

MUJICA A., JACOBSEN S.E., IZQUIERDO J., MARATHEE J.P., 2001. Resultados de la prueba americana y europea de la quinua. FAO, UNA-Puno, CIP. [In Spanish].

NASCIMENTO F.R., CRUZ G.V., PEREIRA P.V., MACIEL M.C., SILVA L.A., AZEVEDO A.P., BARROQUIERO E.S., GUERRA R.N., 2006. Ascitic and solid Ehrlich tumor inhibition by *Chenopodium ambrosioides* L. treatment. Life Sci 78, 2650-2653.

NRC, 1989. Recommended dietary allowances. 10th ed. National Research Council, National Academy of Sciences, Washington DC.

ODHAV B., BEEKRUM S., AKULA U.S., BAIJNATH H., 2007. Preliminary assessment of nutritional value of traditional leafy vegetables in Kwa-Zulu Natal, South Africa. J Food Comp Anal 20, 430-435.

PARTAP T., JOSHI B.D., GALWEY N.W., 1998. Chenopods: *Chenopodium* spp. Promoting the conservation and use of underutilized and neglected crops. IPGRI, Rome, Italy.

PRAKASH D., NATH P., PAL M., 1993. Composition, variation of nutritional contents in leaves, seed protein, fat and fatty acid profile of *Chenopodium* species. Int J Food Sci Agr 62, 203-205.

REPO-CARRASCO R., ESPINOZA C., JACOBSEN S.E., 2003. Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). Food Rev Intern 19, 179-189.

SEILER G.J., CAMPBELL L.G., 2004. Genetic variability for mineral element concentrations of wild Jerusalem artichoke forage. Crop Sci 44, 289-292.

SHUKLA S., BHARGAVA A., CHATTERJEE A., SINGH S.P., 2006. Genotypic variability in vegetable amaranth (*Amaranthus tricolor* L.) for foliage yield and its contributing traits over successive cuttings and years. Euphytica 151, 103-110.

SINGH R.K., CHAUDHARY B.D., 1985. Biometrical methods in quantitative genetic analysis. Kalyani Publ, New Delhi.

SINGH G., KAWATRA A., SEHGAL S., 2001. Nutritional composition of selected green leafy vegetables, herbs and carrots. Plant Foods Hum Nutr 56, 359-364.

WILSON H.D., 1990. Quinua and relatives (*Chenopodium* sect. *Chenopodium* subsect. Cellulata. Econ Bot 44, 92-110.