Variability and genotype × cutting interactions for different nutritional components in *Chenopodium album* L.

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ABSTRACT: Thirteen germplasm lines of vegetable *Chenopodium* (*C. album*) were evaluated in a randomized block design with three replications to estimate the foliage yield and its seven contributing quality traits for three successive cuttings. The variability present in vegetable *Chenopodium* and interactions operating at various levels were also studied. The mean foliage yield was maximum for CA-II (3.03 ± 0.39 kg/plot), followed by CA-VII (2.94 ± 0.27 kg/plot) and CA-VI (2.41 ± 0.20 kg/plot). Moisture content showed a constant decrease in all germplasm lines with successive cuttings except for CA-IX in 3rd cutting. Protein content exhibited a strong trend of increase with each successive cutting and was maximum in 3rd cutting. Protein content showed the highest heritability in 1st cutting (96.35%) while the values were highest for ascorbic acid in 2nd and 3rd cutting. The carotenoid content and ascorbic acid exhibited consistently high genetic gain in all the three cuttings.

Keywords: *Chenopodium album*; foliage yield; carotenoids; protein; ascorbic acid; interactions

Chenopodium is one of the largest genera of the family Chenopodiaceae and comprises over 250 species (Giusti 1970). This genus includes herbaceous, suffrutescent and arborescent perennials although most species are colonizing annuals (Wilson 1990). *C. album* has been used in the Himalayan region as an important subsidiary grain crop, as a potherb, for secondary fodder and salad dressings (Partap 1990; Partap et al. 1998). The plant is a rich source of high quality proteins (30–47 g/kg), vitamin A (78–129 mg/kg), vitamin C (1.9–2.3 g/kg), vitamin E and a variety of minerals (Prakash et al. 1993; Partap et al. 1998). *C. album* also has the ability to flourish in intercropping systems and the presence of mycorrhizal associations maximizes the use of scarce nutrients (Partap et al. 1998). The *C. album* complex has been attributed three ploidy levels $2n$ = 18, 36, 54, which is due to the fact that the complex is used as a 'convenient taxonomic receptacle' for material not readily assigned to other species of the genus (Wilson 1980; Bhargava et al. 2005).

Chenopods did not gain much significance until recently when *C. quinoa* came to the limelight (FAO 1998). *C. quinoa* has gained worldwide attention and is used both as a valuable grain and an oil seed crop (Koziol 1992). But in spite of being a rich and cheap source of nutrients and the ability to grow in marginal environments, the neglected status of *C. album* still persists. Although reports on morphological variability in *C. album* are available (Bhargava et al. 2003a,b), the information on quality traits is totally missing. Keeping in view the immense nutritive importance of vegetable chenopods and lack of information on many aspects, the present investigation was undertaken. The primary objectives of the study were:

(*i*) to estimate foliage yield in different germplasm lines of vegetable *Chenopodium* over different cuttings;
(*ii*) to observe the existing genetic variability for quality traits in *C. album* over successive cuttings;
(*iii*) to determine the interactions operating at various levels viz. within germplasm lines, within cuttings and between cuttings and germplasm lines;
(*iv*) to identify the best performers, both in terms of yield and quality, for future breeding programmes.

Table 1. Germplasm lines, their ploidy level, chromosome number and origin

S. No.	Germplasm lines	2*n*	Origin
CA-I	*C. album* PRC 9802	54	Himachal Pradesh, India
CA-II	*C. album* IC 107297	54	Himachal Pradesh, India
CA-III	*C. album* Mexico	36	Mexico
CA-IV	*C. album* local red	18	Lucknow, India
CA-V	*C. album* Siliguri	18	Siliguri, India
CA-VI	*C. album amaranticolor*	54	Himachal Pradesh, India
CA-VII	*C. album* H.P.	54	Himachal Pradesh, India
CA-VIII	*C. album* PI 605700	54	Michigan, USA*
CA-IX	*C. album* CHEN 60/76	54	Belgium**
CA-X	*C. album* CHEN 95/97	54	unknown**
CA-XI	*C. album* Czech	54	Czech Republic
CA-XII	*C. album* Iowa	54	Iowa, USA
CA-XIII	*C. album* chandanbathua	18	India

Source: * USDA, ** IPK Gatersleben, Germany

This study is an attempt to fill the gap in available knowledge of vegetable *Chenopodium* and it will also contribute to a better understanding of this underutilized crop.

MATERIAL AND METHODS

Experimental site and material

The experiment was conducted in an experimental field of National Botanical Research Institute, Lucknow. The experimental site is situated at an altitude of 120 m above sea level at 26.5°N latitude and 80.5°E longitude. In the tropical regions of India there are two main crop seasons, summer (kharif – March to July) and winter (rabi – October to February). *C. album* is generally grown in the rabi season during which the minimum and maximum temperature ranges from 2.5°C–19°C and 14°C–29°C, respectively.

The experimental material comprised 13 germplasm lines of *C. album* (Table 1), which have been maintained for several years at National Botanical Research Institute, Lucknow. The lines under the present study comprised three ploidy levels, diploid (2*n* = 18), tetraploid (2*n* = 36) and hexaploid (2*n* = 54). The primary objective of selecting the material was to incorporate all available *C. album* lines that might serve as potential vegetable types.

Experiment

Each germplasm line was sown in November 2002 in a randomized block design with 3 replications. The plot size for each replication was 4 m^2 with 6 rows per plot, spaced 30 cm apart. Weeding was done once in a 15-day interval to remove the unwanted off type plants. During the crop period, no chemical fertilizer or pesticide was used. The first cutting was performed after the 3rd week of sowing and thereafter, successive cuttings were done at an interval of 15 days. Foliage yield was recorded on the plot basis for different cuttings in kg/plot. Fresh leaves of each cutting were analyzed separately for five quality characters, namely moisture content (%), chlorophyll *a* (mg/g), chlorophyll *b* (mg/g), carotenoids (mg/100 g) and proteins (g/100 g). Dried leaves were estimated for fibre (%) and ascorbic acid (g/100 g). The data on qualitative traits was taken from randomly selected samples for all the three cuttings separately. Moisture content was estimated by the ratio of fresh leaf weight to 100°C dry weight. The extraction and estimation of chlorophyll *a*, chlorophyll *b* and carotenoids were done according to Jensen (1978). Protein content was estimated according to Lowry et al. (1951) while fibre was estimated by the method described by Watson (1994). Ascorbic acid content was estimated according to Glick (1954).

Data analysis

Analysis of variance was used to test the significance of differences within germplasm lines, within cuttings and interactions due to cutting × germplasm line. Statistical analysis was done according to Panse and Sukhatme (1978). Data was analyzed using mean values of each treatment in different cuttings over 3 replications. Phenotypic and genotypic coef-

Table 2. Analysis of variance for different characters over successive cuttings in *C. album*

Mean sum of squares									
	Cuttings	Moisture	Chlorophyll *a*	Chlorophyll *b*	Carotenoids	Fibre	Proteins	Ascorbic acid	Foliage yield
Cuttings	I	4.718	0.0007	0.004	7.513	1.589	0.051	1.646	0.219
	II	14.500*	0.0068	0.007	0.592	0.102	0.025	0.794	0.118
	III	0.274	0.0051	0.002	0.419	3.483	0.002	2.284	0.046
Germplasm lines	I	10.457	0.2148	0.054	46.404**	7.036**	0.900**	52.874**	1.463**
	II	14.672**	0.2759**	0.048**	25.125**	9.387**	0.377**	43.995**	2.280**
	III	8.215**	0.0540**	0.002*	32.710**	11.314**	0.431**	44.665**	2.809**
G. line × cutting	I	5.090	0.0103	0.002	3.691	0.799	0.032	5.835	0.105
	II	3.514	0.0160	0.003	4.309	0.512	0.023	0.623	0.058
(G × C)	III	0.986	0.009	0.001	1.839	1.634	0.048	0.604	0.073

*, ** significance at 5% and 1%, respectively

ficients of variation, heritability in broad sense and genetic advance were estimated according to Singh and Chaudhary (1985).

RESULTS

Analysis of variance due to germplasm lines was significant for all the traits over all the cultivars in all the cuttings except for moisture, chlorophyll *a* and chlorophyll *b* in 1st cutting (Table 2).

Foliage yield: The mean foliage yield over 13 germplasm lines increased with each successive cutting (Table 3) and was maximum in 3rd cutting (2.09 ± 0.26 kg/plot). The highest foliage yield was observed in line CA-II (3.03 ± 0.39 kg/plot), followed by CA-VII (2.94 ± 0.27 kg/plot) and CA-VI (2.41 ± 0.20 kg/plot). CA-XI gave the lowest yield in all the three cuttings (0.24, 0.40 and 0.58 kg/plot, respectively) and on the mean basis (0.40 ± 0.09 kg/plot).

Moisture content: Moisture content showed a constant decrease in all germplasm lines with successive cuttings except for CA-IX in 3rd cutting (Table 4). Out of the 13 lines CA-I showed the highest moisture content in 1st and 2nd cutting (89.58 and 86.92%, respectively) while CA-III had the highest moisture content (84.40%) in 3rd cutting. Mean moisture content over all the cuttings was highest for CA-I (86.56 ± 1.85%) and lowest for CA-IX (81.56 ± 1.07%).

Chlorophyll *a*: CA-II had the highest amount of chlorophyll *a* over 3 cuttings (0.998 ± 0.09 mg/g) while the lowest amount was found in CA-IV (0.535 ± 0.06 mg/g) (Table 5). The mean chlorophyll a over 13 lines was minimum in 1st cutting (0.684 ± 0.07 mg/g), it increased considerably in 2nd cutting (0.976 ± 0.08 mg/g) and later on it declined in 3rd cutting (0.762 ± 0.03 mg/g).

Chlorophyll *b*: Highest chlorophyll *b* was observed in CA-II (0.297 ± 0.11 mg/g), followed by CA-IX (0.280 ± 0.12 mg/g) and CA-VIII (0.256 ± 0.08 mg/g) (Table 6). CA-XII recorded the lowest amount of chlorophyll *b* over three cuttings (0.170 ± 0.05 mg/g). The mean chlorophyll *b* over 13 lines was maximum in 2nd cutting (0.307 ± 0.035 mg/g) and minimum in 3rd cutting (0.171 ± 0.007 mg/g).

Carotenoids: On the basis of the overall mean of 13 lines it was noticed that with the progression of cuttings carotenoid content initially increased and reached the maximum in 2nd cutting (13.10 ± 0.80 mg/100 g), but later on it decreased in 3rd cutting (12.90 ± 0.91 mg/100 g) though the decrease was marginal (Table 7). The lines CA-II, CA-X and CA-VI had high carotenoid content on the basis of the mean of 3rd cuttings (14.48 ± 1.29, 14.14 ± 3.26 and 13.79 ± 2.65 mg/100 g, respectively).

Table 3. Foliage yield (kg/plot) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	0.69	2.17	3.64	2.16 ± 0.84	**	NS	NS
CA-II	2.24	3.50	3.36	3.03 ± 0.39	**	NS	NS
CA-III	1.54	2.04	2.29	1.95 ± 0.21	**	NS	NS
CA-IV	1.11	1.13	0.88	1.04 ± 0.07	*	*	NS
CA-V	1.22	1.55	1.84	1.53 ± 0.17	**	NS	NS
CA-VI	2.00	2.66	2.58	2.41 ± 0.20	**	NS	NS
CA-VII	2.48	3.43	2.91	2.94 ± 0.27	NS	NS	NS
CA-VIII	0.71	1.87	2.35	1.64 ± 0.48	**	**	NS
CA-IX	1.04	1.09	0.92	1.01 ± 0.05	NS	NS	NS
CA-X	0.59	1.68	1.23	1.16 ± 0.31	**	NS	NS
CA-XI	0.24	0.40	0.58	0.40 ± 0.09	**	NS	NS
CA-XII	2.06	2.37	2.09	2.17 ± 0.09	NS	NS	NS
CA-XIII	1.43	2.06	2.61	2.03 ± 0.34	**	NS	NS
Mean ± SE	1.33 ± 0.19	1.99 ± 0.24	2.09 ± 0.26	1.80 ± 0.21			

For Tables 3 to 10: I – 1st cutting, II – 2nd cutting, III – 3rd cutting, C – cutting, G – germplasm line, C × G – cutting × germplasm line, *, ** significance at 5% and 1%, respectively

Fibre: Fibre content showed a general trend of initial increase, and then it decreased over successive cuttings in 9 of the 13 germplasm lines under study (Table 8). Mean fibre content over three cuttings ranged from 12.60 ± 0.31% (CA-X) to 10.04 ± 1.16% (CA-IX).

Proteins: Protein content exhibited a strong trend of increase in successive cuttings and was maximum in 3rd cutting (Table 9). The mean protein content over all the cuttings was maximum for CA-III (4.51 ± 0.20 g/100 g), followed by CA-II (4.40 ± 0.02 g/100 g) and CA-XIII (4.29 ± 0.51 g/100 g). Table 9 clearly shows that after 1st cutting protein content increased markedly by 24% (1st cutting – 3.38 ± 0.14, 2nd cutting – 4.20 ± 0.09 g/100 g) but this increase lowered after 2nd cutting and came down to 9.76% (3rd cutting – 4.61 ± 0.10 g/100 g).

Ascorbic acid: *C. album* leaves contain an appreciable amount of ascorbic acid ranging from 11.15 ± 1.61 (CA-XI) to 26.12 ± 1.53 g/100 g (CA-IV) (Table 10). All the lines under study exhibited a trend of rapid increase in ascorbic acid after 1st cutting, the

Table 4. Moisture content (%) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	89.58	86.92	83.17	86.56 ± 1.85	**	NS	NS
CA-II	87.20	80.83	80.31	82.78 ± 2.21	**	NS	NS
CA-III	86.44	84.53	84.40	85.12 ± 0.65	**	**	NS
CA-IV	87.56	84.80	82.63	85.00 ± 1.42	**	NS	NS
CA-V	87.90	85.91	83.25	85.69 ± 1.34	**	**	NS
CA-VI	83.38	82.02	80.50	81.97 ± 0.82	NS	NS	NS
CA-VII	86.27	82.58	80.75	83.20 ± 1.62	**	NS	NS
CA-VIII	87.80	86.10	82.00	85.30 ± 1.71	**	NS	NS
CA-IX	83.64	80.03	81.01	81.56 ± 1.07	NS	NS	**
CA-X	88.41	81.94	81.38	83.91 ± 2.25	**	**	NS
CA-XI	88.74	81.92	78.45	83.04 ± 3.01	**	NS	NS
CA-XII	88.80	85.61	83.87	86.09 ± 1.44	**	NS	NS
CA-XIII	87.40	83.23	81.67	84.10 ± 1.7	**	NS	*
Mean ± SE	87.16 ± 0.51	83.57 ± 0.61	81.79 ± 0.45				

Table 5. Chlorophyll *a* content (mg/g) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	0.489	1.133	0.860	0.827 ± 0.18	**	NS	NS
CA-II	1.189	0.874	0.931	0.998 ± 0.09	**	**	NS
CA-III	0.966	0.477	0.839	0.760 ± 0.14	**	NS	NS
CA-IV	0.394	0.564	0.649	0.535 ± 0.06	**	NS	NS
CA-V	0.492	1.034	0.660	0.728 ± 0.15	**	NS	NS
CA-VI	0.903	0.685	0.874	0.821 ± 0.06	**	**	NS
CA-VII	1.098	0.687	0.915	0.900 ± 0.11	**	NS	NS
CA-VIII	0.723	1.151	0.744	0.873 ± 0.13	**	NS	NS
CA-IX	0.587	1.503	0.748	0.946 ± 0.28	**	NS	NS
CA-X	0.604	1.201	0.732	0.846 ± 0.18	**	NS	NS
CA-XI	0.442	1.307	0.783	0.844 ± 0.25	**	NS	NS
CA-XII	0.445	1.062	0.425	0.644 ± 0.20	**	NS	NS
CA-XIII	0.568	1.013	0.755	0.778 ± 0.12	**	NS	NS
Mean ± SE	0.684 ± 0.07	0.976 ± 0.08	0.762 ± 0.03				

increase being 36.87%. However, after 2nd cutting ascorbic acid content decreased by 9.22%.

Interactions: The analysis of variance due to cuttings over all the lines was non-significant except for the moisture content in 2nd cutting (Tables 3–10). For individual lines, cuttings showed significant differences for all the traits except in CA-VII, CA-IX and CA-XII for foliage yield; in CA-VI and CA-IX for moisture content; in CA-IX for carotenoids; in CA-V, CA-X, CA-XI and CA-XII for fibre content; in CA-II and CA-VI for proteins; and CA-IV for ascorbic acid. The pooled analysis of variance over all the lines due to cuttings × lines was significant for moisture in 1st and 2nd cuttings, carotenoids in all the cuttings, fibre in 3rd cutting and ascorbic acid in 1st cutting while for individual lines no significant differences were observed for any character except moisture (CA-IX and CA-XIII) and ascorbic acid (CA-II, CA-III, CA-IV, CA-V and CA-XIII) (Tables 3–10). Similarly, the individual germplasm lines did not show any significant differences for all the traits except CA-IV and CA-VIII for foliage yield; CA-III, CA-V and CA-X for moisture content; CA-II and CA-VI for chlorophyll *a*; CA-IV for chlorophyll *b*;

Table 6. Chlorophyll *b* content (mg/g) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	0.116	0.403	0.212	0.243 ± 0.08	**	NS	NS
CA-II	0.531	0.207	0.155	0.297 ± 0.11	**	NS	NS
CA-III	0.386	0.113	0.190	0.230 ± 0.08	**	NS	NS
CA-IV	0.113	0.273	0.139	0.175 ± 0.04	**	**	NS
CA-V	0.132	0.302	0.172	0.202 ± 0.04	**	NS	NS
CA-VI	0.348	0.150	0.176	0.225 ± 0.06	**	NS	NS
CA-VII	0.289	0.155	0.205	0.216 ± 0.03	**	NS	NS
CA-VIII	0.171	0.421	0.177	0.256 ± 0.08	**	NS	NS
CA-IX	0.137	0.532	0.172	0.280 ± 0.12	**	NS	NS
CA-X	0.153	0.429	0.171	0.251 ± 0.08	**	NS	NS
CA-XI	0.103	0.408	0.186	0.232 ± 0.09	**	NS	NS
CA-XII	0.123	0.288	0.100	0.170 ± 0.05	**	NS	NS
CA-XIII	0.125	0.317	0.168	0.203 ± 0.05	**	NS	NS
Mean ± SE	0.209 ± 0.037	0.307 ± 0.035	0.171 ± 0.007				

Table 7. Carotenoid content (mg/100 g) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	6.43	13.97	10.02	10.14 ± 2.17	**	NS	NS
CA-II	16.76	12.26	14.43	14.48 ± 1.29	**	NS	NS
CA-III	12.87	10.58	6.23	9.89 ± 1.94	**	NS	NS
CA-IV	7.80	9.82	13.47	10.36 ± 1.65	**	NS	NS
CA-V	7.97	14.24	14.18	12.13 ± 2.07	**	NS	NS
CA-VI	18.60	13.36	9.41	13.79 ± 2.65	**	*	NS
CA-VII	10.02	17.36	12.65	13.34 ± 2.14	**	NS	NS
CA-VIII	8.27	17.04	12.01	12.44 ± 2.54	**	NS	NS
CA-IX	11.25	12.66	12.07	11.99 ± 0.40	NS	NS	NS
CA-X	7.61	17.33	17.49	14.14 ± 3.26	**	NS	NS
CA-XI	6.72	11.86	18.61	12.40 ± 3.44	**	NS	NS
CA-XII	7.60	8.01	11.93	9.18 ± 1.37	**	NS	NS
CA-XIII	6.94	11.91	15.21	11.35 ± 2.40	**	**	NS
Mean ± SE	9.91 ± 1.08	13.10 ± 0.80	12.90 ± 0.91				

CA-VI and CA-XIII for carotenoids; CA-X and CA-XIII for fibre content; CA-II and CA-VIII for protein content and CA-I, CA-III, CA-VI and CA-X for ascorbic acid.

Variability studies: The characters foliage yield, carotenoids and ascorbic acid exhibited consistently high values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for all the cuttings (Table 11). Chlorophyll *a*, chlorophyll *b* and protein content showed a decline in GCV and PCV values during successive cuttings while fibre content showed an increase in these values. But the other characters, i.e. moisture content, carotenoids, ascorbic acid and foliage yield, exhibited high GCV and PCV in 1st and 3rd cuttings but had comparatively low values in the 2nd cutting.

Coefficient of variability alone is of little help in determining the heritable portion of variation. The estimate of heritability provides a correct picture about the heritable portion that is transmitted from the parents to the offspring based on which an authentic selection programme can be chalked out. In the present study, heritability values were high for all the traits in all the cuttings and ranged from

Table 8. Fibre content (%) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	8.38	11.93	14.11	11.48 ± 1.66	**	NS	NS
CA-II	10.81	12.48	8.40	10.56 ± 1.18	**	NS	NS
CA-III	9.36	14.71	9.66	11.24 ± 1.73	**	NS	NS
CA-IV	11.15	8.46	13.16	10.92 ± 1.35	**	NS	NS
CA-V	11.07	11.34	10.97	11.12 ± 0.10	NS	NS	NS
CA-VI	9.70	11.41	11.26	10.79 ± 0.54	**	NS	NS
CA-VII	10.50	12.93	8.00	10.48 ± 1.42	**	NS	NS
CA-VIII	9.78	13.42	14.17	12.46 ± 1.35	**	NS	NS
CA-IX	7.92	11.94	10.27	10.04 ± 1.16	**	NS	NS
CA-X	13.22	12.33	12.24	12.60 ± 0.31	NS	*	NS
CA-XI	10.46	11.61	10.89	10.99 ± 0.33	NS	NS	NS
CA-XII	13.00	13.15	11.64	12.59 ± 0.47	NS	NS	NS
CA-XIII	10.80	15.82	10.02	12.21 ± 1.81	**	*	NS
Mean ± SE	10.47 ± 0.42	12.42 ± 0.49	11.13 ± 0.53				

Table 9. Protein content (g/100 g) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	3.02	3.59	4.46	3.69 ± 0.41	**	NS	NS
CA-II	4.40	4.36	4.44	4.40 ± 0.02	NS	**	NS
CA-III	4.33	4.92	4.28	4.51 ± 0.20	**	NS	NS
CA-IV	3.33	3.89	5.27	4.16 ± 0.57	**	NS	NS
CA-V	3.38	3.95	4.98	4.12 ± 0.45	**	NS	NS
CA-VI	3.65	4.25	4.24	4.05 ± 0.19	**	NS	NS
CA-VII	3.98	4.17	4.25	4.13 ± 0.07	NS	NS	NS
CA-VIII	3.01	4.15	4.25	3.80 ± 0.39	**	*	NS
CA-IX	2.82	4.48	4.59	3.96 ± 0.57	**	NS	NS
CA-X	2.98	3.93	4.26	3.72 ± 0.38	**	NS	NS
CA-XI	3.04	4.38	5.14	4.18 ± 0.60	**	NS	NS
CA-XII	2.78	3.96	4.90	3.88 ± 0.61	**	NS	NS
CA-XIII	3.28	4.64	4.96	4.29 ± 0.51	**	NS	NS
Mean ± SE	3.38 ± 0.14	4.20 ± 0.09	4.61 ± 0.10				

51.26 to 98.65%. Protein content showed the highest heritability in 1st cutting (96.35%) while the values were highest for ascorbic acid in 2nd and 3rd cutting (98.58 and 98.65%, respectively). In spite of high heritability it is not guaranteed that a large gain can be achieved through selection unless sufficient genetic advance attributable to the additive gene action is present. Genetic advance is a product of heritability and selection differential and is expressed in units of standard deviation. Thus, a study of genetic advance is also advantageous in a selection programme where the improvement of a character is desirable. In the present study foliage yield, carotenoid content and ascorbic acid exhibited consistently high genetic advance in all the three cuttings, however they showed the same trend as GCV and PCV. Chlorophyll *a* and *b* showed high estimates of genetic gain in the first two cuttings, but the values for 3rd cutting were much lower. These values also followed the same pattern as GCV and PCV. Only moisture content showed very low values for genetic advance in all the three cuttings.

DISCUSSION

The analysis of variance based on individual lines clearly showed significant differences between the

Table 10. Ascorbic acid content (g/100 g) in different cuttings and their effects in *C. album*

Germplasm lines	I	II	III	Mean ± SE	C	G	C × G
CA-I	9.43	14.55	13.16	12.36 ± 1.51	**	**	NS
CA-II	17.80	21.16	19.43	19.46 ± 0.96	**	NS	*
CA-III	14.93	19.16	17.66	17.25 ± 1.23	**	*	**
CA-IV	23.16	28.56	26.86	26.12 ± 1.53	NS	NS	**
CA-V	16.93	20.66	19.00	18.86 ± 1.07	**	NS	*
CA-VI	15.50	20.63	18.83	18.32 ± 1.50	**	**	NS
CA-VII	12.03	18.00	16.66	15.56 ± 1.80	**	NS	NS
CA-VIII	11.60	17.86	16.46	15.31 ± 1.89	**	NS	NS
CA-IX	10.53	16.46	14.80	13.93 ± 1.76	**	NS	NS
CA-X	10.63	16.00	13.23	13.28 ± 1.54	**	**	NS
CA-XI	8.03	13.46	11.96	11.15 ± 1.61	**	NS	NS
CA-XII	12.56	18.13	16.10	15.60 ± 1.62	**	NS	NS
CA-XIII	17.16	22.06	19.83	19.68 ± 1.41	**	NS	*
Mean ± SE	13.86 ± 1.16	18.97 ± 1.07	17.22 ± 1.06				

Table 11. GCV, PCV, heritability and genetic gain for foliage yield and different quality traits in vegetable *Chenopodium*

Characters	Cutting	GCV	PCV	Heritability (%)	Genetic advance (%)
Moisture	I	1.53	2.14	51.26	2.26
	II	2.30	2.64	76.05	4.14
	III	1.89	2.02	87.99	3.66
Chlorophyll *a*	I	38.11	39.07	95.16	76.59
	II	30.10	31.05	94.02	60.14
	III	16.04	17.69	82.22	29.97
Chlorophyll *b*	I	62.76	64.39	95.01	126.03
	II	39.76	41.33	92.54	78.80
	III	12.84	16.69	59.21	20.36
Carotenoids	I	38.06	39.62	92.05	75.22
	II	20.08	22.07	82.85	37.66
	III	24.85	25.58	94.38	49.74
Fibre	I	13.76	14.61	88.64	26.69
	II	13.83	14.23	94.54	27.71
	III	16.12	17.43	85.56	30.72
Proteins	I	15.86	16.16	96.35	32.07
	II	8.16	8.42	93.88	16.30
	III	7.73	8.21	88.81	15.02
Ascorbic acid	I	28.54	30.26	88.96	55.46
	II	20.05	20.19	98.58	41.02
	III	22.23	22.39	98.65	45.49
Foliage yield	II	50.23	52.14	92.80	99.68
	II	43.21	43.78	97.42	87.86
	III	45.46	46.06	97.39	92.41

GCV – genotypic coefficient of variation, PCV – phenotypic coefficient of variation

cuttings but the differences within the lines and cutting × line interactions were not significant for all the traits with few exceptions, which suggests that successive cuttings had a definite impact on foliage yield and other quality traits. Out of the 13 lines, 6 had maximum foliage yield in 2nd cutting and the decrease in yield was marginal in 3rd cutting. The study showed that in general foliage yield increased in subsequent cuttings. The improvement of yield could be due to an increase in branches/plant and leaves/plant after 1st cutting as is evident from our earlier study (Bhargava et al. 2003a). It is quite understandable that an increase in the number of branches/plant will lead to an increase in the number of leaves/plant resulting in more photosynthesis that ultimately improves the foliage yield. The germplasm line CA-II showed maximum foliage yield, followed by CA-VII and CA-VI while two exotic lines (CA-XII and CA-III) also showed good yield performance. Maximum chlorophyll *a* and *b* was noticed in the 2nd cutting in all germplasm lines with few exceptions. However, chlorophyll content decreased in 3rd cutting, which might be due to the crop maturation leading to chlorophyll degradation.

Chenopod leaves are a rich source of protein, carotenoids, ascorbic acid and a wide range of minerals (Koziol 1992; Prakash et al. 1993). Our study indicates that *C. album* foliage is high in proteins, which supports earlier reports of 3.0 to 4.7 g/kg (Prakash et al. 1993). The protein content in *C. album* is considerably higher than that reported in the foliage of other crops such as *Lactuca sativa* (0.7–1.1%) (Watson 1971), *Euphorbia hirta* (3.42%) (Wallace et al. 1998) and vegetable amaranth (2.51%) (Shukla et al. 2003) but lower than that reported for cassava (7.1–8.2%) (Watson 1971). The carotenoid content in fresh leaves of *C. album* compares favourably to other species of *Chenopodium* (Prakash et al. 1993), but is lower to that reported for *Amaranthus* (Shukla et al. 2003). Carotenoid and fibre content were the highest in 2nd cutting. Considering palatability and digestibility, low fibre

content in vegetable crops is considered more desirable. The fibre content is directly associated with protein content, the germplasm lines CA-III, CA-II, CA-XIII and CA-XI were most promising as they contained high protein and low fibre content (4.51, 11.24; 4.40, 10.56; 4.29, 12.21; 4.18, 10.99, respectively). In general high protein content was observed in those lines that have low fibre content indicating the nutritive as well as palatable and digestible quality of these lines.

Moisture content decreased with each cutting in all the germplasm lines except for CA-IX, which showed a partial increase after 2nd cutting. The decrease in moisture content could be due to the fact that as the cuttings progressed, weather was getting warmer (summers were approaching), which resulted in a greater loss of water from the aerial parts, especially leaves, resulting in a decrease of moisture with successive cuttings. It was also observed that the moisture content of the leaves did not have an impact on foliage yield as the yield increased in successive cuttings while moisture content decreased.

The study of genetic parameters provides valuable information regarding possible improvement in yield through its contributing traits. High GCV and PCV values recorded in the present study are supported by similar findings in other foliage crops such as lettuce (Thakur et al. 1997) and vegetable amaranth (Shukla, Singh 2000). Our results suggest that foliage yield, carotenoids and ascorbic acid are more important for exercising selection in vegetable chenopods. These traits had high GCV values in all the cuttings and also exhibited high heritability, coupled with high genetic advance indicating a possible role of the additive gene effect for the genotypic variance for these characters. Selection based on the phenotypic performance of these characters would be more beneficial for achieving the desired gain.

CONCLUSION

It was concluded from the present investigation that a considerable amount of variability existed in the experimental material, both in terms of yield and quality. The study shows that *C. album* leaves have high amounts of protein, carotenoids and ascorbic acid, which can constitute a good and inexpensive source of these nutrients in human diet especially for the vegetarian people in developing countries. Selection of vegetable *Chenopodium* should be based mainly on the carotenoid and ascorbic acid content. The germplasm lines CA-II, CA-VII and CA-VI having high foliage yield and carotenoid content and considerable amount of protein and ascorbic acid could serve as the most promising lines for a future selection programme to isolate better plant types rich in quality characters in vegetable *Chenopodium*.

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References

BHARGAVA A., SHUKLA S., OHRI D., 2003a. Genetic variability and heritability of selected traits during different cuttings of vegetable *Chenopodium*. Indian Journal of Genetics and Plant Breeding, *63*: 359–360.

BHARGAVA A., SHUKLA S., OHRI D., 2003b. Relative selection efficiency for foliage yield and quality characters in vegetable *Chenopodium* over different cuttings. Journal of Applied Horticulture, *5*: 85–86.

BHARGAVA A., SHUKLA S., OHRI D., 2005. Karyotypic studies on some cultivated and wild species of *Chenopodium* (Chenopodiaceae). Genetic Resources and Crop Evolution (in press).

FAO, 1998. Underutilized Andean food crops. Latin America and the Carribean. Rome.

GIUSTI L., 1970. El genero *Chenopodium* en Argentina 1: Numeros de cromosomas. Darwiniana, *16*: 98–105.

GLICK D., 1954. Methods of Biochemical Analysis. Vol. 1. New York, Interscience Publishers Inc.

JENSEN A., 1978. Chlorophylls and carotenoids. In: HELLEBUST J.A., CRAIGIE J.S. (eds.), Handbook of Physiological Methods: Physiological and Biochemical Methods. Cambridge, Cambridge University Press: 5–70.

KOZIOL M.J., 1992. Chemical composition and nutritional value of quinoa (*Chenopodium quinoa* Willd.). Journal of Food Composition and Analysis, *5*: 35–68.

LOWRY O.H., ROSEBROUGH N.J., FARR A.L., RANDALL R.J., 1951. Protein measurement with the folin-phenol reagent. Journal of Biochemistry, *193*: 265–275.

PANSE V.G., SUKHATME P.V., 1978. Statistical methods for Agricultural Workers. New Delhi, ICAR.

PARTAP T., 1990. Exploiting underexploited crop plants of mountain agriculture: Chenopods. In: RILEY K.W., MATEO N., HAWTIN G.C., YADAV R.P. (eds.), Mountain Agriculture and Crop Genetic Resources. New Delhi, Oxford and IBH Publishing Company Pvt. Ltd.: 165–183.

PARTAP T., JOSHI B.D., GALWEY N.W., 1998. Chenopods: *Chenopodium* spp. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Gatersleben, International Plant Genetic Resources Institute: 22.

PRAKASH D., NATH P., PAL M., 1993. Composition, variation of nutritional contents in leaves, seed protein, fat and fatty acid profile of *Chenopodium* species. Journal of the Sciences of Food and Agriculture, *62*: 203–205.

SHUKLA S., SINGH S.P., 2000. Studies on genetic parameters in vegetable amaranth. Journal of Genetics and Breeding, *54*: 133–135.

SHUKLA S., PANDEY V., PACHAURI G., DIXIT B.S., BANERJI R., SINGH S.P., 2003. Nutritional contents of different foliage cuttings of vegetable amaranth. Plant Foods for Human Nutrition, *58*: 1–8.

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

THAKUR M.C., JOSHI A.K., SINGH N.P., SHUKLA Y.R., 1997. Variability studies in heading lettuce (*Lactuca sativa* L). Horticultural Journal, *10*: 43–49.

WALLACE P.A., MARFO E.K., PLAHAR W.A., 1998. Nutritional quality and antinutritional composition of four non-conventional leafy vegetables. Food Chemistry, *61*: 287–291.

WATSON C.A., 1994. Official and Standardized Methods of Analysis. 3rd Edition. Cambridge, The Royal Society of Chemistry: 6.

WATSON J.D., 1971. Investigations of the nutritive value of some Ghanaian food stuffs. Ghana Journal of Agricultural Sciences, *4*: 95–111.

WILSON H.D., 1980. Artificial hybridization among species of *Chenopodium* sect. *Chenopodium*. Systematic Botany, *5*: 253–263.

WILSON H.D., 1990. Quinua and relatives (*Chenopodium* sect. *Chenopodium* subsect. Cellulata). Economic Botany, *44*: 92–110.

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Variabilita a interakce genotypu a sklizně u jednotlivých nutričních složek druhu *Chenopodium album* L.

ABSTRAKT: V pokusu, uspořádaném v náhodných blocích se třemi opakováními, jsme hodnotili 13 genofondových linií rodu *Chenopodium* (*C. album*), používaného jako zelenina, abychom zjistili výnos nadzemních částí a jeho sedm kvalitativních složek ve třech po sobě následujících sklizních. Rovněž jsme sledovali variabilitu projevující se v zeleninovém merlíku a interakce vznikající na různých úrovních. Průměrný výnos nadzemních částí dosahoval maximálních hodnot u linie CA-II (3,03 ± 0,39 kg/dílec), následovaly linie CA-VII (2,94 ± 0,27 kg/dílec) a CA-VI (2,41 ± 0,20 kg/dílec). Obsah vlhkosti vykazoval u všech genofondových linií stálý pokles ve sklizních po sobě následujících s výjimkou linie CA-IX ve třetí sklizni. Obsah bílkovin vykazoval silný trend nárůstu s každou další sklizní a byl nejvyšší ve třetí sklizni. Nejvyšší dědivost obsahu bílkovin jsme zjistili v první sklizni (96,35 %), zatímco nejvyšší hodnoty kyseliny askorbové jsme naměřili ve druhé a třetí sklizni. Obsah karotenoidů a kyseliny askorbové trvale vykazoval ve všech třech sklizních vysoký genetický zisk.

Klíčová slova: *Chenopodium album*; výnos nadzemních částí; karotenoidy; bílkoviny; kyselina askorbová; interakce

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