Estimates of genetic variability in vegetable amaranth (*A. tricolor*) over different cuttings

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ABSTRACT: The present investigation was carried out to study different selection parameters for foliage yield and its important yield contributing traits in 29 strains of vegetable amaranth (*A. tricolor*). The data were recorded for plant height (cm), stem diameter (cm), branches/plant, leaves/plant, leaf size (cm^2), and protein content (mg/100 mg) in each cutting separately. Foliage yield (kg) was recorded on plot basis comprising 4 cuttings. The highest foliage yield per plot was recorded for strain AV-38, followed by AV-23 and AV-31. In general, protein content was high in the 2nd cutting in all strains. The heritability estimates were in general high for all the characters in all the cuttings and ranged from 74.87% to 93.33%. Genetic advance was maximum for foliage yield (42.50%), followed by leaf size (31.02%) and stem diameter (21.13%). It was concluded that foliage yield could be increased substantially in vegetable amaranth through indirect selection based on the characters leaf size and stem diameter.

Keywords: *A. tricolor*; foliage yield; heritability; genetic advance; selection

Amaranthus species have been cultivated as a leafy vegetable as well as an important subsidiary food crop for centuries (NRC 1984; Tucker 1986). Amaranth leaves are a rich and inexpensive source of dietary fibre, protein, vitamins and a wide range of minerals (Prakash, Pal 1991; Shukla et al. 2003). Unlike other leafy vegetables, amaranth does not require cold climate for good growth and can be cultivated during mild summers (Singh, Whitehead 1996). Vegetable amaranth serves as an alternative source of nutrition for vegetarian people in developing countries where the bulk of the population has little access to protein rich food. Besides its immense nutritional importance, it can grow successfully under varied soil and agro-climatic conditions (Katiyar et al. 2000; Shukla, Singh 2000).

Being a cheap source of protein, emphasis is laid on its genetic improvement to enhance its potentiality for foliage yield through different contributing traits. Through collection and selection programmes, a number of strains have been introduced and acclimatized in various parts of the world, but evaluation studies of yield and its contributing quantitative and qualitative traits are scarce (Shukla, Singh 2000, 2002). Improvement of foliage yield requires in-depth knowledge of the magnitude of variation present in the available germplasm, interdependence of quantitative characters with yield, extent of environmental influence on these factors, heritability and genetic gain of genetic material. Therefore, to fill the lacuna, an experiment was carried out to study different selection parameters for yield and important yield contributing traits to chalk out an effective breeding plan. The present study was conducted to quantify the foliage yield in different strains on the one hand and genetic variability among the strains on the other. Based on the biometrical studies a selection programme for the improvement of foliage yield through its contributing traits has been chalked out.

MATERIAL AND METHODS

The National Botanical Research Institute, Lucknow, has large collection of various species of grain and vegetable *Amaranthus*. 29 strains of vegetable amaranth (*A. tricolor*) were sown in March 2003 in a randomized block design with three replications in the experimental field of NBRI, Lucknow. The plot size for each treatment was 2 m^2 with row-to-row and plant-to-plant distance of 25 cm and 15 cm, respectively. Weeding was done once in 15 days to remove unwanted plants. Irrigation was applied as and when needed. The 1st cutting of foliage started after the 3rd week from sowing and subsequent cuttings were done at an interval of 15 days. The data were recorded on 10 randomly selected plants in each replication for plant height (cm), stem diameter (cm), branches/plant, leaves/plant, leaf size (cm^2) and protein content (mg/100 mg) in each cutting separately. Data on foliage yield (kg) was recorded on plot basis comprising 4 cuttings.

Heritability and genetic advance were calculated according to the method suggested by Johnson et al. (1955). The protein content in green leaves was estimated in mg/100 mg for each cutting following Lowry et al. (1951).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences between the strains in all the seven characters, which was validated by further statistical and genetic analyses (Table 1).

The mean performance of twenty-nine strains based on individual cuttings and their means for foliage yield is presented in Table 2. The strain AV-38, followed by AV-23 and AV-31, showed the highest foliage/plot and significantly outyielded the remaining strains by constituting a top non-significant group for higher foliage yield. In spite of this, AV-17 having high mean values for stem diameter, plant height, primary branches/plant and leaves/plant also showed the above-average mean performance for foliage yield. Similarly AV-18 exhibited high mean values for plant height, leaf size and stem diameter and it also had above-average mean performance for foliage yield. These strains may serve as promising for foliage yield and other yield contributing traits for which they showed high performance. The mean protein content ranged from 1.01 ± 0.07 (AV-29) to 1.49 ± 0.14 (AV-38) (Table 3). The strains AV-30 and AV-41 also showed considerably higher protein contents than the mean value. The highest protein content was found in the 2nd cutting. In general, it was observed that foliage yield was optimum in the 3rd cutting. The plant height, leaf size, stem diameter and protein content showed higher values generally in the 2nd and 3rd cuttings.

Genetic variability in the base population plays an important role in any crop-breeding programme. For an effective breeding programme it is essential to have a large amount of variation in the material at the hand of the breeder. The extent of diversity in a crop determines the limits of selection for improvement. The characters of economic importance are generally quantitative in nature and exhibit a considerable degree of interaction with environment. Thus it becomes necessary to compute variability present in the breeding material and its partitioning

Table 1. Analysis of variance for different characters in different cuttings in vegetable amaranth

Source		Degree of freedom	M.S.S.						
			plant height (cm)	number of primary branches	number of leaves	leaf size (cm^2)	stem diameter (cm)	foliage yield (kg/plot)	protein content (mg/100 mg)
Treatment	I	28	76.45**	14.12**	20.72**	49.38**	0.0475**	0.124**	0.160**
	II	28	18.97**	6.57**	7.44**	110.28**	0.0359**	0.311**	0.102**
	III	28	43.61**	9.60**	15.33**	33.00**	0.0158**	0.536**	0.086**
	IV	28	24.97**	12.73**	30.83**	33.70**	0.0114**	0.443**	0.194**
	P	–	7.65**	2.37**	4.94**	19.82**	0.0096**	0.132**	0.048**
Replication	I	2	1.90	4.29*	4.24**	6.48**	0.0019	0.002	0.010
	II	2	2.13	0.07	0.66	0.89	0.0040	0.032	0.020
	III	2	3.76*	0.81	1.64	3.61*	0.0002	0.091	0.084
	IV	2	1.08	10.69**	3.76*	0.17	0.0018	0.011	0.034
	P	–	0.51	0.08	0.76	1.16	0.0001	0.021	0.015
Error	I	56	5.54	5.17	5.04	2.17	0.0031	0.002	0.025
	II	56	1.72	0.51	1.42	5.09	0.0020	0.013	0.035
	III	56	6.78	2.31	2.57	7.05	0.0043	0.061	0.015
	IV	56	1.08	3.71	2.94	4.61	0.0006	0.027	0.025
	P	–	0.79	0.59	0.65	1.45	0.0006	0.019	0.007

For Tables 1, 4 and 5: *, ** – significance at 5% and 1%, respectively

I – cutting 1st, II – cutting 2nd, III – cutting 3rd, IV – cutting 4th, P – pooled cutting

Table 2. Mean values for foliage yield (kg/plot) in different cuttings of *A. tricolor*

Strains	Cuttings				Mean ± SE
	I	II	III	IV	
AV-11	0.35	0.64	1.76	1.40	1.04 ± 0.33
AV-12	0.17	0.74	1.12	0.78	0.70 ± 0.19
AV-13	0.15	0.83	1.34	1.03	0.84 ± 0.25
AV-14	0.03	0.41	1.28	0.81	0.63 ± 0.26
AV-15	0.09	0.94	1.09	0.57	0.67 ± 0.22
AV-16	0.11	0.62	1.36	1.37	0.87 ± 0.31
AV-17	0.43	0.95	1.68	0.33	0.85 ± 0.31
AV-18	0.44	0.90	1.61	1.30	1.06 ± 0.25
AV-19	0.13	1.14	1.42	0.45	0.79 ± 0.29
AV-20	0.11	0.71	1.51	1.48	0.95 ± 0.34
AV-21	0.22	0.97	2.01	1.05	1.06 ± 0.37
AV-22	0.03	0.64	1.82	0.74	0.81 ± 0.37
AV-23	0.80	0.90	1.45	1.55	1.18 ± 0.19
AV-24	0.17	0.54	1.18	1.36	0.81 ± 0.28
AV-25	0.30	0.98	1.13	1.15	0.89 ± 0.20
AV-26	0.18	0.56	1.07	0.43	0.56 ± 0.19
AV-28	0.03	0.47	1.31	1.11	0.73 ± 0.29
AV-29	0.02	1.27	1.57	0.55	0.85 ± 0.35
AV-30	0.66	1.44	1.40	1.10	1.15 ± 0.18
AV-31	0.18	1.65	2.13	0.69	1.16 ± 0.44
AV-33	0.35	0.51	0.74	0.48	0.52 ± 0.08
AV-36	0.24	1.26	1.84	1.20	1.35 ± 0.33
AV-37	0.03	1.00	1.82	0.89	0.94 ± 0.37
AV-38	0.09	1.20	2.36	1.14	1.19 ± 0.46
AV-40	0.08	0.96	1.57	0.58	0.79 ± 0.31
AV-41	0.62	0.72	0.51	0.36	0.55 ± 0.08
AV-42	0.29	1.30	0.74	0.35	0.67 ± 0.23
AV-43	0.13	0.33	0.92	1.04	0.61 ± 0.22
AV-45	0.02	0.36	1.55	1.39	0.83 ± 0.38
Mean	0.22	0.86	1.42	0.92	0.86
± SE	± 0.04	± 0.06	± 0.08	± 0.07	± 0.04
CD 5%	0.08	0.13	0.16	0.15	0.08
CV	91.15	39.06	29.57	41.30	23.54

into genotypic, phenotypic and environmental ones. In the present investigation maximum variability was observed for foliage yield in all cuttings (Table 4).

The values of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient of variation (GCV) for all the characters in all the cuttings as well as on pooled basis, though the differences were small in all the cuttings. Similar results were obtained by Rastogi et al. (1995) in *Brassica* and Revanappa and Madalageri (1998) in *Amaranthus*. The small differences between PCV and GCV for all the traits indicated that the variability was primarily due to genotypic differences.

In the strict sense, the question whether a character is hereditary or environmental has no meaning. The gene cannot cause a character to develop unless they have proper environment, and conversely manipulation of environment will not cause a character to develop unless necessary genes are present. Nevertheless, it must be recognized that the variability observed in some characters is caused primarily by differences in the genes carried by different individu-

Table 3. Mean values for protein content (mg/100 mg) in different cuttings of *A. tricolor*

Strains	Cuttings				Mean ± SE
	I	II	III	IV	
AV-11	0.93	1.39	1.17	0.99	1.12 ± 0.10
AV-12	1.27	1.11	1.01	1.04	1.11 ± 0.06
AV-13	1.19	1.55	1.09	1.30	1.28 ± 0.09
AV-14	1.19	1.23	1.16	1.46	1.26 ± 0.07
AV-15	0.98	1.13	1.04	1.05	1.05 ± 0.03
AV-16	0.94	1.38	1.04	0.96	1.08 ± 0.10
jAV-17	1.02	1.23	1.65	0.99	1.22 ± 0.15
AV-18	1.09	1.07	1.09	1.04	1.07 ± 0.01
AV-19	1.30	1.41	1.06	0.96	1.18 ± 0.10
AV-20	1.03	1.03	1.09	0.98	1.03 ± 0.02
AV-21	1.31	1.46	0.96	0.98	1.18 ± 0.12
AV-22	1.07	1.34	1.42	1.00	1.21 ± 0.10
AV-23	1.25	1.16	1.08	1.10	1.15 ± 0.04
AV-24	1.35	1.51	1.07	0.97	1.23 ± 0.12
AV-25	0.95	1.31	1.01	0.97	1.06 ± 0.08
AV-26	1.38	1.20	1.43	0.96	1.24 ± 0.10
AV-28	1.48	1.64	0.98	0.98	1.27 ± 0.17
AV-29	0.97	1.08	1.17	0.83	1.01 ± 0.07
AV-30	1.30	1.67	1.23	1.50	1.42 ± 0.09
AV-31	1.46	1.45	1.11	1.10	1.28 ± 0.10
AV-33	1.47	1.10	1.25	1.54	1.34 ± 0.10
AV-36	1.47	1.37	1.22	0.96	1.26 ± 0.11
AV-37	1.57	1.34	1.05	1.42	1.35 ± 0.10
AV-38	1.76	1.40	1.14	1.69	1.49 ± 0.14
AV-40	1.60	1.19	1.15	0.95	1.22 ± 0.13
AV-41	1.48	1.45	0.99	1.77	1.42 ± 0.16
AV-42	1.01	1.08	0.77	1.30	1.04 ± 0.11
AV-43	1.22	1.48	1.34	1.38	1.36 ± 0.05
AV-45	1.51	1.04	1.04	0.94	1.13 ± 0.13
Mean	1.26	1.30	1.13	1.14	1.21
SE	0.04	0.03	0.03	0.05	0.02
CD 5%	0.09	0.07	0.06	0.09	0.05
CV	18.35	14.16	14.96	22.27	10.64

als and that the variability in other characters is due to differences in the environment to which individuals have been exposed.

The knowledge of heritability of a character is important as it indicates the extent to which improvement is possible through selection (Robinson et al. 1949). It is a measure of the genetic relationship between parent and progeny and has widely been used to assess the degree to which a character may be transmitted from parent to offspring. It also indicates the relative importance of heredity and environment in the expression of these characters. The heritability estimates were in general high for all the characters in all the cuttings and ranged from 74.87% to 93.33%. Revanappa and Madalageri (1998) also observed high heritability values in amaranth. However, the estimates of heritability were low for primary branches/plant in all the cuttings except in the second cutting, compared to other characters. The high value of heritability also suggests that all the characters are under genotypic control. However, it will be pertinent to admit here that the total genotypic variance is made up of additive genetic variance and non-additive or unfixable variance.

Table 4. Genetic variability, heritability and genetic advance for different traits in *A. tricolor*

Characters		*F* value	Mean ± SE	Range	$\sigma^2 g$	$\sigma^2 p$	$\sigma^2 e$	GCV	PCV	Heritability (%)	Genetic gain	Genetic gain (%)
	I	13.79	11.21 ± 1.33	5.09–23.80	23.63	25.48	1.84	43.36	45.03	92.75	9.64	86.03
	II	11.02	17.60 ± 0.74	11.46–22.96	5.75	6.32	0.57	13.62	14.28	90.93	4.71	26.76
Plant height (cm)	III	6.42	22.53 ± 1.47	13.63–32.56	12.27	14.53	2.26	15.54	16.91	84.44	6.63	29.43
	IV	23.02	17.35 ± 0.59	11.16–21.86	7.96	8.32	0.36	16.26	16.62	95.66	5.68	32.76
	P	9.65	17.16 ± 0.50	13.29–20.55	2.28	2.55	0.26	8.80	9.30	89.64	2.94	17.18
	I	2.73	12.00 ± 1.29	8.06–15.13	2.98	4.70	1.72	14.39	18.07	63.38	2.83	23.60
	II	12.79	8.02 ± 0.40	5.46–10.76	2.01	2.19	0.17	17.70	18.44	92.18	2.81	35.02
Branches/plant	III	4.15	12.48 ± 0.86	10.00–16.83	2.43	3.20	0.77	12.48	14.32	75.95	2.79	22.41
	IV	3.42	15.92 ± 1.09	12.26–22.00	3.00	4.24	1.23	10.88	12.93	70.81	3.00	18.86
	P	3.97	12.10 ± 0.43	10.32–13.94	0.59	0.79	0.19	6.36	7.35	74.87	1.37	11.34
	I	4.11	13.79 ± 1.27	8.86–20.23	5.22	6.90	1.68	16.57	19.05	75.68	4.09	29.70
	II	5.20	12.94 ± 0.67	10.33–16.10	2.00	2.48	0.47	10.93	12.16	80.80	2.62	20.25
Leaves/plant	III	5.96	15.89 ± 0.90	12.33–21.26	4.25	5.11	0.85	12.98	14.22	83.24	3.87	24.39
	IV	10.47	13.97 ± 0.97	9.96–24.00	9.29	10.27	0.98	21.81	22.93	90.45	5.97	42.73
	P	7.56	14.15 ± 0.45	11.90–16.42	1.43	1.64	0.21	8.44	9.06	86.79	2.29	16.21
	I	22.75	13.15 ± 0.83	7.23–21.89	15.73	16.46	0.72	30.14	30.83	95.61	7.99	60.72
	II	21.63	18.09 ± 1.28	6.67–30.51	35.06	36.76	1.69	32.72	33.50	95.38	11.91	65.83
Leaf size (cm^2)	III	4.68	18.66 ± 1.50	11.80–25.56	8.65	11.00	2.35	15.76	17.77	78.64	5.37	28.79
	IV	7.30	13.37 ± 1.21	8.48–21.00	9.69	11.23	1.53	23.38	25.06	86.32	5.96	44.56
	P	13.62	15.81 ± 0.68	9.11–20.19	6.12	6.60	0.48	15.64	16.25	92.66	4.90	31.02
	I	15.13	0.43 ± 0.03	0.15–0.65	0.014	0.015	0.0010	27.69	28.66	93.39	0.24	55.14
	II	17.53	0.57 ± 0.02	0.41–0.84	0.011	0.012	0.0007	18.64	19.19	94.30	0.21	37.28
Stem diameter (cm)	III	3.63	0.63 ± 0.03	0.50–0.77	0.003	0.005	0.0010	9.81	11.53	72.48	0.10	17.21
	IV	17.08	0.43 ± 0.01	0.36–0.68	0.003	0.003	0.0002	13.79	14.21	94.15	0.11	27.56
	P	14.99	0.51 ± 0.01	0.41–0.60	0.003	0.003	0.0002	10.62	10.99	93.33	0.10	21.13

Table 4 to be continued

Characters		*F* value	Mean ± SE	Range	$\sigma^2 g$	$\sigma^2 p$	$\sigma^2 e$	GCV	PCV	Heritability (%)	Genetic gain	Genetic gain (%)
	I	6.35	1.26 ± 0.09	0.93–1.76	0.045	0.053	0.008	16.81	18.32	84.26	0.40	31.79
	II	2.83	1.30 ± 0.10	1.03–1.67	0.022	0.034	0.012	11.36	14.12	64.77	0.24	18.84
Protein (mg/100 mg)	III	5.50	1.13 ± 0.07	0.77–1.65	0.023	0.028	0.005	13.54	14.97	81.84	0.28	25.24
	IV	7.60	1.14 ± 0.09	0.83–1.77	0.056	0.064	0.008	20.70	22.21	86.86	0.45	39.74
	P	6.26	1.21 ± 0.04	1.01–1.49	0.013	0.016	0.002	9.62	10.49	84.05	0.22	18.17
	I	52.55	0.22 ± 0.02	0.02–0.80	0.040	0.041	0.008	89.43	90.29	98.10	0.41	182.47
	II	23.67	0.87 ± 0.06	0.33–1.65	0.099	0.103	0.004	35.84	36.62	95.78	0.63	72.26
Foliage yield (kg/plot)	III	8.69	1.42 ± 0.14	0.51–2.36	0.158	0.179	0.020	27.88	29.64	88.50	0.77	54.04
	IV	16.05	0.92 ± 0.09	0.33–1.55	0.138	0.147	0.009	40.32	41.65	93.77	0.74	80.46
	P	6.89	0.87 ± 0.07	0.51–1.19	0.037	0.044	0.006	22.31	24.13	85.50	0.37	42.50

In the present investigation it was not possible to partition the total genetic variance in these two subgroups and therefore the estimates of variability may be slightly higher.

High heritability alone does not guarantee large gain from selection unless sufficient genetic gain attributable to additive gene action is present. Genetic advance in a trait is the product of heritability and selection differential and has an added advantage over heritability as a guiding factor in a selection programme where characters to be improved are desired. The values of genetic advance varied in different cuttings for different characters. In the present study high heritability coupled with high genetic advance was recorded for foliage yield (42.50%), leaf size (31.02%) and stem diameter (21.13%), which indicated a major role of additive gene action in the inheritance of these characters. Earlier Shukla and Singh (2000) also obtained high values of heritability and genetic gain for the characters leaf size and foliage yield. Branches/plant and leaves/plant showed moderate and high heritability respectively, along with a low genetic advance, which points to a major role of non-additive gene action in the transmission of these characters from parents to offspring.

Coheritability is the ratio of genotypic to phenotypic covariances expressed in percentage and reveals simultaneous inheritance of the characters. The coheritability for different character combinations of four cuttings separately is presented in Table 5. In general, high values of coheritability were observed for all the traits in all the cuttings. The coheritability of foliage yield was highest with the combination of yield and protein followed by number of branches/plant and leaf size.

CONCLUSION

It is concluded from the present study that foliage yield can be increased substantially either through direct selection or through indirect selection based on the characters leaf size and stem diameter. The strains AV-38, AV-23 and AV-31 showed that they could be a more suitable and beneficial material for the isolation of promising plant types through an appropriate selection programme.

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Table 5. Coheritability among different traits in different cuttings of *A. tricolor*

		Plant height (cm)	Number of branches/plant	Number of leaves/plant	Leaf size (cm²)	Stem diameter (cm)	Protein content (mg/100 mg)
Foliage yield (kg/plot)	I	102.2	154.4	117.2	103.1	108.2	100.0
	II	100.9	101.3	105.2	105.8	158.3	79.6
	III	113.1	66.3	148.7	171.1	147.9	128.8
	IV	125.3	68.5	138.7	119.6	104.5	120.8
	P	105.3	131.3	123.6	125.5	89.6	180.0
Plant height (cm)	I		134.8	112.2	109.2	108.1	111.7
	II		113.8	123.7	104.8	103.0	63.1
	III		106.0	108.3	162.7	91.8	136.0
	IV		94.3	37.5	112.2	108.5	109.3
	P		124.2	94.7	109.6	104.4	511.1
Number of branches/plant	I			146.8	154.8	126.2	140.4
	II			98.9	121.9	102.4	157.2
	III			103.4	345.0	94.9	27.5
	IV			120.2	110.0	125.7	131.8
	P			117.3	130.5	114.7	134.5
Number of leaves/plant	I				135.6	122.3	132.9
	II				108.7	117.7	247.5
	III				48.7	101.4	259.0
	IV				95.1	106.0	80.8
	P				103.1	107.6	104.4
Leaf size (cm²)	I					105.5	112.4
	II					99.5	156.4
	III					91.9	109.2
	IV					80.9	129.6
	P					98.2	109.6
Stem diameter (cm)	I						111.4
	II						129.8
	III						99.8
	IV						122.8
	P						113.6

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Odhady genetické variability u laskavce trojbarevného (*A. tricolor*) zeleninového typu v několika sklizních

ABSTRAKT: Během šetření jsme sledovali různé parametry selekce na výnos listů a důležité výnosotvorné znaky u 29 kmenů laskavce trojbarevného (*A. tricolor*) zeleninového typu. Při každé sklizni jsme zaznamenávali odděleně údaje o výšce rostlin (v cm), tloušťce stonku (cm), počtu větví na rostlinu, počtu listů na rostlinu, velikosti listů (cm^2) a obsahu bílkovin (mg/100 mg). Ve čtyřech sklizních jsme výnos listů (kg) registrovali na jednotlivých pokusných dílcích. Nejvyšší výnos listů na pokusný dílec jsme zjistili u kmene AV-38, následovaly kmeny AV-23 a AV-31. Obsah bílkovin byl všeobecně vysoký u všech kmenů ve druhé sklizni. Odhady variability byly obecně vysoké pro všechny znaky ve všech sklizních a pohybovaly se od 74,87 % do 93,33 %. Genetický pokrok dosahoval maximální hodnoty u výnosu listů (42,50 %), následovala velikost listů (31,02 %) a tloušťka stonku (21,13 %). Z toho lze vyvodit, že nepřímou selekcí na základě znaků velikost listu a tloušťka stonku by bylo možné u laskavce trojbarevného zeleninového typu podstatně zvýšit výnos listů.

Klíčová slova: *A. tricolor*; výnos listů; dědivost; genetický pokrok; selekce

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