Genetic Association Analysis in Asiatic Radish (*Raphanus sativus* L.)

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Genotypic and phenotypic coefficient of variation, heritability, expected genetic advance and character association of root weight and its contributing characters were studied in 18 diverse genotypes of Asiatic radish (*Raphanus sativus* L.) at Indian Institute of Vegetable Research, Varanasi during spring/summer season 2000-2001. Wide range of genetic variability was observed in all the 18 genotypes of the radish for almost all characters. Relatively high genotypic and phenotypic coefficients of variation were recorded for leaf size, leaf weight/plant, leaf length, root size and leaf: root weight ratio. Leaf length, leaf size, leaf weight/plant, leaf: root length ratio and leaf: root weight ratio has high genetic advance as percent of mean alongwith high heritability. Correlation studied revealed that root weight should positively and significantly correlated with plant height, leaf length, leaf width, leaf size, leaf weight/plant, root length, root thickness, root size and leaf: root weight ratio, while negative and significant correlation were found with root shape at both phenotypic and genotypic levels. The characters *viz.* leaf weight, leaf length and root length showed strong positive direct effects while number of leaves/plant, root thickness and leaf size had less direct effects or root weight.

Key Words: Asiatic radish (*Raphanus sativus* L.), Correlation, GCV, Genetic Advance, Heritability, Path Analysis, PCV,

Asiatic radish (*Raphanus sativus* L.) is an important root vegetable grown for its enlarged fleshy roots and tender foliage. It is cultivated throughout the country and is consumed by all sections of people. Due to high yielding and early maturing nature, it can be easily fit in different cropping systems to get higher returns/unit area and time. A wide range of variability is available for root and shoot characters in radish, which may be utilized for its genetic improvement. Genetic improvement of crop is largely depending on the magnitude of genetic variability and the extent to which desirable traits are heritable. Lal and Srivastava (1975) reported high phenotypic and genotypic variability, heritability and genetic advance by utilizing few lines. Till now very little information is available on genetic association in this crop. Therefore, an attempt was made in the present investigation to estimate the extent of variability, heritability, genetic advance, correlation and path analysis by utilizing 18 divergent lines of Asiatic radish.

Materials and Methods

The experiment was carried out at the Research Farm, Indian Institute of Vegetable Research, Varanasi during spring/summer season 2000-2001. Eighteen divergent genotypes (lines) *viz.*, Moto Towai, IIVR-1, Sungro Chetki, IIVR-2, Hill Queen, IIVR-3, Hong Mong, Local-10, Pusa Chetki, Japanese White, Punjab Local, NIC-1569, C-2, NIC-7214, NIC-7215, Chinese Pink. Mooli Early and Mino Early were grown in randomized block design with three replications. Recommended cultural practices were adopted for proper growth and stand of the crop. The observations were recorded on five randomly selected plants on different characters *viz.*, plant height (cm), number of leaves/plant, leaf length (cm), leaf width (cm), leaf size (cm^2), leaf shape, leaf weight/plant (g), root length (cm), root thickness (cm), root size (cm^2), root shape, leaf: root length ratio, leaf: root weight ratio and root weight (g). The mean value obtained were used for determining phenotypic coefficient of variation and genotypic coefficient of variation (Burton and De Vane, 1953), heritability (Hanson *et al.,* 1956) and expected genetic advance (Johnson *et al.,* 1955). The correlation coefficients were calculated as per methods given by Al-Jibouri *et al.* (1958). The path analysis was performed according to the methods followed by Dewey and Lu (1959).

Results and Discussion

The analysis of variance revealed that all the characters were found statistically significant. The mean, range, genotypic and phenotypic coefficient of variation, heritability, genetic advance (GA) and GA as per cent of mean are given in Table 1. In the present study, the range of variation was high for leaf size followed by root weight, root size and leaf weight/plant. The genotypic and phenotypic variances were high for leaf size, leaf weight/plant, root size and root weight. Leaf size (27.78, 30.66 cm^2), leaf weight/plant (24.87, 27.60

Table 1. Estimates of range, mean, genotypic and phenotypic variance, (σg & σp), genotypic and phenotypic coefficient of variation (GCV, PCV), heritability, genetic advance and genetic advance as percent of mean for different characters in radish

Characters	Range Max.	Min.	Mean	SE±	MSS Values	5%	σg	σp	GCV	PCV	Heritability (b.s.)	GA	GA% of mean
Plant height (cm)	75.17	51.72	59.17	2.60	141.14	2.60	43.65	53.85	11.17	12.40	81.06	12.25	20.71
Number of leaves/plant	14.97	11.93	13.87	0.73	2.86	0.73	0.69	1.48	5.99	8.77	46.62	1.17	8.42
Leaf length (cm)	44.85	23.93	31.56	1.49	103.60	1.49	33.42	36.79	18.32	19.22	90.84	11.35	35.96
Leaf width (cm)	8.83	6.00	7.57	0.58	2.41	0.58	0.64	1.14	10.57	14.11	56.14	1.24	16.38
Leaf size (cm²)	391.53	160.63	239.36	26.95	13972.2	626.95	4294.42	5384.14	27.78	30.66	79.76	120.56	50.37
Leaf shape	5.18	3.19	4.11	0.26	0.96	0.26	0.29	0.38	13.10	15.20	76/32	0.97	23.58
Leaf wt./plant (g)	110.37	53.00	76.94	7.51	1183.03	7.15	366.12	450.82	24.87	27.60	81.21	35.52	46.17
Root length (cm)	32.77	25.20	28.19	1.89	16.27	1.89	3.63	9.02	6.76	10.65	40.24	2.49	8.83
Root thickness (cm)	4.50	2.97	3.67	0.30	0.97	0.30	0.28	0.42	14.42	17.66	66.67	0.89	24.25
Root size (cm²)	141.38	78.44	101.86	11.69	1295.43	11.69	363.37	568.69	18.71	23.41	63.90	31.39	30.82
Root shape	9.82	6.07	7.87	0.89	4.40	0.89	1.07	2.26	13.14	19.10	46.35	1.47	18.63
L: R length ratio	1.48	0.82	1.15	0.08	0.11	0.08	0.034	0.043	16.03	18.03	79.07	0.34	29.37
L : R wt. Ratio	0.82	0.43	0.59	0.06	0.04	0.06	0.012	0.017	18.57	22.10	70.59	0.19	32.14
Root wt. (g)	149.33	117.67	128.67	5.38	277.12	5.38	77.87	121.38	6.86	8.56	64.15	14.56	11.32

*, ** Significant at 5% and 1% levels, respectively   GA = Genetic Advance   L = Leaf,   R = Root   G = genotypic
Wt. = Weight   P = Phenotypic

g), root size (18.71, 23.41 cm²), leaf: root weight ration (1857,22.10), leaf length (18.32, 19.22) and leaf: root length ratio (16.03, 18.03) had high genotypic and phenotypic coefficient of variation value indicating the nature of genetic variability for these characters. The characters possessing high genotypic coefficients of variation value have better scope of improvement through selection. The influence of the environment on each trait could be determined on the basis of difference between phenotypic and genotypic coefficient of variation. The high difference between phenotypic and genotypic coefficient of variation for characters such as leaf size, leaf weight/plant and root size has shown wider range of variability and high covariance, therefore, indicating ample scope for effective improvement in these characters through selection. Other characters with low coefficient of variation are indication of less scope of selection. Similar results were reported by Pandey et al. (1981) and Khan et al. (1983) Characters such as plant height, leaf length, root weight, leaf: root length ratio and leaf shape had nearly equal genotypic and phenotypic coefficient of variation values indicating least influence of the environment on their expression. In such situation, selection can be effective on the basis of the phenotype alone with equal probability of success.

On the basis of genotypic coefficient of variation alone, it is not possible to determine the amount of heritable variation. It can be find out with greater degree of accuracy when heritability in conjunction with genetic advance is studied (Dudley and Moll, 1969). In the present study, all the characters showed high to moderate heritability. The high heritability was recorded for leaf length (90.84) followed by leaf weight/ plant (81.21), plant height (81.06), leaf size (79.76), leaf: root length ratio (79.07) and leaf shape (76.32). The characters which exhibited high heritability, suggested that the selection will be more effective whereas the characters showing low heritability indicated that the selection will be difficult as the expression of genotypes will be affected by the environmental factors (Arumugam and Muthu Krishnan, 1975). The higher heritability value may be attributed to additive gene action (Majumdar et al., 1969). The estimate of genetic advance expressed as percentage of mean showed a wide range from 8.42 for number of leaf/plant to 50.37 for leaf size. Thus, the highest genetic advance was expressed by number of leaves/ plant followed by leaf weight/plant, leaf length, leaf: root weight ratio and root size. High heritability estimates in conjunction with high genetic advance is more useful than heritability alone in predicting the results and for selecting the best individual. High heritability alongwith high genetic advance observed for leaf length, leaf size, leaf weight/plant, leaf : root length ratio and leaf : root weight ratio indicated greater scope for improvement for the characters in breeding programme (Sirohi and Kutty, 2000; Singh et al., 2001).

Estimates of correlation coefficients among yield contributing characters in radish population at genotypic and phenotypic level are presented in Table 2. In present investigation, root weight was found to be significantly and positively associated with plant height, leaf length, leaf width, leaf size, leaf weight/plant, root length, root

Table 2. Phenotypic and genotypic correlation coefficients for different traits in radish

Characters	No. of leaves/ plant	Leaf length (cm)	Leaf width (cm)	Leaf size (cm2)	Leaf shape	Leaf wt/ plant (g)	Root length (cm)	Root thickness (cm)	Root size (cm2)	Root shape	L : R length ratio	L : R wt ratio	Root wt (g)
Plant height (cm)	**0.217**	**0.896****	**0.615****	**0.881****	**0.518****	**0.734****	**0.614****	**0.721****	**0.860****	**-0.288**	**0.547***	**0.657****	**0.508***
	0.314	0.954**	0.754**	0.968**	0.691**	0.850**	0.598**	0.830**	0.902**	-0.586*	0.780**	0.778**	0.797
No. of leaves/plant		**0.301**	**0.275**	**0.318**	**0.111**	**0.483***	**-0.073**	**-0.331**	**0.225**	**-0.331**	**0.312**	**0.540***	**0.134**
		0.340	0.375	0.390	0.152	0.569**	0.067	0.298	0.266	-0.213	0.317	0.624**	0.326
Leaf length (cm)			**0.602****	**0.933****	**0.683****	**0.785****	**0.233**	**0.779****	**0.732****	**-0.562***	**0.852****	**0.719****	**0.515***
			0.696**	0.971**	0.810**	0.847**	0.329	0.881**	0.844**	-0.767	0.933**	0.823**	0.647**
Leaf width (cm)				**0.840****	**-0.164**	**0.533***	**0.337**	**0.468***	**0.521***	**-0.179**	**0.407**	**0.500***	**0.332**
				0.848**	0.149	0.607**	0.569*	0.575*	0.669**	-0.230	0.525*	0.571*	0.528*
Leaf size (cm²)					**0.381**	**0.758****	**0.322**	**0.737****	**0.736****	**-0.452****	**0.737****	**0.694****	**0.503***
					0.647**	0.829**	0.469*	0.834**	0.854**	-0.615**	0.849**	0.801**	0.660**
Leaf shape						**0.476***	**-0.069**	**0.509***	**0.385**	**-0.537***	**0.705****	**0.427**	**0.323**
						0.660**	-0.042	0.729**	0.594*	-0.865**	0.872**	0.664**	0.431
Leaf wt/plant (g)							**0.193**	**0.633****	**0.599****	**-0.484***	**0.658****	**0.946****	**0.615****
							0.384	0.701**	0.729**	-0.555*	0.742**	0.971**	0.806**
Root length (cm)								**0.226**	**0.640****	**0.376**	**-0.306**	**0.131**	**0.219**
								0.381	0.668	0.099	-0.302	0.229	0.701**
Root thickness (cm)									**0.889****	**-0.792****	**0.644****	**0.527***	**0.533***
									0.941**	-0.885**	0.795**	0.587*	0.777**
Root size (cm²)										**-0.450**	**0.373**	**0483***	**0.535**
										-0.676**	0.644**	0.579**	0.777**
Root shape											**-0.753****	**-0.421**	**-0.379**
											-0.858**	-0.492*	-0.520*
L : R length ratio												**0.625****	**0.387**
												0.775**	0.421
L : R weight ratio													**0.332**
													0.642**

*, **, Significant at 5% and 1% levels, respectively L = Leaf, R = Root
Figures presented in bold are phenotypic values

thickness, root size and leaf : root weight ratio, while negative and significant correlation were found with root shape at genotypic and phenotypic levels. Therefore, these characters should be taken into consideration while making selection for improvement of root yield. Leaf: root weight ratio showed significant and positive correlations with all the characters except root length and root shape at both the levels. Muthu Krishan and Arumugam (1977) and Khan et al. (1983) were found significant positive association between yield and leaf length, root length and root weight and leaf weight.

Path coefficient at phenotypic level revealed that leaf weight/plant (2.988), leaf length (0.656), root length (0.152), leaf size (0.081), root thickness (0.049) and number of leaves/plant (0.046) had highest positive direct effect on root weight, indicating these are the main contributors to yield (Table 3). Leaf weight had high direct positive effects towards root weight whereas number of leaves/plant (0.049), root thickness (0.049) and leaf size (0.081) had less direct effects on root weight. High direct negative effects were observed for leaf: root weight ratio (-2.469), root size (-0.453), leaf:

Table 3. Direct (Diagonal) and indirect effect of leaf and root attribute on root weight (phenotypic level)

Characters	Plant height	No. of leaves	Leaf length	Leaf width	Leaf size	Leaf shape	Leaf weight	Root length	Root thickness	Root size	Root shape	L : R length	L : R wt ratio	Pheno corrl. with root wt
Plant height (cm)	-0.108	0.010	0.587	-0.103	0.071	-0.089	2.193	0.093	0.035	-0.390	0.071	-0.223	-1.640	0.508*
No. of leaves/plant	-0.0.023	0.046	0.197	-0.046	0.026	-0.019	1.444	-0.011	0.016	-0.102	0.082	-0.127	-1.348	0.134
Leaf length (cm)	-0.097	0.014	0.656	-0.101	0.076	-0.117	2.345	0.035	0.038	-0.332	0.139	-0.347	-1.795	0.515*
Leaf width (cm)	-0.067	0.013	0.395	-0.167	0.068	0.028	1.593	0.051	0.023	-0.236	0.014	-0.166	-1.248	0.332
Leaf size (cm²)	-0.095	0.015	0.612	-0.141	0.081	-0.065	2.266	0.049	0.036	-0.334	0.112	-0.300	-1.732	0.503*
Leaf shape	-0.056	0.005	0.448	0.027	0.031	-0.171	1.421	-0.011	0.025	-0.175	0.133	-0.287	-1.067	0.323
Leaf weight (g)	-0.076	0.022	0.515	-0.089	0.061	-0.081	2.988	0.029	0.031	-0.272	0.120	-0.268	-2.362	0.615**
Root length (cm)	-0.066	-0.003	0.153	-0.56	0.026	0.012	0.577	0.152	0.011	-0.290	-0.093	0.125	-0.326	0.219
Root thickness (cm)	-0.078	0.015	0.511	-0.078	0.060	-0.087	1.891	0.034	0.049	-0.403	0.196	-0.262	-1.315	0.533*
Root size (cm²)	-0.093	0.010	0.480	0.087	0.060	-0.066	1.790	0.097	0.043	-0.453	0.112	-0.152	-1.206	0.535*
Root shape	0.031	-0.015	-0.368	0.030	-0.037	0.092	-1.445	0.057	-0.039	0.204	-0.248	0.307	1.051	-0.379
L : R length ratio	-0.059	0.014	0.558	-0.068	0.060	-0.121	1.967	-0.047	0.031	-0.169	0.187	-0.407	-1.560	0.387
L : R wt Ratio	-0.071	0.025	0.471	-0.048	0.056	-0.073	2.827	0.020	0.026	-0.219	0.104	-0.225	-2.496	0.332

*, ** Significant at 5% and 1% levels, respectively. The residual effect (Phenotypic) = 0.0188

root length ratio (-0.43), root shape (-2.496), root size (-0.453), leaf: root length ratio (-0.43), root shape (-0.248), leaf shape (-0.17), leaf width (-0.16) and plant height (-0.108) at phenotypic levels.

Root size had positive and significant association with plant height, leaf length, leaf width, leaf size, leaf shape, leaf weight/plant, root length and root thickness. Thus, in selection programme, more emphasis should be given for these characters due to more direct and indirect effect on root weight. In this study, the residual effect was relatively low (0.0188) indicating that adequate characters were utilized for the study. It is also evident that root shape, leaf width, root size, leaf : root weight ratio, leaf : root length ratio, leaf shape and plant height had the negative direct and indirect effect on root weight, thus these characters should be rejected during selection programme.

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