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Genetic Analysis for Foliage Yield Attributes in Vegetable Red Amaranth (*Amaranthus tricolor* L.)

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A B S T R A C T

The present investigation was undertaken to know genetic variability, correlation and path coefficient among yield and its contributing characters in 23 germplasm of red Amaranth collected from different parts of India. The experiment was laid at Pt KLS College of Horticulture and Research Station, Rajnandgaon, Chhattisgarh during 2018-19. The experiment was laid out in randomized complete block design (RCBD) with three replications. High magnitude of genotypic as well as phenotypic coefficient of variations were recorded for traits dry stem, dry plant weight, harvest index, leaf stem ratio and fresh stem weight suggested the substantial improvement on amaranth through selection for these traits. High heritability coupled with high genetic advance was observed for dry stem weight, dry plant weight, leaf stem ratio, fresh stem weight, dry leaf weight, harvest index, leaf area, plant fresh weight, fresh leaf weight indicating that most likely the heritability is due to additive gene effects and selection may be effective. The correlation coefficient analysis revealed that number of leaves per plant and fresh stem weight exhibited the significant positive correlation with leaf yield. Hence, direct selection for these traits may lead to the development of high yielding genotypes of amaranth. The path coefficient analysis revealed that the fresh stem weight, dry leaf weight, petiole length, leaf length, leaf stem ratio, dry stem weight, plant fresh weight, plant height and stem base diameter should be considered in selection criteria for increasing leaf yield.

Introduction

Amaranth (Chaulai) is one of the important and popular leafy vegetable of India. Vegetable amaranth belongs to the genus Amaranthus and family Amaranthaceae, composed by approximately 60-70 species. Amaranth (*Amaranthus spp*.) includes a group of versatile food crops exhibiting high adaptability to new environments, even in the presence of different biotic and abiotic stresses (Rana *et al.*, 2007). Red amaranthis a rich source of nutrients it serves as an alternative source of nutrition for rural people in India. In spite of the excellent nutritional qualities of amaranth, not much work has been done on its genetic improvement to increase its foliage yield potential.

Generally the success of any crop improvement program largely depends on the magnitude of genetic variability, heritability, genetic advance, and character association. Genetic variability is important for selection of parents with transgressive segregation (Patro & Ravisankar, 2004). Heritability estimates provide information on the proportion of phenotypic variance that is due to genetic factors for different traits, but these estimates alone are not a sufficient measure of the level of possible genetic progress. Effective selection can be made when the value of broad sense heritability estimates is considered together with the selection differential or genetic advance (Ibrahim & Hussein, 2006). Knowledge of correlation between yield and its contributing characters are basic and for most endeavour to find out guidelines for plant selection. Partitioning of total correlation into direct and indirect effect by path coefficient analysis helps in making the selection more effective.

Materials and Methods

The present investigation was conducted at Pt KLS College of Horticulture and Research Station, Rajnandgaon, Chhattisgarh during 2018-19. Twenty three diverse genotypes of vegetable amaranth were collected from different agro climatic regions of country (Table 1) and evaluated for various yield and yield attributing traits, correlation and path coefficients were worked out. The single factor experiment was laid out in randomized complete block design (RCBD) with three replications. The seeds are sown in direct field at the distance 15cm for row to row and 5 cm for plant to plant was maintained and the plot size was 1m^2.

Recommended package of practices were adopted for better crop growth. Five competitive plants were selected randomly from each plot to record observation on various characters. Statistical analysis was done by using method suggested by Panse and Sukhatme (1978).

Genotypic and phenotypic coefficients of variation were calculated using the formulae of Burton (1952). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) as suggested by Sivasubramanian and Madhavamenon (1973).

The broad sense heritability was estimated for all the characters as the ratio of genotypic variance to total or phenotypic variance (Lush, 1940). The heritability values were classified as low (<50%), moderate (50%-70%) and high (>70%) as suggested by Robinson (1966). The magnitude of genetic advance as percentage of mean easy categorized as high (>20%), moderate (20- 10%) and low (<10%) as suggested by Johnson *et al.*, (1955).

The correlation coefficients were determined using variances and co variances to obtain relationship among various characters and their relationship with leaf yield per plant both at genotypic and phenotypic levels by Al-jibouri *et al.*, (1958).

The methodology suggested by Wright (1921) and the formula given by Dewey and Lu (1959) to carry out path coefficient analysis to measure the direct influence of one variable upon the other and to partition the total correlation into direct and indirect effects.

Results and Discussion

The analysis of variance of all the characters under study revealed that mean sum of squares due to genotypes was highly significant for all the studied characters. This is an indication of existence of sufficient variability among the genotypes for leaf yield and its component traits. These findings are in general agreement with the findings of Shukla *et al.,* (2005) and Joshi *et al.,* (2011).The extent of variability present in twenty three genotypes of vegetable amaranth was measured in terms of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance as per cent of mean (GAPM) (Table 2).

Variability refers to the presence of differences among the individuals of a population. Variability is essential for wide adaptability and resistance to biotic and abiotic factors and hence, an insight into the magnitude of genetic variability present in a population is of paramount importance to a plant breeder for starting a judicious breeding programme. The phenotypic and genotypic variances measure the magnitude of variation arising out of difference in phenotypic and genotypic values. The absolute values of phenotypic and genotypic variances cannot be used for comparing the magnitude of variability for different characters, since the mean and units of measurement of the characters may be different. Hence, the coefficients of variation expressed at phenotypic and genotypic levels have been used. The phenotypic coefficient of variation was marginally higher than the corresponding genotypic coefficient of variation indicated the influence of environment in the expression of the character under study (Table 2). High magnitude of genotypic as well as phenotypic coefficient of variations were recorded for traits *viz*., dry stem weight (32.00 and 33.41 %), dry plant weight (28.88 and 31.41 %), harvest index % (28.32 and 20.07 %), leaf stem ratio (27.14 and 30.39 %), fresh stem weight (25.60 and 27.81 %), suggested the substantial improvement on amaranth through selection for these traits. The results are in consonance with Dhangrah *et al.,* (2015) and Gerrano *et al.,* (2015).Moderate GCV and PCV were recorded for dry leaf weight (18.41 and 21.29 %), leaf area (18.38 and 21.91 %) fresh leaf weight (15.85 and 21.67 %), plant fresh weight (15.68 and 18.78 %), petiole length (10.73 and 16.71 %), leaf length (10.60 and 15.23 %) and leaf width (10.28). Suggested existence of considerable variability in the population. Selection for these traits may also be given the importance for improvement programme. Similar findings were also reported earlier by Anuja and Mohideen (2007a) and Venkatesh *et al.,* (2014b).

Heritability estimate provide the information regarding the amount of transmissible genetic variation to total variation and determine genetic improvement and response to selection. In the present investigation high magnitude of heritability was recorded for most of characters. The highest heritability was recorded for the characters dry stem weight (91.7 %), fresh stem weight (84.7 %), dry plant weight (84.6 %), harvest index % (83.3 %), Leaf stem ratio (79.7%), dry leaf weight (74.8 %), leaf area (70.4 %). Similar results reported by Shukla *et al*., (2006), Anuja and Mohideen (2007a), Das and Kumar (2012). The moderate heritability was observed for Plant fresh weight (69.8 %) and Fresh leaf weight (53.5 %). High genetic advance as percentage of mean was observed for dry stem weight (66.66),dry plant weight (56.66 %), leaf stem ratio (50.57 %), fresh stem weight (48.68 %), dry leaf weight (34.48 %), harvest index % (34.43 %), leaf area (31.76 %), plant fresh weight (26.90 %) and fresh leaf weight (23.84 %). The high value of genetic advance for these traits showed that these characters are governed by additive genes and selection will be rewarding for the further improvement of such traits. Heritability estimates along with genetic advance are more useful than the heritability value alone for selecting the best individual. High heritability coupled with high genetic advance was observed for dry stem weight, dry plant weight, leaf stem ratio, fresh stem weight, dry leaf weight, harvest index, leaf area, plant fresh weight, fresh leaf weight indicating that most likely the heritability is due to additive gene effects and selection may be effective. Therefore, selection based on phenotypic performance of these traits would be effective to select desirable plant type. Similar results were also reported Shukla *et al.,* (2005), Anuja and Mohideen (2007a) and Pan *et al.,* (2008).

Association analysis is an important approach in a breeding programme. It gives an idea about relationship among the various characters and determines the component characters, on which selection can be used for genetic improvement in the foliage yield.

The phenotypic correlations were normally of genetic and environmental interaction which provided information about the association between the two characters. Genotypic correlation provided a measure of genetic association between the characters and normally used in selection, while environmental as well as genetic architecture of a genotypes plays a great role in achieving higher yield combined with better quality.

The genotypic and phenotypic correlation for leaf yield and its component in amaranth are presented in Table 3. Plant height showed significant negative correlation with leaf stem ratio, harvest index, number of branches per plant, leaf length, leaf width. Number of branches per plant positively associated with harvest index and also showed significant negative correlation with petiole length. Number of leaves per plant exhibited positive association with fresh stem weight, petiole length, leaf yield, on other hand, it also showed negative correlation with leaf length, leaf stem ratio.

Leaf stem ratio showed significant positive correlation with leaf length, leaf width, leaf area and dry leaf weight at both phenotypic and genotypic levels, whereas, leaf stem ratio exhibited positive association with fresh leaf weight and it also negatively associated with number of leaves per plant at genotypic level only. Plant fresh weight expressed positive correlation with fresh leaf weight and dry leaf weight whereas, fresh leaf weight showed significant positive correlation with dry leaf weight, dry plant weight, leaf stem ratio.

Harvest index showed significant positive correlation with leaf area, leaf stem ratio, number of branches per plant, leaf width showed significant positive correlation with this traits (harvest index), whereas number of leaves per plant showed significant negative correlation with harvest index. The findings clearly indicated that genotypic correlations were of higher magnitude to the corresponding phenotypic ones, thereby establishing strong inherent relationship among the characters studied. The low phenotypic value might be due to appreciable interaction of the genotypes with the environments.

An overall observation of correlation coefficient analysis revealed that number of leaves per plant and fresh stem weight exhibited the significant positive correlation with leaf yield (kg/ plot). Hence, direct selection for these traits may lead to the development of high yielding genotypes of amaranth. The present findings are in conformity with Navangburuka and Denton (2012), Ahammed *et al.,* (2013) Akaneme and Ani (2013) and Arif *et al.,* (2013).

Table.1 Treatment Details

S. No.	Treatments/Genotypes	Source
01	AMAR-01	Local collection from Hyderabad
02	AMAR-02	Local collection from Delhi
03	AMAR-03	Local collection from Delhi
04	AMAR-04	Local collection from Raipur
05	AMAR-05	Local collection from Jalna
06	AMAR-06	Local collection from Faizabad
07	AMAR-07	Local collection from Bemetra
08	AMAR-08	Local collection from Mungeli
09	AMAR-09	Local collection from Raipur
10	AMAR-10	Local collection from Kolkata
11	AMAR-11	Local collection from Mungeli
12	AMAR-12	Local collection from Rajnandgaon
13	AMAR-13	Local collection from Hyderabad
14	AMAR-14	Local collection from Rajnandgaon
15	AMAR-15	Local collection from Bilaspur
16	AMAR-16	Local collection from Janjgir
17	AMAR-17	Local collection from West Bengal
18	AMAR-18	Local collection from Raipur
19	AMAR-19	Local collection from Bilaspur
20	AMAR-20	Local collection from Raipur
21	AMAR-21	Local collection from Raipur
22	AMAR-22	Local collection from Rajnandgaon
23	PusaLalChaulai	Check variety from IARI, New Delhi

Table.2 Genetic parameter of variability for leaf yield and its quantitative characters in amaranth

S..No.	Character	Mean	Range		Coefficient of variation (%)		Heritability (h^2 %)	GA as percent of mean
			Min.	Max.	GCV	PCV		
01	Plant height (cm)	15.88	12.89	17.96	7.13	12.48	32.6	8.37
02	No. of branches per plant	3.11	2.67	3.53	4.59	8.83	27.0	4.82
03	Stem base diameter (cm)	0.35	0.30	0.40	5.85	8.51	47.2	8.57
04	No. of leaves per plant	7.46	6.40	8.13	5.32	9.36	32.3	6.30
05	Leaf length (cm)	4.59	3.82	6.10	10.60	15.23	48.4	15.25
06	Leaf width (cm)	3.75	3.05	4.82	10.28	14.85	47.9	14.66
07	Leaf area (cm^2)	18.70	14.13	26.86	18.38	21.91	70.4	31.76
08	Petiole length (cm)	2.91	2.27	3.47	10.73	16.71	41.2	14.08
09	Plant fresh weight (gm)	3.42	2.35	4.76	15.68	18.78	69.8	26.90
10	Fresh leaf weight (gm)	1.51	0.95	2.06	15.85	21.67	53.5	23.84
11	Fresh stem weight (gm)	1.52	0.95	2.37	25.60	27.81	84.7	48.68
12	Dry leaf weight (gm)	0.29	0.22	0.43	18.41	21.29	74.8	34.48
13	Dry stem weight (gm)	0.12	0.07	0.19	32.00	33.41	91.7	66.66
14	Dry plant weight (gm)	0.30	0.21	0.49	28.88	31.41	84.6	56.66
15	Foliage yield (kg/plot)	474.68	360.67	602.87	9.64	14.34	45.2	13.35
16	Leaf stem ratio	0.87	0.57	1.63	27.14	30.39	79.7	50.57
17	Harvest Index(%)	82.06	57.93	122.98	28.32	20.07	83.3	34.43

Table.3 Genotypic and phenotypic correlation coefficient between leaf yield and its quantitative characters in amaranth

Characters		01. Plant height (cm)	02. No. of Branches per plant	03. Stem base diameter (cm)	04. No. of leaves Per plant	05. Leaf length (cm)	06. Leaf width (cm)	07. Leaf Area (cm^2)	08. Petiole length (cm)	09. Plant fresh weight (gm)	10. Fresh Leaf weight (gm)	11. Fresh stem weight (gm)	12. Dry Leaf weight (gm)	13. Dry stem weight (gm)	14. Dry plant weight (gm)	15. Foliage yield (kg/plot)	16. leaf stem ratio	17. Harvest Index (%)
01	P	**1.000**	-0.305	0.282	0.198	-0.061	0.067	-0.154	0.181	0.185	-0.072	0.325	-0.133	0.100	0.040	0.069	-0.512*	-0.528*
	G	**1.000**	-0.659**	0.028	0.534	-0.720**	-0.502*	-0.462	0.407	0.389	-0.048	0.539	-0.348	0.173	0.127	-0.071	-0.828**	-0.843**
02	P		**1.000**	-0.175	-0.164	-0.017	0.071	0.136	-0.040	-0.206	0.076	-0.035	0.024	-0.032	0.024	-0.018	0.095	0.226
	G		**1.000**	0.129	-0.254	0.390	0.340	0.322	-0.491*	-0.365	-0.043	0.178	-0.238	-0.015	0.115	0.150	0.320	0.675**
03	P			**1.000**	0.276	0.342	0.250	0.140	0.270	0.279	0.167	0.460	0.010	0.128	0.233	0.229	0.054	0.202
	G			**1.000**	0.516	0.211	0.378	0.199	0.431	0.483*	0.242	0.633**	0.112	0.205	0.347	0.281	0.227	0.299
04	P				**1.000**	-0.167	-0.283	-0.453	0.294	0.101	-0.074	0.492*	-0.148	0.210	0.222	0.283	-0.226	-0.294
	G				**1.000**	-0.506*	-0.812	-0.810	0.710**	0.302	-0.189	0.852**	-0.200	0.307	0.262	0.490*	-0.507*	-0.488*
05	P					**1.000**	0.711**	0.811**	0.227	0.313	0.468	-0.058	0.441	0.075	0.346	0.254	0.586*	0.547*
	G					**1.000**	0.904**	0.936**	0.220	0.477	0.868**	-0.081	0.757**	0.096	0.474	0.416	0.927**	0.895**
06	P						**1.000**	0.727**	0.050	0.201	0.358	-0.116	0.329	0.103	0.257	0.114	0.493*	0.403
	G						**1.000**	0.983**	-0.011	0.259	0.580	-0.129	0.459	0.049	0.379	0.077	0.784**	0.800**
07	P							**1.000**	-0.047	0.234	0.523*	-0.226	0.477	-0.052	0.274	0.156	0.614**	0.605*
	G							**1.000**	-0.096	0.328	0.753**	-0.259	0.640**	-0.084	0.298	0.128	0.795**	0.814**
08	P								**1.000**	0.316	0.234	0.328	0.055	0.445	0.363	0.112	-0.085	-0.120
	G								**1.000**	0.503*	0.456	0.518*	0.090	0.700**	0.697**	0.368	-0.192	-0.045
09	P									**1.000**	0.454	0.163	0.360	0.020	0.247	0.150	0.056	-0.042
	G									**1.000**	0.705**	0.211	0.488*	0.006	0.379	0.222	0.064	-0.067
10	P										**1.000**	-0.122	0.598*	0.175	0.483*	0.149	0.374	0.319
	G										**1.000**	-0.095	0.852**	0.300	0.690**	0.225	0.506	0.477
11	P											**1.000**	-0.192	0.063	0.202	0.437	-0.290	-0.170
	G											**1.000**	-0.202	0.082	0.240	0.834**	-0.344	-0.220
12	P												**1.000**	0.053	0.418	0.161	0.493*	0.252
	G												**1.000**	0.071	0.528*	0.275	0.612**	0.344
13	P													**1.000**	0.389	-0.073	-0.130	-0.009
	G													**1.000**	0.129	-0.197	-0.147	0.003
14	P														**1.000**	0.201	0.252	0.159
	G														**1.000**	0.254	0.310	0.167
15	P															**1.000**	0.093	0.156
	G															**1.000**	0.125	0.226
16	P																**1.000**	0.725**
	G																**1.000**	0.882**
17	P																	**1.000**
	G																	**1.000**

Table.4 Direct and indirect effect of component character on leaf yield in amaranth (*Amaranthus tricolor L.)*

Characters	Plant height (cm)	No. of Branches per plant	Stem base diameter (cm)	No. of leaves Per plant	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Petiole length (cm)	Plant fresh weight (gm)	Fresh leaf weight (gm)	Fresh stem weight (gm)	Dry leaf weight (gm)	Dry stem weight (gm)	Dry plant weight (gm)	leaf stem ratio	Harvest Index (%)	Foliage yield (kg/plot)
Plant height (cm)	**-0.355**	0.048	-0.009	0.007	-0.373	0.032	-0.023	0.279	-0.204	0.002	0.593	-0.266	-0.128	-0.031	0.647	-0.290	-0.071
No. of branches per plant	0.234	**-0.073**	-0.040	-0.004	0.202	-0.022	0.016	-0.336	0.191	0.002	0.196	-0.182	0.011	-0.028	-0.250	0.232	0.150
Stem base diameter (cm)	-0.010	-0.009	**-0.306**	0.007	0.110	-0.024	0.010	0.295	-0.253	-0.009	0.696	0.085	-0.151	-0.085	-0.177	0.103	0.281
No. of leaves per plant	-0.190	0.019	-0.158	**0.014**	-0.263	0.052	-0.041	0.487	-0.159	0.007	0.938	-0.153	-.228	-0.065	0.396	-0.168	0.490
Leaf length (cm)	0.256	-0.029	-0.065	-0.007	**0.519**	-0.061	0.047	0.151	-0.250	-0.032	-0.089	0.579	-0.071	-0.117	-0.724	0.308	0.416
Leaf width (cm)	0.178	-0.025	-0.116	-0.011	0.487	**-0.065**	0.049	-0.008	-0.136	-0.022	-0.142	0.351	-0.036	-0.093	-0.612	0.275	0.077
Leaf area (cm^2)	0.164	-0.024	-0.061	-0.011	0.486	-0.063	**0.050**	-0.066	-0.172	-0.028	-0.285	0.490	0.062	-0.073	-0.621	0.280	0.128
Petiole length (cm)	-0.144	0.036	-0.132	0.010	0.114	0.001	-0.005	**0.686**	-0.264	-0.017	0.570	0.069	-0.519	-0.172	0.150	-0.015	0.368
Plant fresh weight (gm)	-0.138	0.027	-0.148	0.004	0.247	-0.017	0.016	0.345	**-0.524**	-0.026	0.232	0.374	-0.004	-0.093	-0.050	-0.023	0.222
Fresh leaf weight (gm)	0.017	0.003	-0.074	-0.003	0.450	-0.037	0.038	0.313	-0.370	**-0.037**	-0.105	0.652	-0.222	-0.170	-0.395	0.164	0.225
Fresh stem weight (gm)	-0.192	-0.013	-0.194	0.012	-0.042	0.008	-0.013	0.355	-0.111	0.004	**1.100**	-0.155	-0.061	-0.059	0.269	-0.076	0.834
Dry leaf weight (gm)	0.124	0.017	-0.034	-0.003	0.392	-0.030	0.032	0.062	-0.256	-0.032	-0.223	**0.766**	-0.052	-0.130	-0.478	0.199	0.275
Dry stem weight (gm)	-0.062	0.001	-0.063	0.004	0.050	-0.003	-0.004	0.480	-0.003	-0.011	0.090	0.054	**-0.741**	-0.106	0.115	0.001	-197
Dry plant weight (gm)	-0.045	-0.008	-0.106	0.004	0.246	-0.024	0.015	0.478	-0.199	-0.026	0.265	0.404	-0.318	**-0.246**	-0.242	0.057	0.254
Leaf stem ratio	0.294	-0.023	-0.069	-0.007	0.481	-0.051	0.040	-0.132	-0.034	-0.019	-0.379	0.469	0.109	-0.076	**-0.781**	-0.304	0.125
Harvest Index(%)	0.299	-0.050	-0.092	-0.007	0.464	-0.052	0.041	-0.031	0.035	-0.018	-0.242	0.264	-0.002	-0.041	-0.689	**0.344**	0.226

Residual value: 0.4712, Diagonal and bold underline figures shows direct effect on leaf yield

Path coefficient analysis is an important tool for partitioning the correlation coefficients into the direct and indirect effects of independent variables on a dependent variable. With the inclusion of more variables in correlation study, their indirect association becomes more complex. Two characters may show correlation, just because they are correlated with a common third one. In such circumstances, path coefficient analysis provides an effective means of a critical examination of specific forces action to produce a given correlation and measure the relative importance of each factor.

In this analysis, leaf yield was taken as dependent variable and the rest of the characters were considered as undependable variables (Table 4). The path coefficient analysis revealed that fresh stem weight of plant showed the highest positive direct effect (1.100) on fresh stem weight followed by dry leaf weight (0.766), petiole length (0.686), leaf length (0.519), harvest index % (0.344), leaf area (0.050) and number of leaves per plant (0.014) whereas, the leaf stem ratio (-0.781), dry stem weight (-0.741), plant fresh weight (-0.524), plant height (-0.355), stem base diameter (-0.306), number of leaves per plant (-0.073), leaf width (-0.065), fresh leaf weight (-0.037), showed maximum negative direct effects on leaf yield kg per plot.

Therefore, the higher fresh stem weight and number of leaves per plant should be considered in selection criteria for increasing leaf yield. The present study suggested that more emphasis should be given to selecting genotypes with high fresh stem weight and number of leaves per plant. Directly or indirectly all characters showed positive effect on leaf yield per plant, which is in confirmation to the finding of Sarker *et al.*, (2014) and Venkatesh *et al.,* (2014a). The analysis of variance indicated that the mean sum of square due to genotypes were highly significant for all the studied characters. Significant mean sum of squares due to leaf yield and attributing characters revealed existence of considerable variability in material studied for improvement of various traits. High magnitude of genotypic as well as phenotypic coefficient of variations were recorded for traits dry stem, dry plant weight, harvest index, leaf stem ratio and fresh stem weight suggested the substantial improvement on amaranth through selection for these traits.

High heritability coupled with high genetic advance was observed for dry stem weight, dry plant weight, leaf stem ratio, fresh stem weight, dry leaf weight, harvest index, leaf area, plant fresh weight, fresh leaf weight indicating that most likely the heritability is due to additive gene effects and selection may be effective.

The correlation coefficient analysis revealed that number of leaves per plant and fresh stem weight exhibited the significant positive correlation with leaf yield. Hence, direct selection for these traits may lead to the development of high yielding genotypes of amaranth. The path coefficient analysis revealed that the fresh stem weight, dry leaf weight, petiole length, leaf length, leaf stem ratio, dry stem weight, plant fresh weight, plant height and stem base diameter should be considered in selection criteria for increasing leaf yield.

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