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Genetic variability, character association and path analysis for yield and yield attributing traits in lettuce (*Lactuca sativa*)

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ABSTRACT

An experiment was conducted to assess the genetic variability and relationship among the important horticultural traits in lettuce **(***Lactuca sativa* L.**)**. A wide range of variability among selected genotypes was observed for specific traits. A little or very less difference was observed between the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for all traits indicated the least environmental influence, which suggests that selection can be done based on the phenotypic performance. Higher estimates of heritability coupled with higher genetic advance for plant weight, yield, average leaf weight, leaf width indicated the presence of additive gene action, through which selection can be done. Yield (q/ha) showed highly significant positive correlation with plant weight, stem diameter, leaf size at genotypic and phenotypic level. Significant positive direct effect on yield by average plant weight, leaf length, average leaf weight and stem diameter and their significant positive correlation with yield as well as high heritability coupled with high genetic advance suggested them as the most important components contributing to yield. Thus, more weight should be given to these traits in yield improvement programme of lettuce for future line of work.

Key words: Correlation, Genetic advance, Heritability, *Lactuca sativa* , Path analysis

Lettuce (*Lactuca sativa* L.) belongs to family Asteraceae. It is mostly used as a salad and praised for its high vitamins (A and C) and mineral (calcium, iron, magnesium, potassium and sodium) contents. It is also known for its sedative, diuretic and expectorant medicinal properties. The flavonoids and polyphenols present in lettuce play a very important role in preventing carcinogenic infections and other terminal health challenges (Kayode *et al.* 2015). In India, area under lettuce crop is increasing significantly because of increasing demand due to change in food habit of the society and its high medicinal and nutritional properties. Being a temperate crop it is very much popular in winter season at subtropical regions of India, which fetches good price to the growers. The productivity of lettuce is quite low in India (6.33 t/ha) as compared to world average (21.89 t/ha) (Manisha *et al.* 2016). In order to maximize its productivity, there is a need for restructuring of lettuce germplasm under Indian subtropics also because it is native to Mediterranean coast and like the cold weather (Yingyan *et al.* 2013).

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However, there is limited options for breeding in lettuce, as yield is a complex trait influenced by many component characters, which makes the direct selection ineffective based on yield performance. Success of a breeding programme depends on variability available in the germplasm. Knowledge in respect of nature and magnitude of associations of yield with various component characters is pre requisite to bring the improvement in desired level. A crop breeding programme, aimed at increasing plant productivity requires consideration not only of yield but also its components that have direct or indirect bearing on yield. Knowledge with respect to nature and magnitude of association of yield with various other components is a prerequisite to bring out improvement in desired direction.

Correlation empowers the breeder to know the degree of association between the dependent and independent traits of economic importance. Path coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficient in to component of direct and indirect effects which can effectively assist in crop improvement through selection (Sonia *et al.* 2011). Hence the present investigation was made with specific objective to examine the genetic parameters of variability in order to identify the major contributing characters to the higher leaf yield in lettuce under sub-tropical conditions of India.

MATERIALS AND METHODS

Present investigation was carried out for two consecutive years, i.e. 2015 -16 and 2016-17 at experimental farm of ICAR-Central Institute for Subtropical Horticulture Rehmankhera, Kakori, Lucknow located at 10' N latitude, 80º 30' to 80º 55' E longitude and 123 m above mean sea level. The experimental material comprised 20 genotypes (CITH-L-1,CITH-L-2, CITH-L-3, CITH-L-4, CITH-L-5, CITH-L-6, CITH-L-7, CITH-L-8, CITH-L-9, CITH-L-10, LS-2, Lolo Rosa, Grand Rapid, Bal Moral, Lob Jolt, Bogambo, Simpsion, Grisma, Gentelena and Revolution Red) planted in Randomised Block Design with three replications. One month old seedlings were transplanted at 30 × 30 cm spacing in 1.50 × 1.20 m plot size in well prepared beds.

Uniform agronomical standard practices were adopted in order to obtain the good phenotypic expression of characters. Ten plants were randomly selected to record the data on leaf length, leaf width, number of leaves per plant, stem diameter, average plant weight and yield (q/ha). Total flavonoids, vitamin C and carotenoids were determined according to protocol of Ranganna (1995). Pooled data for two years were considered for statistical analysis. Genotypic and phenotypic correlations were calculated as per the method given by Burton and De-vane (1953). Heritability (Broad sense) was calculated as suggested by Allard (1960). Genetic gain and genetic advance in per cent means was calculated by the method of Johanson (1955). Genotypic and phenotypic correlations were calculated as per Al-Jibouri (1958). Direct and indirect effects were obtained by following Dewey and Lu (1959).

RESULTS AND DISCUSSION

Genotypes used in study varied significantly for all the horticultural traits, which reveals a wider genetic variability among the genotypes. The average leaf length ranged from 17.50 to 44.00 cm, leaf width (12 to 30 cm), number of leaves per plant (18.5 to 37.00), average leaf weight (11g to 34 g), stem diameter (1.8 to 5.00 cm), total flavonoids (14.25 to 34.00 mg/100g), vitamin C (4.48 to 10.80 mg/100g), carotenoids (1.02 to 2.85mg/100g), average plant weight (275 to 830g) and yield (310 to 915 q/ha) were estimated. Range and mean differences of studied traits indicated the existence of ample genetic variability among the genotypes for majority of the traits which reflects the potentiality of improvement in lettuce. Similar pattern of variability in the germplasm evaluation of lettuce at different locations for various horticultural traits have been reported by Thakur *et al.* (1997), Kausal and Kumar (2010) and Manisha *et al.* (2014).

The amount of variability present among the 20 genotypes can be estimated by genotypic and phenotypic coefficient of variation. The magnitude of phenotypic coefficient of variability was slightly higher than genotypic coefficient of variability, though the differences were narrow (Table 1). A close proximity in phenotypic and genotypic coefficient of variation indicated the less influence of environment in expression of various horticultural traits. This suggested that the amount variability present among the genotypes studied is inherent in nature. Therefore the effective selection can be done on phenotypic basis. These results were in confirmation with the findings of Kausal and Kumar (2010). Moderate to high PCV and GCV were observed for average plant weight (44.01 and 43.98), yield (45.44 and 45.43), average leaf weight (42.43 and 42.32), leaf carotenoids (33.80 and 33.73), leaf width (31.5 and 31.28) and stem diameter (28.65 and 27.95). The very less or narrow difference between GCV and PCV indicated that

Table 1 Range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advances (GA) in lettuce

Trait	Range		Mean	Genotypic variance (%)	Phenotypic variance (%)	Phenotypic coefficient variation (%)	Genotypic coefficient variation (%)	Heritability in broad sense (%)	Genetic advance (%)	Genetic gain means (%)
	Min	Max								
Leaf length(cm)	17.50	44.00	30.75	49.384	49.962	28.444	28.279	98.843	17.81	57.92
Leaf width (cm)	12.00	33.00	25.50	27.242	27.710	31.553	31.285	98.309	45.37	63.90
No. of leaves/plant	18.50	37.00	27.75	35.077	35.735	21.870	21.668	98.157	12.27	44.22
Average leaf weight (g)	11.00	41.00	26.00	64.950	65.297	42.433	42.320	99.467	22.61	86.95
Stem diameter (cm)	1.80	5.00	3.40	0.583	0.613	28.656	27.950	95.132	1.91	56.16
Total flavonoids (mg/100g)	14.25	34.00	24.13	32.030	32.207	29.589	29.507	99.449	14.63	60.62
Vitamin C (mg/100g)	4.48	10.80	7.64	3.231	3.237	24.164	24.140	99.804	3.80	49.68
Total carotenoids (mg/100g)	1.02	2.85	1.94	0.329	0.331	33.809	33.738	99.584	1.35	69.36
Average plant weight (g)	275.00	830.00	552.50	37237.48	37289.18	44.011	43.980	99.861	500.22	90.54
Yield (q/ha)	310.00	915.00	612.50	47578.00	47593.50	45.439	45.432	99.967	573.14	93.57

the selection can be effective on the basis of these traits. These findings are in conformity with the findings of Gupta *et al.* (2008) and Dolma *et al.* (2010), who suggested that the variability present among the genotypes are inherent in nature and also less influence of environment.

The estimates of heritability act as an important tool for selection of a parent for crop improvement programme. Hence it helps a breeder for selection of particular trait, when the heritability is high (>78%). High heritability indicates that a large proportion of phenotypic variance is attributed to genotypic variance and reliable selection could be made for these traits on the basis of phenotypic variability. The magnitude of heritability in this study for different traits varied from 98.13 to 99.96 %. Heritability was very high for all the traits studied reflecting negligible influence of environment on these traits. But the estimates of heritability alone are not sufficient for predicting the effect of selection therefore genetic advance/genetic gain was calculated (Hanson *et al.* 1956).

Heritability coupled with genetic advance is more useful than the heritability alone in selection of desire genotypes. Genetic advance is an important tool used for the selection of prominent population performing better. High estimates of heritability along with higher genetic advance (in per cent means) were observed for average plant weight (90.54 %), yield (93.57 %), average leaf weight (86.95 %) and leaf width (63.90 %) indicated that heritability of these traits is owing to additive gene action and as such selection will be effective. These findings are in support with Manisha *et al.* (2016), Jamwal *et al.* (1995) and Kumar *et al.* (2004).

Association among different component of characters were due to pleiotropic gene action or linkage or both. Phenotypic correlation includes genetic and environmental effects which provides information about total association between two characters, whereas genotypic correlation provides the magnitude of genetic association between the characters and it can be used in selection process. The environmental as well as genetic architecture of genotype plays a vital role in achieving the higher yield with better quality. Yield is not an independent character, but it is a resultant of interaction of a number of characters among themselves as well as with the environment. Therefore it becomes difficult to evaluate this complex trait directly. Since not much work has been done on this aspect in lettuce in sub-tropical conditions of India, therefore the results of the present study were utilized to find out the correlations among the horticultural and also quality characters contributing towards yield.

Genotypic and phenotypic correlation for yield and its components are presented in Table 2. Genotypic correlation coefficient were generally higher in magnitude than their corresponding phenotypic correlation coefficient for all the

Table 2 Genotypic (G) and phenotypic (P) coefficient correlation among the traits of lettuce genotypes

Trait		Leaf length (cm)	Leaf width (cm)	No. of leaves/ plant	Average leaf weight (g)	Stem diameter (cm)	Total flavonoids (mg/100g)	Vitamin C (mg/100g)	Total carotenoids (mg/100g)	Average plant weight (g)	Yield (q/ha)
Leaf length(cm	G		0.0997	0.7039**	0.0887	0.8685**	-0.0235	-0.1918	0.1709	0.7499**	0.7582**
	P		0.0918	0.6891**	0.0921	0.8304**	-0.0261	-0.1921	0.1714	0.7444**	0.7539**
Leaf width (cm)	G			-0.0793	0.9784**	0.4903*	0.2543	-0.0488	-0.1209	0.7030**	0.6967**
	P			-0.0711	0.9662**	0.4855*	0.2549	-0.0455	-0.1238	0.6947**	0.6906**
No. of leaves/plant	G				-0.1887	0.4550*	-0.4432	-0.2003	-0.0973	0.4082	0.4108
	P				-0.1854	0.4457*	-0.4320	-0.1961	-0.0948	0.4025	0.4079
Average leaf weight (g)	G					0.4657*	0.4332	0.0147	-0.0944	0.6731**	0.6714**
	P					0.4538*	0.4324	0.0141	-0.0935	0.6708**	0.6701**
Stem diameter (cm)	G						0.0567	-0.3264	0.0187	0.9411**	0.9474**
	P						0.0597	-0.3162	0.0141	0.9189**	0.9238**
Total flavonoids (mg/100g)	G							0.0589	0.2494	0.1134	0.1262
	P							0.0586	0.2481	0.1130	0.1256
Vitamin C (mg/100g)	G								0.2432	-0.1117	-0.1289
	P								0.2421	-0.1119	-0.1286
Total carotenoids (mg/100g)	G									0.0004	-0.0124
	P									0.0002	-0.0124
Average plant weight (g)	G										0.9996**
	P										0.9986**
Yield (q/ha)	G										
	P										

*Significant at 5% level, ** significant at 1% level.

traits studied indicated the strong inheritance association among these traits, which is in agreement with findings of Kaushal and Kumar (2010). Results indicated that yield (q/ha) exhibited highly significant and positive correlation with plant weight, stem diameter, leaf length and width at genotypic and phenotypic level. These characters may be considered as a major yield contributing traits in lettuce. Hence for effective crop yield improvement, selection should be oriented towards the higher value of these characters. Significant positive correlation for yield, plant weight, stem diameter, leaf weight, leaf length and width was also reported by Dolma *et al.* (2010) and Gupta *et al.* (2008) in lettuce.

Although correlation studied are helpful in determining the components of yield but it does not provide a clear picture of nature and extent of contributions made by number of independent traits. Two characters may show the correlation just they are correlated with common one. Under such circumstances path coefficient analysis provide an effective mean of critical examination of specific force of action to produce a given correlation and measure the relative importance of each factor. Path coefficient analysis is an important tool for partitioning the correlation coefficient into direct and indirect effects of independent variable on dependent variable.

In this analysis, yield was taken as dependent variable and rest of the associated characters were considered as an independent variables. Path coefficient analysis splits the total correlation coefficient of different characters into direct and indirect effects on yield varied in such a manner that the sum of direct and indirect effect is equal to genotypic correlation (Table 3). Plant weight showed highest positive direct effect (r=0.904) on yield followed by leaf length (r=0.061), leaf weight ((r=0.039), stem diameter (r=0.026), total flavonoids (r=0.013). The positive indirect effect of leaf length was found for leaf weight (0.003), stem diameter (0.022), vitamin C (0.001) and average plant weight (0.678), whereas the leaf width showed positive indirect effect on yield via leaf length (r= 0.023), number of leaves (0.001) average leaf weight (r=0.032), stem diameter (r=0.006), total flavonoids (r=0.06), vitamin C (r=0.001), carotenoids (r =0.018) and average plant weight (0.538). Number of leaves reflected in direct effect on yield by leaf length (0.043), stem diameter (r=0.012), vitamin C (r=0.001), carotenoids (r=0.002) and plant weight (r=0.369). Stem diameter contributed indirectly to yield via leaf length (r=0.053), leaf weight (r=0.018), total flavonoids (0.001) and plant weight (r=0.851). The total flavonoids showed positive indirect effect on yield via number of leaves (0.001), leaf weight(r=0.017), stem diameter (r=0.002), plant weight (r=0.103). Vitamin C contributed positively to yield via leaf width, number of leaves, leaf weight, total flavonoids and carotenoids, whereas carotenoids contributed positively on yield indirectly via leaf length (r=0.010), leaf width (r=0.001), number of leaves (0.008), stem diameter (r= 0.0005), total flavonoids (0.003) and average plant weight (0.0004). The positive indirect effect of plant weight on yield was observed via leaf length (r=0.046), average leaf weight (0.026), stem diameter (r=0.024) total flavonoids (r=0.001), vitamin C and average plant weight (0.904).

Significant positive direct effect on yield by average plant weight, leaf length, average leaf weight and stem diameter, their significant positive correlation with yield coupled with high heritability coupled with high genetic advance suggested them as the most important components contributing to yield. Thus, more weight should be given to these traits in yield improvement programme of lettuce. The findings are in conformity with findings of Dolma *et al.* (2010) and Kumar *et al.* (2010).

Yield of lettuce crop is one of the important factors

Table 3 Estimates of direct (bold) and in direct effects of significant traits on leaf yield of lettuce

Character	Leaf length (cm)	Leaf width (cm)	No. of leaves/plant	Average leaf weight (g)	Stem diameter (cm)	Total flavonoids (mg/100g)	Vitamin C (mg/100g)	Total carotenoids (mg/100g)	Average plant weight (g)	Yield (q/ha)
Leaf length(cm)	0.061	-0.001	-0.002	0.003	0.022	-0.001	0.001	-0.004	0.678	0.758
Leaf width (cm)	0.023	-0.002	0.001	0.032	0.006	0.006	0.001	0.018	0.538	0.623
No. of leaves/plant	0.043	0.001	-0.003	-0.007	0.012	-0.006	0.001	0.002	0.369	0.411
Average leaf weight (g)	0.005	-0.002	0.001	0.039	0.012	0.005	-0.001	0.002	0.609	0.671
Stem diameter (cm)	0.053	-0.001	-0.001	0.018	0.026	0.001	0.002	-0.001	0.851	0.947
Total flavonoids (mg/100g)	-0.001	-0.001	0.001	0.017	0.002	0.013	-0.001	-0.006	0.103	0.126
Vitamin C (mg/100g)	-0.011	0.001	0.001	0.001	-0.008	0.001	-0.005	-0.006	-0.101	-0.129
Total carotenoids (mg/100g)	0.010	0.001	0.003	-0.004	0.001	0.003	-0.001	-0.024	0.0004	-0.012
Average plant weight (g)	0.046	-0.001	-0.001	0.026	0.024	0.001	0.001	0.001	0.904	0.999

Residual effect -0.0197.

in improvement because of the increasing demand for lettuce is increasing day by day. Being a temperate crop it is performing well in subtropical conditions of India also during winter season. Therefore it can be concluded that yield of lettuce was positively and significantly associated with most of the horticultural traits. Selection based on higher plant weight, stem diameter, leaf length and leaf width may improve the plant yield of lettuce. These traits can be considered as a major contributing character for lettuce yield under subtropical conditions of India.

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