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Studies on genetic variability, correlation and path analysis in lettuce (*Lactuca sativa* L.) under protected conditions

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Abstract: Twenty-eight genotypes of lettuce including check cultivars *viz.,* Simpson Black Seeded and Great Lakes were grown in a RCBD with three replications during *Rabi* 2011-12 and 2012-13 at Vegetable Experimental Research Farm, Nauni, Solan H.P. to estimate the parameters of genetic variability, correlation and path analysis under naturally ventilated polyhouse. Analysis of variance showed highly significant differences among genotypes for all the characters under study. Variability revealed that phenotypic co-efficient of variation (PCV) in general were higher than the corresponding genotypic co-efficient of variation (GCV) for all the characters. High co-efficient of variability were found for heading percentage (37.00% and 36.01%), incidence of sclerotinia rot (63.49% and 61.475%), gray mould (90.13% and 88.08%) and yield per plot (39.55% and 33.09%) indicated wider range of variation and offer better scope for improvement through selection. High heritability estimates coupled with moderate genetic gain were observed for yield and other horticultural traits. Correlation study indicated that yield per plot was positively correlated with gross and net head weight, seed germination, seed vigour index-I & II, 1000-seeds weight and also showed maximum direct effects towards yield per plot. The path co-efficient analysis revealed that net head weight has maximum positive direct effect on yield per plot followed by gross head weight, days to marketable maturity, seed germination, 1000-seeds weight, head shape index and incidence of sclerotinia rot. While, negative direct effect of number of non-wrapper leaves and incidence of gray mould was observed on yield. The new multicoloured cultivars indigenous and exotic mostly procured from CGN, Netherlands , identified for commercial cultivation under protected conditions in the mid hills of North Western Himalayas, may act as a substitute to the old cultivars with good quality and higher yielding potential.

Keywords: Correlation, Genetic variability, Heritability, *Lactuca sativa*, Path analysis

INTRODUCTION

The genus *Lactuca* L. (Compositae, tribe Cichorieae, a subclade Lactucinae comprises about 100 wild species, mainly distributed in the Northern Hemisphere (Beharav *et al.,* 2014). Lettuce (*Lactuca sativa* L.) is one of the important leafy vegetable used as salad and also marketed as fresh vegetable (Mousavi *et al.,* 2013). It occupies the largest area of the salad crops world wide. In India area under lettuce and other exotic high value, cash vegetable crops has increased significantly for the last one decade because of its high nutritional and medicinal value. Lettuce is unique among major vegetables and is rich in vitamin C, A and minerals (Samnotra *et al.,* 2012).

Estimates of parameters of variability importantly, heritability and genetic gain are reliable indicators for improvement of characters in a particular genetic material through selection. Since, the selection for highly heritable characters is more effective, therefore, heritability along with other parameters can be used in predicting the gain for a given selection intensity and expected genetic gain further gives the idea of the extent of improvement in a character through simple selection (Kumar *et al.,* 2015).

The various colours and textures of loose-leaf and head types indicate large variability amongst the lettuce genotypes. The success of any breeding programme depends upon the extent of genetic variability and degree of translocation of characters from generation to generation. For exploitation of genetic variability, the knowledge of correlation between complex character like yield and its component characters is of considerable importance for a rational approach towards yield improvement (Samnotra *et al.,* 2012). Simple correlation co-efficients provide information regarding association of characters. A better insight into the cause of association is provided by path coefficient analysis, a method of partitioning correlation co-efficient into direct and indirect effects of component

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characters.

Correlation of various characters with yield is useful and provides criteria for direct selection of component characters. Partitioning of total correlation into direct and indirect effects by path analysis helps in making selection more effective. Path co-efficient analysis studies were used to separate correlation co-efficient into components of direct and indirect effects toward yield (Kumar *et al.,* 2010). The present study was, therefore, undertaken with a view to evaluate the lettuce germplasm under protected conditions for yield and other horticultural traits to work out the association among different characters.

MATERIALS AND METHODS

The present investigation involving twenty eight genotypes of lettuce including two check cultivars *viz.,* Simpson Black Seeded and Great Lakes was carried out in naturally ventilated polyhouse at Experimental Farm of the Department of Vegetable Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2011-12 and 2012-13. The genotypes along with their sources of availability have been presented in Table 1.

The experiment was laid out in a randomized complete block design with three replications in 1.50 m× 1.20 m plots. One month old seedlings were transplanted to naturally ventilated polyhouse at a spacing of 30 × 30 cm between and within rows, respectively, accommodating 20 plants/ plot. Manual weeding and earthing up (pulling soil around the base of plant) was done four to five times until the final harvest and irrigation was applied at 15-days interval from mid-October to mid-December and later as needed, depending upon weather.

The standard cultural practices recommended in the package of practices for vegetable crops were followed to ensure a healthy crop stand. Ten plants were randomly selected to record observations on days to marketable maturity, leaf color, number of non-wrapper leaves, gross head weight, net head weight (gross head weight means total weight of head including non-wrapper leaves and stalk weight; net head weight excludes the weight of non-wrapper leaves and stalk weight), heading percentage, yield per plot, β-carotene contents, calcium contents, iron contents, seed germination percentage, seed vigor index I and II, 1000-seeds weight, head shape index and incidence of diseases. Seed vigor indices I and II were determined by the formula of Abdul-Baki and Anderson (1973). Non-wrapper leaves were removed from heads that were weighed for yield and head shape index determined (Odland and Noll, 1954). Contents of β -carotene and iron were determined according to methods of Ranganna (1995). Analysis of variance (ANOVA) was calculated according to Gomez and Gomez (1983). The genotypic and phenotypic coefficients of variation were calculated as per formulae given by Burton and De-Vane (1953). Heritability (broad sense) was calculated by the formula as suggested by Allard (1960). Genetic gain was genetic advance as per cent of mean, calculated by the method of Johanson *et al.* (1955). The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958). The direct and indirect effects were obtained by following Dewey and Lu (1959). Traits that differed significantly were further utilized for estimation of the genetic parameters.

RESULTS AND DISCUSSION

The analysis of variance indicated highly significant differences among the genotypes for all the traits studied, which revealed the existence of good deal of variability in the germplasm.

Parameters of variability: The estimates of co-efficients of variability (phenotypic and genotypic) gave a clear picture of amount of variability present in the available germplasm (Table 2). For all the characters studied, phenotypic co-efficients of variability were higher in magnitude than genotypic co-efficients of variability, though difference was very less in majority the cases.

The characters under study *viz*. gross head weight, net head weight, heading percentage, yield, β-carotene content and incidence of sclerotinia rot recorded wide range of variation and have better scope for improvement through selection. Moderate to high PCV and GCV were observed for gross head weight, net head weight, non-wrapper leaves, β-carotene and incidence of gray mould diseases. These findings are in contradictory to the findings of Sharma (2001), Kumar (2004) and Dutt (2006) who had reported low co-efficients of variability for non-wrapper leaves and heading percentage in different genotypes of cabbage while high co-efficients of variability for net head weight (Thakur *et al*., 1997) in lettuce and in cabbage Kumar (2004) reported moderate genotypic and phenotypic coefficient of variability for gross head weight, net head. weight, head shape index, number of non wrapper leaves, yield per plot, heading percentage and days to marketable maturity. These results are also in line with the findings of Sharma (2001) who have also reported high to moderate co-efficients of variability for non-wrapper leaves and net head weight in cabbage,Meglic and Vozlic (2000) for various traits in lettuce and Gupta *et al*. (2008) observed high phenotypic as well as genotypic variance for carotenoids only, while the characters like number of leaves per plant, leaf yield per plant, vitamin C, average leaf weight, calcium, plant spread and potassium exhibited moderate PCV as well as GCV whereas Kaushal and Kumar (2010) have also reported moderate to high genotypic co-efficient of variation for gross head weight, net head weight, yield per plot, and β-carotene with wider range of values. Phenotypic performance

Table 1. List of the lettuce genotypes and sources.

S. N.	Genotypes	Sources
1	CGN-04508	Crop Genetic Resources, the Netherlands
2	CGN-04543	Crop Genetic Resources, the Netherlands
3	CGN-04933	Crop Genetic Resources, the Netherlands
4	CGN-04934	Crop Genetic Resources, the Netherlands
5	CGN-04987	Crop Genetic Resources, the Netherlands
6	CGN-04990	Crop Genetic Resources, the Netherlands
7	CGN-05167	Crop Genetic Resources, the Netherlands
8	CGN-05169	Crop Genetic Resources, the Netherlands
9	CGN-05198	Crop Genetic Resources, the Netherlands
10	CGN-09373	Crop Genetic Resources, the Netherlands
11	CGN-10944	Crop Genetic Resources, the Netherlands
12	CGN-11358	Crop Genetic Resources, the Netherlands
13	CGN-14629	Crop Genetic Resources, the Netherlands
14	CGN-14651	Crop Genetic Resources, the Netherlands
15	CGN-19009	Crop Genetic Resources, the Netherlands
16	CGN-19088	Crop Genetic Resources, the Netherlands
17	CGN-20721	Crop Genetic Resources, the Netherlands
18	UHF-Sel.-01	UHF, Nauni, Solan
19	UHF-Sel.-02	UHF, Nauni, Solan
20	UHF-Sel.-03	UHF, Nauni, Solan
21	UHF-Sel.-04	UHF, Nauni, Solan
22	UHF-Sel.-05	UHF, Nauni, Solan
23	UHF-Sel.-06	UHF, Nauni, Solan
24	UHF-Sel.-07	UHF, Nauni, Solan
25	Sol. Let-I	UHF, Nauni, Solan
26	Sol. Let-II	UHF, Nauni, Solan
27	Simpson Black Seeded*	UHF, Nauni, Solan
28	Great Lakes*	UHF, Nauni, Solan

*Check cultivars

would be good index for selection in lettuce for characters like gross head, net head weight, heading percentage, yield per plots and incidence of sclerotinia rot, and for quality characters *viz.,* β-carotene and iron contents.

Heritability and genetic gain: The genotypic coefficient of variation does not offer full scope to estimate the variations that are heritable and therefore, estimation of heritability becomes necessary. Burton and De-Vane (1953) has suggested that genetic coefficient of variability along with heritability estimates would give a reliable indication of expected amount of improvement through selection. High heritability (>80%) 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 variation. The magnitude of heritability for characters under studies ranged from 43.3 per cent (1000-seeds weight) to 95.6 per cent (head shape index) (Table 2). The estimates of heritability (broad sense) were found high for the characters *viz.,* number of non-wrapper leaves, heading percentage, seed vigour index-I, seed vigour index-II, head shape index, incidence of sclerotinia rot and gray mould and yield per plot; moderate for days to marketable maturity, gross head weight, net head weight, carotene, calcium, iron contents and seed germination and was low for 1000-seeds weight. High heritability estimates for number of non-wrapper leaves, heading percentage, seed vigour index-I, seed vigour index-II and head shape index whereas moderate for gross head weight, net head weight and seed germination were also reported by Kumar *et al*. (2010). In the light of results obtained in the present studies, it is concluded that selection can be performed at phenotypic performance for highly heritable characters *viz.,* number of non-wrapper leaves, heading percentage, seed vigour index -I, seed vigour index-II, head shape index and yield per plot.

High heritability suggested the major role of genetic constitution in the expression of characters and such performance of characters are considered to be repeatable. However, the estimates of heritability alone are not sufficient for predicting the effect of selection and therefore the genetic advance/gain is also equally important (Hanson *et al*., 1956). The value of genetic

Table 2. Estimates of phenotypic and genotypic co-efficients of variability, heritability, genetic advance and genetic gain for different traits in lettuce (Mean values are of three replicates).

Characters	Range	Mean ± SE	Co-efficients of variability (%)		Heritability (%)	Genetic advance	Genetic gain (%)
			Phenotypic	Genotypic			
Days to marketable maturity	52.82-81.82	66.65+3.27	13.35	11.93	80.00	14.63	21.95
Non wrapper leaves	6.38-12.28	9.66+0.54	16.91	15.45	83.50	2.81	29.09
Gross head weight (g)	299.22-602.02	398.96+36.78	19.16	15.49	65.30	102.85	25.78
Net head weight (g)	175.72-537.05	301.61+36.77	29.64	25.61	74.60	137.45	45.56
Heading percentage (%)	71.07-95.00	73.87+5.12	37.00	36.01	94.70	53.33	72.18
β- Carotene (µg/100g)	2.58-10.21	4.96+0.72	27.56	21.00	58.10	1.63	32.86
Calcium content (%)	4.88-11.47	8.73+1.18	25.58	19.49	58.10	2.67	30.58
Iron content (mg/100g)	0.99-1.83	1.40+0.11	16.25	13.02	64.30	0.30	21.43
Seed germination (%)	90.55-97.00	94.57+0.75	2.09	1.85	78.30	3.18	3.36
Seed vigour index-I	932.72-1277.18	1114.18+26.82	9.49	9.02	90.40	196.74	17.65
Seed vigour index-II	0.264-0.735	0.49+0.03	23.38	21.80	86.90	0.21	42.86
1000 seed weight (g)	0.83-1.02	0.91+0.04	7.15	4.70	43.30	0.06	6.59
Head shape index	0.96-1.29	1.02+0.06	36.91	36.09	95.60	0.74	72.55
Incidence of sclerotinia rot (%)	0.00-67.92	29.73+3.86	63.49	61.47	93.70	36.45	122.57
Incidence of gray mould (%)	0.00-35.17	11.87+1.85	90.13	88.08	95.50	21.06	177.34
Yield per plot (kg)	2.58-10.21	5.14+0.91	39.55	33.09	80.00	2.94	57.20

advance as per cent of mean (genetic gain) ranged from 3.36 per cent (seed germination) to 177.34 per cent (incidence of gray mould) for different characters under study.

In the present investigations, high heritability coupled with high estimates of genotypic co-efficients of variability and moderate genetic gain was recorded for heading percentage, head shape index and yield per plot, offering better scope for selection, indicates the presence of additive gene action and as such selection will be very effective. High heritability (80%) coupled with low genetic gain (21.95%) for days to marketable maturity indicated the non-additive gene action. These findings are in line with Dutt (2006) who reported high heritability with low genetic gain for days taken to marketable maturity, moderate heritability with moderate genetic gain for gross head weight, net head weight, heading percentage and yield per plot and contradictory to the work of Kumar (2004) who reported high heritability coupled with moderate gentic gain in 1000 seed weight in cabbage. Moderate heritability with low genetic gain was observed for gross and net head weight. The present findings are in line with the work of Kumar *et al.,* (2010) they have reported moderate heritability coupled with low genetic gain for gross and net head weight. But the present finding for gross head weight is in contradiction with the work of Kumar (1998) who reported moderate heritability and genetic gain. The observation on net head weight is in contradiction with the finding of Arumugam *et al.* (1978) who have reported moderate heritability with moderate genetic gain and also in contradiction with the work of Lal and Solanki (1975), Jamwal *et al.* (1995) as they recorded high heritability coupled with high genetic gain.

Correlation studies: The yield is not an independent character, but resultant of interaction of a number of component characters among themselves as well as with the environment in which the plants grow. Further, each character itself is likely to be modified by the actions of genes present in the genotypes of the plant and also by the environment. Therefore, it becomes difficult to evaluate this complex character directly. Consequently, the selection pressure is exerted easily on those characters which are simply inherited and showing close association with yield. Since not much work has been done on this aspect in lettuce grown under protected conditions (naturally ventillated polyhouse) in the temperate conditions of India, therefore, results of the present investigations were utilized to find out the correlations among the horticultural and quality characters contributing towards yield.

The results showed that genotypic correlations were, in general, higher in magnitude than phenotypic ones (Table 3). Yield had significant positive correlation with gross head weight, net head weight, heading percentage, seed germination, seed vigour index-I & II,

Table 3. Phenotypic (P) and genotypic (G) co-efficients of correlation among different characters in lettuce genotypes.

Traits		DMM	NWL	GHW	NHW	HP	β -caro	CAC	Fe C	SG	SV-I	SV-II	1000-SW	HSI	ISR	IGM	YIELD
DMM	P	1.000	0.239	0.074	0.042	0.347	0.144	-0.055	-0.177	0.000	-0.052	-0.099	0.129	0.403**	0.133	0.295	0.062
	G	1.000	0.071	-0.263	-0.237	0.290	-0.208	-0.477**	-0.617*	-0.263	-0.224	-0.135	-0.347	0.360	0.033	0.373	-0.242
NWL	P		1.000	-0.620*	-0.691*	-0.069	0.129	0.064	-0.053	-0.725*	-0.816*	-0.831*	-0.539*	0.336	0.254	0.505	-0.672*
	G		1.000	-0.998*	-0.997*	-0.174	-0.184	-0.258	-0.400**	-0.885*	-1.083*	-0.990*	-0.997*	0.288	0.181	0.600*	-0.758*
GHW	P			1.000	0.995	0.078	0.273	0.254	0.419**	0.882*	0.882*	0.787*	0.944*	-0.262	-0.015	-0.504*	0.992*
	G			1.000	0.993	-0.058	-0.167	-0.161	0.108	0.851*	0.911*	1.021*	0.953*	-0.479*	-0.194	-0.582*	0.996*
NHW	P				1.000	0.090	0.242	0.235	0.397**	0.907*	0.916*	0.824*	0.941*	-0.275	-0.048	-0.526*	0.996*
	G				1.000	-0.019	-0.120	-0.103	0.143	0.881*	0.926*	0.993*	0.997*	-0.443**	-0.198	-0.578*	0.998*
HP	P					1.000	0.106	0.049	-0.098	0.198	0.157	0.021	0.217	0.887*	0.157	0.051	0.110
	G					1.000	-0.034	-0.108	-0.288	0.116	0.099	0.013	0.090	0.882*	0.113	0.071	-0.011
β -caro	P						1.000	0.232	0.673*	0.244	0.182	0.010	0.371	0.052	-0.014	0.072	0.252
	G						1.000	-0.267	0.483*	-0.078	-0.020	0.005	-0.212	-0.096	-0.216	0.155	-0.142
CAC	P							1.000	0.118	0.310	0.242	0.116	0.353	0.013	0.200	-0.024	0.258
	G							1.000	-0.384**	0.045	0.078	0.125	-0.177	-0.144	0.075	0.008	-0.106
Fe C	P								1.000	0.400**	0.358	0.173	0.489*	-0.231	-0.194	-0.209	0.406**
	G								1.000	0.176	0.229	0.200	0.086	-0.446**	-0.428**	-0.209	0.124
SG	P									1.000	0.983*	0.784*	0.936*	-0.205	-0.154	-0.548*	0.912*
	G									1.000	0.998*	0.933*	0.965*	-0.344	-0.306	-0.591*	0.893*
SV-I	P										1.000	0.817*	0.904*	-0.262	-0.168	-0.572*	0.917*
	G										1.000	0.911*	0.974*	-0.348	-0.261	-0.591*	0.941*
SV-II	P											1.000	0.691*	-0.351	-0.105	-0.427**	0.814*
	G											1.000	0.994*	-0.396**	-0.124	-0.455**	0.789*
1000 SW	P												1.000	-0.130	-0.059	-0.484*	0.954*
	G												1.000	-0.433**	-0.365	-0.655*	0.994*
HSI	P													1.000	0.311	0.313	-0.253
	G													1.000	0.278	0.344	-0.445**
ISR	P														1.000	0.502*	-0.035
	G														1.000	0.543*	-0.200
IGM	P															1.000	-0.507*
	G															1.000	-0.571*
YIELD	P																1.000
	G																1.000

*Significant at 1 per cent level of significance; ** Significant at 5 per cent level of significance; Where DMM=Days to marketable maturity, NWL = Non wrapper leaves, GHW=Gross head weight, NHW=Net head weight, HP = Heading percentage, β-caro= β-carotene contents, CAC- Calcium contents, Fe C= Iron contents, SG= Seed germination, SV; I= Seed vigour index-I, SV-II- Seed vigour index-II, 1000-SW-1000-seeds weight , HSI=Head shape index, ISR= Incidence of sclerotinia rot, and IGM= Incidence of gray mould.

Table 4. Estimates of direct and indirect effects of different traits on yield of lettuce.

Traits	DTMM	NWL	GHW	NHW	HP	BCC	CAC	Fe C	SG	SVI-I	SVI-II	1000 -SW	HSI	ISR	IGM	GCCYP
DTMM	0.014	-0.016	0.404	-0.608	-0.026	0.002	0.000	0.004	-0.065	0.191	0.021	-0.165	0.001	0.002	-0.002	-0.242
NWL	0.001	-0.818	1.778	-2.903	0.016	0.002	0.000	0.003	-0.278	0.924	0.158	-0.663	0.001	0.011	-0.004	-0.758
GHW	-0.004	0.254	1.539	2.566	0.005	0.002	0.000	-0.001	0.210	-0.777	-0.163	0.453	-0.001	-0.012	0.004	0.996
NHW	-0.003	0.247	1.541	2.564	0.002	0.001	0.000	-0.001	0.218	-0.085	-0.002	0.043	0.002	0.007	0.000	0.998
HP	0.004	0.038	0.090	-0.048	-0.090	0.000	0.000	0.002	0.029	-0.085	-0.002	0.043	0.002	0.007	0.000	-0.011
BCC	-0.003	0.040	0.257	-0.309	0.003	-0.010	0.000	-0.003	-0.019	0.017	-0.001	-0.101	0.000	-0.013	-0.001	-0.142
CAC	-0.007	0.056	0.248	-0.263	0.010	0.003	0.000	0.003	0.011	-0.066	-0.020	-0.084	0.000	0.005	0.000	-0.106
Fe C	-0.008	0.087	-0.166	0.365	0.026	-0.005	0.000	-0.007	0.043	-0.195	-0.032	0.041	-0.001	-0.026	0.001	0.124
SG	-0.004	0.246	-1.310	2.259	-0.010	0.001	0.000	-0.001	0.247	-0.852	-0.149	0.481	-0.001	-0.019	0.004	0.893
SV-I	-0.003	0.237	-1.402	2.374	-0.009	0.000	0.000	-0.002	0.246	-0.153	-0.145	0.511	-0.001	-0.016	0.004	0.941
SV-II	-0.002	0.216	-1.572	2.575	-0.001	0.000	0.000	-0.001	0.230	-0.777	-0.160	0.523	-0.001	-0.008	0.003	0.789
1000-SW	-0.005	0.305	-1.467	2.556	-0.008	0.002	0.000	-0.001	0.250	-0.919	-0.176	0.475	-0.001	-0.022	0.004	0.994
HSI	0.005	-0.063	0.738	-1.136	-0.080	0.001	0.000	0.003	-0.085	0.297	0.063	-0.206	0.002	0.017	-0.002	-0.445
ISR	0.000	-0.040	0.298	-0.507	-0.010	0.002	0.000	0.003	-0.076	0.223	0.020	-0.173	0.001	0.061	-0.004	-0.200
IGM	0.005	-0.131	0.896	-1.682	-0.006	-0.001	0.000	0.001	-0.146	0.505	0.073	-0.311	0.001	0.033	-0.007	-0.571

Where DTMM= Days to marketable maturity, NWL= Non-wrapper leaves, GHW = Gross head weight, NHW = Net head weight, HP = Heading percentage, BCC = β-carotene contents, CAC= Calcium contents, Fe C = Iron contents, SG = Seed germination, SV-I = Seed vigour index I, SV-II= Seed vigour index-II, 1000-SW= 1000-Seeds weight, HSI = Head shape index, ISR= Incidence of sclerotinia rot, IGM= incidence of gray mould, GCCYP = Genotypic correlation coefficient with yield/plot

Residual effect: -0.0003; Diagonal figures represent the direct effect

1000-seeds weight and significant negative correlation with non- wrapper leaves and incidence of gray mould. The minimum difference in the magnitude of the genotypic and phenotypic correlations in these characters indicates that environmental factors have less influence on the expression of these characters. As such the selection based on these characters will certainly affect the improvement in yield. Gross head weight was positively and significantly correlated with net head weight and seed vigour index-I. Similar findings have also been reported by many workers like Sharma (2001), Kumar (2004), Dutt (2006) in cabbage and Kaushal and Kumar (2010) in lettuce who showed that genotypic correlation was higher than phenotypic correlation, indicating a low influence due to environment and the expression of characters being mainly due to genetic factors.. Number of non-wrapper leaves had negative association with yield in lettuce. Kaushal and Kumar (2010) have also reported negative association between yield and number of non-wrapper leaves in lettuce.

Path co-efficient: Although correlation studies 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. Path co-efficient analysis devised by Dewey and Lu (1959), however, provide a realistic basis for allocation of appropriate weightage to various attributes while designing a pragmatic programme for the improvement of yield.

Path co-efficient analysis was conducted on yield per plot using all characters that showed significant association (Table 4). The co-efficient analysis revealed that average net head weight had maximum positive direct effect on yield per plot followed by gross head weight, 1000-seeds weight, seed germination, incidence of sclerotinia rot, days to marketable maturity and head shape index. While maximum negative direct effect of non-wrapper leaves and incidence of gray mould was observed on yield per plot. Its direct effects irrespective of signs have true relationship between them and net head weight is observed in correlation studies. Thus, selection can be predicted for such characters to improve yield. These findings are in line with Kumar *et al.* (2010) in lettuce who reported positive direct effects toward net head weight contributed by gross head weight, equatorial diameter, disease severity, heading percentage, seed vigor index I, and number of nonwrapper leaves. Negative effects for days to marketable maturity and head shape index. The greatest positive indirect effects were for equatorial diameter, seed vigor index I, and disease severity in relation to gross head weight. Maximum negative indirect effects were observed in head shape index, number of nonwrapper leaves, and days to marketable maturity in relation to gross head weight. To improve yield of lettuce, selection should be done for gross head weight and heading percentage.

Conclusion

It can be concluded that yield per plot was positively and significantly associated with most of the horticultural traits. While, negative direct effect of number of non-wrapper leaves and incidence of gray mould was observed on yield which is desirable for these traits and six genotypes *viz.* UHF-Sel.-06, UHF-Sel.-03, UHF-Sel.-01, CGN-05167, CGN-10944 and CGN-14629 performed better for other horticultural traits *viz.* days taken to marketable maturity, gross head weight, net head weight, heading percentage, 1000 seed weight, seed germination percentage, seed vigor index-I and II. These genotypes need further testing to be released as a substitute of existing varieties in HP or can be further used in future breeding programmes.

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