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Variability and diversity estimates of yield and yield contributing characters in lentil (*Lens culinaris* Medic.)

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Abstract

Investigation on variability and diversity estimates of eight yield and yield contributing characters viz., plant height at first flower (PHFF), number of branches per plant at maximum flower (NBPMF), plant area per plant (PAPP), number of pods per plant (NPdPP), pod weight per plant (PdWPP), number of seeds per plant (NSPP), seed weight per plant (SWPP) and plant weight per plant (PWPP) were carried out in six irradiated lentil lines in 2005-2006 and 2006-2007. Presence of wide range of variation of all the characters indicated that they are quantitative in nature and are under polygenic control. The lines were genetically well differentiated as indicated by the analysis of variance. Significant differences among the doses for most of the characters showed that the four irradiation doses included in the analysis were different from each other. Significant year and dose and respective interaction items with lines for most of the characters indicated that the environments were different and they interacted with genotypes differently. Lines, years and doses interacted among themselves as indicated by significant L×D×Y. Heritability and genetic advance were estimated to be low for all the characters under study. However, the different components of variation and coefficient of variabilities, as calculated were more or less high for PAPP, NSPP, NPdPP, NBPMF and PHFF which indicated a wide scope of improvement of these traits through selection.

Key words: Lentil, variability, diversity and yield.

Introduction

Pulses are important food crops in Bangladesh. The major pulses grown in Bangladesh are lentil, chickpea, black gram, mung bean, khesary and field pea. Among these, lentil (*Lens culinaris* Medic.) is the second most important pulse crop in Bangladesh (Sarker *et. al*.1991). More than 85 per cent of lentil area is concentrated within the nine greater districts viz. Jessore, Faridpur, Kushtia, Rajshahi, Pabna,Comilla Noakhali, Manikganj and Khulna in Bangladesh. It is grown in the winter season. Lentil is a nutritious food legume and cultivated for its seed and mostly eaten as dhal. Its seed is rich source of protein (up to 28%) for human consumption, and its straw is a valuable animal feed in Bangladesh. Though it is cultivated extensively all over the country, its yield is very low. Hence, its varietal trial is needed for its improvement with respect to seed yield. In the present investigation, several irradiated lentil lines were taken to see their radiation effect (whose four irradiation doses were considered as four treatment i.e. environment) on the agronomical characters. In future breeding research, it may be seen whether these affect the characters which in turn will influence high yield. The present research work deals with the variability and diversity estimates of yield and yield contributing characters in 16 lentil lines.

Materials and methods

In the present investigation twelve lentil lines (*Lens culinaris* Medic.) viz. line No. ILL 1, ILL 2, ILL 3, ILL 4, ILL 5, ILL 6, ILL 7, ILL 8, ILL 9, ILL 10, ILL 11 and ILL 12 were collected from International Center for Agricultural Research in the Dry Areas (ICARDA), Syria and other four of lentil lines viz. line No. Bm1, Bm2, Bm3, Bm4 collected from Regional Agricultural Research Station (RARS), Ishurdi, Pabna, Bangladesh. Above lines were irradiated with Co^{60} source considering different doses i.e., no irradiation (D1), 20kr (D2), 25kr (D3) and 30kr (D4) in the institute of Food and Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka. The experiment was done in the research field of the Department of Botany, University of Rajshahi during the Rabi crop season of 2005-2006 and 2006-2007. Layout of the experimental field and trial of the irradiated lines was conducted under randomized complete block design with two replications having sixty four plots in each. The plot size was about 120cm × 150cm with five rows and in each row seven hills was maintained. In each hill, one plant was maintained. Screening of the mutant lines was maintained on the basis of survibability and maturity for flowering. For this study the data of eight agronomical characters were collected on individual plant basis. The measurement of a character was done following C.G.S system. The collected data were analysed following the biometrical techniques of analysis as developed by Mather (1949) based on the mathematical models of Fisher *et. al.* (1932). The analysis of variance of a mixed model was used, where line (L) and dose (D) were fixed and year (Y) effect is random.

Results and Discussion

Analyses were done for the study of variability, heritability and genetic advance of economically eight important characters in two consecutive years in four irradiation doses. The estimates of mean with standard error and least significant difference are given in Table 1- 4 separately for each of the characters. Mean of the six lentil lines of these characters as compared with their respective standard error were found to be highly significant in both of the two years. This indicated that the lines were different regarding these characters. This result is in agreement with the analysis of variance in which the line item was found to be highly significant for all the eight characters. It shows that the lines are genetically different from each other. Alam *et. al.* (1978) reported a significant differences among 41 strains of *Brassica campestris* L. Similar results were also obtained in lentil by Azad (1991), in chickpea by Deb (2002) and in rape seed and mustard by Mandal *et. al.* (1978). For each of the characters the mean differences between the doses in each line were tested with L.S.D values in two consecutive years, 2005-2006 and 2006-2007. The significant differences were found from dose to dose except PdWPP and SWPP in line-11 in the year 2006-2007. However, for all the lines the significant differences of a particular character varied from dose to dose. Similar results were also obtained in lentil by Azad (1991), in chickpea by Deb (2002).In this study, for all the lines the CV% of a particular character varied from dose to dose and also line to line. Similar results were obtained in lentil by Azad (1991), in chickpea by Deb (2002).

The results of the analysis of variance for all the eight quantitative characters were done separately and are shown in Table 5. In the analysis of variance the main line (L) item was highly significant for all the characters when it was tested against within error. Again it was highly significant for all the characters except NPdPP, which showed significance at 5% level when tested against pooled error. These results indicated that genotypes were significantly and genotypically different from each other and it justifies their inclusion in the present investigation as materials. Similar results were obtained in lentil by Babar Ali (1988), by Azad (1991), by Islam *et. al.* (2002), in sugarcane by Nahar (1997) and in chickpea by Deb (2002).

The dose (D) item was highly significant for all the characters except PHFF, NSPP, which showed significance at 5% level and non-significance only for NPdPP when tested against within error. Again it was highly significant for NBPMF, PdWPP, SWPP, and significant for PHFF, PAPP, PWPP but was non-significant for NPdPP and NSPP, when tested against its pooled error. For most of the characters the results indicating that doses were different. Significant differences among the doses for most of the characters showed that the four doses included in the analysis were different from each other. Similar results were obtained by Azad (1991) in lentil, by Nahar (1997) in sugarcane. The L × D interaction was highly significant for all the characters except PHFF which was just significant when tested against within error but it was also highly significant for all the characters except PHFF and NSPP, which showed significance at 5% level when tested against pooled error. The significance of this item indicated that there was evidence of L × D interaction in the present investigation. These results also indicated that the lines significantly interacted with the doses. Similar results were obtained by Islam *et. al.* (2002) in lentil, by Bicer and Sakar (2004) in lentil, by Azad (1991) in lentil, by Nahar (1997) in sugarcane.

The year (Y) item was highly significant for all the characters, which indicated that years were significantly different.

The interaction L×Y was highly significant for all the characters except PHFF and NPdPP, where NPdPP was significant only when tested against within error but it was highly significant for all the characters except PHFF and NPdPP when tested against pooled error. These results indicated that the genotype (L) interacted with the year. Similar results were obtained by Islam *et. al.* (2002) in lentil, by Nahar (1997) in sugarcane. On the other hand, the interaction item D × Y was non-significant for all the characters except NBPMF and PWPP, which showed significance at 1% and 5% level, respectively when tested against within error. Significant NBPMF and PWPP indicated that year interacted with dose only in these cases. Similar results were obtained in chickpea by Hasan (2001), Deb (2002). The second order interaction L × D ×Y was highly significant except PHFF. The results of this interaction indicated that genotype (L), dose (D) and year (Y) interacted among themselves. Similar results were obtained by Islam *et. al.* (2002) in lentil, by Nahar (1997) in sugarcane.

The estimates of phenotypic (σ^2_p), genotypic (σ^2_g), dose (σ^2_D), year (σ^2_Y), interactions (σ^2_{LD}, σ^2_{LY}, σ^2_{DY}, and σ^2_{LDY}) and error (σ^2_w) components of variation were calculated separately for all the eight quantitative characters. The results are presented in Table 6. The different components of variation varied differently in different characters. Phenotypic component of variation (σ^2_p) was higher than genotypic (σ^2_g), interactions (σ^2_{LD}, σ^2_{LY}, σ^2_{DY}, and σ^2_{LDY}) and error (σ^2_w) components of variation in maximum cases. This results are in conformity with the findings of Samad (1991), Nahar (1997) and Deb (2002). The difference between phenotypic and genotypic variation were greater in magnitude for NBPMF, PAPP, NPdPP and NSPP which indicated that the environment had considerable effect on these characters. These results are in agreement with the findings of Podder (1993), Mohamed *et.al.*(1991), Nahar and Khaleque (1996), Nahar (1997) and Dev (2002). In the present study, the highest phenotypic and genotypic variations were observed for PAPP followed by NSPP, NPdPP, NBPMF and PHFF. These results are in agreement with the findings of Mian and Awal (1979). The pronounced environmental variation indicated that greater portion of the phenotypic variation was environmental in nature. Chandra (1968) reported in gram that variability was affected by environment. Similar results were also obtained in chickpea by Deb (2002). The character PAPP also showed the highest values for σ^2_D, $\sigma^2_{Y,}$ σ^2_{LD}, $\sigma^2_{LY,}$ σ^2_{LDY} and σ^2_w components of variation which indicated better scope for improvement of this character through selection. On the other hand, σ^2_{DY} showed the highest value for PWPP. Again, σ^2_{DY} for PAPP, σ^2_D, σ^2_{LD} and σ^2_{LY} for NPdPP, σ^2_g and σ^2_w for PdWPP, σ^2_p, σ^2_Y and σ^2_{LDY} for SWPP showed the lowest values in the present materials indicating difficulties in improvement of these traits through selection.

The estimates of phenotypic (PCV), genotypic (GCV), dose (DCV), year(YCV), interactions (L × D CV, L ×Y CV, D ×Y CV and L×D×Y CV) and within error coefficient of variability (ECV) for eight quantitative characters of lentil were computed. The results are presented in Table 6. In the analysis, phenotypic coefficient of variability was greater than genotypic and all other coefficient of variabilities except YCV for NBPMF, PAPP, NPdPP, PdWPP, NSPP, SWPP and PWPP. The results are in agreement with the findings of Samad (1991), Nahar (1997) and Deb (2002). The difference between PCV, and GCV were greater in magnitude for NBPMF, PAPP, NPdPP and NSPP which indicated that environment had considerable effect on these characters. These results are in agreement with the findings of Singh and Sharma (1984) and Podder (1993). The highest amount of PCV, GCV, DCV, YCV, L × DCV, L × YCV and L× D × YCV were observed for PAPP indicating wide scope of selection for this trait. While, the highest values of D×YCV and ECV were recorded for PWPP and NSPP, respectively. Again, YCV and L× D×YCV , D×YCV, DCV, L × DCV and L ×YCV, PCV, GCV and ECV exhibited the lowest values for PHFF, PAPP, NPdPP and PdWPP, respectively. These results are in conformity with the results of Singh *et. al.*(1981), Mian and Awal (1979), Podder (1993), Nahar (1997) and Deb (2002).

Broad sense heritability ($h^2{}_b$), genetic advance(GA) and the genetic advance expressed as percentage of mean (GA%) were estimated and the results are shown in Table 6. The heritable portion of variability cannot be judged by genetic coefficient of variation alone. The heritability together with genotypic coefficient of variation can give the actual picture in heritable variation. The heritability estimate in the present investigation was found to be low. The lowest values of heritability indicated that the environment constituted a major portion of total phenotypic variation for the characters. Bicer and Sakar (2004) found low heritability for biological yield per plant, seed yield per plant, number of pods per plant and number of seeds per plant in lentil. Podder (1993) observed low heritability for MCC and Nahar (1997) got low heritability for TC and MCC in sugarcane. Deb (2002) also obtained low heritability for the nine yield and yield contributing characters (DFF, NPBFF, NSBFF, PHMF, PWH, NPd/P, PdW/P, NS/P and SW/P) in chickpea. However, heritability does not provide indication of amount of genetic progress that would result from selecting the best individuals. Johnson *et. al.* (1955), Ramanujam and Thirumalachar (1967) and Singh *et. al*. (1981) suggested that heritability estimate with genetic gain are more useful for effective improvement. In the present materials, comparatively high value of heritability ($h^2{}_b$) was estimated for PHFF and high value of genetic advance (GA) and genetic advance as percentage of mean (GA%) were observed for PAPP and PHFF respectively. Different workers obtained high values of $h^2{}_b$, GA and GA% for different characters in different crops viz. Khatun (1997) for PHMF in lentil, Kabir (1997) for 100 SW/P in lentil and Deb (2002) for DFF and NS/P in chickpea.

The results of the present investigation revealed that the characters included are quantitative in nature and the genetic variability existed with the lentil lines under study. Therefore, the genetic progress may be achieved with the effective selection of these characters, since the character PAPP showed the highest values for σ^2_p, σ^2_g, PCV, GCV followed by NSPP, NPdPP, NBPMF and PHFF. Provided environmental factors are to be controlled as for as possible as low heritability was observed in these materials.

Table 1. Mean with standard error (SE), least significant difference (L.S.D) at 5% and 1% level of eight characters in lentil in 2005-2006.

		PHFF				NBPMF				PAPP				NP_dPP			
Line	Dose	Mean ± SE	LSD 5%	LSD 1%	CV%	Mean ± SE	LSD 5%	LSD 1%	CV%	Mean ± SE	LSD 5%	LSD 1%	CV%	Mean ± SE	LSD 5%	LSD 1%	CV%
LL6	D1	16.83 ± 1.25	2.7828	3.8343	23.44	15.07 ± 0.69	1.5011	2.0683	14.59	127.30 ± 26.45	55.2866	76.1755	65.69	13.35 ±1.93	3.4939	4.8140	45.70
	D2	14.45 ± 1.01			15.69	7.00 ± 0.55			17.49	38.27 ± 6.03			35.18	5.80 ± 0.20			7.71
	D3	18.50 ± 3.55			3.211	13.33 ± 2.19			28.39	91.657 ± 27.87			52.66	14.00 ± 3.79			46.84
	D4	18.05 ± 4.45			34.17	12.00 ± 1.00			11.78	195.71 ± 142.28			102.81	12.50 ± 2.50			28.28
LL11	D1	24.20± 2.61	3.5072	4.767	34.17	14.04 ± 0.76	2.1686	2.9476	17.08	158.80 ± 10.29	39.928	54.344	20.50	26.99 ± 4.31	6.6703	9.0786	50.60
	D2	21.86 ± 1.33			17.20	13.96 ± 0.87			17.63	126.36± 6.49			13.59	9.81 ± 1.83			49.46
	D3	25.94 ± 2.25			19.43	15.0 ± 3.27			48.76	179.79± 48.34			60.12	18.4 ± 6.61			80.39
	D4	25.0 ± 0.58			4.0	19.0 ± 0.87			7.89	165..08 ± 0.58			0.61	13.0 ± 0.87			11.54
Bm1	D1	24.72± 1.19	1.7272	2.3346	15.22	10.32 ± 0.71	0.8907	1.204	21.68	109.91 ± 13.78	17.6609	23.8714	39.66	10.54 ± 1.25	2.0857	2.8387	37.42
	D2	18.15 ± 1.08			16.82	6.85 ± 0.28			11.73	47.26 ± 8.66			51.84	4.93 ± 1.17			62.65
	D3	18.63 ± 1.34			17.84	7.97 ± 0.74			22.76	65.20 ±7.97			29.96	5.80 ± 1.74			67.22
	D4	18.22± 0.98			13.17	5.426± 0.49			22.17	52.22 ± 13.62			63.90	6.0 ± 1.0			28.87
Bm2	D1	23.54± 1.51	2.1657	2.9273	20.34	9.36 ± 0.70	1.1124	1.5036	23.57	93.16 ± 6.45	16.102	21.7643	21.90	7.04 ± 0.75	1.6887	2.2952	33.68
	D2	20.35 ± 1.22			15.84	5.8 ± 0.53			24.06	69.49 ± 17.92			68.24	6.046 ± 1.51			55.84
	D3	25.55± 0.97			9.259	9.72± 1.00			25.19	71.25 ± 11.76			40.43	7.25 ± 1.44			48.52
	D4	21.27± 1.40			22.38	7.64 ± 0.83			28.67	23.25 ± 7.76			39.29	5.63 ± 1.26			49.85
Bm3	D1	24.79 ± 1.11	1.8391	2.4767	14.15	12.66 ± 1.31	1.8236	2.4559	32.62	126.97± 13.58	24.5206	33.0224	33.82	9.35 ± 0.93	1.1165	1.5036	31.30
	D2	21.42 ± 1.44			21.27	7.72± 0.56			22.88	107.32 ± 16.35			48.19	5.20 ± 0.34			19.61
	D3	23.19 ± 1.01			13.08	10.49 ± 1.51			43.24	85.60 ± 5.71			20.01	7.33 ± 1.09			44.83
	D4	22.84± 1.46			19.13	8.74 ± 1.53			52.60	101.13 ± 26.39			78.12	3.36 ± 0.38			34.43
Bm4	D1	22.47 ± 0.57	0.8187	1.1025	8.0506	14.22 ± 1.86	1.7348	2.3363	41.342	97.85 ± 4.83	8.5715	11.5435	15.60	24.26 ± 3.60	3.0015	4.0421	46.93
	D2	20.12 ± 0.36			5.70	12.84 ± 0.89			21.95	86.06 ± 5.77			21.20	8.66 ± 1.58			57.59
	D3	21.08 ± 0.74			10.48	12.25 ± 0.89			21.72	77.14 ± 5.26			20.45	8.31 ± 0.76			27.56
	D4	20.13 ± 0.57			8.97	10.89 ± 0.77			22.39	76.62 ± 7.41			30.58	6.04± 0.68			35.74
		P_dWPP				NSPP				SWPP				PWPP			
LL6	D1	0.29 ± 0.04	0.0825	0.1136	44.05	14.95 ± 2.73	4.9086	6.7632	57.71	0.21 ± 0.03	0.0684	0.0943	49.81	1.02 ± 0.11	0.2443	0.3366	33.94
	D2	0.12 ± 0.02			43.53	6.8 ± 0.58			19.17	0.10 ±0.01			25.38	0.43 ± 0.08			43.45
	D3	0.34 ± 0.08			42.46	15.67± 3.38			37.40	0.26 ±0.06			40.55	0.98 ± 0.29			50.58
	D4	0.33 ± 0.15			63.09	14.5 ± 7.5			73.15	0.22 ±0.14			91.14	1.41 ± 0.46			57.06
LL1	D1	0.55 ± 0.09	0.1378	0.1876	50.64	25.52 ± 4.28	6.4327	8.7553	53.03	0.40 ± 0.06	0.1003	0.1365	51.38	1.30 ± 0.15	0.5685	0.7738	37.65
	D2	0.24 ± 0.06			71.35	11.40 ± 2.25			52.20	0.16 ± 0.05			75.35	1.38 ± 0.31			58.70
	D3	0.30 ± 0.09			72.75	16.2 ± 4.63			63.91	0.21 ± 0.06			67.20	1.81 ± 0.75			92.20
	D4	0.18 ± 0.01			5.56	10.0 ± 0.87			15.0	0.11 ± 0.02			36.36	0.52 ± 0.03			9.61
Bm1	D1	0.19 ± 0.04	0.0534	0.0727	60.45	8.39 ± 1.78	2.5638	3.4895	66.96	0.13 ± 0.03	0.0393	0.0535	64.95	0.44 ± 0.05	0.106	0.1438	35.98
	D2	0.10 ± 0.02			68.21	4.28 ± 1.17			72.19	0.06 ± 0.02			85.04	0.42 ± 0.08			53.74
	D3	0.10 ± 0.04			79.46	5.8 ± 1.56			60.22	0.07 ± 0.02			68.51	0.28 ± 0.09			75.78
	D4	0.13 ± 0.02			25.38	6.33 ± 1.20			32.87	0.10 ± 0.01			26.03	0.26 ± 0.03			20.91
Bm2	D1	0.11 ± 0.01	0.0566	0.0769	25.05	5.51 ± 0.43	1.6869	2.2929	24.58	0.08 ± 0.01	0.0293	0.0398	30.70	0.44 ± 0.05	0.0973	0.1322	39.30
	D2	0.14 ± 0.05			80.34	8.09 ± 2.50			69.07	0.15 ± 0.04			62.55	0.34 ± 0.11			74.39
	D3	0.17 ± 0.07			101.82	4.67 ± 0.94			49.64	0.06 ± 0.02			80.10	0.43 ± 0.04			20.77
	D4	0.09 ± 0.02			49.45	4.77± 1.03			48.15	0.06 ± 0.02			64.99	0.32 ± 0.06			42.79
Bm3	D1	0.16 ± 0.02	0.0358	0.0482	43.18	5.91 ± 0.58	1.2406	1.6707	30.88	0.11 ± 0.01	0.0306	0.0412	41.92	0.57 ± 0.07	0.0857	0.1154	38.03
	D2	0.08 ± 0.01			49.11	4.67±0.44			28.35	0.07 ± 0.02			42.60	0.31 ± 0.03			30.34
	D3	0.13 ± 0.04			93.37	5.65± 1.53			81.53	0.10 ± 0.04			113.91	0.41 ± 0.04			28.37
	D4	0.06 ± 0.01			60.09	3.44 ± 0.40			35.14	0.05 ± 0.01			62.60	0.41 ± 0.08			62.84
Bm4	D1	0.51 ± 0.10	0.0816	0.1099	65.08	22.41± 4.46	3.4249	4.6123	62.91	0.36 ± 0.08	0.0653	0.088	74.84	0.67 ± 0.10	0.0935	0.1259	45.24
	D2	0.17 ± 0.03			48.13	6.75 ± 1.02			47.86	0.11 ± 0.02			56.79	0.53 ± 0.04			25.20
	D3	0.13 ± 0.02			53.54	4.63 ± 0.62			40.27	0.08 ± 0.02			62.97	0.54 ± 0.05			29.43
	D4	0.09 ± 0.01			37.25	3.90 ± 0.32			26.33	0.05 ± 0.01			32.61	0.45 ± 0.05			35.62

Table 2. Mean with standard error (SE), least significant difference (L.S.D) at 5% and 1% level of eight characters in lentil in 2006-2007.

		PHFF				NBPMF				PAPP				NP_dPP			
Line	Dose	Mean±SE	LSD 5%	LSD 1%	CV%	Mean±SE	LSD 5%	LSD 1%	CV%	Mean±SE	LSD 5%	LSD 1%	CV%	Mean±SE	LSD 5%	LSD 1%	CV%
LL6	D1	21.34±1.75	2.3402	3.1851	25.93	60.20±2.76	4.2549	5.7911	14.49	556.07 ± 74.55	102.5043	139.5142	2.39	97.85 ± 9.08	18.5397	'5.2335	29.35
	D2	18.12±0.64			7.87	40.48±1.56			8.60	323.75 ± 12.10			8.36	129.68 ±16.48			28.42
	D3	20.12±1.21			13.49	40.78±3.30			18.09	306.01 ± 42.79			31.26	166.61± 18.65			25.03
	D4	19.88±0.97			10.96	38.73±2.71			15.64	416.35± 69.91			37.55	115.63± 7.22			13.97
LL1	D1	29.17±0.63	1.5367	1.5367	6.85	75.55± 2.19	2.684	3.6145	9.19	756.40 ± 42.14	98.3346	132.429	17.62	137.82 ± 5.11	18.8408	25.3732	11.72
	D2	30.17±0.84			8.78	51.80±1.625			9.92	717.04 ± 48.37			21.33	130.61 ±8.62			20.87
	D3	26.58±1.32			15.67	46.62±1.24			8.27	635.323± 62.76			31.24	129.51 ± 5.66			13.83
	D4	18.58±1.61			19.41	41.3±2.57			13.92	296.274 ± 72.70			54.87	151.56±13.11			19.35
Bm1	D1	29.05±1.39	2.2423	3.0518	15.14	68.53±4.30	5.8316	7.9371	19.85	733.27 ± 36.81	71.7415	97.6444	15.88	188.27± 12.42	7.6851	'4.0704	20.86
	D2	20.76±0.79			8.539	53.95 ±3.55			14.72	373.14 ± 56.27			33.72	112.21± 10.89			21.70
	D3	22.59±0.71			7.06	48.40±1.51			6.99	367.76 ± 51.52			31.32	129.65±10.15			17.50
	D4	24.15±2.33			21.55	71.93±2.23			6.94	428.63 ± 60.79			31.71	139.34 ± 5.77			9.279
Bm2	D1	23.681±1.15	2.0221	2.7232	15.34	50.16±1.77	3.641	4.9034	11.18	571.21 ± 66.60	127.907	172.2548	36.87	129.42 ± 9.44	14.2575	19.2009	23.07
	D2	21.361±1.83			27.10	61.33±2.24			11.55	622.35 ± 124.93			63.48	20.07 ± 11.48			30.22
	D3	28.27 ±0.84			6.672	56.06±1.68			6.70	655.14 ± 49.02			16.73	144.16± 10.52			16.32
	D4	24.05 ±1.04			13.68	52.72±3.22			19.32	526.37 ± 55.43			33.32	108.75 ± 6.96			20.23
Bm3	D1	24.12±0.98	1.372	1.8477	12.89	31.38±3.64	4.6776	6.2994	36.69	506.47 ± 51.55	79.8043	107.474	32.19	77.69 ± 8.85	10.1489	13.6677	36.02
	D2	24.50±0.90			11.67	32.72±1.86			17.96	483.51 ± 57.46			37.58	66.91 ± 3.77			17.82
	D3	26.33±0.83			9.93	34.69±3.79			34.56	594.454± 40.70			21.65	82.34 ± 5.10			19.58
	D4	27.10±1.07			8.80	66.07±1.56			5.29	690.77 ± 84.60			27.39	151.55± 11.69			I7.25
Bm4	D1	20.01 ± 0.46	1.415	1.9056	7.33	46.77± 2.80	5.4526	7.3431	18.95	454.97 ± 57.82	105.523	142.110	40.19	102.16 ± 4.89	15.7542	21.2164	15.15
	D2	21.31±0.89			13.16	55.52 ± 4.40			25.06	494.32 ±71.95			46.03	159.39± 18.17			36.05
	D3	20.41 ±0.89			13.80	43.58 ±5.03			36.51	469.50 ±41.99			28.29	45.39 ± 9.93			21.61
	D4	24.674±1.43			18.33	41.96± 2.13			16.03	596.86 ±105.26			5.77	99.954 ± 4.83			15.29

		P_dWPP				NSPP				SWPP				PWPP			
LL6	D1	2.26 ± 0.32	0.5988	0.8150	44.41	143.66±16.29	46.33	63.0644	35.87	1.68 ± 0.27	0.4544	0.6185	50.64	6.155 ± 0.7153	1.0715	1.4584	6.7481
	D2	2.36 ± 0.29			27.65	185.0 ± 39.85			48.17	1.61 ± 0.20			27.43	4.806 ± 0.7143			3.2353
	D3	3.44 ± 0.70			45.66	259.32 ± 57.23			49.34	2.44 ± 0.47			43.50	3.412 ± 0.5249			4.3967
	D4	228 ± 0.24			23.83	146.64 ± 21.33			32.52	1.49 ± 0.19			28.17	4.336 ± 0.6287			2.4216
LL1	D1	3.01 ± 0.16	0.5483	0.7384	16.83	05.465± 10.28	34.71	46.7448	15.81	2.30 ± 0.13	0.4007	0.5397	17.78	9.032 ± 0.9414	1.2232	1.6473	2.9604
	D2	3.03 ± 0.26			26.85	87.40 ± 16.27			27.45	2.22 ± 0.18			25.73	7.708 ± 0.6587			7.0223
	D3	3.27± 0.26			25.29	200.86 ± 17.69			27.85	2.37 ± 0.21			27.70	5.225 ± 0.3818			3.1086
	D4	2.80 ± 0.61			49.07	137.2 ± 35.24			57.43	2.01 ± 0.46			51.62	4.86 ± 1.1149			1.2992
Bm1	D1	4.60 ± 0.54	1.002	1.3638	36.84	270.96 ± 31.73	54.34	73.9589	37.03	3.38 ± 0.41	0.7572	1.0306	38.70	6.676 ± 0.3414	0.8499	1.1567	6.1723
	D2	2.60 ± 0.40			34.70	162.46 ± 23.76			32.71	1.99 ± 0.26			29.65	3.808 ± 0.5889			4.5809
	D3	2.76 ± 0.23			18.40	157.5 ± 14.64			20.78	2.00 ± 0.17			19.14	5.428 ± 0.5113			1.0645
	D4	4.07 ± 1.24			68.20	251.76 ± 60.41			53.65	2.93 ± 0.93			71.34	7.364 ± 1.0287			1.2375
Bm2	D1	2.63 ± 0.21	0.4507	0.6069	5.44	173.02 ± 12.40	24.39	32.8416	22.66	1.91 ± 0.19	0.3737	0.5032	31.22	5.076 ± 0.3491	0.9099	1.2254	1.7483
	D2	3.08 ± 0.38			39.63	92.85 ± 20.21			33.13	2.36 ± 0.33			43.53	4.617 ± 0.5569			8.1419
	D3	3.16 ± 0.56			39.63	193.27 ± 25.32			29.29	2.19 ± 0.43			44.21	6.932 ± 0.3465			1.1763
	D4	2.77 ± 0.17			19.99	63.90 ± 12.46			24.04	1.97 ± 0.14			21.81	6.719 ± 0.8592			0.438
Bm3	D1	3.15 ± 0.68	0.6797	0.9154	68.32	152.43 ± 33.67	31.61	42.5729	69.85	2.48 ± 0.54	0.5442	0.7329	9.52	5.383 ± 0.7615	1.4549	1.9594	4.7331
	D2	1.81± 0.26			44.88	92.02 ± 12.54			43.09	1.37 ± 0.19			44.51	3.872 ± 0.4632			7.8271
	D3	2.31 ± 0.29			39.73	121.87 ± 10.84			28.13	1.73 ± 0.24			44.46	6.771 ± 1.4507			7.7532
	D4	3.44± 0.50			32.34	178.00± 12.75			16.02	2.61 ± 0.40			34.24	10.67 ± 0.8515			7.8452
Bm4	D1	559 ± 0.18	5257	0.7080	22.37	152.09 ± 13.56	23.94	32.2349	28.19	1.89 ± 0.15	0.4033	0.5431	24.40	3.597 ± 0.2981	0.7749	1.0435	6.2064
	D2	3.60 ± 0.54			47.47	195.40 ± 19.11			30.92	2.49 ± 0.41			52.62	4.399 ± 0.4625			3.2496
	D3	3.17 ± 0.25			24.62	183.69 ± 16.46			28.34	2.15 ± 0.17			24.35	4.472 ± 0.6708			7.4364
	D4	2.89 ± 0.38			41.54	167.57± 16.71			31.54	2.11± 0.30			45.37	4.529 ± 0.6318			4.1146

Table 3. Differences between dose means and their significances of eight characters in lentil in 2005-2006.

Year: 2005-2006

		PHFF			NBPMF			PAPP			NP_dPP			P_dWPP			NSPP			SWPP			PWPP		
Line	Dose	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2
LL6	D1	1.22	1.67	2.38	3.07**	1.74*	8.07**	68.40*	35.65	89.04**	0.85	0.65	7.54**	0.03	0.05	0.17**	0.449	0.72	8.15**	0.01	0.0447	0.11**	0.12	0.04	0.59**
	D2	3.6*	4.05**		5.0**	6.33**		157.44**	53.38		6.7**	8.2**		0.20**	0.22**		7.7**	8.87**		0.12**	0.155**		0.71**	0.55**	
	D3	0.45			1.33			104.06**			1.5			0.01			1.67			0.03			0.16		
LL1	D1	0.80	1.74	2.34	4.96**	0.96	0.08	6.28	20.99	32.44	13. 99**	8.59*	17.18**	0.37**	0.25**	0.31**	15.52**	9.32**	14.11**	0.29**	0.189**	0.24**	0.78**	0.51	0.08
	D2	3.14	4.08*		5.04**	1.04		38.73	53.43*	62.65**	3.19	8.59*		0.06	0.06		1.40	4.79		0.05	0.0511		0.86**	0.43	
	D3	0.94			4.0**			14.71			5.4			0.12			6.2			0.10*			1.29**		
Bm1	D1	6.49**	6.09**	6.57**	4.90**	2.35**	3.46**	57.69**	44.71**		4.54**	4.74**	5.61**	0.06*	0.09**	0.09**	2.05	2.59*	4.10**	0.04	0.062**	0.07**	0.17**	0.15**	0.02
	D2	0.08	0.48		1.44**	1.11*		4.96	17.94*		1.07	0.87		0.03	0.01		2.06	1.51		0.03	0.0071		0.16**	0.14*	
	D3	0.40			2.55**			12.98			0.2			0.02			0.53			0.037			0.02		
Bm2	D1	2.28*	2.01	3.19**	1.72**	0.36	3.55**	40.87**	21..91**	23.67**	1.41*	0.21	0.99	0.02	0.06	0.03	0.74	0.83	2.58**	0.01	0.02	0.07**	0.12*	0.01	0.10*
	D2	0.92	5.20**		1.84**	3.92**		17.20*	1.76		0.41	1.20*		0.05	0.03		3.32**	3.42**		0.08**	0.09**		0.02	0.09	
	D3	4.28**			2.08**			18.96*			1.62**			0.08*			0.10			0.01			0.11*		
Bm3	D1	1.95*	1.60	3.37**	3.92**	2.16*	4.94**	25.65*	41.37**	19.65	5.99**	2.02**	4.15**	0.10**	0.03	0.08**	2.47**	0.26	1.25*	0.06**	0.01	0.04**	0.17**	0.17**	0.27**
	D2	1.42	1.77		1.02	2.77**		5.99	21.72		1.84**	2.13**		0.02	0.05		1.22	0.98		0.02	0.03**		0.10*	0.10*	
	D3	0.35			1.75			15.72			3.97**			0.01**			2.20**			0.05**			0.0033		
Bm4	D1	2.33**	1.38**	2.35**	3.33**	1.97*	1.38	21.24**	20.71**	11.79*	18.22**	15.96**	15.61**	0.42**	0.38**	0.32**	18.51**	17.78**	15.66**	0.31**	0.27**	0.25**	0.22**	0.13**	0.14**
	D2	0.01	0.96*		1.95*	0.59		9.44*	8.92*		2.61	0.35		0.09*	0.05		2.85	2.12		0.06	0.02		0.08	0.01	
	D3	0.95*			1.36			0.52			2. 26			0.04			0.73			0.33			0.089		

Table 4. Differences between dose means and their significances of eight characters in lentil in 2006-2007.

		Year: 2006-2007																							
		PHFF			NBPMF			PAPP			NP_dPP			P_dWPP			NSPP			SWPP			PWPP		
Line	Dose	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2	D4	D3	D2
LL6	D1	1.46	1.22	3.22**	21.47**	19.42**	19.72**	139.72**	250.06**	232.32**	17.79	68.78**	31.84**	0.03	1.18**	0.09	2.98	115.66**	41.34	0.19	0.76**	0.07	1.82**	2.74**	1.35*
	D2	1.76	1.99		1.75	0.3		92.59	17.74**		14.05	36.93**		0.13	1.08**		38.36	74.32**		0.13	0.83**		0.47	1.39*	
	D3	0.24			2.05			110.34*			50.98**			1.21**			112.68**			0.96**			0.92		
LL1	D1	10.59**	2.59**	1.0	34.26**	28.93**	23.76**	460.13**	121.08*	39.36	13.74	8.31	7.21	0.21	0.25	0.02	68.26**	4.60	18.06	0.29	0.07	0.09	4.17**	3.81**	1.32*
	D2	11.59**	3.59**		10.49**	5.18**		420.77**	81.72		20.95*	1.09		0.23	0.24		50.20**	13.46		0.21	0.16		2.85**	2.48**	
	D3	8.0**			5.32**			339.05**			22.05*			0.46			63.66**			0.36			0.36		
Bm1	D1	4.89**	6.46**	8.29**	3.41	20.13**	14.58**	304.65**	365.51**	360.13**	48.94**	58.62**	76.06**	0.54	1.84**	2.0**	19.19	113.46**	108.50**	0.45	1.37**	1.39**	0.69	1.25**	2.87**
	D2	3.39**	1.84		17.98**	5.55		55.48	5.38		27.13**	17.44		1.46**	0.16		89.30**	4.96		0.94*	0.02		3.56**	1.62**	
	D3	1.56			23.54**			60.86			9.69			1.30*			94.26**			0.92*			1.94**		
Bm2	D1	0.37	4.59**	2.32*	2.55	5.89**	11.16**	44.85	83.93	51.14	20.66**	14.73*	9.34	0.14	0.53*	0.45	9.12	20.25	19.84	0.054	0.28	0.45*	1.64**	1.86**	0.46
	D2	2.69*	6.91**		8.61**	5.27**		95.99	32.79		11.32	24.08**		0.31	0.09		28.96*	0.41		0.39*	0.17		2.10**	2.32**	
	D3	4.22**			3.34			128.78*			35.39**			0.39			29.37*			0.23			0.21		
Bm3	D1	2.98**	2.21**	0.38	34.69**	3.31	1.34	184.30**	87.98*	22.97	73.86**	4.66	10.77*	0.29	0.84*	1.34**	25.58	30.56	60.41**	0.13	0.74**	1.11**	5.29**	1.39	1.51*
	D2	2.59**	1.82*		33.36**	1.98		207.27**	110.95**		84.64**	15.43**		1.64**	0.50		85.99**	29.85		1.24**	0.36		6.79**	2.89**	
	D3	0.77			31.38**			96.32*			69.21**			1.13			56.14**			0.87**			3.89**		
Bm4	D1	4.67**	0.4	1.30	4.81	3.19	8.75**	141.89*	14.53	39.36	2.19	43.24**	57.24**	0.33	0.61*	1.05**	15.48	31.59*	43.30**	0.22	0.26	0.59**	0.93*	0.86*	0.80*
	D2	3.36**	0.90		13.56**	11.94**		102.54	24.83		59.43**	14.0		0.72**	0.43		27.82*	11.71		0.37	0.34		0.13	0.07	
	D3	4.27**			1.61			127.36*			45.43**			0.29			16.12			0.04			0.06		

Table 5. Analysis of variance of eight characters in 6 lines of lentil.

Item	df	PHFF		NBPMF		PAPP		NP$_d$PP		P$_d$WPP		NSPP		SWPP		PWPP	
		VR_1	VR_2	VR_1	VR_2	VR_1	VR_2	VR_1	VR_2	VR_1	VR_2	VR_1	VR_2	VR_1	VR_2	VR_1	VR_2
Line (L)	5	8.94**	8.48 **	20.62**	9.55 **	32.82 **	12.44 **	4.53 **	3.04 *	13.50 **	6.58 **	8.29 **	6.33 **	11.88**	9.12 **	27.82 **	15.37 **
Dose (D)	3	3.02 *	2.86 *	13.19 **	6.11 **	8.28 **	3.14 *	0.37 ^{NS}	0.25 ^{NS}	9.33**	4.54 **	3.18 *	2.43 ^{NS}	6.21**	4.76 **	5.24 **	2.89 *
Year (Y)	1	14.06**	13.34 **	2629.18 **	1217.55 **	1721.23 **	652.59 **	**1318.50****	895.32 **	2152.74 **	1048.66 **	1129.79 **	862.42 **	821.49**	630.51 **	2126.29 **	1174.96 **
L×D	15	2.12 *	2.01 *	9.74 **	4.51 **	13.86**	5.25 **	3.64 **	2.47 **	7.77 **	3.79 **	3.48 **	2.65 *	3.03 **	2.32 **	8.68 **	4.79 **
L×Y	5	0.99 ^{NS}	0.94 ^{NS}	13.20 **	6.11 **	19.99 **	7.58 **	3.02 *	2.05 ^{NS}	9.91 **	4.83 **	7.15 **	5.45 **	8.46 **	6.49 **	19.47 **	10.76 **
D×Y	3	0.56 ^{NS}	0.53 ^{NS}	7.28 **	3.37 *	0.34 ^{NS}	0.13 ^{NS}	1.92 ^{NS}	1.30 ^{NS}	3.03 *	1.47 ^{NS}	2.38 ^{NS}	1.82 ^{NS}	2.10 ^{NS}	1.61 ^{NS}	9.28 **	5.13 **
L×D ×Y	15	1.39 ^{NS}	1.33 ^{NS}	9.58 **	4.44 **	13.12 **	4.97 **	4.49 **	3.05**	8.79 **	4.28 **	3.29 **	2.51 **	3.24 **	2.49 **	6.99 **	3.86 **
Within error	96	14.74		19.1054		2604.21		379.89		0.16		896.62		0.17		0.43	
Pooled error	111	15.54		41.2564		6868.72		559.44		0.32		1174.59		0.22		0.77	

* and ** , indicate significance at 5% and 1% level, respectively. NS, indicate non-significant.

VR_1, denominator is within error and VR_2, denominator is pooled error.

Table 6. Components of variation, coefficient of variability, heritability, genetic advance and genetic advance as percentage of mean of eight characters in lentil.

Components		Characters							
		PHFF	NBPMF	PAPP	NPPP	PWPP	NSPP	SWPP	PWPP
Components of variation	σ^2_p	21.0854	85.4199	16007.9624	799.9682	0.6031	1912.9704	0.4009	1.8778
	σ^2_g	4.8817	5.9103	1391.9682	23.8691	0.0235	42.8721	0.0246	0.1491
	σ^2_D	1.0062	3.136	574.3391	-16.3891	0.0275	19.9038	0.0196	-0.0480
	σ^2_Y	2.6749	697.3963	62219.9984	6951.4148	4.6932	14056.9492	1.9652	12.6410
	σ^2_{LD}	1.7760	0.5066	321.0169	-54.5581	-0.0266	27.3523	-0.0061	0.1206
	σ^2_{LY}	-0.4947	5.7652	1492.6525	-46.6964	0.0147	287.7982	0.0750	0.4452
	σ^2_{DY}	-0.6844	-2.4398	-1849.1661	-54.4047	-0.0503	-45.4452	-0.0109	0.0544
	σ^2_{LDY}	1.9530	54.6389	10519.1325	442.9083	0.4078	685.6824	0.1289	0.8553
	σ^2_W	14.7454	19.1054	2604.2091	379.8872	0.1570	896.6176	0.1725	0.4282
Coefficient of variability	PCV	91.1426	271.5531	5302.6007	1111.3692	34.1179	1979.4283	34.1343	55.7966
	GCV	21.1014	18.7891	461.0863	33.1605	1.3287	44.3615	2.0949	4.4301
	DCV	4.3492	9.9694	190.2485	-22.7688	1.5541	20.5953	1.6730	-1.4266
	YCV	11.5622	2217.0505	20610.2313	9657.3695	265.5083	14545.2974	167.3432	375.6072
	L×DCV	7.6769	1.6105	106.3361	-75.7957	-1.5035	28.3026	-0.5218	3.5823
	L×Y CV	-2.1384	18.3278	494.4377	-64.8738	0.8325	297.7966	6.3826	13.2282
	D×YCV	-2.9584	-7.7561	-612.5320	-75.5827	-2.8446	-47.0240	-0.9277	1.6171
	L × D × YCV	8.4419	173.6994	3484.4384	615.3178	23.0724	709.5035	709.5035	25.4136
	ECV	63.7376	60.7370	862.6383	527.7647	8.8843	927.7668	14.6847	12.7247
Heritability	h^2_b	23.1521	6.9191	8.6955	2.9838	3.8945	2.2411	6.1373	7.9397
Genetic advance	GA	2.1900	1.3173	22.6636	1.7385	0.0623	2.0192	0.0800	0.2241
GA as % mean	GA%	9.4664	4.1879	7.5073	2.4152	3.5246	2.0894	6.8161	6.6597

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