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Genetic Variability and Association Analysis for Various Quantitative Traits in Lentil (*Lens culinaris* Medik. ssp. *culinaris*)

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ABSTRACT

Background: Lentil (microsperma) is the earliest domesticated grain legume grown for its lens shaped seeds. The current study was carried out to assess genetic variability, trait association between seed yield and its attributing components and to assess the direct and indirect effects of various attributing components on seed yield.

Methods: The current experiment evaluated hundred lentil germplasm lines with three checks in augmented design across two environments *viz.,* timely sown (E_1) and late sown (E_2) during *rabi* 2022-23. The data was recorded on 11 quantitative traits and all the statistical analyses were done using R studio.

Result: High PCV and GCV coupled with high heritability and genetic advance as percent of mean was observed for seed yield per plant, biological yield per plant, 100 seed weight and number of pods per plant suggesting that these traits are genetically controlled by additive gene action and their direct selection is effective. Path analysis revealed that biological yield per plant, harvest index, number of primary branches, seeds per pod and days to flowering were the highest positive direct contributors to the seed yield. Based on the observations of the present study, genotypes PL 105, LH 18-03, IPL 406, LH 18-38, LH 18-42, LH 18-45 and LH 18-46 were found to be better performing under timely sown conditions. Similarly, genotypes LH 09-18, LH 09-19, LH 09-20, LH 09-26, LH 09-27, WBL 77 and Kota Masoor 2 were found superior under late sown conditions.

Key words: Correlation, Genetic parameters, Heritability, Lentil, Path coefficient.

INTRODUCTION

Lentil (*Lens culinaris* Medik. ssp. *culinaris*) is a diploid (2x=2n= 14 chromosomes) autogamous annual species with a large genome size of about 4063 bp (Arumuganathan and Earle, 1991). The genus *Lens* belongs to the family *Fabaceae*, subfamily Faboideae and tribe Fabeae. The cultivated species *Lens culinaris* Medik. ssp. *culinaris* is classified into varietal types *microsperma* (small seeded with red cotyledon) and *macrosperma* (large seeded with green cotyledon). In India, lentil is grown in Uttar Pradesh, Madhya Pradesh, Jharkhand, Bihar and West Bengal with an area of 1.74 million ha and the production of 1.79 million tonnes an average yield 1028 kg/ha during 2021-22 (INDIASTAT, 2023). Success in crop breeding is a function of heritability, genetic diversity and selection. Selection is an integral part of a breeding program and selection for high yield is extremely difficult because of its complex nature.

The estimates of correlation coefficients alone may be misleading due to the mutual cancellation of component characters. So, the study of correlation coupled with a path analysis is a more effective tool in the study of yield contributing characters (Chavan *et al*., 2011). Thus, the current study was carried to assess genetic variability, trait association between seed yield and its attributing components and to assess the direct and indirect effects of various attributing components on seed yield.

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MATERIALS AND METHODS

Hundred lentil genotypes were evaluated infield trials with three checks *viz.,* WBL 77, Kota Masoor 2 and L 4717 for eleven quantitative traits. The genotypes were grown in an augmented design across two environments during *rabi* 2022-23, at Research farm of Pulses Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. Two sowing dates, namely timely sowing (E_1; November 22, 2022) and late sowing (E_2; December 15, 2022), were used to generate the required environments. The data was observed for eleven quantitative traits *viz.,* days to flowering, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of pods per plant, seeds per pod,

100 seed weight (g), biological yield per plant (g), seed yield per plant (g) and harvest index (%). R Studio (2020) was used to conduct all the statistical analyses of the data.

RESULTS AND DISCUSSION

Analysis of variance was performed for augmented design with 100 lentil genotypes and 3 checks were sown under timely (E_1) and late (E_2) sown condition (Table 1). The analysis of variance revealed significant differences among the test genotypes for all the traits in both the environments. Estimation of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was done to compare the relative magnitude of genotypic and phenotypic variance present for all the traits studied which revealed about the impact of environment on the particular trait. In all the characters studied, the PCV were slightly higher than their corresponding GCV signifying some influence of environmental factor in causing variations for all the traits. Reddy *et al*. (2016); Meena *et al.* (2020); Kishor *et al*. (2020) and Khatun *et al*. (2022) also observed higher PCV value than GCV value for all the traits. The values of coefficient of variation, heritability, genetic advance and genetic advance as per cent of mean for different traits are presented in Table 2.

In the investigation, high PCV and GCV coupled with high heritability and high genetic advance (as per cent of mean) was observed for seed yield per plant, biological yield per plant, 100 seed weight and number of pods per plant in E_1 whereas, in E_2 high PCV, GCV, heritability and genetic advance (as per cent of mean) was observed for 100 seed weight and seed yield per plant suggesting that these traits are genetically controlled by additive gene action and can be improved by direct selection. These results are in agreement with Singh *et al*. (2014), Reddy *et al.* (2016) and Meena *et al.* (2020).

The identification of important yield components and their association with yield and also with each other is very useful for selecting superior genotypes for evolving high yielding varieties. Therefore, the correlation coefficients were estimated for eleven quantitative traits in lentil grown under timely sown (E_1) and late sown (E_2) conditions and the results are presented in Table 3. Positive correlation was observed among most of the yield attributing traits in both the environments. Seed yield per plant exhibited positive and significant ($p<0.01$) correlation with days to flowering, days to maturity, plant height, number of primary branches, number of secondary branches, number of pods per plant, seeds per pod, biological yield per plant and harvest index in both the environments. Seed yield per plant and biological yield per plant exhibited strongest correlation ($r = 0.808$ in E_1 and $r = 0.637$ in E_2. The results obtained in the present study were in consonance with the findings of Ghimire and Mandal (2019), Sakthivel *et al.* (2019), Maurya *et al.* (2020), Pawar *et al.* (2022) and Sharma *et al.* (2022). Path coefficient analysis was carried out by taking seed yield per plant as dependent variable and all

Table 1: Analysis of variance for eleven quantitative traits in 103 lentil genotypes under timely sown (E1) and late sown (E2) conditions.

Sources of variation	DF	Environment	DTF	DTM	PH	NPB	NSB	NPP	SP	HSW	BY	SY	HI
Block	8	E_1	1.29	0.75	0.86	0.04	0.33	22.51	0.00053	1.34**	0.21	0.11 **	9.4
		E_2	2.15	3.25	6.61	0.04	0.24	26.08	0.0005	0.00098	0.21	0.01	10.34**
Treatment	102	E_1	59.83 **	66.02 **	40.27 **	0.21 **	4.29 **	527.2 **	0.09 **	0.52 **	4.82 **	1.02 **	46.67 **
		E_2	30.29**	27.3**	20.44**	0.26*	1.4**	146.82**	0.05**	0.29**	0.69**	0.17**	10.34**
Check	2	E_1	21.93 **	39 **	294.79 **	1.5 **	13.86 **	1175.05 **	0.67 **	0.92 **	13.92 **	6.58 **	192.84 **
		E_2	6.26	6.78	88.9**	0.7*	6.14**	1842.49**	0.78**	0.82**	5.17**	2.75**	262.98**
Test	99	E_1	26.32 **	17.6 **	26.41 **	0.23 **	4.17 **	621.29 **	0.08 **	0.55 **	5.89 **	1.16 **	41.91 *
		E_2	19.3**	21.08**	23.59**	0.31*	1.44**	130.41**	0.03**	0.34**	0.67**	0.11**	26.31**
Test vs. Check	100	E_1	60.59 **	66.56 **	35.18 **	0.18 *	4.1 **	514.24 **	0.07 **	0.52 **	4.64 **	0.91 **	43.75 *
		E_2	30.77**	27.71**	19.07**	0.25	1.3**	112.91**	0.03**	0.28**	0.6**	0.12**	27.15**
Error	16	E_1	0.84	2.54	0.85	0.07	0.44	25.85	0.0012	0.0014	0.31	0.04	16.1
		E_2	3.09	2.69	4.18	0.12	0.37	30.43	0.0011	0.00051	0.15	0.01	3.58

DF= Degrees of freedom; * Significant at 5% level of probability; ** Significant at 1% level of probability; DTF = Days to 50% flowering, DTM = Days to maturity, PH = Plant height (cm), NPB = Number of primary branches, NSB = Number of secondary branches, NPP = Number of pods per plant, SP = Seeds per pod, HSW = 100 seed weight (g), BY = Biological yield per plant (g), SY = Seed yield per plant (g) and HI = Harvest index (%).

other traits as independent variable. The direct and indirect effects of various traits on seed yield per plant are given in Table 4. In timely sown (E_1) environment, the highest direct positive direct effect on seed yield per plant was exerted by biological yield per plant (0.819) followed by harvest index (0.568), number of primary branches (0.037), seeds per pod (0.022), plant height (0.018), days to flowering (0.010) and number of secondary branches (0.006). Similar results were presented by Dalbeer *et al*. (2013) and Khanam*et al*. (2021). However, number of pods per plant (-0.053), 100 seed weight (-0.010) and days to maturity (-0.007) had negative direct effect on seed yield per plant. Sakthivel *et al.* (2019) and Kumar *et al*. (2020) also observed negative direct effect of plant height and number of pods per plant on seed yield per plant. Latif *et al*. (2020) also found negative direct effect of 100 seed weight on seed yield per plant. Number of pods per plant exhibited positive indirect effect via days to flowering, plant height, number of primary branches, number of secondary branches, seeds per pod, biological yield and harvest index. Residual effect was 0.017, which showed that 98.3% of the variability in seed yield per plant was explained by the component factors. In both the environments maximum direct positive effect on seed yield per plant was of biological yield per plant (0.819 in E_1 and 0.775 in E_2) followed by harvest index (0.568 in E_1 and 0.722 in E_2). Akter *et al*. (2020); Kumar *et al.* (2020); Meena *et al.* (2020) and Sharma *et al.* (2022) also found similar results. In general, from path analysis, it can be deduced that biological yield, harvest index, seeds per pod and number of primary branches had direct positive effects on seed yield per plant; hence the selection for these traits should be done for enhancing the seed yield in lentil. The traits seed yield per plant, biological yield per plant and harvest index have relatively high coefficient of variation along with high heritability and genetic advance as per cent of mean, thus selection for these traits could bring about significant genetic gain. Also, these traits have positive and significant correlation with seed yield per plant along with positive direct effect. Thus, the traits seed yield, biological yield and harvest index may be used as selection indices for improvement of lentil. Also, these traits have positive and significant correlation with seed yield per plant along with positive direct effect. Thus, the traits seed yield, biological yield and harvest index may be used as selection indices for improvement of lentil. In timely sown environment, the genotype, LH 09-27 (16.2 g) had maximum biological yield per plant followed by LH 18-42 (14.9 g), PL 105 (14.7g), IPL 406 (14.3) and LH 18-49 (13.1 g).

Table 2: Estimates of genetic parameters for yield and yield contributing characters in 103 lentil genotypes under timely sown (E_1) late sown (E_2) conditions.

Characters	Environments	PCV	GCV	h^2_{BS}(%)	GA	GAM (%)
DTF	E_1	6.48	6.37	96.80	10.24	12.93
	E_2	6.43	5.89	83.98	7.61	11.13
DTM	E_1	3.52	3.26	85.56	7.41	6.22
	E_2	4.21	3.93	87.22	8.26	7.58
PH	E_1	11.64	11.45	96.77	10.26	23.23
	E_2	13.62	12.35	82.29	8.25	23.12
NPB	E_1	17.05	14.15	68.85	0.68	24.21
	E_2	21.14	16.47	60.69	0.69	26.47
NSB	E_1	18.84	17.82	89.49	3.77	34.78
	E_2	14.60	12.59	74.41	1.84	22.41
NPP	E_1	21.61	21.15	95.84	49.28	42.72
	E_2	15.97	13.98	76.67	18.06	24.26
SP	E_1	19.42	19.26	98.41	0.56	39.42
	E_2	12.24	12.02	96.57	0.36	24.38
HSW	E_1	24.56	24.53	99.75	1.52	50.55
	E_2	21.80	21.78	99.85	1.21	44.91
BY	E_1	25.22	24.56	94.81	4.75	49.33
	E_2	17.45	15.32	77.04	1.30	27.74
SY	E_1	30.64	30.16	96.85	2.15	61.23
	E_2	20.75	20.10	93.88	0.63	40.18
HI	E_1	17.72	13.90	61.59	8.23	22.51
	E_2	15.20	14.13	86.40	9.14	27.09

PCV = Phenotypic coefficient of variation; GCV = Genotypic coefficient of variation; h^2 = Heritability (Broad sense); GA = Genetic advance and GAM = Genetic advance as per cent of mean. DTF = Days to 50% flowering, DTM = Days to maturity, PH = Plant height (cm), NPB = Number of primary branches, NSB = Number of secondary branches, NPP = Number of pods per plant, SP = Seeds per pod, HSW = 100 seed weight (g), BY = Biological yield per plant (g), SY = Seed yield per plant (g) and HI = Harvest index (%).

Similarly, the genotypes PL 105 and LH 09-27 (6.02 g) produced maximum seed yield per plant followed by LH 18-03 (5.5 g), IPL 406 (5.5 g) and PL 01 (5.4 g). The performance of the genotypes was highly affected by the environment, hence the genotypes which performed better for biological yield per plant under the late sown conditions are *viz.,* LH 09-26 (6.6 g), LH 09-22 (6.4 g), LH 18-34 (6.0 g), LH 18-16 (5.9 g) LH 18-53 (5.9 g). Similarly, the genotypes

Table 3: Correlation coefficients among eleven quantitative traits of lentil genotypes under timely sown (above diagonal) and late sown (below diagonal) conditions.

	DTF	DTM	PH	NPB	NSB	NPP	SP	HSW	BY	SY	HI
DTF	1.000	0.578**	0.490**	0.450**	0.323**	0.481**	0.477**	0.313**	0.363**	0.423*	0.186
DTM	0.511**	1.000	0.514**	0.448**	0.482**	0.443**	0.110	0.297**	0.349**	0.474**	0.310**
PH	0.466**	0.500**	1.000	0.476**	0.318**	0.600**	0.409**	-0.102	0.606**	0.613**	0.178
NPB	0.444**	0.548**	0.580**	1.000	0.528**	0.522**	0.428**	-0.017	0.428**	0.536**	0.275**
NSB	0.356**	0.370**	0.460**	0.414**	1.000	0.465**	0.206*	-0.125	0.402**	0.472**	0.240*
NPP	0.439**	0.512**	0.417**	0.346**	0.537**	1.000	0.431**	-0.016	0.643**	0.693**	0.308**
SP	0.486**	0.167	0.438**	0.330**	0.292**	0.235*	1.000	-0.172	0.340**	0.415**	0.200*
HSW	0.143	0.211*	-0.126	0.026	-0.160	0.090	-0.148	1.000	-0.004	-0.001	-0.003
BY	0.366**	0.261*	0.311**	0.246*	0.436**	0.540*	0.361**	0.131	1.000	0.808**	-0.023
SY	0.375**	0.383**	0.336**	0.543**	0.430**	0.447**	0.269*	-0.024	0.639**	1.000	0.553**
HI	0.102	0.244*	0.119	0.470**	0.112	0.023	0.006	-0.086	-0.189	0.580**	1.000

*Significant at 5% level of probability; **Significant at 1% level of probability; DTF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NPB= Number of primary branches, NSB= Number of secondary branches, NPP= Number of pods per plant, SP= Seeds per pod, HSW= 100 seed weight (g), BY= Biological yield per plant (g), SY= Seed yield per plant (g), HI= Harvest index (%).

Table 4: Path coefficient analysis showing direct (diagonal) and indirect effects (off diagonal) of different characters on seed yield inlentil genotypes under timely sown (E_1) and late sown (E_2) conditions.

	Environment	DTF	DTM	PH	NPB	NSB	NPP	SP	HSW	BY	HI
DTF	E_1	0.010	0.006	0.005	0.005	0.003	0.005	0.005	0.003	0.004	0.002
	E_2	0.030	0.015	0.014	0.013	0.011	0.013	0.003	0.005	0.011	0.003
DTM	E_1	-0.004	-0.007	-0.004	-0.003	-0.004	-0.003	-0.001	0.002	-0.003	-0.002
	E_2	0.005	0.011	0.005	0.006	0.004	0.005	0.001	0.002	0.003	0.003
PH	E_1	0.009	0.009	0.018	0.009	0.006	0.011	0.007	-0.00	0.011	0.003
	E_2	-0.011	-0.012	-0.024	-0.014	-0.011	-0.010	0.003	0.003	-0.007	-0.003
NPB	E_1	0.018	0.017	0.018	0.037	0.020	0.020	0.016	-0.00	0.016	0.010
	E_2	0.007	0.008	0.009	0.015	0.006	0.005	0.002	0.001	0.004	0.007
NSB	E_1	0.002	0.003	0.002	0.003	0.006	0.003	0.001	-0.001	0.002	0.001
	E_2	-0.009	-0.009	-0.012	-0.010	-0.025	-0.013	0.003	0.003	-0.011	-0.003
NPP	E_1	-0.026	-0.024	-0.032	-0.028	-0.025	-0.053	-0.023	-0.004	-0.034	-0.016
	E_2	0.012	0.014	0.012	0.010	0.015	0.028	0.003	0.002	0.015	0.001
SP	E_1	0.010	0.002	0.009	0.009	0.004	0.009	0.022	-0.004	0.008	0.005
	E_2	0.002	0.002	-0.003	0.001	-0.002	0.002	0.019	0.012	0.001	0.000
HSW	E_1	0.003	0.003	-0.001	0.000	-0.001	-0.001	-0.002	-0.010	0.000	0.000
	E_2	-0.017	-0.021	0.010	-0.005	0.013	-0.006	0.029	-0.095	-0.015	0.004
BY	E_1	0.308	0.286	0.497	0.358	0.331	0.527	0.285	-0.029	0.819	-0.019
	E_2	0.287	0.192	0.240	0.184	0.336	0.417	0.205	0.123	0.775	-0.146
HI	E_1	0.109	0.177	0.101	0.154	0.136	0.174	0.121	0.012	-0.013	0.568
	E_2	0.068	0.181	0.087	0.336	0.084	0.020	0.016	-0.033	-0.136	0.722
Corr. with	E_1	0.423**	0.474**	0.613**	0.536**	0.472**	0.693**	0.415**	-0.001	0.808**	0.553**
seed yield	E_2	0.375**	0.383**	0.336**	0.543**	0.430**	0.447**	0.269*	0.024	0.637**	0.580**

Residual effect = 0.017 (E_1) and 0.065 (E_2); **Significant at 1% level of probability; DTF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NPB= Number of primary branches, NSB= Number of secondary branches, NPP= Number of pods per plant, SP= Seeds per pod, HSW= 100 seed weight (g), BY= Biological yield per plant (g), HI= Harvest index (%).

PL 01 and LH 18-03 (2.4 g) had maximum seed yield per plant followed by DPL 58 (2.3 g), LH 09-22 (4.3 g), IPL 315 (2.3 g) and Kota Masoor 2 (2.3 g).

CONCLUSION

This study clearly showed that for selecting high yielding genotypes, the breeder should give more emphasis to the genotypes with higher seed yield per plant, higher number of pods per plant and plants with high biomass. Based on the observations it was found that, genotypes PL 01, PL 105, LH 18-03, IPL 406, LH 18-38, LH 18-42, LH 18-45 and LH 18-46 were found to be better performing under timely sown conditions. Similarly, genotypes PL 01, LH 09-18, LH 09-19, LH 09-20, LH 09-26, LH 09-27, WBL 77 and Kota Masoor 2 were found superior under late sown conditions and genotype PL 01 showed good seed yield per plant under both the conditions. Hence, these genotypes can be used as suitable breeding materials for further genetic improvement of lentil based on their performance.

Conflict of interest

The authors declare that there is no conflict of interest.

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