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Genetic variability and association studies in lentil (*Lens culinaris* Medik) under mid-hill sub-temperate conditions of Himachal Pradesh

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Abstract

Forty four lines collected from different sources were evaluated for yield and yield contributing traits under monocropping (E1), intercropping (E2) and combined over environment (E3). Wide range of variability was observed for all the traits. High heritability coupled with high genetic advance for days to 50% flowering indicated additive genetic variance implying that direct selection would be quite effective for this trait. Moderate heritability coupled with moderate genetic advance for harvest index revealed non-additive genetic variance. Therefore, direct selection of this trait may not be effective. Inturn, heterosis breeding would be effective for effective improvement of this trait. Seed yield showed significant positive correlation with pod clusters per plant, pods per plant, pods per cluster and seeds per plant under both the environments, while significant negative association with days to 75% maturity . Maximum direct effect on seed yield was observed for biological yield per plant followed by harvest index and seeds per plant. Days to 50% flowering, plant height, pod cluster per plant and pods per plant exhibited negative direct effect on seed yield. Therefore, numbers of pods per plant, pod cluster per plant, biological yield per plant and harvest index were emphasized as primary seed yield determinants and genetic improvement in lentil would be effective through these traits.

Key words: Lentil, variability, correlations, path analysis, monocropping, intercropping

Introduction

Pulses are important component along with cereals in the staple diet of vegetarian population of the country. They are also important for sustainable agriculture enriching the soil through biological nitrogen fixation. In spite of the important role played by the pulses in protein energy supply and nutritional security, the efforts gone into the research and development of pulse crops appear to be low. Lentils probably originated in the Near East and rapidly spread to Egypt, central and southern Europe, the Mediterranean basin, Ethiopia, Afghanistan, India and Pakistan, China and later to the New World including Latin America (Cubero, 1981). It is probably the oldest of grain legumes to be domesticated (Bahl *et al.*, 1993). It is now cultivated in most subtropical and also in the Northern hemisphere such as Canada and Pacific Northwest regions. Despite a modest status in terms of world trade, lentil is a key food crop in many parts of Africa and Asia (Whitehead *et al.*, 1998). In India, it is cultivated in an area of 1393 x 10^3 ha with a total production of 983 x 10^3 metric tonnes and average yield of 705 kg/ha (Anonymous, 2002). In Himachal Pradesh, lentil is cultivated over an area of 500 ha with total production of 150 metric tonnes and an average yield of 300 kg/ha. It has however, exhibited yield potential of 1400-1500 kg/ha at research farms as far as Vipasha variety is concerned (Anonymous, 2004). A thorough knowledge of the nature and magnitude of genetic variability and the extent of association between yield and yield attributes are essential before launching any breeding programme. Similarly, heritability and genetic advance estimates may be helpful selecting superior individuals. Correlation studies give an idea of the associations of quantitative characters especially of seed yield and its attributes. Path coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficients into direct and indirect effects. The present investigation was undertaken to determine the magnitude of genetic variation, heritability and genetic advance and also to identify characters which in turn will help in framing suitable breeding strategies aimed at developing high yielding lentil varieties.

Material and Methods

The present investigation was carried out at the Experimental Farm of the Department of Plant Breeding and Genetics, CSK HPKV, Palampur, situated at 1290.8 m above mean sea level and at 32°6' N latitude and 76°3' E longitude under two environments viz., I-monocropping of lentil and II-intercropping with linseed (1:1) during *rabi* 2002-2003. This region is characterized as sub-temperate mid hill zone of Himachal Pradesh having high rainfall. The experimental material comprising 44 diverse lentil genotypes, including

one check (Vipasha) was grown in a randomized complete block design with two replications under both the environments. The plot size consisted of single row of 2.25 m length of each genotype spaced 30 cm apart in each replication. The data were recorded on days to 50 per cent flowering, days to 75 per cent maturity, plant height (cm), primary branches per plant, pod clusters per plant, pods per plant, pods per cluster, seeds per plant, 100-seed weight (g), biological yield per plant (g), seed yield per plant (g) and harvest index (%) on the basis of five randomly taken plants from each replication of each environment.

The data were statistically analyzed separately for each environment as well as over environments for each character studied as per the procedure given by Panse and Sukhatme (1984). Estimates of parameters of variability genotypic and phenotypic coefficient of variation were calculated as per the procedure given by Burton and De Vane (1953). The expected genetic advance (GA) was calculated as per Burton and De Vane (1953) and Johnson *et al.* (1955). The phenotypic, genotypic and environmental coefficients of correlation were computed following Al-Jibouri *et al.* (1958). The path coefficients were calculated by employing the method suggested by Dewey and Lu (1959).

Results and Discussion

The present investigation revealed sufficient variability for characters days to 50 per cent flowering, days to 75 per cent maturity, pod clusters per plant, seeds per plant, 100-seed weight, biological yield per plant, seed yield per plant and harvest index under monocropping system, intercropping system and in combined analysis (Table 1). Thus, there appears to be a greater scope for bringing about improvement in these traits. Wide variability for pods per plant, seeds per plant and seed yield per plant has also been reported in lentil by Sharma and Luthra (1987) and Jain and Rao (1955).

High phenotypic coefficient of variation (PCV) was observed for pod clusters per plant, pods per plant, seeds per plant and seed yield per plant in both the systems as well as combined over systems, while 100-seed weight and biological yield per plant recorded high phenotypic coefficient of variation in monocropping only. High genotypic coefficient of variation in general was observed for these traits, reflecting high magnitude of genetic variation and thus greater scope for improvement in these traits through selection.

Phenotypic coefficient of variation and genotypic coefficient of variation were observed to be moderate for days to 50 per cent flowering and harvest index in both the systems as well as combined over systems and for primary branches per plant, 100-seed weight and biological yield per plant in inter-cropping system. The study in general, revealed the estimates of phenotypic coefficient of variation to be higher than their corresponding genotypic coefficient of variation for all the characters. Similar findings with respect to PCV and GCV in lentil have been reported earlier by Thakur and Bajpai (1993) and Rasul *et al.* (1994).

Days to 50 per cent flowering recorded high heritability, however characters namely, days to 75 per cent maturity, 100-seed weight and harvest index recorded moderate to high heritability and for rest of the traits, low heritability was recorded in both the systems as well as combined over systems. High heritability for these traits indicates lesser influence of environment and greater role of genetic component of variation. Chakraborty and Haque (2000) also observed similar results in lentil.

High heritability for days to 50 per cent flowering coupled with high genetic advance indicated the role of additive genetic variance in the inheritance of this trait and thereby implies that the phenotypic selection for this trait would be effective, which is similar to finding of Singh *et al.* (1999). Moderate to high heritability coupled with low genetic advance for days to 75 per cent maturity and 100-seed weight indicated more likelihood of dominance and epistatic effects in the inheritance of these traits. The remaining traits including seed yield per plant, having low heritability and genetic advance, suggest non-additive gene action and consequently low genetic gain is expected through simple selection in such situation. Panse (1975) also reported that if heritability is mainly due to additive gene effects then genetic gain will be more than, when it is due to non-additive gene effects. Seed yield per plant exhibited stable positive association with biological yield per plant, pod clusters per plant, pods per plant, seeds per plant and harvest index at phenotypic, genotypic and environment levels in both the systems as well as combined over systems. Similar associations have also been observed among these traits (Table 2). Thus, it can be inferred that selection focused on any of these traits is likely to bring about improvement in seed yield. Positive association of biological yield per

Table 1. Mean performance and parameters of variability for different characters studied in Environment-E1, E2 and combined over environment (E3)

Character		Mean ± SE(m)			Range			PCV (%)	GCV (%)	ECV (%)	H (%)	GA (% of mean)
Days to 50% flowering	E1	118.07	±	1.4	77.5	–	147	19.37	19.3	1.68	99.01	46.76
	E2	118.31	±	1.94	82	–	150	19.98	19.84	2.32	99	48.04
	E3	118.19	±	1.69	81.75	–	148.25	19.39	19.29	2.03	99	46.7
Days to 75% maturity	E1	173.84	±	1.37	163.5	–	181	3.06	2.86	1.11	87	9.53
	E2	176.93	±	1.44	167.5	–	184	2.49	2.21	1.14	79	7.13
	E3	175.39	±	1.4	165.5	–	182	2.74	2.5	1.13	83	8.22
Plant height (cm)	E1	27.13	±	1.68	23	–	30.2	9.3	3.19	8.74	12	0.61
	E2	26.77	±	1.35	18.85	–	29.9	10.97	8.31	7.15	57	3.47
	E3	26.95	±	1.52	21.67	–	29.9	9.75	5.57	8	33	1.77
Primary branches/ plant	E1	1.93	±	0.3	1.2	–	2.9	23.67	9.43	21.71	16	0.15
	E2	1.82	±	0.23	1.3	–	2.3	22.79	13.73	18.18	36	0.31
	E3	1.88	±	0.26	1.35	–	2.35	22.24	9.44	20.14	18	0.15
Pod clusters/plant	E1	19.81	±	4.39	8.5	–	41.7	45.27	32.69	31.31	52	9.64
	E2	19.12	±	4.72	8.8	–	38.8	46.08	30.1	34.89	43	7.74
	E3	19.47	±	4.55	9.9	–	34.75	44.65	29.97	33.09	45	8.07
Pods/plant	E1	34.88	±	8.86	14.5	–	76.8	51.55	36.98	35.9	52	19.07
	E2	32.51	±	8.48	10.6	–	72	51.25	35.6	36.87	48	16.56
	E3	33.69	±	8.67	16.25	–	64.6	49.94	34.22	36.38	47	16.27
Pods/cluster	E1	1.71	±	0.14	1.41	–	1.98	12.7	4.33	11.9	12	0.05
	E2	1.62	±	0.12	1.14	–	2	13.96	9.38	10.34	45	0.21
	E3	1.67	±	0.14	1.22	–	1.97	13.88	8.17	11.22	35	0.17
Seeds/plant	E1	50.15	±	20.05	17.1	–	139.3	76.84	52.03	56.54	46	36.4
	E2	44.6	±	13.96	12	–	132.8	67.61	51.1	44.27	57	35.48
	E3	47.37	±	17.28	16.85	–	122.55	73.24	52	51.58	50	36.04
100-seed weight (g)	E1	2.89	±	0.33	1.66	–	5.12	31.77	27.35	16.17	74	1.4
	E2	3	±	0.32	1.43	–	4.5	28.96	24.72	15.09	73	1.31
	E3	2.95	±	0.32	1.55	–	4.76	29.85	25.43	15.63	72	1.32
Biological yield/plant	E1	3.1	±	0.85	1.42	–	7.41	49.38	30.59	38.76	38	1.21
(g)	E2	2.89	±	0.77	1.42	–	5.45	45.21	24.58	37.94	30	0.8
	E3	3	±	0.81	1.73	–	5.81	44.3	22.07	38.41	25	0.68
Seed yield/plant (g)	E1	1.26	±	0.44	0.51	–	3.59	62.61	38.54	49.34	38	0.62
	E2	1.13	±	0.34	0.5	–	2.45	52.23	30.23	42.59	34	0.41
	E3	1.2	±	0.39	0.47	–	2.54	58.09	34.78	46.53	36	0.51
Harvest index (%)	E1	39.17	±	2.79	27.07	–	49.12	18.74	15.8	10.08	71	10.75
	E2	39.15	±	3.46	22.46	–	48.92	21.23	17.17	12.48	65	11.2
	E3	39.16	±	3.14	26.1	–	46.71	20.38	16.93	11.35	69	11.35

PCV, GCV, ECV, E1, E2 and E3 = phenotypic coefficient of variation, Genotypic coefficient of variation, Environmental coefficient of variation, E1: Environment 1, E2: Environment 2 and E3: Combined over environment, respectively.

plant and pods per plant with seed yield per plant as observed in this investigation is confirmatory to that of and Esmail and Mohamed (1994). Ramgiri (1989) also reported positive association between seed yield per plant and pods per plant. Positive association of pod clusters per plant and harvest index with seed yield per plant has earlier also been reported by Singh *et al,* (1999).

The negative association of days to 50 per cent flowering, days to 75 per cent maturity and 100-seed weight with seed yield per plant as observed in the present study is indicative of the fact that any improvement in positive direction in any of these traits would lead to reduction in seed yield. However, such association signifies the possibility of development of high yielding and early maturing but small seeded genotypes of lentil. Such associations have also been reported by Kumar and Singh (1995). Further, genetic and environmental correlations have been observed of same sign in case of seed yield per plant with pod clusters per plant, pods per plant, seeds per plant and biological yield per plant indicating thereby that such associations are governed by more or less similar physiological mechanisms.

The study on direct and indirect effects further confirmed that characters like pod cluster per plant, pods per plant, biological yield per plant and harvest index, which exhibited stable positive association with seed yield per plant (Table 3) in general also showed desirable direct or indirect effects and thus are likely to bring about improvement in seed yield if selection is focused upon them.

Table 2. Estimates of correlation coefficients at phenotypic (P) level among different traits studied in E1, E2 and combined over environments

Traits			Days to 75 % maturity	Plant height (cm)	Primary branches / plant	Pod cluster/ plant	Pods/ plant	Pods/ cluster	Seeds/ plant	100-seed weight (g)	Biological yield/ plant (g)	Seed yield/ plant (g)	Harvest index (%)
Days to 50% flowering	E1	P	0.747*	0.01	0.278	-0.362*	-0.26	0.196	-0.164	0.052	-0.149	-0.271	-0.605*
	E2	P	0.595*	0.274	0.514*	-0.22	-0.119	0.332*	-0.091	0.17	0.071	-0.138	-0.502*
	E3	P	0.713*	0.189	0.436*	-0.291	-0.19	0.257	-0.123	0.108	-0.049	-0.211	-0.542*
Days to 75% maturity	E1	P		0.113	0.128	-0.465*	-0.429*	-0.009	-0.328*	0.212	-0.231	-0.329*	-0.594*
	E2	P		0.256	0.29	-0.191	-0.134	0.192	-0.205	0.333*	0.148	-0.078	-0.505*
	E3	P		0.197	0.266	-0.315*	-0.271	0.087	-0.252	-0.29	-0.039	-0.195	-0.547*
Plant height (cm)	E1	P			0.17	0.093	0.116	0.112	0.068	0.235	0.175	0.088	-0.118
	E2	P			0.266	0.215	0.253	0.145	0.176	0.17	0.420*	0.256	-0.24
	E3	P			0.098	0.103	0.11	0.11	0.09	0.2	0.256	0.128	-0.132
Primary branches/ plant	E1	P				0.315*	0.408*	0.375*	0.349*	0.022	0.442*	0.298*	-0.279
	E2	P				0.328*	0.417*	0.419*	0.411*	-0.067	0.553*	0.421*	-0.249
	E3	P				0.271	0.394*	0.449*	0.371*	-0.002	0.492*	0.343*	-0.21
Pod clusters/ plant	E1	P					0.950*	0.298*	0.903*	-0.346*	0.831*	0.874*	0.606*
	E2	P					0.971*	0.321*	0.915*	-0.431*	0.799*	0.927*	0.455*
	E3	P					0.958*	0.339*	0.890*	-0.396*	0.805*	0.869*	0.560*
Pods/plant	E1	P						0.512*	0.933*	-0.384*	0.877*	0.894*	0.553*
	E2	P						0.493*	0.952*	-0.450*	0.819*	0.937*	0.424*
	E3	P						0.534*	0.933*	-0.429*	0.852*	0.898*	0.533*
Pods/cluster	E1	P							0.422*	-0.334*	0.404*	0.343*	0.129
	E2	P							0.499*	-0.296*	0.320*	0.372*	0.153
	E3	P							0.466*	-0.320*	0.417*	0.385*	0.17
Seeds/plant	E1	P								-0.453*	0.838*	0.881*	0.538*
	E2	P								-0.554*	0.723*	0.883*	0.467*
	E3	P								-0.490*	0.794*	0.882*	0.538*
100-seed weight (g)	E1	P									-0.092	-0.174	-0.387*
	E2	P									-0.085	-0.265	-0.416*
	E3	P									-0.097	-0.217	-0.386*
Biological yield/ plant (g)	E1	P										0.952*	0.312*
	E2	P										0.901*	-0.008
	E3	P										0.925*	0.213
Seed yield/ plant (g)	E1	P											0.530*
	E2	P											0.388*
	E3	P											0.510*

*Significant at $P \leq 0.05$

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Table 3. Estimates of direct and indirect effects at phenotypic (P) level for different characters studied in Environment I, II &III

Character			Days to 50% flowering	Days to 75% maturity	Plant height (cm)	Primary branches/ plant	Pod cluster/ plant	Pods/ plant	Pods/ cluster	Seeds/ plant	100-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Correlation coefficient with seed yield
Days to 50% flowering	E_1	P	-0.013	0.032	0.000	-0.003	0.039	-0.004	-0.012	-0.027	0.001	-0.127	-0.157	-0.271
	E_2	P	-0.038	0.013	-0.010	-0.006	0.000	-0.007	-0.005	-0.023	0.012	0.050	-0.135	-0.138
	E_3	P	-0.016	0.032	-0.011	-0.014	0.015	0.024	-0.007	-0.032	0.003	-0.042	-0.163	-0.211
Days to 75% maturity	E_1	P	-0.010	0.042	-0.004	-0.001	0.051	-0.006	0.001	-0.054	0.006	-0.198	-0.155	-0.329*
	E_2	P	-0.023	0.022	-0.010	0.004	0.000	-0.008	-0.003	-0.051	0.024	0.103	-0.136	-0.078
	E_3	P	-0.011	0.045	-0.012	-0.008	0.016	0.034	-0.002	-0.067	0.008	-0.033	-0.164	-0.195
Plant height (cm)	E_1	P	0.000	0.005	-0.037	-0.002	-0.010	0.002	-0.007	0.011	0.007	0.150	-0.031	0.088
	E_2	P	-0.010	0.006	-0.038	0.003	0.000	0.016	-0.002	0.044	0.012	0.291	-0.065	0.256
	E_3	P	-0.003	0.009	-0.059	-0.003	-0.005	-0.014	-0.003	0.024	0.006	0.216	-0.040	0.128
Primary branches/ plant	E_1	P	-0.004	0.005	-0.006	-0.010	-0.034	0.006	-0.023	0.057	0.001	0.378	-0.073	0.298*
	E_2	P	-0.020	0.006	-0.10	0.013	0.000	0.026	-0.006	0.102	-0.005	0.384	-0.067	0.421*
	E_3	P	-0.007	0.012	-0.006	-0.031	-0.014	-0.050	-0.012	0.098	0.000	0.415	-0.063	0.343*
Pod clusters/ plant	E_1	P	0.005	-0.020	-0.003	-0.003	-0.109	0.014	-0.018	0.149	-0.010	0.711	0.158	0.874*
	E_2	P	0.008	-0.004	-0.008	0.004	-0.001	0.060	-0.005	0.228	-0.031	0.555	0.122	0.927*
	E_3	P	0.005	-0.014	-0.006	-0.009	-0.050	-0.120	-0.009	0.236	-0.011	0.680	0.168	0.869*
Pods/plant	E_1	P	0.003	-0.018	-0.004	-0.004	-0.104	0.015	-0.031	0.154	-0.011	0.750	0.144	0.894*
	E_2	P	0.005	-0.003	-0.010	0.005	-0.001	0.062	-0.007	0.237	-0.033	0.568	0.114	0.937*
	E_3	P	0.003	-0.012	-0.006	-0.012	-0.048	-0.126	-0.015	0.247	-0.012	0.719	0.160	0.898*
Pods/cluster	E_1	P	-0.003	0.000	-0.004	-0.004	-0.033	0.008	-0.060	0.069	-0.009	0.346	0.034	0.343*
	E_2	P	-0.013	0.004	-0.006	0.005	0.000	0.031	-0.015	0.124	-0.022	0.222	0.041	0.372*
	E_3	P	-0.004	0.004	-0.006	-0.014	-0.017	-0.067	-0.027	0.124	-0.009	0.352	0.051	0.385*
Seeds/plant	E_1	P	0.002	-0.014	-0.003	-0.003	-0.099	0.014	-0.025	0.165	-0.013	0.717	0.140	0.881*
	E_2	P	0.003	-0.005	-0.007	0.005	-0.001	0.059	-0.007	0.249	-0.040	0.502	0.126	0.883*
	E_3	P	0.002	-0.011	-0.005	-0.012	-0.045	-0.117	-0.013	0.265	-0.014	0.670	0.162	0.882*
100-seed weight (g)	E_1	P	-0.001	0.009	-0.009	0.000	0.038	-0.006	0.020	-0.075	0.028	-0.079	-0.101	-0.174
	E_2	P	-0.006	0.007	-0.006	-0.001	0.000	-0.028	0.004	-0.138	0.073	-0.059	-0.112	-0.265
	E_3	P	-0.002	0.013	-0.012	0.000	0.020	0.054	0.009	-0.130	0.029	-0.082	-0.116	-0.217
Biological yield/ plant (g)	E_1	P	0.002	-0.010	-0.006	-0.004	-0.091	0.013	-0.024	0.138	-0.003	0.855	0.081	0.952*
	E_2	P	-0.003	0.003	-0.016	0.007	-0.001	0.051	-0.005	0.180	-0.006	0.694	-0.002	0.901*
	E_3	P	0.001	-0.002	-0.015	-0.015	-0.040	-0.107	-0.011	0.210	-0.003	0.844	0.064	0.925*
Harvest index (%)	E_1	P	0.008	-0.025	0.004	0.003	-0.066	0.008	-0.008	0.089	-0.011	0.267	0.260	0.530*
	E_2	P	-0.019	-0.011	0.009	-0.003	0.000	0.026	-0.002	0.116	-0.030	-0.005	0.269	0.388*
	E_3	P	0.009	-0.025	0.008	0.007	-0.028	-0.067	-0.005	0.143	-0.011	0.180	0.300	0.510*
Residual	E_1	P	0.027	-	-	-	-	-	-	-	-	-	-	-
	E_2		0.021	-	-	-	-	-	-	-	-	-	-	-
			0.006	-	-	-	-	-	-	-	-	-	-	-
	E_3		0.029	-	-	-	-	-	-	-	-	-	-	-
			0.018	-	-	-	-	-	-	-	-	-	-	-

*Significant at $P \leq 0.05$; Underlined values indicate direct effects

The negative association of days to 50 per cent flowering, days to 75 per cent maturity and 100-seed weight with seed yield has also been confirmed by their high negative indirect effect via pod cluster per plant. Similar observations have also been recorded by Om Vir and Gupta (2001) in lentil.

The low estimates of correlation coefficient for seed yield with plant height and primary branches per plant have been recorded due to low direct and indirect effects of these traits towards seed yield indicating that improvement in these traits is not expected to bring an improvement in seed yield and thus selection of high yielding genotypes can be done independent of these traits.

Thus, early maturity coupled with high number of pods per plant, pod cluster per plant, biological yield per plant and harvest index appear to be important constituents of an ideal high yielding lentil plant ideotype.

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