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Research Note

Genetic variability, character association and path coefficient analysis in chickpea grown under heat stress conditions

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Abstract
Genetic variability, correlation and path analysis was studied for seed yield and its component characters in 100 advance breeding lines of chickpea sown under heat stress environments of Jabalpur. The analysis of variance revealed the significant differences among the genotypes for all the traits indicating presence of sufficient variability among the genotypes for various traits. The High GCV and PCV were observed for seed yield per plant, 100- seed weight, harvest index, number of effective pods per plant, total number of pods per plant and number of secondary branches. High heritability with high genetic advance as percentage of mean was noted for seed yield per plant, followed by 100 - seed weight, harvest index, number of effective pods per plant and total number of pods per plant indicated that selection may be effective for this character. Seed yield per plant was positively and significantly correlated with plant height, number of primary branches, number of secondary branches, number of pods per plant, number of effective pods per plant and 100-seed weight indicating that these three traits were main yield attributing traits. The Path analysis indicated that number of effective pods per plant and 100- seed weight had maximum direct effect on seed yield. On the basis of seed yield ICCV 84251, ICCV 04303, ICCV 06108, ICCV 03209, ICCV 04312 have been identified as heat tolerant lines. The potential for indirect selection for heat stress tolerance using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the genotype which tolerate high temperature conditions.

Keywords:
Chickpea, correlation, heat tolerance, path coefficient

Chickpea (*Cicer arietinum* L.) family Leguminosae, is a self pollinated diploid (2n = 2x = 16) food legume originated in Turkey. In India, the total area under chickpea is 9.01 M ha with 7.58 M t production and the total area in Madhya Pradesh reached 3.04 M ha with 3.29 M t of production with productivity of 1082 kg/ha (FAOSTAT, 2013-14). Breeding efforts have contributed to improve yield potential regional adaptation through resistance to stresses, plant type and seed characteristics. Chickpea is a cool season food legume and incurs heavy yield losses when exposed to high temperatures (≥35°C) at reproductive stage. Heat stress is increasingly becoming a major constraint to chickpea production in India because of continuing shift in its area from cooler long-season environments (northern India) to warmer short-season environments (southern India), increase in area under late sown conditions due to increasing cropping intensity or late maturity of rainy season crop, and expected increase in overall temperatures due to climate change. (Gaur *et al.,* 2008 and Gowda *et al.,* 2009). Reproductive stages (flowering and podding) in chickpea are susceptible to changes in external environment and heat stress (Krishnamurthy *et al.*, 2011). Frequent reductions in chickpea seed yields were observed when plants at flowering and pod development stages were exposed to high (>35^0C) temperatures (Wang *et al.,* 2006). Heat tolerant varieties/cultivars are needed for improving chickpea yields in warm season environments and late sown conditions, expansion of its cultivation to new niches and improving its resilience to the impacts of climate change. The genetic variability present in the base population for desired characters play an important role in development of desirable plant type. Less information is present in the cultivated chickpea lines grown under heat stress conditions. Therefore, the identification of divergent genotypes is essential, considering this, the present investigation was carried out to assess the genetic variability, association of different traits towards yield and selection of high yielding genotypes with better architecture under heat stress conditions.

The experimental material consisted of 100 advance breeding lines of chickpea (received from ICRISAT) were sown on 26^{th} January 2012. Atmospheric temperature varied from 4.0°C minimum in January to 45.0°C maximum in May. The experiment was laid out in a randomized complete block design with three replications during Rabi 2012-13 under All India Coordinated Research Project on Chickpea, in the experimental field of Seed Breeding Farm, JNKVV Jabalpur. Size of each plot was kept 4.0 x 0.60 m, with 1 row of 4 m length. Row to row distance 30 cm and plant to plant spacing was 7-10 cm. The recommended packages of practices were followed to raise a healthy crop. Data were recorded on days to flower initiation, days to 50% flowering, days to pod initiation, days to maturity, plant height (cm), number of primary branches, number of secondary branches, total number of pods per plant, number of effective pods per plant, 100 seed weight (g), seeds per pod, seed yield per plant and harvest index (%). Data were subjected to statistical analysis to work out genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance as per cent of mean as per standard methods. Genotypic and phenotypic coefficients of correlation were computed following the method of Singh and Chaudhary (1985). The correlations were further partitioned into direct and indirect effects as suggested by Dewey and Lu (1959).

The estimates of various parameters viz., general mean, range and different parameters of genetic variability presented in Table 1 revealed that sufficient variability was present in the germplasm for all the traits. This variability can be utilized effectively to develop high yielding, heat tolerant cultivars/genotypes through hybridization followed by selection. Phenotypic coefficient of variation (PCV) was the maximum for Seed yield per plant; followed by 100- seed weight, harvest index and number of effective pods per plant, whereas days to flower initiation, days to 50% flowering, days to pod initiation, days to maturity and plant height had low estimates of PCV. Similar trend was observed for genotypic coefficient of variation (GCV) for almost all the traits, though they were slightly low compared to PCV. These results were in conformity with the findings of Chaudhary *et al*. (2012).

The heritability estimates help the breeders in selection based on the phenotypic performance. The heritability estimate was the highest for 100-seed weight (94.9%), followed by harvest index (94.4%), seed yield per plant (93.8%), number of pods per plant (93.6%), number of effective pods per plant (92.3%), days to pod initiation, days to maturity (91.1%), days to flowering initiation (84.2%), days to 50% flowering (81.9%), number of secondary branches (66.1%) and seeds per pod (61.9%). The character number of primary branches showed low heritability. High estimates of heritability for 100- seed weight, harvest index, seed yield per plant, number of pods per plant and number of effective pods per plant were also reported earlier (Khan and Khan, 2011; Singh *et al*. 2012). Though high heritability indicates the effectiveness of selection on the basis of phenotypic performance, it does not show any indication of the amount of genetic progress for selecting the best individuals. The highest genetic advance was observed for seed yield per plant, followed by 100 - seed weight, harvest index, number of effective pods per plant, total number of pods per plant and number of secondary branches. Plant height, seeds per pod and days to flower initiation had moderate genetic advance. 100 -seed weight, harvest index, seed yield per plant, number of effective pods per plant, total pods per plant and number of secondary branches had high heritability coupled with high genetic advance indicated that these characters are under additive genetic control and simple selection will be effective for their improvement.

Most of the phenological traits *viz*., days to flower initiation, days to 50% flowering, days to pod initiation and days to maturity showed high heritability estimates accompanies with low genetic advance as percentage of mean. This reflects the presence of non-additive gene effects. Selection based on such traits may not be rewarding. These findings are in conformity with Patel and Babbar (2004) and Usmani *et al*. (2005).

Correlation analysis suggested that the magnitude of genotypic correlation were higher as compared to their corresponding phenotypic correlations indicating the inherent relationship among the characters studied (Table 2). Correlation studies showed that for most character pairs, genotypic and phenotypic associations were in same direction and the genotypic estimates were higher than the phenotypic ones, indicating an inherited association between the characters.

Seed yield per plant exhibited highest significant positive association with 100- seed weight (0.3737), and followed by number of effective pods per plant (0.3694), total number of pods per plant (0.3096), number of primary branches (0.1680) and plant height (0.1855). Thus, these characters turned out to be the major components of seed yield. Such positive interrelationships between seed yield and these attributes have also been reported in chickpea by Sial *et al*. (2003) Arshad *et al.* (2004), Jeena *et al.* (2005) and Akhtar *et al.* (2011). Thus, providing that these attributes were more influencing the seed yield in chickpea and could serve as marker / indicator characters for improvement in seed yield. Since early maturity is considered as a desirable criterion, the relationship of days to pod initiation and days to maturity with seed yield per plant found was in desirable direction. Such negative associations were also reported by Rao and Kumar (2003) and Sial *et al.* (2003).

The characters days to pod initiation and days to maturity were negatively associated with seed yield per plant. This indicates that late flowering genotypes had short reproductive period that results into low yield. The study is conducted under heat stress conditions (Late planting) it indicates that for late planting early maturing genotypes are more preferable.

Among the yield contributing characters, days to 50% flowering showed significant positive correlation with days to pod initiation, days to maturity, plant height and number of seeds per pod while negatively correlated with 100 seed weight and harvest index. 100-seed weight exhibited negative significant association with phenological traits and most of the yield attributing traits except plant height. Days to maturity exhibited significant positive correlation with plant height, 100-seed weight and significant negative correlation with pods per plant, seeds per pod, biological yield and harvest index. This indicates that in late maturing genotypes, the size of seed increased but the seeds per pod and pods per plant reduced.

In order to further elucidate the association of yield components as a function of their relative influence on the complex dependent character yield, path analysis was performed (Table 3). Results reveal highest direct and positive effect on seed yield was exhibited by number of effective pods per plant (0.8818) followed by 100- seed weight (0.7365), number of primary branches (0.4721), days to 50% flowering (0.3648). Thus, these characters turned out to be the major components of seed yield. Selection of these traits may rewarded in other words these traits should given importance, while practicing selection aimed at improvement of seed yield in chickpea. Similar results have also been reported by Sontakey *et al.* (1991) for 100-seed weight, number of seeds per pod, number of branches per plant, Dasgupta *et al,* (1992) for 100-seed weight, Yadava and Singh (2008) for 100-seed weight and Borate and Dalvi (2010) for number of primary branches. However, number of secondary branches (-0.0222), days to flower initiation (-0.0579), harvest index (-0.1718), plant height (-0.2027), total number of pods per plant (-0.4111) and days to pod initiation (-0.5755) showed negative direct effect.

Similarly, as direct effect, the indirect effects will also find it contribution *via* different traits towards seed yield per plant. Majority of indirect effects of various independent traits *via* other traits were extremely low of either signs. The indirect effect of day to 50% flowering, day to maturity, number of primary branches, number of secondary branches, total number of pods per plant, seed per pod and harvest index was positive on seed yield *via* day to flower initiation. The correlation between seed yield and days to flower initiation was mainly due to direct positive effect of day to flower initiation on seed yield. It shows that direct selection for these traits may improve seed yield per plant.

The study on correlation and path coefficient revealed that the traits days to 50% flowering, seeds per pod, number of effective pods per plant, 100-seed weight, number of primary branches and days to maturity showed positive and significant correlation with seed yield per plant as well as its have direct effect on seed yield. Thus these traits might be considered for selecting the high yielding genotypes suitable for late planting. On the basis of mean values (Table 4), promising genotypes were identified for major characters under high temperature conditions. On the basis of phenological and yield attributing traits ICCV 93014, ICCV 96317, ICCV 01302 and ICCV 063301 were found superior used as donor for in hybridization programme.

The present study conducted under high temperature conditions indicated that number of effective pods per plant, and harvest index had the maximum contribution in determining seed yield under heat stress in kabuli chickpea. Breeding strategies for improvement of yield potential in late sown chickpea would aim on selection of plants having higher number of effective pods, high seed yield per plant and harvest index. Therefore, breeding strategies for improvement of yield potential in late sown desi and kabuli lines would be to select plants having higher number of effective pods, high 100-seed weight, high harvest index and more number of branches and low mean value of phenological traits.

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Table 1. Genetic parameters for yield and its attributing traits

Characters	Mean	Range		Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance	Genetic advance (as percentage of mean)
		Min.	Max.					
Days to flower initiation	38.63	34.00	47.00	6.49	7.07	84.2	4.74	12.27
Days to 50% flowering	48.86	45.00	56.00	5.35	5.91	81.9	4.87	9.96
Days to pod initiation	56.96	51.00	66.33	5.81	6.08	91.1	6.51	11.42
Days to maturity	84.67	76.67	93.33	4.38	4.59	91.1	7.29	8.61
Plant height (cm)	38.09	31.90	46.90	7.47	8.28	81.4	5.29	13.88
Number of primary branches	2.77	2.00	3.33	6.07	16.54	13.5	0.13	4.59
Number of secondary branches	8.13	5.00	12.33	17.85	21.95	66.1	2.43	29.89
Total number of pods per Plant	35.17	23.10	51.90	18.34	18.96	93.6	12.86	36.57
Number of effective pods per Plant	29.15	14.43	43.30	20.34	21.17	92.3	11.73	40.27
Number of seeds per pod	1.02	0.85	1.20	8.24	10.48	61.9	0.14	13.36
100-seed weight (g)	25.06	14.33	38.40	22.61	23.21	94.9	11.37	45.36
Harvest index (%)	54.70	16.60	76.13	21.05	21.67	94.4	23.04	42.12
Seed yield per plant (g)	6.67	2.53	12.70	27.24	28.12	93.8	3.63	54.34

Table 2. Genotypic (rg) and Phenotypic (rp) correlation coefficient for seed yield and other characters in chickpea

Characters		DFI	DFF	DPI	DM	PH	NPB	NSB	TNPPP	NEPPP	NSPP	100-SW (g)	HI (%)
	r_p	0.8196**											
DFF	r_g	0.8851											
	r_p	0.6842**	0.8398**										
DPI	r_g	0.7487	0.9090										
DM	r_p	0.6029**	0.7491**	0.8588**									
	r_g	0.6769	0.8457	0.9263									
PH	r_p	0.1804**	0.1691**	0.1703**	0.1873**								
	r_g	0.2159	0.2171	0.2094	0.2173								
NPB	r_p	0.0332	0.0377	0.0506	0.0524	0.1926**							
	r_g	0.1198	0.1132	0.1709	0.1153	0.4204							
NSB	r_p	-0.0013	-0.0304	0.0075	0.0506	0.0154	0.2563**						
	r_g	-0.0056	-0.0437	-0.0115	0.0733	-0.0264	0.4828						
TNPPP	r_p	-0.0069	-0.0367	-0.0086	0.0598	-0.0256	0.1941**	0.4896**					
	r_g	-0.0056	-0.0437	-0.0115	0.0733	-0.0264	0.4828	0.5945					
NEPPP	r_p	-0.0584	-0.1082	-0.0720	-0.0064	-0.0361	0.1770**	0.4842**	0.8539**				
	r_g	-0.0760	-0.1252	-0.0830	-0.0105	-0.0463	0.4041	0.5834	0.9011				
NSPP	r_p	0.1414*	0.1692**	0.1824**	0.1204*	-0.0857	-0.0030	-0.0994	-0.0876	0.1393*			
	r_g	0.1880	0.2499	0.2482	0.1673	-0.0881	0.1169	-0.1101	-0.1135	-0.1619			
100-SW (g)	r_p	-0.2298**	-0.2728**	-0.3581**	-0.3846**	0.2204**	-0.0464	-0.0498	-0.3392**	-0.3147**	-0.2132**		
	r_g	-0.2503	-0.3112	-0.3880	-0.4169	0.2533	-0.1601	-0.0803	-0.3532	-0.3411	-0.2617		
HI (%)	r_p	-0.3731**	-0.3834**	-0.3922**	-0.3875**	-0.3242**	0.0411	-0.0997	0.0414	0.1693**	0.0280	-0.0591	
	r_g	-0.4188	-0.4405	-0.4199	-0.4198	-0.3755	0.0515	-0.1498	0.0385	0.1671	0.0569	-0.0628	
SY (g)	r_p	-0.0645	-0.1108	-0.1830**	-0.1806**	0.1855**	0.1680**	0.3065**	0.3096**	0.3694**	0.0391	0.3737**	0.0253
	r_g	-0.0790	-0.1272	-0.1909	-0.1896	0.2020	0.4126	0.3416	0.3172	0.3764	0.0453	0.3953	0.0158

* = Significant at 5% probability level, ** = Highly significant at 1% probability level, DFI= Days to flower initiation, DFF= Days to 50% flowering, DPI= Days to pod initiation, DM= Days to maturity, PH= Plant height, NPB= Number of primary branches, NSB= Number of secondary branches, TNPPP= Total number of pods/Plant, NEPPP= Number of Effective pods/plant, NSPP = Number of seeds per pod, 100-SW = 100-seed weight (g), HI= Harvest index (%),SY= Seed yield (g)

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Table 3. Path coefficient analysis showing direct and indirect effects of twelve causal on seed yield per plant variables in chickpea

Characters	DFI	DFF	DPI	DM	PH	NPB	NSB	TNPPP	NEPPP	NSPP	100-SW (g)	HI (%)	Genotypic correlation with SY (g)
DFI	-0.0579	0.3228	-0.4308	0.1978	-0.0438	0.0566	0.0005	0.0023	-0.067	0.053	-0.1843	0.072	-0.0790
DFF	-0.0513	0.3648	-0.5231	0.2471	-0.044	0.0534	0.0014	0.018	-0.1104	0.0705	-0.2292	0.0757	-0.1272
DPI	-0.0434	0.3316	-0.5755	0.2706	-0.0424	0.0807	-0.0003	0.0047	-0.0732	0.07	-0.2858	0.0722	-0.1909
DM	-0.0392	0.3085	-0.533	0.2922	-0.044	0.0544	-0.0014	-0.0301	-0.0092	0.0472	-0.307	0.0721	-0.1896
PH	-0.0125	0.0792	-0.1205	0.0635	-0.2027	0.1985	0.0002	0.0109	-0.0408	-0.0248	0.1866	0.0645	0.2020
NPB	-0.0069	0.0413	-0.0984	0.0337	-0.0852	0.4721	-0.0079	-0.1985	-0.3563	-0.0333	-0.1179	-0.0645	0.4126
NSB	0.0013	-0.0227	-0.0088	0.0179	0.0019	0.1687	-0.0222	-0.2444	0.5144	-0.0311	-0.0591	0.0257	0.3416
TNPPP	0.0003	-0.0159	0.0066	0.0214	0.0054	0.2279	-0.0132	-0.4111	0.7947	-0.032	-0.2601	-0.0066	0.3172
NEPPP	0.0044	-0.0457	0.0478	-0.0031	0.0094	0.1908	-0.013	-0.3705	0.8818	-0.0457	-0.2512	-0.0287	0.3764
NSPP	-0.0109	0.0912	-0.1428	0.0489	0.0179	0.0552	0.0024	0.0467	-0.1428	0.2821	-0.1927	-0.0098	0.0453
100-SW (g)	0.0145	-0.1135	0.2233	-0.1218	-0.0513	-0.0756	0.0018	0.1452	-0.3008	-0.0738	0.7365	0.0108	0.3953
HI (%)	0.0243	-0.1607	0.2417	-0.1226	0.0761	0.0243	0.0033	-0.0158	0.1474	0.016	-0.0463	-0.1718	0.0158

DFI= Days to flower initiation, DFF= Days to 50% flowering, DPI= Days to pod initiation, DM= Days to maturity, PH= Plant height, NPB= Number of primary branches, NSB= Number of secondary branches, TNPPP= Total number of pods/Plant, NEPPP= Number of Effective pods/plant, NSPP = Number of seeds per pod, 100-SW = 100-seed weight (g), HI= Harvest index (%),SY= Seed yield (g)

Table 4. Promising genotypes for different traits

Characters	Genotypes
Days to maturity (<80 days)	ICCV 03405, ICCV 05307, ICCV 05303, ICCV 95332, ICCV 00105
Harvest index (>70 %)	ICCV 11113, ICCV 11311, ICCV 93014, ICCV 05303, ICCV 06102
Seed yield per plant (>12g)	ICCV 84251, ICCV 04303, ICCV 06108, ICCV 03209, ICCV 04312
100-seed weight (>35 g)	ICCL 82216, ICCV 04303, ICCV 04312, ICCV 05107
Number of effective pods per plant (>40)	ICCV 91007, ICCV 91011, ICCV 93005