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Assessment of Genetic Variability and Yield Stability in Chickpea Genotypes under Diverse Environments

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A B S T R A C T

The chickpea crop is highly sensitive to temperature and other climate condition. Genotype × environment interaction (G x E) is a major constraint to identify single superior genotype for a number of variable environments. Present study was undertaken for estimation of the impact of G x E interaction on seed yield of chickpea and to identify relatively stable genotypes across environments using 40 chickpea genotypes. Data were collected on twelve yield related traits. The variability analysis revealed that the PCV was higher in magnitude than its corresponding GCV for all the characters studied under three environments. This indicates the influence of the environment on the expression of these characters. Characters showing high heritability coupled and high genetic advance as percentage of mean were biological yield per plant (97.8% & 108.2%), seed yield per plant (97.3% & 104%) and total number of pod per plant (95.5% & 83%) in all the three environments and pooled analysis. The genotypes namely GG 2, ICC 4958, ICC 8474, ICCL 81248, ICCV 07102, ICCV 07109, ICCV 07110, ICC 1882, JG 1307, MP JG 2003-115, MP JG 99-115, JG 130 and JAKI 9218 had the regression coefficients greater than one coupled with high mean values indicating specific adaptation of these genotypes for exploitation of character for seed yield per plant. The above results have provided the opportunity of growing chickpea under late planting condition in double cropping (after rice) and very late (after soybean-potato/garden pea).

Introduction

Chickpea (*Cicer arietinum* L.) is an annual legume and the only cultivated species within genus *Cicer*. It is an important pulse crop in the world as a source of diet for human and livestock and ranks third after dry bean and dry pea. In pulses, chickpea (*Cicer arietinum* L.) is one of the important crops with high acceptability and wider use, its ability to use atmospheric nitrogen through biological nitrogen fixation is economically sounder and environmentally acceptable grown in *Rabi* season. It is valued for its nutritive seeds with high protein content, 25.3-28.9%, after de-hulling (Hulse, 1991). Chickpea covers 11.7 mha area and 12.00mt production in over 55 countries of the world. The major chickpea producing countries include India, Australia, Pakistan, Turkey, Myanmar, Ethiopia, Iran, Mexico, Canada, and the United States. It is the most important pulse crop of India contributing to over 40% of countries total pulse production and largest chickpea producing country with a share of 72% in the global chickpea production. India is the largest producer accounting a share of about 8.39 mha area, 7.03 mt production and average productivity 840 kg/ha. In M.P., it covers 3017 thousand ha area with a production of 3364 thousand tonnes and an average productivity 1115 kg/ha which is the highest among different pulses crop. Variability in the base population is essential for any successful breeding programme. Quantum of genetic variability and the extent to chickpea heritable and non-heritable variation are related to the characters determine the extent of genetics amelioration. Accurate estimation of the levels and patterns of genetic diversity is useful to estimate the potential of heterotic combinations before attempting crosses and hence saving time and resources (Halluer and Miranda, 1988) Such information can serve for introgression of desirable genes from wild germplasm to the high yielding germplasm resource (Thompson *et al.,* 1998), analysis of genetic variability in germplasm (Cox *et al.,* 1986) and identification of different combinations for creating segregating progenies with greatest genetic variability (Barrett and Kidwell, 1998). The seed yield of chickpea is influenced by many factors including genotype, growing season, geographical site, and agronomic practices (Tawaha *et al.,* 2005). The fluctuation in chickpea production may be affected by environmental changes and use of varieties that are not adapted to wide range of environments. Genotypes are considered to be more adapted or stable if they show low degree of fluctuation in yielding ability under different environments. Chickpea production in India can be increased and stabilized by two approaches. The first one is stratification of chickpea growing areas followed by development of suitable varieties for target regions and the second one is development of cultivars with wide adaptability for its cultivation in diversified environments. The climatic factors, such as rainfall and temperature change from year to year even in the same region. Therefore, most suitable approach to attain stability would be development of widely adapted varieties with high yield potential.

Genotype X environment interaction is the change in relative performance of genotypes across sites (DeLacy *et al.,* 1996). G X E interaction should be investigated so that the breeder can decide to restructure the programme to minimize the interaction effect, or exploit it to produce varieties with specific adaptation to particular environments (Eisemann *et al.,* 1990). Eberhart and Russell (1966) model consists of three parameters, (a) mean yield over locations or seasons, (b) regression coefficient and (c) deviation from regression. According to this model a stable variety is one with a regression coefficient of unity (b=1) and a minimum deviation from the regression line (S2 d=0). Using their definition a breeder would usually desire to develop a variety with high mean yield and satisfying the above requirements for stability (Phundan and Narayanan, 2004). Present study was undertaken for estimation of the impact of genotypes environment interaction on grain yield of chickpea and to identify relatively stable genotypes across environments.

Materials and Methods

Forty chickpea genotypes were evaluated for three environments (normal sown, late sown and very late sown planting condition) during *Rabi* 2011-2012 under All India Coordinated Research Project on Chickpea in the experimental field of Seed Breeding Farm, College of Agriculture, Jabalpur (M.P). Data were collected on days to flower initiation, days to 50% flowering, days to pod initiation, days to maturity, plant height (cm), total number of pods per plant, number of effective pods per plant, number of seeds per pod, 100-

Seed weight (g), biological yield (g), harvest index (%) and seed yield per plant. These were estimated from five randomly selected plants. The genotypes were arranged in RCB design with 3 replicates. Separate analysis of variance for each season was performed for seed yield and its component before running the combined analysis. The mean differences were separated using Duncan′s multiple range test (DMRT). The genetic parameters and broad-sense heritability were estimated as suggested by Burton (1952) and Hanson *et al.,* (1956). Each season was used as a separate environment to measure stability parameters following regression analysis. Eberhart and Russell (1966) models were employed to investigate yield stability.

Results and Discussion

Coefficient of variability, heritability and genetic advance

A wide range of variability was observed for different yield attributing traits. The PCV was higher in magnitude than its corresponding GCV for all the characters studied under three environments. This indicates the influence of the environment on the expression of these characters. In the pooled analysis, biological yield showed the highest phenotypic and genotypic coefficient of variation (53.8% and 53.2%), followed by seed yield per plant (51.9% and 51.2%), effective pods per plant (44.6% to 43.6%) and total number of pods per plant (43.2% and 41.2%) (Table 1). Whereas, plant height (29.3% and 29.1%) had moderate phenotypic and genotypic coefficient of variation while, other traits *viz*. harvest index, 100-seed weight, days to maturity, days to flower initiation, days to 50% flowering, days to pod initiation and number of seeds per pod exhibited low phenotypic and genotypic coefficient of variation. These results were in accordance with Usmani *et al.,* (2005), Khan *et al.,* (2011), Babbar *et al.,* (2012). High heritability was found in days of maturity (99.0%), followed by plant height (98.6%), days to pod initiation (98.5%), days to 50% flowering (97.9%), biological yield (97.8%), days to flower initiation (97.7%), seed yield per plant (97.3%), effective pods per plant (95.7%), total number of pods per plant (95.5%), harvest index (92.0%), 100-seed weight (91.0%) and number of seeds per pod (81.1%) in pooled analysis (Table 1). Characters showing high heritability coupled with high genetic advance as percentage of mean were biological yield per plant, seed yield per plant and total number of pod per plant in all the three environments and pooled analysis, these finding match with the results of earlier researchers Patel and Babbar (2004), Saleem *et al.,* (2005), Durga *et al.,* (2007) and Sidramappa *et al.,* (2008).

Stability analysis

The stability parameters such as Mean (X), regression coefficient (βi) and deviation from regression (s^2di) were estimated for all the twelve characters of each genotype. Partitioning of analysis of variance (Table 2) displayed highly significant results for genotype, environment linear and pooled deviations, Env. + Var X Env. and var. X Env. Linear. A significant G X E interaction may be either crossover in which a significant change in rank occurs from one environment to another (Matus *et al.,* 1997) or a non-crossover type in which ranking of genotype remains constant across environments and the interaction is significant due to change in the magnitude of response (Baker, 1988; Blum 1983, Matus *et al.,* 1997). It was observed that deviation from linearity in magnitude for most of the characters suggesting large influence of the environment in the expression of characters over different environments (Eberhert and Russel 1966). In the stability analysis genotypes found highly significant for all the character except total number of pods per plant and effective pods per plant. In genotype x environment interaction days to maturity, plant height, number of seeds per pod and biological yield were found significant. The variation due to environment (linear) was found significant for all the character. The distribution of genotypes has been presented in Table 2. The component G X E (linear) was significant for plant height, days to maturity and biological yield, suggesting that major portion of G X E interaction was attributed to linear component in respect to these traits, although non-linear component (pooled deviation) was highly significant for all character except harvest index.

The predominance of linear component would help in predicting the performance of genotypes across environments. This also suggested that prediction for these attributes would be perfect, these results supporting the earlier findings of Hasan *et al.,* (2008), Segherloo *et al.,* (2008), Alwawi, Choumane (2010) and Tilahun *et al.,* (2015). The genotypes had regression coefficient lesser than unity coupled with mean values less to grand mean revealed that above average stability of genotypes.

The genotype had the regression coefficient above unity and also with very low mean values over the environments indicating below average stability of these genotypes. These genotypes were stable under poor / unfavorable environment. The genotypes had the regression coefficients greater than one, coupled with high mean values indicting specific adaptation of these genotypes for exploitation of these characters. Genotype was found to be highly stable with mean values greater than population mean and regression coefficient lesser than one with minimum deviation from regression indicating stability of these genotypes for change of environmental condition in the expression of this character. Genotypes ICC 7441, ICC 3325 and ICCV 01709 for character days to 50 % flowering, total number of pod per plant, effective pod per plant had the regression coefficients greater than one, coupled with high mean values deviation from regression less indicting specific adaptation of these genotypes for exploitation of these characters.

The responses of genotypes in terms of all yield related traits were different both same and different planting condition. This indicated that the efficiency of a breeding program aimed at yield improvement is impaired due to genotype by environment interaction, which complicates the process of crop variety development especially when varieties are selected in one environment and used in others (Ahmad *et al.,* 2011).

The genotypes ICC 3325, ICC 9942, ICC 4182, ICC 10018, ICC 15888, ICC 14402, ICC 67, ICC 15618, JG 2003-14-16, JG 17, JG 18, JG 21, JG 22, JG 16 and JG 14 had regression coefficient lesser than unity coupled with mean values less to grand mean revealed above average stability of these genotypes for seed yield per plant. The genotypes ICC 16181, ICCV 07105, ICC 14815, ICC 7441, ICC 6816, ICC 6874 and JG 14-11 had the regression coefficient above unity and also with very low mean values over the environment indicating below average stability these genotypes. These genotypes were stable for seed yield per plant in unfavorable environment. The genotypes namely GG 2, ICC 4958, ICC 8474, ICCL 81248, ICCV 07102, ICCV 07109, ICCV 07110, ICC 1882, JG 1307, MP JG 2003-115, MP JG 99-115, JG 130 and JAKI 9218 had the regression coefficients greater than one coupled with high mean values indicating specific adaptation of these genotypes for exploitation of character for seed yield per plant.

Table.1 Genetic parameters of variability for chickpea genotypes in E-I, E-II E-III and pooled analysis

Characters	Environment	General mean	Range		Coefficient of variation		h^2 (B)%	GA as% of mean
			Min.	Max.	PCV (%)	GCV (%)		
FI	E-I	46.1	41.0	52.3	6.2	6.0	94.3	12.1
	E-II	57.2	41.0	65.0	10.0	9.9	98.7	20.3
	E-III	42.6	36.3	52.0	10.5	10.4	97.7	21.2
	POOLED	48.6	39.1	63.3	14.7	14.5	97.7	29.6
$F_{50\%}$	E-I	52.5	46.7	59.0	5.5	5.3	92.5	10.6
	E-II	61.9	45.0	69.3	8.5	8.5	98.3	17.4
	E-III	45.7	40.0	54.0	8.8	8.6	96.1	17.4
	POOLED	53.3	41.7	67.3	13.8	13.7	97.9	27.9
PI	E-I	63.6	58.7	72.0	4.4	4.1	89.5	8.1
	E-II	71.1	60.0	80.3	7.0	6.9	97.8	14.1
	E-III	51.0	46.0	58.0	7.2	7.1	96.6	14.4
	POOLED	61.9	47.2	77.8	14.2	14.1	98.5	28.8
DM	E-I	122.6	119.7	128.0	1.5	1.4	83.0	2.7
	E-II	100.4	94.0	108.0	2.9	2.9	94.4	5.8
	E-III	82.2	66.0	94.0	11.6	11.6	99.6	23.9
	POOLED	101.7	72.1	125.2	16.7	16.7	99.0	34.2
PH.(cm)	E-I	72.1	54.9	97.1	13.9	13.9	98.9	28.4
	E-II	53.5	43.1	66.0	10.3	10.2	97.1	20.7
	E-III	35.6	30.0	42.3	8.4	7.6	81.9	14.3
	POOLED	53.8	32.2	89.1	29.3	29.1	98.6	59.6
TNPPP	E-I	98.0	53.0	170.0	25.0	24.9	99.2	51.2
	E-II	72.4	37.0	123.7	30.3	30.2	98.9	61.9
	E-III	33.5	10.0	58.3	27.0	25.8	91.4	50.9
	POOLED	67.9	27.6	122.1	43.2	41.2	95.5	83.0
EPPP	E-I	86.9	44.3	45.0	25.2	25.1	99.4	56.6
	E-II	67.8	30.6	119.0	31.9	31.8	99.1	65.2
	E-III	27.2	7.3	51.0	28.6	26.8	88.1	51.9
	POOLED	60.6	21.8	109.3	44.6	43.6	95.7	87.9
SPP	E-I	1.3	0.7	1.0	25.8	25.6	98.3	52.3
	E-II	1.1	0.5	1.7	21.5	21.4	99.1	44.0
	E-III	1.2	0.8	1.5	12.9	12.5	93.7	25.0
	POOLED	1.2	0.9	1.8	13.8	12.4	81.1	23.1
100SW	E-I	23.7	14.7	32.6	27.1	26.9	98.6	55.2
	E-II	21.8	14.7	35.4	23.9	23.7	98.0	48.2
	E-III	21.4	14.2	33.3	25.9	25.7	98.6	52.7
	POOLED	22.0	14.8	29.2	20.0	19.1	91.0	37.6
BY (g)	E-I	62.0	33.7	97.1	26.0	26.0	99.6	53.4
	E-II	30.5	16.3	57.9	30.4	30.3	99.2	62.2
	E-III	18.4	12.0	26.2	18.0	16.3	82.2	30.5
	POOLED	37.0	15.5	80.4	53.7	53.1	97.8	108.2
HI (g)	E-I	43.8	20.3	63.6	17.4	17.3	98.5	35.4
	E-II	55.9	33.1	80.6	18.6	18.3	96.8	37.1
	E-III	37.4	12.5	51.4	30.5	29.9	95.4	60.1
	POOLED	47.7	21.9	60.0	21.9	21.0	92.0	41.6
SYPP (g)	E-I	26.6	11.0	38.4	23.2	23.2	99.7	47.7
	E-II	17.0	5.9	30.1	33.9	33.7	99.4	69.4
	E-III	6.8	1.6	12.2	29.5	27.7	80.0	53.6
	POOLED	16.8	4.3	32.9	51.9	51.2	97.3	104.0

Abbreviation: FI=flower initiation, F50%=days to 50% flowering, PI=pod initiation, DM=days to maturity, PH=plant height, TNPPP=total number of pods per plant, EPPP=effective pods per plant, SPP=seeds per pod, 100-SW=100-seed weight, BY- Biological yield, HI (%) = harvest index, SYPP=seed yield per plant.

Table.2 Stability ANNOVA

Characters	DF	FI	F $_{50\%}$	D.PI	DM	PH	TNPPP	EPPP	SPP	100-SW	BY(g)	HI	SYPP
Rep within Env.	6	1.81	1.28	1.77	0.77	5.44	7,41	10.32	0.001	1.84	7.16	7.24	0.20
Varieties	39	39.27***	34.31***	30.35***	48.11***	39.15***	449.42	378.40	0.097***	87.85***	123.63*	105.72	34.15
Env. +(var.*Env)	80	68.9***	75.30***	110.68***	436.64***	356.79***	1405.81***	1240.97***	0.058*	4.68	621.56***	182.82**	118.81***
Environments	2	2322.97***	2644.66***	4108.69***	16358.85***	13332.97***	42147.68***	37283.73***	0.198**	16.73*	20266.20***	3561.49***	3938.08***
Var.*Env	78	11.12	9.42	8.17	28.38*	24.07**	361.15	316.80	0.055*	4.37	117.85*	96.19	20.88
Environments(Lin)	1	4645.95***	5289.33***	8217.38***	32717.70***	26665.94***	84295.35***	74567.47***	0.396**	33.47*	40532.40***	7122.98***	7876.16***
Var.*Env.(Lin)	39	10.21	9.09	5.08	41.94***	37.83***	287.42	205.02	0.075**	3.58	170.94**	107.31	17.10
Pooled deviation	40	11.74***	9.50***	10.98***	14.45***	10.05***	424.00***	417.87***	0.034***	5.03***	63.14***	82.94	24.05***
Pooled error	234	0.45	0.58	0.61	0.51	1.21	5.66	4.89	0.001	0.50	1.25	3.43	0.26
Total	119	59.20	61.87	84.36	309.31	270.39	1092.37	958.28	0.071	31.94	458.37	157.56	91.07

Where, *** Highly Significant; ** High significant; *Significant
Abbreviation: FI=flower initiation, F50%=days to 50% flowering, PI=pod initiation, DM=days to maturity, PH=plant height, TNPPP=total number of pods per plant, EPPP=effective pods per plant, SPP=seeds per pod, 100-SW=100-seed weight, BY- Biological yield, HI (%) = harvest index, SYPP=seed yield per plant.

Table.3 Stability parameters for days to flower initiation, days to 50% flowering, days to pod initiation and days to maturity

S. No	Entry name	Days to flower initiation			Days to 50% flowering			Days to pod initiation			Days to maturity		
		μ	Bi	$σ^2$di	μ	Bi	$σ^2$di	μ	Bi	$σ^2$di	μ	Bi	$σ^2$di
1	GG 2	47.2	0.9	26.3	52.1	0.7	25.4	61.1	0.7	16.6	101.4	1.0	11.7
2	ICC 3325	53.6	1.1	0.6	57.6	1.0	0.2	67.7	1.0	3.8	105.8	0.8	13.2
3	ICC 4958	48.7	1.3	80.5	54.1	1.4	55.6	63.8	1.3	55.9	98.0	1.5	12.6
4	ICC 8474	48.1	1.5	0.5	52.8	1.4	-0.6	62.3	1.2	6.0	102.9	0.9	1.2
5	ICC 9942	54.1	1.1	18.7	58.6	1.0	13.5	66.6	1.0	14.7	106.1	0.8	5.7
6	ICC 16181	49.9	1.5	-0.5	54.2	1.4	0.9	63.6	1.3	11.6	102.7	0.9	-0.2
7	ICCL 81248	49.4	1.3	13.2	54.6	1.2	9.0	63.3	1.1	9.5	102.4	0.9	2.0
8	ICCV 07102	43.3	0.8	0.3	48.2	0.8	-0.6	57.8	0.8	-0.3	102.0	0.8	7.1
9	ICCV 07105	51.1	1.3	0.4	56.3	1.3	-0.6	62.4	0.9	2.1	108.3	0.9	0.4
10	ICCV 07109	49.2	1.2	9.1	53.1	1.2	9.7	60.4	1.0	4.8	102.2	1.0	4.8
11	ICCV 07110	47.1	1.0	66.2	52.2	1.1	43.0	61.0	1.1	35.0	105.4	0.9	3.7
12	ICCV 07117	48.0	1.0	21.1	52.2	1.1	43.0	61.0	1.1	35.0	105.4	0.9	3.7
13	ICCV 07118	44.8	1.2	-0.3	50.6	1.2	-0.2	58.8	1.1	-0.4	96.4	1.4	13.7
14	ICC 4182	47.8	1.0	1.8	52.3	1.2	-0.6	60.2	1.0	0.2	102.3	0.9	14.2
15	ICC 8950	52.4	0.9	23.7	56.8	0.8	16.7	64.9	0.8	4.8	105.6	0.9	2.3
16	ICC 10018	52.2	1.3	3.2	56.4	1.3	3.6	63.8	1.0	-0.3	105.1	0.9	2.1
17	ICC 15888	53.1	1.2	1.0	57.0	1.2	3.3	63.7	1.0	0.2	106.2	0.8	-0.5
18	ICC 14831	50.3	1.2	8.4	55.6	1.1	0.8	62.9	1.0	1.4	105.1	0.8	8.3
19	ICC 14815	53.8	1.3	1.9	58.4	1.2	1.0	66.4	1.1	-0.6	105.0	0.7	3.1
20	ICC 14402	49.9	0.8	1.9	54.6	0.9	-0.6	62.4	0.9	-0.6	103.2	0.8	17.7
21	ICC 7441	54.4	1.1	16.3	58.9	1.0	16.2	65.8	0.8	4.4	105.3	0.8	10.1
22	ICC 6816	53.4	1.0	52.3	57.2	0.9	50.3	65.4	0.8	30.8	106.9	0.7	12.4
23	ICC 67	52.0	1.1	7.4	56.2	1.1	5.3	66.1	1.2	30.1	97.2	1.3	84.4
24	ICC 6874	53.6	0.9	17.2	58.3	0.8	12.8	68.0	1.1	25..39	98.4	1.4	104.2
25	ICC 1882	50.0	1.2	0.0	54.1	1.2	-0.6	65.9	1.2	27.9	104.8	0.9	16.3
26	ICC 15618	49.1	1.1	0.3	53.7	1.2	-0.6	62.3	1.1	-0.2	97.3	1.4	44.4
27	JG 2003-14-16	40.3	0.2	16.2	45.4	0.3	41.2	56.0	0.7	21.8	94.3	1.3	42.7
28	JG 1307	46.8	0.9	-0.5	51.7	1.0	-0.2	61.4	1.2	-0.4	102.4	0.9	5.6
29	MPJG 2003-115	39.8	0.0	2.2	44.6	0.2	7.1	55.3	0.7	11.5	94.8	1.3	36.1
30	JG 14-11	47.4	0.8	0.8	52.1	0.9	3.8	61.8	1.1	1.1	103.3	0.9	15.0
31	MPJG 99-115	43.9	1.0	-0.3	48.6	1.1	0.8	56.4	0.9	0.9	94.0	1.4	4.1
32	JG 17	44.8	0.9	2.9	50.1	0.8	1.3	58.7	0.8	2.2	100.9	1.0	7.8
33	JG 18	46.8	1.0	7.1	51.3	1.0	4.7	59.4	1.1	7.6	102.7	1.0	-0.4
34	JG 19	44.1	1.0	-0.5	49.2	1.0	0.1	57.3	1.0	-0.6	93.7	1.3	6.0
35	JG 21	46.4	1.0	31.9	52.4	1.1	35.3	59.6	1.0	50.5	93.6	1.4	6.7
36	JG 22	46.4	0.9	14.7	52.0	0.8	5.7	59.3	1.0	24.4	100.6	1.0	-0.4
37	JG 16	49.1	0.8	-0.4	53.8	0.9	0.9	61.6	0.9	2.0	103.6	0.9	8.4
38	JG 130	47.3	0.5	1.2	52.6	0.7	-0.4	61.9	0.9	-0.5	104.7	0.9	26.1
39	JAKI 9218	47.4	0.9	3.0	52.2	1.0	3.5	60.4	1.1	0.0	101.9	0.9	-0.3
40	JG 14	48.6	0.7	0.5	52.9	0.8	2.7	62.2	1.0	2.6	101.6	0.9	-0.5
	Population mean	48.6			53.4			61.9			101.8		

Table.4 Stability parameters for plant height, Total pod, effective pod and seeds per plant

S.No	Entry name	Plant height			Total Pod			Effective Pod			S/P		
		μ	σi	σ^2di	μ	μ	μ	μ	σi	σ^2di	μ	σi	σ^2di
1	GG 2	52.9	1.0	-1.0	73.9	0.5	1157.0	68.6	0.7	1290.7	1.1	-0.1	**0.0**
2	ICC 3325	48.8	0.9	4.5	99.1	2.1	242.2	86.4	1.9	248.1	1.1	-0.9	**0.0**
3	ICC 4958	51.7	0.8	24.2	72.8	1.2	1261.7	63.4	1.2	1334.5	0.9	0.7	**0.0**
4	ICC 8474	48.7	0.9	39.7	74.3	0.7	1147.2	68.8	0.8	981.8	1.1	0.0	**0.0**
5	ICC 9942	47.3	0.6	34.1	62.9	0.7	282.4	53.0	0.6	59.4	1.6	5.1	**0.2**
6	ICC 16181	50.7	0.9	4.0	64.4	0.8	88.3	58.9	0.8	97.9	1.4	4.2	**0.0**
7	ICCL 81248	53.2	0.8	1.8	74.0	1.1	148.1	67.3	1.1	108.3	1.6	0.4	**0.1**
8	ICCV 07102	62.8	1.3	6.6	69.0	1.0	118.2	62.0	1.0	76.2	1.3	0.5	**0.0**
9	ICCV 07105	53.6	1.0	19.8	60.9	1.0	356.6	54.7	1.1	356.9	1.4	-1.4	**0.0**
10	ICCV 07109	50.4	0.9	19.1	64.6	1.0	38.6	58.4	0.9	36.4	0.9	-0.6	**0.0**
11	ICCV 07110	53.3	1.0	-1.2	83.2	1.0	1980.4	76.1	1.1	1951.8	0.9	4.2	**0.1**
12	ICCV 07117	49.8	1.0	38.8	58.7	1.0	390.2	51.8	1.0	365.0	1.1	-0.2	**0.0**
13	ICCV 07118	52.2	1.1	6.8	55.0	0.4	772.4	48.9	0.4	788.0	1.1	-0.3	**0.0**
14	ICC 4182	56.4	1.0	0.9	71.6	1.4	135.8	65.4	1.4	81.2	1.4	-3.8	**0.0**
15	ICC 8950	50.4	0.8	6.2	97.0	1.2	335.2	84.0	1.2	294.3	1.3	-0.1	**0.1**
16	ICC 10018	52.9	1.2	10.3	79.3	1.2	76.3	74.4	1.3	37.3	1.3	2.3	**0.0**
17	ICC 15888	49.5	0.8	15.0	66.7	1.1	677.0	52.6	0.9	315.9	1.1	-2.3	**0.0**
18	ICC 14831	56.8	1.5	12.0	79.2	1.1	802.2	70.3	1.2	810.5	1.4	-0.5	**0.0**
19	ICC 14815	51.6	0.9	-1.2	75.6	1.5	-5.3	67.7	1.5	5.0	1.3	4.0	**0.1**
20	ICC 14402	53.7	1.2	-1.0	55.4	0.6	572.8	50.0	0.6	567.0	1.1	-4.7	**0.0**
21	ICC 7441	42.7	0.7	-0.8	59.8	1.7	728.1	53.0	1.6	1044.0	1.4	-0.8	**0.0**
22	ICC 6816	45.7	0.7	-1.1	65.7	1.4	1838.0	57.0	1.3	1990.2	1.3	1.1	**0.0**
23	ICC 67	52.5	0.9	3.5	52.9	0.6	870.4	47.0	0.7	720.0	1.3	-0.5	**0.0**
24	ICC 6874	49.7	0.9	3.6	70.6	1.5	237.2	63.0	1.4	379.1	1.3	3.5	**0.0**
25	ICC 1882	50.1	0.9	3.2	84.6	1.6	246.4	75.9	1.6	191.3	1.3	1.9	**0.0**
26	ICC 15618	50.1	0.8	2.1	91.8	0.9	109.5	85.8	1.0	94.8	1.1	2.7	**0.0**
27	JG 2003-14-16	54.7	1.0	-1.0	51.7	0.7	142.2	45.1	0.6	125.7	1.3	-0.4	**0.0**
28	JG 1307	54.3	0.9	30.4	79.7	1.2	78.4	71.8	1.2	92.3	1.1	1.6	**0.0**
29	MPJG 2003-115	65.2	1.4	8.7	50.7	0.7	10.3	46.8	0.7	7.0	1.4	1.8	**0.0**
30	JG 14-11	63.2	1.3	2.6	59.2	1.2	777.0	53.1	1.1	839.1	1.3	3.5	**0.0**
31	MPJG 99-115	63.8	1.2	2.4	65.1	1.0	35.8	57.4	1.0	22.6	1.3	4.9	**0.1**
32	JG 17	56.0	1.1	-1.3	62.4	1.1	49.4	54.2	1.0	76.4	0.9	-1.7	**0.2**
33	JG 18	57.6	1.0	9.9	60.1	0.5	68.7	55.0	0.7	79.8	1.1	-1.3	**0.0**
34	JG 19	56.6	1.1	7.5	60.4	0.9	214.5	51.1	0.8	379.7	1.4	-1.7	**0.0**
35	JG 21	65.2	1.6	2.4	51.0	0.6	51.9	46.6	0.6	39.1	1.1	1.8	**0.0**
36	JG 22	67.5	1.6	5.0	51.8	0.7	137.0	45.9	0.8	110.2	1.1	0.6	**0.2**
37	JG 16	49.2	0.9	-1.2	70.8	1.0	7.1	63.1	1.1	24.0	1.3	2.6	**0.0**
38	JG 130	53.3	0.9	2.2	74.4	1.0	16.0	63.7	0.9	116.0	1.2	2.8	**0.0**
39	JAKI 9218	56.7	1.2	-1.1	58.0	0.5	163.6	52.6	0.5	134.7	1.6	10.7	**0.3**
40	JG 14	50.8	1.0	33.1	61.8	1.0	373.4	56.3	1.1	241.5	1.3	0.2	**0.0**
	Population mean	**53.8**			**68.0**			**60.7**			**1.2**		

Table.5 Stability parameters for 100-seed weight, biological yield, HI and seed yield

S. No	Entry name	100 SW			BY			HI			SY		
		μ	σi	σ^2di	μ	σi	σ^2di	μ	σi	σ^2di	μ	σi	σ^2di
1	GG 2	29.0	3.4	30.9	46.6	0.9	154.5	52.7	0.3	1.2	24.6	1.1	**19.2**
2	ICC 3325	17.8	-0.6	-0.5	35.9	0.8	22.3	41.9	2.0	12.8	15.3	1.0	**0.6**
3	ICC 4958	34.1	-0.3	1.9	43.8	1.4	101.7	49.5	1.5	2.6	20.9	1.4	**23.6**
4	ICC 8474	27.0	9.0	42.3	43.4	0.7	133.4	46.7	1.5	17.3	21.5	1.0	**85.3**
5	ICC 9942	15.6	-0.3	4.5	30.6	0.6	4.1	44.9	1.2	111.3	14.4	0.9	**2.2**
6	ICC 16181	16.5	-0.4	0.2	36.9	1.1	21.7	42.7	0.0	10.0	16.2	1.1	**47.5**
7	ICCL 81248	17.1	1.2	-0.5	43.3	1.3	26.2	48.4	-0.2	62.7	19.8	1.1	**0.6**
8	ICCV 07102	22.0	0.3	-0.4	44.0	1.6	4.9	51.2	0.3	28.1	21.6	1.5	**24.3**
9	ICCV 07105	21.8	0.5	9.1	31.7	0.8	2.5	51.5	0.8	4.4	16.6	1.0	**7.3**
10	ICCV 07109	28.9	-0.3	11.5	40.7	1.0	23.8	45.1	0.5	-2.1	18.4	1.0	**0.2**
11	ICCV 07110	28.4	1.2	10.6	52.2	1.1	273.5	42.7	0.8	8.0	22.7	1.1	**77.4**
12	ICCV 07117	25.5	3.2	7.9	37.3	1.4	132.3	44.9	1.2	28.8	15.5	1.1	**29.8**
13	ICCV 07118	28.9	4.0	4.3	31.1	0.5	104.6	56.2	0.7	51.8	17.4	0.6	**54.0**
14	ICC 4182	15.7	0.1	1.0	33.3	0.7	24.8	39.3	1.5	72.8	14.1	0.9	**11.5**
15	ICC 8950	15.4	-0.9	0.1	32.6	0.6	4.4	55.3	2.5	-2.6	18.6	0.9	**48.0**
16	ICC 10018	15.0	0.3	4.4	28.9	0.8	1.0	52.1	1.6	-1.1	15.5	1.0	**1.7**
17	ICC 15888	17.9	3.1	11.6	30.8	0.6	-1.1	38.0	0.5	145.4	12.5	0.8	**4.9**
18	ICC 14831	16.6	1.1	-0.3	38.4	0.7	150.9	42.7	1.5	-1.6	17.5	0.9	**81.6**
19	ICC 14815	16.4	0.2	2.7	34.8	1.2	157.2	44.7	2.7	-2.3	14.6	1.2	**9.9**
20	ICC 14402	18.7	0.7	2.1	30.9	0.7	168.5	38.1	0.8	18.2	11.0	0.4	**15.7**
21	ICC 7441	17.4	-0.1	-0.5	29.4	1.1	44.8	41.4	2.0	508.0	14.5	1.5	**41.5**
22	ICC 6816	15.3	0.2	-0.4	32.7	0.8	139.0	32.7	0.5	273.1	12.0	1.0	**57.9**
23	ICC 67	16.5	-1.5	-0.1	30.1	0.2	25.5	34.4	2.0	4.6	10.9	0.4	**71.3**
24	ICC 6874	15.1	-1.1	1.7	30.2	0.8	-0.4	38.4	0.7	218.7	13.0	1.1	**9.5**
25	ICC 1882	18.3	-1.1	2.6	47.5	1.9	174.8	42.6	2.2	23.1	18.5	1.4	**7.2**
26	ICC 15618	17.7	1.9	3.1	34.9	0.9	20.2	49.1	1.7	31.2	16.5	0.8	**0.3**
27	JG 2003-14-16	23.7	1.8	5.1	26.9	0.6	-1.3	51.0	0.0	-2.3	13.8	0.7	**6.2**
28	JG 1307	23.6	3.9	4.2	45.0	1.6	1.9	48.8	0.5	35.4	20.9	1.5	**13.3**
29	MPJG 2003-115	28.8	2.3	-0.4	36.5	0.9	35.0	52.8	0.8	-2.1	19.4	1.1	**5.3**
30	JG 14-11	23.1	2.3	3.3	41.8	1.6	111.2	35.9	0.2	13.8	15.7	1.3	**80.0**
31	MPJG 99-115	26.6	0.5	12.8	43.2	1.7	53.1	53.1	1.1	97.5	21.0	1.5	**20.9**
32	JG 17	28.5	-1.8	0.2	45.5	2.0	62.4	44.7	-0.1	934.8	13.9	0.6	**-0.1**
33	JG 18	25.8	1.6	1.1	39.3	0.8	60.3	41.7	-0.1	7.3	16.0	0.7	**0.4**
34	JG 19	24.2	3.2	0.8	41.4	1.3	0.0	46.5	2.1	193.6	17.9	0.8	**65.4**
35	JG 21	26.9	0.8	-0.4	32.4	0.9	-0.6	48.3	1.4	7.2	15.5	0.9	**0.7**
36	JG 22	30.4	0.8	-0.3	36.1	0.9	16.2	40.5	0.2	26.4	14.1	0.7	**-0.2**
37	JG 16	20.3	-2.9	1.0	31.0	0.8	3.7	51.9	1.3	6.1	15.9	0.8	**-0.2**
38	JG 130	25.8	2.9	0.6	36.2	0.7	97.3	53.7	0.1	156.6	20.3	1.2	**-0.2**
39	JAKI 9218	24.9	0.2	2.4	45.5	1.5	1.6	48.7	0.5	23.4	21.5	1.5	**1.9**
40	JG 14	19.4	1.0	0.0	28.6	0.6	114.0	45.1	1.2	55.0	14.0	0.8	**25.6**
	Population mean	**22.0**			**37.0**			**45.7**			**16.8**		

It is evident that high yielding genotypes ICCV 07118, ICC 8950, ICC 14831 and JG 19 which were stable with respect to most of the yield attributing trait indicating that the stability of various characters might be responsible for observed seed yield. The above results have provided the opportunity of growing chickpea under late planting condition in double cropping (after rice) and very late (after soybean-potato/garden pea) (Table 3, 4 and 5). The results of the present study indicated that seed yield was influenced by the environmental changes because there were significant variations in seed yield of the genotypes tested at diverse environments. The stability based on the mean seed yield, regression coefficient and deviation from regression indicated that the genotypes, GG 2, ICC 4958, ICC 8474, ICCL 81248, ICCV 07102, ICCV 07109, ICCV 07110, ICC 1882, JG 1307, MP JG 2003-115, MP JG 99-115, JG 130 and JAKI 9218 were the most stable and adapted to the diverse planting condition.

Author's contributions

Dr Anita Babbar conducted this experiment, guided Dr Akansh Tiwari for taking observations, analysis of data and interpretation of results.

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