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Research Article

Stability analysis for yield and yield related traits in advance breeding lines of chickpea (*Cicer arietinum* L.)

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Abstract
An experiment was carried out during *Rabi* 2018-19 at three locations (Nandyal, Gulbarga and Vijayapura) in Southern India to identify high yielding and stable chickpea genotypes for cultivation in South Zone. At each of the locations, the stability and adaptability of 35 advance breeding lines and two checks *viz.,* JG 11 and JAKI 9218 were tested in a Randomized Block Design with three replications. Highly significant genotype × environment interaction was evident for days to 50 percent flowering, days to maturity, 100 seed weight and seed yield. Among three locations, Gulbarga was the most favourable environment for expression of the traits. The study identified BDNG 2017-1, RKG 13-22, RVSSG 67, DBGC-2 and DC 17-1111 as stable genotypes which can be recommended for all the three locations where as NBeG 798, BG 4001, PG 215, CSJ 1065, H15-27, RG 2016-134, DC17-115 and ICCV 171117 are appropriate for favourable environments.

Keywords: Chickpea, genotype × environment interaction, regression coefficient and stability

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important pulse crop in India and is well adapted to drought prone semi-arid tropical regions. Chickpea seed contains 17-24 % of protein, 61.2% carbohydrates (Smartt, 1976) and essential amino acids like isoleucine, leucine, lysine, phenylalanine and valine (Karim and Fattah, 2006). Introduction of chickpea crop in a cereal based crop rotation can break the disease and pest cycle and increase the productivity of the entire rotation (Jodha and Subbarao, 1987) and thus plays an important role in sustaining soil fertility (Singh and Shiv, 2013). In view of its role in sustaining nutritional security and soil fertility, the crop is being preferred by marginal farmers of India.

India ranks first in terms of chickpea production and consumption in the world. In Southern states, chickpea is being grown in vast areas in Karnataka (7,13,000 ha), Andhra Pradesh (4,69,000 ha), Telangana (1,43,000 ha) states and also to some extent in Tami Nadu. Southern states contribute to nearly 13 % of the chickpea area of the country (9.99 m ha) (AICRP on Chickpea Annual Report 2021-22). In contrast to the traditional chickpea area of North India, the environment of southern India is characterised by short and warm winters. Therefore, special focus has been laid to develop chickpea varieties specifically suited to this type of climate. Under AICRP on Chickpea, research efforts are initiated at Regional

Agricultural Research Stations (RARS) of Nandyal (Andhra Pradesh), Kalaburagi (Karnataka), and Vijayapura (Karnataka) with the lead centre being RARS, Nandyal. Systematic crop improvement programmes in these stations have led to the development of many breeding lines which are contributed for testing under various trials as per the procedures laid down by AICRP on Chickpea. The seed yield of chickpea genotypes tested across varying locations may vary with the genotypes due to genotype × environment interaction. It is essential to identify genotypes which are stable by examining their performance under different environments. Understanding the nature of genotype × environment interaction is important in plant breeding programs because a significant genotype × environment interaction can seriously impair efforts in selecting superior genotypes in relation to new crop introductions and cultivar development programs. Despite the potential to be confounded by other environmental factors, examining the impact of environments on plant development remains a practical and inexpensive screening approach to test for adaptability of species to new production environments (Kaloki *et al*., 2019).

In the present investigation, an attempt was made to study the nature and extent of genotype by environment interaction on seed yield of 35 advance breeding lines of chickpea along with two popular check varieties of southern India to investigate the stability and adaptability of the advance breeding lines.

MATERIALS AND METHODS

Thirty seven chickpea genotypes (35 advance breeding line belonging to *desi* group and two popular checks of southern India *viz.,* JG 11 and JAKI 9218) were sown during *Rabi* 2018-19 at three locations, namely Regional Agricultural Research Station, Nandyal, Andhra Pradesh, Zonal Agricultural Research Station, Kalaburagi, Karnataka and Regional Agricultural Research Station, Vijayapura, Karnataka. In South zone, 1169.9 mm rainfall received at Kalaburagi in Karnataka, 163.6 mm at Gulbarga and 119.8 mm at Nandyal during the crop season. Kalaburagi, Gulbarga and Nandyal, deep black soil with medium fertility was evident. The experiment was conducted in randomized complete block design with three replications at each location. The experimental area of each genotype was four rows of 4 m long with inter-row spacing of 0.3 m. Data were recorded on important yield attributing characters *viz.,* days to 50 percent flowering, days to maturity, 100 seed weight (g) and seed yield per plot (g). The statistical analysis was carried out according to stability analysis by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The data collected on yield and yield related traits of 37 chickpea genotypes over three locations were pooled and analysed (**Table 1**). Highly significant differences among the genotypes were observed for days to 50 per cent flowering, days to maturity, 100 seed weight (g) and seed yield per plot (g) at all the three locations. The performance of the genotypes was subjected to regression analysis to arrive at the extent of genotype and environment interaction. Genotype × environment interactions against pooled error were significant for days to 50 per cent flowering, days to maturity, 100 seed weight (g) and seed yield per plot (g). Thus, the performance of genotypes across various locations was affected by the environments in various locations. Significant genotype × environment interactions for yield traits have been reported by Kandaswamy *et al.* (1985), Hemant Kumar *et al.* (2020), Reddy *et al.* (2016), Sharma and Johnson (2017), Pouresmael *et al*. (2018) and Karakoy *et al.* (2018).

The characters which exhibited significant genotype × environment interaction were further subjected to stability analysis as per the model proposed by Eberhart and Russell (1966). The results of the analysis revealed that the environment E2 (Gulbarga) was favourable for most of the characters *viz.,* days to 50 per cent flowering, days to maturity and seed yield per plot. E1 (Nandyal) was favourable for 100 seed weight and E3

Table 1. Stability analysis of variance in chickpea

Source of variation	Degrees of freedom	Days to 50 per cent flowering	Days to maturity	100 Seed weight (g)	Seed yield per plot (g)
G	36	55.02*	56.57*	55.54**	25320.36*
E + (G × E)	74	41.72*	140.65**	9.70*	197541.82**
G × E	72	23.38**	44.42**	9.65**	24080.43**
E (Linear)	1	1403.61**	7209.78**	22.57	12884303.43**
G × E (Linear)	36	17.91	40.26	6.30	31370.36*
Pooled Deviation	37	28.07**	47.27**	12.65**	16336.71**
Pooled Error	216	3.24	1.81	1.65	7928.66
Total	110	46.07	113.13	24.70	141178.43

*, ** Significant at 5% and 1% levels, respectively, G - Genotype, E-Environment

Table 2. Estimation of environment index under different locations of southern India

S. No.	Characters	Nandyal (E1)	Gulbarga (E2)	Vijayapura (E3)
1	Days to 50 per cent flowering	-4.64	0.64	4.00
2	Days to maturity	-0.86	10.27	-9.41
3	100 Seed weight (g)	0.58	-0.52	-0.06
4	Seed yield per plot (g)	-336.40	466.93	-130.54

(Vijayapura) was favourable for days to 50 per cent flowering (**Table 2**). Genotype × environment interaction can be further reduced by selecting cultivars with a better stability across a wide range of environments which helps to obtain expected performance from the cultivars (Eberhart and Russell, 1966 and Tai, 1971). Genotype × environment interaction can be used to facilitate genotype characterization utilising mean yield of the cultivars, variance of the regression deviations as a measure of cultivar stability and the linear regression coefficient as a measure of the cultivar adaptability.

Crop maturity is an important attribute of a genotype, which directly or indirectly affects the economic yield. Maturity itself is expressed by several components in chickpea of which days to 50 per cent flowering is one of the important traits. In pooled analysis over three locations, days to 50 per cent flowering ranged from 40.4 days (BDNG 2015-9 and GJG1610) to 53.9 days (IPC14-39). The genotypes BDNG 2015-9 and GJG1610 (40.4 days) were early to flower followed by NBeG 857, DC 17-1111, RKG 18-1, BDNG 2017-1 and JG 11 (41.2 days).

The stability of advance breeding lines for days to 50% flowering was further assessed by estimating stability parameters. The genotypes PG 215, DBGV 217, RVSSG 67 and ICCV 171117 had high mean values, regression coefficient around unity and non-significant deviation from the regression coefficient (**Tables 3, 4 & 5**). They are categorised as be stable and widely adaptable to different environments. NBeG 798, JG 2018-51, JAKI 9218 and RLBG 3showed specific adaptation since they had high mean, regression coefficient greater than one and high mean. Therefore, these genotypes may be exploited under optimal favourable environmental condition. BDNG 2015-9 exhibited above average stability as its regression coefficient was less than one with high mean for days to 50 per cent flowering. The stability pattern in days to 50 per cent flowering in chickpea had been reported in previous studies by Duzdemir *et al.* (2011) and Gupta and Sharma, (2009).

The *perse* performance of days to maturity over three locations revealed that the genotypes *viz.,* NBeG 857 (95.9 days), PG 216 (96.6 days), RLBG 3 (97.0 days), RLBG 4 (97.2 days), ICCV 171117 (97.3 days), RVSSG 69 (97.4 days), DC17-115 (97.6 days), DBGV 217 (98.4 days) and BDNG 2015-9 (99.7 days) were early in maturity. This trait showed wide variability among the genotypes studied and ranged from 95.9 days (NBeG 857) to 112.0 days (GNG2340). Days to maturity followed almost the same trend as that of days to 50 per cent flowering showing good correspondence between the characters days to 50 per cent flowering and days to maturity.

The genotypes which had stable performance across three environments for days to maturity are RLBG 4 and RVSSG 69 which had regression coefficient around unity with non-significant deviation from the regression coefficient. While, DBGV 217, BDNG 2015-9, RLBG 3, DC17-115, PG 216, NBeG 857 and ICCV 171117 may be considered as sensitive genotype to environmental changes and should be recommended for favourable environment as they exhibited high mean with regression coefficient greater than one and non-significant deviation from regression. Neha and Anita, (2018), Ali *et al.* (2018) and Tilahun *et al*. (2015) also reported stable genotypes of chickpea for days to maturity.

The mean performance of genotypes for 100 seed weight over three locations ranged from 14.6g (RVSSG 68) to

Table 3. Distribution of stable genotypes (S^2d_i=0) with high mean on the basis of regression coefficient (b_i)

Parameter	Days to 50 per cent flowering	Days to maturity	100 Seed weight (g)	Seed yield per plot (g)
High mean and stability	9	9	7	15
Average stability (b_i=1) (suitable for all environments)	4	2	1	5
Above average stability (b_i>1) (suitable for favourable environment)	4	7	2	8
Below average stability (b_i<1) (suitable for poor environment)	1	0	4	2

Table 4. Stability parameters of chickpea for yield and yield attributing traits

S.No.	Entry	Days to 50 % flowering			Days to maturity			100 Seed weight (g)			Seed yield per plot (g)		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	ICCV 171105	47.11	2.25	-2.10	105.40	0.56	14.50**	28.88	0.62	8.62*	788.30	1.10	89445.90**
2	NBeG 798	45.56	2.08	-0.11	104.70	0.51	34.40**	23.46	0.15	3.64	880.70	1.38	-6726.10
3	BDNG 2017-1	41.22	0.66	30.22 **	103.20	0.70	51.60**	27.27	5.10	16.24**	698.00	1.20	-5338.80
4	Bidhanchola -1	48.56	1.13	24.57 **	102.80	0.60	57.30**	20.65	0.62	38.68**	650.80	0.63	-433.30
5	JG 2018-52	48.11	2.02	5.52	103.80	0.75	16.30**	17.29	0.20	35.01**	722.10	1.56	81778.70**
6	JG -11 (check)	41.22	0.81	28.85 **	103.20	1.45	59.20**	24.90	1.70	1.61	672.10	1.12	-7759.10
7	BG 4001	52.11	0.22	33.60**	109.60	0.47	20.20**	20.14	1.77	0.45	805.90	1.40*	-7929.80
8	RKG 13-22	46.78	1.62*	-3.26	109.80	0.57	-0.40	24.41	7.36	-1.43	601.20	1.10	454.70
9	PG 215	45.78	1.16	-3.26	102.00	0.82	64.40**	24.04	-0.05	38.90**	802.70	1.43	-7060.70
10	DBGV 217	44.89	1.35	0.51	98.40	1.42	1.90	24.78	-0.74	-0.81	662.70	0.75*	-7951.80
11	RKG 18-1	41.22.	0.67	17.36 *	105.10	0.94	64.60**	27.84	0.01	38.03**	750.10	1.05	-1375.20
12	JG 2018-51	45.67	1.43*	-3.28	102.10	0.57	57.90**	18.06	3.64	-1.39	606.60	0.85	-1290.20
13	CSJ 1065	47.78	0.77	29.01 **	105.30	0.83	93.50**	22.07	3.44	29.00**	737.90	1.26	-5396.30
14	RVSSG 68	52.89	-1.14	42.66 **	109.80	0.54	2.30	14.56	-0.70	17.48**	662.90	0.93	-3885.10
15	JAKI 9218 (check)	42.56	1.52	-2.95	105.10	1.26	128.90**	23.53	-1.12	3.69	616.80	0.55	-7170.10
16	H15-27	50.44	0.82	110.40 **	105.10	0.65	62.90**	20.84	0.64	53.66**	731.80	1.23	-6936.40
17	RG2016-134	41.67	0.53	21.05 **	104.80	1.19	146.40**	26.17	-1.38	0.24	722.30	1.23	5548.30
18	RLBG 4	46.56	1.75	2.76	97.20	1.29*	-1.70	26.27	0.02	-1.62	611.30	0.83	915.90
19	Phule G 16109	51.00	0.38	56.13**	105.80	1.24	238.50**	29.41	-1.67	7.88*	870.40	1.15	90791.70**
20	BG4000	51.33	2.20	122.20**	103.70	0.53	10.70**	23.40	0.07	5.26*	568.60	0.87	-7600.00
21	PBC 546-18	49.67	0.65	1.37	103.20	1.43	65.40**	21.67	-0.88*	-1.64	615.10	1.27	-219.30
22	BDNG 2015-9	40.44	0.60	6.25	99.70	1.45	2.80	26.46	-2.01	1.81	651.20	0.78	-3988.50
23	GJG1607	50.44	0.35	10.43*	108.00	0.69	45.40**	24.66	0.16	8.30*	703.10	0.76	5620.00
24	RVSSG 69	43.22	0.29.	20.17 **	97.40	1.35	1.10	35.97	-4.84	6.91*	492.80	0.33	29597.50*
25	NDG17-2	51.00	0.02	40.25**	106.60	0.51	5.00	24.25	-4.27	0.04	685.30	0.77	17166.30
26	RLBG 3	43.67	1.42	8.30	97.00	1.57	0.80	30.75	1.00	-1.40	616.20	0.41	-292.60
27	DC17-115	42.00	0.38	47.24**	97.60	1.60	-0.70	26.24	0.16	6.88*	809.90	1.23	-5163.40
28	GNG2340	52.56	1.37	41.64**	112.00	0.17	3.20	19.69	6.04	7.33*	578.70	1.01	-7371.70
29	RVSSG 67	42.89	0.88	9.34	102.90	1.44	87.30**	22.71	13.57	1.39	776.70	1.19	7744.30
30	DBGC-2	51.11	1.02	5.70	105.00	0.52	145.50**	28.95	3.29	26.49**	714.90	0.83	3121.90
31	DC 17-1111	41.22	0.67	58.23**	100.70	1.60	59.60**	27.54	1.85	11.17**	799.60	1.05	5042.40
32	PG 216	43.89	1.40	15.89 *	96.60	1.68*	-1.50	22.04	-0.27	3.70	738.80	0.57	12456.40
33	IPC14-39	53.89	1.29	17.76 *	109.80	0.71	43.80**	21.45	1.36	8.10*	527.60	0.80	-2089.50
34	GJG1610	40.44	0.82	35.26**	100.10	1.71	72.80**	20.35	0.47	12.59**	613.80	0.67*	-7982.80
35	H14-14	52.78	1.67	15.24 *	109.30	0.61	29.10**	17.04	1.71	14.26**	593.40	1.32	25009.80*
36	NBeG 857	41.22	0.56	66.24 **	95.90	1.53	-0.60	24.23	-1.00	-1.37	739.00	1.20	26469.80*
37	ICCV 171117	43.78	1.38	7.60	97.30	1.57	-0.20	29.60	1.00	9.76**	694.40	1.22	11873.30
Grand Mean		46.40	0.86		103.40	0.50		24.10	4.55		689.60	0.20	
SEm±		2.07			2.25			1.42			67.67		
CD at P≤0.05		5.75			6.25			3.96			188.63		
CV %		13.37			6.52			17.73			29.48		

*, ** Significant at 5% and 1% levels, respectively

Table 5. Nature of stability and suitability of chickpea genotypes to different environments

Parameter	Days to 50 per cent flowering	Days to maturity	100 Seed weight (g)	Seed yield per plot(g)
Average stability(b_i=1) (suitable for all environments)	PG 215, DBGV 217, RVSSG 67, ICCV 171117	RLBG 4, RVSSG 69	RLBG 3	BDNG 2017-1, RKG 13-22, RVSSG 67, DBGC-2 DC 17-1111
Above average stability(b_i>1) (suitable for favourable environment)	NBeG 798, JG 2018-51, JAKI 9218, RLBG 3	DBGV 217, DNG 2015-9, RLBG 3, DC17-115, PG 216, NBeG 857, ICCV 171117	JG 11, RKG 13-22	NBeG 798, BG 4001, PG 215, CSJ 1065, H15-27, RG 2016-134, DC17-115, ICCV 171117
Below average stability (b_i<1) (suitable for poor environment)	BDNG 2015-9		DBGV 217, BDNG 2015-9, NDG17-2, ICCV 171117	GJG 1607, PG 216

36.0g (RVSSG 69). The genotypes *viz.,* ICCV 171105 (28.9g), BDNG 2017-1 (27.3g), JG -11 (24.9g), RKG 13-22 (24.4g), DBGV 217 (24.8g), RKG 18-1 (27.8g), RG2016-134 (26.2g), RLBG 4 (26.3g), Phule G 16109 (29.4g), BDNG 2015-9 (26.5g), GJG1607 (24.7g), NDG17-2 (24.3g), RLBG 3 (30.8g), DC17-115 (26.2g), DBGC-2 (29.0g), DC 17-1111 (27.5g), NBeG 857 (24.2g) and ICCV 171117 (29.6g) had recorded better seed weight in comparison to the grand mean (24.1g).

The genotypes JG 11 (24.9g) and RKG 13-22 (24.4g) had regression coefficient greater than unity, therefore the performance is highly sensitive to environmental fluctuations but they are adapted to favourable environments. Similarly, DBGV 217 (24.8g), BDNG 2015-9 (26.5g), NDG17-2 (24.3g) and ICCV 171117 (29.6) had regression coefficient less than unity, which indicates less sensitivity to environmental changes. Stable genotypes for yield attributing traits have also been reported by Neha and Anita, (2018) and Karakoy *et al*. (2018).

Per se performance for seed yield per plot over three locations ranged from 492.8g (RVSSG 69) to 880.7g (NBeG 798). Two genotypes Phule G 16109 (870.4g), and NBeG 798 (880.7g) were significantly superior to the best check JG 11 (672.1g).

The high mean performance, regression coefficient nearer to unity and non-significant deviation from the regression coefficient was exhibited by the genotypes BDNG 2017-1, RKG 13-22, RVSSG 67, DBGC-2 and DC 17-1111 for seed yield. NBeG 798, BG 4001, PG 215, CSJ 1065, H15-27, RG 2016-134, DC17-115 and ICCV 171117 had recorded regression coefficient greater than unity and are suitable for favourable environments only. In contrast, GJG 1607 and PG 216 had regression coefficient less than unity and non-significant deviation from the regression coefficient and also had the high mean for genotypes indicating that they can perform well in poor environments. Using the Eberhart and Russel (1966) model, Hemant Kumar *et al.* (2020) and suggested cultivating the stable chickpea genotypes *viz.,* NBeG 806, JG 74315-2, BDNG 2015-1 and BG 372, DCP 92-3, RSG 888 in the south zone and NWPZ of India.

Stability analysis has revealed that out of 37 chickpea genotypes, BDNG 2017-1, RKG 13-22, RVSSG 67, DBGC-2 and DC 17-1111 were stable and widely adaptable over environments for realising satisfactory seed yields in Southern India. NBeG 798, DC17-115 and ICCV 171117 can be recommended for favourable environments with assured rainfall. Gulbarga was favourable for better expression of most of the characters *viz.,* days to 50 per cent flowering, days to maturity and seed yield. The stable genotypes identified in this study for various yield components can be recommended for cultivation in southern states and also can be deployed for developing chickpea genotypes that could show wider adaptability and stability under diverse environments.

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