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EVALUATION OF CHICKPEA (*CICER ARIETINUM* L.) GENOTYPES UNDER DIFFERENT GROWING ENVIRONMENTS

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ABSTRACT

Identifying stable genotypes help in strategic planning for yield improvement through component trait breeding. An experiment was carried out to estimate Genotype x Environment interaction, the stability parameters and the best genotype over three environments *i.e.* 31st October (E1), 14th November (E2) and 29th November (E3) during the *Rabi* season (2018-19) with 32 genotypes and three checks. G×E interaction analysis revealed significant differences among the genotypes for most of the characters over the environment. A significant linear component of G × E interaction for all the characters except the number of seeds per pod and hundred seed weight under the study suggested that the genotype differed for their linear response to the environments. Considering all the stability parameters seven genotypes namely PAO3216R-9559, PAO2616R-3072, PAO2716R-3167, PAO4116R-13898, BIRSA CHANA-3, KWR-108 and F3-5/F9 were identified as stable genotypes with higher seed yield with most of the yield attributing characters over population mean and both the checks under a wide range of the environments. Among the seven stable genotypes, PAO3216R-9559 was identified as the most stable one. Considering all the environments PAO3616R-13780 was the best genotype over the environment and PAO2616R-3072 was the best genotype for the E1. In the E2 and E3, PAO3616R-13780 was the best genotype over high yield performance under a wide range of environments.

Key words : G × E, ANOVA, Regression, Stability analysis, Chickpea.

Introduction

Climate change and global warming is a major concern for humankind that hampers the food availability in adequate amount. Pulses are the major source for protein that can be provided in diet of millions of children and lactating women to tackle the malnutrition or hidden hunger (Iqbal *et al.*, 2006). Also in countries like India were 80 million people are dependent on government free ration, pulses can be part of their diet if available in large quantity. Chickpea is an important *Rabi* pulse crop cultivated mainly for its seed and consumed all over the world. It is also one of the major pulse crops of India and also known as Bengal gram. In India it accounts for about 46% of total pulses India, contributes to over 75% of total world chickpea production (13.5 Mt) and content about 18-22% of protein (Maurya and Kumar, 2018). It is also constitute ~40% carbohydrates, cholesterol-free dietary fiber, vitamins, minerals and many micronutrients like zinc, iron, potassium, magnesium etc. (Gil *et al.*, 1996). It covers 14.81 Mhaarea globally, producing 18.09 Mt with a productivity of 1.22 t/ha, ranking second after dry beans in food legume production worldwide (FAOSTAT, 2024).

It is a self-pollinated crop, belongs to genus *Cicer*, tribe *Cicereae*, family Fabaceae and sub-family *Papilionaceae*. The genus *Cicer* includes 22 species of which *Cicer arietinum* L. (Chromosomes no. 2n = 16) is the most widely cultivated. Cooler area like Northern India taking a longer period, compared to relatively warm weather in the Southern parts of India. In any breeding programme, it is necessary to find out phenotypically stable genotypes for yield, which could perform more or less uniformly under different environmental conditions. Seed yield is a complex character and largely depends upon its component characters, with an interaction with the environment resulting into the ultimate product, *i.e.*, seed yield. To breed a stable variety, it is necessary to get the information on the extent of G × E interaction for yield and its component characters. Therefore, an attempt has been made in the present study to evaluate different chickpea genotypes across the seasons to know the role of G × E interaction and also to analyze the stability of genotypes for different traits.

Materials and Methods

The experiment was conducted during *Rabi* 2018-19,35 genotype (Table 1) including 3 checks (BG-372, BIRSA CHANA-3 and KWR-108) were sown in Randomized Block Design with two replications over three environments *i.e.* 31st October (E1), 14th November (E2) and 29th November (E3) during the *Rabi* season (2018-19) at Western section of Birsa Agricultural University Research Farm, Kanke (Department of Genetics and Plant Breeding), which is situated in the plateau region of Jharkhand at 23°17′ N latitude and 85° 19′ E longitude with an altitude of 625 meters above mean sea level (MSL) (Fig. 1). The distance between row to row and plant to plant was 30 cm and 10 cm, respectively whereas number of rows was three and its length was 3 meters in each plot. A basal dose of fertilizer at the rate of 25:50:25 N:P:K kg per hectare was applied at the time of sowing and three time irrigation (time of sowing, pre-flowering and pod development). All other recommended package of practices is followed during the crop growth to raise a good crop. The genotypes were harvested at the time of pod maturity. Germination % was calculated

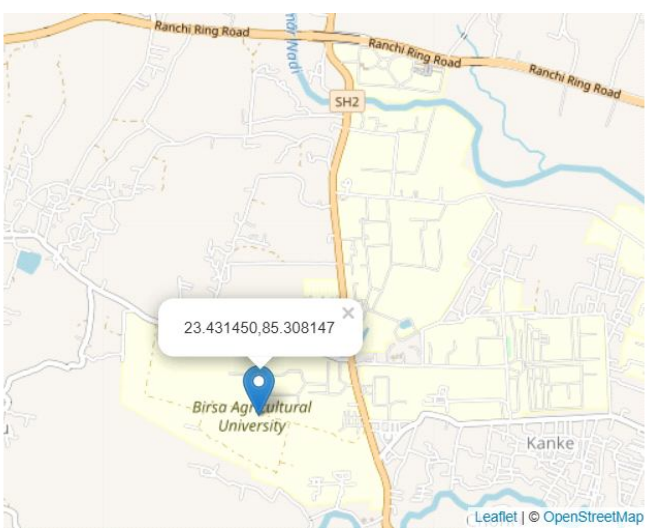

Fig. 1 : Western section of Birsa Agricultural University Research farm, Kanke with geographical coordinates (taken from https://www.latlong.net/).

Table 1 : List of genotypes used in the present investigation.

S. no.	Genytype	Source
1.	PAO2616R-3029	ICRISAT
2.	PA02616R-3040	ICRISAT
3.	PAO2616R-3062	ICRISAT
4.	PAO2616R-3071	ICRISAT
5.	PAO2616R-3072	ICRISAT
6.	PAO2616R-3075	ICRISAT
7.	PAO2716R-3113	ICRISAT
8.	PAO2716R-3164	ICRISAT
9.	PAO2716R-3167	ICRISAT
10.	PAO2716R-3182	ICRISAT
11.	PAO2716R-3188	ICRISAT
12.	PAO3216R-9527	ICRISAT
13.	PAO3216R-9536	ICRISAT
14.	PAO3216R-9547	ICRISAT
15.	PAO3216R-9559	ICRISAT
16.	PAO3616R-13622	ICRISAT
17.	PAO3616R-13780	ICRISAT
18.	PAO3616R-13871	ICRISAT
19.	PAO3616R-13898	ICRISAT
20.	PAO4116R-1001	ICRISAT
21.	PAO4116R-1006	ICRISAT
22.	PAO4116R-1031	ICRISAT
23.	PAO4116R-1036	ICRISAT
24.	PAO41161R-1041	ICRISAT
25.	PAO4116R-1097	ICRISAT
26.	BAUG -15	BAU, Ranchi
27	BAUG -103	BAU, Ranchi
28.	BAUG- 108	BAU, Ranchi
29.	GG-02	Junagadh
30.	GCP- 105	Junagadh
31.	GNG -1581	Sri Ganganagar
32.	F3-5/F9	New Delhi
33.	BG-372 (C)	New Delhi
34.	BIRSA CHANA -3 (C)	BAU, Ranchi
35	KWR-108 (C)	Faizabad

by recording the no. of germinated seed divided by total no. of sown seed multiplied by 100. Days to first flowering was calculated by subtracting the date of sowing and the date when the first flower bloomed in the plot. Days to 50% flowering was calculated by subtracting the date of sowing and the date when about 50 percent of the flowers have bloomed in a plot. Days to maturity was calculated by subtracting the date of sowing to complete maturity of the crop in each replication for each plot. Plant height, number of primary branches per plant, number of pods per plant, number of seeds per pod and grain yield per plant were was recorded manually on five competitive and randomly selected plants in each replication for all the genotypes. 100-seed weight was recorded from 100 seed randomly selected, counted and weighed on an electronic balance in gram. Infestation of pod borer (%) is the ratio of the number of pods damaged to the total number of pods. Protein content (%) was estimated by determining total nitrogen content by using the standard Micro- Kjeldahl method as given in A.O.A.C. (1970). Wilt incidence the ratio of the number of wilted plants over total number of plants was recorded in percentage.

Statistical analysis

Replicated mean value recorded for all the quantitative characters of each treatment were subjected to statistical analysis as per the method suggested by Singh and Chaudhary (1979). Stability Analysis was performed by Eberthart and Russel Method (1966), the regression of the variety mean on the environmental index and a function of the squared deviations from this regression would provide estimates of the desired stability parameters.

Results and Discussion

Genotype × environment interaction and Stability

In the present investigation, the pooled analysis of variance for stability has shown the mean the square due to genotypes was significant for all the traits under varying environments (Table 2). This indicated the presence of considerable genetic variability among the genotypes. Mean square due to G × E interaction was found to be significant for all the characters except number of seeds per pod revealed the presence of a considerable amount of variability for different environments. The analysis of variance for stability parameters indicated that both linear and non-linear components of GxE interaction played an important role in the expression of all characters. Environment (linear) was significant for all the characters except 100-seed weight and protein content, which indicated the response of the environment was predictable. G × E (linear) was significant for all the characters except number of seed per pod and hundred seed weight. The significant G × E interaction for 100-seed weight, grain yield, days to maturity, number of branches per plant, number of pods per plant, protein content have also been reported earlier by Karimizadeh *et al*. (2023), Shimray *et al*. (2022) and Kumar *et al*. (2021).

The phenotype of an individual is the result of the effects of its genotype (G) and environment (E) and their interaction (G × E). When genotypes are grown at several different dates of sowing for testing their relative ranking

Table 2 : Analysis of variance for stability for different characters of chickpea pooled over three environments.

Characters	Source of variation						
	Genotype	Environment (E)	G × E	E (L)	G × E (L)	Pooled deviation	Pooled error
DF	**34**	**2**	**68**	**1**	**34**	**35**	**102**
Germination %	108.58**	575.28**	62.30**	1150.56**	61.89**	60.91**	14.82
Days to first flowering	59.36**	72.75**	8.96**	145.50**	10.74**	6.98**	1.48
Days to 50% flowering	56.66**	281.79**	9.88**	563.58**	10.13**	9.36**	1.80
Days to maturity	43.47**	294.20**	3.93**	588.40**	5.12**	2.66*	1.76
Plant height (cm)	57.84**	122.73**	48.20**	245.46**	63.98**	31.50**	12.84
Number of primary branches per plant	0.57	13.60**	0.61*	27.20**	0.85**	0.37	0.40
Number of pods per plant	328.55**	2359.87**	227.76**	4719.74**	454.06**	1.43	24.50
Number of seeds per pod	0.06	0.13	0.06	0.26**	0.07	0.04	0.05
100-seed weight (g)	94.14**	0.12	0.57**	0.24	0.54	0.59**	0.20
Grain yield per plant (g)	122.16**	263.32**	69.73**	524.63**	30.63**	105.72**	6.31
Wilt incidence (%)	3.67**	19.82**	3.15**	39.63**	2.58**	3.61**	1.22
Infestation of pod borer (%)	2.63*	426.27**	3.36**	852.55**	2.54**	4.06**	1.64
Protein content (%)	27.63**	2.44	1.57*	2.44	2.20**	0.92	5.57

Significant at 1% - **, Significant at 5% - *

usually does not remain the same. The genotypes which can adjust in varying environments express more or less uniform phenotypic performance is indicative of no or low magnitude of G × E interaction. But unfortunately, this is a rare phenomenon itself and most of the genotypes lack such qualities. Hence, the need for a variety with consistent superior performance over a wide range of environments. G × E interaction also indicates the objective of the plant breeder to select genotypes either for the limited condition or for a wide range of environments (Annicchiarico, 1997).

Stability parameters like regression coefficients (bi) and the deviations from the regression coefficients (S^2di) indicated that none of the genotypes were stable over the environments for yield per plant except genotype PAO26R-3029. On perusal of the Table 5, it is evident that maximum grain yield per plant was found in PAO3616R-13780 (35.51 g), whereas BAUG-15 recorded minimum (14.57 g). Mean performance of seventeen genotypes were observed to be higher than the population mean (25.15 g). Almost all genotype exhibited mean seed yield per plant higher than the best check except (BAUG-15, BG-372 and KWR-108) BIRSA CHANA-3 (17.06 g). Out of the 35 genotypes, however, the deviation from regression ($S^2di \neq 0$) was significant for twenty genotypes and accordingly these were found unstable for seed yield per plant. On the basis of different stability parameters one genotype (PAO26R-3029) were judged to be stable with high mean and found suitable for average environment. Expression of stability of genotypes for seed yield has also been reported by Shafi *et al*. (2012) and Hasan *et al*. (2017).

It is clear that no variety was stable for all the fourteen characters under study. The genotype PAO3216R-9559 exhibited stable performance concerning days to first flowering, days to 50 % flowering, days to maturity and number of pods per plant (Tables 3 and 4). The other genotype PAO2616R-3072 expressed stable performance for plant height, number of pods per plant and number of seeds per, while the genotype PAO2716R-3167 shows stable performance for days to first flowering, number of pods per plant and wilt incidence. The genotype PAO4116R-1001 performed stable nature for days to first flowering, days to 50 % flowering and number of pods per plant, while BIRSA CHANA-3 exhibited stable performance for days to first flowering, number of pods per plant and wilt incidence. The genotype KWR-108 showed stable performance for number of primary branches, number of pods per plant and incidence of pod borer. The genotype F3-5/F9 show stable performance for days to first flowering, days to 50% flowering and number of pods per plant. While the genotype PAO2616R-3029 show stable performance for number of pods per plant and grain yield per plant. In the genotype, PAO2616R-3062 shows stable performance for plant height and number of seed per pod. The genotype PAO2716R-3188 shows stable performance for days to maturity and number of pods per plant, in the genotype PAO3216R-9527 and PAO4116R-1031 stable performance for number of pods per plant. Non-linear component of environment was highly significant for test weight indicating the unpredictable nature of environment which is also in agreement with the earlier reports of Shivani and Sreelakshmi (2015). The genotype PAO3216R-9536 shows stable performance for days to first flowering and number of pods per plant. While the genotype PAO3616R-13780 show stable performance for germination percentage and number of pods per plant. In the genotype, PAO3616R-13871 shows stable performance for number of pods per plant and number of seeds per pod. The genotype BAUG-108 shows stable performance for days to maturity and number of pods per plant. While, the fifteen genotypes (PAO2616R-3075, PAO2716R-3113, 3164, 3182, PAO3616R-13622, 13898, PAO4116R-1006, 1036, 1097 BAUG-15, 103, GG-02, GCP-105, GNG-1581 and BG-372) genotypes having only one stable performance for number of pods per plant. The genotype (PAO2616R-3040 and PAO3216R-9547) shows no stable performance. Among the 35 genotypes, PAO3116R-9559 proved to be the most stable genotype for the majority of the characters. Similar results have been found by Kumar *et al*. (2021), Hasan *et al*. (2017), and Choudhary *et al.* (2010). While the study didn’t find genotypes consistently stable across multiple traits affecting seed yield, it’s crucial for identifying genotypes adaptable across year, seasons or suited to specific ones. Thus, further evaluations with a larger number of genotypes over year are needed to pinpoint those with stable yield and influencing traits.

Environmental indices for different characters

The environmental indices of the different environments for all the characters have been presented in Table 3. The mean value of environmental indices showed that the environment second (E2) were favourable environment for the expression of the traits. However, the negative environmental indices value for the (E1) and (E3) indicated that these environments were an unfavourable environment for the expression of the traits. On perusal of the Table 6, it is evident that E1 was favourable for expression of days to first flowering, days to 50% flowering, days to maturity, plant height, number of primary branches per plant, grain yield per plant and

Table 3 : Stability performance of different genotype for different traits under wide range of environment.

Genotype	Gemination %			Days to first flowering			Days to 50% maturity			Days to maturity			Plant height (cm)		
	Mean	Bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
PAO2616R-3029	62.59	-0.03	-5.51	54.67	0.32	4.19	62.67	0.36	9.18*	114.30	1.28	-1.10	48.60	0.04	-8.85
PA02616R-3040	56.28	-0.96	-9.02	60.00	2.35	4.03	68.00	1.43	-1.35	118.70	0.75	-1.20	46.87	3.47	10.01
PAO2616R-3062	57.22	1.01	21.34	54.33	1.87	24.00***	63.83	1.66	9.79*	115.30	1.56	-1.60	55.10	-0.95*	-13.42
PAO2616R-3071	58.87	-0.04	-5.50	52.00	2.27	22.55***	60.17	1.53	65.30***	114.50	1.41*	-1.80	52.50	2.28	-6.67
PAO2616R-3072	60.47	-1.66	82.71*	55.50	0.19	2.79	64.83	0.50	1.31	111.70	0.92	-1.00	46.70	3.30*	-13.24
PAO2616R-3075	57.78	0.43	102.53**	59.50	2.41	7.81*	69.83	1.26	0.57	113.20	0.98	-1.80	52.23	-0.18*	-13.39
PAO2716R-3113	60.00	-0.29	127.89**	58.83	2.95	-1.57	68.00	1.83	-1.40	113.70	1.20	-1.50	51.47	0.26	30.25
PAO2716R-3164	68.70	-0.06	67.27*	58.00	-1.02	20.07***	65.33	0.64	24.79***	114.50	1.19	-1.00	49.80	1.48	-13.13
PAO2716R-3167	67.60	0.17	255.81**	57.67	-1.71*	-1.49	66.50	-0.43	-1.38	114.70	1.43	-1.60	56.43	-0.70	5.91
PAO2716R-3182	65.95	-1.88	36.50	64.17	1.81	-0.49	72.50	1.23	-1.81	111.00	1.55	-0.80	49.20	0.91	3.67
PAO2716R-3188	64.63	0.29	17.76	54.50	0.19	2.79	63.50	0.87	1.61	111.00	1.41*	-1.80	48.97	-0.18	2.44
PAO3216R-9527	71.48	2.32	-14.11	54.00	-0.57	7.56*	63.17	0.64	14.81**	115.80	1.56	-1.60	53.53	4.83	0.77
PAO3216R-9536	69.44	1.50	7.17	52.67	-1.77*	-1.39	62.50	0.17	7.19*	114.50	1.69	0.10	68.70	6.82	111.30**
PAO3216R-9547	64.08	0.06	28.97	59.67	-0.65	0.86	67.33	0.20	-0.34	104.00	1.13	2.90	55.33	2.04	23.67
PAO3216R-9559	64.26	2.75	-10.86	57.00	0.00*	-1.57	66.00	0.17*	-1.80	112.50	0.62*	-1.80	57.60	8.84	-7.97
PAO3616R-13622	69.08	3.39	-12.64	61.83	2.17	1.97	70.00	1.43	4.55	116.70	1.38	-0.50	52.67	4.80	-5.54
PAO3616R-13780	48.70	0.52*	-15.54	49.33	-0.66	-1.20	59.00	0.20	-0.99	106.70	0.86	14.40**	53.93	6.72	-2.23
PAO3616R-13871	60.56	0.62	68.28*	56.83	3.15	-0.21	65.00	2.01	0.70	110.70	2.27	2.50	57.53	4.33	8.19
PAO3616R-13898	58.89	0.70	-14.26	60.50	0.53	-0.73	68.67	0.93	-0.71	109.00	1.30	-1.60	56.73	3.30	-2.14
PAO4116R-1001	57.22	2.18	91.39*	49.67	-0.20*	-1.56	58.00	0.47*	-1.86	111.00	1.07	0.40	51.60	-2.44	38.51
PAO4116R-1006	63.70	1.58	-14.93	51.83	-0.66	-1.20	60.00	0.20	-0.10	110.30	0.26	1.70	55.17	-4.09	61.74*
PAO4116R-1031	52.78	1.74	-7.46	51.00	1.29	16.03**	59.50	1.36	4.70	110.80	0.65	6.10*	54.00	-1.52	145.92***
PAO4116R-1036	53.15	0.50	31.31	52.83	0.65	0.86	61.33	1.07	-1.46	112.80	0.21	-1.40	52.07	0.39	8.02
PAO41161R-1041	61.30	2.73	-12.36	52.67	0.01	-0.40	61.17	0.53	-1.76	111.50	0.39	-0.90	50.17	-1.85*	-13.41
PAO4116R-1097	61.11	1.30	36.74	56.83	1.99	14.18**	65.33	1.54	32.33***	115.80	1.79	-1.50	51.70	-3.85	8.90
BAUG-15	65.44	0.92	113.23**	58.83	1.75	11.87**	66.83	0.90	11.37**	113.20	0.24	-1.70	55.10	0.50	1.19
BAUG-103	61.67	0.80	-9.92	49.33	3.26	10.45**	58.83	2.13	9.83*	108.00	1.52	-0.30	57.13	-1.19	-11.93
BAUG-108	63.70	3.18	7.05	43.50	3.22	0.83	51.83	2.27*	-1.77	101.80	0.27	1.60	49.70	-0.75	46.04*
GG-02	55.74	0.64	-10.31	53.83	0.46	-1.29	62.17	0.57	-0.84	114.50	-0.06	-1.40	57.20	0.21	153.08***
GCP-105	60.19	0.41	77.96*	55.83	2.25	18.02***	63.50	1.43	4.55	112.70	0.70	1.10	47.43	-0.27	-3.33
GNG-1581	62.30	2.48	51.55*	59.83	-0.38	8.01*	65.83	-0.34	13.00**	117.80	0.50	6.70*	56.40	0.86	-7.00
F3-5/F9	70.54	1.22	182.12***	51.83	-0.72*	-1.56	61.50	-0.17*	-1.80	117.70	1.49	-1.80	55.93	2.64	-11.67
BG-372 (C)	66.85	-0.21	-6.27	61.83	4.12*	-1.37	71.17	2.60	2.06	115.30	0.61	10.10*	46.77	-2.12	-1.30
BIRSA CHANA -3 (C)	73.15	3.98	35.27	59.33	3.70	26.73***	68.50	2.40	67.13***	114.30	0.33	7.50*	48.07	-0.95	-12.70
KWR-108 (C)	75.89	2.64	293.27**	60.33	0.40	-0.06	68.83	1.33	-1.77	119.30	0.55	3.20	50.33	-1.97	121.17**
62.61	**SE Mean**	5.52	55.72	**SE Mean**	1.87	64.32	**SE Mean**	2.16	112.90	**SE Mean**	1.20	52.93	**SE Mean**	3.97	

Table 4 : Stability performance of different genotype for different traits under wide range of environment.

Genotype	Number of primary branches per plant			Number of pods per plant			No of seeds per pod			Hundred seed weight (g)		
	Mean	Bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
PAO2616R-3029	3.8	0.17	-0.38	63.27	1.53*	-28.24	1.33	-0.01	-0.05	27.69	-6.45	1.79**
PA02616R-3040	3.63	2.1	-0.29	61.93	-1.41	-5.46	1.2	0.83	-0.04	27.73	10.33	-0.2
PAO2616R-3062	3.9	1.66	-0.39	77.5	-0.23	-15.61	1.37	-5.70*	-0.05	25.61	0.33	-0.05
PAO2616R-3071	3.8	2.04	0	63.87	-0.73*	-28.32	1.17	1.6	-0.02	27.74	-20.21	-0.2
PAO2616R-3072	3.63	1.71	-0.05	71.87	-2.14*	-28.25	1.2	3.26*	-0.05	26.92	-3.26	0.54
PAO2616R-3075	3.77	1.81	-0.2	75.7	-0.7	-16.46	1.37	4.06	-0.05	23.83	-1.54	0.16
PAO2716R-3113	4.2	2.5	-0.41	63.23	0.53*	-28.32	1.23	-0.01	-0.05	17.4	-3.84	0.06
PAO2716R-3164	3.53	1.55	-0.25	53.23	2.18*	-28.24	1.17	-1.62	-0.04	27.23	2.55	-0.19
PAO2716R-3167	4.03	3.39	-0.19	74.83	2.77*	-28.19	1.47	-2.41	-0.01	24.65	10.64	0.35
PAO2716R-3182	3.77	1.95	0.02	71.37	-1.21*	-28.3	1.1	-0.83	-0.04	24.75	14.78	0.07
PAO2716R-3188	2.87	1.79	-0.06	48.77	1.74*	-28.27	1.1	0.8	-0.04	26.38	10.82	-0.13
PAO3216R-9527	3.77	0	-0.29	79.83	3.49*	-28.11	1.27	1.57	0.12	24.54	7.42	-0.21
PAO3216R-9536	3.07	1.69	-0.36	75	0.38*	-28.32	1.13	1.62	-0.04	24.91	-11.84	0.3
PAO3216R-9547	2.9	0.98	-0.42	62.4	1.16	-28.3	1.17	3.27	-0.05	24.77	5.46	1.75**
PAO3216R-9559	3.63	1.55	-0.25	62.9	-0.46*	-28.32	1.37	4.9	-0.05	23.42	-1.83	0.27
PAO3616R-13622	2.47	0.44	-0.39	52.47	2.27*	-28.24	1.4	2.39	0.09	26.01	-8.98	-0.21
PAO3616R-13780	3.17	-0.68	-0.37	78.47	1.83*	-28.27	1.23	4.08	-0.05	40.38	1.81	0.92*
PAO3616R-13871	3.17	1.05	0.37	77.93	0.16*	-28.32	1.4	3.26*	-0.05	26.01	1.63	1.52**
PAO3616R-13898	3.53	1.01	-0.21	69.27	1.20*	-28.3	1.433	4.91	-0.03	21.13	4.73	0.14
PAO4116R-1001	3.5	0.26	-0.39	76.73	2.83*	-28.19	1.5	4.85	0.01	33.01	1.5	1.31**
PAO4116R-1006	3.37	0.68	-0.09	68.63	-0.73*	-28.32	1.37	0.01	-0.05	21.7	-10.96	-0.2
PAO4116R-1031	3.23	-0.48	0.53	68.23	-0.48*	-28.32	1.4	-0.04	0.01	31.53	0.09	1.26*
PAO4116R-1036	3.57	0.31	0.51	64.53	-0.73*	-28.32	1.47	5.65	0.03	34.44	-0.9	0.05
PAO41161R-1041	3.2	-0.41	-0.41	57.8	1.94*	-28.26	1.43	5.7	-0.05	30.45	1.74	0.05
PAO4116R-1097	3.17	0.24	0.02	60.33	2.05*	-28.25	1.3	0.83	-0.04	28.08	19.69	-0.17
BAUG -15	3.37	0.96	-0.15	48.13	1.84*	-28.27	1.47	0.85	0	17.11	-7.68	0.53
BAUG -103	3.57	0.03	0.57	87.17	-2.12*	-28.24	1.33	4.87	-0.04	29.42	5.33	0.12
BAUG- 108	3	-0.75	-0.24	60.23	1.42*	-28.29	1.47	-0.82	-0.05	18.46	-9	0.15
GG-02	3.03	0.94	0.62	54.27	4.04*	-28.04	1.23	2.49	0.03	30.67	15.15	-0.04
GCP- 105	4.07	0.31	0.51	92.67	-0.26*	-28.32	1.4	-0.87	0.08	18.55	14.49	0.56
GNG -1581	4.27	2.78	2.01*	61.63	5.77*	-27.75	1.63	-4.82	0.12	15.76	-0.34	-0.04
F3-5/F9	4.07	2.5	-0.06	61.67	-0.87*	-28.31	1.27	-0.03	-0.03	19.38	2.81	0.06
BG-372 (C)	4.4	0.88	-0.31	77.47	2.63*	-28.21	1.67	0.05	0.06	17.56	2.64	0.78*
Birsa Chana-3 (C)	3.73	0.37*	-0.42	59.57	2.48*	-28.22	1.5	-2.39	0.07	19.32	-3.17	0.04
KWR-108 (C)	3.7	-0.31	-0.36	61.67	2.80*	-28.19	1.5	-7.27	0.09	16.7	-9.54	1.83**
	3.54	SE Mean	0.43	66.99	SE Mean	0.85	1.34	SE Mean	0.15	24.95	SE Mean	0.54

wilt incidence but it was an average environment for expression of protein content. However it was unfavourable for the expression of germination percentage, number of pods per plant, number of seeds per pod, hundred seed weight, and infestation of pod borer. The E2 was favourable for expression of days to first flowering, days to 50% flowering, days to maturity, number of pods per plant, yield per plant and infestation of pod borer, but it was an average environment for expression of number of seeds per pod, hundred seed weight, wilt incidence and protein content and unfavourable for the expression of germination percentage, plant height, number of primary branches per plant. The third (E3) environment was favourable for expression for

Table 5 : Stability performance of different genotype for different traits under wide range of environment.

Genotype	Garin yield per plant (g)			Wilt incidence (%)			Infestation of pod borer (%)			Protein content (%)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	Bi	S^2di	Mean	Bi	S^2di
PAO2616R-3029	28.01	2.26*	-6.7	6.48	0.17	-1.04	6.7	1.17	-0.35	19.91	8.39	-455
PA02616R-3040	30.87	1.03	334.76***	8.61	0.12	4.89*	7.29	1.5	1.31	19.32	2.2	-0.45
PAO2616R-3062	32.9	2.03	133.85***	6.47	2.2	12.96***	5.19	1.25	2.5	24.82	4.77	-0.17
PAO2616R-3071	30.71	1.9	245.32***	7.66	-1.24	5.91*	7.03	1.75	1.02	22.57	0.58	-0.26
PAO2616R-3072	33.62	1.41	466.04***	6.18	-1.2	-0.92	6.27	1.32	5.44*	15.85	-0.83	-0.26
PAO2616R-3075	26.74	0.39	37.95*	6.63	2.7	5.33*	7.39	1.29	0.89	22.46	8.3	4.68**
PAO2716R-3113	20.28	1.97	69.32***	4.99	-3.04	-1.1	5.71	1.24	9.80*	21.76	6.8	1.41
PAO2716R-3164	27.43	3.55	32.35*	4.2	-0.08	-0.98	5.07	0.96	-1.61	21.22	1.38	0.22
PAO2716R-3167	32.86	3.45	17.88	5.17	-0.42*	-1.21	4	0.88	-1.75	19.5	-6.24	-0.45
PAO2716R-3182	25.96	-0.54	31.94*	5.85	1.51	0.19	6.11	1.29	-1.75	22.17	1.96	0.1
PAO2716R-3188	19.64	1.35	7.95	6.79	1.89	0.12	6.04	1.25	17.26**	21.32	3.56	0.14
PAO3216R-9527	29.35	2.15	63.16**	4.75	1.06	3.18	6.02	1.02	-0.03	23.77	9.64	-0.37
PAO3216R-9536	25.01	-0.12	0.86	5.67	1.57	5.09*	4.62	0.87	1.58	18.12	-14.06	0
PAO3216R-9547	22.35	0.56	-3.63	5.96	3.19	-0.77	5.32	0.73	-1.37	22.58	5.78	2.55*
PAO3216R-9559	22.62	0.58	24.65*	3.87	1.25	-1.19	5.48	1.09	-1.05	22.6	9.19	-0.26
PAO3616R-13622	19.91	1.53	36.98*	5.62	3.17	-0.38	7.33	1.15	1.07	20.93	1.07	0.39
PAO3616R-13780	35.51	-1.74	758.20***	8.85	4.2	23.99***	4.86	1.05	-1.22	20.51	4.01	0.78
PAO3616R-13871	24.37	-1.07	95.02***	7.42	3.67	13.48***	5.25	0.83	-1.73	21.02	2.62	-0.4
PAO3616R-13898	19.21	0.05	42.92**	5.43	0.93	-1.02	5.23	0.62	1.62	20.55	3.36	3.38**
PAO4116R-1001	30.37	-0.1	327.05***	6.85	-0.3	-0.66	5.01	0.7	5.23*	19.54	-2.87	-0.48
PAO4116R-1006	20.69	-0.17	-1.29	5.25	0.81	-1.22	5.57	0.98	0.45	18.16	-9.01	0.23
PAO4116R-1031	28.15	-0.78	0.28	4.93	0.61	-1.05	5.44	1.07	3.66	18.59	-7.67	-0.5
PAO4116R-1036	35.21	0.87	150.71***	6.19	2.1	10.83**	7.02	0.95	0.79	18.23	-2.04	2.28
PAO41161R-1041	27.41	2.03	1.34	4.32	1.67	-1.12	5.28	1.15	-0.16	18.81	-3.05	-0.48
PAO4116R-1097	23.64	0.86	54.36**	6.11	-0.35	-0.19	5.81	1.22	-1.62	18.16	1.71	0.54
BAUG -15	14.57	1.65	1.64	6.72	-0.47	9.98**	5.47	1.13	-1.73	16.48	-3.76	0.08
BAUG -103	33.07	-2.06	-0.22	6.6	1.56	-0.58	5.56	1.16	-0.59	19.01	-2.08	-0.45
BAUG- 108	17.9	1.41	55.94**	4.89	0.98	-0.05	6.36	1.27	-1.68	20.71	5.45	-0.44
GG-02	28.51	4.08	63.43**	6.21	0.44	-1.22	5.84	1.04	14.56**	19.43	-5.68	0.42
GCP- 105	25.02	-0.35	-1.04	6.56	1.77	-0.98	4.12	0.8	-1.71	21.8	-0.18	-0.38
GNG -1581	17.06	2.92	16.19	5.84	0.37	5.60*	4.63	0.33	8.88*	20.36	-2.31	-0.13
F3-5/F9	23.33	1.95	234.04***	5.06	1.54	-0.83	3.93	0.65	3.14	24.06	11.87	-0.49
BG-372 (C)	17.45	0.16	66.77**	6.06	-0.88*	-1.22	4.22	0.64	22.25***	20.05	0.43	1.61
BIRSA CHANA -3 (C)	15.02	0.54	60.29**	6.07	1.75	0.84	6	0.39	-0.86	21.66	1.77	0.8
KWR-108 (C)	14.7	1.26	46.33**	5.73	1.73	-1.19	4.92	0.27*	-1.73	16.51	-0.15	0.88
	25.13	SE Mean	7.27	6	SE Mean	1.34	5.6	SE Mean	1.43	20.36	SE Mean	0.94

Table 6 : Environmental indices of three environments.

Characters	First sowing (E1)	Second sowing (E2)	Third sowing (E3)
Germination	-2.686	-1.978	4.664
Days to first flowering	0.562	1.076	-1.638
Days to 50% flowering	1.081	2.138	-3.219
Days to maturity	0.657	2.514	-3.171
Plant height (cm)	2.098	-1.502	-0.596
Number of primary branches per plant	0.715	-0.428	-0.288
Number of pods per plant	-4.648	9.481	-4.833
Number of seeds per pod	-0.061	0.062	-0.001
100-seed weight (g)	-0.065	0.014	0.051
Grain yield per plant (g)	1.708	1.450	-3.158
Wilt incidence (%)	0.645	0.181	-0.827
Infestation of pod borer (%)	-4.030	2.026	2.004
Protein content (%) Mean	0.049 -0.167	0.032 1.059	0.029 -0.884
Types of environment	Poor	Favourable	Poor

germination percentage and infestation of pod borer, it was an average environment for expression of hundred seed weight and protein content. However, this environment was unfavourable for the expression of days to first flowering, days to 50 % flowering, days to maturity, plant height, number of primary branches per plant, number of pods per plant, number of seeds per pod, yield per plant and wilt incidence. Considering all the environments PAO3616R-13780, PAO4116R-1036, PAO2616R-3072, BAUG-103 and PAO2616R-3062 are best genotypes over the environments and PAO2616R-3072, 3040, PAO4116R-1036, PAO2616R-3071 and PAO2616R-3062 in the E1 specific genotypes. In second (E2) environment-specific genotypes are PAO3616R-13780, PAO4116R-1001, GG-02, PAO3216R-9527 and PAO2716R-3167 and third environment (E3) specific genotypes are PAO3616R-13780, BAUG-103, PAO4116R-1036, 1031 and PAO2616R-3072 high yield performance under a wide range of environments.

Conclusion

Genotype × environment interactions analysis revealed significant differences among the genotypes for most of the characters over the environments except plant height and number of seeds per plant, which reflects that genotype interact considerably with the environment in the expression of the traits. Based on environmental indices, out of three different dates of sowing environments, E1 was categorized as poor, E2 as favourable and E3 was poor environment(s) for the expression of different traits in Chickpea. Considering all the stability parameters, seven genotypes namely PAO3216R-9559, PAO2616R-3072, PAO2716R-3167, PAO4116R-13898, BIRSA CHANA-3, KWR-108 and F3-5/F9 had high stability performance for number of pods per plant along with most of the yield attributing characters under a wide range of environments and were considered as comparatively more stable genotypes. Considering all the environments PAO3616R-13780 was the best genotype over the environment and PAO2616R-3072 was the best genotype for the E1. In the E2 and E3, PAO3616R-13780 was the best genotype over high yield performance under a wide range of environments.

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Authors' contributions

AKM and KK executed and designed the experiment, data collection and analysis of experimental data; interpretation of experimental findings. R K, M P and A K A preparation of the manuscript, tables and editing. KK supervised the overall experiment; all authors read and edited the draft of the manuscript.

References

Annicchiarico, P. (1997). Additive main effects and multiplicative interaction (AMMI) analysis of genotypelocation interaction in variety trials repeated over years. *Theor. Appl. Genet*., **94**, 1072–1077.

Choudhary, R.N. and Haque M.F. (2010). Stability of yield and its components in chickpea (*Cicer arietinum* L.) for Chhotanagpur region. *Legume Res*., **33(3)**, 164–170.

FAOSTAT (2024). Available online: http://www.fao.org/faostat/en/#data/QC (accessed on 24 April, 2024).

Gil, J., Nadal S., Luna D., Moreno M.T. and Haro A.D. (1996). Variability of some physico-chemical characters in Desi and Kabuli chickpea types. *J. Sci. Food Agril*., **71**, 179–184.

Hasan, M.T. and Deb A.C. (2017). Stability analysis of yield and yield components in chickpea (*Cicer arietinum* L.). *Horticult Int J*., **1(1)**, 4-14.

Iqbal, A., Khalil I.A., Ateeq N. and Sayyar K.M. (2006). Nutritional quality of important food legumes. *Food Chem*., **97**, 331–335.

Karimizadeh, R., Pezeshkpour P., Mirzaee A., Barzali M., Sharifi P. and Safari Motlagh M.R. (2023). Stability analysis for seed yield of chickpea (*Cicer arietinum* L.) genotypes by experimental and biological approaches. *Vavilovskiizhurnalgenetikiiselektsii*, **27(2)**, 135–145.

Kumar, V., Singh B. and Singh A.P. (2021). Evaluation of Phenotypic Stability in Chickpea Genotypes tested under Diverse Environments. *Chem Sci Rev Lett.*,**10 (39)**, 383-387.

Maurya, O. and Kumar H. (2018). Growth of chickpea production in India. *J Pharmacogn Phytochem.*, **7(5)**, 1175-1177.

Eberart, S.A. and Russell W.A. (1996). Stability parameters for comparing varieties. *Crop Sci.*, **6**, 36-40.

Shafi, A., Shabbir G., Akram Z., Mahmood T., Bakhsh A. and Noorka I.R. (2012). Stability analysis of yield and yield components in chickpea (*Cicer arietinum* L.) genotypes across three rainfed locations of Pakistan. *Pak. J. Bot.*, **44(5)**, 1705-1709.

Shimray, P.W., Bharadwaj C., Patil B.S., Sankar S.M., Kumar N., Reddy S.P.P., Singhal T., Hegde V., Parida S.K., Roorkiwal M. and Varshney R.K. (2022). Evaluation and Identification of Stable Chickpea Lines for Yield-Contributing Traits from an Association Mapping Panel. *Agron.*, **12(12)**, 3115.

Shivani, D. and Sreelakshmi C. (2021). Stability analysis in chickpea (*Cicer arietinum* L). *J Glob Biosci.*, **4(7)**, 2822-2827.

Singh, R.K. and Chaudhary B.D. (1979). Biometrical Methods in Quantitative Genetic Analysis. *Am. J. Plant Sci.*, **7(3)**.