RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 10: 1131-1137 (October 2021)

Selection of Drought Tolerant High Yielding Chickpea Genotypes based on Field Performance and Genetic Variation in Bangladesh

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10.18805/LR-629

ABSTRACT

Background: Drought is the most familiar abiotic stress limiting chickpea production. Genotypes may vary in their capacity to tolerate drought stress. Therefore, the study was undertaken to find out suitable genotypes in the drought prone ecosystems.

Methods: The experiments were carried out at the Bangladesh Agricultural Research Institute, Gazipur, Bangladesh during 2017 and 2018 with thirty chickpea genotypes and four moisture stresses. Through cluster analysis, genotypes were distinguished in five clusters based on similarity in characters.

Result: Among the thirty chickpea genotypes BD-6048 and BD-6045 were found the most droughts tolerant based on field performance. Dendrogram was prepared based on similarity by Euclidean distance among genotypes. Dendrogram showed that members falling in clusters III and IV were more diverse. Data certified that significant genetic variation exists in chickpea genotypes in performance of various attributes in this study and these genotypes can potentially be used for chickpea breeding program.

Key words: Chickpea, Cluster analysis, Drought tolerance, Physiological traits.

INTRODUCTION

Crop plants are suppressed by different biotic and abiotic stresses which acutely obstruct their growth, development and reproduction. Scientific research has demonstrated that water deficiency adversely affected the crop growth and productivity that is a serious threat for agriculture (Sharma and Lavanya, 2002). Currently about one-third of total world's population is living in water-deficit conditions and it is forecasted that drought stress is expected to increase because of elevated CO_2 in atmosphere (Anonymous, 2011). Current prevailing weather extremity could be the innovative adaptation for resiliency of the legume crops (Cutforth, 2007).

Chickpea (*Cicer arietinum* L.) is the second most widely grown legume crop in the world, with a total production of 17.19 million tons from an area of 17.81 million t ha^{-1} (FAOSTAT, 2018). Chickpea is usually sown under stored soil moisture condition, with very little rainfall during the cropping season, leading to a constantly receding soil water condition. This type of receding soil water conditions imposes a ceiling on the cropping duration demanding selection for a matching duration of varieties for the best adaptability and productivity.

To build up drought tolerant or resistant crop plant understanding of genetic manipulation to encounter the drought stress like, drought escape, drought avoidance and drought tolerance is essential (Turner *et al.,* 2001; Maqbool *et al.,* 2017). Drought tolerance is composite event created through biosynthesis of osmolytes or compatible solutes, osmoprotectants and secondary metabolites and adjusting water relations (Nguyen *et al.,* 1997; Maqbool *et al.,* 2015). Continuous evaluation of genotypes for stress tolerance in drought prone regions and selection of genotypes on the basis of yield performance is necessary to meet up food demands of ever growing world populations (Heatherly and Elmore, 2004; Pathan *et al.,* 2007). Therefore, the objective of this study was to investigate the drought tolerant chickpea genotypes with high yield performance for releasing commercial cultivar from Bangladesh Agricultural Research Institute (BARI), Bangladesh.

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How to cite this article: Karim, A.N.M.A., Sarker, U.K., Hasan, A.K., Islam, N. and Uddin, M.R. (2021). Selection of Drought Tolerant High Yielding Chickpea Genotypes based on Field Performance and Genetic Variation in Bangladesh. Legume Research. 44(10): 1131-1137. DOI: 10.18805/LR-629.

Submitted: 05-05-2021 **Accepted:** 15-07-2021 **Online:** 11-08-2021

MATERIALS AND METHODS

The experiments were conducted during *rabi* season of 2017 and 2018 in the pot yard of the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The experimental site was located at 23°59′ Latitude and 90°24′ longitude and at the elevation of 34.5 m above the sea level. The soil is clay loam in texture. The pH of the soil is 5.6. The soil contained 1.12% organic matter, 0.054% total nitrogen, 7.6 meq phosphorus, 0.14 meq 100 g^{-1} potash, 11.4 µg g^{-1}

sulphur, 0.74 µg g^{-1} zinc and 0.23 µg g^{-1} boron. Thirty genotypes (G_1- BD-6042, G_2- BD-6048, G_3- BD-6036, G_4- BD-6045, G_5- BD-6071, G_6- BD-6093, G_7- BD-6233, G_8- BD-6035, G_9- BD-6058, G_{10}- BD-6124, G_{11}- BD-6084, G_{12}- BD-6089, G_{13}- BD-6117, G_{14}- BD-6123, G_{15}- BD-6135, G_{16}- BD-6107, G_{17}- BD-6141, G_{18}- BD-6114, G_{19}- BD-6132, G_{20}- BD-6106, G_{21}- BD-6118, G_{22}- BD-6105, G_{23}- BD-6090, G_{24}- BD-6088, G_{25}- BD-6097, G_{26}- BD-6102, G_{27}- BD-6104, G_{28}- BD-6092, G_{29}- BD-6379, G_{30}- BARI Chola-5) along with four moisture stress (4)T_1- 30% of field capacity, T_2- 50% of field capacity, T_3- 70% of field capacity T_4- 90% of field capacity were included in the study. The experiment was laid out in complete randomized design (CRD) where each treatment was replicated thrice.

Before setting the experiment, weight of each pot was recorded individually. Then 6.0 kg sun dried soil was placed into each pot. This soil sample was oven dried and the moisture percentage was determined (15%). An empty core was weighted with a digital balance. A filter paper was placed on end of the core and the core was filled up with the fresh sample soil. The core was then placed in water for 72 hours. After drainage of excess water the constant saturated weight was determined and the core with saturated soil was oven dried for 72 hours at 80°C. Then the field capacity (100%) for 6000 g (5100 g oven dry soil) soil was determined and it was 2040 ml water. These measured amount of water then multiplied by 0.9, 0.7, 0.5 and 0.3 to know the amount of water to maintain 90% FC, 70% FC, 50% FC and 30% FC respectively. Water requirement was 1836 ml for 90% FC, 1428 ml for 70% FC, 1020 ml for 50% FC and 612 ml for 30% FC.

Seeds of the chickpea genotypes were sown on 28 November, 2017 and 30 November, 2018. An appropriate amount of water was applied to all the pots every day until the beginning of the treatments. The stress treatments were applied at 30 days after sowing and continued up to maturity. One day before starting the treatment, 500 ml of water was applied to each pot so that the soil moisture content (%) of all the genotypes was equal. The amount of water according to the treatments was applied in each pot needed according to the treatments applied in each pot with the help of the measuring cylinder. Data on growth, yield contributing parameters and seed yield were recorded separately. Data were assessed by analysis of variance and by Duncan's multiple range test (Gomez and Gomez, 1984) with a probability P\0.05.

RESULTS AND DISCUSSION

Growth parameters

Genotypes and moisture stress showed significant influence on the growth of chickpea. The maximum days required for 50% flowering (91.74 DAS) was in BD-4048 with treatment T_4 (90% FC) (data not shown). The results showed that different treatment had different degrees of soil moisture levels for production of 50% flowering. Devasirvatham *et al.* (2015) reported large genetic variation for phenology, growth, yield components and grain yield. Genotype G_2 (BD-6048) with T_4 treatment (90% FC) took significantly the longest time (127.26 DAS) required to maturity and the lowest (110 DAS) time required to maturity was in genotype G_{11} (BD-6084) with treatment 30% FC (data not shown). Soil moisture availability has been regarded as the major factor determining the plant for days to maturity. Soil moisture affects plant growth indirectly by affecting water and nutrient uptake as well as root growth. Durga *et al.* (2005) also observed the significant differences between chickpea for days to maturity and found the genotype BD-6089 and BD-6101 was superior under both the irrigated and non-irrigated conditions. Similar result was also found by Sharma *et al.,* (2007). In case of shoot dry weight $plant^{-1}$, interaction effect between genotypes and moisture regimes was found significant. The highest shoot dry weight $plant^{-1}$ (5.14 g) was found in the treatment combination of G_2T_4 (BD-6048 × 90% FC) and the lowest shoot dry weight (1.13 g) was recorded from the treatment of combination $G_{18}T_1$ (BD-6114 × 30% FC) (Table 1). The interaction effect of genotypes and moisture regimes was found significant for root dry weight $plant^{-1}$ (g). The maximum root dry weight (2.80 g) was obtained from the treatment combination of G_2T_4 (BD-6048 with 90% FC) and minimum root dry weight $plant^{-1}$ (0.44 g) was obtained from the treatment combination of $G_{30}T_1$ (BARIChola-5 with 30% FC) (Table 2). These might be due to the fact that root dry weight increased with increasing soil moisture level. Reduction of root dry weight $plant^{-1}$ under moisture level condition might be fact that, under moisture level, plants were not able to produce enough assimilates for inhibited photosynthesis.

Yield and yield attributes

The interaction effect of genotypes and moisture regimes on branches $plant^{-1}$ was significant. The highest number of branches $plant^{-1}$ (4.79) was at treatment combination of G_2T_4 (BD-6048 × 90% FC) and the lowest (1.39) was in the treatment combination of $G_{28}T_1$ (BD-6092 × 30% FC) (data not shown). The better response of soil moisture at 90% field condition than other recognized field condition may be explained that the higher nutrient content and lower C: N ratio leading to increase nutrient availability in soil. Chohan *et al.* (2011) showed morphological characters *viz*. plant height, number of branches and number of leaves were recorded highest in chilling tolerant genotypes at early stages (90 and 120 DAS) these characters were recorded highest in chilling sensitive genotypes. The effect of interaction between genotypes and different soil moisture levels on number of seeds pod^{-1} was found significant. The maximum number of seeds pod^{-1} (2.14) was observed at genotype G_2 (BD-6048) with 90% FC and the minimum number of seeds pod^{-1} (0.12) was observed in genotype BD-6102 with 30% FC (data not shown). The effect of genotypes and soil moisture level (% FC) on seed yield $plant^{-1}$ was found significant (Fig 1 and 2). The highest seed yield plant^{-1} (42.95 g) was recorded from genotypes G_2 (BD-6048) closely followed by genotype G_4 (BD-6045), G_{28} (BD-6092) and G_{23} (BD-6090). Significantly the highest seed yield plant^{-1} (18.00 g) found from treatment T_4 (90% FC) followed by treatment T_3 (70% FC), while the lowest seed yield plant^{-1} (9.74 g) was noted at treatment T_1 (30% FC). The results indicate that seed yield plant^{-1} decreased with decreasing moisture level. Shah *et al.* (2020) stated that genotypes D0091-10, K010-10 and D0099-10 were high yielding and drought tolerant based on their performance. Ton and Anlarsal (2017) demonstrated that seed yield of chickpea can be improved by selecting yield contributing parameters characters and these can be inserted during breeding chickpea materials.

Genetic divergence analysis

All of the 30 chickpea genotypes grouped into five clusters (Table 3). Maximum number of genotypes were retained in

Table 1: Interaction effect between genotypes and moisture regimes (% field capacity) on shoot dry weight (g) of chickpea (two year means).

Genotypes	Soil moisture regimes			
	T_1	T_2	T_3	T_4
G_1	3.71f	3.13o-v	3.92e	4.12d
G_2	3.28k-o	3.42h-k	4.33c	5.14a
G_3	3.20l-r	3.24k-q	3.35j-m	4.86b
G_4	3.15n-t	3.65fg	3.66fg	4.17cd
G_5	1.87uv	2.35no	2.90y-e	3.42h-k
G_6	0.00z	2.60h-m	3.12o-v	3.27k-p
G_7	2.23opq	2.60h-m	3.12o-v	3.69f
G_8	2.10p-s	2.61g-m	2.98t-a	3.55f-i
G_9	1.95stu	2.45mn	2.61g-m	3.01r-a
G_{10}	2.11p-s	2.78b-h	2.79b-g	3.10o-x
G_{11}	2.06qrst	2.56klm	2.95u-b	3.17m-s
G_{12}	2.19opq	2.90y-e	3.19m-s	3.38i-l
G_{13}	1.20y	1.99r-u	2.17o-r	2.92x-d
G_{14}	2.24opq	3.00s-a	3.27k-p	3.49g-j
G_{15}	2.16pqr	2.25opq	2.89z-e	3.62fg
G_{16}	2.18opq	2.55lm	3.09o-y	3.49g-j
G_{17}	0.00z	1.68w	2.26op	2.93w-d
G_{18}	1.13y	2.64f-l	3.08p-y	3.55f-i
G_{19}	0.00z	2.18o-r	2.76c-j	3.14n-u
G_{20}	1.93stu	2.72e-l	3.20l-r	3.33j-n
G_{21}	2.14pqr	2.76c-i	2.91y-d	3.12o-w
G_{22}	2.72e-l	2.94v-c	3.09o-y	3.32j-n
G_{23}	1.43x	1.74vw	2.57j-m	3.15n-t
G_{24}	2.08p-t	2.83a-f	3.12o-v	3.49g-j
G_{25}	2.11p-s	2.74de-k	3.16m-t	3.60fgh
G_{26}	0.00z	1.45x	2.10pqrs	2.60h-m
G_{27}	2.22opq	2.58i-m	2.86a-e	3.09o-y
G_{28}	2.25op	2.90y-e	3.07q-z	3.56fghi
G_{29}	1.90tuv	2.09p-s	2.62g-m	2.90y-e
G_{30}	2.08p-t	2.67f-l	3.00s-a	3.28k-o
CV (%)	4.29	4.29	4.29	4.29
LSD (0.05)	0.19	0.19	0.19	0.19

In a column, means followed by same letters are not significantly different at 5% probability level by duncan's multiple range test (DMRT).

Here,

G_1= BD-6042	G_2= BD-6048	G_3= BD-6036	G_4= BD-6045	G_5= BD-6071	G_6= BD-6093	G_7= BD-6233
G_8= BD -6035	G_9= BD-6058	G_{10}= BD-6124	G_{11}= BD-6084	G_{12}= BD-6089	G_{13}= BD-6117	G_{14}= BD-6123
G_{15}= BD-6135	G_{16}= BD-6107	G_{17}= BD-6141	G_{18}= BD-6114	G_{19}= BD-6132	G_{20}= BD-6106	G_{21}= BD-6118
G_{22}= BD-6105	G_{23}= BD-6090	G_{24}= BD-6088	G_{25}= BD-6097	G_{26}= BD-6102	G_{27}= BD-6104	G_{28}= BD-6092
G_{29}= BD-6379	G_{30}= BARIChola-5					

T_1 = 30% of field capacity, T_2 = 50% of field capacity, T_3 = 70% of field capacity, T_4 = 90% of field capacity.

Table 2: Interaction effect between genotypes and moisture regimes (% field capacity) on root dry weight (g) of chickpea (two year means).

Genotypes	Soil moisture regimes			
	T_1	T_2	T_3	T_4
G_1	0.64x-e	0.70u-c	0.79q-z	0.94g-r
G_2	1.01e-p	1.11y-i	1.25t-c	1.37r-w
G_3	0.83n-y	0.86l-w	0.91i-u	1.08a-k
G_4	1.74m-p	1.93j-m	2.18f-i	2.31c-g
G_5	0.83n-y	0.87k-w	1.02e-o	1.22v-e
G_6	0.00f	0.62y-e	0.72s-c	0.84n-y
G_7	0.51cde	0.57a-e	0.67w-d	0.80p-z
G_8	0.71t-c	0.75r-b	0.83o-xy	0.95f-qr
G_9	1.30t-z	1.13y-h	1.25t-c	1.44q-u
G_{10}	1.83l-o	2.02i-l	2.63ab	2.80a
G_{11}	0.89j-v	0.94g-r	1.04c-n	1.23u-e
G_{12}	0.89j-v	0.99f-q	1.10z-j	1.32t-y
G_{13}	2.01i-l	2.12g-j	2.22e-i	2.37c-f
G_{14}	0.92i-t	0.97f-q	1.07a-l	1.27t-b
G_{15}	1.26t-b	1.43q-v	2.10g-k	2.41cde
G_{16}	0.90j-u	0.91i-u	1.16w-f	1.36r-w
G_{17}	0.00 f	0.48de	0.60z-e	0.70u-c
G_{18}	1.35s-x	1.14x-h	1.56p-s	1.63opq
G_{19}	0.00f	1.87lmn	2.25d-h	2.49bc
G_{20}	0.67v-d	0.91i-u	1.05b-m	1.46q-t
G_{21}	0.94g-r	1.04c-n	1.15x-g	1.24u-c
G_{22}	0.80q-z	0.63y-e	0.77q-a	1.03d-o
G_{23}	0.55b-e	1.03d-o	1.10z-j	1.24u-c
G_{24}	1.33t-y	2.04h-l	2.44bcd	2.26d-g
G_{25}	1.13y-h	1.27t-a	1.41r-v	1.63opq
G_{26}	0.00f	1.24u-d	1.74m-p	2.02i-l
G_{27}	0.72s-c	0.84m-x	0.93h-s	1.14x-h
G_{28}	1.79mno	1.90klm	2.35c-f	2.21e-i
G_{29}	1.57pqr	1.68nop	2.39c-f	2.49bc
G_{30}	0.44e	0.59z-e	0.67w-d	0.83n-y
CV (%)	10.65	10.65	10.65	10.65
LSD (0.05)	0.21	0.21	0.21	0.21

In a column, means followed by same letters are not significantly different at 5% probability level by duncan's multiple range test (DMRT).

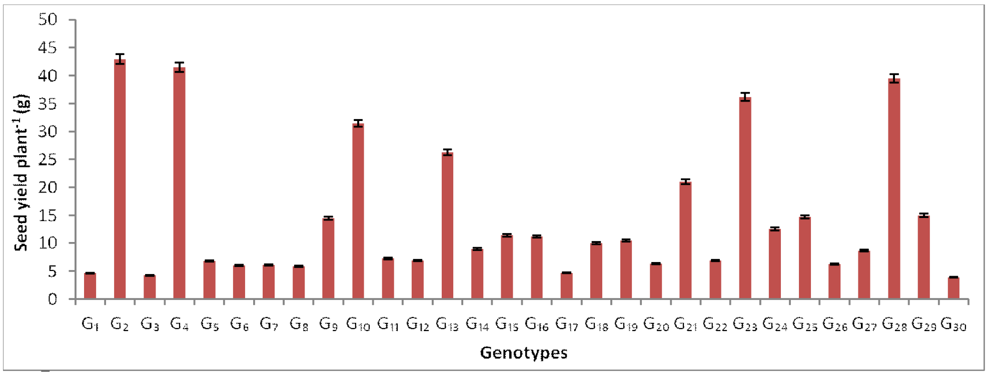

Fig 1: Effect of genotypes on seed yield plant^{-1} (g) of chickpea.

Here,

G_1= BD-6042	G_2= BD-6048	G_3= BD-6036	G_4= BD-6045	G_5= BD-6071	G_6= BD-6093	G_7= BD-6233
G_8= BD -6035	G_9= BD-6058	G_{10}= BD-6124	G_{11}= BD-6084	G_{12}= BD-6089	G_{13}= BD-6117	G_{14}= BD-6123
G_{15}= BD-6135	G_{16}= BD-6107	G_{17}= BD-6141	G_{18}= BD-6114	G_{19}= BD-6132	G_{20}= BD-6106	G_{21}= BD-6118
G_{22}= BD-6105	G_{23}= BD-6090	G_{24}= BD-6088	G_{25}= BD-6097	G_{26}= BD-6102	G_{27}= BD-6104	G_{28}= BD-6092
G_{29}= BD-6379	G_{30}= BARIChola-5					

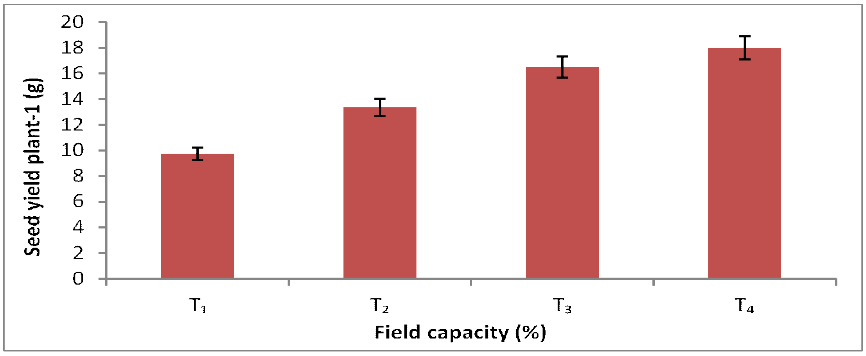

Fig 2: Effect of moisture regimes on seed yield plant^{-1} of chickpea.
Here, T_1 = 30% of field capacity, T_2 = 50% of field capacity, T_3 = 70% of field capacity, T_4 = 90% of field capacity.

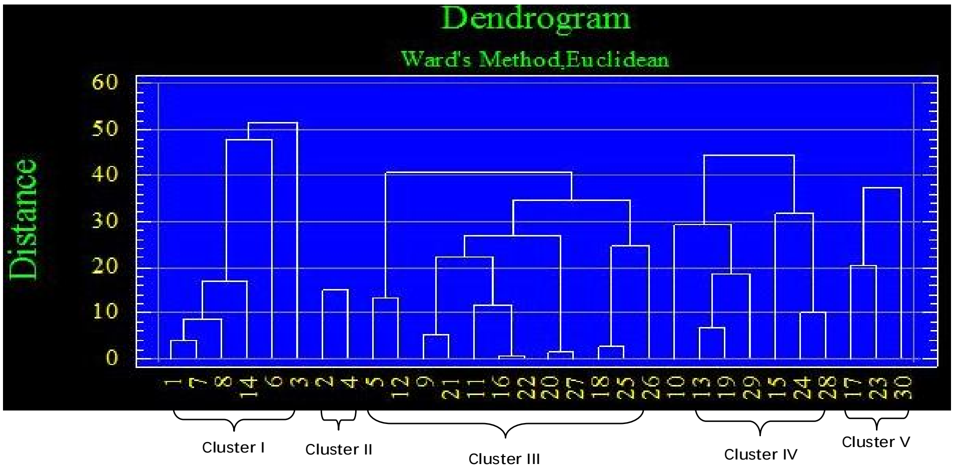

Fig 3: Dendrogram based on summarized data on differentiation among 30 genotypes of chickpea according to Ward's method.

Table 3: Cluster membership of chickpea genotypes with percentage.

Cluster number	Number of genotypes	Name of genotypes
I	6	BD-6042, BD-6036, BD-6093, BD-6233, BD -6035, BD-6123
II	2	BD-6048, BD-6045
III	12	BD-6071, BD-6058, BD-6084, BD-6089, BD-6107, BD-6114, BD-6106, BD-6118, BD-6105, BD-6097, BD-6102, BD-6104
IV	7	BD-6124, BD-6117, BD-6135, BD-6132, BD-6088, BD-6092, BD-6379
V	3	BD-6141, BD-6090, BARIChola-5

cluster III (12) followed by cluster IV (7). The highest mean values for seed yield/plant, number of seeds pod^{-1}, number of pods plant^{-1} and plant height were depicted by cluster II (Table 4). Cluster II also exhibited maximum mean values for days to flowering and number of branches plant^{-1} and cluster II had the highest mean value for 100 seed weight. The maximum contribution towards divergence was due to days to flowering followed by 100 seed weight and number of pods plant^{-1}. Parashi *et al.* (2013) reported days to 50% flowering donated maximum towards genetic diversity. Pahre *et al.* (2014) and Kuldeep *et al.* (2015) stated that 100 seed weight and number of pods plant^{-1} contributed maximum towards genetic diversity. Very high contribution of number of pods plant^{-1} and 100 seed weight towards total diversity was also reported by Malik *et. al.* (2010). Days to maturity and seed yield plant^{-1} contributed least to the total diversity. Kayan and Adak (2012) have confirmed the involvement of pods plant^{-1} in genetic diversity. Janghel *et. al.* (2020) stated that the understanding of many inter-related traits involved in the genetic variation of chickpea seed yield. Dendrogram distributed the genotypes on the basis of number among the clusters (Fig 3) which depicted that members of cluster

Table 4: Cluster analysis of various traits of chickpea genotypes.

Variables	I	II	III	IV	V
Days to 50% flowering	74.00	90.50	84.50	85.86	86.00
Plant height (cm)	43.83	48.50	38.75	40.00	37.00
Days to maturity	122.33	127.00	123.83	124.43	125.00
Canopy height (cm)	33.00	37.50	32.08	32.57	47.00
Canopy width (cm)	59.83	77.50	61.42	65.43	62.67
Shoot dry weight (g)	3.83	4.50	3.17	3.29	3.00
Root dry weight (g)	1.00	1.50	1.25	2.14	1.00
Number of branches plant^{-1}	4.00	5.00	4.00	4.00	4.00
Number of pods plant^{-1}	72.50	85.50	73.92	77.29	78.00
Number of seeds pod^{-1}	1.17	2.00	1.17	1.14	1.00
100-seed weight (g)	16.83	20.00	18.75	16.86	15.67
Seed yield plant^{-1} (g)	9.17	44.50	13.67	29.00	11.67

III and IV were more diverse and hybridization between their members could generate a significant diversity for selection process.

CONCLUSION

The study revealed that genotype BD-6048 and BD-4045 produced highest days to 50% flowering canopy height (cm), days to maturity, shoot dry weight^{-1} (g) and root dry weight plant^{-1} (g), number of pod plant^{-1}, number of seeds pod^{-1}, 100-seed weight, seed yield pod^{-1}. Therefore, the present study was useful in the screening of most efficient genotype, which could be strongly recommended to chickpea grown in drought prone ecosystems. Besides considerable genetic variation exists in chickpea genotypes for grain yield, harvest index, pods plant^{-1}, 100-seed weight, days to maturity and plant height which is highly desirable in breeding programs. Results of this study suggest that these genotypes may be employed in future chickpea breeding program to develop genetically improved chickpea varieties.

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