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Original Research Article

FIELD-BASED ASSESSMENT OF GENETIC DIVERSITY AND YIELD CHARACTERS IN EXOTIC KABULI CHICKPEA (*CICER ARIETINUM L.*) GERMPLASM UNDER NORMAL AND WATER DEFICIT CONDITIONS

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Abstract: *Drought stress is a major factor that affects chickpea production, especially in dry areas of the world. This study assessed the genetic variation of one hundred Kabuli chickpea germplasm accessions from the International Center for Agricultural Research in the dry areas under control and stress conditions. The study was done at the University of Agriculture Faisalabad, in the Department of Plant Breeding and Genetics. Using analysis of variance (ANOVA), it was established that genotypes in the two environments, that is, controlled and water-deficit environments differed significantly. Thirty-seven genotypes offered higher standard checks under water stress in addition to 61 under normal growing disorders. Regression analysis revealed that plant height had a significantly positive effect on biological yield (r=0.376**), pods per plant (r=0.251*), hundred-seed weight (r=0.278**) and yield per plot (r=0.339**). Plot yield was significantly related to seed yield at r = 1.000**. The scatter biplot analysis revealed that 14 genotypes (22225, 22228, 22219, 22274, 22267, 22256, 22266, 22264, 2204, 22276, 22271, 22236, 22215, 22277) were significantly less sensitive to drought stress as they were distinctly clustered away from other genotypes in the plot. High variability was observed in traits such as hundred-seed weight, harvest index, and biological yield. The results indicate a high level of genetic variation in the chickpea germplasm that can be utilized to develop improved drought-tolerant chickpea varieties with enhanced yield potential.*

Keywords: Chickpea, Water Deficit, Genotypes, Kabuli, Genetic Diversity, Yield, Drought Tolerance

Introduction

The chickpea or garbanzo bean, scientifically known as Cicer arientinum L., is a self-pollinated, annual edible legume crop belonging to Leguminaceae. Pakistan ranked 7th and is one of the major producers of chickpeas (Tania et al., 2023).Chickpeas are a significant source of vegetable protein, and to meet its demand, Punjab contributes 80% of the chickpea production (Hussain et al., 2024). Along with satisfying the nutrient requirements of humans and animals, chickpeas are crucial in improving soil fertility (Phiri et al., 2023). Chickpeas fulfill 80% of their nitrogen needs from symbiotic nitrogen and can fix up to 140 kg per hectare of atmospheric nitrogen. Thus, they contribute a fairly large amount of residual nitrogen to the organic matter, improving soil health for succeeding crops (Abisankar M et al., 2024). This crop in association with bacterium species of the genus Mesorhizobium is highly effective in maintaining soil fertility (Zehara, 2021). Crop rotation with chickpeas is considered a promising strategy for promoting sustainability in agriculture production (Lago-Olveira et al., 2023).

Chickpeas are highly susceptible to many abiotic stresses such as drought, shortage of water, salinity, heat, and temperature, during critical stages of growth these deteriorating factors affect the development (Arriagada et al., 2022). Drought is a major stress during the grain filling and flowering stage that severely affects the yield of chickpea crops in rainfed production systems (Korbu et al., 2022). Normally, growth and development are damaged at the time of water-deficient conditions (Ullah & Farooq, 2022).

Under the current climate trends, drought stress greatly influences chickpea crops. Chickpea breeders are exploring the new germplasm and are searching for new genes that can be correlated with stress resilience and can be utilized to produce more stress-tolerant varieties and high-yielding cultivars of chickpea (Karalija et al., 2022). However, the narrow genetic diversity in chickpeas brings hurdles in developing new varieties (Singh et al., 2022). Water deficit conditions are responsible for reducing the uptake of water and minerals under the soil surface, and they also decrease the rate of photosynthesis and stomatal conductance (Bhattacharya, 2021). Water scarcity decreases the growth and development of the plant because of a decline in the capability of photosynthesis (Ahluwalia et al., 2021). During water deficit conditions, the ROS (Reactive oxygen

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species) are produced and accumulated in excess amounts that destroy the structural and functional integrity of chloroplast (Li & Kim, 2022). Accumulation of ROS triggers the oxidation of biomolecules destroying protein-pigment complexes during extreme water deficit conditions (Sachdev et al., 2021).
Chickpea is mostly cultivated in rainfed areas; therefore, farmers do not pay attention to this crop. Thus, this crop is labeled under the umbrella of a minor crop. There is a need to develop drought-tolerant varieties for accelerating resilience under water deficit conditions (Sachdeva et al., 2022). Management of genetic variability is the most efficient and cost-effective methodology. Genetic diversity is extremely important in almost all breeding programs. It is very helpful for selecting suitable genotypes to improve the production level of crops. However, the purpose of the present study is to evaluate genetic diversity and several yield-related traits in Kabuli chickpeas under water deficit and normal conditions based on statistical analysis. So that suitable germplasm can be used for the cultivation in water deficit fields.

Methodology

One hundred genotypes (Kabuli) were collected from the International Center for Agriculture Research in the Dry Areas (ICARDA) along with two Kabuli checks (Noor 2009 and Noor 2013) and two desi checks (NIAB 2016 and Bital 2016). The trial was conducted in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad with 4 replications in augmented block design under normal and drought conditions. Sowing was done in the second week of November 2017. All the standard agricultural practices were used to obtain better results. Under normal conditions, plants were irrigated thrice during their life cycle. This study induced water deficit conditions artificially by stopping the water supply. Sowing was carried out in two fields. Under water deficit conditions all the genotypes were sown in one block while under normal conditions; two blocks with two standard checks. Sixteen seeds of each genotype were sown in each line. The varieties were sown in Plant × Plant distance 0.5 ft, Row × Row distance 1 ft, and Genotype × Genotype distance 1 ft in both fields.
After maturity, randomly five plants were selected from each genotype to record the data for various traits including (Plant height (cm), Number of pods per plant, Number of seeds per plant, Biological yield (kg/ha), Yield per plant (g), Yield per plot (kg/ha^{-1}), 100-seed weight (g) and Harvest index).
An augmented block design was used to arrange the treatments. ANOVA was performed by using the data to determine the genetic diversity among the different genotypes (Behera et al., 2024). Agristat software was used to make ANOVA (Abdelhaleim et al., 2022).The correlation coefficient was achieved by evaluating raw and adjusted mean data. SPSS software was used to evaluate the correlation between the understudied parameters of chickpea genotypes.

Results

Analysis of variance (ANOVA)

All the parameters were subjected to variance analysis (ANOVA) to evaluate significance. Highly significant differences have been found by ANOVA in all the genotypes among all the parameters under normal conditions (Table 4.3). A significant difference has been shown by ANOVA in all the genotypes for plant height. It was found that there exists a highly significant difference between all the blocks (1736.00**). However, the interaction between checks and total entries in the field also showed a highly significant difference (1251.34**). The results of the present study revealed a huge variation in the field which could be helpful in the future breeding program (Table 4.3). Ali *et al.* (2010) also found the same results in terms of plant height. (Chopdar et al., 2017) Examined genetic variability in the chickpea genotypes. It was also found that all the understudied parameters showed significant differences especially plant height showed maximum variation in 20 genotypes which were understudied. Hence these results were quite similar to our results. Yadav *et al.* (2015) also explained similar results in the context of plant height (cm). Mean square and ANOVA showed a relative difference between both Desi and Kabuli varieties. Only a few cultivars showed better performance and it was suggested to use them in future breeding programs for the development of high-yield producing varieties (Hussain *et al.*, 2017).
The maximum plant height has been attained by genotype 22221 (70 cm), while 22300 carries the minimum plant height (33 cm). Some other better-performing genotypes (22259, 22253, and 22247) were found which have also maximum height (69, 69, and 67 cm) respectively. These genotypes have performed better under water deficit conditions as compared to standard checks because Noor 2013 attained only 45 cm plant height. Our results revealed that there exists a huge variation between genotypes in terms of plant height. That genetic variability can be used in future breeding pools to develop superior chickpea varieties.
The trend of all the parameters revealed that almost 37 genotypes were better than standard checks under water deficit conditions while 61 genotypes showed better performance under normal conditions. Similar results were found to evaluate the variations in the crop at the time of limited water supply (Majnoun Hosseini et al., 2009) studied twenty accessions of chickpeas under controlled conditions viz. (22/15°^{C}). A split-plot design was used in which soil moisture contents were used as the main plot and cultivars were used as a subplot. Plants showed a significant difference in germination and early growth and development under different levels of water contents i.e. 25 to 50 % moisture contents.

Table 1 Mean squares for various traits of 100 chickpea genotypes under normal irrigation

SOURCE	DF	PH	BY(g)	BY kg/ha	PP	SP	SY(g)	SY kg/ha	HSW	HI	YP(g)
Block	1	1736.00**	13.58*	681515.99*	1820.64**	2491.77**	0.549	27576.67	550.13**	60.51	76.03
Treat	103	146.65	245.23**	12321708.37**	1512.66**	1503.04**	40.524*	1941317.34*	52.64**	148.28**	41926.31**

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Checks	3	44.33	330.11**	16583753.24**	175.55	185.05	19.82	995077	6.37	259.62	3977.33
T. Entry	99	138.59	239.18**	12017884.00**	1558.70**	1555.95**	39.59*	1989690.23*	53.16**	145.59	24750.23**
Chk vs test	1	1251.34**	589.11**	29614186.81**	966.329*	219.01**	194.71**	8878.32	140.29**	80.38	1856205.74**
Error	3	19	0.862	43149.96	51.21	45.91	4.04	203145.06	1.43	48.54	878.15
Total	107										

**=significant at 5% level of significance (P<0.05) and NS = Non-significant. DF) Degree of freedom, PH) Plant Height, By/g) Biological Yield g, Bykg/ha) Biological Yield kilogram per hectare, PP) Pods/Plants, SP) Seeds/Plants, Syg) Seed Yield per gram, Sykg/ha) Seed Yield kilogram per hectare, HSW) Hundred Seed Weight, HI) Harvest Index, YPg) Yield per plot in gram.

Performance of chickpea genotypes under water deficit conditions

To evaluate the genetic diversity 100 Kabuli chickpea genotypes with two checks Noor 2009 & Noor 2013 were used. Superior genotypes under 1 irrigation are mentioned in Table 4.2. Noor 2013 has maximum pods/plant (49.2) & Noor 2009 has 39.4 pods/plant. That genetic variability can be used in future breeding pools to develop high-yielding genotypes. Variability in the context of pods/plants is elaborated in the form of graphs. Fang *et al.* (2010) also found the same results in terms of pods/plants. Noor 2013 & Noor 2009 have 41.8 & 35 number of seeds/plant. Yield/plant (g) for Noor 2013 and Noor 2009 were recorded as 12.8 & 9.10 g.

Genotype 22279 carries a minimum harvest index (20.05 %) which is very lower as compared with the superior genotype (90.12 %). Noor 2009 and Noor 20013 have 67.53 & 47.02 % respectively. This type of result was studied under water stress, Kabuli types showed earlier germination and larger plant size as compared to Desi types. Susceptible cultivars under water-deficient conditions revealed lower germination and a decrease in the seedlings as compared to the resistant cultivars. Plant biomass was reduced up to (79-85%) in kabuli and desi genotypes while, plant height showed a significant reduction (79-85%) in both types (Zaman-Allah *et al.*, 2011; Fatnassi *et al.*, 2018). Yield and yield-related components are controlled by different parameters of the crop. It is quite challenging to expose all the patterns and relationships involved in the yield and yield-related traits. Several yield-related traits were severely affected by the limited supply of water, which ultimately decreased the total yield. Different stages of the crop were affected by the shortage of water viz. plant height, leave color, leaf size, pod size, dry mass, and flowering stage (Khamssi *et al.*, 2014).

Table 2 Trend of all the parameters under normal conditions

Parameter	Trend	Average	Noor 2013	Noor 2009	Average	Better than better check	Better than Aveg check
Plant height (cm)	33-70	51	42	45	43	71	82
Biological yield (g)	12.8-53.7	28.6	30.4	51.9	41.1	1	2
No. of pods/plant	6-77.7	28.6	29	20	24.5	33	45
No. of seeds/plant	4.4-97.4	40.9	33	23.3	28.2	63	69
Yield/Plant (g)	2.0-17.56	7.8	10.4	6.5	8.5	23	37
100-seed weight(g)	4.8-38.8	19.3	31.1	28.1	29.6	5	7
Harvest index (%)	10.1-51.6	27.3	34.3	12.6	23.4	19	62

Correlation Coefficient under normal and drought conditions

Correlation is a statistical tool that shows a relationship and fluctuation between two variables (dependent and independent). Correlation analysis showed that plant height has a significant correlation with all other parameters viz. Biological yield, number of pods, number of seeds, grain yield, hundred seed weight, and yield per plot. However, Plant height has a non-significant relationship and negative correlation with the harvest index. A similar type of result among PH with other parameters was described by Kumar *et al.* (2002) in various chickpea cultivars. The biological yield with the harvest index has a negative correlation. The hundred seed weight has a non-significant negative correlation with pods/plants. There exists a non-significant relationship between harvest index and hundred seed weight with many seeds per plant. The seed yields with yield/plot (1.000**) were found to be highly significant and positively correlated with each other. The hundred seed weight positively correlated and highly significant relationship with other understudied parameters under natural conditions. Under the water deficit condition, the plant height has a highly significant relationship and is positively correlated. Biological yield with HSW shows a negative correlation. The hundred seed weight has a non-significant negative correlation with pods/plants. A negative correlation and significant relationship was found of hundred seed weight with many seeds per plant. Seed yields with yield/plot were found to be highly significant and positively correlated with each other. The hundred seed weight has a positive and highly significant relation with other understudied parameters. The same results were carried out by Mallu *et al.* (2015) to evaluate the association among yield-related traits for forty-eight genotypes of chickpeas along with two chickpea genotypes. Agro-morphological traits for chickpeas were tested.

by using Genstat 2015. Pod filling period pods number plant^{-1}, biomass, and the total number of primary and secondary branches plant^{-1} indicated a positive relationship with the grain yield. Plant height, plant spread, pod length, pods per plant, pod filling period, 100-seed weight, and seed yield were positively correlated with the second principal component. It denoted considerable agro-morphological and genetic diversity among genotypes

Table 3. Correlation Coefficient of the parameters under normal conditions

	PH	BY(g)	PP	SP	SY(g)	HSW	HI	Y/plot
BY(g)	.376**							
PP	.251*	.765**						
SP	.252*	.764**	.983**					
SY(g)	.339**	.846**	.856**	.858**				
HSW	.278**	0.048	-0.045	-0.053	0.059			
HI	-0.159	-.396**	0.019	0.032	0.103	0.057		
Y/plot	.339**	.846**	.856**	.858**	1.000**	0.059	0.103	

Table 4. Correlation Coefficient of the parameters under stress conditions

	PH	BYg	PP	SP	YP	HSW	HI
PH							
BYg	.364**						
PP	.178	.366**					
SP	.102	.534**	.644**				
YP	.327**	.592**	.773**	.577**			
HSW	.121	-.173	-.101	-.635**	.140		
HI	.159	.033	.678**	.339**	.805**	.274**	

**=significant at 5% level of significance (P<0.05) and NS = Non-significant. GP) germination percentage, Plant Height, By/g) Biological Yield g, Bykg/ha) Biological Yield kilogram per hectare, PP) Pods/Plants, SP) Seeds/Plants, Syg) Seed Yield per gram, Sykg/ha) Seed Yield kilogram per hectare, HSW) Hundred Seed Weight, HI) Harvest Index, YPg) Yield per plot.

Biplot Analysis under controlled vs Water deficit conditions

Biplot analysis represents the data in the form of graphs (Nishisato et al., 2021). Principal components generating maximum variance were utilized to construct a scatter biplot diagram for metric traits and chickpea genotypes under controlled and water stress conditions. Genotypes were showing considerable genetic diversity in terms of studied traits. Maximum divergent genotypes showing diversity under controlled conditions include; 22220, 22229, 22221, 22218, 22250, 22217, 22230, 22223, 22219, 22213, 22210, 22216, while Scatter biplot depicted those fourteen genotypes (22225, 22228, 22219, 22274, 22267, 22256, 22266, 22264, 2204, 22276, 22271, 22236, 22215, 22277) as highly diverse as they were spotted far away from other genotypes under water stress condition. These genotypes could be a better source to develop drought-tolerant lines. Traits i.e. HSW, Harvest index, YP(g), SP, PP, and Biological yield showed more variation as these traits were found far away from the point of origin, and lines representing these traits are longer. Plant height was less variable as the line showing this trait was very close to the origin and shorter (Fig. 1 and 2). HSW showed a negative correlation with all other traits under study

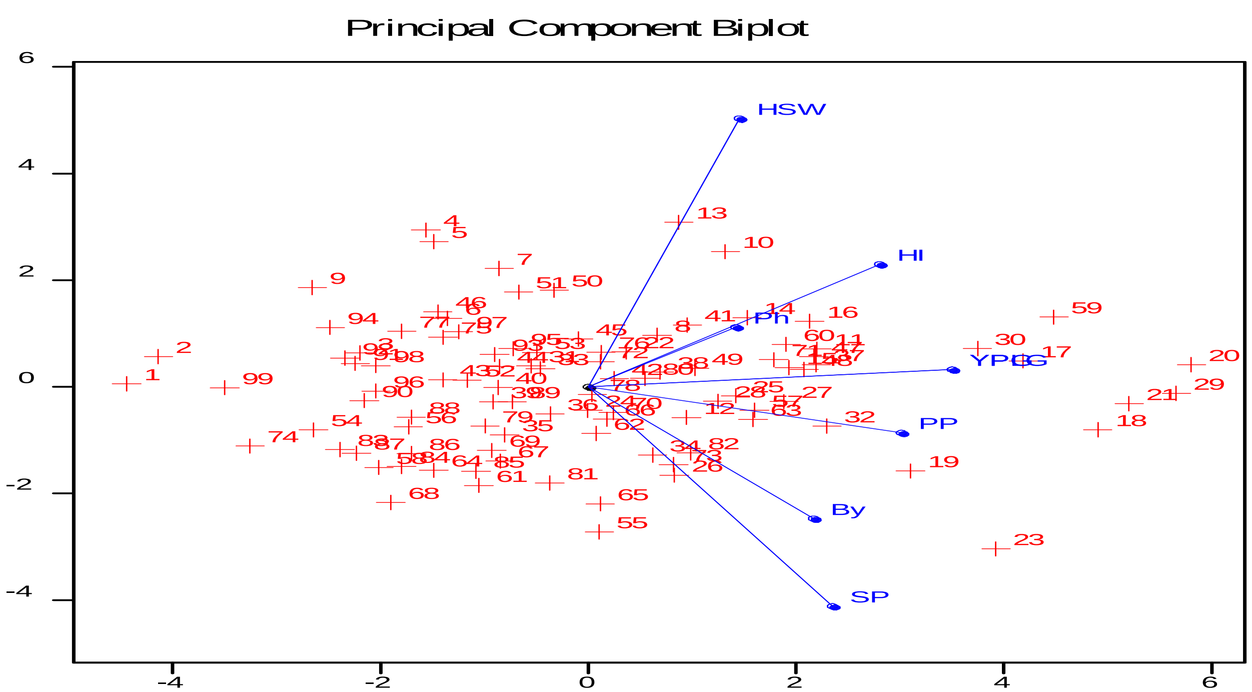

Figure 1. Biplot Analysis under controlled conditions

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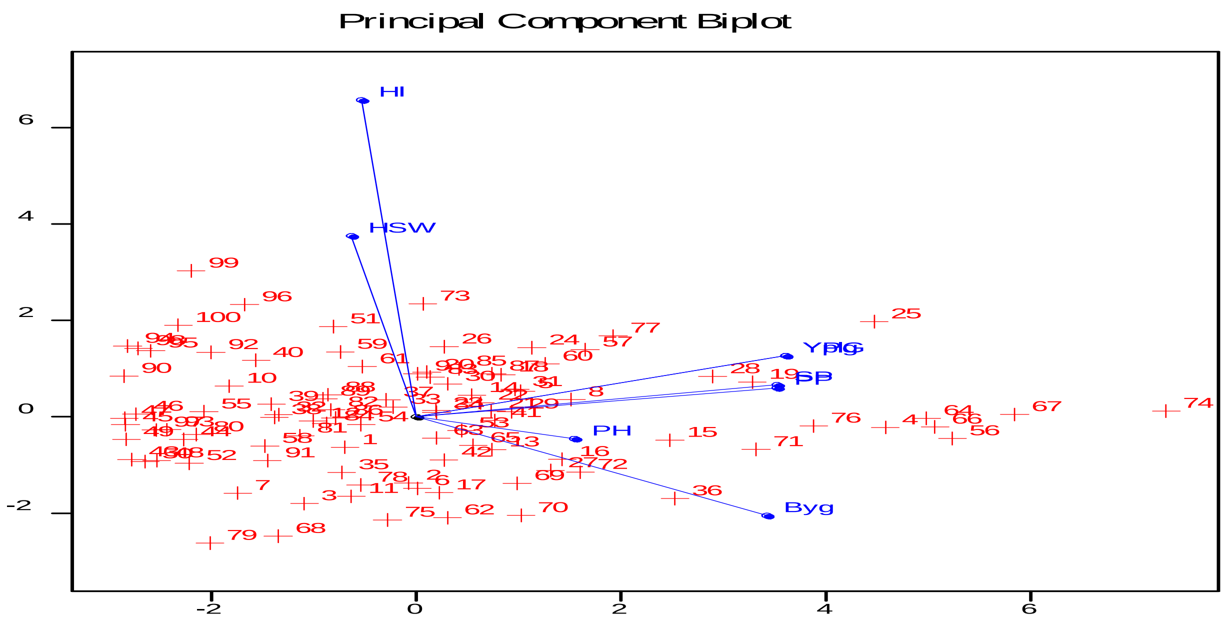

Figure 2. Biplot Analysis under Water Deficit Condition

Conclusion

The highly significant difference has been found by ANOVA in all the genotypes among all the parameters under normal conditions. The trend of all the parameters revealed that 37 genotypes were better than standard checks under water deficit conditions while 61 showed suitable performance under normal conditions. A huge genetic variation was found in the germplasm of chickpea which is responsible for the variation among cultivars. Variability is an important factor for plant breeding. Therefore, the genotypes having better yield and yield-related traits should be used in future breeding programs to develop chickpea lines with the maximum potential to attain high yields.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
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Approved by the department Concerned.
Consent for publication
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Conflict of interest

The authors declared absence of conflict of interest.

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