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Evaluation of chickpea (*Cicer arietinum* L.) elite lines for adaptability under semi-arid climatic conditions

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Abstract

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Chickpea is a major pulse crop in Pakistan. It contributes more than 73% in terms of pulses area. It is mainly grown in arid and semi-arid climatic regions. The present study was conducted in Sargodha, Punjab region in semi-arid conditions. The study was done for the evaluation of elite genotypes collected from the University of Agriculture Faisalabad. Experiment was laid out in Randomized Complete Block Design with three replications. The genotypes used for the experiment were UDC-02, UDC-04, UDC-06, UDC-08, UDC-10, UDC-12, UDC-14, UDC-20, UDC-30, UKC-03, UKC-05, UKC-1, UKC-15, and UKC-25. Among the genotypes, 9 were selected from desi and five genotypes from kabuli chickpea. Growth, yield components and yield were recorded to assess the performance of the studied genotypes. Statistical analysis was Analysis of variance, heritability for broad sense, least significant difference, and correlation among genotypes. All traits showed significant variation among genotypes. Genotypes UKC-01 and UDC-10 showed better results than other genotypes. Seed yield (g) has positive correlations with Plant height (cm) and No. of primary branches and negative correlations with days to flowering, days to pod initiation, No. of pods /m^2, and No. of seeds per m^2 with 73.3% heritability. Overall, Approximately UKC-1 showed 3431.8 kg seed yield per hectare and UDC-10 2904.5 kg seed yield per hectare and are good candidates for future breeding programs as well as farmers of Sargodha and related climatic areas.

Keywords: chickpea; climate resilience; adaptability; correlation; heritability; yield

Introduction

Legumes are a rich source of dietary protein (Semba et al., 2021). It has several agricultural and medicinal benefits. After meat legumes are the best source of lysine protein (Qin et al., 2022). Pakistan has some major pulses however, chickpea (*Cicer arietinum* L.) is on top of all major pulses occupying 73% area (Ullah et al., 2020), others include lentil (*Lens culinaris* L.), Mash bean (*Vigna mungo*), Mung bean (*Vigna radiate* L.) . Chickpea (2n = 2x = 16) belongs to the Fabaceae family and it is a highly self-pollinated diploid crop (Kushwah et al., 2020; Diapari et al., 2014). Chickpeas are grown as multipurpose crops in the world. It is used as a nitrogen fixing crop in the field and also used as food and feed for humans and animals (Kumara Charyulu and Deb, 2014). Chickpea is a deep root crop and hence can easily grow under dry land and sandy loam soils (Pardo et al., 2000). The highest yields are achieved when the chickpea crop is grown under well-drained sandy or loam soils, which are highly susceptible to excessive water. Additionally, extremely cold weather can significantly decrease chickpea productivity (Rastgoo et al., 2023). Primarily considered a Rabi crop, it is planted between September and November and harvested from February to April. The time from sowing to maturity ranges from 95 to 110 days (Gaur et al., 2010).

The variety (Noor-2022) released in 2023 showed 3413kg per hectare. Chickpea yield is low due to the lack of hybridization done in chickpea owing to very small flowers and difficulty in emasculation and crossing. So, a researcher needs to find such varieties having high yield potential of chickpeas. Chickpea is typically cultivated in cool, rain-fed areas or dry climates within semi-arid regions (Rezapour et al., 2021). Its ideal temperature for growth is between 30°C during the day and 10°C at night (Imtiaz et al., 2011).

Chickpeas importance is increasing worldwide due to climate change as it contains high rank healthy food to feed the increasing world population. Worldwide chickpea importance is highlighted by the scientific community. About 14.56 million hectares of land and 2.3 million tonnes of production of chickpeas are observed worldwide per annum (Merga and Haji, 2019). Chickpea encompassed Kabuli and Desi types (Sahu et al., 2022). The desi type is categorized by comparatively small angular seeds with various tinting and occasionally speckled (Xiao et al., 2023). The Kabuli type chickpeas are smoother and larger in size with a light colour (Eker et al., 2022). In South Asia, a large quantity of dal (chickpea halves) and hummus are largely consumed (Merga and Haji, 2019). Research efforts at Pulses Research Institute, Faisalabad, and Barani Agricultural Research Institute, Chakwal have slowly but steadily increased the yield potential of chickpea germplasm.

In Pakistan, there are three regions in which legumes are grown, the Northern region which has high rainfall for surface irrigation, the Central region which has highly fertile soil and a climate semiarid type and the Southern region rainfall is very limited, and the whole cropping system depends on irrigation. Chickpea has a very low genetic diversity and among several factors, its yield is low in which biotic and abiotic factors take part (Gaur et al., 2012). In addition, production is decreasing day by day because of a lack of breeding work on chickpeas due to low success in crosses and a lack of awareness and the government has no plan to subsidize chickpea farmers. It is important to improve chickpea production (El-Beltagi et al., 2022). The improvement in crops depends upon the presence of genetic variability in available material, and the extent to which this variability present in quantitative characters is heritable for successful breeding programmes. Sargodha' (district of Punjab, Pakistan) temperature is a semi-arid condition (Asif et al., 2021). The study aimed to assess the yield performance of chickpea genotypes under semi-arid climatic conditions in Sargodha and find the most promising genotypes.

Material and Methods

Experimental details

Chickpea (*Cicer arietinum* L.) experiment was conducted in field conditions at the Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha, 32°08′01.3″N 72°41′11.1″ E in rabi season 2022 – 2023. The experiment was laid out in a randomized completely block design with three replications. Each block was 3 m^2 and seed-to-seed distance was maintained 10 cm and line to line 30 cm with 4 cm seed sowing depth. Surface sterilized seeds with a 2 percent hypochlorite solution of 14 chickpea genotypes (9+5,) namely UDC-02, UDC-04, UDC-06, UDC-08, UDC-10, UDC-12, UDC-14, UDC-20, UDC-30 (9 desi) UKC-03, UKC-05, UKC-1, UKC-15 and UKC-25 (5 kabuli) were used to evaluate the genetic potential of genotypes in experiment. The material was taken from the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad.

Plant height was measured using a meter tape to ensure precision. Measurements were taken by holding the tape vertically from the ground level to the tip of the tallest part of each plant. This was done for all selected plants, and the average height was calculated to represent the overall plant growth. The number of primary branches was recorded by manually counting all branches emerging directly from the main stem in plants located within one square meter. This parameter was assessed during the vegetative growth phase to evaluate structural development.

Reproductive and yield traits

The number of pods and seeds per square meter was determined through manual counting. Pods were harvested once fully developed, and their seeds were extracted and counted individually for accuracy. For yield estimation, seeds collected from 1 m^2 area were cleaned and weighed using an electronic balance to ensure precise measurement. Days to flowering and pod initiation were recorded as phenological markers. Days to flowering were counted from the sowing date until the appearance of the first flower on sampled plants, while days to pod initiation were noted from sowing to the emergence of the first pods. Observations were made daily during the reproductive stage to ensure accuracy in recording these critical developmental stages.

Statistical analysis

By using Fisher's statistical technique all parameters were analyzed and genotype means were compared at a probability level of 5% (d Steel and Torrie, 1986; Steel, 1997). Using R software correlation analysis and heritability were found.

Estimation of phenotypic and genotypic variance by ANOVA table

Estimate the variance suggested by (Johnson et al., 1983) formula. σ_p^2, σ_g^2 and σ_e^2 showed phenotypic, genotypic, and environmental variances respectively using (n-1) degree of freedom.

$\sigma_g^2 = (GMS - EMS)/r$,

$\sigma_e^2 = EMS$, and $\sigma_p^2 = \sigma_g^2 + \sigma_e^2$

Estimation of Heritability (H_B)

The ratio of genotypic to phenotypic variance is known as heritability (Fisher, 1919). Broad sense heritability was found for traits, using a formula generated by (Johnson et al., 1983).

$H_B^2 = (\sigma_g^2 / \sigma_p^2)$ *100 where σ_g^2 = Genotypic variance, σ_p^2 = Phenotypic variance, and H_B = Broad sense Heritability.

Correlation

Correlation describes the strength of a linear relationship between two variables. It is measured as correlation coefficient and denoted by *r*.

$$r = \frac{\sum(Xi-\bar{x})(Yi-\bar{y})}{\sqrt{\sum(Xi-\bar{x})2\sum(Yi-\bar{y})2}}$$

where *Xi* and *Yi* are the individual data points for variables *X* and *Y*, respectively.

$\bar{x}$ and $\bar{y}$ are the means (average) of variables X and Y, respectively.

Results and Discussions

***Plant height*:** PH is an important parameter that plays a significant role in the yield of the crops. Sometimes it causes high yield, and sometimes a cause of low yield due to crop and yield specific. In sugarcane PH shows a high yield because we need its canes for sugar production, while when we need yield related to seed it is not the task for breeders to get maximum height, the only breeder task is to increase seed yield with no matter with PH. When we need high seed yield, we should reduce plant height because plants waste nutrients to increase PH. Variation analysis (ANOVA) showed highly significant results means variation is present among all genotypes (Table 1) with a heritability of 67%. The maximum height of plants was obtained by the genotypes UKC-15 (74.1 cm) followed by UKC-25 (70.6 cm), which are statistically similar to each other. Present research revealed good yield shown by the genotypes with moderate plant height UDC-10 and UKC-1 (Table 2). (Mallu et al., 2014) showed the same results that moderate plants had higher yields. Plant height showed significant effects on the yield of pulses, pulses having significantly higher yields exhibited moderate plant heights. Moderate PH (cm) showed a low positive correlation with yield (g) (Table 3). Law et al. (1978) also reported similar findings as shown in the present research. Yücel et al. (2006) observed the same in pulses that moderate PH showed high yield and less lodging while tall plants showed higher lodging and lodging had a significant adverse impact on yield.

Days to flowering: Flowers are responsible for seed production, the greater the flowers higher the seed production. As a plant gives earlier flowering higher will be the number of pods and seeds at harvesting. DtF Showed a highly significant analysis of variance with a heritability of 96% (Table1). This indicated the presence of sufficient variation among the available genotypes, which is heritable. It is depicted from the data that genotypes UDC-10 and UKC-1 took the minimum number of days (49 – 50) to initiate flowers indicating that these genotypes are early maturing and displayed maximum yield (Table 2). The genotypes UDC-04 and UDC-12 recorded maximum days (92 – 95), to initiate flowers among all the genotypes. DtF showed a significant negative correlation with yield means that DtF is increasing as well as yield decreasing and vice versa. The same was reported by Mallikarjuna et al. (2019), and the equivalent phenomenon was observed by Cobos et al. (2007), because more days taken by the plant for flowering, gives low yield till a specific harvest time. Low temperature increases DtF as in present research UDC-10 and UKC-01 showed less number of days to flowering (Kiran and Chimmad, 2018). It is concluded that these genotypes are screened as better performers in the cold season under climatic conditions of Sargodha.

***Days to pod initiation*:** Days to first pod appear is the time taken by a plant to get pods from sowing day. It is a very important phenological parameter that is responsible for high yield. ANOVA showed a highly significant difference among genotypes (Table 1), with a very high heritability of 98%. Higher heritability showed this trait is expressed most due to the genetics of the genotypes. The Least significant difference showed good yield in UDC-10 and UKC-01, with minimum days taken to initiate pod formation in Table 2. Among all genotypes, the UDC-04 took a maximum of days (112) to start pods. DtP gave a significant negative correlation with yield (Table 3), which means when prolonged DtP lower will be yield and vice versa. Similar to DtF same phenomenon was observed by Devasirvatham et al. (2015) and Mallikarjuna et al. (2019).

No. of pods/m² (NoPs): It determines the basic factor for the number of seeds produced. An increase in NoPs may indeed increase No. of seeds, but depends upon number of seeds in pods. The greater the number of seeds per pod higher maybe yield. Variation analysis showed a significant difference among genotypes (Table 1), getting moderate heritability of 39%. LSD showed a higher mean value in UDC-10 and UKC-1 had the greater yield due to the high rate of number of pods mentioned in Table 2. NoPs showed a significant positive correlation with yield (Table 3) similarity observed by Hama (2019) and Sharifi et al. (2018). This table acts as a guide through the intricate world of statistical relationships, where the correlation coefficient tells us about the strength and direction of these relationships, ranging from –1 to +1. At one end, +1 signals a perfect positive linear relationship, a scenario where if one trait increases, the other does too, moving together in harmony. The middle point, 0, indicates a neutral ground, where traits move independently of each other, showing no linear connection. On the opposite end, –1 reveals a perfect negative linear relationship, a situation where an increase in one trait is matched by a decrease in the other, showcasing their inverse relationship. This table isn't just a set of numbers; it's a map that helps us to understand the complex interactions between variables, with each coefficient providing insight into the nature of their relationship.

No. of seed/m² (NoS): If the number of seeds increases it may or may not increase in yield weight, because it depends upon seed size and its compactness. Compact large seed will increase seed weight, but noncompact seed size may not have higher seed weight. ANOVA showed highly significant results among genotypes (Table 1) with a high heritability of 77%, so the trait is mostly influenced by genetic factors. The maximum number of seeds per meter square was recorded in genotypes UDC-10 and UKC-1 respectively, while minimum NoS was observed in UDC-20. The good yield was observed by UDC-10 and UKC-1 in desi chickpea and kabuli chickpea respectively (Table 2). The number of seeds has a significant positive correlation with yield per meter square (Table 3) higher will be the number of seeds observed yield also be expected higher. Similar results were shown by Kobraee et al. (2010) and Astereki et al. (2017).

Seed yield/m² (Yi(g)): The ultimate goal of breeding endeavors is mostly to improve seed yield and the same was the case with the present study. Seed weight is the final product of the farmers in the context of pulses production. Any farmer's demand is the weight of seeds as a final product, because they will sell in the form of weight. The present research revealed that in the Sargodha region, which genotype is the most suitable for farmers as well as for breeders specially in the present location. Trait for seed yield expressed highly significant results (Table 1) with a highly significant 73% heritability. UKC-1 (343.18) from Kabuli and UDC-10 (290.45) for desi chickpeas showed the highest value of seed yield per meter square shown in Table 2. "DtF" and "DtP" have the strong negative correlations with "Yi(g)." Similar results were observed by Devasirvatham et al. (2015) and Mallikarjuna et al. (2019). Approximately, UKC-1 showed 3431.8kg seed yield per hectare and UDC-10 2904.5kg seed yield per hectare.

No of primary branches/m²: The branching habit has fluctuated in chickpea varieties. Some varieties produce naturally more primary branches, while others may have fewer but longer branches. A particular variety can impact how it responds to variations in the number of primary branches in terms of yield depending upon its genetics. There is a highly significant difference among genotypes with 91% of very high heritability means the trait is strongly influenced by genetic factors. Highest mean values showed in UDC-10 (146.33) and followed by UDC-30 (143.33), UDC-20 (130.67), UDC-06 (129.67), UDC-02 (122.33), UKC-1 (119.33), UDC-12 (103.33), UDC-08 (94.33), UKC-15 (93), UDC-04 (88.67), UDC-14 (82.67), UKC-25 (82.67), UKC-05 (75.67) and UKC-03 (70.67) higher number of primary branches were observed in UDC-10 (Table 2). NoPB showed a very weak positive correlation with Yi(g) The higher the number of primary branches higher the number of fruits that appeared automatically higher the seed yield, similar observed by Bhanu et al. (2017). Week correlation may be due to differences in genetic qualities of the genotypes.

Conclusion

In summary, the comparative analysis of 14 chickpea genotypes across various traits highlighted UDC-10 and UKC-1 as the most promising in terms of yield-related parameters. These genotypes exhibited superior performance in key traits such as plant height, days to flowering, days to pod initiation, number of pods per square meter, and number of seeds per square meter. These attributes collective-

Table 1. Analysis of variance

Traits	Sum Sq	Mean Sq	F value	Pr(>F)	H^2
PH (cm)	613.0	47.16	7.173	1.13e-05 **	0.673134
DtF	8567	659.0	85.284	<2e-16 **	0.965747
DtP	8850	680.8	170.432	<2e-16 **	0.982578
NoPs	371099	28546	2.975	0.00869 **	0.396921
NoS	1409222	108402	11.159	1.55e-07 **	0.772025
Yi(g)	171984	13230	9.24	1.03e-06 **	0.733068
NoPB	25511	1962.4	32.538	9.39e-13 **	0.913154

PH (cm) = Plant Height (cm), DtF = Days to Flowering, DtP = Days to Pod initiation, NoPs = No. of Pods /m^2, NoS= No. of Seed /m^2, Yi(g) = Seed Yield /m^2 (g), NoPB = No of Primary Branches/m^2,
** = Highly significant
Source: Authors' own elaboration

Table 2. Means of 14 genotypes of chickpea for 7 characters with LSD

Genotypes	PH (cm)	DtF	DtP	NoPs	NoS	Yi(g)	NoPB
UDC-02	64.1^{D}	76.6^{FG}	99.33^{D}	471.33^{ABC}	581.67^{EF}	164.37^{GH}	122.33^{C}
UDC-04	58.6^{E}	95.0^{A}	112.67^{A}	447.00^{ABC}	799.67^{BCD}	167.12^{GH}	88.67^{EF}
UDC-06	59.4^{E}	72.3^{GH}	93.67^{E}	410.00^{BCD}	558.33^{FG}	231.21^{BCDEF}	129.67^{C}
UDC-08	64.4^{D}	79.6^{EF}	102.67^{CD}	450.00^{ABC}	817.33^{ABCD}	193.21^{DEFG}	94.33^{DE}
UDC-10	66.8^{BCD}	49.3^{K}	60.33^{J}	585.67^{A}	972.33^{A}	290.45^{AB}	146.33^{A}
UDC-12	66.7^{BCD}	92.3^{AB}	106.33^{B}	407.33^{BCD}	654.67^{DEF}	113.78^{HI}	103.33^{D}
UDC-14	69.1^{BC}	85.6^{CD}	107.67^{B}	469.00^{ABC}	746.33^{CDE}	217.21^{CDEFG}	82.67^{EFG}
UDC-20	66.4^{BCD}	81.6^{DE}	104.33^{BC}	238.00^{E}	371.67^{H}	170.89^{FGH}	130.67^{BC}
UDC-30	66.3^{BCD}	89.6^{BC}	105.67^{BC}	449.33^{ABC}	882.00^{ABC}	180.00^{EFG}	143.33^{AB}
UKC-03	66.5^{BCD}	58.6^{J}	82.00^{H}	312.00^{CDE}	503.67^{FGH}	100.30^{I}	70.67^{G}
UKC-05	66.5^{BCD}	70.0^{H}	90.33^{EF}	470.00^{ABC}	534.33^{FGH}	235.27^{BCDE}	75.67^{FG}
UKC-1	64.4^{D}	50.6^{K}	71.00^{I}	552.67^{AB}	925.00^{AB}	343.18^{A}	119.33^{C}
UKC-15	74.1^{A}	65.0^{I}	87.67^{FG}	403.67^{BCD}	607.33^{EF}	258.38^{BC}	93.00^{DE}
UKC-25	70.6^{AB}	63.3^{I}	86.33^{G}	266.67^{DE}	416.00^{GH}	251.85^{BCD}	82.67^{EFG}

PH (cm) = Plant Height (cm), DtF = Days to Flowering, DtP = Days to Pod initiation, NoPs = No. of Pods /m^2, NoS = No. of Seed /m^2, Yi(g)= Seed Yield /m^2 (g), NoPB = No of Primary Branches/ m^2
Source: Authors' own elaboration

Table 3. Correlation

	PH (cm)	DtF	DtP	NoPs	NoS	Yi(g)	NoPB
PH (cm)	1						
DtF	-0.57325	1					
DtP	-0.58651	0.966444	1				
NoPs	-0.00861	-0.03704	-0.16383	1			
NoS	0.018675	0.118862	-0.03081	0.846519	1		
Yi(g)	0.46798	-0.62529	-0.6323	0.356742	0.230818	1	
NoPB	0.055886	-0.05142	-0.17478	0.208301	0.261642	0.236504	1

PH (cm) = Plant Height (cm), DtF = Days to Flowering, DtP = Days to Pod initiation, NoPs = No. of Pods /m^2, NoS = No. of Seed /m^2, Yi(g) = Seed Yield /m^2 (g), NoPB= No of Primary Branches/ m^2
Source: Authors' own elaboration

ly contribute to enhanced seed yield, positioning UDC-10 and UKC-1, as the most favorable genotypes for chickpea cultivation under the semi-arid agro-climatic conditions of Sargodha. The correlation analysis between yield and other traits showed a consistent relationship with findings from previous research, suggesting that improvements in these traits are likely to result in higher yields. Furthermore, heritability analysis revealed that most of the traits observed are predominantly influenced by genetic factors, indicating the potential for these traits to be passed on to future generations through selective breeding. However, while these genotypes have shown strong performance under the agro-climatic conditions studied, it is important to consider that the performance of these genotypes might vary when exposed to different environmental or regional conditions. Therefore, broader testing across diverse agro-ecological zones is recommended to validate the consistency of their performance. In conclusion, UDC-10 and UKC-1 offer great potential for improving chickpea production, but further studies should assess their adaptability and stability across different growing environments.

References

Asif, M., Rahman, H., Aziz, A., Adnan, M., Ali, A. & Safdar, M. E. (2021). Seed Priming improves Growth, yield and seed oil contents of Soybean (Glycine max L.) cultivars under semi-arid conditions of sargodha, pakistan. *Plant Cell. Biotechnol Mol. Biol.*, *22*(5&6), 27 – 37.

Astereki, H., Sharifi, P. & Pouresmael, M. (2017). Correlation and path analysis for grain yield and yield components in chickpea (*Cicer arietinum* L.). *Genetika*, *49*(1), 273 – 284.

Bhanu, A. N., Singh, M., Tharu, R. & Saroj, S. (2017). Genetic variability, correlation and path coefficient analysis for quantitative traits in chickpea genotypes. *Indian Journal of Agricultural Research*, *51*(5), 425 – 430.

Cobos, M., Rubio, J., Fernández-Romero, M., Garza, R., Moreno, M., Millán, T. & Gil, J. (2007). Genetic analysis of seed size, yield and days to flowering in a chickpea recombinant inbred line population derived from a Kabuli× Desi cross. *Annals of Applied Biology*, *151*(1), 33 – 42.

d Steel, R. G. & Torrie, J. H. (1986). *Principles and procedures of statistics: a biometrical approach*. McGraw-Hill New York, NY, USA.

Devasirvatham, V., Gaur, P., Raju, T., Trethowan, R. & Tan, D. (2015). Field response of chickpea (*Cicer arietinum* L.) to high temperature. *Field Crops Research*, *172*, 59 – 71.

Diapari, M., Sindhu, A., Bett, K., Deokar, A., Warkentin, T. D. & Tar'an, B. (2014). Genetic diversity and association mapping of iron and zinc concentrations in chickpea (*Cicer arietinum* L.). *Genome*, *57*(8), 459 – 468.

Eker, T., Sari, D., Sari, H., Tosun, H. S. & Toker, C. (2022). A kabuli chickpea ideotype. *Scientific reports*, *12*(1), 1611.

El-Beltagi, H. S., Shah, S., Ullah, S., Sulaiman, Mansour, A. T. & Shalaby, T. A. (2022). Impacts of ascorbic acid and alpha-tocopherol on Chickpea (*Cicer arietinum* L.) grown in water deficit regimes for sustainable production. *Sustainability*, *14*(14), 8861.

Fisher, R. A. (1919). XV. – The correlation between relatives on the supposition of Mendelian inheritance. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, *52*(2), 399 – 433.

Gaur, P. M., Jukanti, A. K. & Varshney, R. K. (2012). Impact of genomic technologies on chickpea breeding strategies. *Agronomy*, *2*(3), 199 – 221.

Gaur, P. M., Tripathi, S., Gowda, C. L., Ranga Rao, G., Sharma, H., Pande, S. & Sharma, M. (2010). Chickpea seed production manual.

Hama, S. J. (2019). Correlation and path coefficient analysis for seed yield and yield components in chickpea under rainfed condition. *Journal of Kerbala for Agricultural Sciences*, *6*(1), 26 – 35.

Imtiaz, M., Malhotra, R. S. & Yadav, S. S. (2011). Genetic adjustment to changing climates: Chickpea. *Crop adaptation to climate change*, 251 – 268.

Johnson, D. A., Richards, R. A. & Turner, N. C. (1983). Yield, Water Relations, Gas Exchange, and Surface Reflectances of Near-Isogenic Wheat Lines Differing in Glaucousness 1. *Crop Science*, *23*(2), 318 – 325.

Kiran, B. & Chimmad, V. (2018). Studies on morpho-phenological traits and heat unit accumulation in chickpea genotypes under different temperature regimes. *Journal of Pharmacognosy and Phytochemistry*, *7*(3), 2956 – 2961.

Kobraee, S., Shamsi, K. & Rasekhi, B. (2010). Investigation of correlation analysis and relationships between grain yield and other quantitative traits in chickpea (Cicer arietinum L.). *African Journal of Biotechnology*, *9*(16), 2342 – 2348.

Kumara Charyulu, D. & Deb, U. (2014). Proceedings of the" 8th International Conference viability of small farmers in Asia".

Kushwah, A., Bindra, S., Singh, I., Dixit, G., Sharma, P., Srinivasan, S., Gaur, P. & Singh, S. (2020). Advances in chickpea breeding and genomics for varietal development and trait improvement in India. *Accelerated Plant Breeding, Volume 3: Food Legumes*, 31 – 66. Cham: Springer International Publishing.

Law, C., Snape, J. & Worland, A. (1978). The genetical relationship between height and yield in wheat. *Heredity*, *40*(1), 133 – 151.

Mallikarjuna, B. P., Viswanatha, K. P., Samineni, S. & Gaur, P. M. (2019). Association of flowering time with phenological and productivity traits in chickpea. *Euphytica*, *215*, 1 – 8.

Mallu, T. S., Mwangi, S. G., Nyende, A. B., Rao, N. R. G., Odeny, D. A., Rathore, A. & Kumar, A. (2014). Assessment of genetic variation and heritability of agronomic traits in chickpea (*Cicer arietinum* L). *International Journal of Agronomy and Agricultural Research*, *5*(4), 76 – 88.

Merga, B. & Haji, J. (2019). Economic importance of chickpea: Production, value, and world trade. *Cogent Food & Agriculture*, *5*(1), 1615718.

Pardo, A., Amato, M. & Chiarandà, F. Q. (2000). Relationships between soil structure, root distribution and water uptake of chickpea (*Cicer arietinum* L.). Plant growth and water distribution. *European Journal of Agronomy*, *13*(1), 39 – 45.

Qin, P., Wang, T. & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*, *7*, 100265.

Rastgoo, M., Nezami, A., Hasanfard, A., Nabati, J. & Ahmadi-Lahijani, M. J. (2023). Freezing stress induces changes in the morphophysiological of chickpea and wild mustard seedlings. *Legume Science*, *5*(2), e173.

Rezapour, S., Jooyandeh, E., Ramezanzade, M., Mostafaeipour, A., Jahangiri, M., Issakhov, A. Chowdhury, S., & Techato, K. (2021). Forecasting rainfed agricultural production in arid and semi-arid lands using learning machine methods: A case study. *Sustainability*, *13*(9), 4607.

Sahu, V. K., Tiwari, S., Gupta, N., Tripathi, M. & Yasin, M. (2022). Evaluation of physiological and biochemical contents in desi and Kabuli chickpea. *Legume Research-An International Journal*, *45*(10), 1197 – 1208.

Semba, R. D., Ramsing, R., Rahman, N., Kraemer, K. & Bloem, M. W. (2021). Legumes as a sustainable source of protein in human diets. *Global Food Security*, *28*, 100520.

Sharifi, P., Astereki, H. & Pouresmael, M. (2018). Evaluation of variations in chickpea (*Cicer arietinum* L.) yield and yield components by multivariate technique. *Annals of Agrarian Science*, *16*(2), 136 – 142.

Steel, R. (1997). Analysis of variance I: The one-way classification. *Principles and procedures of statistics a biometrical approach*, 139 – 203.

Ullah, A., Shah, T. M. & Farooq, M. (2020). Pulses production in Pakistan: status, constraints and opportunities. *International Journal of Plant Production*, *14*(4), 549 – 569.

Xiao, S., Li, Z., Zhou, K. & Fu, Y. (2023). Chemical composition of kabuli and desi chickpea (*Cicer arietinum* L.) cultivars grown in Xinjiang, China. *Food Science & Nutrition*, *11*(1), 236 – 248.

Yücel, D. Ö., Anlarsal, A. E. & Yücel, C. (2006). Genetic variability, correlation and path analysis of yield, and yield components in chickpea (*Cicer arietinum* L.). *Turkish Journal of Agriculture and Forestry*, *30*(3), 183 – 188.

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