GENOTYPIC PERFORMANCE OF KABULI CHICKPEA FOR PRODUCTION TRAITS

*Zarafshan Aftab[1], *Rozina Gul[1], *Hamid Ullah Khan[2], *Muhammad Anas[2], Maheen Bukhari[2], Zainab, Aleena Arshad, Samra Aftab, Bakhtawar Asif Hussain, Ayesha Jehan. Zunaira Khan, Ushna Riaz.

Department of Plant Breeding and Genetics. Faculty of Crop Production Sciences, The University of Agriculture, Peshawar-Pakistan.

Corresponding authors: Zarafshan Aftab, Rozina Gul, Hamid Ullah Khan, Muhammad Anas

ABSTRACT

In this present study various genotypes of chickpea were evaluated for various production traits at Peshawar, in The University of Agriculture during 2021-22 cropping season. The research was performed on 36 advanced lines in randomized complete block design. Data was recorded on twelve morphological traits. Significant differences were observed for the majority of the parameters except for days taken by genotypes to emerge, days to flowering and harvest index. Maximum days to emergence were recorded for genotype BG4 (9 days), followed by ICC-19181, NDC-122, and NDC-4-20-4 (8 days).Maximum days to flowering were recorded by genotype MG5 (113 days) fallowed by SL-08-14 and AG1 (112 days). Genotype NDC-15-01 took more days to maturity (187 days) fallowed by NDC-15-4-0, BG4 and NDC-4-20-6 (186 days). While highest numbers primary branches per plant which were (3) observed for genotypes KG1, IG1, NDC-4-20-5, KARAK-3 and SL-3-29. Genotype NDC-4-20-5 and IG1 showed maximum secondary branches per plant (16), followed by AG1 (15), while genotype KARAK-3 had greater plant height (93cm). Maximum number of pods in each plant (50) were produced by genotype KG1, followed by NDC-15-01 (47). Genotype NDC-4-20-40 had the highest weight of hundred seeds (21.0 g), followed by CG1 and IG1 (20g). Genotype SL-3-29 had the highest grain yield. (533 kg per hac), followed by KG1 (525 kg per hac). Moderate heritability was observed for plant height (0.592), primary branches in each plant (0.453), and seeds per pod (0.4077).Low Genetic advance values were observed for plant height (8.584), Biological yield (10.28), and seed yield (8.267). Low Genetic advance values were observed for plant height (8.584), Biological yield (10.28), and seed yield (8.267). The genotypic and phenotypic relationship between seed yield and primary branches (r_g = 0.65**, r_p = 0.49**), secondary branches (r_g = 0.58**, r_p = 0.64**), number of pods (r_g = 0.86**, r_p = 0.89**), grains per pod (r_g = 0 .47**, r_p = 0.58**), plant height (r_g=0.68**, r_p = 0.31*), biological yield (r_g = 0.94**, r_p = 0.94**) and weight of hundred grains (r_g=0.66**, r_p = 0.90**) were significant and positive. So, the number of pods in each plant, seeds per pod, weight of hundred seeds, biological yield and harvest index could be used as selection criteria to improve chickpea production. Based on superior performance for yield-related attributes, genotypes CG1, IG1, NDC-4-20-5 and KARAK3 are recommended for further evaluation.

Index Terms: chickpea, pod borer, correlation, heritability, genetic advance, genotypic performance.

INTRODUCTION

Chickpea (*Cicer Arietinum*) is one of the largely planted grain legume in the world after peas and dry beans (Al-Saady et al., 2019). The region between Turkey and Syria is considered to be the center of origin of chickpea because of the presence of its close relatives in the area. According to the five-kingdom classification chickpea belongs to the family ' Leguminaceae' the genus 'Cicer,' and the species 'arietinum (Maesen, 1987). Chickpea is a self-pollinated crop due to its cleistogamous flower (Sajja et al., 2017). It has 16 chromosomes and is a diploid pulse (Coyne et al., 2020). With the recent inclusion of C. *turcicum* genus Cicer currently consist of 46 species, including 10 annuals and 36 perennials (Toker et al., 2021).

There are two morphs of chickpea, i.e., Desi and Kabuli, which differ in seed size and color. The Desi type seeds are small (about 0.2 g per seed), with a thick seed coat in a variety of colors including cream, yellow, brown, black, and green. Pigmentation due to presence of anthocyanin can be seen in the stem and leaves of desi chickpea. While Kabuli seeds are often larger than Desi seeds, the seed coat is thin and mostly cream or beige in color, with a few white seeds. The flower of the chickpea is Papilionaceous in nature, but the two forms differ in appearance. The Kabuli flower is white due to the absence of anthocyanin, while the desi flower is pink or bluish-purple due to the presence of anthocyanin (Sajja et al., 2017). Chickpeas, on the other hand, can endure drought because of their deep root structure. Drought is the most important and significant non-biological factor in the key producing areas of chickpea, because water accumulate as crop expand and suddenly causing crop to suffer from drought.

Chickpea is a widely grown crop around the world, with a total area of cultivation of 14.9 million hectares, which produced about 15.1 MT with an average yield of 1015 kg per hectare according to FAOSTAT (2020). It is a main rabi pulse crop mainly grown in rain-fed areas. In the 2019-20 season, it was cultivated on 0.943 million hectares in Pakistan, resulting in a production of 0.440 million tons and an average yield of 467 kg ha^{-1} as reported by PBS. In Khyber Pakhtunkhwa, it covered approximately 0.29 million hectares which produced about 0.134 million tons and an average yield of 462 kg ha^{-1} (CSKP, 2019-20).

Chickpeas are widely recognized as most important food legumes worldwide, ranking third in terms of production and consumption. It is grown in temperate and semi-arid areas. Pakistan is a protein-deficient country, and pulses meet the majority of the country's protein needs. Chickpeas are a high-nutritional-value and low-cost source of protein, with 23% protein, 64% total carbohydrate, 5% fat, 6% crude fiber, and 3% ash. As the population grows, so does the demand for protein, which necessitates increased production of pulses because protein is rare and expensive, and hence beyond the purchasing power of the poor (Sattar et al., 1990). Adding chickpeas to food can boost its nutritional value while decreasing its acrylamide levels. Acrylamide is an anti-nutrient that can be found in bread, sandwiches, and potato chips. Chickpea flour and protein could be a novel strategy to minimize acrylamide levels in such goods. (Rachwa-Rosiak et al., 2015). It is an important crop that feeds many of the poor in Africa and Asia, where it acts as an inexpensive alternative to animal protein (Jukanti et al., 2012).

Yield is a complicated trait that can be influenced by numerous environmental factors. Understanding the correlation between traits and yield is essential for selecting successful varieties based on morpho-agronomic traits. The relationship between variables has helped in identifying the most efficient selection procedures for superior genotypes. When there is a positive correlation between major yield components, breeding strategies can be highly effective, but if the correlation is negative, selection becomes more challenging (Agarwal et al., 2018).

Heritability is the percentage of phenotypic variation in a population that can be attributed to genetic diversity between individuals. Phenotypic variation in individuals can be endorsed to factors. Heritability analyzes the extent of genetic and non-genetic variables contributed to overall phenotypic variance in a population. Heritability is affected by both environmental and genetic factors, and its magnitude can vary between populations and environments. The impact of the environment on a trait can be dependent on the specific genes involved in its expression. In other words, the interaction between genes and environment can affect the heritability of a trait. However, it is important to note that heritability estimates are always specific to the population and environment in which they are measured (Acquah, 2007; Hailu, 2020).

MATERIALS AND METHODS

This study was conducted during the Rabi growing season of 2021-22 at the research farm of the Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar. The objective of the study was to evaluate the performance of 36 chickpea genotypes during rabi crop growing season. The data was collected on Days to 50% emergence, Days to 50% flowering, Days to 90% maturity, Primary branchesplant^{-1} , Secondary branches plant^{-1} , Plant height (cm), Pods plant^{-1} , Seeds pod^{-1}, 100-seed weight (g), Seeds* yields (kg ha^{-1}), Harvest index (%). The experiment was conducted using RCB design with 3-replications (Table 1). Each experimental plot comprised of 3 rows plot of 3m length with 30cm distance between rows and 10 cm between plants. Data at various crop stages were recorded on the fallowing morphological parameters using ten plants from each entry. Recommended agronomic practices were performed from sowing till maturity for all genotypes uniformly.

Table 1. List of 36 chickpea genotypes that were evaluated in experiment

Genotypes	Parentage	Source	Genotypes	Parentage	Source	Genotype	Parentage	Source
AG1	ICC 19181 X NDC-4-20-4	PBG,UAP	IG3	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-3	C44/M	NIFA
BG2	ICC 19181 X NDC-4-20-4	PBG,UAP	KG1	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-4	C44/M	NIFA
BG4	ICC 19181 X NDC-4-20-4	PBG,UAP	MG1	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-5	C44/M	NIFA
BG5	ICC 19181 X NDC-4-20-4	PBG,UAP	MG2	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-6	C44/M	NIFA
CG1	ICC 19181 X NDC-4-20-4	PBG,UAP	MG3	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-40	C44/M	NIFA
DG3	ICC 19181 X NDC-4-20-4	PBG,UAP	MG5	ICC 19181 X NDC-4-20-4	PBG,UAP	SL-08-14	Local	ARI, Karak
DG4	ICC 19181 X NDC-4-20-4	PBG,UAP	MG6	ICC 19181 X NDC-4-20-4	PBG,UAP	SL-03-15	Local	ARI, Karak
EG1	ICC 19181 X NDC-4-20-4	PBG,UAP	ICC-19181	Local Selection	ICRISAT/India	SL-3-29	Local	ARI, Karak
FG1	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-122	C44 X ILC-19	NIFA	KARAK-1	Local	ARI, Karak
GG1	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-15-01	Pb-91/M	NIFA	KARAK-2	Local	ARI, Karak
IG1	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-15-4-0	Pb-91/M	NIFA	KARAK-3	Local	ARI, Karak
IG2	ICC 19181 X NDC-4-20-4	PBG,UAP	NDC-4-20-2	C44/M	NIFA	NIFA-2005	PB91/M	ARI, Karak

PBG, AUP= Department of Plant Breeding and Genetics; NIFA= Nuclear Institute for Food and Agriculture
ARI= Agriculture Research Institute. Ahmad Wala karak.

Statistical analysis

Collected data was subjected to analysis of variances (ANOVA) techniques as proposed by steel and Torrie (1980). Moreover, LSD test was conducted for such traits which had significant differences among genotypes.

Table 2. ANOVA for studied parameters at University of Agriculture Peshawar during 2021-22.

Source of variation	Df	SS	Mean Square	Computed F
Replication	r-1	RSS	RMS	RMS/EMS
Genotypes	g-1	GSS	GMS	GMS/EMS
Error	(r-1) (g-1)	ESS	EMS	-
Total	gr-1	TSS	-	

Heritability (Broad sense)

Broad-sense heritability will be estimated by the following formula.

$$h^2 = \frac{Vg}{Vp}$$

$$h^2BS= \frac{vg}{vg+ve}$$

Where,

$h^2{}_{BS}$= broad sense heritability for a trait

Vg = genetic variance

Ve = environmental variance

Vp = phenotypic variance

The magnitude of heritability will be characterized as low, moderate and high as shown below.

0-30%: Low

30-60%: Moderate

>60%: High

Genetic Gain

Genetic gain was determined by using formulasuggested byPanse and Sukhatme (1967),

$$GA = i\times \sqrt{(Vp)} \times h^2$$

Where,

GA: Expected genetic advance

"i": percentage of selection intensity

(The value of "i" was taken as 1.76 assuming 10% selection intensity)

V_p: Phenotypic variance

h^2: Broad sense heritability

Correlation

The association among different traits of chickpea will be find out by using the formula given by Kwon and Torrie (1964).

$$rxy = \frac{CO_{xy}}{\sqrt{Var\ x.\ Var\ y}}$$

Where,

rxy= correlation of x and y

COxy= covariance of trait x and y

var x=variance of x

vary=variance of y

RESULTS AND DISCUSSION

Days to 50% emergence

Statistical study of data for number of days taken by 50% emergence of chickpea genotypes showed non-significant (Table 3). The coefficient of variation of this trait was 8.02%. The genotype means emergence of seedlings varied from 7 to 9 days. Minimum days to emergence (7 days) were recorded for genotypes CG1, IG1, KG1, and NDC-4-20-5 while maximum days (9 days) were taken by genotype BG4, followed by 1CC-19181, MG6, and NDC-4-20-4 (Table 4). Vishwavidyalaya *et al*. (2022) who also worked on chickpea genotypes and recorded non-significant differences among the studied genotypes.

The genetic and environmental variances for days taken by 50% emergence were 0.9246 and 1.207, respectively. A low heritability of 0.084 was recorded for the trait under study. Whereas low Genetic advance values for days to emergence was (0.1045) (Table 8). Many researchers reported moderate heritability 0.37 for days to 50% emergence while studying chickpea genotypes which are contrary to our findings (Banik *et al*. 2018; Manoj *et al*. 2018 and Pezeshkpour and Roohi 2019).

The results of the study indicated that days to emergence is an essential parameter that influences various plant traits. Our findings showed a highly significant a phenotypic and genetic relationship between days of emergence and plant height (r_g=0.80**, r_p=-0.99**), signifying that early emergence leads to increased plant height. However, we had also observed a significant negative genotypic correlation between days to emergence and primary branch plant^{-1} (r_g=-0.53**, r_p=-0.99**), the number of secondary branches on each plant (r_g=-0.69**, r_p=-0.97**), no of pods in each plant (r_g=-0.50**, r_p=-0.53**), and harvest index (r_g=-0.57**, r_p=-0.51**), suggesting that early emergence is associated with reduced branching and lower yields. These findings are consistent with previous experiments that have found similar correlations between days to emergence and plant traits (Huang et al., 2018; Li et al., 2019).

Days to 50% flowering

Early maturity and yield are the main traits in chickpeas that determine the selection of variety by the farmer. An early flowering character shortened harvest times and allowed them to avoid most climatic hazards such as storms, floods and diseases. ANOVA revealed non-significant variances between chickpea genotypes for above parameter (Table 3). The coefficient of variation was 0.75%. The means values for genotypes varied from 109 to 113. Minimum (109) days to 50% flowering were recorded for genotype KG1 followed by CG1 and IG1 (110 each), while genotype SL-08-14 showed highest days of 112 to 50% flowering followed by AG1 and NIFA-2005 (112 each) (table 4). Their result is contrary to our findings which is due to environmental differences or different genotypes they used.

The environmental and genotypic variationfor days taken by 50% flowering were 0.04 and 0.689, respectively. Days to 50% flowering had moderate heritability of 0.054. The calculated selection response for this trait was low (0.082) (Table 8). Nearly moderate heritability estimate indicates that there is chances of getting similar results upon selection, as environmental variance contributed a less proportion to the phenotype which shows that total variability was due to genetic influences, and selection will be effective. Xalxo *et al*. (2021) reported moderate heritability 0.48 for days to flowering while studying different chickpea genotypes.

The study revealed a positive and significant phenotypic and genetic association between days to 50% flowering and maturity (r_g=0.34*, r_p=0.32*). This finding suggests that genotypes with a more time to 50% flowering will also have a longer time to maturity. However, we also found a significant negative genotypic correlation between days to 50% flowering and number of seed on each pod (r_g=-0.36**, r_p=0.09). This result suggests that genotypes with a more time to 50% flowering have fewer seeds per pod. These findings are consistent with previous studies that have reported similar correlations between days to flowering and other plant traits (Abbate *et al*., 2004; Zhang *et al*., 2015).

Days to maturity

The earliness and lateness of a crop can be determined by time it takes to get mature. Statistical analysis for days taken by chickpea genotypes to get mature showed highly significant differences (Table 3). The coefficient of variation was 1.80%. The means of genotypes for days to maturity varied between 175 and 187 days. Early maturity was recorded for genotypes CG1 and NDC-4-20-5 which is 175 and 177 days respectively, while maximum days to maturity were observed for genotypes NDC-15-01, NDC-15-4-0, BG4 and NDC-4-20-6 each with 186 days (Table 4). De Santis *et al*. (2022) also observed significant association while studying chickpea genotypes, their results are supporting to our findings.

Genotypic and environmental variances for time taken by crop to get mature were 3.496 and 10.75. A low heritability of 0.245 was recorded for the days to maturity coupled with low genetics advanced (1.630) calculated for this trait (Table 8). Hussain *et al*. (2022) worked on twentygenotypes of chickpea and also found low heritability 0.23 for days to maturity.

The study reported that there was a negative and significant genetic and phenotypic relationship between the grain yield, harvest index, and no of pods in each plant with maturity. The correlation coefficient values for genetic relationship (rg) and phenotypic relationship (rp) between grain yield and 90% maturity were -0.31** and -0.43** respectively, while for harvest index, the values were -0.46** and -0.45** respectively. For pods per plants, the values were -0.39** and -0.27 respectively. This implies that as days to 90% maturity increases, the seed yield and pods per plant decreases.These results are in line with the results reported by Paul et al. (2022), where they also observed a negative and significant relationship between maturity and grain yield (r = -0.73**) and harvest index (r = - 0.31*) in grams. These results suggest that early maturing cultivars may be preferred over late maturing ones in order to achieve higher seed yield and harvest index.

Primary branches Plant^{-1}

Primary branches are vitalyields related trait. Highly significant variances within the chickpea genotypes were observed (Table 3). The coefficient of variation was 18.11% for the primary branches. The means of the chickpea genotypes varied from 1 to 3. Genotype AG1 recorded minimum primary branches (1), followed by BG4, BG5, and KARAK-1 (1 each), while the highest number of primary branches was observed for genotypes KG1, IG1, NDC-4-20-5, KARAK-3 and SL-3-29 (3 branches per plant) (Table 5). Similar to our results for primary branches Ashfaq *et al*. (2017) also observed highly significant diversity betweenchickpea genotypes during rabi growing season. Likewise, Mohibullah *et al*. (2020) also found significant variation within chickpea genotypes for primary branches.

Environmental and genetic variations for the number of primary branches were 0.337 and 0.406. The said trait had a moderate heritability of 0.453. (Table 8). For primary branches low genetic advance values were calculated (0.688). The traits of moderate to heritability showed that it is unaffected by environmental fluctuations. thus, selection will likely result in improvement as there is greater effect ofgenotype. Sachdeva *et al.* (2022) also worked on 20 chickpea genotypes and three species, and they found high heritability 0.77 for their studied traits.

The study revealed that number of primary branches had positive and significant phenotypic and genotypic relationship with secondary branches, number of pods, weight of hundred seeds, plant height, seed yield, and harvest index. The correlation coefficient values for the genetic relationship (rg) and phenotypic relationship (rp) between primary and secondary branches were 0.78** and 0.99** respectively. For number of pods, the values were 0.61** and 0.74**, while for 100 seed weight, the values were 0.35* and 0.33* respectively. For plant height, the values were 0.72** and 0.71** respectively, for seed yield, the values were 0.65** and 0.49** respectively, and for harvest index, the values were 0.66** and 0.54** respectively.

Secondary branches Plant^{-1}

Secondary branches are important trait contributing to grain yield indirecty. They are fruit bearing branches in chickpeas and pods develop directly on secondary branches. Various studies have found that side branches are favourably associated with yield and yield-related attributes. Statistical analysis of the secondary branches showed significant differences between the chickpea genotypes (Table 3). Secondary branches had coefficient of variation of 13.47%. The mean genotypes ranged from 10 to 16. Genotype CG1, IG1 and NDC-4-20-5 had the maximum secondary branches per plant (16), followed by genotypes AG1 (15), and NDC-4-20-3 (15). and NIFA-2005 (14), while genotype BG2 had the fewer pods per plant (10), followed by genotypes ICC-191811 (11), KARAK-3 (12), NDC-4-20-4, and NDC-15-4-0 (12) (Table 5.) Shimray *et al*. (2022) also reported highly significant differences among chickpeas.

The genetic and environmental variations for secondary branches were 1.20 and 3.1743. Secondary branches were low heritable 0.274 coupled with low genetics advance 1.009 (table 8). Low heritability estimates for a trait indicates the greater influence of environment. The results of this study are in contrary with those of Shengu *et al*. (2018) who studied 30 chickpea genotypes and estimated high heritability for secondary branches.

The study found that there is a significant positive relationship between secondary branches and various yield-related parameters such as harvest index, height of plant, seed yield and weight of hundred grains. The genetic relationship (rg) and phenotypic relationship (rp) values for secondary branches and seeds per pod were 0.41** and 0.50** respectively. The values for pods per plant were 0.62** and 0.83** respectively, for plant height were 0.54** and 0.52**, for weight of hundred grain values were 0.48** and 0.50**, biological yield were 0.71** and 0.52* for seed yield values were 0.58** and 0.64** respectively, and for harvestindex,was 0.64** and 0.68**.

Plant height (cm)

Plant height is important parameter which gives support to plant. We like plants that are lower than the ground to avoid lodging. However, there should be a limit to plant height. Desai *et al*., (2016). A statistical analysis showed significant variations in plant height between chickpea genotypes (Table No 3). The coefficient of variance for plant height was 7.38%. The average height of a plant is between 61 and 93 cm. The maximum plant height (93 cm) was found for genotype KARAK-3 followed by NDC-4-20-5 (86 cm), and the minimum plant height (61 cm) was found for genotype NDC-122 followed by DG4 (63 cm) (table.5). Hussain *et al*. (2022) also worked on chickpea genotypes and found significant differences in plant height.

Heredity refers to the ability of characters to be passed from one generation to the next. The genetic and phenotypic variations in plant height were 40.139 and 67.72, respectively. Plant height had a moderate heritability of 0.592 (Table No.8). Plant height showed low selection response values 8.584. Estimates of heritability for the said trait have been moderate, and selection will be beneficial to improve this trait for succeeding generation. Bouri *et al*. (2019) worked on 23 chickpea genotypes and found that plant height had a moderate heritability 0.43.

Plant height was observed to be strongly related with seed yield (rg =0.68**), emergence (rg =0.80**), primary branches (rg =0.72**), secondary branches (rg = 0.54**), number of pods (rg = 0.43**) and harvest index (rg= 0.38**). (Table 9). Upadhyay *et al*. (2022) also showed strong and positive relationship between plant height and seed yield while studying chickpea genotypes.

Pods plant^{-1}

Number of Pods issignificant yield-related trait of chickpea crops that directly impacts grain production. ANOVA showed extremely significant differences in pods per plant between the chickpea genotypes (Table 3). The coefficient of variance for pods per plant was 18.74%. The genotype means for pods per plant varied from 24 to 50. Genotype NDC-4-20-5, and KG1 produced the most plants (50). Genotype NDC-4-20-40 had the fewest (24) pods plant^{-1} (Table 6). Consistent with our results Hussain *et al*. (2022) discovered significant variance between chickpea genotypes for pod per plant.

For pods per plant, the environmental and genetic variances were 17.81 and 44.76. Pods plant-1was found to have a low heritability of 0.284 (Table 8). For Pods per plant genetic advance values were low 3.964. Previously, Nawaz *et al.* (2018) and Kumar *et al.* (2018) also reported low heritability 0.26 for pods per plant in chickpea (2020).

According to the study, there is significant and positive association between number of pods and several other traits in chickpeas. The genetic relationship (rg) between pods per plant and seed pod per plant was 0.57**, while the phenotypic relationship (rp) was 0.55**. The values for plant height were rg=0.43** and rp=0.89**, for weight of hundred grains, the values were rg=0.57** and rp=0.61**, for biological yield, the values were rg=0.75** and rp=0.80**, for grain yield, the values were rg=0.86** and rp=0.89** and for harvest index, the values were rg=0.70** and rp=0.80**. These findings suggest that pods per plant is positively associated with yield-related traits in chickpeas, including seed pod-1, plant height, biological yield, weight of hundred grains and harvest index. This information may be useful for developing breeding method for improvement of yield and productivity in chickpeas. (Sulaiman *et al*., 2021)

Seeds pod^{-1}

A higher quantity of seeds per pod corresponds to a higher kernels in each plant, making it a significant yield attribute. Analysis of variance for seeds per pod revealed that the variances for chickpea genotypes were not significant (Table 3). The coefficient of variance for the above trait was 30.27%. The mean values for seeds per pod ranged from 1.0 to 2.0 across the chickpeas. Genotypes BG2, BG4, CG1, KG1, NDC-4-20-5, NDC-4-20-2, and KARAK-3 had the highest seeds per pod (each with a 2.0), while AG1, CG1, IG3, NDC-122, NDC-15-4-0 and NDC-4-20-40 had the lowest seeds per (each with a 1.0) (Table 6). These findings are comparable to those of Hussain *et al*. (2022) who also found non-significant differences in number of seeds among chickpea genotypes.

The genetic variance (0.113) was greater than the environmental variance (0.165). This trait had a moderate heritability of 0.407 (Table 8). Seeds per pod showed moderate heritability coupled with low genetic advance (0.378) Moderate heritability indicates more influence of the genotype on the number of seeds per pod and that selection for genetic improvement will bemore effective. Sohai *et al*. (2018) also reported moderate heritability 0.49 for number of seeds in each pod among chickpeas.

The genotypic and phenotypic ratio of seeds per pod of 100-grain weight (rg = 0.41*, rp = 0.34), plant height (rg = 0.30*, rp = 0.36*), seed yield (rg = 0.47, rp = 0.58), biomass yield (rg = 0.32, rp = 0.44*) and Harvest Index (rg = 0.51, rp = 0.66) proved positive and significant (Table 9). (Thapa *et al.*, 2022) discovered a positive and substantial relationship between seeds per pod and yield index (r=0.51*) in chickpeas

100-seed weight (g)

Seed weight, in combination with other yield related traits, plays an important role in increasing final seed yield. Statistical studies revealed significant differences in weight of hundred seeds between chickpea genotypes (Table 3). The coefficient of variance for the weight of 100 grains was 2.91%. The mean values for weight of hundred seeds ranged between 18.5 and 21 g. Genotypes NDC-4-20-5 and KARAK-3 had the highest 100-grain weight (21), followed by CG1 and IG1 (20). Genotype AG1 had the lowest 100 seed weight (18.5), followed by BG4, BG5 and MG2 (19 g each) (Table 6). These results are in uniformity to the results of Zeeshan *et al*. (2013) who reported non-significant differences in 100 seed weights within chickpea genotype. Similarly, Hussain *et al*. (2022) also found significant differences in 100-grain weight within chickpeas.

The genotypic and environmental variances for 100 seed weight were 0.072and 0.319. The parameter mentioned had a low heritability of 0.184 (Table 8). 100-seed weight shows low genetic advance values (0.203). low heritability it indicates more influence of the environment on 100-seed weight. These results agreed with those of Guatam *et al*. (2021). who examined genetic variation for yield and yield-determining factors in 225 chickpea genotypes using five control cultivars and found low heritability 0.18 for 100-seed weight.

The genotypic and phenotypic association of 100 seed weight with secondary branches per plant (r_g = 0.48**, r_p = 0.50**), primary branches per plant (r_g = 0.35**, r_p = 0.33*), pods per plant (r_g = 0.57**, r_p = 0.61**), seeds per Pod (r_g = 0.41**, r_p = 0.34*), seed yield (r_g = 0.66**, r_p = 0.90**), biological yield (r_g = 0.79**, r_p = 0.91**) and harvest index (r_g = 0.57**, r_p = 0.67**) were positive and significant (Table 9). (Upadhyay et al., 2022) also discovered a statistically significant positive relationship between hundred-seed weight and secondary branches per plant (r_g = 0.45*, r_p = 0.37*)

The genotypic and phenotypic correlations were both positive and significant, indicating that the relationship between 100 seed weight. The values of rg and rp indicate the strength of the correlation, with values closer to 1 indicating a stronger correlation. The positive association between weight of hundred seeds and traits such as number of pods, seed yield, and biological yield is consistent with previous studies (Singh *et al.,* 2013; Kumar *et al.,* 2016).

Seed yield (kgha^{-1})

It is a complex parameterwhich is due to interplay of different variables that are affected by environmental and generic makeup in which it is grown. Analysis of variance supported highly significant differences in grain production between chickpea genotypes (Table 3). The coefficient of variable was 6.81% in the studied materials of chickpea genotypes, the mean seed yield values ranged from 439 to 533 kg per hectare. Genotype SL-3-29 had the highest grain yield 533kgha^{-1}, followed by KG1 with 525 kg per ha, while genotype GG1 showed the lowest seed yield that is 439 kgha^{-1} (Table 7). Our results are in agreement with Hussain *et al*. (2016) who worked on chickpea genotypes and reported significant differences among the studied genotypes of chickpea.

The genetic and environmental variation of seed yield were 166.74 and 1093.21 respectively. A low heritability value of 0.132 was observed for seed yield kgha^{-1} with low genetic advance 8.267. Hailu (2020) reported moderate heritability which is bit contrary for seed yield while studying chickpea genotypes.

The genotypic and phenotypic relationship between seed yield and primary branches (r_g = 0.65**, r_p = 0.49**), secondary branches (r_g = 0.58**, r_p = 0.64**), number of pods (r_g = 0.86**, r_p = 0.89**), grains per pod (r_g = 0 .47**, r_p = 0.58**), plant height (r_g=0.68**, r_p = 0.31*), biological yield (r_g = 0.94**, r_p = 0.94**) and weight of hundred grains (r_g=0.66**, r_p = 0.90**) were significant and positive (Table.9). (Upadhyay et al., 2022) examined 20 chickpea genotypees and found a significant positive association between seed yield and 100-grain weight (r=0.51*), secondary branches (r=0.66) and biomass production (r= 0.83**). The genotypic correlation (rg) and phenotypic correlation (rp) values suggest that both genetic and environmental factors influence these correlations. One study reported a positive correlation between primary and secondary branches per plant and chickpea yield (Singh *et al.,* 2019).

Biological yield (kg ha^{-1})

Biological yield refers to total dry matter accumulation of a plant system. A statistical study revealed significant differences in biological yield between chickpea genotypes (Table 3). The coefficient of variation of the biological yield was 3.77%. The genotypic mean values for the biological yield were between 1899 and 2178 kg per ha. Genotype DG3 had the highest biological yield (2178 kg ha^{-1}), followed by IG1, NDC-4-20-5 and KARAK-2 each have (2123kg ha^{-1}), while Genotype SL-08-14 had the lowest biological yield (1899 kg ha^{-1}), followed by FG1 which had mean values of 1971 kg ha^{-1} (Table 7). Similarly, Nawaz *et al*., (2018) and Hailu (2020) found significant differences in biological yield between chickpea genotypes.

Genetic variance exceeded environmental variance, showing that genetic control has a greater impact on this trait. The genetic and environmental variations for biological yield were 170.39 and 679.89, respectively. The estimated heritability for the given parameter was 0.200 of biological yield showed low heritability 0.25 and moderate genetic advance 10.28 (Table 8). Consistent with our results, Gautam *et al*. (2021) observed a low heritability for the above trait in chickpea genotypes.

Biological yield essentially correlated with primary branches (r_g = 0.32*, r_p = 0.40**), secondary branches (r_g = 0.71 **, r_p = 0.52**), number of pods (r_g= 0.75**, r_p = 0.80**), Grains per pod (r_g=0.32*, r_p = 0.44**), weight of hundred grains (r_g=0.79**, r_p = 0.91**), and grain yield (r_g=0.94**, r_p = 0.94**). (Table 9). Similarly, Verma et al. (2020) examined the substantial and positive correlation between biological yield and harvest index (r= 0.80**).

The results suggest that in chickpeas, there is a significant correlation between biological yield and various yield components. This is consistent with previous research on chickpeas that have also reported a strong association between yield components and biological yield (Gupta *et al.,* 2018; Singh *et al.,* 2019). Likewise Gupta *et al.* (2018) found that the pods per plant and weight of hundred grains had a significant association with biological yield in chickpeas. Similarly, Singh *et al.* (2019) reported a positive association between primary branches, secondary branches, and number of pods with biological yield in chickpeas.

Harvest index (%)

The harvest index is directly proportional to crop yield. With increasing seed yield in total dry matter, the harvest index increases. For the harvest index, the mean square analysis revealed non-significant variance between chickpea genotypes (Table 3). The coefficient of variance for the harvest index was 10.33%. The average harvest index values for chickpea genotypes ranged from 20.34 to 25.90%. The maximum harvest index (25.90%) was recorded for genotype IG3, followed by NDC-4-20-5 (25.56%), while the minimum harvest index (20.34%) was reported for genotype SL-03-15, (20.52%) and GG1(21.68%), (Table 7). Padmavathi *et al*. (2013) and Swetha and Lavanya (2019) found significant differences in harvest index between chickpea genotypes.

Th environmental and genotypic variations for the harvest index were 0.212 and 5.79, respectively. The under-study parameter had a low heritability of 0.035 and low genetic advance (0.152) values were calculated (Table 8). Similarly, Thakur *et al*. (2018) also calculated a heritability value of 0.38 for the harvest index in chickpea genotypes.

The association revealed a positive and significant relationship between the parameter and primary branches (r_g=0.66**, r_p = 0.54**), secondary branches (r_g=0.64**, r_p = 0.68**), number of pods (r_g=0.70**, r_p = 0.80**), seeds per plant (r_g=0.51**, r_p = 0.66**), plant height (r_g=0.38**, r_p = 0.40**), weight of hundred grains(r_g=0.57**, r_p = 0.67**), seed yield (r_g=0.78**, r_p = 0.86**) and biological yield (r_g=0.50**, r_p = 0.65**). Likewise, the character reported had a negative relationship with 50% emergence (r = -0.57**) and 90% maturity (r = -0.46). (Table 9). (Panda et al., 2022) discovered a significant positive relationship between harvest index and pod plant1 and boll1 in chickpeas.

Table 3: Mean squares of 36 Chickpea genotypes for various traits studied at Peshawar during 2021-22.

SOV	Reps	Geno	Error	CV%
	2	**35**	**70**	
Days to Emergence	0.02778	0.19048^{ns}	0.44683	8.02
Days to Flowering	4.52778	0.55238^{ns}	0.68968	0.75
Days to Maturity	0.2593	21.2339**	10.7450	1.80
Primary Branches	0.45370	1.41799**	0.40608	18.11
Secondary Branches	16.8981	6.7775**	3.1743	13.47
Plant Height	24.009	148.009 **	27.590	7.38
Pods per plant	108.565	98.224**	44.765	18.74
Seeds per Pod	0.2956	0.5064**	0.16527	26.36
100-seed weight	3.869	0.5363*	0.3196	2.91
Biological yield	32.86	1191.08*	679.89	3.77
Seed yield	9391.68	1593.45*	1093.21	6.81
Harvest index	41.80	6.428^{ns}	5.79	10.33

NS= non-significant. *= significant at 5% **= highly significant at 1%

Table 4: Means for days to emergence (DTE), days to flowering (DTF) and days to maturity (DTM) of 36chickpea genotypes for various traits evaluated at The University of Agriculture, Peshawar during 2021-22.

Genotypes	DTE 50%	DTF 50%	DTM
AGI	8	112	181
BG2	8	111	184
BG4	9	110	186
BG5	8	111	178
CG1	7	110	175
DG3	9	110	181
DG4	8	110	181
EG1	8	110	179
FG1	7	110	183
CG1	8	111	184
IG1	7	110	181
IG2	8	111	182
IG3	8	110	181
KG1	7	109	181
MG1	8	111	180
MG2	8	111	180
MG3	9	111	183
MG5	8	113	183
MG6	9	109	183
1CC-19181	8	111	185
NDC-15-01	8	111	187
NDC-15-4-0	8	111	186
NDC-4-20-2	8	111	178
NDC-4-20-3	8	111	175
NDC-4-20-4	9	111	176
NDC-4-20-5	7	110	177
NDC-4-20-6	8	111	186
NDC-4-20-40	8	111	182
SL-08-14	9	112	184
SL-03-15	8	111	185
SL-3-29	8	111	181
KARAK-1	9	111	184
KARAK-2	8	111	179
KARAK-3	8	111	181
NIFA-2005	9	111	184
MEAN	8	111	182
LSD	1.080	1.321	5.30

Table 5: Means for primary branches (PB), secondary branches (SB) and plant height (PH) of 36 chickpea genotypes for various traits evaluated at The University of Agriculture, Peshawar during 2021-22.

Genotypes	PB	SB	PH (cm)
AGI	1	15	64
BG2	2	10	74
BG4	1	12	73
BG5	1	13	80
CG1	3	16	78
DG3	2	16	69
DG4	1	12	63
EG1	1	14	75
FG1	1	12	74
CG1	2	12	76
IG1	3	16	67
IG2	1	16	73
IG3	2	12	74
KG1	3	14	67
MG1	2	16	73
MG2	1	16	67
MG3	3	12	67
MG5	2	13	74
MG6	1	12	72
1CC-19181	2	11	68
NDC-122	2	12	68
NDC-15-01	3	14	78
NDC-15-4-0	1	13	74
NDC-4-20-2	3	14	69
NDC-4-20-3	1	15	75
NDC-4-20-4	2	12	73
NDC-4-20-5	3	16	86
NDC-4-20-6	1	14	55
NDC-4-20-40	2	14	61
SL-08-14	2	13	71
SL-03-15	3	13	65
SL-3-29	3	14	63
KARAK-1	1	14	64
KARAK-2	2	13	72
KARAK-3	3	12	93
NIFA-2005	2	14	65
MEAN	2	13	71
LSD	1.030	2.88	8.49

Table 6: Means for seeds per pod, pods per plant and 100-seed weight of 36 chickpea genotypes for various traits evaluated at The University of Agriculture, Peshawar during 2021-22.

Genotypes	Seeds per pod	Pods per plant	100-seeds weight (g)
AGI	1	37	18.5
BG2	2	31	19
BG4	2	31	19
BG5	2	36	19
CG1	2	38	20
DG3	2	41	19
DG4	1	38	20
EG1	2	43	19
FG1	2	37	19
CG1	2	32	20
IG1	2	36	20
IG2	2	40	20
IG3	1	36	20
KG1	2	50	20
MG1	2	35	20
MG2	2	36	19
MG3	2	31	20
MG5	2	42	19
MG6	2	36	19
1CC-19181	1	33	19
NDC-15-01	2	47	20
NDC-15-4-0	1	39	20
NDC-4-20-2	2	44	19
NDC-4-20-3	2	30	19
NDC-4-20-4	2	36	20
NDC-4-20-5	2	50	21
NDC-4-20-6	2	31	19
NDC-4-20-40	1	24	21
SL-08-14	2	32	21
SL-03-15	1	36	19
SL-3-29	2	38	19
KARAK-1	2	39	19
KARAK-2	2	36	19
KARAK-3	2	28	21
NIFA-2005	2	43	19
MEAN	2	36	19
LSD	0.653	10.814	0.913

Table 7: Means for biological yield (BY), grain yield (GY), and harvest index (HI) of 36 chickpea genotypes for various traits evaluated at The University of Agriculture, Peshawar during 2021-22.

Genotypes	BY (ha^{-1})	GY (kg ha^{-1})	HI (%)
AGI	2078	463	22.36
BG2	2045	454	22.30
BG4	2096	478	22.81
BG5	2189	478	21.86
CG1	2089	456	21.91
DG3	2178	447	20.52
DG4	2089	462	22.15
EG1	2116	500	23.66
FG1	1971	501	25.48
CG1	2023	439	21.68
IG1	2123	520	24.84
IG2	2056	515	25.16
IG3	1930	499	25.90
KG1	2123	525	23.50
MG1	2030	495	24.48
MG2	2122	494	23.38
MG3	2149	487	22.69
MG5	2096	510	24.25
MG6	2067	470	22.89
1CC-19181	2045	457	22.33
NDC-15-01	2126	497	23.48
NDC-15-4-0	2104	487	23.18
NDC-4-20-2	2057	460	22.36
NDC-4-20-3	2078	486	23.42
NDC-4-20-4	2018	491	24.39
NDC-4-20-5	2123	463	25.56
NDC-4-20-6	2113	480	21.52
NDC-4-20-40	2134	492	22.28
SL-08-14	1899	489	22.04
SL-03-15	1986	465	20.34
SL-3-29	2226	533	24.00
KARAK-1	2107	522	24.81
KARAK-2	2123	502	23.84
KARAK-3	2122	510	25.67
NIFA-2005	2108	503	23.91
MEAN	2107	485	23.11
LSD	42.15	53.45	

Table 8: Genetic (Vg), environmental (Ve) variances, heritability estimates (h^2) and Genetic Advance (GA)for various studied parameters of 36 chickpea genotypes at TheUniversity of Agriculture Peshawar, during 2021-22.

Traits	Vg	Ve	Vp	h^2	GA
DTE	0.041	0.446	0.488	0.084	0.1045
DTF	0.04	0.689	0.729	0.054	0.082
DTM	3.496	10.75	14.241	0.245	1.630
PB	0.337	0.406	0.743	0.453	0.688
SB	1.200	3.174	4.374	0.274	1.009
PH	40.139	27.59	67.72	0.592	8.584
PPP	17.81	44.76	62.58	0.284	3.964
SPP	0.113	0.165	0.278	0.407	0.378
100SW	0.072	0.319	0.391	0.184	0.203
BY	170.39	679.8	850.2	0.200	10.28
SY	166.74	1093.21	1259.95	0.132	8.267
HI	0.212	5.79	6.002	0.035	0.152

Table 9. Genotypic and Phenotypic correlation among various traits for 36 chickpea genotypes. (below the diagonal is genotypic and above the diagonal is phenotypic correlation).

Traits	DE	DF	DM	PBP	SBP	PPP	SPP	PH	HSW	SY	BY	HI
DE	--	0.20	0.21	-0.99**	-0.97**	-0.53**	-0.21	-0.99**	-0.06	-0.20	0.02	-0.51**
DF	0.2	--	0.32*	-0.18	-0.17	-0.05	0.09	-0.01	0.11	0.05	-0.04	0.31*
DM	0.25	0.34*	--	-0.06	-0.01	-0.27	-0.28	0.02	-0.12	-0.43**	-0.33*	-0.45**
PBP	-0.53**	-0.12	-0.15	--	0.99**	0.74**	0.30**	0.71**	0.33*	0.49**	0.40**	0.54**
SBP	-0.69**	-0.13	-0.22	0.78**	--	0.83**	0.50**	0.52**	0.50**	0.64**	0.52**	0.68**
PPP	-0.50**	0.07	-0.39**	0.61**	0.62**	--	0.55**	0.64**	0.61**	0.89**	0.80**	0.80**
SPP	-0.17	-0.36**	-0.19	0.35*	0.41**	0.57**	--	0.36**	0.34*	0.58**	0.44**	0.66**
PH	0.80**	-0.03	0.05	0.72**	0.54**	0.43**	0.30*	--	0.09	0.31*	0.20	0.40**
HSW	-0.04	0.09	-0.11	0.35**	0.48**	0.57**	0.41**	0.08	--	0.90**	0.91**	0.67**
SY	-0.28	0.02	-0.31*	0.65**	0.58**	0.86**	0.47**	0.68**	0.66**	--	0.94**	0.86**
BY	-0.13	-0.01	-0.26	0.32*	0.71**	0.75**	0.32*	0.15	0.79**	0.94**	--	0.65**
HI	-0.57**	0.13	-0.46**	0.66**	0.64**	0.70**	0.51**	0.38**	0.57**	0.78**	0.50**	--

DE: Days to 50% emergence; DF: Days to 50% flowering; DM: Days to 90% maturity; PBP: Primary branches per plant; SBP: Secondary branches per plant; PPP: Pods per plant; SPP: Seeds per pod; PH: Plant height; HSW: 100-seed weight; SY: Seed yield; BY: Biological yield; Hl: Harvest index

CONCLUSION AND RECOMENDATTIONS

Conclusion

Based on the results of current study, the fallowing conclusions and recommendations are made.

1. Analysis of variances showed significant differences for the majority of traits except for days to emergence, days to flowering and harvest index which showed non-significant differences among the chickpea genotypes.
2. Low to moderate value of heritability was estimated for most of the studied traits.
3. Low genetic advance was observed for plant height, biological yield and seed yield.
4. Grain yield displayed positive and significant genetic relation with secondary branches per plant, primary branches per plant, seeds per pod, pods per plant, 100-seed weight, plant height, biomass yield and harvest index.

Recommendation

Based on above conclusions, it is recommended that:

1. There is positive and significant correlation of grain yield with secondary branches per plant, primary branches per plant, seeds per pods, pods plant^{1}, 100-seed weight, plant height, biological yield and harvest index shows that these traits could be used as selection criteria for developing high yielding chickpea genotypes.
2. Those genotypes which revealed maximum values for most of yield contributing trait are recommended for use in future chickpea breeding programs.
3. Genotypes IG1, NDC-4-20-5 and KARAK-3 are recommended for evaluation at multi-location and multi-year trials for the release of possible varieties in Khyber Pakhtunkhwa.

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Authors list

Corresponding authors: Zarafshan Aftab, Rozina Gul, Hamid Ullah Khan, Muhammad Anas

Zarafshan Aftab: Ms. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Dr. Rozina Gul: Professor. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Muhammad Anas: Ms. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Hamid Ullah Khan: Ms. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Maheen Bukhari: Ms. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Zainab: Ms. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan

Aleena Arshad: Ms. Department of Plant Breeding and Genetics. Peer Mehar Ali Shah University Rawalpindi Pakistan.

Bakhtawar Asif Hussain: Bs. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan.

Ayesha Jehan: Bs. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan.

Samra Aftab: Ms. Department of Agricultural Chemistry. The University of Agriculture, Peshawar-Pakistan.

Zunaira Khan: Bs. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan.

Ushna Riaz: Bs. Department of Plant Breeding and Genetics. The University of Agriculture, Peshawar-Pakistan.