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# Genetic variability for yield and yield related traits in chickpea (*Cicer arietinum* L.) cultivars evaluated at Taba and Gurumo-Koysha, Wolaita, Ethiopia

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## Abstract

Chickpea (*Cicer arietinum L.*) is a potential crop in the Wolaita Zone in Southern Ethiopia for both domestic use and export. However, the unavailability of suitable chickpea cultivars that fit the Wolaita area is a major constraint for production. Therefore, field experiments were conducted to evaluate the yield and yield-related traits of 12 chickpea cultivars (*Dz-02-54*, *Dz-02-53*, *Hora*, *Kasech*, *Ejeri*, *Acose-dubie*, *Teji*, *Shasho*, *Dhera*, *Minjar*, *Dalota* and *Habru*). The results revealed that days to emergence, days to 50% flowering, days to 90% maturity, and harvest index were found to have significant differences ($p<0.05$) among the cultivars during the analysis of variance for individual locations and combined across locations. Cultivar × location interaction effect was significant for 23.08% of the evaluated traits. The phenotypic coefficient of variation (PCV) values ranged from 4.30 (number of seeds per plant) to 41.68 (grain yield) whereas the genotypic coefficient of variation (GCV) values ranged from 2.53 (thousand seed weight) to 22.68 (number of seed per plant). The cultivar *Hora* demonstrated the highest performance, achieving a maximum grain yield of 11.68 q/ha. It was closely followed by *Ejeri* (11.34 q/ha) and *Kasech* (11.08 q/ha). These cultivars show potential for cultivation in Taba and Gurumo-Koysha, Wolaita, Ethiopia and may serve as valuable resources for future chickpea enhancement efforts.

**Keywords:** Chickpea cultivars, Genetic variation, Heritability, Mean performance, Ethiopia

## Introduction

Chickpea (*Cicer arietinum* L.) is a cool-season crop cultivated in various parts of Ethiopia. It is the second most important legume crop, following faba beans. It is primarily grown in the central, northeastern, and southern highlands, with the annual rainfall of 700 and 1200 mm and the altitude range of 1400 to 2300 m above sea level (Yadeta et al., 2007). In 2018/19, 1,620,497.30 hectares of grain crop area were planted with pulses. Of which, 163,067.24 hectares were planted with chickpeas, producing 3,301,531.98 quintals of chickpea grain yield (CSA, 2019).

Chickpea is high in energy, protein, minerals (potassium, phosphorus, calcium, magnesium, copper, iron, and zinc), vitamins, fiber, and phytochemicals that may be beneficial to health (Wood and Grusak, 2007). Its straw is used as forage, fodder, and silage. It also helps maintain soil fertility as a rotational crop through biological nitrogen fixation (Kantar et al., 2007; Katerji et al., 2001).

Desi-microsperma and Kanuli-macrosperma are the two predominant types of chickpea cultivated globally. They differ significantly in terms of seed size, color, surface, and seed coat thickness (Purushothaman et al., 2014). The Desi type is characterized by small seeds with an angular appearance, sharp edges, and usually a light brown color. It has a higher protein content and lower lipid and carbohydrate content than Kanuli types. In contrast, The Kanuli type yields large, round seeds that are white, pale cream, or yellow in color (Wood and Grusak, 2007; Yadeta et al., 2007). Ethiopia is the largest African nation that grows chickpea, accounting for approximately 37% of the total area and 48% of the production. Desi varieties dominate Ethiopian chickpea production. However, there has been an increase in the interest of farmers in growing large-seeded Kanuli types because of their higher prices in the market (Daba et al., 2005).

The performance of any crop depends on its genotype and the environment in which it is grown. Genotype and environmental sources of variation can be used to express phenotypic variance. Enhancing crop yield relies on the extent of genetic variability and heritability. For yield improvement, it is useful to understand genotypic and phenotypic coefficients of variation, heritability, and genetic advances (Johnson et al., 1995). The existence of diverse chickpea genotypes is a valuable resource for developing new cultivars, new quality yields, and diversification of production (Jing et al., 2010). Yield is a multifaceted trait shaped by numerous environmental factors. Thus, selecting an elite genotype is made possible by identifying key characters and how they interact and evaluating performance in different locations (Studnicki et al., 2016; Falconer and Mackay, 1996). It is important to recognize the type and strength of the correlations between yield and yield-related traits (Rensink, 2017). Correlation coefficient analysis is a useful technique to identify the important traits that influence seed yield. It also helps in establishing the selection criteria for the concurrent development of multiple characters and economic yield (Jivani et al., 2013).

Farmers in Northern Ethiopia dedicated their farms to chickpea production, cultivating both local and improved varieties. Improved seeds were primarily sourced from neighboring farmers, the district office of agriculture, and the research center (Abiro et al., 2020). However, In the Wolaita Zone, Southern Ethiopia, chickpea production occurs at the individual farmer or community level, relying on indigenous knowledge for seed selection, sourcing, retention, management, and local diffusion mechanisms (Goa and Ashamo, 2016). Apart from simple trial knowledge, seeds of the evaluated chickpea cultivars were not popular in the area. Many released cultivars are not known by farmers, and seed production is limited to landraces. There are very few improved cultivars that are being used by farmers. It is essential to evaluate variations among chickpea cultivars for yield and related traits to select appropriate cultivars for promotion to farmers and breeders. Therefore, the aim of this study was to assess chickpea cultivars for yield and yield related traits to identify desirable characteristics for a better yield to popularize in the study districts (Damot-Gale and Boloso-Sore) of the Wolaita zone in southern Ethiopia.

## Materials and methods

### Experimental sites

The experiment was carried out during the 2021/2022 rainy seasons on farmers' fields under natural conditions, following traditional farming practices in the Taba kebele in Damot-Gale District (Taba site) and Gurumo-Koysha kebele in Boloso-Sore District (Gurumo-Koysha site), Wolaita Zone in Southern Ethiopia. The latitude and longitude of the Taba site are 6.5718 N and 37.0542 E, respectively, and the altitude is 2000 m.a.s.l. The area is characterized by a mean minimum and maximum temperature of 19.1°C and 29°C, respectively, with a mean annual rainfall of 1180 mm. The latitude and longitude of the Gurumo-Koysha site are 6.5817 N and 37.4429 E, respectively, and the altitude is 2000 m.a.s.l. The area is characterized by a mean annual rainfall of 1055 mm and a mean minimum and maximum temperatures of 19°C and 28°C, respectively.

Treatments and experimental design

For this study, twelve chickpea cultivars were sourced from the highland pulse research program of the Debre Zeite Agricultural Research Center, Ethiopia. A description of chickpea cultivars is presented in Table 1. The experiment was designed with three replicates at each experimental site using a randomized complete block design (RCBD). The size of each experimental plot was 2 m × 1.8 m, with a total area of 3.6 $m^2$, which consisted of six rows. The distances between rows and plants were 30 cm and 10 cm, respectively.

Table 1. Chickpea (*Cicer arietinum* L.) cultivar used for the study

| No | Cultivars | Type | Seed color | Release year |
|---|---|---|---|---|
| 1 | *Dz-02-54* | Desi | Brown | 2016 |
| 2 | *Dz-02-53* | Desi | Brown | 2013 |
| 3 | *Hora* | Desi | Brown beige | 2013 |
| 4 | *Kasech* | Desi | Orange | 2010 |
| 5 | *Ejeri* | Kanuli | Brown beige | 2007 |
| 6 | *Acose-dubie* | Kabuli | White cream | 2009 |
| 7 | *Teji* | Kabuli | Brown beige | 2005 |
| 8 | *Shasho* | Kanuli | White | 1999 |
| 9 | *Dhera* | Kanuli | Yellow beige | 1999 |
| 10 | *Minjar* | Kanuli | Golden | 2010 |
| 11 | *Dalota* | Kanuli | Brown beige | 2005 |
| 12 | *Habru* | Kanuli | Orange | 2004 |

Source of data: Debre Zeite Agricultural Research Center, Ethiopia

Experimental procedures

The experimental land was cleared and plowed using oxen, following traditional farming practices. Then, the experimental field was well-tilled for a uniform seedbed. At each location, 36 experimental plots (12 cultivars × three replicates) were created. The rows were prepared using hand-pulled row markers. The seeds were planted by hand drilling at the appropriate planting time for each location in a well-prepared seedbed to ensure successful germination. Fertilizer was applied at the recommended rate of 100 kg/ha (diammonium phosphate providing phosphorus) and 50 kg/ ha urea providing nitrogen. All agronomic practices were uniformly followed as recommended for legume crops, but herbicides and insecticides were not used.

Data collection

Ten plants were randomly selected from the four middle rows of each plot. Plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of pods

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per plant, number of seeds per pod, number of seeds per plant, thousand seed weight (gm), grain yield, and biomass yield were documented on a plot basis. The distribution between economic and total biomass yield was estimated as harvest index (HI) $=\frac{\text{Grain yield}}{\text{Biomass yield}}$.

Data analysis

Analysis of variance (ANOVA) was computed for each location before the combined analysis of variance computed using the Generalized Linear Model (GLM) procedure (Minitab, 2013). Least significant difference (LSD) test at 5% level of significance was performed when significant difference was detected among cultivars for a given trait. Genotypic and phenotypic variances and coefficients of variation were estimated according to the formula of Singh and Chaudhary (1999). Genotypic variance ($\sigma^2$g) = $\frac{\text{MSg}-\text{MSe}}{\text{r}}$, phenotypic variance ($\sigma^2$p) = $\sigma^2$g + $\sigma^2$e, and environmental variance ($\sigma^2$e) = MSe, where MSg is the mean square due to cultivar, MSe is the mean square due to error, and r is the number of replications. The genotypic coefficient of variation was estimated as GCV = $\frac{\sqrt{\text{Genotypic variance}}}{\text{Grand mean of a trait}} = \frac{\sqrt{\sigma 2\text{g}}}{\bar{\text{X}}}$ x100 and phenotypic coefficient of variation was estimated as PCV = $\frac{\sqrt{\text{Phenotypic variance}}}{\text{Grand mean of a trait}} = \frac{\sqrt{\sigma 2\text{p}}}{\bar{\text{X}}} \times 100$, where x = grand mean of a character.

Heritability in broad sense was calculated for each trait by using the formula described by Allard (Allard, 1960). Heritability in a broad sense ($h^2$b) (%) = $\frac{\sigma 2\text{g}}{\sigma 2\text{p}}$ x100, $\sigma 2\text{g} =$ genotypic variance, and $\sigma 2\text{p} =$ phenotypic variance. The estimates were categorized as low (0-30%), moderate (30 to 60%), or high (>60%) according to the method by Robinson *et al*. (1949). Genetic advance (GA) and genetic advance as percentage of mean (GAM) were calculated using the formula adopted by Johnson and Wichern (1988), i.e., GA = $k \times \sqrt{\sigma^2\text{p}} \times hb^2$ and GAM= $\frac{\text{GA}}{\bar{\text{X}}} \times 100$, where k is the selection differential (k = 2.06 at 5% selection intensity), $\sigma^2$p is the phenotypic standard deviation. GAM is categorized as follows: high, >20%; moderate (10-20) %; and low, < 10% (Johnson and Wichern, 1988).

**Results and discussion**

Analysis of variance

The analysis of variance computed for each location revealed highly significant variation among the chickpea cultivars for days to germination, days to 50% flowering, number of seeds per pod, days to 90% maturity, and harvest index at both sites (Table 2 and Table 3). Other authors have also stated the presence of significant difference among chickpea genotypes in terms of yield and yield-related traits (Shengu et al., 2018; Raju et al., 2017).

Table 2. Mean squares from analysis of variance for 13 traits of 12 chickpea cultivars evaluated at Taba site

| Trait | Replication (df =2) | Cultivar (df =11) | Error (df =24) | CV (%) | Mean |
|---|---|---|---|---|---|
| GD | 0.03 | 1.71** | 0.39 | 7.46 | 11.89 |
| PH | 122.89** | 19.38 | 18.25 | 13.55 | 36.59 |
| DF | 3.44** | 79.54*** | 0.47 | 7.63 | 66.14 |
| NPB | 0.84 | 1.69 | 0.94 | 31.94 | 3.38 |
| NSB | 135.10*** | 11.46 | 10.43 | 29.50 | 14.33 |
| NPP | 1860.50** | 238.90 | 228.90 | 34.58 | 52.16 |
| NSP | 0.11 | 0.44*** | 0.50 | 34.50 | 1.22 |
| NSPP | 5958.20 | 1508.90 | 790.90 | 55.65 | 65.09 |
| MD | 3.69 | 88.57*** | 8.15 | 4.38 | 131.44 |
| TSW | 0.13 | 0.17 | 0.21 | 19.40 | 2.26 |
| GY | 139.36** | 24.33 | 18.22 | 17.09 | 10.35 |
| BMY | 416.03* | 117.59 | 77.36 | 16.01 | 22.48 |
| HI | 117.90 | 188.70** | 104.10 | 22.19 | 51.67 |

***, ** and * significant at 0.001, 0.01 and 0.05 probability level, respectively. GD, germination date; PH=Plant height (cm); DF= Days to 50% flowering; NPB= Number of primary branches; NSB= Number of secondary branches; NPP= Number of pods per plant; NSP= Number of seeds per pod; NSPP= Number of seeds per plant; MD= Days to 90% maturity; TSW, thousand-seed weight (gm); GY= Grain yield (q/ha); BMY= Biomass yield (q/ha); HI= Harvest index.

Table 3. Mean squares from analysis of variance for 13 traits of 12 chickpea cultivars evaluated at Gurumo-Koysha site

| Trait | Replication (df =2) | Cultivar (df =11) | Error (df =24) | CV (%) | Mean |
|---|---|---|---|---|---|
| GD | 1.78 | 3.12** | 0.63 | 10.39 | 11.69 |
| PH | 4.71 | 66.51** | 16.44 | 10.44 | 53.76 |
| DF | 62.69* | 47.73** | 9.48 | 7.68 | 64.47 |
| NPB | 1.40 | 1.11 | 0.51 | 27.06 | 3.21 |
| NSB | 32.25 | 37.63 | 19.86 | 33.57 | 15.23 |
| NPP | 1802* | 478.50* | 229 | 27.30 | 70.68 |
| NSP | 0.83 | 0.13* | 0.05 | 25.87 | 1.08 |
| NSPP | 1566 | 1435.9* | 728 | 40.38 | 78.24 |
| MD | 49.69 | 38.75* | 15.97 | 3.72 | 134.44 |
| TSW | 0.16 | 0.35 | 0.45 | 23.14 | 2.71 |
| GY | 53.03 | 78.04* | 22.04 | 19.22 | 10.58 |
| BMY | 135.2 | 157.9 | 113.10 | 21.43 | 38.38 |
| HI | 28.57 | 230.46** | 47.00 | 24.59 | 41.39 |

***, ** and * significant at 0.001, 0.01 and 0.05 probability level, respectively. GD, germination date; PH= Plant height (cm); DF= Days to 50% flowering; NPB= Number of primary branches; NSB= Number of secondary branches; NPP=Number of pods per plant; NSP= Number of seeds per pod; NSPP= Number of seeds per plant; MD= Days to 90% maturity; TSW= thousand-seed weight (gm); GY= Grain yield (q/ha); BMY= Biomass yield (q/ha); HI= Harvest index.

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The outcome of the combined analysis using the averaged mean value across sites is shown in Table 4. The analysis revealed a highly significant variation among chickpea cultivars for the majority (76.92%) of the evaluated traits, such as days to germination, plant height, days to 50% flowering, number of primary branches, number of secondary branches, number of seeds per pod, days to 90% maturation, grain yield, biomass yield, and harvest index. This implies that these traits can be used for the selection of chickpea cultivars. Jida and Alemu (2019) reported significant variation among the chickpea genotypes for all evaluated traits except hundred seed weight and grain yield. Atta and Shah (2009) reported highly significant variation in grain yield among common bean genotypes.

Table 4. Mean squares from combined analyses of variance over locations for 13 traits of 12 chickpea cultivars evaluated at Taba and Gurumo-Koysha sites

| Traits | Location df =1 | Cultivar df =11 | Location*cultivar | Error df = 55 | CV% | Mean |
|---|---|---|---|---|---|---|
| GD | 0.68 | 3.73*** | 1.10* | 0.54 | 8.99 | 11.79 |
| PH | 5304.50** | 47.82* | 38.07 | 21.49 | 22.39 | 45.18 |
| DF | 50.00* | 123.27*** | 4.00 | 7.32 | 7.71 | 65.31 |
| NPB | 0.57 | 2.11** | 0.70 | 0.76 | 29.66 | 3.29 |
| NSB | 14.58 | 32.43* | 16.67 | 20.86 | 31.66 | 14.78 |
| NPP | 6171.2*** | 438.80 | 243.4 | 352.3 | 33.79 | 61.79 |
| NSP | 0.35* | 0.41*** | 0.17** | 0.06 | 31.43 | 1.15 |
| NSPP | 3115 | 1737.20 | 1208 | 1010 | 47.99 | 71.29 |
| MD | 1276.4*** | 116.04** | 11.27 | 13.28 | 4.19 | 132.94 |
| TSW | 4.2864** | 0.29 | 0.23 | 0.31 | 23.77 | 2.50 |
| GY | 374.88** | 61.66* | 40.71 | 27.58 | 10.62 | 13.68 |
| BMY | 4552.17** | 186.92** | 88.56 | 110.24 | 21.76 | 30.43 |
| HI | 1903.66 | 162.90* | 256.25** | 75.34 | 25.67 | 46.53 |

***, ** and * significant at 0.001, 0.01 and 0.05 probability level, respectively. GD, germination date; PH= Plant height (cm); DF= Days to 50% flowering; NPB=Number of primary branches; NSB= Number of secondary branches; NPP= Number of pods per plant; NSP= Number of seeds per pod; NSPP= Number of seeds per plant; MD= Days to 90% maturity; TSW, thousand-seed weight; GY= Grain yield; BMY= Biomass yield; HI= Harvest index

The mean squares for location were also significant for 61.54% of the traits, indicating the performance of the evaluated cultivars cannot be evaluated on the basis of pooled mean values over locations. Traits such as the number of pods per plant and thousand-seed weight were not significantly different for combined data over locations, implying that they are less important for characterizing chickpea cultivars. Significant genotype-by-location interaction effects were detected for days to germination, the number of seeds per pod, and harvest index. Wang et al., 2017 and Arshad et al., (2003) reported a significant influence of genotype-location interaction on chickpea performance. The differential performance of genotypes across environments varies significantly, and the performance of plants depends directly on the environmental conditions (Fox et al., 1990).

Mean comparison of chickpea cultivars phenological traits

The mean performance of the 12 chickpea cultivars for the phenological traits is presented in Table 5. The findings revealed that there was variation in the phenological traits among the evaluated chickpea cultivars. The differences in days to germination, flowering, and maturity could be caused by other variations in genotypes and the environments in which genotypes were assessed, as reported by Bakhsh et al. (1998). At the Taba site, the cultivars *Hora* and *Dhera* germinated early (on average, 10.83 days), followed by *Acose-dubie* and *Kasech*, each of which has taken 11.0 days to germinate. At the Gurumo-Koysha site, chickpea cultivars also differed significantly in phenological traits. The cultivars *Hora* and *Teji* germinated early (on average, 10.33 days). The cultivar *Dalota* took the shortest average days (123.67) to mature at the Taba site. This cultivar also took days to mature at the Gurumo-Koysha site (Table 5). At the Taba site, the early germinated cultivar *Dhera* flowered and matured late, whereas the late-germinated cultivar *Dalota* flowered and matured early at both experimental sites, suggesting a higher chance of selecting early maturing cultivars at both locations.

A comparison of mean values from the combined data over locations revealed that the cultivars *Hora* and *Dhera* germinated early (10.83 average days), whereas the cultivar *Minjar* took longer (13.00) days to germinate. Cultivars *Kasech*, *Acose-dubie*, *Shasho*, *Dhera*, *Minjar*, and *Dalota* took significantly longer to flower and reach physiological maturity than the other cultivars (Table 5). Difference of average 10.33 days for flowering and 16 days for maturity were observed between the longest and shortest days, suggesting extensive range of variability among the cultivars in terms of days to flowering and maturity.

Table 5. Mean performance of 12 chick pea cultivars for phenological traits

| Chickpea cultivars | Taba site | | | Gurumo-Koysha site | | | Combined over locations | | |
|---|---|---|---|---|---|---|---|---|---|
| | GD | DF | DM | GD | DF | DM | GD | DF | DM |
| *Dz-02-54* | 12.67[a] | 61.17[b] | 132.17[bc] | 12.67[ab] | 61.00[b] | 134.33[ab] | 12.67[a] | 61.17[b] | 132.17[abc] |
| *Dz-02-53* | 11.67[abc] | 61.33[b] | 136.00[ab] | 12.00[ab] | 61.00[b] | 138.67[a] | 11.67[abc] | 61.33[b] | 136.00[ab] |
| *Hora* | 10.83[c] | 61.67[b] | 136.00[ab] | 10.33[b] | 60.33[b] | 137.00[ab] | 10.83[c] | 60.67[b] | 136.00[ab] |
| *Kasech* | 11.00[bc] | 69.50[a] | 134.00[ab] | 11.33[ab] | 67.67[b] | 133.67[ab] | 11.00[bc] | 69.50[a] | 134.00[ab] |
| *Ejeri* | 12.17[abc] | 61.00[b] | 135.50[ab] | 12.00[ab] | 60.67[b] | 135.33[ab] | 12.17[abc] | 61.00[b] | 135.50[ab] |
| *A.dubie* | 11.00[bc] | 70.00[a] | 132.67[ab] | 10.67[ab] | 68.33[ab] | 133.67[ab] | 11.00[bc] | 70.00[a] | 132.67[bc] |
| *Teji* | 11.5[abc] | 61.67[b] | 132.50[ab] | 10.33[b] | 60.33[b] | 133.67[ab] | 11.50[abc] | 60.67[b] | 132.50[abc] |
| *Shasho* | 11.67[abc] | 69.33[a] | 135.67[ab] | 11.67[ab] | 67.33[b] | 137.00[ab] | 11.67[abc] | 69.33[a] | 135.67[ab] |
| *Dhera* | 10.83[c] | 71.00[a] | 139.67[a] | 10.67[ab] | 71.00[a] | 139.67[a] | 10.83[c] | 71.00[a] | 139.67[a] |
| *Minjar* | 13.00[a] | 69.00[a] | 131.17[bc] | 13.00[a] | 67.33[ab] | 133.33[ab] | 13.00[a] | 69.00[a] | 131.17[bc] |
| *Dalota* | 12.67[a] | 68.83[a] | 123.67[d] | 13.00[a] | 67.33[ab] | 126.33[b] | 12.67[a] | 68.83[a] | 123.67[d] |
| *Habru* | 12.5[ab] | 61.17[b] | 126.33[cd] | 12.67[ab] | 61.33[b] | 130.67[ab] | 12.50[ab] | 61.17[b] | 126.33[cd] |

Means that do not share a letter in superscript in the same column are significantly different at $p < 0.05$, as determined by Tukey's mean comparison. GD= Germination date; DF=Days to 50% flowering; MD= Days to 90% maturity

Mean comparison of growth traits

Table 6 presents the average values of chickpea cultivars examined for growth parameters. The plant height (cm) ranged from 34.1 cm (*A. dubie*) to 40.40 cm (*Dalota*) without significant difference at the Taba site. The tallest cultivar, *Dhera*, was measured at 61.27 cm at the Gurumo-Koysha site, which was significantly taller than the shortest cultivar, *Minjar* (48.13 cm). Chickpea cultivars attained relatively higher plant heights at the Gurumo-Koysha site than at the Taba site. Previously, Admas et al. (2021) stated similar results for the difference in the range of plant height of chickpea cultivars. The cultivars did not exhibit significant variations in the number of primary and secondary branches at either experimental site. However, a higher number of primary branches were counted for *Dhera* (4.57), followed by *Ejeri* (4.50), whereas a lower number of primary branches was recorded from *Acose-dubie* (2.50) at the Taba site.

The maximum number of primary branches was reported at *Dz-02-53* (4.37), whereas the lowest number of primary branches was reported from *Habru* (2.37) at the Gurumo-Koysha site (*Habru*, 2.37). Significant variation among chickpea genotypes with respect to the number of primary branches was also described by Bhanu et al. (2027). The mean values from the combined data across locations showed that the plant height ranged from 41.32 cm for *Minjar* to 49.98 cm for *Dz-02-53*.

Table 6. Mean performance of 12 chickpea cultivars for growth traits

| chickpea | Taba site | | | Gurumo-Koysha site | | | Combined across locations | | |
|---|---|---|---|---|---|---|---|---|---|
| cultivars | PH | NPB | NSB | PH | NPB | NSB | PH | NPB | NSB |
| *Dz-02-54* | 39.17[a] | 2.80[a] | 13.73[a] | 56.93[abc] | 2.67[a] | 17.50[a] | 48.05[ab] | 2.73[bc] | 15.62[ab] |
| *Dz-02-53* | 40.3[a] | 3.57[a] | 13.43[a] | 59.67[abc] | 4.37[a] | 16.80[a] | 49.98[a] | 3.97[a] | 15.12[ab] |
| *Hora* | 34.60[a] | 3.10[a] | 13.97[a] | 60.40[ab] | 4.03[a] | 19.77[a] | 47.50[abc] | 3.55[ab] | 16.87[a] |
| *Kasech* | 36.13[a] | 4.10[a] | 13.63[a] | 53.80[abc] | 3.20[a] | 10.33[a] | 44.97[abcd] | 3.65[ab] | 11.98[b] |
| *Ejeri* | 34.53[a] | 4.50[a] | 13.63[a] | 48.37[c] | 3.53[a] | 17.30[a] | 41.45[d] | 4.02[a] | 15.47[ab] |
| *A.dubie* | 34.1[a] | 2.50[a] | 13.07[a] | 52.87[abc] | 2.57[a] | 9.73[a] | 43.48[bcd] | 2.53[c] | 11.40[b] |
| *Teji* | 35.8[a] | 2.47[a] | 11.97[a] | 51.77[abc] | 3.10[a] | 12.53[a] | 43.78[bcd] | 2.78[bc] | 12.25[b] |
| *Shasho* | 34.57[a] | 3.60[a] | 14.67[a] | 50.70[abc] | 2.97[a] | 19.60[a] | 42.63[cd] | 3.28[abc] | 17.13[a] |
| *Dhera* | 35.2[a] | 4.57[a] | 19.20[a] | 61.27[a] | 3.77[a] | 16.73[a] | 48.23[ab] | 4.17[a] | 17.97[a] |
| *Minjar* | 34.50[a] | 3.83[a] | 17.13[a] | 48.13[c] | 3.07[a] | 17.03[a] | 41.32[d] | 3.45[abc] | 17.08[a] |
| *Dalota* | 40.40[a] | 2.90[a] | 14.17[a] | 52.00[abc] | 2.83[a] | 14.60[a] | 46.20[abcd] | 2.87[bc] | 14.38[ab] |
| *Habru* | 39.83[a] | 2.70[a] | 13.40[a] | 49.23[bc] | 2.37[a] | 10.87[a] | 44.53[bcd] | 2.53[a] | 12.13[b] |

Means that do not share a letter in superscript in the same column are significantly different at $p < 0.05$, as determined by Tukey's mean comparison. PH= plant height; NPB= number of primary branches; NSB= number of secondary branches

Mean comparison of yield and yield related traits

The evaluated chickpea cultivars showed significant differences in yield and related traits. at both the Taba and Gurumo-Koysha sites (Table 7). The number of pods per plant was as low as 31.33 (*Teji*) and as high as 65.10 (*Dalota*) at the Taba site, whereas it was as low as 47.16 (*Habru*) and as high as 91.17 (*DZ-02-53*) at the Gurumo-Koysha site. The mean performance of chickpea cultivars in terms of the number of pods per plant was higher at the Gurumo-Koysha site than at the Taba site (Tables 2 and 3). The highest number of seeds per plant (97.13) was recorded for the cultivar *Hora* at Taba site. The presence of significant variation among chickpea cultivars for the number of pods per plant and number of seeds per plant was also reported by Anusha *et al*. (2020).

At the Taba site, the lowest number of pods per plant (31.33) and number of seeds per plant (31.83) were recorded in *Habru*. The highest number of pods per plant (65.10) and seeds per plant (105.53) were recorded for *Dalota* and *Habru*, respectively. The lowest number of pods per plant (47.16) and number of seeds per plant (41.17) were recorded for *Habru* at the Gurumo Koysha site, while the highest number of pods per plant (91.17) and number of seeds per pod (129.40) were recorded for *DZ-02-53* and *Hora*, respectively. The lowest grain yield (4.58 q/h) was recorded from the cultivar *Teji* at the Taba site, while the lowest grain yield (7.68 q/ha) was recorded from the cultivar *Acose-dubei* at the Gurumo Koysha site. Cultivar *Ejeri* (12.00 q/ha) is a significantly well-performing cultivar at the Taba site, whereas cultivar Hora (11.59 q/ha) is a significantly well-performing cultivar at the Gurumo-Koysha. A difference of 20.29 q/ha in biological yield was recorded between *Ejeri* (3232 q/ha) and *Teji* (12.03 q/ha) at the Taba site. The lowest biomass yield (25.37 q/ha) was recorded for the cultivar *Dz-02-54*, while the highest biomass yield (49.82 q/ha) was recorded for *Hora* at the Gurumo Koysha site. At the Taba site, the grain yield of 75% of the cultivars was greater than the overall mean grain yield of cultivars, whereas at the Gurumo Koysha site, the grain yield of 41.6% of the cultivars was greater than the overall mean grain yield of cultivars (Tables 2 and Table 7).

Table 7. Mean performance of 12 check pea cultivars for yield and yield-related traits

| Traits | Chickpea cultivars | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Dz-02-54* | *DZ-02-53* | *Hora* | *Kasech* | *Ejeri* | *A.dubei* | *Teji* | *Shasho* | *Dhera* | *Minjar* | *Dalota* | *Habru* |
| Location: Taba site | | | | | | | | | | | | |
| NPP | 55.20$^{ab}$ | 57.83$^{ab}$ | 48.57$^{ab}$ | 46.33$^{ab}$ | 61.93$^{ab}$ | 44.27$^{ab}$ | 31.33$^{b}$ | 55.77$^{ab}$ | 55.87$^{ab}$ | 50.97$^{ab}$ | 65.10$^{a}$ | 52.77$^{ab}$ |
| NSPP | 82.27$^{abc}$ | 57.83$^{abc}$ | 97.13$^{a}$ | 46.33$^{bc}$ | 61.93$^{abc}$ | 44.26$^{abc}$ | 31.83$^{c}$ | 82.50$^{abc}$ | 55.87$^{abc}$ | 50.33$^{abc}$ | 65.10$^{abc}$ | 105.53$^{a}$ |
| TSW | 2.27$^{ab}$ | 2.39$^{ab}$ | 2.28$^{ab}$ | 2.62$^{a}$ | 2.40$^{ab}$ | 2.04$^{ab}$ | 2.28$^{ab}$ | 1.83$^{b}$ | 2.62$^{a}$ | 2.25$^{ab}$ | 2.17$^{ab}$ | 2.00$^{ab}$ |
| GY | 10.93$^{ab}$ | 10.50$^{ab}$ | 11.44$^{ab}$ | 10.11$^{ab}$ | 12.00$^{a}$ | 8.59$^{ab}$ | 4.58$^{b}$ | 10.77$^{ab}$ | 11.57$^{ab}$ | 11.17$^{ab}$ | 11.41$^{ab}$ | 11.07$^{ab}$ |
| BMY | 17.59$^{ab}$ | 25.65$^{ab}$ | 22.32$^{ab}$ | 26.85$^{ab}$ | 32.32$^{a}$ | 12.96$^{b}$ | 12.03$^{b}$ | 31.20$^{a}$ | 21.20$^{ab}$ | 22.22$^{ab}$ | 24.07$^{ab}$ | 21.29$^{ab}$ |
| HI | 64.06$^{ab}$ | 50.56$^{bc}$ | 50.35$^{bc}$ | 44.80$^{c}$ | 50.31$^{bc}$ | 68.47$^{a}$ | 38.75$^{c}$ | 48.50$^{bc}$ | 53.88$^{bc}$ | 52.26$^{bc}$ | 47.02$^{bc}$ | 51.09$^{bc}$ |
| Location: Gurumo-Koysha site | | | | | | | | | | | | |
| NPP | 72.77$^{abc}$ | 91.17$^{a}$ | 83.93$^{ab}$ | 52.17$^{bc}$ | 72.40$^{bc}$ | 62.16$^{bc}$ | 70.03$^{abc}$ | 92.93$^{a}$ | 76.40$^{abc}$ | 72.60$^{abc}$ | 71.07$^{abc}$ | 47.16$^{c}$ |
| NSPP | 72.77$^{ab}$ | 91.17$^{ab}$ | 129.40$^{a}$ | 66.17$^{ab}$ | 61.17$^{ab}$ | 62.16$^{ab}$ | 70.03$^{ab}$ | 89.60$^{ab}$ | 76.40$^{ab}$ | 101.6$^{ab}$ | 71.07$^{ab}$ | 47.17$^{b}$ |
| TSW | 2.85$^{a}$b | 2.15$^{b}$ | 3.01$^{ab}$ | 2.62$^{ab}$ | 2.87$^{ab}$ | 2.35$^{ab}$ | 2.79$^{ab}$ | 2.90$^{ab}$ | 3.44$^{a}$ | 2.50$^{ab}$ | 2.57$^{ab}$ | 2.99$^{ab}$ |
| GY | 10.47$^{ab}$ | 10.05$^{ab}$ | 11.59$^{a}$ | 10.19$^{ab}$ | 10.35$^{ab}$ | 7.68$^{b}$ | 10.38$^{ab}$ | 11.09$^{ab}$ | 11.96$^{ab}$ | 11.33$^{ab}$ | 11.28$^{ab}$ | 10.11$^{ab}$ |
| BMY | 25.37$^{c}$ | 40.83$^{abc}$ | 49.82$^{a}$ | 37.87$^{abc}$ | 37.32$^{abc}$ | 34.17$^{abc}$ | 29.82$^{abc}$ | 36.48$^{abc}$ | 42.41$^{abc}$ | 47.22$^{abc}$ | 45.93$^{abc}$ | 33.33$^{abc}$ |
| HI | 54.34$^{a}$ | 47.19$^{ab}$ | 49.80$^{ab}$ | 38.05$^{abc}$ | 39.67$^{abc}$ | 22.68$^{c}$ | 40.09$^{abc}$ | 40.89$^{abc}$ | 32.84$^{bc}$ | 47.78$^{ab}$ | 48.92$^{ab}$ | 46.39$^{ab}$ |
| Combined data over two locations | | | | | | | | | | | | |
| NPP | 63.98$^{ab}$ | 74.50$^{a}$ | 62.91$^{ab}$ | 49.25$^{b}$ | 67.17$^{ab}$ | 53.21$^{ab}$ | 50.68$^{ab}$ | 69.35$^{ab}$ | 66.13$^{ab}$ | 71.78$^{ab}$ | 68.08$^{ab}$ | 49.96$^{b}$ |
| NSPP | 77.52$^{ab}$ | 74.05$^{ab}$ | 113.27$^{a}$ | 56.28$^{ab}$ | 61.67$^{ab}$ | 53.21$^{b}$ | 50.68$^{c}$ | 86.05$^{ab}$ | 66.13$^{ab}$ | 76.28$^{ab}$ | 68.08$^{bc}$ | 76.35$^{ab}$ |
| TSW | 2.56$^{ab}$ | 2.27$^{b}$ | 2.65$^{ab}$ | 2.62$^{ab}$ | 2.64$^{ab}$ | 2.20$^{b}$ | 2.54$^{ab}$ | 2.36$^{ab}$ | 3.03$^{a}$ | 2.37$^{a}$b | 2.37$^{ab}$ | 2.49$^{ab}$ |
| GY | 11.05$^{ab}$ | 10.77$^{abc}$ | 11.68$^{a}$ | 10.02$^{abc}$ | 10.11$^{ab}$ | 8.14$^{c}$ | 8.48$^{bc}$ | 10.03$^{abc}$ | 10.77$^{abc}$ | 11.05$^{ab}$ | 11.34$^{ab}$ | 11.09$^{ab}$ |
| BMY | 24.48$^{a}$ | 33.24$^{a}$ | 36.07$^{a}$ | 32.36$^{a}$ | 34.82$^{a}$ | 25.23$^{a}$ | 24.93$^{a}$ | 33.84$^{a}$ | 31.81$^{a}$ | 34.72$^{a}$ | 35.00$^{a}$ | 28.32$^{a}$ |
| HI | 60.80$^{a}$ | 48.88$^{ab}$ | 50.08$^{ab}$ | 41.43$^{b}$ | 44.99$^{b}$ | 45.58$^{b}$ | 39.42$^{b}$ | 44.50$^{b}$ | 43.36$^{b}$ | 50.02$^{ab}$ | 47.97$^{ab}$ | 48.74$^{b}$ |

Means that do not share a superscript letter in the same row are significantly different at $p < 0.05$, as determined by Tukey mean comparison. NPP = Number of pods per plants; NSP =Number of seeds per pod; NSPP = Number of seeds per plant; TSW= Thousand seed weight (kg/p); GY = Grain yield (kg/ha); BMY = Biomass yield (kg/ha); HI = Harvest index

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The mean performance of cultivars in terms of the number of pods per plant and number of seeds per pod differed significantly by location. The number of pods per plant varied from 49.25 (*Kasech*) to 74.50 (*Dz-02-53*) and the number of seeds per pod varied from 50.68 (*Teji*) to 113.27 (*Hora*). The presence of significant genetic variation in the number of pods per plant has also been reported by other authors in chickpeas (Anusha et al., 2020; Tsehaye et al., 2020). The grain yield ranged from 8.14 q/ha (*Acose-dubei*) to 13.22 q/ha (*Hora*), with significant differences among the cultivars ($p < 0.05$). The difference in biomass yield between cultivars *Dz-02-54* (24.48) and *Hora* (36.07) was 11.59 q/ha. Harvest index ranged from 39.42 for the cultivar *Teji* to 60.80 for cultivar *Dz-02-54.*

Genotypic and phenotypic variances and coefficients of variations

The highest $\delta^2$g (42.0) and $\delta^2$p (270.8) were recorded for days for 50% flowering, while the lowest $\delta^2$g was 0.004 for thousand seed weight, and $\delta^2$p (014) was recorded for number of pods per plant. The GCV or PCV were categorized as "high" as categorized by Parameshwarappa et al. (2009) if it is greater than 20%, moderate if it is between 10% and 20%, and low if it is below 10%. GCV (%) varied from the lowest (2.53) for the thousand-seed weight to the highest (22.68) for the number of pods per plant. Number of seeds per plant, days to 90% maturity, and days to germination exhibited low PCV (%), 4.30, 8.17, 8.46, and 9.37, respectively. Plant height was moderate PCV (11.4%), but the other traits had high PCV (Table 8). Similar results have been reported by Raju et al. (2017) and Banik et al. (2018). GCV and PCV were used to measure the variability that exists in a given population under consideration (Falconer and Mackay, 1996). A higher magnitude of difference between GCV and PCV was observed in the number of seeds per plant, indicating that environmental factors had the greatest influence on the phenotypic expression of this trait. The effectiveness of selection in any crop depends on the extent and nature of the phenotypic and genotypic variability present in different agronomic traits within the population (Keneni et al., 2011; Arora, 1991).

Table 8. Genotypic and phenotypic variances, coefficients of variations and heritability

| Traits | $\delta^2$g | $\delta^2$e | $\delta^2$p | GCV (%) | PCV (%) | $h^2$b (%) | GA | GAM |
|---|---|---|---|---|---|---|---|---|
| GD | 0.68 | 0.31 | 0.99 | 7.01 | 8.46 | 82.95 | 1.70 | 14.45 |
| PH | 5.27 | 21.49 | 26.76 | 5.08 | 11.45 | 44.36 | 4.73 | 10.46 |
| DM | 23.70 | 4.78 | 28.48 | 7.45 | 8.17 | 91.22 | 10.03 | 15.35 |
| NPB | 0.28 | 0.72 | 1.00 | 16.03 | 30.36 | 52.78 | 1.09 | 33.01 |
| NSB | 3.40 | 15.45 | 18.85 | 12.47 | 29.37 | 42.45 | 3.80 | 25.68 |
| DF | 42.00 | 228.8 | 270.8 | 10.49 | 26.63 | 39.38 | 13.35 | 21.61 |
| NPP | 0.07 | 0.07 | 0.14 | 22.68 | 32.30 | 70.20 | 0.54 | 46.71 |
| NSP | 7.6 | 9.1 | 26.7 | 8.69 | 4.95 | 1.59 | 7.45 | 8.51 |
| NSPP | 20.83 | 11.9 | 32.72 | 3.43 | 4.30 | 79.77 | 9.40 | 7.07 |
| TSW | 0.004 | 0.29 | 0.294 | 2.53 | 21.69 | 11.66 | 0.13 | 5.21 |
| GY | 7.29 | 25.22 | 32.51 | 19.73 | 41.68 | 47.35 | 5.56 | 40.65 |
| BMY | 18.61 | 93.88 | 112.49 | 14.18 | 34.85 | 40.67 | 8.89 | 29.20 |
| HI | 10.24 | 111.7 | 121.94 | 6.88 | 23.73 | 28.98 | 6.59 | 14.17 |

$\delta^2$g= genotypic variance; $\delta^2$e=environmental variance; $\delta^2$p= phenotypic variance; GCV= genotypic coefficient of variation; PCV= phenotypic coefficient of variation, $hb^2$= broad sense heritability, GA= genetic advance, GAM; genetic advance as percentage of mean, GD= Germination date, PH= Plant height (cm), DF= Days to 50% flowering, NPB= Number of primary branches, NSB= Number of secondary branches, NPP= Number of pods per plant, NSP=Number of seeds per pod, NSPP= Number of seeds per plant, MD= Days to 90% maturity; TSW= Thousand seed weight; GY=Grain yield (kg/ha); BMY= Biomass yield (kg/ha); HI= Harvest index.

Heritability in a broad sense ($h^2$b) ranged from 11.66% for thousand seed weight to 82.95% for days to germination. Heritability is estimated as low (<30%), moderate (30–60%), and high (>60%) (Johnson and Wichern, 1988). Days to 90% maturity, Days to germination, number of seeds per plant, and number of pods per plant all had high $hb^2$, indicating that the traits could be used to select desirable cultivars due to the lower influence of environment on genotypic variation expression (Table 8). Different characters have varying degrees of heritability, which can help improve yield in breeding programs (Wada et al., 2022). Heritability is crucial for predicting the reliability of phenotypic value as an indicator of breeding value (Allard, 1960). Thus, selecting these traits could be important because high $hb^2$ estimates indicate their effectiveness for improvement through selection, as fewer environmental effects are involved. Dev et al. (2017) reported a similar result of high $hb^2$ for days to flowering and days to maturity. Selecting superior individuals based solely on $hb^2$ estimates may not provide evidence for genetic improvement. The $h^2$b estimate, along with the genetic advance, would be more useful in predicting the effectiveness of selecting the best individuals (Jing et al., 2010). Genetic advance as a percentage of the mean (GAM) ranged from 5.21% for thousand seed weight to 46.71% for number of pods per plant (Table 8), signifying that selecting the top 5% of the cultivars could result in an advance of 5.21% to 46.71% over the respective population mean. The GAM was categorized as low (<10%), moderate (10–20%), and high (>20%) (Rao et al., 985). According to this classification, traits such as number of primary branches, number of secondary branches, and number of pods per plant, grain yield, and biomass yield had high genetic advances, implying that progress on improving the evaluated chickpea cultivars could be achieved through simple selection of these traits.

## Conclusion

The results of this study showed significant variation among chickpea cultivars for most of the evaluated traits. The highest mean grain yield was exhibited by the cultivars *Ejeri* (12.0 kg/ha) and *Hora* (11.59 kg/ha) at the Taba site and Gurumo Koysha site, respectively. Based on the cultivar mean performance, from two sites a higher grain yield (11.68 kg/ha) was obtained from the cultivar *Hora*. Significant effects of genotype × location interaction for days to germination, number of seeds per plant, and harvest index indicate the differential performance of genotypes across environments for these traits. The evaluated chickpea cultivars performed better at Taba than at Gurumo-Koysha. At the Taba site, the grain yield of 75% of the cultivars was greater than the overall mean grain yield of cultivars, whereas at the Gurumo-Koysha site, the grain yield of 41.6% of the cultivars was greater than the overall mean grain yield of cultivars. This indicates a greater likelihood of obtaining a high-yielding genotype if it was verified and popularized in the study area. The high heritability and genetic advances recorded for quantitative traits indicated that the evaluated chickpea cultivars had high genotypic variance. The presence of variations in yield and related traits among chickpea cultivars can potentially be exploited for future improvements in chickpea.

## Data availability

All data that support the findings reported in this study are available from the corresponding author upon reasonable request.

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**Conflict of interest**

The authors declare that they have no conflicts of interest.

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