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# Genetic variability and heritability for seed yield and other characters in desi type of chickpea (*Cicer arietium* L.) genotypes

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## ABSTRACT

Chickpea is the major pulse grown in Ethiopia, mainly by subsistence farmers, usually under rain-fed conditions. This study was conducted to determine the variability, heritability, correlations, and path analysis between yield and yield components in 81 desi chickpea (*Cicer arietinum* L.) genotypes. The experiments were conducted at the field area of Jari, Sirinka and Kobo using a simple lattice design with two replications. There were significant genetic differences between genotypes for all characters except, for the number of seeds per pod and number of leaflet studied. This suggested an enormous scope of genotype selection for desirable characters. Broad-sense heritability ranged from 80.00% (pod length) to 99.56% (100- seed weight). High heritability for days to flowering, days to maturity, pod filling period, days to podding, number of pods per plant, 100- seed weight, seed yield, biomass and harvest index with high genetic advance. Estimation of correlation coefficients, except for primary branch and number of seeds per pod a positive correlation with seed yield at phenotypic and genotypic levels. The path coefficient analysis based on seed yield per plant, as a dependent variable, revealed that all other traits, except days to pod and pod filling period exhibited positive direct effects. Biomass, days to maturity and harvest index showed the highest direct influence with 80%, 77%, 35% respectively. Therefore, this research suggests that biomass, days to maturity and harvest index can be good selection criteria for improving seed yield per plant in the Desi-type chickpea.

**Keywords:** Correlation, Environmental variance, Genetic advance, Genetic variability, Heritability.

## INTRODUCTION

Chickpea (*Cicer arietinum* L.) is known in various parts of the world by different names such as Bengal gram, Chickpea or Garbanzo, Chana, Hommes or Hamaz, Nohud or Lablabi and Shimbra in India, Europe, Pakistan, Arabic countries, Turkey, and Ethiopia, respectively. It is self-pollinated diploid (2n = 2x = 16) annual leguminous plant, with a genome size of 738.09 Mbp (Varshney *et al*., 2013), in the family Fabaceae, and subfamily Papilionaceae. It is the third leading legume grain in the world and third in the area and production of pulses following faba bean (*Vicia faba* L.) and common bean (*Phaseolus vulgaris* L.) in Ethiopia. Ethiopia is the leading producer and exporter of chickpea in Africa with productivity of 2 t/ha (CSA, 2021). The crop is grown by subsistence farmers in several regions of the country, usually under rainfed conditions with residual moisture on black *vertisol* soils. The average yield of chickpea in Ethiopia is low compared to other chickpea growing countries. This may be attributed to the lack of high yielding varieties, resistant to diseases and pests, high response to high inputs, and other management practices. Keeping in view these problems, it is of prime importance to evaluate the limiting factors contributing to the growth and yield of chickpea (Geletu and Million, 1996).

Ethiopian farmers have been cultivating chickpea accessions for a long period because of the high potential of genetic diversity, better adaptation and resistance to diseases and insect pests. The diverse agroecology in Ethiopia makes it very suitable for the creation of genetic variation among chickpea farmers' varieties. Exploration of genetic diversity in parental material is important for a successful breeding program (Annicchiarico *et al*., 2018). The study of genetic diversity provides an appropriate basis for the classification of genetic material and information on genetic variability in parental material assists the breeders to identify and select the most suitable types from a mixed population (Agrawal *et al*., 2018). Genetic diversity serves as the most basic source for the production of new and valuable combinations, and measurement of the extent of such variability and its source is, thus, of prime importance in breeding programs (Mahmood *et al*., 2016). Hybridization programme must meet certain requirements in order to produce the desired segregants.

Selection is the fundamental step of breeding (Falconer, 1989). For effective through estimation of genetic parameters, which explain the nature of gene which, actions involved in controlling qualitative traits and determine the effectiveness of different breeding techniques for obtaining genetic gains. Genetic parameters are estimated as variance, coefficient of variance, heritability, genetic advance, correlation studies and path coefficient analysis, which explain the state of a population with respect to breeding objective (Wellmann and Bennewitz, 2019).

Analysis of variability among the traits and the interrelation of certain character with other yield contributing traits are of utmost importance for planning a successful breeding program as it determines its potentiality of genetic improvement (Tiwari, 2019). A correlation study thus provides information on the correlate response to important plant traits and therefore leads to a directional model for yield response. It was found that seed and biological yield per plant were the most important traits for determining the seed yield per hectare in chickpea (Kumar *et al.*, 2019) allowing indirect selection in correlated traits but fails to provide a precise knowledge on relative importance of direct and indirect influences of each component characters to the yield. Path coefficient analysis is used to get more accurate information among variables than correlation coefficient by showing the "path" with which each yield component influences the yield. It evaluates the reason for the link of two variables based on simple correlations among characters and linearity and additively. Kumar *et al.*, (2019) reported that correlation and path coefficient analysis showed that biological yield and harvest index were the major direct contributors to seed yield.

The purpose of this study was to estimate the total genotypic variability, correlations, and path analysis among some important traits for devising selection criteria for improving yield in desi chickpea in the eastern Amhara region of Ethiopia.

## MATERIALS AND METHODS

### Description of Study Sites:

The present study was carried out to seek information on heritable variation and correlation of various characters with seed yield in breeding material for making effective selection of genotypes for yield increments of chickpea during the 2018/19 main cropping season at three locations representing various chickpea growing agro-ecology of Eastern Amhara, region, Ethiopia that represent major agro-ecologies which are potential for the production of chickpea. The three locations were Jari, Sirinka, and Kobo, which are found along the road side from Addis Ababa to Mekele with distance of 437, 508 and of 562 km, respectively. The detailed description of the experimental sites has been described (Table 1)

**Table 1.** Description of the experimental sites.

| Location | Altitude (masl) | Soil type | Average- Rainf all (mm) | Temperature | | Global position | |
|---|---|---|---|---|---|---|---|
| | | | | Min ($^{o}$C) | Max ($^{o}$C) | Latitude | Longitude |
| **Jari** | 1680 | *Vertisol* | 1204.6 | 11.2 | 25.6 | 11$^{0}$21' N | 39$^{0}$38' E |
| **Sirinka** | 1850 | *Eutric fluvisol* | 945 | 13.6 | 27.3 | 11$^{o}$45' N | 39$^{o}$36'E |
| **Kobo** | 1450 | *Eutric fluvisol* | 850 | 15.8 | 29.1 | 11$^{o}$21' N | 39$^{o}$37'E |

*masl = meters above sea level, mm = millimetres, $^{o}$C = degree Celsius*
*Source: Sirinka Agricultural Research Center (SARC)*

### Experimental materials, design and procedure:

The experimental material comprising 81genotypes of desi chickpea including 33 land races, 7 released variety, 40 advance breeding lines. The plant materials were obtained from Debre Zeit Agricultural Research Center, International Crop Research in Semi-arid Tropics (ICRISAT) and Sirinka Agricultural Research Center. Plantings of the genotypes were done in early Mid-August up to the first week of September using a simple lattice design with two replications at each site under rain-fed conditions. Each genotype was planted in a two-row plot with one meter length. Between plant and row distances were maintained at 10 and 30 cm, respectively. The excess plants were thinned out keeping one plant in each hole 15 days after sowing. Recommended cultural practices were adopted to maintain a healthy crop growth under rainfed conditions. The detailed description of the experimental materials is indicated (Table 2).

**Table 2.** Description of chickpea materials

| Trt. | Genotype | Trt. | Genotype | Trt. | Genotype | Trt. | Genotype |
|---|---|---|---|---|---|---|---|
| **1** | IE-16-091 | 22 | IE-16-147 | 43 | ICCMABCA-23 | 64 | ICCX-060045-F3-P152-BP |
| **2** | IE-16-044 | 23 | IE-16-133 | 44 | ICCMABCA-36 | 65 | NATOLI |
| **3** | IE-16-148 | 24 | IE-16-150 | 45 | ICCV-10107 | 66 | DZ-10-11 |
| **4** | IE-16-146 | 25 | IE-16-132 | 46 | ICCX-060045-F3-P113-BP | 67 | ICC-4418 |
| **5** | IE-16-078 | 26 | IE-16-159 | 47 | ICC-6875 | 68 | ICCX-060045-F3-P225-BP |
| **6** | IE-16-072 | 27 | IE-16-156 | 48 | ICCV-09309 | 69 | Kutaye |
| **7** | IE-16-114 | 28 | IE-16-032 | 49 | DZ-2012-CK-0231 | 70 | ICC-1230 |
| **8** | IE-16-110 | 29 | IE-16-069 | 50 | MARIYE | 71 | IE – 16-058 |
| **9** | IE-16-121 | 30 | LOCAL CHECK | 51 | ICCV-4918 | 72 | IE – 16-060 |
| **10** | IE-16-029 | 31 | Fetenech | 52 | ICCV-10 | 73 | MABC-13 |
| **11** | IE-16-125 | 32 | ICC-7413 | 53 | ICCMABCD-21 | 74 | ICCMABCD-6 |
| **12** | IE-16-080 | 33 | DZ-2012-CK-0235 | 54 | ICC-9848 | 75 | MABC-7 |
| **13** | IE-16-115 | 34 | ICC-1882 | 55 | DALOTA | 76 | DZ-2012-CK-0254 |
| **14** | IE-16-066 | 35 | ICCRIL-04-0044 | 56 | IE-16-060 | 77 | MABC-18 |
| **15** | IE-16-030 | 36 | DZ-2012-CK-20115-16-0058 | 57 | ICC-1205 | 78 | ICCV-11108 |
| **16** | IE-16-040 | 37 | ICC-12537 | 58 | ICC-3391 | 79 | ICCMABCD-18 |
| **17** | IE-16-158 | 38 | ICC-11903 | 59 | DZ-2012-CK-240 | 80 | ICCMABCD-7 |
| **18** | IE-16-062 | 39 | ICCV-96836 | 60 | ICCV-4958 | 81 | ICCMABCA-27 |
| **19** | IE-16-149 | 40 | MINJAR | 61 | ICC-15510 | | |
| **20** | IE-16-127 | 41 | ICCX-060045-F3-P139-BP | 62 | DZ-2012-CK-0277 | | |
| **21** | IE-16-120 | 42 | ICC-15614 | 63 | ICCX-060039-F3-P152-BP | | |

Nb: Trt. = Treatment, From Trt. 1-30 and = land race, Marye, Dalota, Natoli, Kutaye, DZ-10-11, Mimjar = variety and the rest are advance breeding line.

**Methods of Data Collection:**

Recording morphological parameters was done following the procedure described in the chickpea descriptor (IBPGR, 1985) with minor modifications. The data were taken on a plot and plant basis. The data on a plant basis were recorded from five plants, from which two harvestable rows were randomly taken and tagged.

**Data collected on Plot Basis:**

Data were recorded on days to 50% flowering, days to podding, days to pod filling, period, days to maturity, 100-seed weight**,** biomass**,** seed yield, and harvest index.

**Data collected on Plant Basis:**

The traits namely plant height; number of leaves let per leaf, number of primary branches, and number of secondary branches, pod length, number of pods per plant, and number of seeds per pod were recorded on plant basis.

**Data analysis:**

All statistical analyses were performed using SAS Computer Statistical Package version 9.2 (SAS Institute Inc., 2008). The analysis of variance and Duncan Multiple Range Test (DMRT) were performed to test differences between means. At maturity, data were recorded for yield and various components. Genetic variability parameters viz., Genotypic (GCV) and phenotypic (PCV) coefficients of variation were computed for all the traits (Singh and Chaudhary, 1985). The GCV and PCV were considered low when less than 10%, moderate when 10 to 20%, and high when greater than 20% as explained by (Deshmukh *et al.*,1986). The Genotypic and phenotypic variance were calculated the procedures suggested by (Miller *et al.*, 1958). The significance of phenotypic correlation coefficients was tested by the formula of (Singh and Chaudhary, 1985). The use of path analysis requires a cause and effect situation among the variables. Path coefficient analysis is calculated using the formula suggested by (Dewey and LU, 1959) to assess direct and indirect effects of different traits on seed yield The estimation of heritability (Hallauer *et al.*, 2010) The heritability estimate was categorized as suggested by (Robinson *et al.,* 1949) (0-30% = low; 31-60% = moderate; above 60% = high). The genetic advances and genetic advance as percent of population mean was also estimated by following the procedure of (Johnson *et al.*, 1955).

## RESULTS

**Analysis of variance:**

Analysis of variance (Table 3) revealed highly significant differences between genotypes for all the characters recorded except the number of seeds per pod and number of leaflet per leaf, indicating the scope for selection of various morphogenetic traits from these highly diversified genotypes. The combined analysis of variance (Table 3) for seed yield exhibited differences P≤0.01 among environments, genotypes, and GEI, indicating differences in environments and the presence of genetic variability among genotypes.

Table 3. Combined mean squares for different sources of variation and the corresponding coefficient of variation (CV) for the 15 traits of chickpea genotypes studied at Jari, Sirinka, and Kobo in 2018.

| Traits | Source of variation | | | | | | |
|---|---|---|---|---|---|---|---|
| | MSL df (2) | MSG Df (80) | MSGL Df (160) | MSBR Df (16) | MSRL Df (2) | MSE Df (224) | CV % |
| **DF** | 154.26** | 102.81** | 9.14** | 2.95 | 4.48 | 2.88 | 3.26 |
| **PFP** | 160.82** | 193.08** | 27.47** | 2.83 | 4.86 | 4.27 | 3.56 |
| **DP** | 147.36** | 105.5** | 9.34** | 3.58 | 6.14 | 2.97 | 2.87 |
| **DM** | 617.09** | 371.76** | 26.72** | 6.18 | 6.77 | 6.54 | 2.32 |
| **NPP** | 7860.66** | 834.85** | 431.44** | 159.71 | 22.51 | 139.39 | 15.57 |
| **NSP** | 0.86** | 0.36** | 0.02$^{ns}$ | 0.03 | 0.04 | 0.02 | 10.74 |
| **HSW** | 34.67** | 336.65** | 7.85** | 1.38 | 3.07 | 1.48 | 5.53 |
| **SY** | 7743928** | 2984367** | 321441.9** | 106840.7 | 78701.3 | 89898.4 | 13.83 |
| **BM** | 31794724** | 8772951** | 1441061** | 402673.7 | 202836 | 391581 | 14.27 |
| **HI** | 43.65ns | 232.08** | 93.36** | 31.25 | 5.85 | 30.09 | 11.05 |
| **PL** | 1.10** | 0.09** | 0.05** | 0.03 | 0.25** | 0.02 | 9.18 |
| **PH** | 1371.67** | 115.07** | 43.45** | 30.36 | 87.45 | 18.13 | 8.20 |
| **PB** | 170.76** | 5.67** | 4.38** | 0.83 | 0.91 | 0.58 | 15.71 |
| **SB** | 48.47** | 31.78** | 13.67** | 2.81 | 1.30 | 1.88 | 15.57 |
| **NLeL** | 6.34* | 5.72** | 0.67$^{ns}$ | 0.79 | 0.59 | 0.76 | 6.27 |

*DF = Days to flowering, PFP = Pod filling period, DP = Days to podding, DM = Days to maturity, NPP = Number of pods per plant, NSP = Number of seeds per pod, HSW = Hundred seed weight, SY = Seed yield, BM = Biomass, HI = Harvest index, PL = Pod length, PH = Plant height, PB = Primary branches, SB = Secondary branches,* NLeL *= number of leaf let per leaf, MSE = Mean square of error, MSL = Mean square by location, MSG = Mean square by genotype, MSGL = Mean square genotype by location interaction, MSBR = Mean square block by replication, MSRL = Mean square replication by location, CV = Coefficient of variation, ns = non - significant and *, ** significant at 5% and 1% probability level, Respectively.*

**Variance components, heritability and genetic advance:**

The estimates of genotypic and phenotypic variance, genotypic and phenotypic coefficient of variability, broad sense heritability and genetic advance expressed as percentage of mean for eighty-one (81) chickpea genotype in fifteen characters are presented in (Table 4). Biomass was found as the maximum variable character with the variability ranging between 1759 to 8141 followed by number of pod per plant (52.1 to 112.4), days to maturity (89.7 to 125.5) and seed yield (705 to 4168). Genotypic and phenotypic variances were high for biomass (8577160.5 – 8968741.50) followed by seed yield per plant with values of (2939417.80 – 89898.4), number of pods per plant (765.16 - 904.55), days to maturity (368.49 - 375.03) and 100- seed weight (335.91 - 337.39). Genotypic coefficients of variation were high (>20) in pod filling period (23.8), number of pods per plant (36.5), number of seed per pod (42.3), 100- seed weight (83.3), seed yield (79.07), biomass (66.79), harvest index (29.7), primary branch (47.3) and secondary branch (63.1), whereas, phenotypic coefficients of variation were high for pod filling period (24.1), number of pod per plant (39.7) number of seed per pod (43.4), 100- seed weight (83.5), seed yield (80.27), biomass (68.29), harvest index (31.7), primary branch (49.8) and secondary branch (65.0) (Table 4).

All the parameter, record maximum broad sense heritability estimate was for 100- seed weight (99.56), days to maturity (98.26 ), pod filling period (97.81 ), days to flowering (97.24 ), days to podding (97.22), seed yield (97.03 ), biomass (95.63 ), number of seed per pod (84.59), secondary branch (90.27), harvest index (87.82), number of leaflet per leaf (87.54), plant height (85.39), number of pods per plant (84.59), primary branch (90.27) and pod length (80%). Estimates of genetic advances (as % of mean) ranged from 30.6% for pod length to 171.2% 100- seed weight. Generally, plant height and secondary branches depicted genetic advance values lower than 20%

and number of seed per pod, pod length, primary branch and number of leaflet per leaf less than 10%. In contrast, pod filling period, days to maturity, number pods per plant, hundred seed weight, biomass, harvest index and seed yield per plant showed relatively high (>25%) genetic advance expectations.

The maximum seed yield was recorded in the genotype ICCMABCA-23, while the minimum was noted in IE-16-080. Day to flowering results revealed significant differences not only for genotypes but also a high magnitude of genotype-environment interaction, reflecting genetic variability in experimental materials as well as the difference in the environmental conditions (Table 3). Two varieties IE-16-156 and Local Check with 43 days to 44 50% flowering were early in flowering whereas DZ-2012-CK-0254 was late in flowering. Days to flowering is mostly used as the basis for determining the maturity. Maturity time of different genotypes varied from 89.7 to 125.2 days. The genotype Local check matured in 89.7 days where as the genotype DZ-2012-CK-0254 matured in 125.2 days.

Plant height ranged from 42.6cm to 67.3cm. The minimum plant height was recorded in IE-16-156 and the maximum plant height was recorded in IE-16-062. Pods per plant ranged from 52.1-112.4. The maximum pods per plant were obtained from the ICC-7413 whereas the minimum pods per plant were recorded from ICCV- 4918. Biomass ranged from 1759g to 8141kg/ha. Minimum biological yield was obtained from ICCV- 4918, whereas genotype ICCMABCA-23 produced maximum biological yield 8141kg/ha, as well as Harvest index of genotype were ranged from 36 to 69%. The highest harvest index was recorded from ICCMABCA-36 and the lowest was recorded in MABC-7. The100- seed weight (41.2g) was also a highly variable character and the largest 100 seed weight was recorded from DZ-2012-CK-0235 and the minimum from IE-16-078 (11.6g) has been described (Table 5).

**Table 4.** Genetic parameters of yield and other traits from the combined ANOVA of 81 desi-type chickpea genotypes grown at Jari, Sirinka, and Kobo in the eastern Amhara region, Ethiopia

| Character | Mean | Range | $V^2g$ | $V^2e$ | $V^2p$ | GCV | PVC | $H^2$ | GA | GA% |
|---|---|---|---|---|---|---|---|---|---|---|
| DF | 52.1 | 43.3-64.7 | 101.37 | 2.88 | 104.25 | 19.3 | 19.6 | 0.97 | 20.40 | 39.2 |
| PFP | 58.0 | 40.3-72.2 | 190.95 | 4.27 | 195.22 | 23.8 | 24.1 | 0.98 | 28.21 | 48.6 |
| DP | 60.1 | 51-72.8 | 104.02 | 2.97 | 106.99 | 17.0 | 17.2 | 0.97 | 20.67 | 34.4 |
| DM | 110.1 | 89.7-125.2 | 368.49 | 6.54 | 375.03 | 17.4 | 17.6 | 0.98 | 39.10 | 35.5 |
| NPP | 75.8 | 52.1-112.4 | 765.16 | 139.39 | 904.55 | 36.5 | 39.7 | 0.85 | 52.66 | 69.5 |
| NSP | 1.4 | 1-2 | 0.35 | 0.02 | 0.37 | 42.3 | 43.4 | 0.95 | 1.19 | 85.0 |
| HSW | 22.0 | 11.6- 41.2 | 335.91 | 1.48 | 337.39 | 83.3 | 83.5 | 1.00 | 37.84 | 172 |
| SY | 2168.2 | 705-4168 | 2939417.80 | 89898.40 | 3029316.20 | 79.07 | 80.27 | 0.97 | 3477.85 | 160.40 |
| BM | 4384.8 | 1759-8141 | 8577160.50 | 391581.00 | 8968741.50 | 66.79 | 68.29 | 0.96 | 5922.49 | 135.07 |
| HI | 49.6 | 36-69 | 217.04 | 30.09 | 247.13 | 29.7 | 31.7 | 0.88 | 28.50 | 57.5 |
| PL | 1.7 | 1.3-2 | 0.08 | 0.02 | 0.10 | 16.6 | 18.6 | 0.80 | 0.52 | 30.6 |
| PH | 51.9 | 42.6-67.3 | 106.01 | 18.13 | 124.14 | 19.8 | 21.5 | 0.85 | 19.51 | 37.6 |
| PB | 4.9 | 2.8-8.1 | 5.38 | 0.58 | 5.96 | 47.3 | 49.8 | 0.90 | 4.53 | 92.5 |
| SB | 8.8 | 4-15.3 | 30.84 | 1.88 | 32.72 | 63.1 | 65.0 | 0.94 | 11.08 | 125.9 |
| NLeL | 13.9 | 11.6-15.6 | 5.34 | 0.76 | 6.10 | 16.6 | 17.8 | 0.88 | 4.48 | 32.2 |

*DF = Days to flowering, PFP = Pod filling period, DP = Days to podding, DM = Days to maturity, NPP = Number of pods per plant, NSP = Number of seeds per pod, HSW = Hundred seed weight, SY = Seed yield, BM = Biomass, HI = Harvest index, PL = Pod length, PH = Plant height, PB = Primary branches, SB = Secondary branches,* NLeL = *number of leaf let per leaf.*

$V^2g$ = genotypic variance, $V^2e$ = environmental variance, $V^2p$ = Phenotypic variance, GCV = Genotypic coefficients of variation, PCV = Phenotypic coefficients of variation, $H^2$ = heritability, GA = genetic advance, GA% = genetic advance in percent.

**Table 5.** Mean performance of yield (kg/ha) and yield-related traits of 81 desi-type chickpea genotypes grown in Jari, Sirinka and Kobo

| Trt. | DF | PFP | DP | DM | NPP | NSP | HSW(g) | SY(kg/ha) | BM(kg/ha) | HI | PL(cm) | PH(cm) | PB | SB | NLeL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $45.5^{g-i}$ | $51.5^{cd}$ | $53.5^{d-g}$ | $97.0^{j-l}$ | $60.1^{c-h}$ | $1.6^{g-k}$ | $13.1^{e-l}$ | $1313.2^{ij}$ | $3122.7^{f-j}$ | $48.1^{p-y}$ | $1.3^{d}$ | $45.9^{z-e}$ | $6.9^{b-d}$ | $6.2^{a-g}$ | $11.7^{b}$ |
| 2 | $47.3^{d-g}$ | $53.5^{z-c}$ | $55.8^{z-c}$ | $100.8^{e-i}$ | $79.5^{i-x}$ | $1.8^{b-g}$ | $13.8^{d-h}$ | $2435.2^{k-q}$ | $5473.3^{d-h}$ | $44.6^{u-e}$ | $1.3^{cd}$ | $52.4^{f-t}$ | $5.3^{i-q}$ | $9.4^{k-p}$ | $12.4^{w-b}$ |
| 3 | $53.8^{k-r}$ | $54.5^{x-b}$ | $61.8^{l-q}$ | $108.3^{u-y}$ | $70.6^{r-e}$ | $1.8^{c-g}$ | $12.9^{f-m}$ | $1706^{y-g}$ | $4083.0^{t-b}$ | $41.9^{y-g}$ | $1.7^{j-x}$ | $47.0^{v-e}$ | $3.7^{c-h}$ | $8.4^{o-v}$ | $15.2^{a-d}$ |
| 4 | $48.2^{a-f}$ | $547^{x-b}$ | $56.2^{y-c}$ | $102.8^{b-f}$ | $58.4^{d-h}$ | $1.8^{c-h}$ | $12.2^{j-m}$ | $1349.7^{h-j}$ | $2442.8^{j-m}$ | $55.1^{c-n}$ | $1.6^{x-a}$ | $46.3^{x-e}$ | $3.9^{z-g}$ | $7.3^{s-c}$ | $13.8^{j-s}$ |
| 5 | $45.7^{g-i}$ | $57.2^{s-w}$ | $53.7^{d-f}$ | $102.8^{b-f}$ | $72.2^{p-c}$ | $1.8^{b-f}$ | $11.6^{m}$ | $1960.7^{t-z}$ | $3213.2^{f-i}$ | $61.0^{bc}$ | $1.5^{x-a}$ | $49.7^{n-b}$ | $4.7^{o-a}$ | $7.6^{q-a}$ | $12.6^{v-b}$ |
| 6 | $48.0^{b-f}$ | $59.8^{n-q}$ | $56.2^{y-c}$ | $107.8^{v-y}$ | $58.3^{d-h}$ | $1.8^{b-f}$ | $12.3^{i-m}$ | $1622.7^{z-i}$ | $4310.7^{q-z}$ | $38.5^{e-g}$ | $1.4^{a-d}$ | $45.1^{b-e}$ | $6.8^{b-e}$ | $7.3^{s-c}$ | $13.1^{r-w}$ |
| 7 | $49.8^{w-b}$ | $50.3^{p-s}$ | $57.8^{u-y}$ | $109.2^{t-x}$ | $69.6^{s-e}$ | $1.8^{b-f}$ | $13.1^{e-l}$ | $1709.3^{y-g}$ | $3199.8^{f-i}$ | $55.1^{c-n}$ | $1.6^{x-a}$ | $52.1^{g-t}$ | $4.5^{p-c}$ | $6.6^{w-f}$ | $13.7^{l-t}$ |
| 8 | $47.3^{d-g}$ | $55.3^{w-a}$ | $55.3^{a-d}$ | $102.7^{c-f}$ | $69.4^{t-e}$ | $1.8^{c-h}$ | $13.6^{d-i}$ | $1840.7^{v-b}$ | $3329.3^{d-i}$ | $58.3^{c-g}$ | $1.5^{y-c}$ | $49.0^{q-c}$ | $4.1^{w-g}$ | $8.0^{p-w}$ | $13.0^{r-x}$ |
| 9 | $48.2^{a-f}$ | $54.7^{x-b}$ | $56.2^{y-c}$ | $102.8^{b-f}$ | $69.5^{s-e}$ | $1.9^{a-e}$ | $13.3^{e-k}$ | $1755.5^{x-f}$ | $4415.3^{n-w}$ | $40.3^{c-g}$ | $1.7^{l-y}$ | $48.0^{s-d}$ | $4.3^{u-e}$ | $7.4^{r-c}$ | $12.0^{t-a}$ |
| 10 | $44.0^{ij}$ | $47.5^{gh}$ | $51.7^{gh}$ | $91.5^{m}$ | $74.1^{o-b}$ | $1.8^{b-g}$ | $14.3^{c-e}$ | $2400.8^{k-r}$ | $4114.7^{s-b}$ | $58.5^{c-f}$ | $1.4^{b-d}$ | $49.9^{m-b}$ | $3.6^{d-i}$ | $6.4^{z-g}$ | $11.8^{ab}$ |
| 11 | $46.5^{f-h}$ | $52.5^{b-d}$ | $54.5^{c-e}$ | $99.0^{h-j}$ | $79.2^{i-y}$ | $1.6^{h-l}$ | $13.2^{e-k}$ | $2432.8^{k-q}$ | $4988.5^{g-q}$ | $49.0^{n-w}$ | $1.5^{x-b}$ | $51.2^{i-w}$ | $5.8^{f-l}$ | $7.7^{q-a}$ | $12.6^{u-b}$ |
| 12 | $47.2^{d-g}$ | $58.5^{q-u}$ | $55.2^{a-d}$ | $105.7^{z-b}$ | $53.2^{gh}$ | $1.8^{b-g}$ | $13.7^{d-i}$ | $705.3^{l}$ | $1790.0^{m}$ | $38.5^{e-g}$ | $1.6^{p-y}$ | $46.4^{w-e}$ | $7.4^{a-c}$ | $7.5^{r-a}$ | $12.9^{s-y}$ |
| 13 | $47.0^{d-g}$ | $51.3^{c-e}$ | $54.8^{b-d}$ | $98.3^{i-k}$ | $62.9^{a-h}$ | $1.8^{d-i}$ | $12.4^{j-m}$ | $1134.7^{jk}$ | $2405.3^{k-m}$ | $49.9^{m-v}$ | $1.6^{u-a}$ | $49.4^{p-b}$ | $4.5^{p-d}$ | $5.7^{d-g}$ | $12.4^{v-b}$ |
| 14 | $55.3^{e-l}$ | $62.5^{i-l}$ | $63.7^{e-k}$ | $117.8^{g-j}$ | $63.1^{a-h}$ | $1.7^{e-j}$ | $13.5^{d-j}$ | $2077.2^{r-x}$ | $3487.5^{a-h}$ | $60.9^{c-d}$ | $1.7^{k-y}$ | $53.5^{e-q}$ | $4.3^{t-e}$ | $9.8^{j-o}$ | $15.1^{a-e}$ |
| 15 | $51.0^{t-v}$ | $58.8^{q-t}$ | $59.0^{s-u}$ | $109.8^{r-v}$ | $85.4^{e-p}$ | $1.4^{n-q}$ | $14.4^{c-e}$ | $2119.7^{q-w}$ | $4457.2^{m-w}$ | $47.6^{q-z}$ | $1.8^{d-t}$ | $61.1^{b}$ | $4.1^{x-g}$ | $10.5^{g-k}$ | $14.2^{e-p}$ |
| 16 | $48.5^{z-e}$ | $55.2^{w-a}$ | $56.5^{x-b}$ | $103.7^{a-e}$ | $66.7^{x--f}$ | $1.8^{d-i}$ | $12.5^{h-m}$ | $1774.2^{x-e}$ | $3603.5^{z-g}$ | $50.0^{l-u}$ | $1.5^{y-b}$ | $50.9^{i-x}$ | $5.0^{l-v}$ | $8.1^{p-w}$ | $12.5^{v-b}$ |
| 17 | $47.7^{c-f}$ | $40.3^{j}$ | $55.3^{a-d}$ | $91.5^{m}$ | $62.7^{b-h}$ | 1.7e-j | $13.1^{e-l}$ | $1390.7^{g-j}$ | $3128.3^{f-j}$ | $45.3^{t-d}$ | $1.7^{n-y}$ | $47.6^{t-d}$ | $5.5^{g-o}$ | $6.6^{w-f}$ | $13.1^{q-w}$ |
| 18 | $55.5^{e-l}$ | $57.3^{r-w}$ | $63.5^{e-l}$ | $112.8^{m-q}$ | $71.5^{q-d}$ | 1.8b-g | $13.8^{d-h}$ | $1877.7^{u-a}$ | $4568.7^{l-v}$ | $41.6^{z-g}$ | $1.8^{d-t}$ | $67.3^{a}$ | $4.2^{v-f}$ | $6.9^{v-d}$ | $15.2^{a-d}$ |
| 19 | $44.8^{h-j}$ | $53.5^{z-c}$ | $52.7^{e-h}$ | $98.3^{i-k}$ | $59.2^{c-h}$ | 1.9ab | $12.0^{k-m}$ | $1516.3^{b-i}$ | $3296.2^{e-i}$ | $48.9^{n-w}$ | $1.5^{y-b}$ | $42.7^{de}$ | $8.1^{a}$ | $5.6^{d-g}$ | $12.6^{u-b}$ |
| 20 | $47.0^{d-g}$ | $55.0^{w-a}$ | $55.0^{a-d}$ | $102^{c-g}$ | $71.6^{q-d}$ | $1.5^{k-o}$ | $12.8^{g-m}$ | $1525.7^{b-i}$ | $3366.2^{c-h}$ | $46.6^{r-b}$ | $1.5^{y-b}$ | $50.9^{i-x}$ | $5.4^{g-o}$ | $7.1^{u-d}$ | $13.2^{p-w}$ |
| 21 | $49.8^{w-b}$ | $49.0^{e-g}$ | $57.5^{u-z}$ | $98.8^{h-j}$ | $67.9^{v-e}$ | $1.7^{f-k}$ | $13.4^{e-j}$ | $1640.8^{z-i}$ | $3641.0^{y-g}$ | $45.6^{s-d}$ | $1.6^{r-z}$ | $47.8^{s-d}$ | $6.1^{d-j}$ | $7.5^{r-a}$ | $13.3^{o-w}$ |
| 22 | $48.7^{y-e}$ | $55.8^{w-z}$ | $56.7^{w-b}$ | $104.5^{z-c}$ | $60.6^{c-h}$ | $1.8^{c-g}$ | $13.4^{e-j}$ | $1589.7^{a-i}$ | $2879.7^{h-k}$ | $54.8^{d-n}$ | $1.6^{u-a}$ | $47.1^{u-e}$ | $6.1^{d-i}$ | $6.5^{x-g}$ | $13.2^{q-w}$ |
| 23 | $48.5^{z-e}$ | $55.3^{w-a}$ | $56.5^{x-b}$ | $103.8^{a-d}$ | $84.5^{f-q}$ | $1.9^{a-d}$ | $13.1^{e-l}$ | $2201.8^{o-u}$ | $4322.2^{p-y}$ | $51.5^{h-t}$ | $1.6^{w-a}$ | $48.9^{q-c}$ | $4.7^{o-b}$ | $6.9^{v-e}$ | $13.4^{n-v}$ |
| 24 | $50.2^{w-z}$ | $56.2^{u-y}$ | $58.2^{u-x}$ | $106.3^{x-a}$ | $82.7^{g-t}$ | $1.4^{l-o}$ | $14.0^{c-g}$ | $1996.7^{s-y}$ | $4101.8^{t-b}$ | $49.0^{n-w}$ | $1.7^{m-y}$ | $52.6^{f-s}$ | $4.4^{q-d}$ | $8.0^{p-y}$ | $13.2^{q-w}$ |
| 25 | $45.7^{g-i}$ | $54.0^{y-b}$ | $53.7^{d-f}$ | $99.7^{g-j}$ | $82.9^{g-s}$ | $1.7^{d-i}$ | $11.8^{lm}$ | $2358.2^{l-r}$ | $4674.5^{j-u}$ | $50.9^{j-t}$ | $1.5^{y-b}$ | $51.3^{i-v}$ | $5.0^{l-w}$ | $12.0^{e-g}$ | $11.6^{b}$ |
| 26 | $47.0^{d-g}$ | $48.7^{fg}$ | $54.8^{b-d}$ | $95.7^{kl}$ | $67.2^{w-e}$ | $1.6^{g-k}$ | $12.3^{i-m}$ | $2430.2^{k-q}$ | $4587.2^{l-v}$ | $53.9^{e-p}$ | $1.6^{s-a}$ | $50.6^{k-z}$ | $4.2^{u-e}$ | $8.0^{p-x}$ | $12.4^{w-b}$ |
| 27 | $43.3^{j}$ | $51.2^{c-e}$ | $51.0^{h}$ | $94.5^{l}$ | $88.4^{d-n}$ | $1.9^{a-c}$ | $12.8^{f-m}$ | $2522^{i-o}$ | $5357.0^{e-j}$ | $47.2^{q-a}$ | $1.6^{w-a}$ | $42.6^{e}$ | $5.0^{l-v}$ | $6.4^{y-g}$ | $11.9^{ab}$ |

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| **28** | 51.3$^{s-w}$ | 50.2$^{d-f}$ | 59.2$^{s-u}$ | 101.5$^{d-g}$ | 74.5$^{n-b}$ | 1.6$^{i-m}$ | 14.2$^{c-f}$ | 1793.3$^{w-d}$ | 3826.0$^{w-f}$ | 46.7$^{r-a}$ | 1.6$^{o-y}$ | 54.3$^{d-o}$ | 3.9$^{b-g}$ | 12.0$^{e-g}$ | 14.5$^{b-m}$ |
| **29** | 53.2$^{m-s}$ | 56.0$^{v-y}$ | 61.2$^{m-r}$ | 109.2$^{t-x}$ | 97.1$^{c-f}$ | 2.0$^{a}$ | 14.2$^{c-f}$ | 2655.5$^{g-m}$ | 4913$^{g-r}$ | 54.1$^{e-p}$ | 1.6$^{t-a}$ | 58.6$^{b-d}$ | 4.4$^{s-d}$ | 7.5$^{r-a}$ | 14.9$^{a-h}$ |
| **30** | 43.5$^{j}$ | 46.2$^{hi}$ | 51.3$^{h}$ | 89.7$^{m}$ | 78.6$^{k-y}$ | 1.6$^{i-m}$ | 13.4$^{e-k}$ | 2388.2$^{l-r}$ | 4952$^{g-q}$ | 48.4$^{o-x}$ | 1.0$^{n-y}$ | 44.5$^{c-e}$ | 3.2$^{f-i}$ | 8.0$^{p-z}$ | 11.9$^{y-b}$ |
| **31** | 48.3$^{z-f}$ | 58.5$^{q-u}$ | 56.3$^{x-c}$ | 106.8$^{w-z}$ | 80.2$^{i-w}$ | 1.3$^{p-u}$ | 20.8$^{a}$ | 2701.3$^{g-j}$ | 5185.0$^{e-l}$ | 51.7$^{h-s}$ | 1.6$^{v-a}$ | 50.8$^{i-x}$ | 5.1$^{k-u}$ | 9.8$^{j-o}$ | 13.1$^{r-w}$ |
| **32** | 52.7$^{o-t}$ | 67.0$^{cd}$ | 60.8$^{n-s}$ | 119.7$^{e-g}$ | 112.4$^{a}$ | 1.0$^{w}$ | 33.6$^{f-i}$ | 3376.5$^{cd}$ | 6696.3$^{bc}$ | 50.4$^{k-u}$ | 1.7$^{k-y}$ | 54.5$^{d-n}$ | 2.8$^{i}$ | 11.0$^{f-j}$ | 14.1$^{g-q}$ |
| **33** | 54.0$^{j–r}$ | 65.7$^{d-f}$ | 62.3$^{j-p}$ | 119.7$^{e-g}$ | 81.8$^{h-u}$ | 1.1$^{u-w}$ | 41.2$^{a}$ | 2541.3$^{h-o}$ | 4681.2$^{j-u}$ | 54.1$^{e-p}$ | 1.8$^{f-u}$ | 57.9$^{b-e}$ | 3.7$^{c-i}$ | 13.9$^{a-c}$ | 14.6$^{a-k}$ |
| **34** | 63.7$^{a}$ | 59.2$^{p-s}$ | 71.8$^{a}$ | 122.8$^{a-d}$ | 100.9$^{a-d}$ | 1.1$^{u-w}$ | 17.6$^{b}$ | 2259.7$^{n-t}$ | 4592.2$^{k-v}$ | 50.0$^{l-u}$ | 1.6$^{u-a}$ | 52.4$^{f-t}$ | 4.7$^{o-b}$ | 8.7$^{m-t}$ | 15.6$^{a}$ |
| **35** | 54.7$^{g-n}$ | 62.8$^{g-l}$ | 62.7$^{g-n}$ | 117.5$^{g-k}$ | 79.6$^{i-x}$ | 1.0$^{w}$ | 26.4$^{v-w}$ | 1883.3$^{u-a}$ | 3984.8$^{u-e}$ | 47.5$^{q-a}$ | 1.8$^{a-n}$ | 45.6$^{a-e}$ | 4.5$^{p-d}$ | 11.1$^{f-j}$ | 15.1$^{a-e}$ |
| **36** | 52.2$^{r-u}$ | 56.0$^{v-y}$ | 60.2$^{q-t}$ | 108.2$^{u-x}$ | 68.7$^{u-e}$ | 1.1$^{u-w}$ | 36.2$^{b-d}$ | 1849.5$^{v-b}$ | 4294.8$^{r-z}$ | 43.4$^{w-f}$ | 1.9$^{a-l}$ | 51.5$^{i-v}$ | 5.2$^{j-s}$ | 5.7$^{d-g}$ | 14.6$^{a-k}$ |
| **37** | 55.8$^{d-i}$ | 59.2$^{p-s}$ | 63.8$^{d-j}$ | 115$^{j-m}$ | 53.4$^{f-h}$ | 1.3$^{p-t}$ | 33.9$^{f-h}$ | 803.7$^{kl}$ | 2072.3$^{lm}$ | 38.9$^{e-g}$ | 1.7$^{g-v}$ | 50.9$^{i-x}$ | 6.0$^{e-k}$ | 4.9$^{gh}$ | 14.8$^{a-i}$ |
| **38** | 58$^{bc}$ | 54.7$^{x-b}$ | 66.0$^{bc}$ | 112.7$^{m-r}$ | 74.7$^{n-b}$ | 1.2$^{q-v}$ | 15.3$^{c}$ | 1566.7$^{a-i}$ | 4011.3$^{u-d}$ | 40.4$^{b-g}$ | 1.6$^{t-a}$ | 44.4$^{c-e}$ | 4.9$^{m-x}$ | 7.4$^{r-b}$ | 15.1$^{a-g}$ |
| **39** | 64.3$^{a}$ | 58.5$^{q-u}$ | 72.3$^{a}$ | 122.8$^{a-d}$ | 87.7$^{d-n}$ | 1.3$^{p-u}$ | 18.8$^{b}$ | 3499.3$^{bc}$ | 7316.7$^{b}$ | 47.1$^{q-a}$ | 1.8$^{a-m}$ | 60.0$^{bc}$ | 5.0$^{l-v}$ | 15.3$^{a}$ | 14.5$^{b-m}$ |
| **40** | 57.7$^{b-d}$ | 62.3$^{j-m}$ | 65.7$^{cd}$ | 120$^{e-g}$ | 83.8$^{f-r}$ | 1.3$^{p-s}$ | 21.5$^{z-a}$ | 3225.2$^{c-e}$ | 4927.8$^{g-r}$ | 65.4$^{ab}$ | 1.7$^{k-y}$ | 54.7$^{d-l}$ | 4.7$^{o-b}$ | 13.3$^{c-e}$ | 15.2$^{a-c}$ |
| **41** | 56.2$^{c-i}$ | 61.8$^{k-o}$ | 64.2$^{c-i}$ | 118$^{g-i}$ | 78.2$^{k-y}$ | 1.3$^{p-u}$ | 31.4$^{l-n}$ | 3065.3$^{d-f}$ | 5877.3$^{de}$ | 52.3$^{f-r}$ | 1.9$^{a-c}$ | 53.5$^{e-q}$ | 5.7$^{f-m}$ | 8.0$^{p-y}$ | 14.4$^{c-n}$ |
| **42** | 55.7$^{e-k}$ | 57.2$^{s-w}$ | 63.7$^{e-k}$ | 112.8$^{m-q}$ | 60.3$^{c-h}$ | 1.2$^{r-w}$ | 17.8$^{b}$ | 1465$^{d-j}$ | 3776.2$^{w-f}$ | 38.2$^{fg}$ | 1.7$^{j-y}$ | 49.1$^{p-c}$ | 5.8$^{f-l}$ | 8.8$^{m-s}$ | 14.2$^{e-p}$ |
| **43** | 49.5$^{w-c}$ | 64.3$^{e-j}$ | 57.5$^{u-z}$ | 113.8$^{l-p}$ | 104.5$^{ab}$ | 1.3$^{p-u}$ | 28.8$^{p-r}$ | 4168.2$^{a}$ | 8140.8$^{a}$ | 51.2$^{i-t}$ | 1.8$^{a-p}$ | 52.5$^{f-s}$ | 3.8$^{c-g}$ | 11.8$^{e-h}$ | 13.7$^{k-s}$ |
| **44** | 56.3$^{c-h}$ | 54.3$^{x-b}$ | 64.3$^{c-h}$ | 110.7$^{q-v}$ | 95.7$^{c-g}$ | 1.2$^{s-w}$ | 36.4$^{bc}$ | 4158.2$^{a}$ | 6090.7$^{cd}$ | 69.2$^{a}$ | 2.0$^{a-c}$ | 57.1$^{b-f}$ | 5.2$^{k-t}$ | 15.1$^{ab}$ | 14.1$^{f-q}$ |
| **45** | 54.8$^{f-m}$ | 57.3$^{r-w}$ | 62.8$^{f-m}$ | 112.2$^{m-s}$ | 92.3c-i | 1.4n-q | 32.2j-m | 38.27.2$^{ab}$ | 6746.3$^{bc}$ | 57.2$^{c-i}$ | 1.9$^{a-f}$ | 56.9$^{b-g}$ | 5.1$^{k-u}$ | 14.9$^{ab}$ | 14.9$^{a-h}$ |
| **46** | 56.7$^{c-f}$ | 59.7$^{o-r}$ | 64.7$^{c-f}$ | 116.3$^{h-l}$ | 91.1c-k | 1.0w | 32.4i-l | 2334.7$^{m-s}$ | 4381.8$^{o-x}$ | 53.9$^{e-p}$ | 1.9$^{a-e}$ | 55.3c-k | 4.4s-d | 12.3$^{d-f}$ | 15.0$^{a-g}$ |
| **47** | 56.2$^{c-i}$ | 63.7$^{f-k}$ | 64.2$^{c-i}$ | 119.8$^{e-g}$ | 82.1h-u | 1.0w | 26.0w | 2538.2$^{h-o}$ | 5455.8$^{d-i}$ | 46.6$^{r-b}$ | 1.8$^{a-o}$ | 52.6f-s | 4.8n-z | 13.3$^{c-e}$ | 15.0$^{a-g}$ |
| **48** | 56.5$^{c-f}$ | 51.3$^{c-e}$ | 64.5$^{c-g}$ | 107.8$^{v-y}$ | 76.3m-a | 1.4o-r | 27.8r-v | 1668.8$^{y-h}$ | 3294.8$^{e-i}$ | 51.3$^{i-t}$ | 1.9$^{a-k}$ | 53.9d-p | 6.2d-g | 8.1$^{p-w}$ | 14.6$^{b-m}$ |
| **49** | 56.8$^{c-e}$ | 40.3$^{j}$ | 64.3$^{c-h}$ | 97.2$^{j-l}$ | 71.3q-e | 1.1w | 28.2p-t | 1840.7$^{v-b}$ | 4053.8$^{t-c}$ | 45.7$^{s-d}$ | 1.9$^{a-d}$ | 52.5f-s | 5.3i-r | 10.1$^{i-n}$ | 15.0$^{a-g}$ |
| **50** | 52.5$^{p-u}$ | 65.0$^{d-h}$ | 60.1$^{o-s}$ | 117.5$^{g-k}$ | 81.4$^{h-u}$ | 1.3$^{p-u}$ | 26.8$^{t-w}$ | 2946.5$^{e-g}$ | 6090.3$^{cd}$ | 48.3$^{o-x}$ | 1.8$^{a-m}$ | 50.7$^{j-y}$ | 4.8$^{m-y}$ | 9.7$^{j-o}$ | 14.3$^{c-n}$ |
| **51** | 54.8$^{f-m}$ | 59.8$^{n-q}$ | 62.8$^{f-m}$ | 114.7$^{k-n}$ | 52.1$^{h}$ | 1.1$^{t-w}$ | 23.1$^{x}$ | 843.3$^{kl}$ | 1758.5$^{m}$ | 47.5$^{q-a}$ | 1.8$^{b-q}$ | 52.0$^{g-t}$ | 6.6$^{c-f}$ | 5.9$^{b-g}$ | 14.1$^{g-q}$ |
| **52** | 52.8$^{n-t}$ | 56.7$^{t-x}$ | 60.8$^{n-s}$ | 109.5$^{s-w}$ | 66.3$^{x-g}$ | 1.3$^{p-t}$ | 18.6$^{b}$ | 1417$^{f-j}$ | 2806.7$^{h-k}$ | 52.1$^{g-r}$ | 1.8$^{a-l}$ | 48.3$^{r-d}$ | 4.7$^{o-b}$ | 8.3$^{o-v}$ | 14.4$^{c-m}$ |
| **53** | 50.0$^{w-a}$ | 58.7$^{q-t}$ | 58.0$^{u-y}$ | 108.2$^{u-x}$ | 63.1$^{a-h}$ | 1.1$^{t-w}$ | 28.3$^{p-s}$ | 816.8$^{kl}$ | 1887.0$^{m}$ | 44.23$^{u-f}$ | 2.0$^{ab}$ | 51.1$^{i-x}$ | 5.6$^{g-n}$ | 9.4$^{k-p}$ | 13.8$^{i-s}$ |
| **54** | 59.5$^{b}$ | 65.2$^{d-g}$ | 67.7$^{b}$ | 124.7$^{ab}$ | 81.6$^{h-u}$ | 1.2$^{q-v}$ | 28.0$^{q-u}$ | 2437.8$^{k-q}$ | 4998.8$^{g-q}$ | 49.0$^{n-w}$ | 1.9$^{a-j}$ | 50.8$^{j-y}$ | 6.1$^{d-i}$ | 11.0$^{f-j}$ | 15.6$^{a}$ |
| **55** | 54.5$^{i-o}$ | 69.0$^{bc}$ | 62.5$^{h-o}$ | 123.5$^{a-c}$ | 79.4$^{i-x}$ | 1.0$^{w}$ | 34.6$^{e-g}$ | 3378.8$^{cd}$ | 5853.5$^{d-f}$ | 57.7$^{c-h}$ | 1.9$^{a-i}$ | 57.5$^{b-e}$ | 5.6$^{g-o}$ | 12.2$^{d-f}$ | 14.2$^{e-p}$ |
| **56** | 46.8$^{e-g}$ | 72$^{a}$ | 54.8$^{b-d}$ | 118.8$^{f-i}$ | 76.2$^{m-a}$ | 1.2$^{q-v}$ | 14.4$^{c-e}$ | 1845.7$^{v-b}$ | 3956.0$^{v-e}$ | 46.2$^{r-d}$ | 1.9$^{a-l}$ | 54.7$^{d-m}$ | 5.5$^{g-o}$ | 7.4$^{r-b}$ | 14.7$^{a-j}$ |

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| **57** | $56.8^{c-e}$ | $64.8^{d-i}$ | $64.8^{c-e}$ | $121.7^{c-f}$ | $78.8^{j-y}$ | $1.4^{o-r}$ | $29.4^{op}$ | $2573.8^{h-n}$ | $4762.3^{h-t}$ | $56.2^{c-l}$ | $2.0^{a}$ | $55.6^{c-i}$ | $4.0^{x-g}$ | $6.9^{v-d}$ | $15.0^{a-g}$ |
| **58** | $52.3^{q-v}$ | $62.5^{i-l}$ | $60.3^{p-t}$ | $114.8^{k-n}$ | $103.9^{a-c}$ | $1.3^{p-t}$ | $35.4^{c-e}$ | $3789.5^{b}$ | $6768.5^{bc}$ | $56.2^{c-k}$ | $1.9^{a-j}$ | $55.6^{c-j}$ | $2.9^{hi}$ | $10.4^{h-l}$ | $14.2^{d-o}$ |
| **59** | $51.0^{t-v}$ | $63.3^{f-k}$ | $59.0^{s-u}$ | $114.3^{l-o}$ | $86.4^{e-o}$ | $1.3^{p-t}$ | $26.7^{u-w}$ | $2986.2^{e-g}$ | $7118.3^{b}$ | $42.5^{x-g}$ | $1.7^{l-y}$ | $50.2^{m-a}$ | $4.0^{y-g}$ | $8.4^{o-v}$ | $14.6^{b-l}$ |
| **60** | $50.5^{v-x}$ | $61.5^{k-p}$ | $58.5^{t-w}$ | $112^{n-t}$ | $77.5^{l-y}$ | $1.3^{p-u}$ | $35.3^{c-e}$ | $2167.2^{p-v}$ | $5150.5^{f-m}$ | $43.7^{v-f}$ | $1.9^{a-l}$ | $60.6^{b}$ | $4.2^{u-e}$ | $8.1^{p-w}$ | $13.6^{m-u}$ |
| **61** | $56.3^{c-h}$ | $58.3^{q-v}$ | $64.3^{c-h}$ | $1147^{k-n}$ | $93.9^{c-h}$ | $1.0^{w}$ | $29.3^{o-q}$ | $2840.8^{f-i}$ | $5068.5^{g-o}$ | $56.3^{c-k}$ | $1.8^{b-r}$ | $54.8^{d-l}$ | $3.7^{c-i}$ | $10.2^{i-m}$ | $13.8^{j-s}$ |
| **62** | $50.7^{u-x}$ | $52.3^{b-d}$ | $58.7^{t-v}$ | $103^{b-f}$ | $81.2^{h-v}$ | $1.3^{p-t}$ | $28.5^{p-r}$ | $2497.3^{j-p}$ | $4235.0^{r-z}$ | $58.1^{c-g}$ | $1.8^{a-l}$ | $51.2^{i-x}$ | $3.7^{c-h}$ | $11.6^{f-i}$ | $13.2^{p-w}$ |
| **63** | $52.7^{o-t}$ | $72.2^{a}$ | $60.8^{n-s}$ | $124.3^{ab}$ | $58.0^{e-h}$ | $1.1^{t-w}$ | $27.0^{s-w}$ | $1470.7^{c-j}$ | $3318.5^{d-i}$ | $49.1^{n-w}$ | $1.9^{a-l}$ | $55.3^{c-k}$ | $3.3^{e-i}$ | $7.2^{t-c}$ | $13.7^{j-s}$ |
| **64** | $56.3^{c-h}$ | $66.8^{cd}$ | $64.5^{c-g}$ | $123.2^{a-c}$ | $77.1^{m-z}$ | $1.1^{t-w}$ | $27.4^{r-v}$ | $1889.3^{u-a}$ | $3456.0^{b-h}$ | $55.5^{c-m}$ | $1.8^{b-r}$ | $53.1^{e-r}$ | $4.4^{q-d}$ | $7.3^{t-c}$ | $14.5^{b-m}$ |
| **65** | $54.2^{j-q}$ | $61.8^{k-o}$ | $62.2^{j-p}$ | $116^{i-l}$ | $92.1^{c-j}$ | $1.0^{w}$ | $30.9^{mn}$ | $3079.3^{d-f}$ | $5564.0^{d-g}$ | $56.8^{c-j}$ | $2.0^{a-c}$ | $53.1^{e-r}$ | $3.6^{d-i}$ | $4.0^{h}$ | $15.1^{a-e}$ |
| **66** | $44.5^{ij}$ | $56.7^{t-x}$ | $52.5^{f-h}$ | $101.7^{d-i}$ | $74.9^{n-b}$ | $1.9^{b-f}$ | $14.0^{c-g}$ | $2173.7^{p-v}$ | $5031.7^{g-p}$ | $43.3^{w-f}$ | $1.5^{z-d}$ | $48.3^{r-d}$ | $5.3^{h-p}$ | $7.1^{u-d}$ | $12.0^{x-b}$ |
| **67** | $55.0^{e-m}$ | $60.0^{m-q}$ | $63.0^{e-m}$ | $115^{j-m}$ | $75.6^{m-b}$ | $1.0^{w}$ | $31.7^{k-n}$ | $2267.3^{n-t}$ | $4101.8^{t-b}$ | $55.6^{c-m}$ | $1.9^{a-k}$ | $51.9^{h-u}$ | $5.0^{l-v}$ | $5.9^{c-g}$ | $15.4^{ab}$ |
| **68** | $48.3^{z-f}$ | $69.8^{ab}$ | $56.3^{x-c}$ | $118.2^{g-i}$ | $66.9^{w-e}$ | $1.3^{p-s}$ | $37.0^{b}$ | $1811^{w-c}$ | $3702.8^{x-g}$ | $50.5^{k-u}$ | $1.9^{a-h}$ | $50.7^{k-z}$ | $5.0^{l-w}$ | $8.1^{p-w}$ | $13.3^{o-w}$ |
| **69** | $47.0^{d-g}$ | $53.3^{a-c}$ | $54.8^{b-d}$ | $100.3^{f-i}$ | $70.8^{r-e}$ | $1.3^{p-s}$ | $22.4^{x-z}$ | $1949.3^{t-z}$ | $4746.3^{i-t}$ | $41.5^{z-a}$ | $1.7^{h-w}$ | $53.3^{e-q}$ | $7.5^{ab}$ | $5.1^{f-h}$ | $12.9^{s-z}$ |
| **70** | $52.8^{n-t}$ | $66.7^{c-e}$ | $60.8^{n-s}$ | $119.5^{e-g}$ | $71.6^{q-d}$ | $1.0^{w}$ | $34.8^{e-g}$ | $2469.5^{j-p}$ | $4822.7^{h-s}$ | $52.4^{f-r}$ | $1.8^{a-q}$ | $56.5^{b-h}$ | $4.8^{m-y}$ | $8.8^{m-t}$ | $14.3^{c-o}$ |
| **71** | $55.5^{e-l}$ | $58.8^{q-t}$ | $63.5^{e-l}$ | $114.3^{l-o}$ | $90.7^{c-l}$ | $1.4^{o-r}$ | $13.5^{d-j}$ | $1949.5^{t-z}$ | $4185.2^{s-a}$ | $46.5^{r-c}$ | $1.7^{i-x}$ | $53.9^{d-p}$ | $4.2^{u-e}$ | $10.5^{g-k}$ | $15.4^{ab}$ |
| **72** | $48.8^{x-d}$ | $62.2^{j-n}$ | $56.8^{v-a}$ | $111^{p-u}$ | $65.8^{y-g}$ | $1.6^{j-n}$ | $14.9^{cd}$ | $955.7^{kl}$ | $1846.2^{m}$ | $51.0^{i-t}$ | $1.9^{a-g}$ | $44.1^{de}$ | $3.4^{d-i}$ | $9.1^{k-q}$ | $15.0^{a-f}$ |
| **73** | $57.8^{bc}$ | $65.0^{d-h}$ | $65.8^{bc}$ | $122.8^{a-d}$ | $81.9^{h-u}$ | $1.1^{w}$ | $35.6^{b-e}$ | $1471^{c-j}$ | $3020.2^{g-k}$ | $49.0^{n-w}$ | $1.9^{a-h}$ | $49.6^{o-b}$ | $4.4^{s-d}$ | $6.7^{w-e}$ | $15.0^{a-g}$ |
| **74** | $56.3^{c-h}$ | $65.7^{d-f}$ | $64.3^{c-h}$ | $122^{b-e}$ | $69.2^{u-e}$ | $1.4^{m-o}$ | $21.0^{za}$ | $1449^{e-j}$ | $3663.0^{y-g}$ | $40.1^{d-g}$ | $1.6^{r-z}$ | $49.2^{p-c}$ | $6.1^{d-i}$ | $8.6^{n-u}$ | $13.8^{i-s}$ |
| **75** | $53.7^{l-q}$ | $65.3^{d-f}$ | $61.8^{l-q}$ | $119^{f-h}$ | $59.3^{c-h}$ | $1.2^{r-w}$ | $35.0^{d-f}$ | $887.2^{kl}$ | $2623.3^{i-l}$ | $36.4^{g}$ | $1.9^{a-h}$ | $55.3^{c-k}$ | $4.4^{r-d}$ | $9.4^{k-p}$ | $13.7^{k-t}$ |
| **76** | $64.7^{a}$ | $60.5^{l-q}$ | $72.8^{a}$ | $125.2^{a}$ | $98.3^{b-e}$ | $1.9^{a-d}$ | $18.8^{b}$ | $3397.3^{cd}$ | $5863.o^{de}$ | $59.0^{c-e}$ | $1.8^{e-u}$ | $66.7^{a}$ | $4.0^{y-g}$ | $13.7^{b-d}$ | $14.8^{a-i}$ |
| **77** | $51.3^{s-w}$ | $58.7^{q-t}$ | $59.3^{r-u}$ | $110^{q-v}$ | $88.4^{d-m}$ | $1.4^{m-o}$ | $22.5^{xy}$ | $2792.8^{f-j}$ | $6748.2^{bc}$ | $41.3^{a-g}$ | $1.8^{c-t}$ | $45.9^{y-e}$ | $3.9^{a-g}$ | $12.3^{d-f}$ | $13.0^{r-x}$ |
| **78** | $54.3^{i-o}$ | $57.3^{r-w}$ | $62.3^{i-o}$ | $111.7^{o-t}$ | $60.4^{c-h}$ | $1.1^{t-w}$ | $33.4^{g-j}$ | $1999.8^{s-y}$ | $5119.5^{g-n}$ | $40.1^{d-g}$ | $1.8^{b-s}$ | $51.2^{i-x}$ | $5.4^{g-o}$ | $5.4^{e-h}$ | $13.9^{h-r}$ |
| **79** | $56.5^{c-f}$ | $62.7^{h-l}$ | $64.5^{c-g}$ | $119.2^{e-h}$ | $63.8^{z-h}$ | $1.2^{s-w}$ | $30.7^{no}$ | $2865^{f-h}$ | $5302.2^{e-k}$ | $54.5^{e-o}$ | $1.9^{a-j}$ | $57.5^{b-e}$ | $6.2^{d-h}$ | $8.9^{l-r}$ | $14.6^{b-l}$ |
| **80** | $56.8^{c-e}$ | $46.7^{gh}$ | $64.8^{c-e}$ | $103.5^{a-e}$ | $67.4^{w-e}$ | $1.3^{p-s}$ | $21.8^{x-a}$ | $2527.7^{h-o}$ | $4923.8^{g-r}$ | $51.2^{i-t}$ | $1.6^{q-y}$ | $50.2^{l-a}$ | $5.2^{k-t}$ | $10.1^{i-n}$ | $14.3^{c-n}$ |
| **81** | $56.3^{c-h}$ | $47.3^{gh}$ | $64.3^{c-h}$ | $103.7^{a-e}$ | $70.9^{r-d}$ | $1.2^{q-v}$ | $32.8^{h-k}$ | $2684^{g-l}$ | $5042.2^{g-o}$ | $53.1^{e-q}$ | $1.9^{a-e}$ | $54.8^{d-l}$ | $3.9^{z-g}$ | $10.2^{i-m}$ | $14.3^{c-n}$ |
| **GM** | 52.1 | 58.0 | 60.1 | 110.1 | 75.8 | 1.4 | 22.0 | 2168.2 | 4384.8 | 49.6 | 1.7 | 51.9 | 4.9 | 8.8 | 13.9 |
| **CV** | 3.3 | 3.6 | 2.9 | 2.3 | 15.6 | 10.7 | 5.5 | 13.8 | 14.3 | 11.1 | 9.2 | 8.2 | 15.7 | 15.6 | 6.3 |
| **Lsd** | 1.9 | 2.4 | 1.9 | 2.9 | 13.4 | 0.2 | 1.4 | 341.1 | 711.9 | 6.2 | 0.2 | 4.9 | 0.9 | 1.6 | 0.9 |

*DF = Days to flowering, PFP = Pod filling period, DP = Days to podding, DM = Days to maturity, NPP = Number of pods per plant, NSP = Number of seeds per pod, HSW = Hundred seed weight, SY = Seed yield, BM = Biomass, HI = Harvest index, PL = Pod length, PH = Plant height, PB = Primary branches, SB = Secondary branches,* NLeL *= number of leaf let per leaf.*

**Correlation analysis of yield and yield components of desi -type chickpea genotypes:**

The seed yield per plant exhibited a significant positive correlation with days to flowering, days to podding, number of pod per plant, hundred seed weight, biomass, pod length, plant height, secondary branch, and number of leaflet per leaf at phenotypic levels, the genotypic and phenotypic correlations for yield and its components are presented in (Table 6), but seed yield per plant had highly significant and positive genotypic correlations with biomass (0.92), secondary branches (0.59), harvest index (0.52) and plant height (0.44). Seed yield per plant also exhibited highly significant positive phenotypic correlations with these traits. Pods per plant displayed positive and significant phenotypic correlation (0.57) with seed yield. Days to maturity had highly significant positive association, phenotypic (0.69) with days to flowering, days to podding (0.75 and 0.70), pod filling period (0.86 and 0.85), 100-seed weight (0.57 and 0.52), pod length (0.58 and 0.38), plant height (0.49 and 0.36), number of leaflet per leaf (0.72 and 0.54) respectively). Negative significant correlation of plant height with other yield traits was observed, like primary branch. Secondary branches were strongly and positively correlated both genotypically and phenotypically with seed yield (0.59 and 0.46, respectively), biomass yield (0.51 and 0.38) and number of pods per plant (0.52 and 0.33, respectively) and negative and significantly with primary branches (-0.281 and -0.10, respectively). Pods per plant had strong positive association with seed yield, biomass and secondary branches. 100-seed weight revealed positive phenotypic correlation days to maturity (0.52) and pod length (0.50).

**Path coefficient analysis**

The genotypic association coefficients of various yields - contributing characters with seed yield per plant were further partitioned into direct and indirect effects (Table 7). The path coefficient analysis based on seed yield per plant as a dependent variable revealed that all traits, except days to podding and pod filling period, exhibited positive direct effects. Compared to the correlation analysis, path analysis of seed yield per plant and its components demonstrated that biomass, days to maturity, and harvest index exerted the highest direct influence, with 80.3, 77.1 and 35.2, respectively and pod filling period (-0.55) and days to podding (-60) highest and negative direct influence on seed yield. The direct effect of days to pod filling period (-0.55) with seed yield was negative but the correlation coefficient was positive (0.28) and it was mostly due to the positive indirect effects via days to maturity (0.67). Direct effect of plant height (0.010) and number of leaf let per leaf (0.004) were positive and low. Plant height revealed positive association (0.44) with seed yield but the direct effect was low (0.010), although positive. Days to maturity exerted maximum positive indirect effect on days to pod filling period.

**Table 6.** Genotypic (below diagonal) and phenotypic (above diagonal) correlation coefficients among 15 traits of 81 chickpea genotypes at Jari, Sirinka and Kobo

| Variable | DF | PFP | DP | DM | NPP | NSP | HSW | SY | BM | HI | PL | PH | PB | SB | NLeL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | | 0.30 | 1.00 | 0.74** | 0.29* | -0.55** | 0.47** | 0.27* | 0.23* | 0.13$^{ns}$ | 0.55** | 0.52** | -0.12$^{ns}$ | 0.42** | 0.81** |
| PFP | 0.21 | | 0.31 | 0.86** | 0.18$^{ns}$ | -0.43** | 0.46** | 0.15$^{ns}$ | 0.14$^{ns}$ | 0.05$^{ns}$ | 0.41* | 0.30* | -0.14$^{ns}$ | 0.15$^{ns}$ | 0.41* |
| DP | 1.00 | 0.22 | | 0.75** | 0.29* | -0.55** | 0.47** | 0.28* | 0.23* | 0.13 $^{ns}$ | 0.55** | 0.52** | -0.12$^{ns}$ | 0.42** | 0.81** |
| DM | 0.69 | 0.85 | 0.70 | | 0.28* | -0.60** | 0.57** | 0.25* | 0.22* | 0.11$^{ns}$ | 0.58** | 0.49** | -0.16$^{ns}$ | 0.33* | 0.72** |
| NPP | 0.18 | 0.12 | 0.18 | 0.18 | | -0.21* | 0.24* | 0.79** | 0.74** | 0.36* | 0.18$^{ns}$ | 0.38* | -0.49** | 0.52** | 0.25* |
| NSP | -0.45 | -0.34 | -0.45 | -0.49 | -0.08 | | -0.79** | -0.21* | -0.21$^{ns}$ | -0.03$^{ns}$ | -0.70** | -0.27* | 0.12$^{ns}$ | -0.27* | -0.55** |
| HSW | 0.42 | 0.40 | 0.42 | 0.52 | 0.17 | -0.68 | | 0.35** | 0.31* | 0.14$^{ns}$ | 0.74** | 0.38* | -0.15$^{ns}$ | 0.26* | 0.44** |
| SY | 0.23 | 0.13 | 0.23 | 0.22 | 0.57 | -0.14 | 0.31 | | 0.92** | 0.52** | 0.23* | 0.44** | -0.34* | 0.59** | 0.15$^{ns}$ |
| BM | 0.19 | 0.12 | 0.18 | 0.19 | 0.55 | -0.12 | 0.26 | 0.88 | | 0.17$^{ns}$ | 0.17$^{ns}$ | 0.37* | -0.29* | 0.51** | 0.11* |
| HI | 0.09 | 0.03 | 0.09 | 0.07 | 0.13 | -0.01 | 0.09 | 0.40 | -0.06 | | 0.12$^{ns}$ | 0.27* | -0.31* | 0.32* | 0.11$^{ns}$ |
| PL | 0.35 | 0.26 | 0.35 | 0.38 | 0.16 | -0.37 | 0.50 | 0.19 | 0.15 | 0.07 | | 0.42* | -0.21$^{ns}$ | 0.30* | 0.64** |
| PH | 0.38 | 0.21 | 0.38 | 0.36 | 0.20 | -0.15 | 0.26 | 0.35 | 0.29 | 0.17 | 0.16 | | -0.26* | 0.40* | 0.42* |
| PB | -0.01 | -0.05 | -0.01 | -0.04 | -0.07 | 0.13 | -0.06 | -0.10 | -0.04 | -0.11 | 0.02 | -0.02 | | -0.28* | -0.20* |
| SB | 0.28 | 0.13 | 0.29 | 0.25 | 0.33 | -0.14 | 0.21 | 0.46 | 0.38 | 0.19 | 0.19 | 0.29 | -0.10 | | 0.28* |
| NLeL | 0.64 | 0.26 | 0.64 | 0.54 | 0.12 | -0.39 | 0.34 | 0.11 | 0.07 | 0.06 | 0.33 | 0.27 | -0.09 | 0.14 | |

*DF = Days to flowering, PFP = Pod filling period, DP = Days to pod setting, DM = Days to maturity, NPP = Number of pods per plant, NSP = Number of seeds per pod, HSW = Hundred seed weight, SY = Seed yield, BM = Biomass, HI = Harvest index, PL = Pod length, PH = Plant height, PB = Primary branches, SB = Secondary branches, NLeL = Number of leaflets per leaf and *, ** significant at 5% and 1%.*

**Table 7.** Combined Genotypic direct (bold and diagonal) and indirect effects of 15 traits on grain yield for 81 chickpea genotypes at Jari, Sirinka and Kobo

| Variable | DF | PFP | DP | DM | NPP | NSP | HSW | BM | HI | PL | PH | PB | SB | NLEL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | **0.19** | -0.17 | -0.60 | 0.57 | 0.01 | -0.01 | 0.03 | 0.18 | 0.05 | 0.01 | 0.01 | -0.01 | 0.02 | 0.00 |
| PFP | 0.06 | **-0.55** | -0.19 | 0.67 | 0.01 | -0.01 | 0.03 | 0.11 | 0.02 | 0.01 | 0.00 | -0.01 | 0.01 | 0.00 |
| DP | 0.19 | -0.17 | **-0.60** | 0.58 | 0.01 | -0.01 | 0.03 | 0.19 | 0.05 | 0.01 | 0.01 | -0.01 | 0.02 | 0.00 |
| DM | 0.14 | -0.47 | -0.45 | **0.77** | 0.01 | -0.00 | 0.04 | 0.18 | 0.04 | 0.01 | 0.01 | -0.01 | 0.02 | 0.00 |
| NPP | 0.05 | -0.09 | -0.18 | 0.22 | **0.05** | -0.00 | 0.02 | 0.60 | 0.13 | 0.00 | 0.00 | -0.02 | 0.03 | 0.00 |
| NSP | -0.10 | 0.24 | 0.32 | -0.46 | -0.01 | **0.04** | -0.05 | -0.17 | -0.01 | -0.01 | -0.00 | 0.01 | -0.01 | -0.00 |
| HSW | 0.09 | -0.25 | -0.28 | 0.44 | 0.01 | -0.01 | **0.06** | 0.25 | 0.05 | 0.01 | 0.00 | -0.01 | 0.01 | 0.00 |
| BM | 0.04 | -0.08 | -0.14 | 0.17 | 0.04 | -0.00 | 0.02 | **0.80** | 0.06 | 0.00 | 0.00 | -0.01 | 0.03 | 0.00 |
| HI | 0.02 | -0.03 | -0.08 | 0.08 | 0.02 | 0.00 | 0.01 | 0.14 | **0.35** | 0.00 | 0.00 | -0.01 | 0.02 | 0.00 |
| PL | 0.10 | -0.23 | -0.33 | 0.45 | 0.01 | -0.01 | 0.05 | 0.14 | 0.04 | **0.019** | 0.00 | -0.01 | 0.02 | 0.00 |
| PH | 0.09 | -0.17 | -0.31 | 0.38 | 0.02 | -0.00 | 0.02 | 0.29 | 0.09 | 0.01 | **0.010** | -0.01 | 0.02 | 0.00 |
| PB | -0.02 | 0.08 | 0.07 | -0.12 | -0.02 | 0.00 | -0.01 | -0.23 | -0.12 | -0.00 | -0.00 | **0.04** | -0.02 | -0.00 |
| SB | 0.08 | -0.08 | -0.26 | 0.26 | 0.02 | -0.00 | 0.02 | 0.41 | 0.11 | 0.01 | 0.00 | -0.01 | **0.05** | 0.00 |
| NLEL | 0.15 | -0.22 | -0.49 | 0.56 | 0.01 | -0.01 | 0.03 | 0.09 | 0.04 | 0.01 | 0.00 | -0.01 | 0.02 | **0.004** |

*DF = Days to flowering, PFP = Pod filling period, DP = Days to podding, DM = Days to maturity, NPP = Number of pods per plant, NSP = Number of seeds per pod, HSW = Hundred seed weight, BM = Biomass, HI = Harvest index, PL = Pod length, PH = Plant height, PB = Primary branches, SB = Secondary branches,* NLeL = *number of leaf let per leaf.*

## DISCUSSTION

Variability plays an important role in crop breeding. An insight in to the magnitude of variability present in crop species is of greatest importance as it provides the basis of selection. Results of analysis of variance revealed that genotypes differed significantly for all characters recorded except the number of seeds per pod and number of leaves let per leaf. Seed yield, biomass, pods per plant, and days to maturity which exhibited most significant contributions to genetic variability among chickpea genotypes in this study, these results are consistent with the findings of (Mahmood *et al*., 2018) in chickpea, (Tamatam and Pandey, 2024). Previous studies in chickpea have reported a significant variation in days to flowering, days to maturity, number of pods per plant, and seed yield (Taera *et al*., 2024) reported similar finding. From the results that plant height is sensitive to environmental fluctuations and indicated that the relative performance of genotypes was markedly inconsistent over the locations. Number of pods per plant, seed yield is an important selection criterion for the development of high yielding genotypes and is strongly influenced by the environment in chickpea. heritability and estimates were found to be very high for 100 seed weight, days to 90% physiological, pod filling period, 50% days to flowering, days to pod setting, biomass, number of seed per pod, secondary branch, primary branch, harvest index, number of leaflet per leaf, plant height and number of pod per plant . The results of this study were in agreement with (Joshi *et al*., 2018) high heritability value for seed yield (99.81%), above ground biomass (99.84%), number of pod per plant (99.27%) and hundred seed weight (99.71%) have been reported and also (Kumar *et al*., 2022) reported similar finding. The present investigation, all traits showed the high heritability ranging from 99.56% to 80.00%. The results of this study were in agreement with (Nimita *et al*., 2022) high heritability value for days to maturity, plant height, height of first pod bearing node, primary branch, secondary branch, number of pod per plant, number of seed per pod, hundred seed weight. There is no evidence of low or moderate heritability in these characters. The present study's high heritability values for the traits under consideration showed that those traits were less influenced by the environment and helped in the effective selection of traits based on phenotypic expression by using a simple selection method. These high heritability values also suggested the potential for genetic improvement.

Genetic advances as a percentage of the mean (GAM) are classified as high (>20%), moderate (10-20%), and low (<10). Considering these categories, high genetic advance estimates as percent of the mean were recorded for the number of pods per plant (69.5%), 100- seed weight (g) (172%), days to maturity (35.5), pod filling period (48.6), days to podding (34.4), days to flowering (39.2), biomass (135.07), number of seed per pod (85.0), harvest index (57.5), pod length (30.6), plant height (37.6), primary branch (92.5), secondary branch (125.9), number of leaves let per leaf (32.2) and seed yield (160.40). A high estimate of these traits indicates that whenever we select the best 5% genotypes for a given trait, the genotypic value of the new population for the trait will be highly improved. According to (Tamatam and Pandey, 2024), high heritability coupled with genetic advance was noted for seed yield (98.15, 45.33), hundred seed weight (99.42, 35.37), number of seed per pod (90.53, 34.73), harvest index (96.24, 27.53), number of unfilled pod (95.17, 22.54) and biomass yield (98.49, 20.85). Amare *et al*., (2020) reported a high value of genetic advance as a percentage of the mean for grain yield and the number of pods per plant. In contrast, low genetic advance as a percent of the mean was obtained for number of primary branches (4.54%) and (1.19%) number of seed per pod. These indicate that selection of genotypes based on those traits as parents might result in a low response in a new population. Amare *et al*., 2020 also reported low genetic advance as a percentage of the mean harvest index, followed by the number of seeds per pod and the number of primary branches. The results of this study were in agreement with (Nimita *et al*., 2022) high genetic advance value for plant height, height of first pod bearing node, primary branch, secondary branch, number of pod per plant, number of seed per pod, hundred seed weight.

The result of correlation analysis revealed that seed yield had significant and positive genotypic and phenotypic correlations with biomass yield, and number of secondary branches, days to flowering, number of secondary branch, days to podding, hundred seed weight, pod length, plant height, number of leaf let per leaf and number of pods per plant, this findings similar to (Fasil *et al*., 2021). Positive correlation between days taken to flowering and grain yield per plant indicated that an improvement in seed yield per plant could be brought about by increasing the days taken to flowering (Menna *et al.,* 2006). A negative and significant association occurred between days to maturity with seeds per pod. Days to maturity showed positive and significant association with seed yield at the genotypic and phenotypic level. These indicate that the genotype with late maturity, the high number of seed per plant and the high number of seed per pod produce high seed yield and a similar finding was previously reported (Fasil *et al*., 2021). Genotypic correlation between plant height and primary branches per plant was negative and significant however; non-significant at the phenotypic level. The number of primary branches had a significant and negative phenotypic and genotypic correlation with the number of secondary branches. This result is in disagreeing with (Sharifi *et al*., 2018) who reported a significant and positive correlation number of primary branches with the number of secondary branches. A positive and significant genotypic and phenotypic correlation of pods per plant with biomass per plant and secondary branches per plant was found but a highly significant genotypic correlation with secondary branches per plant. So pods per plant should be used as selection for yield improvement in chickpea (Fasil *et al*., 2021). However, the genotypic correlation between seed yield and biomass yield was positive and highly significant, which is in agreement with the reports of (Kumar *et al.,* 2019).

Direct and indirect effects of yield components on seed yield per plant were investigated. Compared to the simple, path analysis of seed yield per plant and its components demonstrated that biomass yield, days to maturity, and harvest index exerted the highest direct influence, with 80.3%, 77.1% and 35.2%, respectively. Path coefficient analyses indicated that biomass yield, days to maturity, and harvest index were the major contributors to seed yield per plant. Hence, they could be exploited more confidently for crop improvement. The three traits (biomass, days to maturity and harvest index) had a significant and positive correlation with yield. The highest positive and direct effect of harvest index and the biological yield on seed yield were reported (Fasil *et al.,* 2021). Tamatam and Pandey (2024), who reported the highest direct effect of harvest index (0.606), biomass yields (0.486) and days to maturity (0.009). Biomass, which had a significant and positive association with seed yield, exhibited the highest direct effect on seed yield. The next highest direct effect on seed yield was recorded from days to maturity, which also had a significant and positive association with grain yield, the last not the least recorded harvest index. These results indicate that both traits had a true association with seed yield and their importance in determining these complex traits. Therefore, an important consideration should be given while practicing selection aimed at the improvement of grain yield. These results were in accordance with (Srikhakolanu *et al*., 2022), who reported the highest direct effect of biological yield, harvest index, days to maturity, number of secondary branches, number of pods per plant, number of seeds per pod, and number of secondary branches all had a positive direct impact on seed production per plant. The direct effect of days to pod filling period (-0.55) with grain yield was negative but the correlation coefficient was positive (0.28) and it was mostly due to the positive indirect effects via days to maturity (0.67), this mean late chickpea genotypes gives the highest yield.

## CONCLUSION

There were significant genetic differences among the genotypes for all traits except the number of seeds per pod and number of leaflet per leaf, which suggested a wide scope of selection for genotypes with desirable characters. In the present investigation, high heritability with high estimates of genetic advance recorded for biomass, pods per plant, days to maturity, pod filling period, 100- seed weight and seed yield where careful selection may lead towards improvement of these traits. The seed yield per plant was significantly and positively correlated to days to flowering, days to podding, and days to maturity, number of pod per plant, 100- seed weight, biomass, harvest index, pod length, plant height, secondary branch and number of leaflet per leaf. Improving these traits may increase seed yield per plant. The characters positively and significantly associated with seed yield could be reliable selection criteria for seed yield in chickpea for this set of genotypes. Path analysis of seed per plant indicated that days to maturity, biomass and harvest index exerted the greatest direct effect. These traits had major contributions to seed yield per plant. Hence, it provides better opportunities for selecting plant material for these traits in chickpea. The genotype identified here is examined further for performance homogeneity, and these varieties may be used in future year round studies to assess their stability and adaptability to various environmental conditions.

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