**Studies on genetic variability and character association in Brinjal (*Solanum melongena* L.)**

**ABSTRACT**

Analysis of variance revealed highly significant differences among the genotypes for all the characters studied. The highest total fruit yield per plant (kg) of genotype Kashi Taru (5.73). While lowest total fruit yield per plant (kg) observed for Azad B-1 (2.63). The genotypic and phenotypic coefficient variance value was categorized as low (0-10%), moderate (10-20%) and high (20% and above). In the present study the heritability estimates in broad sense were classified into 3 groups such as high (>75%), moderate (60% - 75%), low (<60%). Genotypic and phenotypic correlation coefficient analysis revealed that fruit yield per plant (kg) showed positive significant association with fruit diameter (cm)(0.510\*\* and 0.388\*), plant height (cm) (0.453\*\* and 0.364\*), total no. of fruits per plant (0.972\*\* and 0.882\*\*), no. of marketable fruits per plant (0.917\*\* and 0.833\*\*), no. of non marketable fruits per plant (0.794\*\* and 0.712\*\*), marketable fruit yield per plant (kg) (0.997\*\* and 0.869\*\*), marketable fruit yield (q ha-1) (0.988\*\* and 0.888\*\*), total phenol content (0.551\*\* and 0.458\*\*). Revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by days to 50% flowering (0.1027), no. of flowers per inflorescent (0.0764), days to marketable fruit harve (0.0029), fruit weight (g) (0.0447), fruit length (cm) (0.1191), plant height (cm) (0.0212), total no. of fruits per plant (0.2268), no. of non marketable fruits p (0.3357), marketable fruit yield per hec (0.611) and total phenol content (0.217) at genotypic. Revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by no. of flowers per inflorescent (0.0221), days to marketable fruit harve (0.0271), fruit diameter (cm) (0.3382), fruit length/breadth ratio (0.4326), total no. of fruits per plant (0.5411), no. of marketable fruits per plant (0.127), no. of non marketable fruits plant (0.3894) marketable fruit yield per hec (0.3402) and total phenol content (0.2539) at phenotypic.

**Kew words:-** Genetic variability, correlation, path and brinjal

**INTRODUCTION**

Brinjal (*Solanum melongena* L.) is a highly regarded vegetable crop cultivated globally, with significant production concentrated in Asia. Commonly known as eggplant or aubergine, it is diploid, possessing a chromosome count of 2n=2x=24. As a key member of the Solanaceae family, its versatility and extensive applications have earned it the title of the 'king of vegetables.' Brinjal is consumed as boiled or cooked, it is also termed as poor man’s vegetable **(Kumar *et al,* 2014).** Analysis of edible parts of fruit (except stalk and calyx) revealed that 100 g of fresh weight of brinjal contains moisture (96%), protein (1.4 g), fat (0.3 g) carbohydrates (4 g), fibre (1.3 g) and essential minerals like calcium (18 mg), phosphorus (47 mg), iron (0.38 mg), sodium (3 mg), chromium (0.07 mg) and sulphur (44 mg). It’s also a rich source of vitamins and 100 g edible portion of fruit contains Carotene (74 mg), Riboflavin (0.11 mg), Thiamine (0.03 mg), Niacin (0.9 mg), Folic acid (5 mg) and vitamin C (1.2 mg). White brinjal is also used in many ayurvedic medicines. Approximately 19.63 lakh ha (48.51 lakh acres) of land were planted with brinjal in the world throughout 2021–2022, yielding 29893 kg/ha (12097 kg/acre) and producing 58.68 lakh tonnes. After tobacco, tomato, potato, and pepper, it is now the fifth-most important solanaceous crop in terms of economic importance (FAO, 2021). The top five producers are Egypt (1.2 million tons), Turkey (0.83 million tons), Indonesia (0.67 million tons), China (37.45 million tons; 63.83% of global total), and India (12.87 million tons; 21.9% of world total). Eggplant is one of the top five most important vegetable crops in Asia and the Mediterranean. In 2022–2023, India's Bhrindabal area amounted to 6.77 lakh hectares (16.72 lakh acres), with a production of 127.79 lakh tonnes. West Bengal, Orissa, Bihar, Gujarat, Maharashtra, Karnataka, Uttar Pradesh, Telangana, and Andhra Pradesh are the states that produce the most brinjal. In Telangana, 2995 acres were covered in brinjal during the Yasangi (Rabi) season of 2022–2023. Telangana's principal areas for the production of brinjal include 393 acres in Rangareddy, 299 acres in Vikarabad, 204 acres in Medchal-Malkajgiri, 143 acres in Asifabad, 134 acres in Sangareddy, 100 acres in Kotthagudem, 63 acres in Medak, and 39 acres in Jangoan **(Anonymous, 2023).** The important element of every population is variability. The heritable element of overall variability is represented by the genotypic coefficient of variation (GCV), which measures the genetic proportion of this variability. The chance of using a certain character in a selection programme increases with increasing GCV. Heritable variability cannot be calculated only based on genetic variability as measured by GCV. In addition, estimation of heritability and genetic advance as percent of the mean is also needed to assess the extent of genetic gain expected from effective selection. The variability available in the genotypes can be partitioned into heritable and nonheritable components, viz., the coefficients of phenotypic and genotypic variation (PCV and GCV), heritability in a broad sense (H), genetic advance (GA), and genetic advance as a percent of the mean. Under varied climatic conditions, phenotypic variability changes, whereas genetic variability remains constant and is more valuable to a plant breeder for selection or hybridization **Soumya *et al.,* (2023).** Correlation analysis measure the relationship between any pairs of traits and determines the component characters that selection can be based for improvement the economic traits. Plant height was positively correlated with average fruit weight, total yield/ plant, Fruit diameter and Fruit length **(Muniappan *et al.,* 2010; Shekar *et al.,* 2014; Ullah *et al.,* 2014; Prabakaran *et al.,* 2015).** Also, significant positive correlations were found between number of branches and total fruit weight **(Tripathy *et al.,* 2018).** Further path coefficient analysis can be used to determine the traits having the greatest influence on yield and allow the partitioning of correlation coefficients into direct and indirect effects, giving the relative importance of each of the causal factors. The concept of path coefficient is a decision making tool helping the breeders to evaluate the contribution of each variable and to determine the direct and indirect effects of an independent variable on dependence variable **(Akinnola, 2012).** Thus, the investigation was undertaken to study the association of traits on yield and the direct and indirect effects of yield attributes on yield of brinjal in order to determine and select best genotypes for further brinjal improvement programme.

**MATERIALS AND METHODS**

The experiment was laid out at Horticulture Research Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur (U.P.), Kanpur during rabi season (October 2024 to March 2025). The farm is situated at 20°16' North latitude and 80°08' East longitude in the southwestern plains of Uttar Pradesh. The experiments comprise of twenty genotypes of brinjal viz. Azad B-1, Azad B-2, Azad B-3, Pant Samrat, Pant Rituraj, Pant Brinjal -4, Narednra Brinjal -1 (NB-1), Narednra Brinjal -1 (NB-2), Narednra Brinjal -1 (NB-5), Kashi Taru, Kahsi Prakash, Kashi Komal, Kashi long, Kashi sandesh, Pusa Purple Long, Pusa Purple Round, Pusa Kranti, BRBL-1, BRBL-49 and Local Faizabad Purple. The experiment materials comprised of 20 genotypes of tomato were collected from IIVR, Varanasi. All the twenty genotypes were evaluated in randomized design block with three replications. Raised nursery beds measuring 4.0 by 1.1 meters were constructed and leveled using well-decomposed farmyard manure. The seeds were treated with Carbendazim at a rate of 3 grams per kilogram of seed before sowing. Plot size was maintained 3 m x 3 m. Healthy brinjal seedlings, one month old, were transplanted into flat beds according to the layout plan. The transplanting was carried out with a spacing of 75 x 60 cm, placing one seedling in each hill. Observations were recorded for days to 50% germination, days to 50% flowering, no. of flowers per inflorescence, days to marketable fruit harvest, fruit weight (g), fruit length (cm), fruit diameter (cm), fruit length/breadth ratio, plant height (cm), total no. of fruits per plant, no. of marketable fruits per plant, no. of non marketable fruits per plant, total fruit yield per plant (kg), marketable fruit yield per plant, marketable fruit yield per hectare(q), ascorbic acid and total phenol content. The mean data of each character was subjected to statistical analysis for variance and test the significance of each character as per the procedure of **Panse and Sukhatme (1967).** GCV and PCV were calculated by standard procedures **(Johnson et al., 1955; Hanson et al., 1956).** Heritability (h2 broad sense) and Genetic advance method by **Robinson *et al.* (1949)** Genetic advance as percentage over mean method by **Johnson *et al*. (1955).** Genotypic and phenotypic correlations calculated as procedure suggested by **Johnson *et al*. (1955).** In path coefficient analysis direct and indirect effect calculated using formula given by **Dewey and Lu (1959).**

**RESULTS AND DISCUSSION**

Analysis of variance Analysis of variance showed significant differences among the genotypes for the 17 characters studied analysis of variance showed significant difference among the genotypes for the different characters at 0.1% and 5% significance. The analysis of variance for different quantitative characters reviled significant differences among the genotypes for parameters like days to 50% germination, days to 50% flowering, no. of flowers per inflorescence, days to marketable fruit harvest, fruit weight (g), fruit length (cm), fruit diameter (cm), fruit length/breadth ratio, plant height (cm), total no. of fruits per plant, no. of marketable fruits per plant, no. of non marketable fruits per plant, total fruit yield per plant (kg), marketable fruit yield per plant, marketable fruit yield per hectare(q), ascorbic acid and total phenol content. The analysis of variance indicated that the mean sum of squares due to genotypes were significantly influenced by all traits and indicated presence of sufficient amount of variability among the genotypes for total fruit yield per plant and its components.These findings are in general agreement with the findings of **Tripathi *et al.* (2009) and Ravali *et al.* (2017).**

**Table 1 Analysis of variance for 17 different growth, yield and quality of brinjal**

|  |  |  |
| --- | --- | --- |
| **Sl.No.** | **Source**  | **Mean Sum of Squares (MSS)** |
| **Replication** | **Treatment** | **Error** |
| **Degrees of freedom** | **2** | **19** | **38** |
| **1** | Days to 50% germination | 0.450 | 17.705\*\* | 1.827 |
| **2** | Days to 50% flowering | 3.5380 | 42.014\* | 18.624 |
| **3** | No. of flowers per inflorescence | 0.0690 | 0.822\*\* | 0.037 |
| **4** | Days to marketable fruit harvest | 11.011\* | 11.933\*\* | 3.262 |
| **5** | Fruit weight (g) | 4.9180 | 846.737\*\* | 305.504 |
| **6** | Fruit length (cm) | 0.6170 | 10.574\*\* | 0.538 |
| **7** | Fruit diameter (cm) | 0.0790 | 1.552\*\* | 0.278 |
| **8** | Fruit length/breadth ratio | 0.059\* | 0.505\*\* | 0.012 |
| **9** | Plant height (cm) | 10.360 | 127.832\*\* | 30.997 |
| **10** | Total no. of fruits per plant | 2.7090 | 106.824\*\* | 4.196 |
| **11** | No. of marketable fruits per plant | 0.4440 | 70.48\*\* | 2.018 |
| **12** | No. of non marketable fruits per plant | 0.650 | 8.772\*\* | 0.287 |
| **13** | Total fruit yield per plant (kg) | 0.2190 | 3.118\*\* | 0.154 |
| **14** | Marketable fruit yield per plant | 0.0540 | 1.988\*\* | 0.089 |
| **15** | marketable fruit yield per hectare(q) | 339.1870 | 8703.542\*\* | 197.2 |
| **16** | Ascorbic acid | 0.4580 | 4.581\*\* | 0.663 |
| **17** | Total phenol content | 5.1540 | 75.097\*\* | 6.883 |

**\* Significant at 5 per cent level of significance**

**\*\* Significant at 1 per cent level of significance**

The estimates of GCV and PCV from present investigation are presented in table 2 and fig. 1. The genotypic and phenotypic coefficient variance value was categorized as low (0-10%), moderate (10-20%) and high (20% and above) given by **Sivasubramanian and Madhavamenon (1973).** Wide range of genotypic coefficient of variation (GCV and PCV) was observed for the characters ranging fruit length/breadth ratio (28.75 and 29.76) to days to marketable fruit harvest (2.25 to 3.29) High magnitude of GCV and PCV were recorded for no. of flowers per inflorescence (20.30 and 21.68), fruit length (cm) (20.44 and 22.02), fruit length/breadth ratio (28.75 and 29.76),total no. of fruits per plant (25.64 and 27.16), no. of marketable fruits per plant (28.44 and (29.68), no. of non marketable fruits per plant (27.94 and 29.32), total fruit yield per plant (kg) (21.44 and 23.05), marketable fruit yield per plant (23.37 and 24.97), marketable fruit yield per hectare(q)(23.63 and 24.44). While as moderate estimates were observed for days to 50% germination (12.37 and 14.35) and ascorbic acid (11.97 and 14.70), and PCV fruit weight (g) (10.71), plant height (cm) (10.27) and total phenol content (10.84) and fruit diameter (cm) (12.71). Whereas low estimates were observed for Days to 50% flowering (5.28 and 9.72) and Days to marketable fruit harvest (2.25 and 3.29) at GCV and PCV and fruit weight (g) (6.52), fruit diameter (cm) (9.88), plant height (cm) (7.33) and total phenol content (9.50) at GCV. Similar results were also reported by **Dhaka and Soni (2012) and Kumar *et al.* (2012)** in brinjal. The estimates of heritability from present investigation are presented in table 2. In the present study the heritability estimates in broad sense were classified into 3 groups such as high (>75%), moderate (60% - 75%), low (<60%). The heritability estimates were found to be high (more than 75%). The high heritability in broad sense was observed for the characters viz. no. of flowers per inflorescence (87.66), fruit length (cm) (86.16), fruit length/breadth ratio (93.33), total no. of fruits per plant (89.07), no. of marketable fruits per plant (91.88), no. of non marketable fruits per plant (90.80), total fruit yield per plant (kg) (86.49), marketable fruit yield per plant (87.62), marketable fruit yield per hectare(q) (93.50) and total phenol content (76.76). Similar results also reported by **Singh and Singh (2016), Sujin et al. (2017) and Singh (2018)** in brinjal with accordance to present findings. In the present investigation, the genetic advance estimates were found to be high for marketable fruit yield per hectare(q) (106.07). While as moderate estimates were observed fruit weight (g) (16.86) and total no. of fruits per plant (11.37). Similar results also reported by **Singh and Singh (2016), Sujin et al. (2017) and Singh (2018)** in brinjal with accordance to present findings. In the present investigation, the genetic adv as % of mean 5% estimates were found to be high for days to 50% germination (21.97), no. of flowers per inflorescence (39.15), fruit length (cm) (39.08), fruit length/breadth ratio (57.22), total no. of fruits per plant (49.84), no. of marketable fruits per plant (56.16), no. of non marketable fruits per plant (54.84), total fruit yield per plant (kg) (41.07), marketable fruit yield per plant (45.07), marketable fruit yield per hectare(q) (47.07) and ascorbic acid (20.07). Whereas low estimates were observed for days to 50% flowering m (5.91), days to marketable fruit harvest (3.18) and fruit weight (g) (8.19). Similar results also reported by **Singh and Singh (2016), Sujin et al. (2017) and Singh (2018)** in brinjal with accordance to present findings.

**Table 2 Estimation of component of variance and genetic parameters for 17 character growth, yield and quality of 20 genotypes in brinjal.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Characters** | **GCV** | **PCV** | **h2 (Broad Sense)** | **Genetic Advancement**  | **Gen.Adv as % of Mean 5%** |
| **1** | Days to 50% germination | 12.37 | 14.35 | 74.34 | 4.09 | 21.97 |
| **2** | Days to 50% flowering | 5.28 | 9.72 | 29.51 | 3.13 | 5.91 |
| **3** | No. of flowers per inflorescence | 20.30 | 21.68 | 87.66 | 0.99 | 39.15 |
| **4** | Days to marketable fruit harvest | 2.25 | 3.29 | 46.98 | 2.40 | 3.18 |
| **5** | Fruit weight (g) | 6.52 | 10.71 | 37.13 | 16.86 | 8.19 |
| **6** | Fruit length (cm) | 20.44 | 22.02 | 86.16 | 3.50 | 39.08 |
| **7** | Fruit diameter (cm) | 9.88 | 12.71 | 60.44 | 1.04 | 15.82 |
| **8** | Fruit length/breadth ratio | 28.75 | 29.76 | 93.33 | 0.81 | 57.22 |
| **9** | Plant height (cm) | 7.33 | 10.27 | 51.01 | 8.36 | 10.79 |
| **10** | Total no. of fruits per plant | 25.64 | 27.16 | 89.07 | 11.37 | 49.84 |
| **11** | No. of marketable fruits per plant | 28.44 | 29.68 | 91.88 | 9.43 | 56.16 |
| **12** | No. of non marketable fruits per plant | 27.94 | 29.32 | 90.80 | 3.30 | 54.84 |
| **13** | Total fruit yield per plant (kg) | 21.44 | 23.05 | 86.49 | 1.90 | 41.07 |
| **14** | Marketable fruit yield per plant | 23.37 | 24.97 | 87.62 | 1.53 | 45.07 |
| **15** | marketable fruit yield per hectare(q) | 23.63 | 24.44 | 93.50 | 106.07 | 47.07 |
| **16** | Ascorbic acid | 11.97 | 14.70 | 66.31 | 1.92 | 20.07 |
| **17** | Total phenol content | 9.50 | 10.84 | 76.76 | 8.61 | 17.14 |





**Fig. 1 Estimation of component of variance and genetic parameters for 17 character growth, yield and quality of 20 genotypes in brinjal.**

**Correlation coefficient analysis at genotypic and phenotypic levels**

Genotypic and phenotypic correlation coefficient analysis revealed that fruit yield per plant (kg) showed positive significant association with fruit diameter (cm)(0.510\*\* and 0.388\*), plant height (cm) (0.453\*\* and 0.364\*), total no. of fruits per plant (0.972\*\* and 0.882\*\*), no. of marketable fruits per plant (0.917\*\* and 0.833\*\*), no. of non marketable fruits per plant (0.794\*\* and 0.712\*\*), marketable fruit yield per plant (kg) (0.997\*\* and 0.869\*\*), marketable fruit yield (q ha-1) (0.988\*\* and 0.888\*\*), total phenol content (0.551\*\* and 0.458\*\*). While non-significant and positive association was observed with No. of flowers per inflorescent (0.1627 and 0.1525) and Days to marketable fruit harvest (0.0546 and 0.0539) at genotypic and phenotypic levels and Ascorbic acid (0.0314) at phenotypic level. Similar finding has also been reported by many workers viz. for fruit yield Association of either of these traits with yield has also been reported by **Pathania et al., (2005), Nair and Mehta (2007), Jadhao (2009); Muniappan (2010) and Karak et al., (2012).**

**Genotypic and phenotypic path coefficient analysis**

The genotypic path coefficient among the different growth, yield and quality with fruit yield per plant (kg) traits in tomato were worked out to assess the association among themselves. Perusal of Table-4,revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by days to 50% flowering (0.1027), no. of flowers per inflorescent (0.0764), days to marketable fruit harve (0.0029), fruit weight (g) (0.0447), fruit length (cm) (0.1191), plant height (cm) (0.0212), total no. of fruits per plant (0.2268), no. of non marketable fruits p (0.3357), marketable fruit yield per hec (0.611) and total phenol content (0.217) at genotypic. The character days to 50% germination (-0.0536), fruit diameter (cm) (-0.0125), fruit length/breadth ratio (-0.0988), no. of marketable fruits per p (-0.1929), marketable fruit yield per plant (-0.0663) and ascorbic acid (-0.0441) showed direct negative effect at genotypic levels. Revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by no. of flowers per inflorescent (0.0221), days to marketable fruit harvest (0.0271), fruit diameter (cm) (0.3382), fruit length/breadth ratio (0.4326), total no. of fruits per plant (0.5411), no. of marketable fruits per plant (0.127), no. of non marketable fruits plant (0.3894) marketable fruit yield per he-1 (0.3402) and total phenol content (0.2539) at phenotypic. The character days to 50% flowering (-0.239), fruit weight (g) (-0.035), fruit length (cm) (-0.0743), plant height (cm) (-0.084), marketable fruit yield per plant (-0.6014) and ascorbic acid (-0.5459) showed direct negative effect at phenotypic levels. Therefore, during selection, these characters should also be taken into consideration. Similar results had also been reported by **(Naliyadhara et al., 2007; Mishra et al., 2007; Bansal and Mehta, 2008; Muniappan et al., 2010; Thangamani and Jansirani, 2012).**

**Table 3 Estimates of genotypic and phenotypic correlation coefficient for 17 Growth, yield and quality with fruit yield per plant (kg).**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Days to 50% germination** | **Days to 50% flowering** | **No. of flowers per inflorescen** | **Days to marketable fruit harve** | **Fruit weight (g)** | **Fruit length (cm)** | **Fruit diameter (cm)** | **Fruit length/breadth ratio** | **Plant height (cm)** | **Total no. of fruits per plant** | **No. of marketable fruits per plant**  | **No. of non marketable fruits plant**  | **Marketable fruit yield per plant (kg)** | **marketable fruit yield (qha-1)** | **Ascorbic acid** | **Total phenol content** | **Total fruit yield per plant (kg)** |
| **Days to 50% germination** | **G** | 1 | 0.612\*\* | -0.609\*\* | 0.1403 | 0.283\* | 0.421\*\* | -0.1594 | 0.440\*\* | -0.1755 | -0.538\*\* | -0.438\*\* | -0.591\*\* | -0.407\* | -0.407\* | -0.595\*\* | 0.0175 | -0.524\*\* |
| **P** | 1 | 0.434\*\* | -0.510\*\* | 0.1177 | 0.2322 | 0.334\* | -0.1046 | 0.406\* | -0.1163 | -0.434\*\* | -0.379\* | -0.515\*\* | -0.362\* | -0.361\* | -0.467\*\* | -0.0442 | -0.423\*\* |
| **Days to 50% flowering** | **G** |   | 1 | -0.408\* | 0.832\*\* | 0.1048 | 0.1023 | 0.322\* | -0.0633 | 0.0275 | -0.298\* | -0.279\* | -0.2393 | -0.282\* | -0.271\* | -0.556\*\* | -0.330\* | -0.350\* |
| **P** |   | 1 | -0.318\* | 0.289\* | 0.086 | 0.0875 | 0.2521 | 0.0137 | 0.1806 | -0.1772 | -0.1786 | -0.1211 | -0.1838 | -0.197 | -0.282\* | -0.2329 | -0.1231 |
| **No. of flowers per inflorescen** | **G** |   |   | 1 | -0.275\* | -0.0212 | -0.345\* | -0.0097 | -0.277\* | 0.0659 | 0.1471 | 0.0546 | 0.348\* | 0.0512 | 0.0458 | 0.324\* | -0.320\* | 0.1627 |
| **P** |   |   | 1 | -0.1324 | 0.0281 | -0.322\* | -0.0239 | -0.263\* | -0.0126 | 0.1381 | 0.0648 | 0.318\* | 0.0433 | 0.0521 | 0.259\* | -0.2311 | 0.1525 |
| **Days to marketable fruit harve** | **G** |   |   |   | 1 | -0.0857 | -0.0657 | 0.520\*\* | -0.2464 | 0.367\* | 0.0186 | 0.0426 | 0.0412 | 0.0438 | 0.059 | -0.463\*\* | 0.0177 | 0.0546 |
| **P** |   |   |   | 1 | 0.0897 | -0.0685 | 0.2058 | -0.1579 | 0.0191 | 0.0486 | 0.0269 | -0.0208 | 0.0656 | 0.0478 | -0.113 | -0.0009 | 0.0539 |
| **Fruit weight (g)** | **G** |   |   |   |   | 1 | 0.0551 | -0.1169 | 0.1619 | -0.428\*\* | -0.753\*\* | -0.741\*\* | -0.425\*\* | -0.474\*\* | -0.486\*\* | -0.603\*\* | -0.2512 | -0.378\* |
| **P** |   |   |   |   | 1 | 0.0186 | -0.0527 | 0.1236 | -0.1722 | -0.472\*\* | -0.526\*\* | -0.297\* | -0.306\* | -0.288\* | -0.435\*\* | -0.313\* | -0.279\* |
| **Fruit length (cm)** | **G** |   |   |   |   |   | 1 | -0.1173 | 0.823\*\* | -0.2443 | -0.0808 | 0.0489 | -0.402\* | 0.0557 | 0.0597 | 0.0833 | 0.2033 | -0.1156 |
| **P** |   |   |   |   |   | 1 | -0.1128 | 0.767\*\* | -0.1234 | -0.0759 | 0.0231 | -0.367\* | 0.0442 | 0.0386 | 0.0903 | 0.202 | -0.075 |
| **Fruit diameter (cm)** | **G** |   |   |   |   |   |   | 1 | -0.696\*\* | 0.255\* | 0.443\*\* | 0.327\* | 0.549\*\* | 0.365\* | 0.365\* | -0.198 | -0.0682 | 0.510\*\* |
| **P** |   |   |   |   |   |   | 1 | -0.574\*\* | 0.1347 | 0.309\* | 0.259\* | 0.459\*\* | 0.327\* | 0.327\* | -0.1588 | -0.1528 | 0.388\* |
| **Fruit length/breadth ratio** | **G** |   |   |   |   |   |   |   | 1 | -0.317\* | -0.380\* | -0.205 | -0.714\*\* | -0.2138 | -0.2192 | 0.1002 | 0.2366 | -0.439\*\* |
| **P** |   |   |   |   |   |   |   | 1 | -0.1921 | -0.345\* | -0.2078 | -0.676\*\* | -0.2195 | -0.2096 | 0.099 | 0.1869 | -0.382\* |
| **Plant height (cm)** | **G** |   |   |   |   |   |   |   |   | 1 | 0.506\*\* | 0.492\*\* | 0.405\* | 0.478\*\* | 0.476\*\* | -0.1086 | 0.2515 | 0.453\*\* |
| **P** |   |   |   |   |   |   |   |   | 1 | 0.346\* | 0.316\* | 0.267\* | 0.304\* | 0.308\* | -0.0961 | 0.2049 | 0.364\* |
| **Total no. of fruits per plant** | **G** |   |   |   |   |   |   |   |   |   | 1 | 0.989\*\* | 0.754\*\* | 0.961\*\* | 0.960\*\* | 0.2192 | 0.597\*\* | 0.972\*\* |
| **P** |   |   |   |   |   |   |   |   |   | 1 | 0.938\*\* | 0.703\*\* | 0.884\*\* | 0.886\*\* | 0.2028 | 0.474\*\* | 0.882\*\* |
| **No. of marketable fruits per pplant**  | **G** |   |   |   |   |   |   |   |   |   |   | 1 | 0.560\*\* | 0.968\*\* | 0.974\*\* | 0.2201 | 0.741\*\* | 0.917\*\* |
| **P** |   |   |   |   |   |   |   |   |   |   | 1 | 0.541\*\* | 0.930\*\* | 0.919\*\* | 0.2034 | 0.601\*\* | 0.833\*\* |
| **No. of non marketable fruits per plant**  | **G** |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.561\*\* | 0.564\*\* | 0.1404 | -0.0212 | 0.794\*\* |
| **P** |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.534\*\* | 0.529\*\* | 0.1298 | -0.0443 | 0.712\*\* |
| **Marketable fruit yield per plant (kg)** | **G** |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.855\*\* | 0.0297 | 0.775\*\* | 0.997\*\* |
| **P** |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.962\*\* | 0.0115 | 0.590\*\* | 0.869\*\* |
| **marketable fruit yield (q ha-1)** | **G** |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.014 | 0.790\*\* | 0.988\*\* |
| **P** |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.0368 | 0.566\*\* | 0.888\*\* |
| **Ascorbic acid** | **G** |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.0603 | -0.0147 |
| **P** |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.0298 | 0.0314 |
| **Total phenol content** | **G** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.551\*\* |
| **P** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1 | 0.458\*\* |

**Significant at 5 per cent level of significance**

**Table 4. Estimates of genotypic and phenotypic path coefficient for 17 Growth, yield and quality with fruit yield per plant (kg).**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   |  | **Days to 50% germination** | **Days to 50% flowering** | **No. of flowers per inflorescen** | **Days to marketable fruit harve** | **Fruit weight (g)** | **Fruit length (cm)** | **Fruit diameter (cm)** | **Fruit length/breadth ratio** | **Plant height (cm)** | **Total no. of fruits per plant** | **No. of marketable fruits per p** | **No. of non marketable fruits p** | **Marketable fruit yield per pla** | **marketable fruit yield per hec** | **Ascorbic acid** | **Total phenol content** | **Total fruit yield** |
| **Days to 50% germination** | **G** | **-0.0536** | -0.0232 | 0.0273 | -0.0063 | -0.0124 | -0.0179 | 0.0056 | -0.0218 | 0.0062 | 0.0232 | 0.0203 | 0.0276 | 0.0194 | 0.0193 | 0.025 | 0.0024 | -0.524\*\* |
| **P** | **-0.3359** | -0.2055 | 0.2044 | -0.0471 | -0.095 | -0.1413 | 0.0536 | -0.1479 | 0.059 | 0.1809 | 0.1472 | 0.1986 | 0.1366 | 0.1367 | 0.1998 | -0.0059 | -0.423\*\* |
| **Days to 50% flowering** | **G** | 0.0445 | **0.1027** | -0.0327 | 0.0296 | 0.0088 | 0.009 | 0.0259 | 0.0014 | 0.0185 | -0.0182 | -0.0183 | -0.0124 | -0.0189 | -0.0202 | -0.029 | -0.0239 | -0.350\* |
| **P** | -0.1462 | **-0.239** | 0.0975 | -0.2482 | -0.025 | -0.0245 | -0.077 | 0.0151 | -0.0066 | 0.0711 | 0.0666 | 0.0572 | 0.0674 | 0.0648 | 0.1329 | 0.0789 | -0.1231 |
| **No. of flowers per inflorescen** | **G** | -0.0389 | -0.0243 | **0.0764** | -0.0101 | 0.0021 | -0.0246 | -0.0018 | -0.0201 | -0.001 | 0.0105 | 0.0049 | 0.0243 | 0.0033 | 0.004 | 0.0198 | -0.0176 | 0.1627 |
| **P** | -0.0134 | -0.009 | **0.0221** | -0.0061 | -0.0005 | -0.0076 | -0.0002 | -0.0061 | 0.0015 | 0.0032 | 0.0012 | 0.0077 | 0.0011 | 0.001 | 0.0072 | -0.0071 | 0.1525 |
| **Days to marketable fruit harve** | **G** | 0.0003 | 0.0008 | -0.0004 | **0.0029** | 0.0003 | -0.0002 | 0.0006 | -0.0005 | 0.0001 | 0.0001 | 0.0001 | -0.0001 | 0.0002 | 0.0001 | -0.0003 | 0 | 0.0546 |
| **P** | 0.0038 | 0.0281 | -0.0075 | **0.0271** | -0.0023 | -0.0018 | 0.0141 | -0.0067 | 0.0099 | 0.0005 | 0.0012 | 0.0011 | 0.0012 | 0.0016 | -0.0125 | 0.0005 | 0.0539 |
| **Fruit weight (g)** | **G** | 0.0104 | 0.0038 | 0.0013 | 0.004 | **0.0447** | 0.0008 | -0.0024 | 0.0055 | -0.0077 | -0.0211 | -0.0235 | -0.0133 | -0.0137 | -0.0129 | -0.0194 | -0.014 | -0.378\* |
| **P** | -0.0099 | -0.0037 | 0.0007 | 0.003 | **-0.035** | -0.0019 | 0.0041 | -0.0057 | 0.015 | 0.0264 | 0.0259 | 0.0149 | 0.0166 | 0.017 | 0.0211 | 0.0088 | -0.279\* |
| **Fruit length (cm)** | **G** | 0.0398 | 0.0104 | -0.0383 | -0.0082 | 0.0022 | **0.1191** | -0.0134 | 0.0913 | -0.0147 | -0.009 | 0.0027 | -0.0437 | 0.0053 | 0.0046 | 0.0108 | 0.0241 | -0.1156 |
| **P** | -0.0313 | -0.0076 | 0.0256 | 0.0049 | -0.0041 | **-0.0743** | 0.0087 | -0.0612 | 0.0182 | 0.006 | -0.0036 | 0.0299 | -0.0041 | -0.0044 | -0.0062 | -0.0151 | -0.075 |
| **Fruit diameter (cm)** | **G** | 0.0013 | -0.0031 | 0.0003 | -0.0026 | 0.0007 | 0.0014 | **-0.0125** | 0.0072 | -0.0017 | -0.0039 | -0.0032 | -0.0057 | -0.0041 | -0.0041 | 0.002 | 0.0019 | 0.510\*\* |
| **P** | -0.0539 | 0.109 | -0.0033 | 0.1758 | -0.0395 | -0.0397 | **0.3382** | -0.2353 | 0.0862 | 0.15 | 0.1107 | 0.1858 | 0.1235 | 0.1236 | -0.067 | -0.0231 | 0.388\* |
| **Fruit length/breadth ratio** | **G** | -0.0401 | -0.0014 | 0.026 | 0.0156 | -0.0122 | -0.0758 | 0.0568 | **-0.0988** | 0.019 | 0.0341 | 0.0205 | 0.0668 | 0.0217 | 0.0207 | -0.0098 | -0.0185 | -0.439\*\* |
| **P** | 0.1905 | -0.0274 | -0.12 | -0.1066 | 0.07 | 0.3561 | -0.301 | **0.4326** | -0.1373 | -0.1646 | -0.0887 | -0.309 | -0.0925 | -0.0948 | 0.0434 | 0.1023 | -0.382\* |
| **Plant height (cm)** | **G** | -0.0025 | 0.0038 | -0.0003 | 0.0004 | -0.0037 | -0.0026 | 0.0029 | -0.0041 | **0.0212** | 0.0073 | 0.0067 | 0.0057 | 0.0065 | 0.0065 | -0.002 | 0.0044 | 0.453\*\* |
| **P** | 0.0147 | -0.0023 | -0.0055 | -0.0309 | 0.036 | 0.0205 | -0.0214 | 0.0267 | **-0.084** | -0.0425 | -0.0413 | -0.034 | -0.0402 | -0.04 | 0.0091 | -0.0211 | 0.364\* |
| **Total no. of fruits per plant** | **G** | -0.0983 | -0.0402 | 0.0313 | 0.011 | -0.1071 | -0.0172 | 0.0701 | -0.0783 | 0.0784 | **0.2268** | 0.2126 | 0.1593 | 0.2004 | 0.201 | 0.046 | 0.1075 | 0.972\*\* |
| **P** | -0.2913 | -0.161 | 0.0796 | 0.0101 | -0.4075 | -0.0437 | 0.2399 | -0.2059 | 0.2738 | **0.5411** | 0.5352 | 0.4082 | 0.5201 | 0.5194 | 0.1186 | 0.323 | 0.882\*\* |
| **No. of marketable fruits per plant**  | **G** | 0.073 | 0.0345 | -0.0125 | -0.0052 | 0.1014 | -0.0044 | -0.0499 | 0.0401 | -0.0609 | -0.1809 | **-0.1929** | -0.1044 | -0.1794 | -0.1772 | -0.0392 | -0.1159 | 0.917\*\* |
| **P** | -0.0557 | -0.0354 | 0.0069 | 0.0054 | -0.0942 | 0.0062 | 0.0416 | -0.026 | 0.0624 | 0.1256 | **0.127** | 0.0711 | 0.123 | 0.1237 | 0.028 | 0.0941 | 0.833\*\* |
| **No. of non marketable fruits plant**  | **G** | -0.173 | -0.0406 | 0.1068 | -0.007 | -0.0995 | -0.1231 | 0.1541 | -0.2269 | 0.0897 | 0.2358 | 0.1817 | **0.3357** | 0.1793 | 0.1775 | 0.0436 | -0.0149 | 0.794\*\* |
| **P** | -0.2302 | -0.0932 | 0.1354 | 0.016 | -0.1656 | -0.1566 | 0.2138 | -0.2781 | 0.1578 | 0.2937 | 0.218 | **0.3894** | 0.2183 | 0.2197 | 0.0547 | -0.0082 | 0.712\*\* |
| **Marketable fruit yield per plant (kg)**  | **G** | 0.024 | 0.0122 | -0.0029 | -0.0044 | 0.0203 | -0.0029 | -0.0216 | 0.0146 | -0.0201 | -0.0586 | -0.0617 | -0.0354 | **-0.0663** | -0.0637 | -0.0008 | -0.0391 | 0.997\*\* |
| **P** | 0.2445 | 0.1695 | -0.0308 | -0.0263 | 0.2851 | -0.0335 | -0.2196 | 0.1286 | -0.2877 | -0.5781 | -0.5822 | -0.3372 | **-0.6014** | -0.6139 | -0.0179 | -0.4659 | 0.869\*\* |
| **marketable fruit yield (q ha-1)** | **G** | -0.2205 | -0.1204 | 0.0318 | 0.0292 | -0.176 | 0.0236 | 0.1999 | -0.1281 | 0.1882 | 0.5415 | 0.5612 | 0.3232 | 0.5875 | **0.611** | 0.0225 | 0.3457 | 0.988\*\* |
| **P** | -0.1384 | -0.0923 | 0.0156 | 0.0201 | -0.1653 | 0.0203 | 0.1243 | -0.0746 | 0.1619 | 0.3266 | 0.3315 | 0.192 | 0.3473 | **0.3402** | 0.0048 | 0.2688 | 0.888\*\* |
| **Ascorbic acid** | **G** | 0.0206 | 0.0125 | -0.0114 | 0.005 | 0.0192 | -0.004 | 0.007 | -0.0044 | 0.0042 | -0.0089 | -0.009 | -0.0057 | -0.0005 | -0.0016 | **-0.0441** | -0.0013 | -0.0147 |
| **P** | 0.3247 | 0.3035 | -0.1769 | 0.253 | 0.329 | -0.0455 | 0.1081 | -0.0547 | 0.0593 | -0.1197 | -0.1202 | -0.0766 | -0.0162 | -0.0076 | **-0.5459** | -0.0329 | 0.0314 |
| **Total phenol content** | **G** | -0.0096 | -0.0505 | -0.0502 | -0.0002 | -0.0679 | 0.0438 | -0.0332 | 0.0406 | 0.0445 | 0.1029 | 0.1304 | -0.0096 | 0.128 | 0.1228 | 0.0065 | **0.217** | 0.551\*\* |
| **P** | 0.0045 | -0.0838 | -0.0812 | 0.0045 | -0.0638 | 0.0516 | -0.0173 | 0.0601 | 0.0638 | 0.1515 | 0.188 | -0.0054 | 0.1967 | 0.2006 | 0.0153 | **0.2539** | 0.458\*\* |
| **Total fruit yield (kg)** | **G** | -0.524\*\* | -0.350\* | 0.1627 | 0.0546 | -0.378\* | -0.1156 | 0.510\*\* | -0.439\*\* | 0.453\*\* | 0.972\*\* | 0.917\*\* | 0.794\*\* | 0.997\*\* | 0.988\*\* | -0.0147 | 0.551\*\* | **1** |
| **P** | -0.423\*\* | -0.1231 | 0.1525 | 0.0539 | -0.279\* | -0.075 | 0.388\* | -0.382\* | 0.364\* | 0.882\*\* | 0.833\*\* | 0.712\*\* | 0.869\*\* | 0.888\*\* | 0.0314 | 0.458\*\* | **1** |

**CONCLUSION**

Analysis of variance revealed highly significant differences among the genotypes for all the characters studied. The highest total fruit yield per plant (kg) of genotype Kashi Taru (5.73). While lowest total fruit yield per plant (kg) observed for Azad B-1 (2.63). The genotypic and phenotypic coefficient variance value was categorized as low (0-10%), moderate (10-20%) and high (20% and above). In the present study the heritability estimates in broad sense were classified into 3 groups such as high (>75%), moderate (60% - 75%), low (<60%). Genotypic and phenotypic correlation coefficient analysis revealed that fruit yield per plant (kg) showed positive significant association with fruit diameter (cm)(0.510\*\* and 0.388\*), plant height (cm) (0.453\*\* and 0.364\*), total no. of fruits per plant (0.972\*\* and 0.882\*\*), no. of marketable fruits per plant (0.917\*\* and 0.833\*\*), no. of non marketable fruits per plant (0.794\*\* and 0.712\*\*), marketable fruit yield per plant (kg) (0.997\*\* and 0.869\*\*), marketable fruit yield (q ha-1) (0.988\*\* and 0.888\*\*), total phenol content (0.551\*\* and 0.458\*\*). Revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by days to 50% flowering (0.1027), no. of flowers per inflorescent (0.0764), days to marketable fruit harve (0.0029), fruit weight (g) (0.0447), fruit length (cm) (0.1191), plant height (cm) (0.0212), total no. of fruits per plant (0.2268), no. of non marketable fruits p (0.3357), marketable fruit yield per hec (0.611) and total phenol content (0.217) at genotypic. Revealed that highest positive direct effect on fruit yield per plant (kg) was exhibited by no. of flowers per inflorescent (0.0221), days to marketable fruit harve (0.0271), fruit diameter (cm) (0.3382), fruit length/breadth ratio (0.4326), total no. of fruits per plant (0.5411), no. of marketable fruits per plant (0.127), no. of non marketable fruits plant (0.3894) marketable fruit yield per hec (0.3402) and total phenol content (0.2539) at phenotypic.

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