**Genetic Variability and Heterosis Analysis for yield and its components in Bread Wheat (*Triticum* *aestivum* L.)**

**Abstract**

An experiment was executed to assess the material in respect to nature of gene action through genetic component analysis, genetic variability, heterosis, heritability and genetic advance of yield and yield contributing traits in ten parents and their twenty-five F1s grown at Crop Research Farm Nawabganj, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during *Rabi*, 2021-22 and 2022-23. The observations were recorded on fourteen quantitative characters. The analysis of variance reflected highly significant differences among the parent for all characters. The variability for all the characters studied was highly significant in parents and F1s. High value of genotypic coefficients of variation and Phenotypic coefficients of variation was observed in F1 generation for number of grains per plant and grain yield per plant. Low GCV and PCV were observed in F1 generation for days to 50% heading, days to 50% anthesis, days to maturity, plant height, spike length and 1000-grain weigh. The moderate heritability was expressed for days to 50% heading, physiological maturity, days to 50% anthesis, number of grains per spike, number of grains per plant and grain yield per plant and low heritability for plant height, harvest index and 1000 grain weight. The high genetic advance was recorded for number of grains per plant, grain yield per plant and harvest index while low genetic advance for physiological maturity, 1000 grain weight and plant height. Cross combination IC574476/DBW187 was also exhibited desirable heterosis for number of spikelets per spike, grain weight per spike, grain yield per plant. K1317/ GW322 was also exhibited desirable heterosis for plant biomass and grain yield per plant; IC574476 / K68 was also exhibited desirable heterosis for number of tillers per plant, 1000 grain weight, grain yield per plant while hybrid K9351/ K68 was exhibited desirable heterosis for number of tillers per plant and spike length.

 **Keywords:** Bread wheat, yield, Genetic variability, Heritability and Heterosis

**Introduction**

Wheat (*Triticum aestivum* L.*)*  serves as the primary food for almost one third of the world's population. It is most popular cereals of the world because of largest acreage, high productivity, prominent position it holds in the international food grain trade, its agronomic adaptability to diverse climatic conditions; easy storage of grains, its conversion into flour for making edible, palatable and a variety of other food items, and provides 20% dietary calories of the world food basket. Wheat is a unique gift of nature to the mankind as a good supplement for nutritional requirement of human body as it contains 12% protein, 1.8% lipids, 1.8% ash, 2% reducing sugar, 59.2% starch, 70% total carbohydrates and provide 314 kcal/100 g of food **(Iqbal *et al*., 2017)**.

 India's wheat production was anticipated to be 112.92 million tonnes from an area of 31.78 million ha, with an average productivity of 36.15 quintals per ha. Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, and Rajasthan are the top wheat-producing states in terms of both area and yield. Uttar Pradesh is the leading producer of wheat among these states, yielding 35.43 million tonnes from an area of 9.31 million ha **(ICAR-IIWBR, 2024)**. The purpose of the study was to evaluate the kind and extent of genetic diversity, heritability, genetic advance among various wheat yield and contributing variables, and extent of economic heterosis to enhance productivity with profitability to the farming community.

**Material and Methods**

The present investigation entitled *Genetic Variability and Heterosis Analysis for yield and its components in Bread Wheat* (*Triticum* *aestivum* L.)was conducted at Crop Research Farm, Nawabganj, C.S. Azad University of Agriculture and Technology, Kanpur-208002 (U.P.) during *Rabi*, 2021-22 and 2022-23. Geographically, this place is located between 25.28° and 26.58° N latitude, 79.31° and 80.34° E longitudes and an altitude of 125.9 m above from mean sea level. This falls in sub-tropical climatic zone. The soil type is sandy loam. The annual rainfall is about 1270 mm. The climate of district Kanpur is semi-arid with hot summer and cold winter The experimental material for present investigation comprised of twenty-five F1 is developed by crossing five lines K9644, K9391, K1317, K402, IC574476, and five testers viz., WB02, DBW187, DBW222, GW322 and K 68 following line x tester mating design. A total of 35 treatments including 10 parents and 25 F1s were evaluated for the study of fourteen different characters in wheat. Five tagged plants from each plot were selected randomly and data were recorded on Days to 50% Heading, Days to 50% anthesis, physiological maturity, plant height, number of tillers per plant, spike length, no of spikelets per spike, plant biomass, grain weight per spike, number of grains per spike, number of grains per plant, 1000 gain weight, harvest index and grain yield per plant. The data recorded were subjected to analysis of variance according to **Steel et al. (1997)**. Genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), Heritability and Genetic Advance as per **Johnson *et al.,* (1955)** were work out following INDOSTAT software, Hyderabad.

**Result and Discussion**

**Analysis of variance for yield and yield attributing traits**

The analysis of variance (ANOVA) for the fourteen traits, including both parents and F1 hybrids, **(Table 1)** revealed highly significant differences for most traits, indicating substantial variability among the treatments. All parental lines and F1 hybrids exhibited significant variability for the traits studied, with F1 hybrids generally outperforming the parent plants in several characteristics, except for days to 50% heading, number of tillers per plant, and grain yield per plant. Notably, significant differences were observed between the lines and testers, particularly for traits such as spike length, number of spikelets per spike, plant biomass, and number of grains per spike. For most traits, variability in the F1 hybrids was greater compared to the parental lines, especially in traits like plant biomass, grain yield per plant, and harvest index. The variability observed in parents ranged from high for traits like number of grains per plant and plant biomass to lower for traits like spike length. In F1 hybrids, the greatest variability was seen in plant biomass, grain yield, and physiological maturity. These results suggest a strong genetic influence on the traits studied, with substantial differences between parental lines, testers, and their F1 hybrids. The observed patterns of variability highlight the potential for further improvement through selection in breeding programs. Similar findings were also reported by **Ghaffar *et al*., (2018); Elahi *et al., (*2020), Singh *et al.* (2021).**

**Means and Variability in Parents and** **F1s**

The mean performance and variability of the fourteen traits for both parent plants **(Table 2)** and F1 hybrids are presented in **Table 3**. Overall, the F1 hybrids exhibited superior performance compared to the parents for most traits, except for days to 50% heading, number of tillers per plant, plant biomass, number of grains per spike, number of grains per plant, 1000-grain weight, and grain yield per plant. The degree of variability among the traits ranged from high to low for both parents and F1s, with the extent of variation varying across different traits. For the parents, high variability was observed in traits such as number of grains per plant (272.33 - 433.61), plant biomass (51.61 - 69.24gm), harvest index (30.57 - 41.02), days to 50% heading (75 - 83.03), number of grains per spike (35.33 - 43.03), and physiological maturity (115.00 - 121.81 Days), followed by plant height, grain yield per plant, 1000-grain weight, and other traits. In contrast, the F1 hybrids exhibited higher variability, particularly in plant biomass (30.66 - 88.57gm), grain yield per plant (13.00 - 45.30), number of grains per spike (32.33 - 61.00), harvest index (28.91 - 54.19), and physiological maturity (112.67 - 134.00). The increased variability in F1 hybrids suggests potential for further improvement and selection in breeding programs. Similar findings were also reported by **Shah *et al*., (2022),** **Baloch *et al.,* (2016), Kalhoro *et al*., (2015).**

**Genotypic and Phenotypic Coefficient of Variance (%)**

High value of GCV (%) was observed in F1 generation for number of grains per plant (30.73) and grain yield per plant (30.76). Moderate value of GCV (%) were observed in F1 generation for number of productive tillers per plant (18.69), grain weight per spike (18.42), harvest index (15.25) and number of grain per spike (12.79) ,whereas low GCV (%) were observed in F1 generation for days to 50% heading (6.11), days to 50% anthesis (5.94), days to physiological maturity (4.35), plant height (4.11), spike length (7.18), number of spikelets per spike (7.07), and 1000-grain weight (4.81).High value of PCV (%) were observed in F1 generation for number of grains per plant (31.84), grain yield per plant (30.76), plant biomass (23.84) and grain weight per spike (20.89). Low PCV (%) were observed for days to 50% heading (6.45), days to maturity (4.53), plant height (4.96), spike length (9.10), number of spikelets per spike (9.41) and 1000-grain weight (5.80), whereas, moderate value of PCV (%) were observed in F1 generation for number of tillers per plant (19.90), number of grains per spike (14.34) and harvest index (16.08) **(Table 4).** Similar results were also reported by **Bhushan *et al.,* (2013), Dutamo *et al.,* (2015), Sarfraz *et al*., (2016), Jaiswal *et al., (*2013), Singh *et al.,* (2021), Kumar and Kumar (2021).**

**Heritability and Genetic advance**:

High estimates of heritability were not observed in F1 generation. The moderate estimates were found for days to 50% heading (15.08), physiological maturity (13.84), days to 50% anthesis (13.65), grain weight per spike (12.77), plant biomass (12.28), number of grains per spike (11.74), number of grains per plant (11.42) and grain yield per plant (10.82). The low heritability estimate was found for plant height (2.78), number of spikelets per spike (5.02), harvest index (5.55), 1000 grain weight (6.77), number of tillers per plant (8.57) and spike length (9.10). Similar findings were also reported by **Dere and Yildirim, (2006), Memon *et al.* (2007)**, **Singh *et al.* (2017).** High estimates of heritability were indicated that selection pressure should be exercised in early generations. The estimates of heritability were low (below 10%) for the character like plant height, number of tillers per plant, spike length, number of spikelets per spike, 1000 grain weight and harvest index in F1 generation. Similar results were also observed by **Malbhage *et al.* (2020).** Genetic advance in per cent of mean was worked out for all the fourteen characters in F1 generation. The estimate of genetic advance in percentage over mean ranged from 7.03 (plant height) to 61.09 (number of grain weight per plant) in F**l** generation. The high value of genetic advance was recorded for number of grain weight per plant (61.09), grain yield per plant (60.35), plant biomass (46.32), number of tillers per plant (36.14), grain weight per spike (33.47) and harvest index (29.71). Moderate genetic advance was recorded for number of harvest index (29.79), grain per spike (23.51), 50 % heading (11.92), days to 50% anthesis (11.63) spike length (11.69) and number of spikelets per spike (10.93). Low values of genetic advance were recorded for physiological maturity (8.60), 1000- grain weight (8.21) and plant height (7.03) in F1 generation. Low genetic advance (below 10%) was observed for physiological maturity, 1000 grain weight and plant height in F1 generation **(Table 4).** Similar findings were also reported **by** **Zewdu *et al.,* (2024), Seyoum and Sisay, (2021), Arya *et al.,* (2017).**

**Heterosis**

Heterosis was calculated in per cent over economic parent (GW-322) in F1s for all the fourteen characters. Estimates on these aspects are presented in **Table 5**. The negative and significant values of heterosis were considered desirable for days to 50% heading, days to 50% anthesis, plant height and physiological maturity. Heterosis was calculated in per cent over economic parent (GBW 322) in F1 generation for all fourteen characters. Estimates of heterosis are presented in **Table 5.** Negative and significant values of heterosis were considered desirable for days to 50% heading, days to 50% anthesis, physiological maturity and plant height, on the other hand positive and significant values were considered desirable for remaining characters. Significant and desirable heterosis over economic parent was noted in sixteen crosses for days to 50% heading, seventeen crosses for days to 50 % anthesis, seventeen crosses for physiological maturity , one cross for plant height, , eleven crosses for number of tillers per plant, six crosses for spike length, two crosses for number of spikelets per spike, twelve crosses for plant biomass, eight crosses for grain weight per spike, twenty crosses for number of grains per spike, twelve crosses for number of grain per plant, twelve crosses for 1000 grain weight, twelve crosses for harvest index and eleven crosses for grain yield per plant. In the present investigation, economic heterosis ranged from -46.13 (K402 X GW322) to 87.71(IC574476 X DBW187) per cent for grain yield per plant. The cross combinations, *viz.*, IC574476 X DBW187, K1317 X GW322, IC574476 X K68, K9351 X K68 and K9351 X DBW187 with positive and significant values were in the order of merit for grain yield per plant. Cross combination IC574476 X DBW187 was also exhibited desirable heterosis for number of spikelets per spike, plant biomass, grain weight per spike, number of grains per spike, number of grains per plant, 1000 grain weight, grain yield per plant and harvest index; K1317 X GW322was also exhibited desirable heterosis for plant biomass, harvest index and grain yield per plant; IC574476 X K68was also exhibited desirable heterosis for six of the attributes namely, number of tillers per plant, spike length, grain weight per spike, 1000 grain weight, grain yield per plant and harvest index; K9351 X K68 was exhibited desirable heterosis for number of tillers per plant, spike length, number of spikelets per spike, grain weight per spike, number of grain per spike, number of grains per plant, 1000 grain weight, grain yield per plant and harvest index; K9351 X DBW187was also exhibited desirable heterosis for number of tillers per plant, spike length, number of spikelets per spike, number of grain per plant, 1000 grain weight, grain yield per plant and harvest index. Similar results were also found that **Kumar *et al.,* (2017), Kumar *et al.,* (2019). Fareed *et al.,* (2024), Sharma, (2020), Singh *et al.,* 2020.**

**Conclusion**

The analysis showed significant differences among both parents and F1 hybrids for the fourteen yield and yield-attributing traits. F1 hybrids generally outperformed parents, except for days to 50% heading, number of tillers per plant, and grain yield per plant. High variability was noted in traits like number of grains per plant, plant biomass, and harvest index. GCV and PCV were high for grain yield and number of grains per plant, indicating potential for effective selection in breeding programs. Moderate heritability estimates and high genetic advance for traits like grain yield per plant and plant biomass suggest effective selection for these traits. These findings indicate potential for improving grain yield through selective breeding, with identified parental combinations and crosses for future breeding programs.

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**References**

**Arya, V. K., Singh, J., Kumar, L., Kumar, R., Kumar, P., & Chand, P. (2017).** Genetic variability and diversity analysis for yield and its components in wheat (Triticum aestivum L.). *Indian Journal of Agricultural Research*, *51*(2).

**Baloch, M. J., Chandio, I. A., Arain, M. A., Baloch, A., & Jatoi, W. A. (2016).** Effect of Terminal Drought Stress on Morpho-physiological Traits of Wheat Genotypes: Drought Stress Effect on Wheat. *Biological Sciences-PJSIR*, *59*(3), 117-125.

**Bhushan, B.; Gaurav, S.S.; Kumar, R.; Pal, R.; Pandey, M.; Kumar, A.; Bharti, S.; Nagar, S.S. and Rahul, V.P. (2013).** Genetic variability, heritability and genetic advance in bread wheat (*Triticum aestivum* L.). Envi. & Eco., 31 (2): 405-407.

**Dere, S. and Yildirim, M.B. (2006).** Inheritance of grain yield per plant, flag leaf width and length in an 8x8 diallel cross population of bread wheat. Turkish Journal of Agriculture and Forestry, 30 (5):339. 345.

**Dutamo, D., Alamerew, S., Eticha, F. and Fikre, G. (2015).** Genetic variability in bread wheat (*Triticum aestivum* L.) germplasm for yield and yield component traits. Journal of Biology, Agriculture and Healthcare, 5(13), 39-46.

**Elahi, T.; Pandey, S. and Shukla, R.S. (2020).** Genetic variability among wheat genotypes based on Agro-morphological traits under restricted irrigated conditions. J.of Pharmac. and Phytochem., 9 (3): 801-805.

**Fareed, G., Keerio, A. A., Mari, S. N., Arain, M. A., Ullah, S., Mastoi, A. A., ... & Badini, M. I. (2024).** Estimation of hetrosis in F1 hybrids of bread wheat genotypes. *Journal of Applied Research in Plant Sciences*, *5*(01), 120-123.

**Ghaffar, M., Khan, S. and Khan, W. (2018).** Genetic variability analysis of wheat (*Triticum aestivum* L.) genotypes for yield and related parameters. Pure and Applied Biology (PAB) 7 (2):547- 555.

**ICAR-IIWBR. Director’s Report of AICRP on Wheat and Barley 2023-24.** Eds: Ratan Tiwari, BS Tyagi, Sindhu Sareen, Anuj Kumar, Mamrutha HM. ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India. 2024;72**.**

**Iqbal, M.; Raja, N.I.; Yasmeen, F.; Hussain, M. and Ejaz, M. (2017).** Impact of heat stress on wheat. Advances in Crop Science And Tecnology,(2017);5:251

**Jaiswal, K.K.; Marker, S. and Kumar, B. (2013).** Combining ability analysis in diallel crosses of wheat (*Triticum aestivum* L.). The Bioscan, 8 (4): 1557-1560.

**Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955).** Estimates of genetic and environmental variability in soybeans.

**Kalhoro, F. A., Rajpar, A. A., Kalhoro, S. A., Mahar, A., Ali, A., Otho, S. A., ... & Baloch, Z. A. (2015).** Heterosis and combing ability in F1 population of hexaploid wheat (*Triticum aestivum* L.). *American Journal of Plant Sciences*, *6*(7), 1011-1026**.**

**Kumar, M. and Kumar, S. (2021).** Estimation of heritability and genetic advance in 24 genotypes of bread wheat (*Triticum aestivum* L.). J. of Pharma, and Phytochem., 10 (1): 1110-1113.

**Kumar, P., Nagar, S. S., Singh, C., Gupta, V., Singh, G., & Tyagi, B. S. (2019).** Assessment of heterosis and inbreeding depression for agro-morphological traits in bread wheat. *Journal of Cereal Research*, *11*(2).

**Kumar, S., Kumar, P., Arya, V. K., Kumar, R., Kamboj, G., & Kerkhi, S. A. (2017).** Identification of heterotic cross combinations for various agromorphological and some quality traits in bread wheat (*Triticum aestivum* L.). *Journal of Applied and Natural Science*, *9*(4), 2013.

**Malbhage, A.B.; Malbhage,M.M.; Shekhawat, V.S. and Mehta, V.R. (2020).** Genetic variability, heritability and genetic advance in durum wheat (*Triticum durum* L.). Phytochem., 9 (4): 3233-3236.

**Memon, S.; Qureshi, M.; Ansari, B.A. and Sial, M.A. (2007).** Genetic heritability for grain yield and its related characters in spring wheat (*Triticum aestivum* L.) Pak. J. Bot., 39 (5): 1503-1509.

**Sarfraz, Z.; Shah, M. M. and Iqbal, M. S. (2016).** Genetic variability, heritability and genetic advance for agronomic traits among A- genome donor wheat genotypes. J. Agric. Res, 54(1): 15-20.

**Seyoum, E. G., & Sisay, A. (2021).** Genetic variability, heritability and genetic advance study in bread wheat genotypes (Triticum aestivum L.). *Advances in Bioscience and Bioengineering*, *9*(3), 81-86.

**Shah, A. H., Rattar, T. M., Zhang, D., Tian, L., Solangi, Z. A., Rattar, Q. A., ... & Anwar, M. (2022).** Heterosis and correlation studies in F1 hybrids of hexaploid wheat (*Triticum aestivum* L.) cultivars. *World Journal Biology Pharmacy Health Sciences*, *11*(3), 119-131**.**

**Sharma, V. (2020).** Heterosis for yield and physio-biochemical traits in bread wheat (*Triticum aestivum* L.) Under different Environmental conditions. *Bangladesh Journal of Botany*, *49*(3), 515-520.

**Singh, Nageshwar.; Singh, S.V.; Singh, M.; Singh, L.; Kumar, S.; Kumar, N and Singh, A.K. (2021)**. Correlation studies among yield and its components in bread wheat (*Triticum aestivum* L.). The Pharma Innovation Journal (2021); 10(12): 978-982.

**Singh, S.V.; Yadav, R.K. and Singh, S.K. (2017).** Genetic variability, heritability, genetic advance and correlation studies for yield components and quality parameters in wheat (*Triticum aestivum* L.). Progressive Research., 12(1): 110-114.

**Steel, R. G. D., & Torrie, J. H. (1960).** Principles and procedures of statistics.

**Tuhina-Khatun, M., Hanafi, M. M., Rafii Yusop, M., Wong, M. Y., Salleh, F. M., & Ferdous, J. (2015).** Genetic variation, heritability, and diversity analysis of upland rice (Oryza sativa L.) genotypes based on quantitative traits. *BioMed research international*, *2015*(1), 290861.

**Zewdu, D., Mekonnen, F., Geleta, N., & Abebe, K. (2024).** Genetic variability, heritability and genetic advance for yield and yield related traits of bread wheat (Triticum aestivum L.) genotypes. *International Journal of Economic Plants*, *11*(1), 38-47.

**Table 1.** Anova for 10 parents and 25 hybrids

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Character s | df | Days to 50%heading | Days to 50%anthesis | Physiolog ical maturity | Plant Height (cm) | No of tillers/p lant | Spike Length (cm) | No. of spikelet s/spikes | Plant Biomass | Grain Wt./Spi ke | No. of Grain/ Spike | No. of Grain/ Plant | 1000Grain wt. (m) | Harvest index (%) | Grain yield/plan t(g) |
| REPLN | 2 | 3.27 | 9.97 | 11.40 | 11.74 | 0.64 | 0.07 | 2.78 | 8.23 | 0.19 | 2.30 | 1224.87 | 4.03 | 3.55 | 3.54 |
| GENO | 34 | 80.71\*\* | 85.51\*\* | 87.58\*\* | 48.69\*\* | 10.31\*\* | 2.31\*\* | 6.67\*\* | 727.85\*\* | 1.03\*\* | 113.86\*\* | 58239.41\*\* | 11.91\*\* | 131.47\*\* | 226.04\*\* |
| CROSS | 24 | 78.75\*\* | 85.69\*\* | 88.55\*\* | 45.52\*\* | 13.24\*\* | 2.20\*\* | 7.05\*\* | 792.35\*\* | 1.14\*\* | 106.77\*\* | 58043.09\*\* | 13.46\*\* | 135.71\*\* | 281.79\*\* |
| PARENT | 9 | 94.18\*\* | 93.74\*\* | 94.67\*\* | 62.41\*\* | 3.39\*\* | 1.62\*\* | 4.82\*\* | 552.99\*\* | 0.85\*\* | 116.58\*\* | 65233.54\*\* | 8.65\*\* | 132.72\*\* | 98.36\*\* |
| LINE(p) | 4 | 88.43\*\* | 86.40\*\* | 80.10\*\* | 15.72\* | 1.40\*\* | 1.39\*\* | 3.60\*\* | 492.46\*\* | 0.73\*\* | 95.77\*\* | 76674.23\*\* | 8.89\*\* | 96.84\*\* | 26.36\*\* |
| TEST(p) | 4 | 79.07\*\* | 80.10\*\* | 88.50\*\* | 9.07 | 5.93\*\* | 1.98\*\* | 5.83\*\* | 499.33\*\* | 1.08\*\* | 142.23\*\* | 69754.43\*\* | 10.52\*\* | 40.60\*\* | 188.46\*\* |
| L(P)vT(P) | 1 | 177.63\*\* | 177.63\*\* | 177.63\*\* | 462.56\*\* | 1.20 | 1.05 | 5.63 | 1009.78\*\* | 0.43\* | 97.20\*\* | 1387.20 | 0.25 | 644.77\*\* | 25.93\*\* |
| CrovsPAR | 1 | 6.56 | 6.88 | 0.28 | 1.25 | 2.19 | 11.11\*\* | 14.41\*\* | 753.45\*\* | 0.04 | 259.51\*\* | 3.90 | 3.81 | 18.48 | 37.45\*\* |
| ERROR | 68 | 2.99 | 2.99 | 2.41 | 6.38 | 0.44 | 0.39 | 1.37 | 14.29 | 0.09 | 8.97 | 1396.18 | 1.57 | 4.71 | 3.70 |
| TOTAL | 104 | 28.41 | 30.10 | 30.43 | 20.31 | 3.67 | 1.01 | 3.13 | 247.45 | 0.40 | 43.13 | 19976.25 | 5.00 | 46.13 | 76.39 |

**Table 2.** Mean performance10 parents and 25 hybrids

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No | Parents and Hybrids | Days to 50%heading | Days to 50%anthesis | Physiol ogical maturity | Plant Height (cm) | No of tillers/p lant | Spike Length (cm) | No. of spikele ts/spikes | Plant Bioma ss | Grain Wt./Spi ke | No. of Grains/ Spike | No. of Grains/ Plant | 1000Grain wt. (m) | Harves t index (%) | Grain yield/pl ant(g) |
|  | **Line** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | K-9644 | 78.67 | 84.33 | 120.33 | 96.07 | 9.67 | 10.97 | 18.67 | 95.28 | 3.63 | 44.67 | 706.00 | 39.03 | 33.44 | 33.40 |
| 2 | K-9351 | 84.33 | 88.33 | 121.33 | 98.17 | 8.67 | 9.67 | 18.00 | 83.21 | 2.60 | 55.00 | 475.33 | 38.37 | 30.57 | 25.43 |
| 3 | K-1317 | 92.67 | 97.33 | 130.67 | 93.50 | 10.33 | 11.03 | 16.00 | 64.83 | 2.83 | 40.00 | 438.67 | 36.17 | 44.13 | 28.59 |
| 4 | K-402 | 85.00 | 89.67 | 121.67 | 92.27 | 10.33 | 9.73 | 18.67 | 65.66 | 3.03 | 43.00 | 272.33 | 40.77 | 36.54 | 28.87 |
| 5 | IC-574476 | 90.00 | 95.67 | 130.33 | 95.30 | 9.67 | 10.80 | 17.67 | 74.26 | 2.33 | 45.00 | 383.00 | 39.70 | 41.96 | 27.17 |
|  | **Tester** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | WB02 | 77.67 | 83.00 | 116.67 | 87.20 | 9.00 | 10.50 | 17.67 | 51.61 | 2.43 | 36.67 | 328.33 | 37.87 | 48.18 | 24.93 |
| 2 | DBW187 | 82.33 | 87.33 | 121.67 | 84.50 | 11.67 | 11.47 | 20.33 | 79.03 | 3.83 | 49.67 | 611.33 | 40.70 | 50.36 | 39.80 |
| 3 | DBW222 | 75.67 | 80.33 | 115.00 | 88.27 | 9.33 | 10.60 | 18.00 | 58.82 | 2.93 | 39.00 | 353.00 | 39.03 | 42.81 | 25.27 |
| 4 | GW322 | 89.00 | 94.00 | 128.67 | 86.97 | 9.00 | 9.73 | 17.33 | 57.04 | 2.77 | 35.33 | 310.67 | 36.48 | 42.51 | 24.13 |
| 5 | K-68 | 81.67 | 86.33 | 118.00 | 89.10 | 11.67 | 11.77 | 20.00 | 78.72 | 3.67 | 49.00 | 604.00 | 40.87 | 49.14 | 38.62 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Mean | **83.70** | **88.63** | **122.43** | **91.13** | **9.93** | **10.63** | **18.23** | **70.85** | **3.01** | **43.73** | **448.27** | **38.90** | **41.97** | **29.62** |
|  | Min | **75.67** | **80.33** | **115.00** | **84.50** | **8.67** | **9.67** | **16.00** | **51.61** | **2.33** | **35.33** | **272.33** | **36.17** | **30.57** | **24.13** |
|  | Max | **83.03** | **87.94** | **121.81** | **90.58** | **9.83** | **10.55** | **18.05** | **69.24** | **2.95** | **43.03** | **433.61** | **38.67** | **41.02** | **29.16** |

**Table 3. Mean performance hybrids**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No | **Hybrids** | Days to 50%heading | Days to 50%anthesis | Physiolo gicalmaturity | Plant Height(cm) | No of tillers/plant | Spike Length(cm) | No. of spikelets/spikes | Plant Biomass | Grain Wt./Spike | No. of Grain/Spike | No. of Grain/Plant | 1000Grainwt. (m) | Harves t index(%) | Grain yield/plant(g) |
| 1 | K-9644 X WB02 | 79.00 | 84.33 | 119.33 | 91.03 | 8.67 | 10.50 | 18.67 | 51.56 | 1.93 | 32.33 | 249.33 | 36.57 | 28.91 | 14.90 |
| 2 | K-9644 X DBW187 | 83.33 | 88.00 | 120.67 | 88.47 | 9.33 | 9.97 | 19.33 | 37.73 | 1.70 | 48.67 | 452.33 | 38.73 | 45.03 | 17.27 |
| 3 | K-9644 X DBW222 | 76.67 | 81.67 | 116.00 | 89.27 | 9.00 | 12.27 | 21.33 | 43.25 | 2.10 | 47.33 | 426.33 | 37.50 | 43.57 | 18.87 |
| 4 | K-9644 X GW322 | 88.00 | 94.33 | 130.00 | 90.53 | 11.33 | 10.87 | 18.67 | 65.99 | 2.70 | 51.33 | 581.33 | 38.90 | 45.22 | 29.86 |
| 5 | K-9644 X K-68 | 81.00 | 85.67 | 119.67 | 92.43 | 9.33 | 12.40 | 19.33 | 57.52 | 2.57 | 47.00 | 437.67 | 39.43 | 44.81 | 25.77 |
| 6 | K-9351 X WB02 | 78.67 | 83.00 | 116.67 | 90.83 | 10.00 | 11.77 | 18.67 | 66.68 | 2.90 | 45.67 | 437.67 | 36.63 | 42.29 | 28.13 |
| 7 | K-9351 X DBW187 | 84.67 | 88.67 | 123.33 | 88.23 | 12.00 | 12.70 | 21.67 | 75.87 | 3.70 | 53.67 | 566.67 | 41.90 | 54.19 | 41.13 |
| 8 | K-9351 X DBW222 | 75.67 | 80.67 | 115.00 | 88.00 | 10.67 | 11.57 | 20.00 | 82.13 | 3.13 | 49.67 | 528.33 | 38.87 | 37.64 | 30.27 |
| 9 | K-9351 X GW322 | 82.67 | 87.33 | 122.33 | 87.40 | 8.67 | 11.87 | 18.67 | 55.35 | 2.90 | 49.33 | 379.00 | 36.93 | 38.91 | 21.53 |
| 10 | K-9351 X K-68 | 85.67 | 90.33 | 125.33 | 87.57 | 12.00 | 12.53 | 23.33 | 77.86 | 3.87 | 61.00 | 642.67 | 42.10 | 53.32 | 41.50 |
| 11 | K-1317 X WB02 | 81.33 | 85.33 | 119.67 | 94.40 | 8.33 | 11.17 | 18.00 | 64.93 | 3.63 | 47.33 | 368.00 | 35.63 | 37.82 | 24.53 |
| 12 | K-1317 X DBW187 | 90.00 | 95.00 | 129.00 | 93.87 | 12.67 | 11.27 | 16.67 | 87.95 | 3.73 | 43.33 | 518.00 | 39.00 | 45.89 | 40.33 |
| 13 | K-1317 X DBW222 | 76.67 | 82.00 | 116.00 | 94.27 | 11.33 | 11.80 | 18.67 | 86.08 | 3.13 | 50.33 | 570.33 | 36.30 | 41.21 | 35.50 |
| 14 | K-1317 X GW322 | 94.00 | 100.33 | 134.00 | 92.03 | 11.33 | 11.63 | 18.33 | 88.57 | 3.80 | 48.33 | 533.67 | 36.23 | 48.11 | 42.53 |
| 15 | K-1317 X K-68 | 83.33 | 87.67 | 122.33 | 98.67 | 9.67 | 12.27 | 20.67 | 79.17 | 3.53 | 55.33 | 533.33 | 37.73 | 42.04 | 33.30 |
| 16 | K-402 X WB02 | 87.33 | 92.67 | 127.33 | 81.93 | 6.33 | 10.37 | 18.67 | 60.56 | 3.10 | 38.67 | 244.33 | 39.20 | 31.49 | 19.60 |
| 17 | K-402 X DBW187 | 83.67 | 88.33 | 121.00 | 88.83 | 6.33 | 10.57 | 18.00 | 54.08 | 2.77 | 39.67 | 251.33 | 38.10 | 32.29 | 17.53 |
| 18 | K-402 X DBW222 | 73.67 | 77.67 | 112.67 | 96.50 | 8.33 | 10.07 | 18.67 | 54.26 | 3.07 | 40.00 | 346.33 | 39.63 | 46.67 | 27.00 |
| 19 | K-402 X GW322 | 91.67 | 96.33 | 131.33 | 94.27 | 4.33 | 10.30 | 16.67 | 30.66 | 3.00 | 40.00 | 160.00 | 39.07 | 42.29 | 13.00 |
| 20 | K-402 X K-68 | 81.67 | 87.33 | 122.67 | 99.47 | 11.00 | 11.23 | 18.67 | 49.03 | 2.27 | 48.33 | 465.00 | 38.27 | 45.48 | 22.30 |
| 21 | IC-574476 X WB02 | 88.00 | 92.67 | 127.67 | 90.33 | 7.67 | 10.93 | 17.33 | 63.88 | 3.13 | 46.00 | 348.00 | 34.07 | 35.49 | 22.67 |
| 22 | IC-574476 X DBW187 | 82.00 | 86.33 | 121.67 | 88.17 | 11.33 | 11.67 | 20.33 | 86.58 | 4.00 | 52.00 | 760.33 | 41.77 | 52.30 | 45.30 |
| 23 | IC-574476 X DBW222 | 78.33 | 84.33 | 119.00 | 92.13 | 11.00 | 10.47 | 17.67 | 69.64 | 2.90 | 45.33 | 467.33 | 37.77 | 43.39 | 30.20 |
| 24 | IC-574476 X GW322 | 87.00 | 92.33 | 127.33 | 94.87 | 7.67 | 10.70 | 18.67 | 54.55 | 3.00 | 49.67 | 364.00 | 38.70 | 40.31 | 22.00 |
| 25 | IC-574476 X K-68 | 84.67 | 89.33 | 123.67 | 90.87 | 12.00 | 12.80 | 19.67 | 79.07 | 3.67 | 50.00 | 564.67 | 42.87 | 53.68 | 42.47 |
|  | Mean | **83.15** | **88.07** | **122.55** | **91.37** | **9.61** | **11.35** | **19.05** | **64.92** | **3.05** | **47.21** | **447.84** | **38.48** | **42.89** | **28.30** |
|  | Min | 73.67 | 77.67 | 112.67 | 81.93 | 4.33 | 9.97 | 16.67 | 30.66 | 1.70 | 32.33 | 160.00 | 34.07 | 28.91 | 13.00 |
|  | Max | 94.00 | 100.33 | 134.00 | 99.47 | 12.67 | 12.80 | 23.33 | 88.57 | 4.00 | 61.00 | 760.33 | 42.87 | 54.19 | 45.30 |
|  | Mean | **83.30** | **88.23** | **122.51** | **91.31** | **9.70** | **11.14** | **18.82** | **66.61** | **3.04** | **46.22** | **447.96** | **38.60** | **42.63** | **28.68** |
|  | Min | 73.67 | 77.67 | 112.67 | 81.93 | 4.33 | 9.67 | 16.00 | 30.66 | 1.70 | 32.33 | 160.00 | 34.07 | 28.91 | 13.00 |
|  | Max | 94.00 | 100.33 | 134.00 | 99.47 | 12.67 | 12.80 | 23.33 | 95.28 | 4.00 | 61.00 | 760.33 | 42.87 | 54.19 | 45.30 |
|  | SE(d) ± | 1.41 | 1.41 | 1.27 | 2.06 | 0.54 | 0.51 | 0.96 | 3.09 | 0.24 | 2.45 | 30.51 | 1.03 | 1.77 | 1.57 |
|  | C.D. at 5% | 2.83 | 2.82 | 2.54 | 4.12 | 1.09 | 1.02 | 1.91 | 6.17 | 0.49 | 4.89 | 61.01 | 2.05 | 3.55 | 3.14 |
|  | C.V. (%) | 2.08 | 1.96 | 1.27 | 2.77 | 6.85 | 5.58 | 6.22 | 5.68 | 9.85 | 6.48 | 8.34 | 3.25 | 5.09 | 6.71 |

**Table 4. Genetic variability**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Genotypes | Heritability (ns) | GA% mean | GCV (%) | PCV (%) |
| Days to 50% heading | 15.08 | 11.92 | 6.11 | 6.45 |
| Days to 50% anthesis | 13.65 | 11.63 | 5.94 | 6.26 |
| Physiological maturity | 13.84 | 8.60 | 4.35 | 4.53 |
| Plant Height (cm) | 2.78 | 7.03 | 4.11 | 4.96 |
| No of tillers/plant | 8.57 | 36.14 | 18.69 | 19.90 |
| Spike Length (cm) | 9.10 | 11.69 | 7.18 | 9.10 |
| No. of spikelets /spikes | 5.02 | 10.93 | 7.07 | 9.41 |
| Plant Biomass | 12.28 | 46.32 | 23.15 | 23.84 |
| Grain Wt./Spike | 12.77 | 33.47 | 18.42 | 20.89 |
| No. of Grain/ Spike | 11.74 | 23.51 | 12.79 | 14.34 |
| No. of Grain/ Plant | 11.42 | 61.09 | 30.73 | 31.84 |
| 1000 Grain wt. (m) | 6.67 | 8.21 | 4.81 | 5.80 |
| Harvest index (%) | 5.55 | 29.79 | 15.25 | 16.08 |
| Grain yield/plant(g) | 10.82 | 60.35 | 30.02 | 30.76 |

**Table 5. Estimates of Heterosis over parent for fourteen characters in parental – line x tester cross**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No | **Hybrids** | Days to50% heading | Days to50% anthesis | Physiologic al maturity | PlantHeight(cm) | No of tillers/pla nt | SpikeLength(cm) | No. of spikelets/spikes | Plant Biomass | Grain Wt./Spike | No. ofGrains/ Spike | No. ofGrains/ Plant | 1000Grain wt.(g) | Harvest index (%) | Grain yield/plant (g) |
| 1 | K-9644 X WB02 | -11.24 \*\* | -10.28 \*\* | -7.25 \*\* | 4.68 | -3.70 | 7.88 | 7.69 | -9.62 | -30.12 \*\* | -8.49 | -19.74 \* | 0.25 | -32.00 \*\* | -38.26 \*\* |
| 2 | K-9644 X DBW187 | -6.37 \*\* | -6.38 \*\* | -6.22 \*\* | 1.72 | 3.70 | 2.40 | 11.54 \* | -33.85 \*\* | -38.55 \*\* | 37.74 \*\* | 45.60 \*\* | 6.19 \* | 5.91 | -28.45 \*\* |
| 3 | K-9644 X DBW222 | -13.86 \*\* | -13.12 \*\* | -9.84 \*\* | 2.64 | 0.00 | 26.03 \*\* | 23.08 \*\* | -24.19 \*\* | -24.10 \*\* | 33.96 \*\* | 37.23 \*\* | 2.81 | 2.48 | -21.82 \*\* |
| 4 | K-9644 X GW322 | -1.12 | 0.35 | 1.04 | 4.10 | 25.93 \*\* | 11.64 \* | 7.69 | 15.68 \*\* | -2.41 | 45.28 \*\* | 87.12 \*\* | 6.64 \* | 6.37 | 23.73 \*\* |
| 5 | K-9644 X K-68 | -8.99 \*\* | -8.87 \*\* | -6.99 \*\* | 6.29 \*\* | 3.70 | 27.40 \*\* | 11.54 \* | 0.83 | -7.23 | 33.02 \*\* | 40.88 \*\* | 8.11 \*\* | 5.40 | 6.77 |
| 6 | K-9351 X WB02 | -11.61 \*\* | -11.70 \*\* | -9.33 \*\* | 4.45 | 11.11 | 20.89 \*\* | 7.69 | 16.90 \*\* | 4.82 | 29.25 \*\* | 40.88 \*\* | 0.43 | -0.52 | 16.57 \* |
| 7 | K-9351 X DBW187 | -4.87 \*\* | -5.67 \*\* | -4.15 \*\* | 1.46 | 33.33 \*\* | 30.48 \*\* | 25.00 \*\* | 33.00 \*\* | 33.73 \*\* | 51.89 \*\* | 82.40 \*\* | 14.87 \*\* | 27.47 \*\* | 70.44 \*\* |
| 8 | K-9351 X DBW222 | -14.98 \*\* | -14.18 \*\* | -10.62 \*\* | 1.19 | 18.52 \*\* | 18.84 \*\* | 15.38 \*\* | 43.98 \*\* | 13.25 | 40.57 \*\* | 70.06 \*\* | 6.55 \* | -11.46 \*\* | 25.41 \*\* |
| 9 | K-9351 X GW322 | -7.12 \*\* | -7.09 \*\* | -4.92 \*\* | 0.50 | -3.70 | 21.92 \*\* | 7.69 | -2.97 | 4.82 | 39.62 \*\* | 22.00 \* | 1.25 | -8.47 \* | -10.77 |
| 10 | K-9351 X K-68 | -3.75 \* | -3.90 \* | -2.59 \* | 0.69 | 33.33 \*\* | 28.77 \*\* | 34.62 \*\* | 36.49 \*\* | 39.76 \*\* | 72.64 \*\* | 106.87 \*\* | 15.42 \*\* | 25.41 \*\* | 71.96 \*\* |
| 11 | K-1317 X WB02 | -8.61 \*\* | -9.22 \*\* | -6.99 \*\* | 8.55 \*\* | -7.41 | 14.73 \*\* | 3.85 | 13.82 \* | 31.33 \*\* | 33.96 \*\* | 18.45 | -2.31 | -11.05 \*\* | 1.66 |
| 12 | K-1317 X DBW187 | 1.12 | 1.06 | 0.26 | 7.93 \*\* | 40.74 \*\* | 15.75 \*\* | -3.85 | 54.18 \*\* | 34.94 \*\* | 22.64 \*\* | 66.74 \*\* | 6.92 \* | 7.94 | 67.13 \*\* |
| 13 | K-1317 X DBW222 | -13.86 \*\* | -12.77 \*\* | -9.84 \*\* | 8.39 \*\* | 25.93 \*\* | 21.23 \*\* | 7.69 | 50.91 \*\* | 13.25 | 42.45 \*\* | 83.58 \*\* | -0.48 | -3.07 | 47.10 \*\* |
| 14 | K-1317 X GW322 | 5.62 \*\* | 6.74 \*\* | 4.15 \*\* | 5.83 \* | 25.93 \*\* | 19.52 \*\* | 5.77 | 55.26 \*\* | 37.35 \*\* | 36.79 \*\* | 71.78 \*\* | -0.67 | 13.17 \*\* | 76.24 \*\* |
| 15 | K-1317 X K-68 | -6.37 \*\* | -6.74 \*\* | -4.92 \*\* | 13.45 \*\* | 7.41 | 26.03 \*\* | 19.23 \*\* | 38.79 \*\* | 27.71 \*\* | 56.60 \*\* | 71.67 \*\* | 3.45 | -1.11 | 37.98 \*\* |
| 16 | K-402 X WB02 | -1.87 | -1.42 | -1.04 | -5.79 \* | -29.63 \*\* | 6.51 | 7.69 | 6.17 | 12.05 | 9.43 | -21.35 \* | 7.47 \*\* | -25.94 \*\* | -18.78 \*\* |
| 17 | K-402 X DBW187 | -5.99 \*\* | -6.03 \*\* | -5.96 \*\* | 2.15 | -29.63 \*\* | 8.56 | 3.85 | -5.19 | 0.00 | 12.26 | -19.10 | 4.45 | -24.04 \*\* | -27.35 \*\* |
| 18 | K-402 X DBW222 | -17.23 \*\* | -17.38 \*\* | -12.44 \*\* | 10.96 \*\* | -7.41 | 3.42 | 7.69 | -4.88 | 10.84 | 13.21 | 11.48 | 8.65 \*\* | 9.78 \* | 11.88 |
| 19 | K-402 X GW322 | 3.00 | 2.48 | 2.07 \* | 8.39 \*\* | -51.85 \*\* | 5.82 | -3.85 | -46.26 \*\* | 8.43 | 13.21 | -48.50 \*\* | 7.10 \* | -0.53 | -46.13 \*\* |
| 20 | K-402 X K-68 | -8.24 \*\* | -7.09 \*\* | -4.66 \*\* | 14.37 \*\* | 22.22 \*\* | 15.41 \*\* | 7.69 | -14.04 \* | -18.07 \* | 36.79 \*\* | 49.68 \*\* | 4.91 | 6.97 | -7.60 |
| 21 | IC-574476 X WB02 | -1.12 | -1.42 | -0.78 | 3.87 | -14.81 \* | 12.33 \* | 0.00 | 11.99 \* | 13.25 | 30.19 \*\* | 12.02 | -6.61 \* | -16.53 \*\* | -6.08 |
| 22 | IC-574476 X DBW187 | -7.87 \*\* | -8.16 \*\* | -5.44 \*\* | 1.38 | 25.93 \*\* | 19.86 \*\* | 17.31 \*\* | 51.79 \*\* | 44.58 \*\* | 47.17 \*\* | 144.74 \*\* | 14.50 \*\* | 23.03 \*\* | 87.71 \*\* |
| 23 | IC-574476 X DBW222 | -11.99 \*\* | -10.28 \*\* | -7.51 \*\* | 5.94 \* | 22.22 \*\* | 7.53 | 1.92 | 22.08 \*\* | 4.82 | 28.30 \*\* | 50.43 \*\* | 3.54 | 2.07 | 25.14 \*\* |
| 24 | IC-574476 X GW322 | -2.25 | -1.77 | -1.04 | 9.08 \*\* | -14.81 \* | 9.93 | 7.69 | -4.38 | 8.43 | 40.57 \*\* | 17.17 | 6.10 \* | -5.18 | -8.84 |
| 25 | IC-574476 X K-68 | -4.87 \*\* | -4.96 \*\* | -3.89 \*\* | 4.48 | 33.33 \*\* | 31.51 \*\* | 13.46 \* | 38.61 \*\* | 32.53 \*\* | 41.51 \*\* | 81.76 \*\* | 17.52 \*\* | 26.27 \*\* | 75.97 \*\* |
|  | SE |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | CD at 5% |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | CD at 1% | - |  |  |  |  |  |  |  |  |  |  |  |  |  |

 **\* Significant at 5% and \*\* highly significant at 1%**