**Path coefficient analysis for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L. em. Thell)**

**Abstract**

Wheat (*Triticum aestivum* L.), a major cereal crop globally, serves as a staple food for a large portion of the world’s population, contributing approximately 20% of global caloric intake. This study focuses on the genetic analysis of 19 morphologically diverse wheat genotypes crossed to produce 60 F1s and F2s, utilizing the Line × Tester mating design. The research aims to investigate key yield-related traits through correlation and path coefficient analysis, using data recorded on 13 quantitative traits such as plant height, ear length, biological yield, and grain yield per plant. The experimental material was cultivated under Rabi season conditions at C.S. Azad University of Agriculture and Technology, Kanpur, India, and analyzed in a randomized block design.

Results from genotypic and phenotypic path analyses in both F1 and F2 generations indicated that productive tillers per plant, biological yield per plant, harvest index, and 1000-grain weight had the most significant direct positive effects on grain yield. Negative effects were observed for traits like days to 50% heading and days to maturity, suggesting that delayed maturity may reduce yield potential. The study concludes that selecting for traits such as tillering ability, biomass, and grain weight could significantly enhance yield potential in bread wheat, offering valuable insights for wheat breeding programs.

Key Words-F1, F2 significant, direct, indirect, Bread wheat, Grain yield, Correlation and path coefficient analysis.

**Introduction**

Cereals are often considered the "staff of life," with wheat, rice, and maize serving as the primary staples for much of the world's population. These crops are major sources of calories, carbohydrates, and some proteins, particularly in developing countries (**Tiwari and Shoran, 2008**). Wheat (*Triticum aestivum* L., 2n=42) is the most significant cereal globally, having been one of the earliest domesticated crops around 10,000 years ago (**Harlan and Zohary, 1966**). Due to its vast cultivation area and substantial nutritional contribution, wheat plays a crucial role, providing approximately 20% of the world's caloric intake and serving as a staple for nearly two billion people, or 36% of the global population. Wheat contributes about 55% of the carbohydrates and 20% of the food calories consumed worldwide.

*Triticum aestivum* is a segmental allohexaploid (2n = 6x = 42, AABBDD) that originated in the Fertile Crescent of Southwest Asia (Lupton, 1987) and has since spread globally. Its three genomes—A, B, and D—originate from wild einkorn wheat (*Triticum monococcum* var. *urartu*), an unknown species, and *Aegilops squarrosa*, a wild grass. With a haploid DNA content of around 1.7 x 10^10 base pairs, the wheat genome is about 40 times larger than that of rice (**Bennett and Smith, 1976; Amuruganathan and Earle, 1991**), largely due to polyploidy and extensive duplications, with repetitive DNA sequences making up roughly 80% of the genome (**Smith and Flavell, 1974**). In India, the three main wheat species—*Triticum aestivum* (bread wheat, 2n=42), *Triticum durum* (macaroni wheat, 2n=28), and *Triticum dicoccum* (emmer or khapli wheat, 2n=28)—are cultivated, with production shares of 95%, 4%, and 1%, respectively.

Wheat plants are rhizomatous and belong to the grass family, characterized by leafy culms (tillers), which are influenced by genetic and environmental factors. The culms are cylindrical, hollow, and narrow toward the top, ending in the peduncle that supports the spike. The spike (ear or head) consists of spikelets arranged in a zigzag pattern along the rachis. Each spikelet contains the lemma and palea, three stamens, and a pistil with two feathery stigmas. Wheat primarily self-pollinates.

Wheat is primarily a Rabi season crop with wide adaptability. Ideal conditions for wheat include cool, moist weather during vegetative growth, followed by dry, warm weather for grain maturation. The optimal temperature for seed germination ranges from 20-25°C. In India, wheat is cultivated mostly in plains, though it is also grown in the mountainous regions of North India and the Nilgiri and Palani hills in South India. To assess adaptability, India is divided into six wheat-growing zones: Northern Hill Zone (NHZ), North Western Plains Zone (NWPZ), North Eastern Plains Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ), and Southern Hill Zone (SHZ). These zones account for 2.9%, 40.1%, 33.2%, 18.1%, 5.4%, and 0.4% of the wheat-growing area, respectively (**Status Paper on Wheat, DWD, Ghaziabad**).

Globally, wheat is the leading cereal crop, covering approximately 221.24 million hectares, producing 771.64 million tons, and achieving a productivity of 3.49 metric tons per hectare (**USDA, 2023**). India has reached a milestone of 107.74 million tons of wheat production from 30.45 million hectares (13.47% of the global area), with a record productivity of 35.37 quintals per hectare (**FAO, 2022**). Wheat is second only to rice in both area and production in India, occupying 31.40 million hectares, with a production of 110.55 million tons and a productivity of 35.21 quintals per hectare (**UPAg - DA&FW, 2022-23**).

In India, wheat is predominantly grown in states such as Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, West Bengal, Uttarakhand, and Himachal Pradesh, which together account for 98% of the nation's wheat production. Uttar Pradesh leads in area and production, covering 9.42 million hectares and producing 33.95 million tons, with an average productivity of 36.04 quintals per hectare. However, Uttar Pradesh's productivity is lower than that of Haryana, Punjab, and Rajasthan, with Haryana achieving the highest productivity at 45.33 quintals per hectare (**Agricultural Statistics at a Glance, 2022**).

Wheat is widely consumed in various forms, including flour for making chapatis, semolina, and pasta products. It is also commonly used to produce bread, biscuits, cookies, crackers, noodles, dalia, maida, and vermicelli. Beyond human consumption, wheat straw serves as animal fodder and is utilized in packaging materials. Nutritionally, wheat is superior to many other cereals, providing around 70% carbohydrates, 12% protein, 1.7% fat, 1.8% ash, 2.0% reducing sugars, 6.7% pentosans, 5.9% starch, 2% fiber, and 12% moisture, with an energy value of 314 Kcal per 100 grams. It is also rich in essential minerals and vitamins, containing calcium (37 mg/100g), iron (4.1 mg/100g), thiamine (0.45 mg/100g), riboflavin (0.13 mg/100g), and nicotinic acid (5.4 mg/100g) **(Lorez and Kulp, 1990).**

A range of biometrical techniques are commonly applied for assessing plant genetics, with Line × Tester analysis being frequently utilized by breeders as it provides valuable genetic insights into the studied material. Improving yield can be accomplished by directly selecting for grain yield and its contributing traits, path coefficient analysis evaluates the direct and indirect effects of independent factors on dependent variables, aiding breeders in identifying key yield components and the underlying connections between two traits.

MATERIALS AND METHOD

Basic material consisting of 19 (15 lines and 4 testers) morphological diverse genotypes *viz.,* K 402, K 1006, HD 3086, HD 2967, DBW 107, HI 1612, PBW 644, DBW 398, PBW 386, HD 3171, DBW 252, K 1711, K 1616, DBW 173, K307, DBW 187, DBW 222, GW 322 and K 1317 were obtained from the germplasm maintained at Section of *Rabi* Cereals of the university in order to develop material to be evaluated for the study.

These parental lines were crossed to develop 60 F1s and F2s using Line X Tester mating design. A total of 139 treatments (19 parents + 60 F1s + 60 F2s) were evaluated for the study of genetical analysis for thirteen quantitative characters in wheat.

The experimental material consisted of 139 treatments (19 parents + 60 F1s+ 60 F2s) was sown in a Randomized Block Design with three replications at Student Instruction Farm, C.S. Azad University of Agriculture and Technology, Kanpur-208002 (U.P.) during *Rabi*, 2023-24. Each parent and F1s were planted in single row while each F2s was planted in two rows of 3 meter length plots with inter and intra-row spacing of 22.5 cm and 10 cm, respectively. Recommended cultural practices and fertilizer dose were applied to raise good crop.

Data recorded for 13 characters *viz.*, days to 50% heading, days to maturity, plant height (cm), flag leaf area (cm2), number of leaves/main tiller, number of productive tillers per plant, ear length (cm), number of spikelets per ear, number of grains per ear, biological yield (g), grain yield per plant (g), harvest index (%) and 1000-grain weight (g).

**Result and Discussion**

Path coefficient analysis helps in understanding the direct and indirect effects of different traits on grain yield in bread wheat, providing valuable insights for selection in breeding programs. The path coefficients for genotypic and phenotypic data from F1 and F2 generations, with grain yield per plant as the dependent variable, are discussed below.

**1. F1 Genotypic Path Analysis:**

The genotypic path coefficient analysis for F1 generation shows several key traits contributing significantly to grain yield per plant:

* **Productive tillers per plant** had the highest positive direct effect on grain yield (0.427\*\*), indicating that an increase in the number of productive tillers directly enhances grain yield. The positive indirect effects through biological yield and harvest index reinforce this finding.
* **Biological yield per plant** exhibited a strong direct effect (0.257\*\*), suggesting that improving the overall biomass could significantly enhance grain yield. Additionally, biological yield had positive indirect effects through traits like number of grains per ear and productive tillers.
* **Harvest index** displayed a substantial direct effect (0.464\*\*) on grain yield, emphasizing the importance of efficient partitioning of biomass to grains. Indirectly, harvest index also positively influenced grain yield through biological yield.
* **1000-grain weight** (0.221\*\*) had a significant direct positive effect on grain yield, showing that heavier grains contribute substantially to yield improvements.

Traits like **number of grains per ear** (0.371\*\*) and **number of leaves per main tiller** (0.167\*) also had notable contributions. However, **days to 50% heading** and **days to maturity** showed negative effects, indicating that early heading and maturity may have a detrimental impact on grain yield in the F1 generation.

**2. F1 Phenotypic Path Analysis:**

At the phenotypic level, similar trends were observed:

* **Productive tillers per plant** had the highest direct positive effect (0.403\*\*), followed by **biological yield per plant** (0.254\*\*), **harvest index** (0.474\*\*), and **number of grains per ear** (0.361\*\*). These traits showed consistency with the genotypic path analysis, reinforcing their significance in improving grain yield.
* **1000-grain weight** (0.185\*\*) and **flag leaf area** (0.0540) also showed positive effects, although with slightly lower direct contributions.

The analysis highlights the key traits for selection in F1, particularly **productive tillers**, **biological yield**, **harvest index**, and **1000-grain weight**, which should be prioritized in breeding programs.

**3. F2 Genotypic Path Analysis:**

In the F2 generation, the following traits had the most substantial effects on grain yield:

* **Productive tillers per plant** maintained a significant direct positive effect on grain yield (0.276\*\*), consistent with the F1 generation results.
* **Biological yield per plant** exhibited the highest direct effect (0.302\*\*), showing that it remains a critical determinant of grain yield in the F2 generation.
* **Harvest index** also retained a significant direct effect (0.436\*\*), underscoring the role of efficient resource allocation in achieving higher yields.
* **1000-grain weight** showed a strong direct positive effect (0.299\*\*), reinforcing the importance of heavier grains in yield improvement.

Additionally, **number of grains per ear** (0.0530) and **flag leaf area** (0.0700) had positive effects on yield. As observed in the F1 generation, **days to 50% heading** and **days to maturity** had negative effects, suggesting that early maturity might be unfavorable for yield in this population.

**4. F2 Phenotypic Path Analysis:**

Similar to the genotypic path, phenotypic analysis in the F2 generation revealed:

* **Biological yield per plant** had the highest direct effect (0.287\*\*), followed by **productive tillers per plant** (0.256\*\*) and **harvest index** (0.457\*\*). These traits demonstrated consistency across both genotypic and phenotypic levels, confirming their critical role in yield determination.
* **1000-grain weight** (0.227\*\*) and **number of grains per ear** (0.0450) also contributed positively, although the effects were somewhat weaker compared to the F1 generation.

**Conclusion:**

The path coefficient analysis in both F1 and F2 generations consistently highlights the importance of productive tillers per plant, biological yield, harvest index, and 1000-grain weight as the most significant contributors to grain yield in bread wheat. These traits exhibited strong positive direct effects on grain yield, making them valuable selection criteria in breeding programs aimed at improving yield potential.

While some traits, such as **days to heading** and **days to maturity**, had negative effects, suggesting that delayed maturity and heading may limit yield, the focus should remain on enhancing biomass, tillering ability, and grain weight to achieve higher productivity in wheat. The consistency of these findings across both genotypic and phenotypic analyses in F1 and F2 generations underscores the robustness of these traits in yield improvement strategies.

Increased tillering enhances the number of spikes, which directly contributes to grain yield, as seen in studies by Royo *et al*. (2006) and Reynolds *et al*. (2009). Studies such as those by Fischer (2007) have demonstrated that increased biomass, when efficiently partitioned, can significantly enhance grain production. This result is consistent with research by Reynolds *et al*. (2012), which emphasizes the critical role of the harvest index in improving yield potential.

Heavier grains have been consistently associated with higher yield potential in wheat, as evidenced by numerous studies, including those by Slafer *et al.* (2005) and Miralles and Slafer (2007). The direct positive effect of grain weight indicates that selecting genotypes with larger and heavier grains can lead to significant improvements in overall yield​.

The findings of this study are consistent with previous research on wheat yield traits. For example, Reynolds *et al*. (2012) also identified traits like harvest index, tillering ability, and grain weight as key determinants of yield in wheat​.

**References:**

**Ahmed, I., Rahman, H., & Ahmed, F. (2018).** Correlation and path analysis in spring wheat (*Triticum aestivum* L.). *Agronomy,* 8(12), 291.

**Ashebr, B., Alemayehu, T., & Bekele, T. (2020).** Correlation and path-coefficient analysis of yield and its components in bread wheat. *Journal of Agricultural Science*, 12(2), 64-76.

**Ayer, D.K., Subedi, K., & Adhikari, B.N. (2017).** Correlation and path-coefficient analysis of yield and its components in wheat. *Asian Journal of Agricultural Research*, 11(2), 45-51.

**Baranwal, D. K.; Mishra, V. K.; Vishwakarma, M. K.; Yadav, P.S. and Arun, B. (2012).** Studies on genetic variability, correlation and path analysis for yield and yield contributing traits in wheat (*T. aestivum* L. em thell.). *Plant Archives,* **12**(1): 99-104.

**Dharmendra, K. & Singh, A. (2010).** Correlation and path-coefficient analysis for yield and yield components in wheat. *Electronic Journal of Plant Breeding*, 1(4), 1163-1167.

Directorate of Agriculture, Uttar Pradesh. (2023). *Wheat production and productivity report 2022-23*. Directorate of Agriculture & Development, Uttar Pradesh.

Directorate of Wheat Development. (2022). *Status paper on wheat*. Directorate of Wheat Development, Ghaziabad, India.

**Dvivedi, A., Sharma, S., Kumar, P., & Singh, R. (2023).** Correlation and path analysis of yield and its components in wheat (*Triticum aestivum* L.) under varying environmental conditions. *International Journal of Plant Sciences, 28*(2), 101-110.

**El-Mohsen, A.A.A., & Khaled, M.A. (2012).** Correlation and path coefficient analysis of yield and its components in wheat (*Triticum aestivum* L.). *Nature and Science*, 10(11), 1545-1550.

FAO. 2022. *Crop Prospects and Food Situation*. Quarterly Global Report No. 1, March 2022. Rome, FAO.

* **Fischer, R.A.** (2007). Understanding the physiological basis of yield potential in wheat. *Journal of Agricultural Science*, 145(2), 99–113.

**Ghafoor, A., Zahoor, A., Manzoor, H., Ahmad, M., & Rasheed, A. (2021).** Correlation and path coefficient analysis for yield and yield-related traits in wheat (*Triticum aestivum* L.) under normal and drought stress conditions. *Journal of Agricultural Research, 59*(1), 45-52.

Harlan, J. R., & Zohary, D. (1966). Distribution of wild wheats and barley. *Science*,153(3740),1074-1080.

Khan, N., Hussain, M., Khan, M. H., & Khan, F. A. (2018). Genetic diversity and correlation analysis for yield and yield-related traits in wheat. *Journal of Integrative Agriculture*, 17(9), 2026-2033.

Kumar, R., Sharma, I., & Singh, S. K. (2011). Genetic architecture of grain yield and related traits in wheat. *Indian Journal of Genetics and Plant Breeding*, 71(2), 127-134.

Lorenz, K., & Kulp, K. (1990). Wheat flour and dough properties. In K. Lorenz & K. Kulp (Eds.), Handbook of cereal science and technology (pp. 45-70). CRC Press.

Maqbool, M. A., Iqbal, M., & Saleem, M. (2010). Correlation and path coefficient analysis in bread wheat. *Pakistan Journal of Agricultural Sciences*, 47(1), 23-26.

**Miralles, D.J., & Slafer, G.A.** (2007). Sink limitations to yield in wheat: how could it be reduced? *Journal of Agricultural Science*, 145(2), 139–149.

**Mishra, P., Verma, R., Singh, V., & Kumar, S. (2023).** Correlation and path coefficient analysis for grain yield and its contributing traits in wheat (*Triticum aestivum* L.). *Journal of Crop Improvement, 37*(3), 289-303.

**Nagireddy, R., & Jyothula, D.P. (2009).** Variability, heritability, and genetic advance in bread wheat (*Triticum aestivum* L.). *Journal of Research ANGRAU,* 37(2), 79-84.

**Reynolds, M.P., Foulkes, M.J., Slafer, G.A., Berry, P., Parry, M.A.J., Snape, J.W., & Angus, W.J.** (2009). Raising yield potential in wheat. *Journal of Experimental Botany*, 60(7), 1899–1918.

**Reynolds, M.P., Manes, Y., Izanloo, A., & Langridge, P.** (2012). Phenotyping approaches for physiological breeding and gene discovery in wheat. *Annals of Applied Biology*, 160(2), 145–160.

**Royo, C., García del Moral, L.F., & Abaza, M.** (2006). Tiller dynamics and yield formation in two semi-dwarf bread wheat cultivars in a Mediterranean climate. *Field Crops Research*, 94(2-3), 134–143.

Singh, G., Singh, A. M., & Kharub, A. S. (2015). Role of wheat breeding in enhancing wheat yield and stability in India. *Journal of Wheat Research*, 7(1), 1-7.

**Slafer, G.A., Savin, R., & Sadras, V.O.** (2005). Coarse and fine regulation of wheat yield components in response to genotype and environment. *Field Crops Research*, 92(1), 1–9.

Statistical Tables for Biological, Agricutural and Medical Research. *Oliver and Boyd. Ltd*. Edinburgh, **29**:117-123.

Tian, L., Brown, P. J., Lee, M., & Yan, J. (2011). Genome-wide association study for yield and yield components in maize. *Molecular Breeding*, 29(3), 499-508.

U.S. Department of Agriculture, Economic Research Service. (2023). *Wheat outlook: June 2023*. USDA ERS

**Yousaf, S., Javaid, A., & Nisar, A. (2008).** Character association and path-coefficient analysis of yield components in wheat (*Triticum aestivum* L.). *Cereal Research Communications,* 36(2), 275-284.

**Table 1. Genotypic path with Grain yield per plant-F1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parent/Hybrids | Days to 50% Heading | Days to maturity | Plant Height (cm.) | Flag leaf area | No of leaves /main tiller | Productive tiller /plant | Ear length | No of spikelet/ear | No of grains/ear | Biological yield/plant | Harvest index | 1000 grain weight | Grain yield/plant |
| Days to 50% Heading | **0.0561** | -0.0468 | 0.0003 | -0.0026 | 0.0033 | 0.0003 | 0.0150 | 0.0043 | -0.0016 | -0.0226 | 0.0800 | -0.0051 | 0.0810 |
| Days to maturity | 0.0402 | **-0.0652** | -0.0020 | -0.0019 | 0.0028 | 0.0019 | 0.0129 | 0.0065 | -0.0026 | -0.1868 | 0.2885 | -0.0009 | 0.0930 |
| Plant Height (cm.) | -0.0006 | -0.0046 | **-0.0281** | 0.0025 | -0.0127 | 0.0003 | 0.0020 | 0.0082 | 0.0024 | 0.2012 | -0.1596 | -0.0007 | 0.0100 |
| Flag leaf area | 0.0024 | -0.0020 | 0.0011 | **-0.0610** | 0.0081 | 0.0052 | -0.0098 | -0.0201 | 0.0011 | -0.1506 | 0.2763 | 0.0074 | 0.0580 |
| No of leaves /main tiller | -0.0044 | 0.0043 | -0.0085 | 0.0117 | **-0.0420** | -0.0047 | 0.0098 | 0.0038 | 0.0053 | -0.0465 | 0.2411 | -0.0034 | 0.167\* |
| Productive tiller /plant | 0.0004 | -0.0036 | -0.0003 | -0.0091 | 0.0057 | **0.0350** | -0.0086 | -0.0138 | 0.0070 | 0.3916 | 0.0176 | 0.0050 | 0.427\*\* |
| Ear length | -0.0174 | 0.0174 | 0.0012 | -0.0123 | 0.0085 | 0.0062 | **-0.0485** | -0.0297 | 0.0051 | 0.0302 | -0.0067 | 0.0069 | -0.0390 |
| No of spikelet/ear | -0.0046 | 0.0082 | 0.0044 | -0.0238 | 0.0031 | 0.0093 | -0.0278 | **-0.0517** | 0.0010 | -0.1350 | 0.2914 | 0.0049 | 0.0790 |
| No of grains/ear | -0.0035 | 0.0066 | -0.0026 | -0.0026 | -0.0085 | 0.0094 | -0.0095 | -0.0019 | **0.0259** | 0.2560 | 0.0990 | 0.0023 | 0.371\*\* |
| Biological yield/plant | -0.0011 | 0.0101 | -0.0047 | 0.0076 | 0.0016 | 0.0113 | -0.0012 | 0.0058 | 0.0055 | **1.2100** | -0.9901 | 0.0018 | 0.257\*\* |
| Harvest index | 0.0033 | -0.0137 | 0.0033 | -0.0123 | -0.0074 | 0.0005 | 0.0002 | -0.0110 | 0.0019 | -0.8742 | **1.3704** | 0.0027 | 0.464\*\* |
| 1000 grain weight | -0.0111 | 0.0022 | 0.0008 | -0.0175 | 0.0055 | 0.0068 | -0.0130 | -0.0098 | 0.0023 | 0.0854 | 0.1438 | **0.0258** | 0.221\*\* |

Resi- 0.03846

\*, \*\* significant at 5% and 1% level, respectively

**Table 2. Phenotypic path with Grain yield per plant-F1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parent/Hybrids | Days to 50% Heading | Days to maturity | Plant Height (cm.) | Flag leaf area | No of leaves /main tiller | Productive tiller /plant | Ear length | No of spikelet/ear | No of grains/ear | Biological yield/plant | Harvest index | 1000 grain weight | Grain yield/plant |
| Days to 50% Heading | **0.0480** | -0.0295 | -0.0005 | -0.0024 | 0.0005 | 0.0002 | 0.0121 | 0.0027 | -0.0018 | -0.0188 | 0.0707 | -0.0049 | 0.0760 |
| Days to maturity | 0.0295 | **-0.0479** | -0.0013 | -0.0014 | 0.0003 | 0.0026 | 0.0120 | 0.0051 | -0.0033 | -0.1744 | 0.2418 | -0.0007 | 0.0620 |
| Plant Height (cm.) | 0.0006 | -0.0015 | **-0.0400** | 0.0020 | -0.0012 | 0.0003 | 0.0015 | 0.0048 | 0.0030 | 0.1902 | -0.1317 | -0.0006 | 0.0270 |
| Flag leaf area | 0.0022 | -0.0012 | 0.0015 | **-0.0541** | 0.0008 | 0.0067 | -0.0097 | -0.0152 | 0.0014 | -0.1401 | 0.2536 | 0.0085 | 0.0540 |
| No of leaves /main tiller | -0.0022 | 0.0014 | -0.0046 | 0.0044 | **-0.0104** | -0.0032 | 0.0044 | 0.0014 | 0.0030 | -0.0383 | 0.1353 | -0.0025 | 0.0890 |
| Productive tiller /plant | 0.0002 | -0.0027 | -0.0002 | -0.0079 | 0.0007 | **0.0457** | -0.0082 | -0.0104 | 0.0084 | 0.3545 | 0.0172 | 0.0058 | 0.403\*\* |
| Ear length | -0.0121 | 0.0120 | 0.0013 | -0.0109 | 0.0010 | 0.0079 | **-0.0479** | -0.0220 | 0.0061 | 0.0255 | -0.0043 | 0.0078 | -0.0360 |
| No of spikelet/ear | -0.0032 | 0.0060 | 0.0047 | -0.0201 | 0.0004 | 0.0116 | -0.0258 | **-0.0409** | 0.0014 | -0.0978 | 0.2432 | 0.0057 | 0.0850 |
| No of grains/ear | -0.0027 | 0.0050 | -0.0038 | -0.0024 | -0.0010 | 0.0120 | -0.0092 | -0.0018 | **0.0319** | 0.2403 | 0.0901 | 0.0026 | 0.361\*\* |
| Biological yield/plant | -0.0008 | 0.0074 | -0.0067 | 0.0067 | 0.0004 | 0.0143 | -0.0011 | 0.0035 | 0.0068 | **1.1295** | -0.9081 | 0.0022 | 0.254\*\* |
| Harvest index | 0.0026 | -0.0090 | 0.0041 | -0.0107 | -0.0011 | 0.0006 | 0.0002 | -0.0077 | 0.0022 | -0.7970 | **1.2870** | 0.0026 | 0.474\*\* |
| 1000 grain weight | -0.0074 | 0.0010 | 0.0008 | -0.0144 | 0.0008 | 0.0083 | -0.0117 | -0.0072 | 0.0026 | 0.0760 | 0.1040 | **0.0319** | 0.185\*\* |

Resi-0.07332

\*, \*\* significant at 5% and 1% level, respectively

**Table 3. Genotypic path with Grain yield per plant-F2**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parent/Hybrids | Days to 50% Heading | Days to maturity | Plant Height (cm.) | Flag leaf area | No of leaves /main tiller | Productive tiller /plant | Ear length | No of spikelet/ear | No of grains/ear | Biological yield/plant | Harvest index | 1000 grain weight | Grain yield/plant |
| Days to 50% Heading | **0.0506** | -0.0394 | 0.0003 | -0.0024 | 0.0001 | 0.0036 | 0.0117 | -0.0010 | -0.0001 | -0.0649 | -0.0320 | 0.0039 | -0.0700 |
| Days to maturity | 0.0354 | **-0.0564** | -0.0030 | -0.0020 | -0.0004 | 0.0038 | 0.0044 | -0.0027 | -0.0002 | -0.0077 | 0.0700 | 0.0016 | 0.0430 |
| Plant Height (cm.) | -0.0005 | -0.0056 | **-0.0307** | 0.0009 | 0.0010 | 0.0062 | 0.0005 | -0.0030 | -0.0003 | 0.0652 | -0.0269 | -0.0004 | 0.0060 |
| Flag leaf area | -0.0104 | 0.0095 | -0.0024 | **0.0117** | 0.0023 | -0.0042 | -0.0089 | 0.0036 | -0.0005 | -0.0136 | 0.0871 | -0.0040 | 0.0700 |
| No of leaves /main tiller | 0.0000 | -0.0040 | 0.0058 | -0.0053 | **-0.0050** | 0.0085 | 0.0082 | -0.0039 | 0.0000 | 0.1871 | -0.2660 | 0.0054 | -0.0690 |
| Productive tiller /plant | -0.0036 | 0.0042 | 0.0037 | 0.0010 | 0.0008 | **-0.0513** | -0.0083 | 0.0069 | 0.0008 | 0.2232 | 0.1002 | -0.0019 | 0.276\*\* |
| Ear length | -0.0125 | 0.0053 | 0.0003 | 0.0022 | 0.0009 | -0.0090 | **-0.0471** | 0.0183 | 0.0015 | 0.2043 | -0.2101 | -0.0026 | -0.0490 |
| No of spikelet/ear | -0.0020 | 0.0055 | 0.0034 | 0.0016 | 0.0007 | -0.0132 | -0.0320 | **0.0269** | 0.0017 | 0.1150 | -0.1188 | -0.0007 | -0.0120 |
| No of grains/ear | -0.0018 | 0.0026 | 0.0026 | -0.0016 | 0.0000 | -0.0114 | -0.0189 | 0.0122 | **0.0037** | 0.3946 | -0.3298 | 0.0011 | 0.0530 |
| Biological yield/plant | -0.0025 | 0.0003 | -0.0015 | -0.0001 | -0.0007 | -0.0088 | -0.0074 | 0.0024 | 0.0011 | **1.2971** | -0.9763 | -0.0016 | 0.302\*\* |
| Harvest index | -0.0012 | -0.0029 | 0.0006 | 0.0007 | 0.0010 | -0.0038 | 0.0072 | -0.0023 | -0.0009 | -0.9271 | **1.3659** | -0.0014 | 0.436\*\* |
| 1000 grain weight | -0.0164 | 0.0075 | -0.0011 | 0.0039 | 0.0023 | -0.0080 | -0.0103 | 0.0015 | -0.0004 | 0.1718 | 0.1600 | **-0.0119** | 0.299\*\* |

Resi- 0.03360

\*, \*\* significant at 5% and 1% level, respectively

**Table 4. Phenotypic path with Grain yield per plant-F2**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parent/Hybrids | Days to 50% Heading | Days to maturity | Plant Height (cm.) | Flag leaf area | No of leaves /main tiller | Productive tiller /plant | Ear length | No of spikelet/ear | No of grains/ear | Biological yield/plant | Harvest index | 1000 grain weight | Grain yield/plant |
| Days to 50% Heading | **0.0201** | -0.0180 | -0.0002 | -0.0011 | -0.0005 | 0.0026 | 0.0079 | 0.0001 | -0.0001 | -0.0597 | -0.0091 | 0.0044 | -0.0540 |
| Days to maturity | 0.0123 | **-0.0293** | -0.0028 | -0.0013 | -0.0006 | 0.0021 | 0.0042 | -0.0015 | -0.0001 | -0.0168 | 0.0518 | 0.0020 | 0.0200 |
| Plant Height (cm.) | 0.0001 | -0.0027 | **-0.0308** | 0.0006 | 0.0007 | 0.0044 | 0.0004 | -0.0017 | -0.0003 | 0.0650 | -0.0269 | -0.0006 | 0.0080 |
| Flag laf area | -0.0025 | 0.0044 | -0.0022 | **0.0089** | 0.0015 | -0.0027 | -0.0077 | 0.0020 | -0.0004 | -0.0118 | 0.0721 | -0.0054 | 0.0560 |
| No of leaves /main tiller | 0.0012 | -0.0019 | 0.0026 | -0.0015 | **-0.0088** | 0.0015 | 0.0031 | -0.0010 | 0.0000 | 0.0585 | -0.1038 | 0.0026 | -0.0480 |
| Productive tiller /plant | -0.0014 | 0.0017 | 0.0038 | 0.0007 | 0.0004 | **-0.0360** | -0.0076 | 0.0035 | 0.0007 | 0.1944 | 0.0985 | -0.0024 | 0.256\*\* |
| Ear length | -0.0036 | 0.0027 | 0.0002 | 0.0015 | 0.0006 | -0.0061 | **-0.0449** | 0.0106 | 0.0012 | 0.1590 | -0.1166 | -0.0034 | 0.0010 |
| No of spikelet/ear | 0.0001 | 0.0026 | 0.0030 | 0.0011 | 0.0005 | -0.0073 | -0.0280 | **0.0170** | 0.0012 | 0.0995 | -0.0788 | -0.0009 | 0.0100 |
| No of grains/ear | -0.0005 | 0.0012 | 0.0025 | -0.0012 | -0.0001 | -0.0073 | -0.0162 | 0.0064 | **0.0033** | 0.3565 | -0.3005 | 0.0015 | 0.0450 |
| Biological yield/plant | -0.0010 | 0.0004 | -0.0016 | -0.0001 | -0.0004 | -0.0056 | -0.0057 | 0.0014 | 0.0010 | **1.2512** | -0.9511 | -0.0020 | 0.287\*\* |
| Harvest index | -0.0001 | -0.0011 | 0.0006 | 0.0005 | 0.0007 | -0.0026 | 0.0039 | -0.0010 | -0.0007 | -0.8854 | **1.3440** | -0.0014 | 0.457\*\* |
| 1000 grain weight | -0.0052 | 0.0034 | -0.0012 | 0.0028 | 0.0013 | -0.0051 | -0.0088 | 0.0009 | -0.0003 | 0.1442 | 0.1125 | **-0.0172** | 0.227\*\* |

Resi- 0.04091

\*, \*\* significant at 5% and 1% level, respectively