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Line × Tester Study in Bread Wheat (*Triticum aestivum* L.) for the Estimation of Correlation and Path coefficients analysis

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Abstract

In this paper, the present investigation aims to evaluate the correlation and path coefficients analysis under timely (E1) and late sown (E2) conditions through line × tester analysis. genotypes including 12 lines, 3 testers and their 36 F1s hybrids were evaluated for 12 morphological traits. The two different conditions were taken characters studied. The correlation coefficient of grain yield per plant showed high degree of positive significant association with days to 50% flowering, days to maturity, tillers per plant, Panicle length, number of spikelet's per spike, number of grains per spike, biological yield per plant, 1000 Grain Weight, harvest index, at phenotypic level and days to 50% flowering, days to maturity, tillers per plant, Panicle length, number of spikelet's per spike, number of grains per spike, biological yield per plant, harvest index, at genotypic level. The path coefficients analysis of such character's plant height, tillers per plant, number of spikelet's per spike, number of grains per spike, biological yield per plant, harvest index exerted positive direct effect on seed yield per plant at both genotypic and phenotypic level while days to maturity, spike length, test weight/1000 grain reaction exerted negative direct effect on seed yield per plant at both phenotypic level and genotypic level.

Keywords- *Randomized Complete Block Design, Line × Tester, Genotype.*

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Introduction

Cereals are generally regarded as the “staff of life”. Wheat, rice, and maize are the major cereals constituting the staple diet of most of the world population. Cereal crops serve as the major source of calories, carbohydrates, and some proteins for the human population in developing countries. Wheat (*Triticum aestivum* L) belongs to the genus *Triticum* of the Poaceae (Gramineae) family originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. The three species of wheat namely, *Triticum aestivum* L $2n = 42$ (bread wheat), *Triticum durum* $2n=28$ (macaroni wheat) and *Triticum dicoccum* $2n=28$ (Emmer or Khapli wheat) grown on a commercial basis in the Indian subcontinent from pre-historic times with share of production in percent 95%, 4% and 1% respectively, are being cultivated in the country. Morphologically, the wheat plant is rhizomatous (showing relationship with the grass family) with the shoot bearing several leafy culms (tillers). The number of culms per plant varies with the seeding depth, density of stand, genetic features and environmental factors. The culms are cylindrical, generally hollow with solid nodes; the diameter reduces gradually towards the top internode (peduncle) which bears the spike. The plant length is attributed to variation in length of the internodes and it is mostly genetically determined. The inflorescence, commonly called ‘ear’ or ‘head’, is a spike having florets (spikelet’s) arranged on opposite sides of the flat rachis. Each spikelet in turn is a condensed reproductive shoot consisting of two sterile bracts (glumes) that enclose 3-5 florets. The florets consist of two bract-like structures, the lemma and the palea, which encase the reproductive organs. There are three stamens and the pistil bear two styles with a feathery stigma. Pollination is predominantly by self-pollination.

Wheat is world's leading cereal crop, cultivated in an area of about 217 million hectares with a production of 780.59 million tonnes and productivity of 3375 kg/ha (**Anonymous, 2022**). India’s wheat production has touched the landmark figure of 106.84 million tonnes from 30.54 million hectares (13.48% of global area) registering an all-time highest crop productivity of 3484 kg/ha (**Anonymous, 2023**). Wheat is used by human beings in form of flour for making Chapatis, Semolina and Pasta products. It is also used for preparation of bread, biscuits, cookies, cracks, noodles, Dalia, maida, vermicelli, etc. Wheat straw is also used for the animal feed as fodder and for packaging materials. The Wheat contains nearly carbohydrates 70%, protein 12%, fat 1.7%, minerals 2.7%, fiber 2% and moisture 12% (**Anonymous, 2008**).

Material and method

The experimental materials for present investigation 'will be conducted at Main Experiment Station of Genetics and plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during Rabi, 2021- 2022 and 2022-23, and the experimental material for present investigation will be derived by crossing 12 lines (BRW-3806, KHTW-1, DWAP-1608, DWAP-1925, DBW-278, GW-477, WH-1252, RWP-2019-41, RWP-2019-38, RWP-2019-32, WSM-138, AKAW-4, including three tester (FLW-15, KRL-1-4, HD-2967,) and Three checks (PBW757, DBW187, HI1563, RAJ3777) 3 parents and 3 checks (12 lines + 3 testers + 3 checks) will be evaluated in Randomized Complete Block Design with 3 replications. Each plot consists of single row of 3m length having row to row and plant to plant distance of 30cm and 10cm, respectively. Five competitive plants in each parent and F1 will be randomly selected for taking observations in each replication.

The normal statistical approach was followed for doing the statistical analyses.

1. Johnson *et al.* (1955). Estimation of Phenotypic and Genotypic Correlation Coefficient Analysis
2. Dewey and Lu, (1959). Estimation of Phenotypic and Genotypic Path Coefficient Analysis

Result and discussion

a. Estimation of the correlation coefficient:

The genotypic and phenotypic correlation coefficient was used to measure the association among the characters in timely sown (E1) and late sown (E2) conditions presented in Table No. – 1 & 2

1. Phenotypic correlation coefficient:

Grain yield per plant (g) in timely sown (E1) exhibited highly significant positive phenotypic correlation with harvest index (0.628) followed by biological yield (0.522), days to maturity (0.232), plant height (0.217) & significant positive phenotypic correlation with number of seeds per spikelet (0.200) and 1000 grain weight (0.167) and non-significant negative phenotypic correlation with tiller/plant (-0.032) and positive non-significant phenotypic correlation with grains per spike (0.123), days to 50% flowering (0.084), flag leaf area (0.037) and panicle length (0.016). Grain yield per plant in late sown (E2) exhibited highly positive phenotypic correlation with harvest index (0.652), biological yield (0.542), 1000 grain weight (0.370) and significant positive phenotypic correlation with plant height (0.201),

number of spikelets per spike (0.194), days to maturity (0.158). It showed non-significant negative phenotypic correlation with days to 50% flowering (-0.061) and tillers per plant (-0.035) and positive phenotypic correlation with flag leaf area (0.003) and GS (0.146).

Days to 50% flowering in timely sown (E1) exhibited significant positive phenotypic correlation with harvest index (0.172) and positive non-significant positive correlation with 1000 grain weight (0.087), plant height (0.074) and number of spikelets per spike (0.029) whereas negative non-significant correlation with panicle length days to maturity (-0.081), flag leaf area (-0.068), biological yield per plant (-0.043), tillers/plant (-0.032) and grains per spike (-0.016). Days to 50% flowering in late sown (E2) exhibited significant negative phenotypic correlation with biological yield per plant (-0.187) whereas positive non-significant correlation with plant height (0.042), number of spikelets per spike (0.002), 1000 grain weight (0.035) and harvest index (0.106). It showed negative non-significant correlation with flag leaf area (0.076), days to maturity (-0.025), tillers/plant (-0.009) and grain per spike (-0.054). Days to maturity in timely sown (E1) exhibited highly significant positive phenotypic correlation with harvest index (0.226) while significant positive correlation with number of seeds per spike (0.168) and negative significant correlation with 1000 grain weight (-0.202). It showed positive non-significant correlation with tillers per plant (0.054), panicle length (0.036), grains per spike biological yield per plant (0.078) .

Plant height in timely sown (E1) exhibited highly significant positive phenotypic correlation with panicle length (0.400), 1000 grain weight (0.294), flag leaf area (0.237), number of spikelets per spike (0.210) while positive and significant correlation harvest index (0.175). It showed negative non-significant correlation with tillers/plant (-0.005) and positive non-significant correlation with grains per spike (0.145), biological yield per plant (0.09). Plant height in late sown (E2) exhibited highly significant positive phenotypic correlation with panicle length (0.412), number of spikelets per spike (0.272), flag leaf area (0.216), and 1000 grain weight (0.206) and significant positive correlation with grains per spike (0.173) whereas positive non-significant correlation with tillers/plant (0.022), biological yield per plant (0.114) and harvest index (0.144) Flag leaf area in timely sown (E1) exhibited non-significant positive phenotypic correlation with biological yield per plant (0.121), tillers/plant (0.107), grains per spike (0.095), panicle length (0.041), number of spikelets per spike (0.029), while negative non-significant correlation with harvest index (-0.044) and 1000 grain weight (-0.027). Flag leaf area in late sown (E2) exhibited significant positive phenotypic correlation with tillers/plant (0.177) and positive non-significant correlation with biological yield (0.144),

panicle length (0.097), grains per spike (0.089), 1000 grain weight (0.017) and negative non-significant correlation number of spikelets per spike (-0.047) and harvest index (-0.080). Tillers/plant in timely sown (E1) exhibited non-significant positive phenotypic correlation with panicle length (0.048), number of spikelets per spike (0.043), grains per spike (0.021) and harvest index (0.034) while negative non-significant correlation with 1000 grain weight (-0.097) and biological yield (0.047). Tillers/plant in late sown (E2) exhibited non-significant positive phenotypic correlation with panicle length (0.120) and harvest index (0.111) whereas negative non-significant phenotypic correlation with biological yield (-0.143), 1000 grain weight (-0.133), number of spikelets per spike (-0.046) and grains per spike (-0.007).

Panicle length in timely sown (E1) exhibited non-significant positive phenotypic correlation with harvest index (0.143) and 1000 grain weight (0.058) whereas negative non-significant phenotypic correlation with biological yield (-0.139), number of spikelets per spike (-0.079) and grains per spike (-0.004). Panicle length in late sown (E2) exhibited non-significant positive phenotypic correlation with 1000 grain weight (0.150), harvest index (0.136), biological yield (0.078), grains per spike (0.038) and number of spikelets per spike (0.034).

Number of spikelets per spike in timely sown (E1) exhibited highly significant positive phenotypic correlation with grains per spike (0.583) while positive and non-significant phenotypic correlation with harvest index (0.141), 1000 grain weight (0.129) and biological yield (0.109). Number of spikelets per spike in late sown (E2) exhibited highly significant positive phenotypic correlation with grains per spike (0.613) whereas positive non-significant phenotypic correlation with 1000 grain weight (0.142), biological yield (0.137) and harvest index (0.078). Grains per spike in timely sown (E1) exhibited significant positive phenotypic correlation with biological yield (0.168) whereas positive non-significant phenotypic correlation with 1000 grain weight (0.004). Grains per spike in late sown (E2) exhibited significant positive phenotypic correlation with biological yield (0.170) whereas positive non-significant phenotypic correlation with 1000 grain weight (0.026) and harvest index (0.013). Biological yield in timely sown (E1) exhibited highly significant positive phenotypic correlation with 1000 grain weight (0.229) whereas highly significant negative phenotypic correlation with harvest index (-0.318). 1000 grain weight in timely sown (E1) exhibited non-significant negative phenotypic correlation with harvest index (-0.006). 1000 grain weight in late sown (E2) exhibited highly significant positive phenotypic correlation with harvest index (0.227).

Similar findings also found by **Thapa *et al.* (2019)**, **Nagar *et al.* (2019)**, **Jaiswal *et al.* (2020)**, and **Mahdy *et al.* (2022)**.

2. Genotypic correlation coefficient:

Grain yield per plant (g) in timely sown (E1) exhibited highly significant positive genotypic correlation with harvest index (0.594), biological yield (0.559), days to maturity (0.278), plant height (0.232) and number of spikelets per spike (0.209) while significant positive genotypic correlation with 1000 grain weight (0.177). It showed positive non-significant correlation with grains per spike (0.136), days to 50% flowering (0.100), flag leaf area (0.047) and panicle length (0.011) whereas negative non-significant correlation with tillers/plant (-0.054). Grain yield per plant (g) in late sown (E2) exhibited highly significant positive genotypic correlation with harvest index (0.643), biological yield (0.570), 1000 grain weight (0.400), number of spikelets per plant (0.220), plant height (0.219) and days to maturity (0.202) while significant positive genotypic correlation with panicle length (0.193) and grains per spike (0.156). It showed positive non-significant correlation with flag leaf area (0.011) and negative non-significant correlation with days to 50% flowering (-0.054) and tiller/plant (-0.048).

Days to 50% flowering in timely sown (E1) exhibited highly significant positive genotypic correlation with harvest index (0.223) while non-significant positive correlation with plant height (0.082), number of spikelets per spike (0.024) and 1000 grain weight (0.110) and negative non-significant correlation with days to maturity (-0.102), flag leaf area (-0.126), tiller/plant (-0.072), panicle length (-0.090) and biological yield (-0.067). Days to 50% flowering in late sown (E2) exhibited highly significant negative genotypic correlation with biological yield (-0.250) and panicle length (-0.219) whereas positive significant correlation with harvest index (0.175). It showed positive non-significant correlation 1000 grain weight (0.036) and plant height (0.034) and negative non-significant correlation with days to maturity (-0.102), flag leaf area (-0.143), tiller/plant (-0.013), grains per spike (-0.080) and number of spikelets of per spike (-0.006). Days to maturity in timely sown (E1) exhibited highly significant positive genotypic correlation with harvest index (0.291) and number of spikelets per spike (0.211) whereas non-significant positive correlation with grains per spike (0.133), biological yield (0.080), panicle length (0.071) and tiller/plant (0.068) and non-significant negative correlation with plant height (-0.037) and flag leaf area (-0.088). Days to maturity in late sown (E2) exhibited highly significant positive genotypic correlation with harvest index (0.243) whereas significant positive correlation with number of spikelets per spike (0.201) and negative significant correlation with flag leaf area (-0.196) and positive non-significant

correlation with panicle length (0.137), grains per spike (0.083), tiller/plant (0.040), biological yield (0.001) and negative non-significant correlation with plant height (-0.025) and 1000 grain weight (-0.027).

Plant height (cm) in timely sown (E1) exhibited highly significant positive genotypic correlation with panicle length (0.429) followed by 1000 grain weight (0.319), flag leaf area (0.247), number of spikelets of spike (0.241) and positive significant correlation with (0.189). It showed positive non-significant correlation with grains per spike (0.151), biological yield (0.101) and negative non-significant correlation with tiller/plant (-0.001). Plant height (cm) in late sown (E2) exhibited highly significant positive genotypic correlation with panicle length (0.440), number of spikelets per spike (302), 1000 grain weight (0.226), flag leaf area (0.223) and positive significant correlation with grains per spike (0.178). It showed positive non-significant correlation with tiller/plant (0.028) and biological yield (0.118).

Flag leaf area in timely sown (E1) exhibited non-significant positive genotypic correlation with tiller/plant (0.126), panicle length (0.027), number of spikelets per spike (0.028), grains per spike (0.092), biological yield (0.128) and negative non-significant correlation with 1000 grain weight (-0.025) and harvest index (-0.044). Flag leaf area in late sown (E2) exhibited highly significant positive genotypic correlation with tiller/plant (0.204) and positive non-significant correlation with biological yield (0.131), panicle length (0.079), grains per spike (0.078), 1000 grain weight (0.011) while negative non-significant correlation with number of spikelets per spike (-0.053) and harvest index (-0.054). Tiller/plant in timely sown (E1) exhibited non-significant positive genotypic correlation with panicle length (0.052), number of spikelets per spike (0.016), grains per spike (0.024), harvest index (0.024) and negative non-significant correlation with biological yield (-0.058) and 1000 grain weight (-0.109). Tiller/plant in late sown (E2) exhibited negative significant correlation with biological yield (-0.155) and non-significant positive genotypic correlation with panicle length (0.132) and harvest index (0.112) and negative non-significant correlation with number of spikelets per spike (-0.049), grains per spike (-0.010), 1000 grain weight (-0.149).

Panicle length in timely sown (E1) exhibited significant positive genotypic correlation with harvest index (0.171) and significant negative genotypic correlation with biological yield (-0.168) while non-significant positive correlation with 1000 grain weight (0.045) and negative non-significant correlation with number of spikelets per spike (-0.100). Panicle length in late sown (E2) exhibited significant positive genotypic correlation with harvest index (0.173) and positive non-significant correlation with 1000 grain weight (0.134), biological yield (0.069),

garins per spike (0.042) and number of spikelets per spike (0.041). Number of spikelets per spike in timely sown (E1) exhibited highly significant positive genotypic correlation with grains per spike (0.623) while positive non-significant correlation with biological yield (0.113), 1000 grain weight (0.139) and harvest index (0.146). Number of spikelets per spike in late sown (E2) exhibited significant positive genotypic correlation with grains per spike (0.657) and significant positive genotypic correlation with biological yield (0.157), 1000 grain weight (0.156) and positive non-significant correlation with harvest index (0.090).

Grains per spike in timely sown (E1) exhibited highly significant positive genotypic correlation with biological yield (0.175) and positive non-significant correlation with 1000 grain weight (0.006) and harvest index (0.004). Grains per spike in late sown (E2) exhibited significant positive genotypic correlation with biological yield (0.178) and positive non-significant correlation with 1000 grain weight (0.036) and harvest index (0.017). Biological yield in timely sown (E1) exhibited highly significant positive genotypic correlation with 1000 grain weight (0.238) whereas negative highly significant genotypic correlation with harvest index (-0.318). Biological yield in late sown (E2) exhibited highly significant positive genotypic correlation with 1000 grain weight (0.303) and negative highly significant genotypic correlation with harvest index (-0.246). 1000 grain weight in timely sown (E1) exhibited non-significant negative genotypic correlation with harvest index (-0.010). 1000 grain weight biological yield in late sown (E2) exhibited highly significant positive genotypic correlation with harvest index (0.255). **similar results were reported by Sabit *et al.* (2017). Chaudhary *et al.* (2022), Sandhu *et al.* (2023), and Jabari *et al.* (2023),**

b. Path coefficient analysis:

The path coefficient analysis using genotypic and phenotypic correlation coefficients estimated in timely sown (E1) and late sown (E2) s were carried out to assess the direct and indirect effects of fourteen characters on the expression of grain yield per plant. The genotypic path coefficient follows approximately the same pattern of the phenotypic path coefficient for direct and indirect path coefficients, presented by table 3 and 4.

1. Phenotypic path

The highest positive phenotypic direct effect on grain yield per plant were exerted by with harvest index (0.9053) followed by biological yield per plant (g) (0.8214), Panicle length (cm) (0.0039), Number of spikelet's per spike(0.0030), in timely sown (E1). Whereas late sown (E2) showed direct effect on grain yield per plant by harvest index (0.8767) followed by

biological yield per plant (g) (0.7942), Number of spikelet's per spike(0.00281), Panicle length (cm) (0.0001).

Days to 50% flowering in timely sown (E₁) have highest phenotypic positive indirect effect from harvest index(0.1557) and other character Days to maturity (0.0037), Flag leaf area (cm²) (0.0017), Tiller/plant (0.0007), Grain per spike(0.0002) and Number of spikelet's per spike(0.0001) also showed positive indirect effect and negative indirect effect from Plant height (-0.0001), Panicle length (cm) (-0.0003), 1000-grain weight (g) (-0.0022) & Biological yield per plant (-0.0357) on grain yield per plant. Days to 50% flowering in late sown (E₂) have highest positive phenotypic indirect effect from harvest index(0.1297) and other character Flag leaf area (cm²) (0.0050), Grain per spike(0.0000), Days to maturity (0.0003), Tiller/plant (0.0007), Number of spikelet's per spike(0.0006), Plant height (cm) (0.0000) and panicle length (0.0000), also showed positive indirect effect & negative indirect effect from, 1000-grain weight (g) (- 0.0023) and Biological yield per plant (-0.1075) on grain yield per plant. Days to maturity in timely sown (E₁) have highest positive phenotypic indirect effect from harvest index(0.2048) and other character biological yield per plant (g) (0.0642), 1000-grain weight (g) (0.0051), Days to 50% flowering (0.0032), Flag leaf area (cm²) (0.0014), Number of spikelet's per spike(0.0005), Panicle length (cm) (0.0001)also showed positive indirect effect and negative indirect effect from Grain per spike(0.0010) and Tiller/plant (0.0013). Days to maturity in late sown (E₂) have highest positive phenotypic indirect effect from harvest index(0.1517) and other character Biological yield per plant (g) (0.0073), Number of spikelet's per spike(0.0048), Flag leaf area (cm²) (0.0039), 1000-grain weight (g) (0.0027), Days to 50% flowering (0.0001) and panicle length (cm) (0.0000), plant hight (0.0000) also showed positive indirect effect and negative indirect effect from Grain per spike(-0.0017) and Tiller/plant (- 0.0003) on grain yield per plant.

Plant height (cm) in timely sown (E₁) have highest positive phenotypic indirect effect from harvest index (0.1586) and other character biological yield per plant (g) (0.0741), Days to maturity (0.0011), panicle length (cm) (0.0016) & Number of spikelet's per spike(0.0006), also showed positive indirect effect and negative indirect effect from Days to 50% flowering (-0.0030), Flag leaf area (cm²) (-0.0059), Grain per spike(-0.0014) and 1000-grain weight (g) (-0.0074), on grain yield per plant. Plant height (cm) in late sown (E₂) have highest positive phenotypic indirect effect from harvest index (0.1514) and other character biological yield per plant (g) (0.1014), Number of spikelet's per spike(0.0084), panicle length (cm) (0.0000) also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0003), Days to 50% flowering (-0.0001), Flag leaf area (cm²) (-0.0103), Tiller/plant (-0.0004), Grain

per spike(-0.0023), 1000-grain weight (g) (-0.0141), on grain yield per plant. Flag leaf area (cm²) in timely sown (E₁) have highest positive phenotypic indirect effect from biological yield per plant (g) (0.0997), Days to maturity (0.0025), Days to 50% flowering (0.0027), 1000-grain weight (g) (0.0007), panicle length (cm) (0.0002) & Number of spikelet's per spike(0.0001), also showed positive indirect effect and negative indirect effect from Tiller/plant (-0.0025), Grain per spike (-0.0010), harvest index (-0.0402) & plant height (-0.0003) on grain yield per plant. Flag leaf area (cm²) in late sown (E₂) have highest positive phenotypic indirect effect from biological yield per plant (g) (0.0962). Other characters 1000-grain weight (g) (0.0047), Days to 50% flowering (0.0027), Days to maturity (0.0006), plant height (-0.0003), panicle length (cm) (0.000) also showed positive indirect effect and negative indirect effect from harvest index(-0.0532), Number of spikelets per spike(-0.0042), Tiller/plant (-0.0029), Grain per spike (-0.0007) and plant height (-0.0003), on grain yield per plant.

Number of tillers per plant in timely sown (E₁) have highest phenotypic positive indirect effect from harvest index(0.0310) and other character 1000-grain weight (g) (0.0024), Days to 50% flowering (0.0013), Days to maturity (0.012), Plant height (cm) (0.000), panicle length (cm) (0.0002), Number of spikelet's per spike(0.0001), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.0387), Flag leaf area (cm²) (-0.0027), Days to maturity (-0.0025), & Grain per spike (-0.0002), on grain yield per plant. Number of tillers per plant in late sown (E₂) have highest positive phenotypic indirect effect from harvest index(0.0973) and other character Days to maturity (0.011), Days to 50% flowering (0.0004), 1000-grain weight (g) (0.0089), panicle length (cm) (0.000), & Plant height (cm) (0.000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.1138), Flag leaf area (cm²) (-0.0076), Number of spikelet's per spike(-0.0013), Days to maturity (-0.0002), & Grain per spike(-0.0006), on grain yield per plant. Panicle length (cm) in timely sown (E₁) have highest positive phenotypic indirect effect from harvest index(0.1294), and other Days to 50% flowering (0.0034) & Grain per spike(0.000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.1146), Days to maturity (-0.0017), 1000-grain weight (g) (-0.0014), Number of tillers per plant (-0.0011), character Flag leaf area (cm²) (-0.0010), Plant height (cm) (-0.0004), & Number of spikelet's per spike(-0.0002) on grain yield per plant. Panicle length (cm) in late sown (E₂) have highest positive phenotypic indirect effect from harvest index(0.1294) and other character Biological yield per plant (g) (0.0973), Number of spikelet's per spike(0.0025), Days to 50% flowering(0.0012) & Plant height (cm) (0.0004) also showed positive indirect effect and negative indirect effect from 1000-grain weight (g) (-0.0126), Flag leaf area (cm²)

(-0.0024), Number of tillers per plant (-0.0023) Days to maturity (-0.0010), & Grain per spike(-0.0010), on grain yield per plant.

Number of spikelet's per spike in timely sown (E_1) have highest positive phenotypic indirect effect from harvest index(0.1273) and other character Spike length (cm) (0.011), Biological yield per plant (g) (0.0893), & also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0076), Grain per spike (-0.0058), Flag leaf area (cm²) (-0.0024), Days to 50% flowering (-0.0012), 1000-grain weight (g) (-0.0032) & Number of tillers per plant (-0.0010), Panicle length (cm) (-0.0003) & Plant height (cm) (-0.0002), on grain yield per plant. Number of spikelet's per spike in late sown (E_2) have highest positive phenotypic indirect effect from Biological yield per plant (g) (0.1091), and other character harvest index (0.0682), Spike length (cm) (0.012), Number of tillers per plant (0.0008), & Plant height (cm) (0.0003) also showed positive indirect effect and negative indirect effect from 1000-grain weight (g) (-0.0095), Grain per spike (-0.0089), Days to maturity (-0.0016), Flag leaf area (cm²) (-0.0007) & Days to 50% flowering (-0.0002) on grain yield per plant. Grain per spike in timely sown (E_1) have highest positive phenotypic indirect effect from Biological yield per plant (g) (0.1380) and other character Number of spikelet's per spike(0.0018), Spike length (cm) (0.009), harvest index(0.0004) & Panicle length (cm) (0.0000), also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0048), Flag leaf area (cm²) (-0.0024), Days to 50% flowering (-0.0006), Number of tillers per plant (-0.0005) Plant height (cm) (-0.0002) & 1000-grain weight (g) (-0.0001) on grain yield per plant. Grain per spike in late sown (E_2) have positive phenotypic indirect effect from Biological yield per plant (g) (0.1426), and other character Number of spikelet's per spike (0.0159), harvest index(0.0021) Spike length (cm) (0.010), 1000-grain weight (g) (0.0008), Days to 50% flowering (0.0000), & Panicle length (cm) (0.0000), also showed positive indirect effect and negative indirect effect from Flag leaf area (cm²) (-0.0020), Days to maturity (-0.0010), Number of tillers per plant (-0.0007) & Plant height (cm) (-0.0001), on grain yield per plant.

1000-grain weight (g) in timely sown (E_1) have highest positive phenotypic indirect effect from Biological yield per plant (g) (0.1885), and other character Spike length (cm) (0.010), Days to maturity (0.0091), Flag leaf area (cm²) (0.0007), Number of spikelet's per spike(0.0004), Grain per spike(0.0000), & Panicle length (0.000) also showed positive indirect effect and negative indirect effect from harvest index (-0.0050), Days to 50% flowering (-0.0035), Plant height (cm)(-0.0003), & Number of tillers per plant (0.0023) on grain yield per plant. 1000-grain weight (g) in late sown (E_2) have highest positive phenotypic indirect effect from Biological yield per plant (g) (0.2274), and other character harvest index (0.1991), Spike

length (cm) (0.010), Number of spikelet's per spike(0.0040), Flag leaf area (cm²) (0.0034), Days to maturity (0.0004), Plant height (cm)(0.0002), Grain per spike(0.0002), & Panicle length (0.0000) also showed positive indirect effect and negative indirect effect from Days to 50% flowering (-0.0003), & Number of tillers per plant (0.0024) on grain yield per plant. Biological yield per plant (g) in timely sown (E₁) s have the highest positive phenotypic indirect effect from Days to 50% flowering (0.0017), and other character Spike length (cm) (0.009), Number of spikelets per spike(0.0003), Number of tillers per plant (0.0011), also showed positive indirect effect and negative indirect effect from harvest index (-0.2881), 1000-grain weight (g) (-0.0058), Days to maturity (-0.0035), Flag leaf area (cm²) (-0.0030), Grain per Spike (-0.0017), Panicle length (-0.0006), Plant height (cm)(-0.0001), & on grain yield per plant.

Biological yield per plant (g) in late sown (E₂) have highest positive phenotypic indirect effect from Number of spikelet's per spike (0.0039), and other character Plant height (cm) (0.0001), Number of tillers per plant (0.0026), Days to 50% flowering (0.0012), Spike length (cm) (0.009), & Panicle length (0.0000) also showed positive indirect effect and negative indirect effect from harvest index (-0.2318) 1000-grain weight (g) (-0.0191), Flag leaf area (cm²) (-0.0059), Grain per spike(-0.0028), & Days to maturity (-0.0001), on grain yield per plant. Harvest index in timely sown (E₁) have highest positive phenotypic indirect effect from Flag leaf area (cm²) (0.0011) and other character Spike length (cm) (0.007), Panicle length (0.0006), Number of spikelet's per spike(0.0004), 1000-grain weight (g) (0.0001), and Grain per spike(0.0000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.2614), Days to maturity (-0.0103), Days to 50% flowering (-0.0068), Number of tillers per plant (-0.0008) & Plant height (cm)(-0.0002), on grain yield per plant. Harvest index in late sown (E₂) have highest positive phenotypic indirect effect from Flag leaf area (cm²) (0.0029) and other character Spike length (cm) (0.008), Number of spikelet's per spike (0.0022), Plant height (cm)(0.0002), Panicle length (0.0000), Grain per spike(0.0000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.2100) 1000-grain weight (g) (-0.0151), Number of tillers per plant (-0.0020) Days to maturity (-0.0016), & Days to 50% flowering (-0.0013) on grain yield per plant. The similar findings were reported by **Tabassum *et al.* (2017)**, **Jaiswal *et al.* (2020)**, **Bilgin *et al.* (2022)**, **Chaudhary *et al.* (2023)**, **Dawwam, *et al.* (2023)**.

The path analysis is a powerful measure that partitions the correlation coefficient and deals with the relative importance of yield-contributing traits on yield. Path coefficient analysis is useful for partitioning direct and indirect causes of correlation and also enables us to compare

the causal factors based on their relative contributions. Path coefficient analysis was used to determine the direct and indirect effects of different characters on grain yield. Shrivastava and Sharma (1976) suggested that only direct yield components should be used for path analysis. The path coefficient analysis using genotypic as well as phenotypic correlation coefficient estimated in timely sown (E₁) and late sown (E₂) were carried out to assess direct and indirect effects of fourteen characters on the expression of grain yield per plant.

Genotypic path

The highest positive genotypic direct effect on grain yield per plant were exerted by with harvest index (0.8954) followed by biological yield per plant (g) (0.8596), Number of spikelet's per spike(0.0146), Panicle length (cm) (0.0131), in timely sown (E₁). Whereas late sown (E₂) showed direct effect on grain yield per plant by harvest index (0.8605) followed by Biological yield per plant (g) (0.8038), Number of spikelet's per spike(0.0309), Panicle length (cm) (0.0005). Days to 50% flowering in timely sown (E₁) have highest positive genotypic indirect effect from harvest index(0.1995) and other character Days to maturity (0.0068), Flag leaf area (cm²) (0.0039), Tiller/plant (0.0017), Grain per spike(0.0004) and Number of spikelet's per spike(0.0003) also showed positive indirect effect and negative indirect effect from Biological yield per plant (-0.0573), 1000-grain weight (g) (- 0.0033), Panicle length (cm) (-0.0012), & Plant height (-0.0011), on grain yield per plant. Days to 50% flowering in late sown (E₂) have highest positive genotypic indirect effect from harvest index(0.1634) and other character Flag leaf area (cm²) (0.0042), Tiller/plant (0.0010), Number of spikelet's per spike(0.0009), Plant height (cm) (0.0000) and also showed positive indirect effect & negative indirect effect from, Biological yield per plant (-0.1323), 1000-grain weight (g) (-0.0032), Days to maturity (-0.0003), Grain per spike(-0.0002), & panicle length (-0.0001), on grain yield per plant. Days to maturity in timely sown (E₁) have highest positive genotypic indirect effect from harvest index(0.2603) and other character Biological yield per plant (g) (0.0688), 1000-grain weight (g) (0.0070), Days to 50% flowering (0.0051), Flag leaf area (cm²) (0.0027), Number of spikelet's per spike(0.0031), Panicle length (cm) (0.0009) plant hight (0.0005)also showed positive indirect effect and negative indirect effect from Grain per spike(0.0018) and Tiller/plant (0.0016). Days to maturity in late sown (E₂) have highest positive genotypic indirect effect from harvest index(0.2087) and other character Biological yield per plant (g) (0.0006), Number of spikelet's per spike(0.0062), Flag leaf area (cm²) (0.0035), 1000-grain weight (g) (0.0020), and panicle length (cm) (0.0001), plant hight (0.0001) also showed positive indirect effect and negative indirect effect from Grain per spike(-0.0021), Tiller/plant (-0.0008) and Days to 50% flowering (-0.0001) on grain yield per plant.

Plant height (cm) in timely sown (E₁) have highest positive genotypic indirect effect from harvest index (0.1696) and other character biological yield per plant (g) (0.0871), Days to maturity (0.0025), panicle length (cm) (0.0056), Number of spikelet's per spike(0.0035), & Tiller/plant (0.0000), also showed positive indirect effect and negative indirect effect from Days to 50% flowering (-0.0041), Flag leaf area (cm²) (-0.0076), Grain per spike(-0.0020) and 1000-grain weight (g) (-0.0096), on grain yield per plant. Plant height (cm) in late sown (E₂) have highest positive genotypic indirect effect from harvest index (0.1549) and other character biological yield per plant (g) (0.1046), Number of spikelet's per spike(0.0101), Days to 50% flowering (0.0001), panicle length (cm) (0.0003) also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0007), Flag leaf area (cm²) (-0.0116), Tiller/plant (-0.0005), Grain per spike(-0.0026), 1000-grain weight (g) (-0.0169), on grain yield per plant.

Flag leaf area (cm²) in timely sown (E₁) have highest positive genotypic indirect effect from biological yield per plant (g) (0.1100), Days to 50% flowering (0.0064), Days to maturity (0.0059), 1000-grain weight (g) (0.0008), panicle length (cm) (0.0004) Number of spikelet's per spike(0.0004), also showed positive indirect effect and negative indirect effect from harvest index(-0.0392), plant hight (-0.0033) Tiller/plant (-0.0030), Grain per spike(-0.0012), on grain yield per plant. Flag leaf area (cm²) in late sown (E₂) have highest positive genotypic indirect effect from biological yield per plant (g) (0.0987), and other character 1000-grain weight (g) (0.0061), Days to 50% flowering (0.0005), Days to maturity (0.0011), plant hight (0.0003), panicle length (cm) (0.0000) also showed positive indirect effect and negative indirect effect from harvest index(-0.0541), Number of spikelet's per spike(-0.0052), Tiller/plant (-0.0033), Grain per spike (-0.0007) and plant hight (-0.0003), on grain yield per plant. Number of tillers per plant in timely sown (E₁) have highest positive indirect effect from harvest index(0.0212) and other character 1000-grain weight (g) (0.0033), Days to 50% flowering (0.0036), Days to maturity (0.0046), panicle length (cm) (0.0007), Number of spikelet's per spike(0.0002) & Plant height (cm) (0.000) also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.0502), Flag leaf area (cm²) (-0.0039), Days to maturity (-0.0025), & Grain per spike (-0.0003), on grain yield per plant. Number of tillers per plant in late sown (E₂) have highest positive indirect effect from harvest index(0.0962) and other character Days to maturity (0.011), 1000-grain weight (g) (0.0112), Days to 50% flowering (0.0003), panicle length (cm) (0.0001), & Plant height (cm) (0.000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.1242), Flag

leaf area (cm²) (-0.0080), Number of spikelet's per spike(-0.0015), Days to maturity (-0.0006), & Grain per spike(-0.0006), on grain yield per plant.

Panicle length (cm) in timely sown (E₁) have highest positive indirect effect from harvest index(0.1534), and other Days to 50% flowering (0.0045) & Grain per spike(0.0000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.1448), Plant height (cm) (-0.0057), Days to maturity (-0.0047), Number of spikelet's per spike(-0.0015) 1000-grain weight (g) (-0.0014), Number of tillers per plant (-0.0013), & character Flag leaf area (cm²) (-0.0008), on grain yield per plant. Panicle length (cm) in late sown (E₂) have highest positive indirect effect from harvest index(0.1297) and other character Biological yield per plant (g) (0.1043), Number of spikelet's per spike(0.0030), Days to 50% flowering(0.0009) & Plant height (cm) (0.0007) also showed positive indirect effect and negative indirect effect from 1000-grain weight (g) (-0.0146), Flag leaf area (cm²) (-0.0025), Number of tillers per plant (-0.0027), Days to maturity (-0.0019), & Grain per spike(-0.0011), on grain yield per plant. Number of spikelet's per spike in timely sown (E₁) have highest positive indirect effect from harvest index(0.1304) and other character Spike length (cm) (0.011), Biological yield per plant (g) (0.0974), & also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0141), Grain per spike (-0.0082), Days to 50% flowering (-0.0012), 1000-grain weight (g) (- 0.0042) & Number of tillers per plant (-0.0004), Panicle length (cm) (-0.0013), Flag leaf area (cm²) (-0.0009), & Plant height (cm) (-0.0032), on grain yield per plant. Number of spikelet's per spike in late sown (E₂) have highest positive indirect effect from biological yield per plant (g) (0.1263), and other character harvest index (0.0778), Flag leaf area (cm²) (0.0085), panicle length (cm) (0.0001), Number of tillers per plant (0.0010), & Plant height (cm) (0.0053) also showed positive indirect effect and negative indirect effect from 1000-grain weight (g) (-0.0117), Grain per spike (-0.0102), Days to maturity (-0.0032), & Days to 50% flowering (-0.0002) on grain yield per plant.

Grain per spike in timely sown (E₁) have highest positive indirect effect from Biological yield per plant (g) (0.1501) and other character Number of spikelet's per spike(0.0091), Days to 50% flowering (0.0015), Spike length (cm) (0.009), harvest index(0.0032) & Panicle length (cm) (0.0000), also showed positive indirect effect and negative indirect effect from Days to maturity (-0.0089), Flag leaf area (cm²) (-0.0028), Number of tillers per plant (-0.0006) Plant height (cm) (-0.0020) & 1000-grain weight (g) (-0.0002) on grain yield per plant. Grain per spike in late sown (E₂) have positive indirect effect from Biological yield per plant (g) (0.1487), and other character Number of spikelet's per spike (0.0188), harvest index (0.0002), Spike length (cm) (0.010), 1000-grain weight (g) (0.0006), & Panicle length (cm) (0.0000), also

showed positive indirect effect and negative indirect effect from Flag leaf area (cm²) (-0.0022), Days to maturity (-0.0020), Number of tillers per plant (-0.0008) Days to 50% flowering (-0.0001), & Plant height (cm) (-0.0002), on grain yield per plant. 1000-grain weight (g) in timely sown (E₁) have highest positive indirect effect from Biological yield per plant (g) (0.2043) and Other character Days to maturity (0.0155), Spike length (cm) (0.010), Number of tillers per plant (0.0026), Number of spikelet's per spike(0.0020), Flag leaf area (cm²) (0.0007) & Panicle length (0.0006) also showed positive indirect effect and negative indirect effect from harvest index (-0.0086), Days to 50% flowering (-0.0055), & Plant height (cm)(-0.0042), Grain per spike(-0.0001), on grain yield per plant. 1000-grain weight (g) in late sown (E₂) have highest positive indirect effect from Biological yield per plant (g) (0.2435), and other character harvest index (0.2192), Spike length (cm) (0.010), Number of spikelet's per spike(0.0048), Number of tillers per plant (0.0031), Flag leaf area (cm²) (0.0041), Days to maturity (0.0004), Plant height (cm)(0.0003), Grain per spike(0.0001), & Panicle length (0.0001) also showed positive indirect effect and negative indirect effect from Days to 50% flowering (-0.0003), & on grain yield per plant.

Biological yield per plant (g) in timely sown (E₁) have the highest positive indirect effect from Days to 50% flowering (0.0034), and other character Spike length (cm) (0.009), Number of spikelets per spike (0.0017), Number of tillers per plant (0.0014), also showed positive indirect effect and negative indirect effect from harvest index (-0.2849), 1000-grain weight (g) (-0.0072), Days to maturity (-0.0054), Flag leaf area (cm²) (-0.0039), Grain per Spike (-0.0023), Panicle length (-0.0022), & Plant height (cm)(-0.0014) on grain yield per plant. Biological yield per plant (g) in late sown (E₂) have highest positive indirect effect from Number of spikelet's per spike (0.0049), and other character Number of tillers per plant (0.0032), Days to 50% flowering (0.0010), Spike length (cm) (0.009), Plant height (cm)(0.0002), Panicle length (0.0001) & Days to maturity (0.0000) also showed positive indirect effect and negative indirect effect from harvest index (-0.2114) 1000-grain weight (g) (-0.0228), Flag leaf area (cm²) (-0.0062), & Grain per spike(-0.0031), on grain yield per plant. Harvest index in timely sown (E₁) has highest positive indirect effect from Flag leaf area (cm²) (0.0013) and other characters Spike length (cm) (0.007), Panicle length (0.0023), Number of spikelet's per spike (0.0021), and 1000-grain weight (g) (0.0003), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.2735) Days to 50% flowering (-0.0112), Days to maturity (-0.0195), Plant height (cm)(-0.0025), Number of tillers per plant (-0.0006) & Grain per spike(-0.0001), on grain yield per plant. Harvest index in late sown (E₂) have highest positive indirect effect from Flag leaf area (cm²) (0.0032) and other character Spike length

(cm) (0.008), Plant height (cm)(0.0003), Panicle length (0.0001), Number of spikelet's per spike(0.0028), Grain per spike(0.0000), also showed positive indirect effect and negative indirect effect from Biological yield per plant (g) (-0.1975) 1000-grain weight (g) (-0.0192), Days to maturity (-0.0039), Days to 50% flowering (-0.0011), & Number of tillers per plant (-0.0023) on grain yield per plant. Similar finding observed by **Rajput & Kandalkar (2018)**, **Gaur and Sahu (2020)**, **Tolwani et al. (2022)**, **Vaghela et al. (2022)**, and **Shah et al. (2023)**.

Conclusion

In summary, we found that the harvest index had the strongest positive phenotypic and genotypic correlation, which was found to be highly significant, with the majority of the characters in E1 and E2. Additionally, the harvest index had the strongest positive phenotypic and genotypic direct effect, which was followed by biological yield with grain yield per plant, and the highest positive phenotypic and genotypic indirect effect, which was found to be highly significant, with the majority of the characters observed, indicating that the data could be used for crop improvement shortly.

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| Characters | Y | Days to 50% flowering | Days to maturity | Plant Height | Flag Leaf Area | Tiller/Plant | Panicle length (cm) | NSS | GS | Biological yield (g) | 1000GW (gm) | Harvest index (%) | Grain yield per plant (g) |
|---------------------------|----|-----------------------|------------------|--------------|----------------|--------------|---------------------|---------|---------|----------------------|-------------|-------------------|---------------------------|
| Days to 50% flowering | E1 | 1.000 | -0.102 | 0.082 | -0.126 | -0.072 | -0.090 | 0.024 | -0.030 | -0.067 | 0.110 | 0.223** | 0.100 |
| | E2 | 1.000 | -0.047 | 0.034 | -0.143 | -0.013 | -0.219** | -0.006 | -0.080 | -0.250** | 0.036 | 0.175* | -0.054 |
| Days to maturity | E1 | | | -0.037 | -0.088 | 0.068 | 0.071 | 0.211** | 0.133 | 0.080 | -0.232** | 0.291** | 0.278** |
| | E2 | | | -0.025 | -0.196* | 0.040 | 0.137 | 0.201* | 0.083 | 0.001 | -0.027 | 0.243** | 0.202** |
| Plant Height | E1 | | | | 0.247** | -0.001 | 0.429** | 0.241** | 0.151 | 0.101 | 0.319** | 0.189* | 0.232** |
| | E2 | | | | 0.223** | 0.028 | 0.440** | 0.302** | 0.178* | 0.118 | 0.226** | 0.169* | 0.219** |
| Flag Leaf Area | E1 | | | | | 0.126 | 0.027 | 0.028 | 0.092 | 0.128 | -0.025 | -0.044 | 0.047 |
| | E2 | | | | | 0.204** | 0.079 | -0.053 | 0.078 | 0.131 | 0.011 | -0.054 | 0.011 |
| Tiller/Plant | E1 | | | | | | 0.052 | 0.016 | 0.024 | -0.058 | -0.109 | 0.024 | -0.054 |
| | E2 | | | | | | 0.132 | -0.049 | -0.010 | -0.155* | -0.149 | 0.112 | -0.048 |
| Panicle length (cm) | E1 | | | | | | | -0.100 | 0.000 | -0.168* | 0.045 | 0.171* | 0.011 |
| | E2 | | | | | | | 0.041 | 0.042 | 0.069 | 0.134 | 0.173* | 0.193* |
| NSS | E1 | | | | | | | | 0.623** | 0.113 | 0.139 | 0.146 | 0.209** |
| | E2 | | | | | | | | 0.657** | 0.157* | 0.156* | 0.090 | 0.220** |
| GS | E1 | | | | | | | | | 0.175* | 0.006 | 0.004 | 0.136 |
| | E2 | | | | | | | | | 0.178* | 0.036 | 0.017 | 0.156* |
| Biological yield (g) | E1 | | | | | | | | | | 0.238** | -0.318** | 0.559** |
| | E2 | | | | | | | | | | 0.303** | -0.246** | 0.570** |
| 1000GW(gm) | E1 | | | | | | | | | | | -0.010 | 0.177* |
| | E2 | | | | | | | | | | | 0.255** | 0.400** |
| Harvest index (%) | E1 | | | | | | | | | | | | 0.594** |
| | E2 | | | | | | | | | | | | 0.643** |
| Grain yield per plant (g) | E1 | | | | | | | | | | | | 1.000 |
| | E2 | | | | | | | | | | | | 1.000 |

Table 2. Genotypic correlation

Table 3. Phenotypic path

| Characters | Y | Days to 50% flowering | Days to maturity | Plant Height | Flag Leaf Area | Tiller/Plant | Panicle length (cm) | NSS | GS | Biological yield (g) | 1000GW (gm) | Harvest index (%) | Grain yield per plant (g) |
|-----------------------|----|-----------------------|------------------|--------------|----------------|--------------|---------------------|---------|---------|----------------------|-------------|-------------------|---------------------------|
| Days to 50% flowering | E1 | -0.0398 | 0.0037 | -0.0001 | 0.0017 | 0.0007 | -0.0003 | 0.0001 | 0.0002 | -0.0357 | -0.0022 | 0.1557 | 0.084 |
| | E2 | -0.0066 | 0.0003 | -0.0002 | 0.0027 | 0.0002 | -0.0012 | 0.0001 | 0.0009 | -0.1475 | -0.0022 | 0.0925 | -0.061 |
| Days to maturity | E1 | 0.0032 | -0.0453 | 0.0000 | 0.0014 | -0.0013 | 0.0001 | 0.0005 | -0.0010 | 0.0642 | 0.0051 | 0.2048 | 0.232** |
| | E2 | 0.0002 | -0.0131 | 0.0000 | 0.0047 | -0.0003 | 0.0006 | 0.0063 | -0.0011 | 0.0072 | 0.0025 | 0.1513 | 0.158* |
| Plant Height | E1 | -0.0030 | 0.0011 | -0.0011 | -0.0059 | 0.0001 | 0.0016 | 0.0006 | -0.0014 | 0.0741 | -0.0074 | 0.1586 | 0.217** |
| | E2 | -0.0003 | 0.0000 | -0.0040 | -0.0076 | -0.0004 | 0.0026 | 0.0100 | -0.0029 | 0.0902 | -0.0127 | 0.1260 | 0.201* |
| Flag Leaf Area | E1 | 0.0027 | 0.0025 | -0.0003 | -0.0250 | -0.0025 | 0.0002 | 0.0001 | -0.0010 | 0.0997 | 0.0007 | -0.0402 | 0.037 |
| | E2 | 0.0005 | 0.0018 | -0.0009 | -0.0351 | -0.0035 | 0.0006 | -0.0017 | -0.0015 | 0.1139 | -0.0011 | -0.0701 | 0.003 |
| Tiller/Plant | E1 | 0.0013 | -0.0025 | 0.0000 | -0.0027 | -0.0232 | 0.0002 | 0.0001 | -0.0002 | -0.0387 | 0.0024 | 0.0310 | -0.032 |
| | E2 | 0.0001 | -0.0002 | -0.0001 | -0.0062 | -0.0199 | 0.0008 | -0.0017 | 0.0001 | -0.1133 | 0.0083 | 0.0971 | -0.035 |
| Panicle length (cm) | E1 | 0.0034 | -0.0017 | -0.0004 | -0.0010 | -0.0011 | 0.0039 | -0.0002 | 0.0000 | -0.1146 | -0.0014 | 0.1294 | 0.016 |
| | E2 | 0.0012 | -0.0011 | -0.0016 | -0.0034 | -0.0024 | 0.0064 | 0.0012 | -0.0006 | 0.0616 | -0.0093 | 0.1185 | 0.170* |
| NSS | E1 | -0.0012 | -0.0076 | -0.0002 | -0.0007 | -0.0010 | -0.0003 | 0.0030 | -0.0058 | 0.0893 | -0.0032 | 0.1273 | 0.200* |
| | E2 | 0.0000 | -0.0022 | -0.0011 | 0.0017 | 0.0009 | 0.0002 | 0.0368 | -0.0104 | 0.1086 | -0.0088 | 0.0680 | 0.194* |
| GS | E1 | 0.0006 | -0.0048 | -0.0002 | -0.0024 | -0.0005 | 0.0000 | 0.0018 | -0.0099 | 0.1380 | -0.0001 | 0.0004 | 0.123 |
| | E2 | 0.0004 | -0.0009 | -0.0007 | -0.0031 | 0.0001 | 0.0002 | 0.0226 | -0.0169 | 0.1343 | -0.0016 | 0.0115 | 0.146 |
| Biological yield (g) | E1 | 0.0017 | -0.0035 | -0.0001 | -0.0030 | 0.0011 | -0.0006 | 0.0003 | -0.0017 | 0.8214 | -0.0058 | -0.2881 | 0.522** |
| | E2 | 0.0012 | -0.0001 | -0.0005 | -0.0051 | 0.0028 | 0.0005 | 0.0051 | -0.0029 | 0.7901 | -0.0177 | -0.2312 | 0.542** |
| 1000GW(gm) | E1 | -0.0035 | 0.0091 | -0.0003 | 0.0007 | 0.0023 | 0.0002 | 0.0004 | 0.0000 | 0.1885 | -0.0251 | -0.0050 | 0.167* |
| | E2 | -0.0002 | 0.0005 | -0.0008 | -0.0006 | 0.0027 | 0.0010 | 0.0052 | -0.0004 | 0.2262 | -0.0618 | 0.1985 | 0.370** |
| Harvest index (%) | E1 | -0.0068 | -0.0103 | -0.0002 | 0.0011 | -0.0008 | 0.0006 | 0.0004 | 0.0000 | -0.2614 | 0.0001 | 0.9053 | 0.628** |
| | E2 | -0.0007 | -0.0023 | -0.0006 | 0.0028 | -0.0022 | 0.0009 | 0.0029 | -0.0002 | -0.2089 | -0.0140 | 0.8743 | 0.652** |

Table 4. Genotypic path

| Characters | Y | Days to 50% flowering | Days to maturity | Plant Height | Flag Leaf Area | Tiller/Plant | Panicle length (cm) | NSS | GS | Biological yield (g) | 1000GW (gm) | Harvest index (%) | Grain yield per plant (g) |
|-----------------------|----|-----------------------|------------------|--------------|----------------|--------------|---------------------|---------|---------|----------------------|-------------|-------------------|---------------------------|
| Days to 50% flowering | E1 | -0.0503 | 0.0068 | -0.0011 | 0.0039 | 0.0017 | -0.0012 | 0.0003 | 0.0004 | -0.0572 | -0.0033 | 0.1995 | 0.100 |
| | E2 | -0.0084 | 0.0012 | -0.0003 | 0.0062 | 0.0003 | -0.0022 | -0.0003 | 0.0018 | -0.2002 | -0.0025 | 0.1505 | -0.054 |
| Days to maturity | E1 | 0.0051 | -0.0670 | 0.0005 | 0.0027 | -0.0016 | 0.0009 | 0.0031 | -0.0018 | 0.0688 | 0.0070 | 0.2603 | 0.278** |
| | E2 | 0.0004 | -0.0264 | 0.0003 | 0.0085 | -0.0008 | 0.0014 | 0.0093 | -0.0019 | 0.0006 | 0.0019 | 0.2089 | 0.202** |
| Plant Height | E1 | -0.0041 | 0.0025 | -0.0133 | -0.0076 | 0.0000 | 0.0056 | 0.0035 | -0.0020 | 0.0871 | -0.0096 | 0.1696 | 0.232** |
| | E2 | -0.0003 | 0.0007 | -0.0100 | -0.0097 | -0.0006 | 0.0043 | 0.0140 | -0.0040 | 0.0947 | -0.0158 | 0.1456 | 0.219** |
| Flag Leaf Area | E1 | 0.0064 | 0.0059 | -0.0033 | -0.0305 | -0.0030 | 0.0004 | 0.0004 | -0.0012 | 0.1100 | 0.0008 | -0.0392 | 0.047 |
| | E2 | 0.0012 | 0.0052 | -0.0022 | -0.0434 | -0.0041 | 0.0008 | -0.0025 | -0.0018 | 0.1045 | -0.0008 | -0.0461 | 0.011 |
| Tiller/Plant | E1 | 0.0036 | -0.0046 | 0.0000 | -0.0039 | -0.0240 | 0.0007 | 0.0002 | -0.0003 | -0.0502 | 0.0033 | 0.0212 | -0.054 |
| | E2 | 0.0001 | -0.0011 | -0.0003 | -0.0089 | -0.0203 | 0.0013 | -0.0023 | 0.0002 | -0.1236 | 0.0105 | 0.0963 | -0.048 |
| Panicle length (cm) | E1 | 0.0045 | -0.0047 | -0.0057 | -0.0008 | -0.0013 | 0.0131 | -0.0015 | 0.0000 | -0.1448 | -0.0014 | 0.1534 | 0.011 |
| | E2 | 0.0018 | -0.0036 | -0.0044 | -0.0034 | -0.0027 | 0.0099 | 0.0019 | -0.0009 | 0.0551 | -0.0094 | 0.1487 | 0.193* |
| NSS | E1 | -0.0012 | -0.0141 | -0.0032 | -0.0009 | -0.0004 | -0.0013 | 0.0146 | -0.0082 | 0.0974 | -0.0042 | 0.1304 | 0.209** |
| | E2 | 0.0001 | -0.0053 | -0.0030 | 0.0023 | 0.0010 | 0.0004 | 0.0462 | -0.0147 | 0.1257 | -0.0109 | 0.0779 | 0.220** |
| GS | E1 | 0.0015 | -0.0089 | -0.0020 | -0.0028 | -0.0006 | 0.0000 | 0.0091 | -0.0132 | 0.1501 | -0.0002 | 0.0032 | 0.136 |
| | E2 | 0.0007 | -0.0022 | -0.0018 | -0.0034 | 0.0002 | 0.0004 | 0.0304 | -0.0224 | 0.1424 | -0.0025 | 0.0143 | 0.156* |
| Biological yield (g) | E1 | 0.0034 | -0.0054 | -0.0014 | -0.0039 | 0.0014 | -0.0022 | 0.0017 | -0.0023 | 0.8596 | -0.0072 | -0.2849 | 0.559** |
| | E2 | 0.0021 | 0.0000 | -0.0012 | -0.0057 | 0.0031 | 0.0007 | 0.0073 | -0.0040 | 0.8000 | -0.0212 | -0.2116 | 0.570** |
| 1000GW(gm) | E1 | -0.0055 | 0.0155 | -0.0042 | 0.0008 | 0.0026 | 0.0006 | 0.0020 | -0.0001 | 0.2043 | -0.0302 | -0.0086 | 0.177* |
| | E2 | -0.0003 | 0.0007 | -0.0023 | -0.0005 | 0.0030 | 0.0013 | 0.0072 | -0.0008 | 0.2424 | -0.0701 | 0.2194 | 0.400** |
| Harvest index (%) | E1 | -0.0112 | -0.0195 | -0.0025 | 0.0013 | -0.0006 | 0.0023 | 0.0021 | -0.0001 | -0.2735 | 0.0003 | 0.8954 | 0.594** |
| | E2 | -0.0015 | -0.0064 | -0.0017 | 0.0023 | -0.0023 | 0.0017 | 0.0042 | -0.0004 | -0.1966 | -0.0179 | 0.8612 | 0.643** |

