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## Comparative analysis of genetic variability, path analysis and correlation coefficient in rice (*Oryza sativa* L.) cultivars under Prayagraj agro-climatic conditions

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### Abstract

This study was conducted to assess the extent of genetic variability, correlation coefficient, and path analysis among different rice cultivars of Rice (*Oryza sativa* L.) under the agro-climatic conditions of Prayagraj. The experiment involved diverse rice genotypes evaluated for important agronomic and yield-related traits including days to flowering, plant height, number of tillers, panicle length, filled grains per panicle, spikelet fertility, test weight, and grain yield. Analysis of variance revealed significant variations between cultivars, indicating a high degree of genetic diversity. High phenotypic and genotypic coefficients of variation were observed for several yield-contributing traits, suggesting broad scope for effective selection. Correlation analysis indicated that grain yield exhibited positive and significant association with productive tillers, panicle length, spikelet fertility, and test weight. Path coefficient analysis further demonstrated that traits such as number of productive tillers, filled grains per panicle, and biological yield exerted strong positive direct effects on grain yield, highlighting their importance in selection strategies. The findings suggest that these characters can be effectively utilized in breeding programs for improving yield potential in rice cultivars under Prayagraj agro-climatic conditions.

**Keywords:** Rice, *Oryza sativa* L., genetic variability, correlation coefficient, path analysis, grain yield, yield traits, rice cultivars, Prayagraj agro-climatic conditions

### Introduction

Although rice (*Oryza sativa* L.) is a staple meal for more than half of the world's population, its yield and quality are essential to ensuring global food security. Grain shape and palatability are two of the most important aspects affecting rice quality. Grain shape, which comprises properties such as grain length, width, and thickness, significantly affects both the production potential and market value of rice Wang *et al.*, (2012)<sup>[20]</sup> & Jahani *et al.*, (2013)<sup>[12]</sup> Niu *et al.*, (2020)<sup>[17]</sup>. For customer acceptance and marketability, palatability which includes flavor, texture, and overall eating quality is equally crucial. In Bangladesh, rice is the most significant grain crop and a staple diet item. On 75% of the total cultivated land, or 11.58 million hectares, we produce roughly 30 million tons of rice annually (BBS, 2018). After Boro, Aman rice accounts for the second-largest portion of all rice output. Bangladeshi agriculture is distinguished by its extensive crop production using a cropping strategy based on rice. Our nation's average rice output is about 4.57 t ha<sup>-1</sup>, which is disappointingly lower than Australia's maximum yield of 9.65 t ha<sup>-1</sup> and lower than the global average of 7.48 t ha<sup>-1</sup> (FAO, 2019). Throughout the two Green Revolutions, rice production increased along with advancements in tolerance and architecture Khush *et al.* (2001)<sup>[14]</sup>. Both conventional breeding methods and contemporary molecular breeding techniques have shown that plant architecture and stress tolerance are closely related, complementing one another during the rice reproductive process and simultaneously influencing rice output Guo *et al.*, (2020)<sup>[10]</sup>. The photosynthetic efficiency, biomass, and stress tolerance of plants can all be enhanced by optimal plant architecture Ma *et al.*, (2020).

The initial NPT rice architecture was for irrigated and suitable rainfed tropical lowlands. Correspondingly, it is crucial to regionalize the criteria according to local cultivation and climate conditions Feng *et al.*, (2013)<sup>[8]</sup>. Numerous nations continued to release NPT rice varieties. A few examples are as follows: Fatmawati Abdullah *et al.*, (2008)<sup>[1]</sup>. IPB3S in Indonesia; and Pusa 1266 in India Marathi *et al.*, (2012)<sup>[16]</sup>. The NPT rice variety Shennong265, which was first introduced in China in 1997, has a yield potential of 11-11.8 t ha<sup>-1</sup>. Farmers are widely using this type as well as others like Shennong 174 and Shennong 606 Chen *et al.*, (2001)<sup>[3]</sup>.

Increasing the number of grains is the simplest method to boost the grain yield in cereals. The main determinants of grain number are branch differentiation and panicle architecture, which are closely related to vascular development and phytohormone pathways Duan *et al.*, (2019)<sup>[6]</sup> & Deveshwar *et al.*, (2020)<sup>[4]</sup>. According to many research, the broad-sense heritability of grain number ranges from about 70 to 90% Tuhina *et al.*, (2015)<sup>[19]</sup> & Roy *et al.*, (2020)<sup>[18]</sup>. Demonstrating that the primary determinant of grain number is genetic. Thus, one effective way for breeders to boost rice production would be to analyze the genetic mechanism controlling the number of grains per panicle.

## 2. Material and Method

### 2.1 Experimental Site

The present experiment was conducted in Kharif season 2025-26 at Agricultural Research Farm of Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh. The of Mirzapur Road, approximately 15 km from Prayagraj city. It lies at a latitude of 25°35'85" and longitude of 81°89'3" and a elevation of 98 meters above sea level. Area is located south of Prayagraj, on the right bank of the Ganga and Yamuna River, and East.

### 2.2 Experimental Material

Prayagraj district falls within the subtropical zone of south-eastern Uttar Pradesh, characterized by intensely hot summers and moderately cold winters. The maximum temperature in this region varies between 25 °C to 35 °C and rarely drops below 5°C to 6°C. The relative humidity fluctuates between 13.9% to 99.7%, while the area receives an average annual rainfall of approximately 1042 mm.

**Table 1:** List shows the name of 14 paddy genotypes

| S. No | Name of Genotypes         | Source (Material Received) |
|-------|---------------------------|----------------------------|
| 1     | BRR1-100                  | IRRI (Varanasi)            |
| 2     | Malviya Manila Sukha Dhan | IRRI (Varanasi)            |
| 3     | MTU- 1010                 | IRRI (Varanasi)            |
| 4     | IR-64 Sub-1               | IRRI (Varanasi)            |
| 5     | DRR-42                    | IRRI (Varanasi)            |
| 6     | DRR-45                    | IRRI (Varanasi)            |
| 7     | Bina Dhan-11              | IRRI (Varanasi)            |
| 8     | Sahbhagi Dhan             | IRRI (Varanasi)            |
| 9     | Sabour Harshit            | IRRI (Varanasi)            |
| 10    | CR Dhan-310               | IRRI (Varanasi)            |
| 11    | Swarna Shreya             | IRRI (Varanasi)            |
| 12    | MTU-1156                  | IRRI (Varanasi)            |
| 13    | Swarna Samriddhi          | IRRI (Varanasi)            |
| Check | GK kuber                  | Local Prayagraj            |

### 2.3 Recording of Quantitative Traits

To assess growth, physiological performance, and yield features, the following quantitative traits were noted from randomly chosen plants in each genotype:

- Days to 50% flowering after transplanting:** This refers to the number of days taken for about half of the plants in a population to start flowering, indicating the crop's earliness.
- Plant height at 30, 60, and 90 DAS:** The height of the plant measured at different growth stages (30, 60, and 90 days after sowing) to understand growth patterns over time.
- Days to maturity:** The total duration from sowing to the stage when the crop is fully mature and ready for harvest.
- Number of tillers per plant:** The total number of shoots produced by a single plant, which directly influences yield potential.
- Panicle length (cm):** The length of the flowering head, which is an important trait affecting grain number and yield.
- Flag leaf area (cm<sup>2</sup>):** The size of the uppermost leaf, which plays a key role in photosynthesis and grain filling.
- Number of spikelets per panicle:** The total number of spikelets present on each panicle, indicating the plant's reproductive capacity.
- Number of fertile spikelets per panicle:** The number of spikelets that successfully develop into grains, reflecting reproductive efficiency.
- Spikelet fertility (%):** The percentage of fertile spikelets out of the total, showing how effectively the plant converts flowers into grains.
- 1000-grain weight (test weight):** Five randomly chosen plants' 1000 filled grain samples were weighed in grams.
- Biological yield per plant:** The total biomass produced by a plant, including both grain and straw.
- Harvest index (%):** The ratio of grain yield to total biological yield, indicating how efficiently the plant converts biomass into economic yield.
- Grain yield per plant (g):** The amount of grain produced by an individual plant, an important measure for selection in breeding.
- Grain yield (q/ha):** The total grain production per hectare, representing the overall productivity of the crop under field conditions.

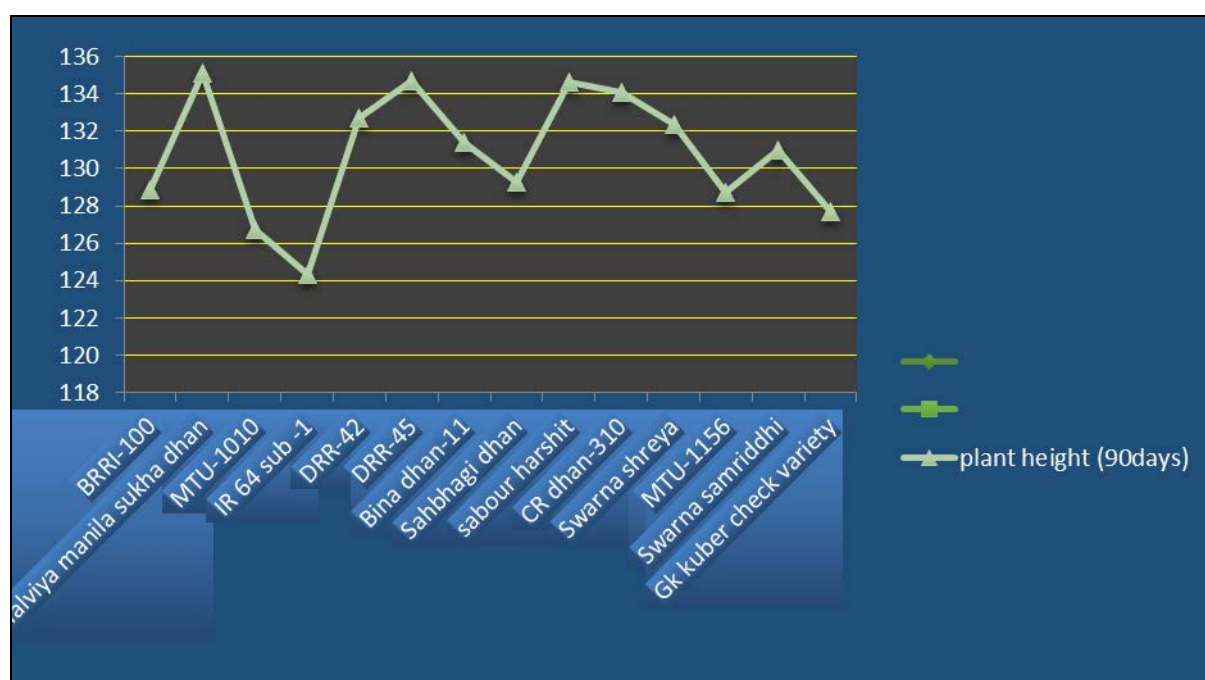
### 2.4 Statistical Analysis

The experimental data were compiled by taking mean of 5 selected plants for each treatment (plot) in each replication. The data will be subjected to various statistical analyses.

- Analysis of variance for Randomised Block Design as per given by (Panse and Sukhatme, 1967).
- Estimation of coefficient of variability (Burton and de Vane, 1953)
- Estimation of Heritability by (Allard *et al.*, 1960) and genetic advance by (Robinson *et al.*, 1949).
- Estimation of correlation coefficients as per method given by (Searle, 1961)<sup>[29]</sup>.
- Estimation of Path-coefficient analysis (Dewey and Lu, 1959).

**Table 2:** Mean performance of 14 paddy genotypes

| Genotypes       | Days of 50% Flowering | Plant Height (cm) | Days of Maturity Time | Number of Tillers /Plant | Panicle Bearing / Plant | Panicle Length(cm) | Flag Leaf Area (cm <sup>2</sup> ) | Number of Spikelets /Panicle | Number of Fertile Spikelets / Panicle | Spikelet Fertility (%) | 1000- Test Weight | Biological Yield / Plant (g) | Harvest Index (%) | Grain Yield /Plant (g) | Grain Yield ( q/ha) |
|-----------------|-----------------------|-------------------|-----------------------|--------------------------|-------------------------|--------------------|-----------------------------------|------------------------------|---------------------------------------|------------------------|-------------------|------------------------------|-------------------|------------------------|---------------------|
| V <sub>1</sub>  | 54                    | 128.867           | 79                    | 21.47                    | 0.93                    | 28.8               | 37.79                             | 250.3                        | 215.87                                | 89.09                  | 20.34             | 59.39                        | 40.97             | 24.33                  | 42.23               |
| V <sub>2</sub>  | 62                    | 135.13            | 86.33                 | 22.87                    | 1.13                    | 29.53              | 41.24                             | 252.13                       | 227.07                                | 83.13                  | 28.16             | 66.9                         | 40.37             | 27                     | 41.1                |
| V <sub>3</sub>  | 64                    | 126.73            | 90                    | 19.93                    | 0.67                    | 28.53              | 38.65                             | 248.9                        | 211.87                                | 84.97                  | 26.91             | 62.4                         | 38.47             | 24                     | 54.37               |
| V <sub>4</sub>  | 64.33                 | 124.33            | 89                    | 23.87                    | 0.87                    | 31.13              | 40.35                             | 247.17                       | 179.8                                 | 85.19                  | 27.07             | 63.5                         | 43.56             | 27.67                  | 51.73               |
| V <sub>5</sub>  | 57                    | 132.73            | 81                    | 27.87                    | 1.6                     | 30                 | 39.14                             | 251                          | 216.53                                | 86.1                   | 26.58             | 66.2                         | 48.84             | 32.33                  | 36.07               |
| V <sub>6</sub>  | 64.67                 | 134.73            | 91.33                 | 21.6                     | 0.83                    | 29.73              | 42.43                             | 250.03                       | 217.6                                 | 87.38                  | 26.8              | 66.6                         | 44.58             | 29.67                  | 50.6                |
| V <sub>7</sub>  | 64                    | 131.4             | 88.67                 | 21.07                    | 0.73                    | 28.47              | 37.93                             | 247.07                       | 164.53                                | 82.36                  | 27.34             | 60.7                         | 41.72             | 25.33                  | 50.07               |
| V <sub>8</sub>  | 62                    | 129.26            | 88                    | 16.2                     | 0.73                    | 28.73              | 42.99                             | 250.87                       | 204.2                                 | 83.55                  | 26.32             | 64.8                         | 43.97             | 28.33                  | 51.07               |
| V <sub>9</sub>  | 60                    | 134.66            | 84                    | 18.07                    | 0.47                    | 30                 | 37.27                             | 248.93                       | 202.8                                 | 84.34                  | 24.86             | 57.1                         | 39.73             | 22.67                  | 41.73               |
| V <sub>10</sub> | 60                    | 134.06            | 83                    | 20.47                    | 1                       | 30.47              | 43.17                             | 251.73                       | 219.33                                | 85.37                  | 23.66             | 65.6                         | 44.73             | 29.33                  | 33.83               |
| V <sub>11</sub> | 62                    | 132.33            | 89                    | 16.67                    | 1                       | 28.73              | 46.66                             | 252.07                       | 235.33                                | 86.71                  | 26.31             | 60.3                         | 42.02             | 25                     | 52.4                |
| V <sub>12</sub> | 73                    | 128.73            | 98                    | 25.07                    | 0.93                    | 27.87              | 38.28                             | 248.63                       | 197                                   | 84.79                  | 20.57             | 58.8                         | 39.15             | 23                     | 35.1                |
| V <sub>13</sub> | 58.33                 | 131               | 107.33                | 19.13                    | 0.93                    | 31.4               | 43.2                              | 250.3                        | 200.27                                | 81.81                  | 22.79             | 67                           | 45.47             | 30                     | 50.73               |
| Check v         | 78                    | 127.66            | 102                   | 16.4                     | 1.27                    | 25.6               | 40.72                             | 250.8                        | 293.13                                | 82.38                  | 18.86             | 62.4                         | 41.69             | 26                     | 50.33               |
| Mean            | 63.09                 | 130.82            | 89.76                 | 20.76                    | 0.93                    | 29.21              | 40.70                             | 249.99                       | 213.23                                | 84.79                  | 24.75             | 62.97                        | 42.51             | 26.76                  | 45.81               |
| C.D.            | 3                     | 3.19              | 1.68                  | 3.72                     | 0.61                    | 1.54               | 4.3                               | 0.54                         | 21.56                                 | 3.28                   | 0.63              | 2.03                         | 3.58              | 4.18                   | 4.69                |
| SE(m+)          | 1.03                  | 1.09              | 0.58                  | 1.27                     | 0.21                    | 0.53               | 1.47                              | 0.18                         | 7.38                                  | 1.12                   | 0.22              | 0.7                          | 1.22              | 1.44                   | 1.6                 |
| C.V.            | 2.82                  | 1.44              | 1.11                  | 10.62                    | 38.89                   | 3.12               | 6.29                              | 0.13                         | 5.99                                  | 2.29                   | 1.52              | 2.74                         | 5.39              | 9.48                   | 6.07                |
| Min             | 54                    | 124.33            | 79                    | 16.2                     | 0.47                    | 25.6               | 37.27                             | 247.07                       | 164.53                                | 81.81                  | 18.86             | 57.1                         | 35.58             | 21                     | 33.83               |
| Max             | 78                    | 135.13            | 107.33                | 27.87                    | 1.27                    | 31.4               | 46.66                             | 252.13                       | 293.13                                | 89.09                  | 28.16             | 66.9                         | 43.56             | 33.33                  | 54.37               |

**Fig 1:** Mean performance of different paddy genotypes for plant height 90 DAS (cm).

### 3. Results and Discussion

#### 3.1 Analysis of variance

The majority of the observed features were statistically significant, according to genotypic mean square values from ANOVA, suggesting that genetic heterogeneity exists among rice genotypes. At the 1% probability level, traits with high genotypic mean square values and the symbol "" were significant, indicating that genotype differences were highly dependable and not the result of chance. Days to 50% flowering (113.36), days to maturity (188.69\*\*), plant height (114.46\*\*), number of tillers per plant (35.00\*\*), panicle length (6.50\*\*),

flag leaf area (158.76\*\*), number of spikelets per panicle (3857.30\*\*), number of fertile spikelets per panicle (2596.46\*\*), 1000-test weight (27.12\*\*), biological yield per plant (1021.00\*\*), harvest index (18.36\*\*), and grain yield per hectare (154.57\*\*) were significant findings. These characteristics demonstrated notable genotype differences and are useful for selection in breeding initiatives. Dhanwani *et al.* (2013) [5], Ketan and Sarkar (2014) [13], Abebe *et al.* (2017) [2], Gupta *et al.* (2021) [11], and Parihar *et al.* (2023) [22] all reported significant genetic variability for various rice yield and quality-related parameters.

**Table 3:** Analysis of variance for I4 characters of Paddy genotypes.

| Source of Variation | df | Days of 50% Flowering | Days of Maturity Time | Plant Height (cm) | Number of Tillers /Plant | Panicle Bearing /Plant | Panicle Length (cm) | Flag Leaf Area (cm <sup>2</sup> ) | Number of Spikelets/Panicle | Number of Fertile Spikelets / Panicle | Spikelet Fertility (%) | 1000- Test Weight | Biological Yield / Plant (g) | Harvest Index (%) | Grain Yield /Plant (g) | Grain Yield ( q/ha) |
|---------------------|----|-----------------------|-----------------------|-------------------|--------------------------|------------------------|---------------------|-----------------------------------|-----------------------------|---------------------------------------|------------------------|-------------------|------------------------------|-------------------|------------------------|---------------------|
| Replications        | 2  | 6.95                  | 2.45                  | 3.42              | 3.49                     | 0.20                   | 1.78                | 190.85**                          | 124.20                      | 97.19                                 | 0.25                   | 0.02              | 14503.4*                     | 9.53              | 4113.3**               | 11.24               |
| Genotypes           | 13 | 113.36**              | 188.69**              | 114.46**          | 35.00**                  | 0.20                   | 6.50**              | 158.76**                          | 3857.3**                    | 2596.46**                             | 12.96**                | 27.12**           | 10218.2**                    | 18.36**           | 1571.0**               | 154.57**            |
| Error (Residuals)   | 26 | 3.16                  | 0.99                  | 14.50             | 4.86                     | 0.12                   | 0.83                | 27.63                             | 168.30                      | 163.16                                | 3.77                   | 0.14              | 3427.50                      | 4.49              | 512.00                 | 7.72                |

\*indicates significance at 5% level, \*\* indicates significance at 1% level

### 3.2 Estimation of Heritability and Genetic Advance as % of Mean:

The observed data revealed considerable variability among all the traits studied, indicating a strong potential for genetic improvement. Days to 50% flowering and days to maturity showed close estimates of genotypic variance (GV) and phenotypic variance (PV), along with high heritability (92.07% and 98.44%) and moderate genetic advance (~18%). This means that the effects of genes are the main influence, and the environment has little impact, which makes these traits easy to select for.

Plant height exhibited low GCV (4.32%) and moderate heritability (69.67%), indicating relatively lower genetic variability and some environmental effect. In contrast, number of tillers per plant recorded high GCV (15.27%), moderate heritability (67.40%), and high genetic advance (25.82%), suggesting good scope for improvement through selection. Panicle bearing per plant showed very high PCV (60.07%) but low heritability (20%), indicating strong environmental

influence and limited reliability for selection.

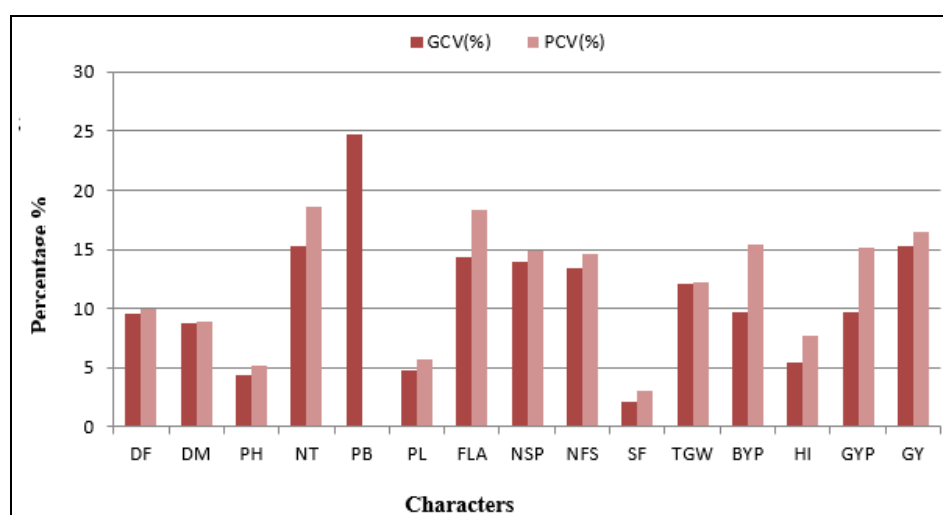
Moderate GCV and heritability were observed for panicle length and flag leaf area, suggesting partial genetic control. Number of spikelets per panicle and fertile spikelets per panicle exhibited high heritability (87.96% and 83.25%) along with high genetic advance (~25%), indicating their importance as selection criteria for yield improvement.

Spikelet fertility showed relatively low heritability (44.80%), suggesting environmental effects. Among yield traits, 1000-test weight had very high heritability (98.46%) and substantial genetic advance, indicating stability. Grain yield per hectare showed high heritability (86.37%) and the highest genetic advance (29.24%), confirming strong additive gene action. Similar results were obtained by Saha *et al.*, (2019) [24] and Parimala and Devi (2019) [23], Yugandhar *et al.*, (2018) [25].

Overall, traits such as tillers per plant, spikelets per panicle, fertile spikelets, test weight, and grain yield are key targets for effective selection and genetic improvement.

**Table 4:** Estimation of components of variance and genetic parameters for different quantitative characters in Paddy.

| Trait                                 | Grand Mean | GV      | PV      | GCV (%) | PCV (%) | Heritability Broad sense h <sup>2</sup> (%) | GA    | GA as % of Mean |
|---------------------------------------|------------|---------|---------|---------|---------|---------------------------------------------|-------|-----------------|
| Days of 50% Flowering                 | 63.10      | 36.73   | 39.89   | 9.61    | 10.01   | 92.07                                       | 11.98 | 18.99           |
| Days of Maturity Time                 | 89.76      | 62.57   | 63.56   | 8.81    | 8.88    | 98.44                                       | 16.17 | 18.01           |
| Plant Height (cm) of Maturity Time    | 133.67     | 33.32   | 47.82   | 4.32    | 5.17    | 69.67                                       | 9.93  | 7.43            |
| Number of Tillers /Plant              | 20.76      | 10.05   | 14.91   | 15.27   | 18.60   | 67.40                                       | 5.36  | 25.82           |
| Panicle Bearing /Plant                | 0.64       | 0.03    | 0.15    | 24.65   | 60.07   | 20                                          | 0.13  | 20.84           |
| Panicle Length (cm)                   | 29.21      | 1.89    | 2.72    | 4.71    | 5.65    | 69.48                                       | 2.36  | 8.08            |
| Flag Leaf Area (cm <sup>2</sup> )     | 46.19      | 43.71   | 71.34   | 14.31   | 18.29   | 61.26                                       | 10.66 | 23.08           |
| Number of Spikelets/Panicle           | 251.38     | 1229.66 | 1397.94 | 13.95   | 14.87   | 87.96                                       | 67.75 | 26.95           |
| Number of Fertile Spikelets / Panicle | 213.24     | 811.10  | 974.26  | 13.36   | 14.64   | 83.25                                       | 53.53 | 25.10           |
| Spikelet Fertility (%)                | 84.80      | 3.06    | 6.83    | 2.06    | 3.08    | 44.80                                       | 2.42  | 2.85            |
| 1000- Test Weight                     | 24.76      | 8.99    | 9.13    | 12.11   | 12.21   | 98.46                                       | 6.13  | 24.76           |
| Biological Yield / Plant (g)          | 489.36     | 2263.56 | 5691.10 | 9.72    | 15.42   | 39.77                                       | 61.81 | 12.63           |
| Harvest Index (%)                     | 39.35      | 4.63    | 9.11    | 5.47    | 7.67    | 59.82                                       | 3.16  | 8.02            |
| Grain Yield /Plant (g)                | 193.45     | 352.99  | 865.02  | 9.71    | 15.20   | 40.80                                       | 24.72 | 12.78           |
| Grain Yield ( q/ha)                   | 45.81      | 48.95   | 56.67   | 15.27   | 16.43   | 86.37                                       | 13.39 | 29.24           |

**Fig 2:** Histogram of phenotypic coefficient of variation and genotypic coefficient of variation.

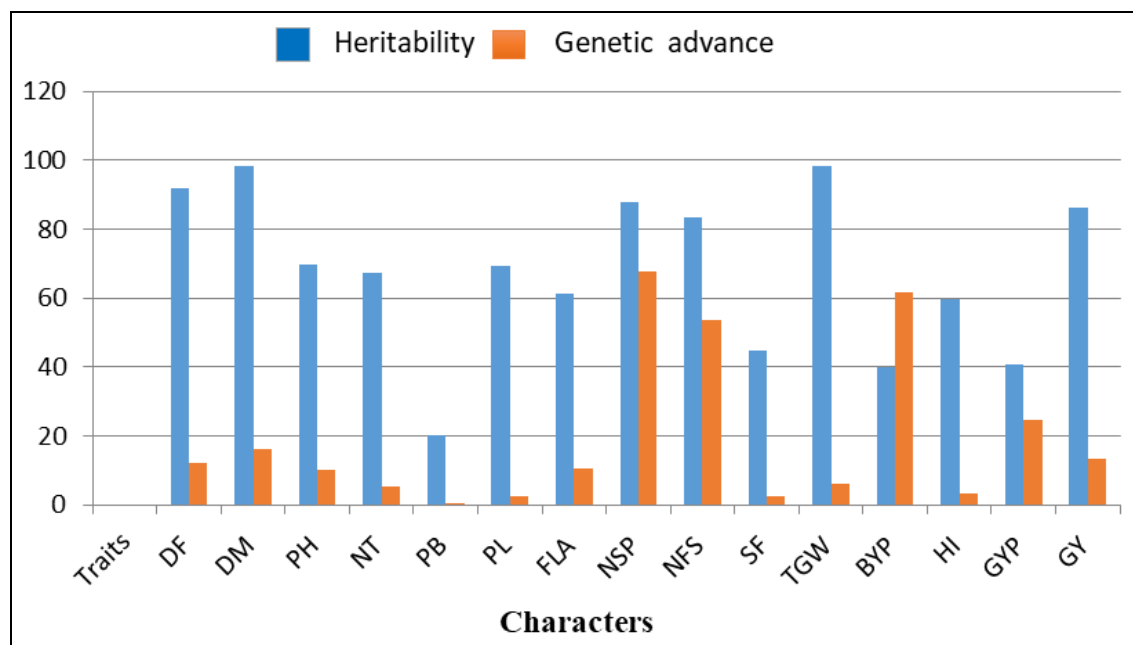


Fig 3: Histogram of heritability  $h^2$  (broad sense) and genetic advance as percentage of mean

### 3.3 Correlation Coefficient Analysis: Positive, Negative, Significant and Non-Significant Associations.

#### 3.3.1 Genotypic correlation

Genotypic correlation analysis in Rice revealed the inherent genetic association among yield and yield-related traits. The magnitude of genotypic correlations was generally higher than phenotypic correlations, indicating strong genetic control over the studied characters.

Days to flowering (DF) showed significant positive association with days to maturity (0.59\*), indicating that late flowering genotypes generally matured later. DF exhibited positive but non-significant correlation with productive branches PB (0.19), flag leaf area (0.20), number of spikelets per panicle (0.49), number of filled seeds (0.43), and grain yield (0.18). Significant negative correlation was observed between DF and panicle length (-0.76\*\*), while moderate negative associations existed with spikelet fertility (SF), biological yield (BYP), harvest index (HI), and grain yield per plant (GYP).

Days to maturity (DM) exhibited positive association with PB (0.41), FLA (0.41), NSP (0.32), BYP (0.38), and GY (0.40). Significant negative correlation was recorded with SF (-0.71\*\*), indicating that delayed maturity may adversely affect spikelet fertility. Negative but non-significant associations were observed with PH, NT, PL, TGW, and HI.

Plant height (PH) showed a significant negative association with grain yield (-0.51), suggesting that taller plants may not contribute positively to productivity. Positive associations of PH with PL, SF, TGW, and BYP were non-significant. Number of tillers (NT) showed a highly significant positive correlation with productive branches (PB, 0.96\*\*), suggesting that increased

tillering directly enhances branching ability. NT exhibited significant negative association with FLA (-0.73\*\*), BYP (-0.65\*), GYP (-0.73\*\*), and GY (-0.60\*), indicating that excessive tillering may reduce yield efficiency.

Productive branches (PB) showed strong positive association with PL (0.53), but significant negative correlation with FLA (-0.82\*\*), NFS (-0.61\*), HI (-0.67\*\*), GYP (-0.88\*\*), and GY (-0.71\*\*). This suggests that excessive branching may adversely influence assimilate partitioning. Panicle length (PL) exhibited positive association with PH, PB, TGW, BYP, HI, and GYP. Significant negative association was observed with NSP (-0.63\*) and NFS (-0.62\*), indicating that longer panicles may not always correspond to higher seed filling. Flag leaf area (FLA) showed positive association with NSP, NFS, BYP, GYP, and GY. Significant positive correlation was observed with BYP (0.55\*) and GYP (0.62\*), indicating that larger leaf area improves photosynthetic efficiency and productivity.

A very strong positive genotypic correlation existed between NSP and NFS (0.99\*\*), indicating close genetic association between spikelet formation and grain filling. NSP also showed significant negative correlation with HI (-0.59\*). Biological yield (BYP) showed highly significant positive association with GYP (0.90\*\*) and significant positive correlation with GY (0.58\*), confirming that higher biomass production contributes directly toward grain yield. Grain yield per plant (GYP) exhibited strong positive correlation with grain yield (GY, 0.67\*\*), suggesting that selection for GYP can effectively improve grain productivity in rice breeding programs. Similar results were reported by Roy *et al.* (1957)<sup>[28]</sup>.

**Table 5:** Estimation of the genotypic correlation coefficient for various quantitative paddy attributes.

| Trait | DF | DM    | PH    | NT    | PB     | PL      | FLA     | NSP    | NFS    | SF      | TGW   | BYP    | HI      | GYP     | GY      |
|-------|----|-------|-------|-------|--------|---------|---------|--------|--------|---------|-------|--------|---------|---------|---------|
| DF    | 1  | 0.59* | -0.4  | -0.17 | 0.19   | -0.76** | 0.2     | 0.49   | 0.43   | -0.48   | -0.36 | -0.46  | -0.27   | -0.46   | 0.18    |
| DM    |    | 1     | -0.46 | -0.29 | 0.41   | -0.23   | 0.41    | 0.32   | 0.21   | -0.71** | -0.39 | 0.38   | -0.5    | 0.15    | 0.4     |
| PH    |    |       | 1     | -0.07 | 0.09   | 0.43    | 0.08    | 0      | 0.04   | 0.22    | 0.21  | 0.14   | -0.09   | 0.03    | -0.51   |
| NT    |    |       |       | 1     | 0.96** | 0.33    | -0.73** | -0.45  | -0.41  | 0.39    | 0.19  | -0.65* | 0       | -0.73** | -0.60*  |
| PB    |    |       |       |       | 1      | 0.53    | -0.82** | -0.51  | -0.61* | -0.48   | -0.16 | -0.4   | -0.67** | -0.88** | -0.71** |
| PL    |    |       |       |       |        | 1       | -0.13   | -0.63* | -0.62* | 0.2     | 0.49  | 0.48   | 0.29    | 0.44    | -0.17   |
| FLA   |    |       |       |       |        |         | 1       | 0.42   | 0.43   | -0.04   | 0.01  | 0.55*  | 0.08    | 0.62*   | 0.47    |
| NSP   |    |       |       |       |        |         |         | 1      | 0.99** | -0.22   | -0.46 | -0.26  | -0.59*  | -0.39   | 0.05    |
| NFS   |    |       |       |       |        |         |         |        | 1      | -0.07   | -0.47 | -0.28  | -0.58*  | -0.43   | 0.02    |
| SF    |    |       |       |       |        |         |         |        |        | 1       | -0.03 | -0.16  | 0.06    | -0.23   | -0.25   |
| TGW   |    |       |       |       |        |         |         |        |        |         | 1     | 0.32   | 0.38    | 0.43    | 0.27    |
| BYP   |    |       |       |       |        |         |         |        |        |         |       | 1      | -0.03   | 0.90**  | 0.58*   |
| HI    |    |       |       |       |        |         |         |        |        |         |       |        | 1       | 0.41    | 0.13    |
| GYP   |    |       |       |       |        |         |         |        |        |         |       |        |         | 1       | 0.67**  |
| GY    |    |       |       |       |        |         |         |        |        |         |       |        |         |         | 1       |

Indicates significance at 5% level, \*\* indicates significance at 1% level

### 3.3.2 Phenotypic correlation

The phenotypic correlation analysis revealed significant associations among the studied traits, indicating their interdependence and potential contribution to yield improvement. Grain yield (GY) showed a significant and positive correlation with biological yield per plant (GYP) (0.41\*) and biomass yield per plant (BYP) (0.36), suggesting that these traits are major contributors to overall productivity. Similarly, flag leaf area (FLA) exhibited a positive and significant correlation with grain yield (0.41\*\*), indicating the importance of photosynthetic surface in yield enhancement.

Days to flowering (DF) showed a significant positive association with number of seeds per plant (NSP) (0.44\*) and number of fertile spikes (NFS) (0.37), but had a negative correlation with plant height (PH) (-0.34\*) and panicle length (PL) (-0.60\*\*). This suggests that early flowering genotypes may favor better vegetative growth and reproductive efficiency.

Number of tillers (NT) demonstrated a strong positive

correlation with panicle branching (PB) (0.42\*) but showed negative associations with FLA (-0.47) and GY (-0.47\*), indicating a possible trade-off between tillering and yield efficiency. A very high positive correlation was observed between NSP and NFS (0.98\*\*), suggesting that these traits are closely related and can be improved simultaneously through selection. However, both NSP and NFS exhibited significant negative correlations with harvest index (HI) and GYP, indicating the need for balanced selection strategies. Thousand grain weight (TGW) showed moderate positive correlations with GY (0.25) and GYP (0.28), indicating its supportive role in yield determination. Kishore *et al* and Sandeep *et al.* (2018)<sup>[26]</sup>

Overall, the study suggests that traits such as GYP, BYP, and FLA are key contributors to grain yield, and selection based on these traits could effectively enhance crop productivity. However, negative correlations among certain traits highlight the complexity of selection and the need for a balanced breeding approach.

**Table 6:** Estimation of the genotypic correlation coefficient for different quantitative characteristics of paddy.

| Trait | DF | DM     | PH      | NT    | PB     | PL      | FLA     | NSP     | NFS     | SF      | TGW     | BYP    | HI      | GYP     | GY      |
|-------|----|--------|---------|-------|--------|---------|---------|---------|---------|---------|---------|--------|---------|---------|---------|
| DF    | 1  | 0.60** | -0.34*  | -0.14 | -0.01  | -0.60** | 0.15    | 0.44**  | 0.37*   | -0.31*  | -0.35*  | -0.27  | -0.21   | -0.29   | 0.15    |
| DM    |    | 1      | -0.40** | -0.24 | 0.14   | -0.19   | 0.33*   | 0.29    | 0.19    | -0.47** | -0.38*  | 0.24   | -0.37*  | 0.09    | 0.36*   |
| PH    |    |        | 1       | -0.03 | -0.21  | 0.26    | 0.04    | -0.02   | 0.01    | 0.14    | 0.18    | 0.14   | -0.04   | 0.1     | -0.42** |
| NT    |    |        |         | 1     | 0.42** | 0.3     | -0.47** | -0.34*  | -0.31*  | 0.15    | 0.13    | -0.36* | -0.05   | -0.43** | -0.47** |
| PB    |    |        |         |       | 1      | 0.33*   | -0.24   | -0.19   | -0.22   | -0.13   | -0.06   | -0.09  | -0.04   | -0.12   | -0.23   |
| PL    |    |        |         |       |        | 1       | 0.01    | -0.52** | -0.50** | 0.04    | 0.40**  | 0.40** | 0.03    | 0.31*   | -0.08   |
| FLA   |    |        |         |       |        |         | 1       | 0.32*   | 0.32*   | -0.04   | 0.02    | 0.41** | -0.17   | 0.36*   | 0.41**  |
| NSP   |    |        |         |       |        |         |         | 1       | 0.98**  | -0.09   | -0.44** | -0.21  | -0.44** | -0.32*  | 0.03    |
| NFS   |    |        |         |       |        |         |         |         | 1       | 0.13    | -0.43** | -0.27  | -0.40** | -0.36*  | 0.01    |
| SF    |    |        |         |       |        |         |         |         |         | 1       | -0.01   | -0.3   | 0.18    | -0.2    | -0.15   |
| TGW   |    |        |         |       |        |         |         |         |         |         | 1       | 0.2    | 0.29    | 0.28    | 0.25    |
| BYP   |    |        |         |       |        |         |         |         |         |         |         | 1      | -0.12   | 0.86**  | 0.36*   |
| HI    |    |        |         |       |        |         |         |         |         |         |         |        | 1       | 0.35*   | 0.04    |
| GYP   |    |        |         |       |        |         |         |         |         |         |         |        |         | 1       | 0.41**  |
| GY    |    |        |         |       |        |         |         |         |         |         |         |        |         |         | 1       |

Indicates significance at 5% level, \*\* indicates significance at 1% level

### 3.4 Path Coefficient Analysis

#### 3.4.1 Genotypic path analysis

The genotypic path analysis reveals that grain yield (GY) is influenced not only by direct effects but also substantially through indirect pathways among traits

Among direct effects, NSP (19.9424) showed the highest positive direct contribution, making it the most decisive trait for yield improvement. In contrast, NFS (-20.2020) had a very

strong negative direct effect. Moderate positive direct effects were observed for FLA (0.7718), TGW (0.4020), and PL (0.3111), while PH (-0.9321), NT (-0.4276), HI (-1.9791), and BYP (-2.1600) exhibited negative direct influences. DF contributed indirectly in a positive manner via NSP (9.8386) and HI (0.5402), but showed negative indirect effects through NFS (-8.6289) and SF (-1.5070). DM had a strong positive indirect effect through NSP (6.3142), while negative indirect effects were

observed via NFS (−4.2921) and SF (−2.2439). PH, despite its negative direct effect, showed small positive indirect contributions via FLA (0.0590) and TGW (0.0857), but negative effects via NFS (−0.8339) and BYP (−0.3035). NT exhibited a large negative indirect effect through NSP (−9.0483) but a strong positive effect via NFS (8.2460) and BYP (1.4127). PB showed negative indirect effects via NSP (−10.0795) and SF (−1.5298), but positive contributions through NFS (12.2735) and FLA (0.6361). PL had a strong negative indirect effect through NSP (−12.5478) but this was compensated by a high positive effect via NFS (12.4630) and SF (0.6208). FLA contributed positively via NSP (8.3140) but negatively via NFS (−8.6965). NSP itself showed negative indirect effects through NFS (−19.9529) but positive via FLA (0.3217) and BYP (0.5668). NFS had a strong positive indirect effect through NSP (19.6965) but negative through BYP (−0.6149). TGW showed positive

indirect effects via NFS (9.3978) and PL (0.1534), but negative via NSP (−9.1737). BYP contributed positively through NFS (5.7515) and FLA (0.4243), but negatively via NSP (−5.2335). HI showed positive indirect effects via NFS (11.7973) and DM (0.4349), but negative via NSP (−11.7124). GYP interactions also reflected both positive (NFS 8.6527) and negative (NSP −7.8444) indirect pathways. Similar results were also reported by Gawai *et al.* (2006)<sup>[9]</sup> for tillers per plant and harvest index and plant height and Ekka *et al.* (2011)<sup>[7]</sup> for panicle length. Overall, the data clearly demonstrate that NSP is the key positive contributor through direct effect, while many traits influence yield indirectly through strong interactions with NSP and NFS. The very low residual value (0.0133) confirms that these traits collectively explain most of the variability in grain yield.

**Table 7:** Effects of component qualities, both direct (diagonal) and indirect, related to grain yield per plant in Paddy at genotypic level.

| Trait | DF      | DM      | PH      | NT      | PB      | PL      | FLA     | NSP      | NFS      | SF      | TGW     | BYP     | HI      | GYP     |
|-------|---------|---------|---------|---------|---------|---------|---------|----------|----------|---------|---------|---------|---------|---------|
| DF    | 0.4266  | -0.5121 | 0.3760  | 0.0717  | 0.0045  | -0.2374 | 0.1565  | 9.8386   | -8.6289  | -1.5070 | -0.1429 | 0.9982  | 0.5402  | -1.2000 |
| DM    | 0.2536  | -0.8614 | 0.4254  | 0.1258  | 0.0095  | -0.0713 | 0.3200  | 6.3142   | -4.2921  | -2.2439 | -0.1552 | -0.8191 | 0.9992  | 0.3934  |
| PH    | -0.1721 | 0.3932  | -0.9321 | 0.0301  | 0.0020  | 0.1325  | 0.0590  | 0.0714   | -0.8339  | 0.7100  | 0.0857  | -0.3035 | 0.1739  | 0.0699  |
| NT    | -0.0715 | 0.2535  | 0.0656  | -0.4276 | 0.0226  | 0.1024  | -0.5629 | -9.0483  | 8.2460   | 1.2393  | 0.0762  | 1.4127  | 0.0004  | -1.9114 |
| PB    | 0.0818  | -0.3503 | -0.0805 | -0.4117 | 0.0234  | 0.1641  | -0.6361 | -10.0795 | 12.2735  | -1.5298 | -0.0639 | 0.8538  | 1.3303  | -2.2832 |
| PL    | -0.3254 | 0.1974  | -0.3970 | -0.1407 | 0.0124  | 0.3111  | -0.0967 | -12.5478 | 12.4630  | 0.6208  | 0.1982  | -1.0393 | -0.5779 | 1.1560  |
| FLA   | 0.0865  | -0.3572 | -0.0713 | 0.3119  | -0.0193 | -0.0390 | 0.7718  | 8.3140   | -8.6965  | -0.1124 | 0.0059  | -1.1874 | -0.1519 | 1.6112  |
| NSP   | 0.2104  | -0.2727 | -0.0033 | 0.1940  | -0.0118 | -0.1958 | 0.3217  | 19.9424  | -19.9529 | -0.7023 | -0.1849 | 0.5668  | 1.1624  | -1.0231 |
| NFS   | 0.1822  | -0.1830 | -0.0385 | 0.1745  | -0.0142 | -0.1919 | 0.3322  | 19.6965  | -20.2020 | -0.2086 | -0.1870 | 0.6149  | 1.1558  | -1.1140 |
| SF    | -0.2034 | 0.6116  | -0.2094 | -0.1677 | -0.0114 | 0.0611  | -0.0274 | -4.4314  | 1.3335   | 3.1605  | -0.0110 | 0.3460  | -0.1153 | -0.5863 |
| TGW   | -0.1516 | 0.3325  | -0.1986 | -0.0810 | -0.0037 | 0.1534  | 0.0112  | -9.1737  | 9.3978   | -0.0865 | 0.4020  | -0.6860 | -0.7613 | 1.1182  |
| BYP   | -0.1971 | -0.3266 | -0.1310 | 0.2797  | -0.0093 | 0.1497  | 0.4243  | -5.2335  | 5.7515   | -0.5062 | 0.1277  | -2.1600 | 0.0692  | 2.3389  |
| HI    | -0.1164 | 0.4349  | 0.0819  | 0.0001  | -0.0158 | 0.0908  | 0.0592  | -11.7124 | 11.7973  | 0.1840  | 0.1547  | 0.0755  | -1.9791 | 1.0755  |
| GYP   | -0.1968 | -0.1303 | -0.0250 | 0.3142  | -0.0206 | 0.1383  | 0.4781  | -7.8444  | 8.6527   | -0.7124 | 0.1728  | -1.9424 | -0.8184 | 2.6009  |

Residual value: 0.0133, indicates significance at 5% level, \*\* indicates significance at 1% level

### 3.4.2 Phenotypic path analysis

The phenotypic path analysis demonstrates that grain yield (GYP) is influenced by both direct and indirect effects of various traits, though the magnitude of effects is comparatively lower than genotypic estimates.

Considering direct effects (diagonal values), GYP (0.8305) itself showed the highest positive direct contribution. Among yield components, DM (0.2938), TGW (0.4622), and FLA (0.0257) exhibited positive direct effects, indicating their importance in improving yield at the phenotypic level. In contrast, several traits showed negative direct effects, including PH (−0.4829), NT (−0.339), PB (−0.1667), NFS (−1.1753), NSP (−1.2094), SF (−0.111), and HI (−0.4423), suggesting that their direct selection may not be beneficial for yield improvement.

DF had a negative direct effect (−0.029) but contributed positively through DM (0.1759) and PH (0.1654), while showing negative influence via NSP (−0.5284) and TGW (−0.1609). DM showed positive indirect effects via PH (0.192) and NT (0.0827), but negative via NSP (−0.3493) and TGW (−0.1771). PH, despite a negative direct effect, contributed positively through TGW (0.0848) and PB (0.0354). NT had negative indirect effects through NFS (−0.3608) but positive via

NSP (0.416) and BYP (0.2278). PB showed positive indirect contributions via NSP (0.2303) but negative via NFS (−0.2599). PL exhibited strong positive indirect effect via NSP (0.6233), while a negative effect was seen through NFS (−0.5868). FLA contributed positively through NFS (0.3726) but negatively via NSP (−0.3834). NSP and NFS showed strong mutual indirect effects, with NSP → NFS (1.1479) and NFS → NSP (−1.1812), indicating a complex interaction. TGW had positive indirect contribution via NSP (0.5329) but negative via NFS (−0.5085). BYP exhibited a strong positive indirect effect on yield through GYP (0.7176) but negative via TGW (−0.126). HI showed positive indirect effects via NSP (0.5327) but negative via NFS (−0.472). Prasad *et al.* (2017)<sup>[21]</sup> and Welalaw *et al.* Estimation of the genotypic correlation coefficient for various quantitative paddy attributes.

Overall, the results indicate that traits such as TGW and DM are important positive contributors, while NSP and NFS show complex and often negative direct effects but strong indirect interactions. The relatively higher residual effect (0.2844) suggests that environmental factors also play a considerable role in influencing grain yield at the phenotypic level.

**Table 8:** Direct (diagonal) and indirect effects of component traits attributing to grain yield per plant in Paddy at phenotypic level.

| Trait | DF      | DM      | PH      | NT      | PB      | PL      | FLA     | NSP     | NFS     | SF      | TGW     | BYP     | HI      | GYP     |
|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DF    | -0.029  | 0.1759  | 0.1654  | 0.0491  | 0.0022  | -0.0205 | 0.0038  | -0.5284 | 0.4305  | 0.0339  | -0.1609 | 0.1731  | 0.0947  | -0.2418 |
| DM    | -0.0174 | 0.2938  | 0.192   | 0.0827  | -0.0243 | -0.0063 | 0.0084  | -0.3493 | 0.218   | 0.0527  | -0.1771 | -0.1532 | 0.1651  | 0.0736  |
| PH    | 0.0099  | -0.1168 | -0.4829 | 0.0107  | 0.0354  | 0.0088  | 0.0009  | 0.0206  | 0.0149  | -0.0153 | 0.0848  | -0.0927 | 0.019   | 0.0793  |
| NT    | 0.0042  | -0.0717 | 0.0153  | -0.339  | -0.0701 | 0.0103  | -0.0121 | 0.416   | -0.3608 | -0.017  | 0.0613  | 0.2278  | 0.0242  | -0.3604 |
| PB    | 0.0004  | 0.0426  | 0.102   | -0.1418 | -0.1667 | 0.0111  | -0.0061 | 0.2303  | -0.2599 | 0.0145  | -0.0296 | 0.0582  | 0.0167  | -0.1022 |
| PL    | 0.0175  | -0.0548 | -0.1245 | -0.1025 | -0.0546 | 0.034   | 0.0002  | 0.6233  | -0.5868 | -0.004  | 0.1867  | -0.2532 | -0.012  | 0.2556  |
| FLA   | -0.0043 | 0.0958  | -0.0176 | 0.1601  | 0.04    | 0.0003  | 0.0257  | -0.3834 | 0.3726  | 0.0041  | 0.01    | -0.2617 | 0.0734  | 0.2951  |
| NSP   | -0.0127 | 0.0848  | 0.0082  | 0.1166  | 0.0319  | -0.0175 | 0.0081  | -1.2094 | 1.1479  | 0.0095  | -0.2036 | 0.1359  | 0.1948  | -0.264  |
| NFS   | -0.0106 | 0.0545  | -0.0061 | 0.1041  | 0.037   | -0.017  | 0.0081  | -1.1812 | 1.1753  | -0.0141 | -0.2    | 0.175   | 0.1776  | -0.2958 |
| SF    | 0.0089  | -0.1395 | -0.0666 | -0.052  | 0.0219  | 0.0012  | -0.001  | 0.103   | 0.15    | -0.111  | -0.0035 | 0.1894  | -0.0806 | -0.165  |
| TGW   | 0.0101  | -0.1126 | -0.0886 | -0.045  | 0.0107  | 0.0137  | 0.0005  | 0.5329  | -0.5085 | 0.0008  | 0.4622  | -0.126  | -0.1262 | 0.23    |
| BYP   | 0.0079  | 0.0703  | -0.07   | 0.1207  | 0.0152  | 0.0134  | 0.0105  | 0.2569  | -0.3214 | 0.0329  | 0.091   | -0.6398 | 0.0519  | 0.7176  |
| HI    | 0.0062  | -0.1096 | 0.0208  | 0.0185  | 0.0063  | 0.0009  | -0.0043 | 0.5327  | -0.472  | -0.0202 | 0.1319  | 0.0751  | -0.4423 | 0.292   |
| GYP   | 0.0084  | 0.026   | -0.0461 | 0.1471  | 0.0206  | 0.0105  | 0.0091  | 0.3845  | -0.4185 | 0.022   | 0.1277  | -0.5528 | -0.1555 | 0.8305  |

**Residual Effect:** 0.2844

### 3.5.3 Details Observation Name

|                                     |                                       |
|-------------------------------------|---------------------------------------|
| DF= Days of flowering               | TGW= Test grain weight                |
| DM= days of maturity                | BYP= Biological yield per plant       |
| PH= Plant height                    | HI= Harvest index                     |
| NT= number of tillers               | GYP= Grain yield per plant            |
| PB= Panicle bearing                 | GV= Genotypic variance                |
| PL = Panicle length                 | PV= Phenotypic variance               |
| FLA= Flag leaf area                 | GCV= Genotypic coefficient variation  |
| NSP =Number of spikelet per panicle | PCV= phenotypic coefficient variation |
| NFS= Number of fertile spikelet     | h <sup>2</sup> = Heritability         |
| SF = Spikelet fertility             | GA= Genetic advance                   |

### 4. Conclusion

These Variety of BRRI- 100 (54 days), DRR-42 (57 days), sabour harshit (60 days), CR dhan- 310 (60 days), sahbhagi dhan (62 days), swarna shreya (62 days), and bina dhan-11 are variety of early 50% flowering. The variety of BRRI-100 (79 days), DRR-42 (81days), CR dhan-310 (83 days), sabour harshit (84 days), and malviya manila sukha dhan (86days) are Variety Of early maturity. Analysis of variance had significant for all characters under study. In the study highest GCV, PCV shown for panicle bearing per plant (24.65%), (60.07%). Whereas highest genetic advance was observed for plant number of spikelet per panicle (67.75%). Number of spikelet per panicle and number of fertile spikelet exhibited highly significant positive association with Biological yield per plant (gm), Grain yield per plant (gm), number of tiller, flag leaf area (cm<sup>2</sup>), panicle length (cm). Number of spikelet per panicle and number of fertile spikelet highly positive direct effect at phenotypic level viz. number of spikelet per panicle (19.9424), spikelet fertility (%) (3.1605), flag leaf area (0.7718), days of flowering (0.4266), and number of spikelet per panicle (-20.2020).direct and indirect effect of the genotypic level viz.

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### 6. Author contribution

Contributed to the conception and design of the analysis paper. Contributed to the data collection. Data and analysis tools were used to write the analyzed paper. Also evaluated the paper and then suggested publishing it in this journal. and resource

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