



P-ISSN: 2349-8528

E-ISSN: 2321-4902

IJCS 2019; 7(4): 1264-1268

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Received: 27-05-2019

Accepted: 29-06-2019

#### Satya Prakash

Department of Genetics and  
Plant Breeding Seed Science &  
Technology Section NDUA & T,  
Faizabad, Uttar Pradesh, India

#### KK Srivastava

Department of Genetics and  
Plant Breeding Seed Science &  
Technology Section NDUA & T,  
Faizabad, Uttar Pradesh, India

#### RDS yadav

Department of Genetics and  
Plant Breeding Seed Science &  
Technology Section NDUA & T,  
Faizabad, Uttar Pradesh, India

#### Correspondence

##### Satya Prakash

Department of Genetics and  
Plant Breeding Seed Science &  
Technology Section NDUA & T,  
Faizabad, Uttar Pradesh, India

## International Journal of Chemical Studies

# Character association and path analysis of yield contributing traits and quality parameter in rice (*Oryza sativa* L.)

Satya Prakash, KK Srivastava and RDS yadav

#### Abstract

Fifty six genotypes including four check varieties of rice (*oryza sativa* L.) were assessed to work out the association of different seed yield traits, direct and indirect effects of their various attributes on seed yield. Seed yield per plant showed significant and positive correlation with seed yield per plant showed highly significant and negative correlation with days to plant height and non-significant correlation with other characters. The characters showing significant positive correlation among yield and important characters would be highly effective and efficient in improving respective traits. Path analysis identified as important components having high order of direct effect to secondary branches per plant and vigour index as important components having high order of indirect effect on seed yield per plant. The characters identified above as important direct and indirect yield components merit due consideration in formulating selection strategy in rice for selection of high yielding varieties.

**Keywords:** Rice, Path analysis, Seed yield, character association, quality parameters

#### Introduction

Rice (*Oryza sativa* L.,  $2n=24$ ) belongs to the genus *Oryza*, tribe *Oryzaceae* and family *Poaceae*, is one of the staple food and the most important cereal crop. It accounts for about 46 per cent of total food grain production in the country. At the current rate of population growth (1.8 per cent), rice requirement by 2020 would be around 125 million tonnes. The need and importance of rice is increasing day by day due to increase in the human population. In the recent years, the world rice production was maximum in China (32.7%) followed by India (27%) and Indonesia (10.2%). Conservative estimate indicated that by 2050, we need to enhance rice production by almost another 50 million tons, to current production level to meet the dietary requirement of ever growing population.

About 90% of all rice grown in the world is produced and consumed in the Asian region. India has the largest area 42.96 million hectare, production 158.75 million tons and productivity 36.95 q/ha (FAO, 2016). More than 80% of our countrymen depend fully or partially on rice as their staple diet. Uttar Pradesh is the second largest rice producing state of country. The area and production of rice in Uttar Pradesh is about 5.96 million hectare and 14.57 million tonnes respectively, with the productivity of 2.5 tonnes/ hectare. The agriculture food production must, continue to meet the demand of growing population.

The concept of path analysis was developed by Wright (1921) but the technique was first used for plant selection by Dewey and Lu (1959). Path-coefficient is simply a standardized partial regression coefficient, which splits the correlation coefficient into the measures of direct and indirect effects. In other words, it measures the direct and indirect contribution of various independent characters on a dependent character. It also estimates residual effects. Path analysis reveals relative importance of yield-contributing characters thus, is useful in indirect selection. The importance of genetic diversity in selecting parents to recover transgressed segregates has been repeatedly emphasized by many workers. Information on the nature and degree of divergence provides a rational basis and helps the plant breeders in choosing suitable parents for realizing superior segregates in breeding Programmes.

#### Materials and Methods

The present experiment was carried out to study the was designated to work out the status of association of different seed yield traits and direct and indirect effect of these different

traits on seed yield per plant among sixty rice genotypes with four check. At field experiment under present investigation was conducted during Rabi 2016-017 at the Crop Research Station (CRS) Masodha, Ayodhya, and Student Instructional Farm of N.D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya and seed quality parameter tested in Seed Testing Laboratory of the Seed Technology Section, Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) India.

The germplasm evaluation experiment involving evaluation of 60 germplasm lines along with four checks viz., Type-3, Lalmati, NDR- 359, NDR- 2064. These varieties were procured from genetic stock available in Crop Research Station (CRS) Masodha, Faizabad, N.D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad.

The experiment was lay out Randomized Block Design (Field) and Complete Randomized Design (Laboratory) during *Kharif*, 2016 and *Kharif*, 2017. The observation were recorded on nineteen different seed yield traits viz., days to 50% flowering, days to maturity, plant height (cm), number of tillers/plant, number of panicles bearing tillers/plant, panicle length (cm), number of grains/panicle, biological yield (g), harvest Index, 1000-seed weight (g), seed yield/plant (g), seed moisture content (%), speed of germination (%), standard germination (%), shoot length (cm), root length (cm), seedling length (cm), seedling dry weight (g) and vigour index (VI-1). Standard statistical techniques such as path coefficient analysis between different characters. Seed germination percentage was investigated under lab condition germination was estimated on the basis of 100 randomly selected kept for germination in germination paper at room temperature in germinator. The sample were kept in seed germinator maintained at 10-15°C temperature and 90±3 per cent relative humidity. Five seedlings were randomly taken from each replication. The vigour index was conducted as per the method prescribed by Abdul-Bali and Anderson (1973) and expressed in whole number. The seed were kept for germinate following ISTA method. The seedlings were measured for seedling length to obtain seedling length.

## Results and Discussion

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of yield components on grain yield. Path analysis provides clear picture of character associations for formulating efficient selection strategy. The concept of Path coefficient analysis was developed which differs from simple correlation in that it points out the causes and their relative importance, whereas, the later measures simply the mutual association ignoring the causation.

In field condition, at phenotypic level the highest direct effect

on seed yield per plant was exhibited by biological yield followed by harvest index, grains per panicle, panicle bearing tillers and days to maturity during both the years (Y1=2016 and Y2=2017) and in pooled analysis.

The high direct effect of biological yield possessing highly significant positive association with seed yield per plant highlighted the importance of this trait for rice improvement. Thus biological yield followed by harvest index and number tillers per plant emerged as most important direct contributor towards the seed yield. Direct effects of remaining characters on seed yield per plant were too low to be considered important. The present findings are in agreement of the earlier researchers namely, Chaudhary and Motiramani (2003) and Khedekar *et al.* (2004) [2], Roy *et al.* (2015), Kumar *et al.* (2014), Rahaman *et al.* (2014), Nikhil *et al.* (2014) [8], Dhurai *et al.* (2014) [1], Reddy *et al.* (2013) [7, 13], Naseer *et al.* (2013), Kumar *et al.* (2011) [3].

Among laboratory observations at phenotypic level seedling length exhibited highest direct effect on the seedling vigour index followed by standard germination % and root length during both the years and in pooled analysis. Vimal *et al.* (2016) [12, 13], Mehata *et al.* (2013)

**Table 1:** Details of genotypes included in experiment

| S. N. | Germplasm        | S. N. | Germplasm     |
|-------|------------------|-------|---------------|
| 1     | Type -3          | 31    | Badshah bhog  |
| 2     | Lalmati          | 32    | Hazaar dana   |
| 3     | NDR-359          | 33    | Heera         |
| 4     | NDR-2064         | 34    | Tinpakani     |
| 5     | Kalamadan        | 35    | Dudhi         |
| 6     | Naina            | 36    | Binni         |
| 7     | Ram gandha       | 37    | Bakain        |
| 8     | Son – kharcha    | 38    | Nankawa       |
| 9     | Karangi          | 39    | Padhani       |
| 10    | Joginiya         | 40    | Mutra         |
| 11    | Gujraj           | 41    | Mazeera       |
| 12    | Bazaar bang      | 42    | Aguwari       |
| 13    | Parson           | 43    | Ghee bhat     |
| 14    | Pahariya         | 44    | Bee           |
| 15    | Akatahawa –BBK   | 45    | Raj muniya    |
| 16    | Moti farm        | 46    | Singul        |
| 17    | Karahani white   | 47    | Chingari      |
| 18    | Sona chur        | 48    | Ketaki        |
| 19    | Ram bilas        | 49    | Sukhawan      |
| 20    | Ram bhog-1       | 50    | Basahwa       |
| 21    | Sakkar chinni    | 51    | Mangla        |
| 22    | Madhuri          | 52    | Hari krishana |
| 23    | Rasi             | 53    | Norin         |
| 24    | Lal surya        | 54    | TCA-52        |
| 25    | Kabira           | 55    | TCA-151       |
| 26    | Sapana           | 56    | IET-16719     |
| 27    | Bagari Gorakhpur | 57    | IET-16717     |
| 28    | Bhadhi black     | 58    | IET-16724     |
| 29    | Karahni          | 59    | IET-16735     |
| 30    | Ram kajara       | 60    | IET-4673      |

**Table 4.5.1:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Y<sup>1</sup>).

| charater                                 | Days to 50% flowering | Days to maturity | Plant height (cm) | Tillers/plant | panicles bearing tillers/plant | Panicle length (cm) | grains/panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|-----------------------|------------------|-------------------|---------------|--------------------------------|---------------------|----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | -0.1353               | -0.1362          | -0.0220           | 0.0072        | 0.0079                         | -0.0011             | -0.0335        | -0.0033              | 0.0343        | -0.0156              | -0.0491              |
| Days to maturity                         | 0.1323                | 0.1315           | 0.0255            | -0.0036       | -0.0157                        | -0.0012             | 0.0342         | 0.0064               | -0.0364       | 0.0115               | -0.0338              |
| Plant height (cm)                        | -0.0019               | -0.0023          | -0.0119           | 0.0035        | 0.0054                         | -0.0007             | -0.0013        | -0.0035              | 0.0089        | -0.0033              | 0.0754               |
| Number of tillers/plant                  | 0.0026                | 0.0014           | 0.0147            | -0.0500       | -0.0272                        | -0.0025             | 0.0049         | -0.0116              | -0.0183       | -0.0007              | 0.3044               |
| Number of panicles bearing tillers/plant | 0.0003                | 0.0005           | 0.0020            | -0.0024       | -0.0044                        | -0.0008             | -0.0001        | -0.0013              | -0.0024       | 0.0000               | 0.4319               |
| Panicle length (cm)                      | -0.0001               | 0.0001           | -0.0009           | -0.0007       | -0.0026                        | -0.0149             | -0.0038        | -0.0022              | -0.0008       | -0.0003              | 0.1539               |

|                           |         |         |         |         |        |         |         |         |         |         |        |
|---------------------------|---------|---------|---------|---------|--------|---------|---------|---------|---------|---------|--------|
| Number of grains/panicle, | 0.0078  | 0.0081  | 0.0034  | -0.0031 | 0.0008 | 0.0079  | 0.0313  | 0.0077  | -0.0013 | -0.0066 | 0.2771 |
| Biological yield (g)      | 0.0254  | 0.0502  | 0.3013  | 0.2397  | 0.2996 | 0.1512  | 0.2564  | 1.0365  | -0.2198 | 0.1819  | 0.9610 |
| Harvest Index             | -0.0790 | -0.0863 | -0.2338 | 0.1139  | 0.1680 | 0.0160  | -0.0131 | -0.0661 | 0.3114  | -0.0984 | 0.0789 |
| 1000-seed weight (g)      | -0.0012 | -0.0009 | -0.0028 | -0.0001 | 0.0001 | -0.0002 | 0.0022  | -0.0018 | 0.0032  | -0.0102 | 0.0584 |

**Table 4.5.2:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Y<sup>1</sup>).

| Charater                                 | Days to 50% flowering | Days to maturity | Plant height (cm) | Tillers/plant | panicles bearing tillers/plant | Panicle length (cm) | grains/panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|-----------------------|------------------|-------------------|---------------|--------------------------------|---------------------|----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | -0.0258               | -0.0241          | -0.0035           | 0.0021        | 0.0029                         | 0.0003              | -0.0048        | 0.0000               | 0.0041        | -0.0022              | -0.0643              |
| Days to maturity                         | 0.0016                | 0.0017           | 0.0003            | -0.0002       | -0.0003                        | -0.0001             | 0.0004         | 0.0000               | -0.0003       | 0.0001               | -0.0525              |
| Plant height (cm)                        | -0.0046               | -0.0051          | -0.0340           | 0.0054        | 0.0098                         | -0.0011             | -0.0031        | -0.0092              | 0.0206        | -0.0090              | 0.0800               |
| Number of tillers/plant                  | 0.0023                | 0.0038           | 0.0046            | -0.0292       | -0.0162                        | -0.0059             | 0.0016         | -0.0070              | -0.0043       | -0.0006              | 0.2657               |
| Number of panicles bearing tillers/plant | -0.0022               | -0.0032          | -0.0057           | 0.0110        | 0.0198                         | 0.0037              | 0.0003         | 0.0049               | 0.0037        | 0.0000               | 0.3128               |
| Panicle length (cm)                      | 0.0000                | 0.0002           | -0.0001           | -0.0006       | -0.0005                        | -0.0027             | -0.0005        | -0.0004              | -0.0001       | -0.0001              | 0.1649               |
| Number of grains/panicle,                | 0.0053                | 0.0061           | 0.0026            | -0.0016       | 0.0004                         | 0.0056              | 0.0286         | 0.0069               | -0.0007       | -0.0053              | 0.2613               |
| Biological yield (g)                     | 0.0004                | 0.0180           | 0.2725            | 0.2424        | 0.2497                         | 0.1579              | 0.2420         | 1.0045               | -0.2141       | 0.1713               | 0.9432               |
| Harvest Index                            | -0.0399               | -0.0488          | -0.1519           | 0.0368        | 0.0472                         | 0.0077              | -0.0065        | -0.0533              | 0.2501        | -0.0681              | 0.0640               |
| 1000-seed weight (g)                     | -0.0015               | -0.0011          | -0.0048           | -0.0004       | 0.0000                         | -0.0006             | 0.0034         | -0.0031              | 0.0050        | -0.0183              | 0.0678               |

**Table 4.5.3:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Y<sup>2</sup>).

| Charater                                 | Days to 50% flowering | Days to maturity | Plant height (cm) | Tillers/plant | panicles bearing tillers/plant | Panicle length (cm) | Grains/panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|-----------------------|------------------|-------------------|---------------|--------------------------------|---------------------|----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | 0.0175                | 0.0181           | 0.0034            | 0.0012        | -0.0024                        | -0.0026             | 0.0035         | -0.0003              | -0.0052       | 0.0023               | -0.0900              |
| Days to maturity                         | -0.0039               | -0.0038          | -0.0007           | -0.0001       | 0.0008                         | 0.0007              | -0.0009        | 0.0000               | 0.0012        | -0.0005              | -0.0667              |
| Plant height (cm)                        | 0.0079                | 0.0079           | 0.0412            | -0.0206       | -0.0184                        | 0.0004              | 0.0060         | 0.0093               | -0.0349       | 0.0104               | 0.0112               |
| Number of tillers/plant                  | -0.0031               | -0.0008          | 0.0229            | -0.0458       | -0.0315                        | 0.0081              | 0.0021         | -0.0072              | -0.0303       | -0.0008              | 0.3259               |
| Number of panicles bearing tillers/plant | -0.0036               | -0.0057          | -0.0118           | 0.0181        | 0.0264                         | 0.0038              | -0.0027        | 0.0026               | 0.0134        | 0.0019               | 0.2315               |
| Panicle length (cm)                      | 0.0037                | 0.0047           | -0.0002           | 0.0044        | -0.0036                        | -0.0250             | -0.0038        | -0.0064              | -0.0047       | -0.0014              | 0.3053               |
| Number of grains/panicle,                | 0.0022                | 0.0025           | 0.0016            | -0.0005       | -0.0011                        | 0.0017              | 0.0111         | 0.0022               | -0.0018       | -0.0007              | 0.1584               |
| Biological yield (g)                     | -0.0158               | 0.0116           | 0.2249            | 0.1563        | 0.0978                         | 0.2575              | 0.1968         | 0.9992               | -0.1012       | 0.1903               | 0.9685               |
| Harvest Index                            | -0.0960               | -0.1022          | -0.2723           | 0.2127        | 0.1629                         | 0.0602              | -0.0533        | -0.0325              | 0.3212        | -0.0907              | 0.1552               |
| 1000-seed weight (g)                     | 0.0012                | 0.0011           | 0.0022            | 0.0001        | 0.0006                         | 0.0005              | -0.0006        | 0.0017               | -0.0025       | 0.0087               | 0.1196               |

**Table 4.5.4:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Y<sup>2</sup>).

| Charater                                 | Days to 50% flowering | Days to maturity | Plant height (cm) | Tillers/plant | panicles bearing tillers/plant | Panicle length (cm) | grains/panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|-----------------------|------------------|-------------------|---------------|--------------------------------|---------------------|----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | 0.0022                | 0.0021           | 0.0003            | -0.0002       | -0.0001                        | -0.0004             | 0.0004         | -0.0001              | -0.0004       | 0.0002               | -0.0910              |
| Days to maturity                         | -0.0067               | -0.0073          | -0.0011           | 0.0005        | 0.0006                         | 0.0015              | -0.0014        | 0.0001               | 0.0017        | -0.0006              | -0.0773              |
| Plant height (cm)                        | -0.0025               | -0.0031          | -0.0203           | 0.0043        | 0.0041                         | -0.0005             | -0.0027        | -0.0046              | 0.0141        | -0.0051              | 0.0314               |
| Number of tillers/plant                  | 0.0010                | 0.0007           | 0.0023            | -0.0110       | -0.0040                        | -0.0014             | 0.0003         | -0.0017              | -0.0032       | -0.0008              | 0.2183               |
| Number of panicles bearing tillers/plant | -0.0005               | -0.0007          | -0.0017           | 0.0031        | 0.0085                         | -0.0001             | -0.0003        | 0.0004               | 0.0024        | 0.0004               | 0.1282               |
| Panicle length (cm)                      | 0.0002                | 0.0002           | 0.0000            | -0.0001       | 0.0000                         | -0.0009             | -0.0001        | -0.0002              | -0.0001       | -0.0001              | 0.2848               |
| Number of grains/panicle,                | 0.0004                | 0.0004           | 0.0003            | -0.0001       | -0.0001                        | 0.0002              | 0.0020         | 0.0004               | -0.0002       | -0.0001              | 0.1497               |
| Biological yield (g)                     | -0.0382               | -0.0132          | 0.2239            | 0.1490        | 0.0480                         | 0.2562              | 0.1778         | 0.9912               | -0.1019       | 0.1855               | 0.9601               |
| Harvest Index                            | -0.0470               | -0.0565          | -0.1724           | 0.0727        | 0.0713                         | 0.0303              | -0.0262        | -0.0256              | 0.2487        | -0.0582              | 0.1608               |
| 1000-seed weight (g)                     | 0.0001                | 0.0001           | 0.0002            | 0.0001        | 0.0000                         | 0.0001              | -0.0001        | 0.0002               | -0.0002       | 0.0009               | 0.1221               |

**Table 4.5.5:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Pool).

| Charater                                 | Days to 50% flowering | Days to maturity | Plant height (cm) | Tillers/plant | panicles bearing tillers/plant | Panicle length (cm) | grains/panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|-----------------------|------------------|-------------------|---------------|--------------------------------|---------------------|----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | -0.0232               | -0.0234          | -0.0041           | 0.0007        | 0.0028                         | 0.0018              | -0.0052        | -0.0002              | 0.0066        | -0.0027              | -0.0730              |
| Days to maturity                         | 0.0163                | 0.0162           | 0.0032            | -0.0007       | -0.0029                        | -0.0018             | 0.0040         | 0.0004               | -0.0048       | 0.0016               | -0.0592              |
| Plant height (cm)                        | -0.0006               | -0.0007          | -0.0036           | 0.0012        | 0.0015                         | -0.0001             | -0.0005        | -0.0010              | 0.0031        | -0.0010              | 0.0523               |
| Number of tillers/plant                  | 0.0006                | 0.0010           | 0.0076            | -0.0231       | -0.0135                        | -0.0009             | 0.0015         | -0.0047              | -0.0105       | -0.0006              | 0.3060               |
| Number of panicles bearing tillers/plant | -0.0005               | -0.0007          | -0.0016           | 0.0023        | 0.0040                         | 0.0006              | -0.0001        | 0.0009               | 0.0020        | 0.0001               | 0.3587               |
| Panicle length (cm)                      | 0.0008                | 0.0012           | -0.0003           | -0.0004       | -0.0016                        | -0.0105             | -0.0021        | -0.0023              | -0.0012       | -0.0005              | 0.2409               |
| Number of grains/panicle,                | 0.0045                | 0.0049           | 0.0027            | -0.0013       | -0.0006                        | 0.0040              | 0.0201         | 0.0049               | -0.0025       | -0.0027              | 0.2278               |

|                      |         |         |         |         |         |         |         |         |         |         |        |
|----------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|
| Biological yield (g) | 0.0070  | 0.0239  | 0.2845  | 0.2035  | 0.2346  | 0.2165  | 0.2430  | 1.0059  | -0.1387 | 0.1920  | 0.9652 |
| Harvest Index        | -0.0773 | -0.0810 | -0.2344 | 0.1239  | 0.1345  | 0.0316  | -0.0336 | -0.0377 | 0.2730  | -0.0868 | 0.1288 |
| 1000-seed weight (g) | -0.0007 | -0.0006 | -0.0015 | -0.0001 | -0.0002 | -0.0002 | 0.0008  | -0.0011 | 0.0018  | -0.0057 | 0.0936 |

**Table 4.5.6:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Pool).

| Charater                                 | Days to 50% flowerin g | Days to maturity | Plant height (cm) | Tillers/ plant | panicles bearing tillers/plant | Panicle length (cm) | grains/ panicle | Biological yield (g) | Harvest Index | 1000-seed weight (g) | Seed yield/plant (g) |
|--|------------------------|------------------|-------------------|----------------|--------------------------------|---------------------|-----------------|----------------------|---------------|----------------------|----------------------|
| Days to 50% flowering                    | -0.0148                | -0.0138          | -0.0019           | 0.0013         | 0.0013                         | 0.0014              | -0.0028         | 0.0003               | 0.0026        | -0.0013              | -0.0778              |
| Days to maturity                         | 0.0008                 | 0.0009           | 0.0001            | -0.0001        | -0.0001                        | -0.0001             | 0.0002          | 0.0000               | -0.0002       | 0.0001               | -0.0652              |
| Plant height (cm)                        | -0.0037                | -0.0043          | -0.0286           | 0.0053         | 0.0070                         | -0.0008             | -0.0033         | -0.0071              | 0.0186        | -0.0074              | 0.0551               |
| Number of tillers/plant                  | 0.0017                 | 0.0019           | 0.0036            | -0.0195        | -0.0089                        | -0.0032             | 0.0008          | -0.0038              | -0.0043       | -0.0010              | 0.2407               |
| Number of panicles bearing tillers/plant | -0.0011                | -0.0016          | -0.0032           | 0.0060         | 0.0130                         | 0.0011              | -0.0002         | 0.0019               | 0.0031        | 0.0003               | 0.2177               |
| Panicle length (cm)                      | 0.0001                 | 0.0001           | 0.0000            | -0.0001        | -0.0001                        | -0.0007             | -0.0001         | -0.0001              | -0.0001       | 0.0000               | 0.2281               |
| Number of grains/panicle,                | 0.0026                 | 0.0028           | 0.0016            | -0.0006        | -0.0002                        | 0.0019              | 0.0140          | 0.0029               | -0.0010       | -0.0017              | 0.1994               |
| Biological yield (g)                     | -0.0192                | 0.0020           | 0.2478            | 0.1937         | 0.1467                         | 0.2098              | 0.2067          | 0.9987               | -0.1564       | 0.1787               | 0.9521               |
| Harvest Index                            | -0.0434                | -0.0526          | -0.1620           | 0.0551         | 0.0592                         | 0.0192              | -0.0170         | -0.0391              | 0.2495        | -0.0632              | 0.1141               |
| 1000-seed weight (g)                     | -0.0007                | -0.0006          | -0.0023           | -0.0004        | -0.0002                        | -0.0005             | 0.0011          | -0.0016              | 0.0022        | -0.0088              | 0.0958               |

**Table 4.5.7:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Y<sup>1</sup>).

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour-index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|-----------------------|
| Seed moisture content (%) | 0.0276                    | 0.0008                   | 0.0043                   | -0.0006           | -0.0037          | -0.0032              | 0.0010                  | -0.0854               |
| Speed of germination (%)  | -0.0039                   | -0.1343                  | -0.1037                  | 0.0856            | 0.0435           | 0.0849               | 0.0644                  | -0.6190               |
| Standard germination (%)  | 0.0294                    | 0.1465                   | 0.1897                   | -0.1301           | -0.0647          | -0.1242              | -0.0862                 | -0.5823               |
| Shoot length (cm)         | -0.0123                   | -0.3469                  | -0.3731                  | 0.5442            | -0.0307          | 0.2760               | 0.4220                  | 0.4164                |
| Root length (cm)          | -0.1405                   | -0.3355                  | -0.3533                  | -0.0584           | 1.0359           | 0.8621               | 0.0610                  | 0.8904                |
| Seedling length (cm)      | 0.0127                    | 0.0701                   | 0.0726                   | -0.0563           | -0.0923          | -0.1109              | -0.0540                 | 1.0048                |
| Seedling dry weight (g)   | 0.0016                    | -0.0198                  | -0.0187                  | 0.0319            | 0.0024           | 0.0201               | 0.0412                  | 0.4493                |

**Table 4.5.8:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Y<sup>1</sup>).

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour- index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|------------------------|
| Seed moisture content (%) | -0.0004                   | 0.0000                   | 0.0000                   | 0.0000            | 0.0001           | 0.0001               | 0.0000                  | -0.1265                |
| Speed of germination (%)  | -0.0010                   | 0.0299                   | 0.0204                   | -0.0044           | -0.0035          | -0.0057              | -0.0064                 | 0.0362                 |
| Standard germination (%)  | -0.0025                   | 0.1996                   | 0.2931                   | -0.0556           | -0.0423          | -0.0645              | -0.0807                 | 0.0885                 |
| Shoot length (cm)         | -0.0013                   | -0.0025                  | -0.0032                  | 0.0171            | 0.0016           | 0.0108               | 0.0101                  | 0.5863                 |
| Root length (cm)          | -0.0029                   | -0.0028                  | -0.0034                  | 0.0022            | 0.0238           | 0.0193               | 0.0017                  | 0.7775                 |
| Seedling length (cm)      | -0.1186                   | -0.1867                  | -0.2165                  | 0.6230            | 0.7973           | 0.9840               | 0.3774                  | 0.9465                 |
| Seedling dry weight (g)   | 0.0001                    | -0.0014                  | -0.0018                  | 0.0039            | 0.0005           | 0.0025               | 0.0066                  | 0.3087                 |

**Table 4.5.9:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Y<sup>2</sup>).

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour- index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|------------------------|
| Seed moisture content (%) | -0.0079                   | 0.0032                   | 0.0046                   | 0.0018            | 0.0009           | 0.0018               | 0.0011                  | -0.3160                |
| Speed of germination (%)  | -0.0058                   | 0.0143                   | 0.0136                   | -0.0006           | 0.0005           | -0.0003              | -0.0010                 | 0.1248                 |
| Standard germination (%)  | -0.0717                   | 0.1165                   | 0.1223                   | -0.0134           | 0.0036           | -0.0059              | -0.0214                 | 0.0948                 |
| Shoot length (cm)         | -0.0501                   | -0.0098                  | -0.0240                  | 0.2191            | -0.0170          | 0.1155               | 0.1547                  | 0.5152                 |
| Root length (cm)          | -0.0357                   | 0.0119                   | 0.0092                   | -0.0242           | 0.3107           | 0.2504               | 0.0032                  | 0.8039                 |
| Seedling length (cm)      | -0.1444                   | -0.0110                  | -0.0303                  | 0.3304            | 0.5051           | 0.6267               | 0.2736                  | 0.9896                 |
| Seedling dry weight (g)   | -0.0004                   | -0.0002                  | -0.0005                  | 0.0021            | 0.0000           | 0.0013               | 0.0030                  | 0.4132                 |

**Table 4.5.10:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Y<sup>2</sup>).

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour- index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|------------------------|
| Seed moisture content (%) | -0.0013                   | 0.0002                   | 0.0002                   | 0.0002            | 0.0001           | 0.0002               | 0.0001                  | -0.2193                |
| Speed of germination (%)  | -0.0002                   | 0.0017                   | 0.0012                   | 0.0000            | 0.0001           | 0.0000               | -0.0001                 | 0.2399                 |
| Standard germination (%)  | -0.0417                   | 0.2186                   | 0.3217                   | -0.0158           | 0.0071           | -0.0076              | -0.0236                 | 0.3010                 |
| Shoot length (cm)         | -0.0091                   | -0.0006                  | -0.0024                  | 0.0479            | -0.0009          | 0.0279               | 0.0306                  | 0.5445                 |

|                         |         |        |         |         |        |         |         |        |
|-------------------------|---------|--------|---------|---------|--------|---------|---------|--------|
| Root length (cm)        | -0.0045 | 0.0026 | 0.0011  | -0.0010 | 0.0517 | 0.0412  | 0.0009  | 0.7630 |
| Seedling length (cm)    | -0.1627 | 0.0173 | -0.0209 | 0.5142  | 0.7050 | 0.8841  | 0.3601  | 0.9453 |
| Seedling dry weight (g) | 0.0002  | 0.0001 | 0.0001  | -0.0010 | 0.0000 | -0.0006 | -0.0016 | 0.3665 |

**Table 4.5.11:** Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm (Pool)

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour-index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|-----------------------|
| Seed moisture content (%) | -0.0056                   | 0.0006                   | 0.0008                   | 0.0007            | 0.0008           | 0.0011               | 0.0002                  | -0.2306               |
| Speed of germination (%)  | -0.0012                   | 0.0109                   | 0.0097                   | -0.0046           | -0.0014          | -0.0041              | -0.0034                 | -0.2634               |
| Standard germination (%)  | -0.0202                   | 0.1230                   | 0.1393                   | -0.0577           | -0.0168          | -0.0484              | -0.0487                 | -0.2123               |
| Shoot length (cm)         | 0.0200                    | 0.0635                   | 0.0625                   | -0.1509           | 0.0105           | -0.0785              | -0.1109                 | 0.4772                |
| Root length (cm)          | 0.0316                    | 0.0296                   | 0.0272                   | 0.0157            | -0.2253          | -0.1838              | -0.0078                 | 0.8354                |
| Seedling length (cm)      | -0.2556                   | -0.4940                  | -0.4550                  | 0.6806            | 1.0680           | 1.3090               | 0.6047                  | 0.9911                |
| Seedling dry weight (g)   | 0.0004                    | 0.0028                   | 0.0031                   | -0.0066           | -0.0003          | -0.0041              | -0.0090                 | 0.4252                |

**Table 4.5.12:** Direct and indirect effects of different characters on seed yield per plant at phenotypic level of rice germplasm (Pool)

| Character                 | Seed moisture content (%) | Speed of germination (%) | Standard germination (%) | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Seedling dry weight (g) | Seedling vigour-index |
|---------------------------|---------------------------|--------------------------|--------------------------|-------------------|------------------|----------------------|-------------------------|-----------------------|
| Seed moisture content (%) | 0.0039                    | -0.0001                  | -0.0001                  | -0.0005           | -0.0005          | -0.0006              | -0.0002                 | -0.1643               |
| Speed of germination (%)  | -0.0006                   | 0.0218                   | 0.0151                   | -0.0016           | -0.0008          | -0.0018              | -0.0026                 | 0.1568                |
| Standard germination (%)  | -0.0093                   | 0.2146                   | 0.3092                   | -0.0346           | -0.0184          | -0.0361              | -0.0497                 | 0.2091                |
| Shoot length (cm)         | -0.0024                   | -0.0013                  | -0.0020                  | 0.0176            | 0.0008           | 0.0108               | 0.0108                  | 0.5702                |
| Root length (cm)          | -0.0021                   | -0.0006                  | -0.0011                  | 0.0008            | 0.0182           | 0.0146               | 0.0008                  | 0.7670                |
| Seedling length (cm)      | -0.1537                   | -0.0772                  | -0.1116                  | 0.5869            | 0.7675           | 0.9550               | 0.3784                  | 0.9430                |
| Seedling dry weight (g)   | -0.0001                   | -0.0003                  | -0.0004                  | 0.0017            | 0.0001           | 0.0011               | 0.0027                  | 0.3403                |

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