Correlation and Path Coefficient Analysis in Rice (Oryza sativa L.) Genotypes under Normal and Cold Condition

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Received: 17-04-2019 Accepted: 28-08-2019 DOI: 10.18805/IJARe.A-5277

ABSTRACT

An experiment was conducted with the objective of determining the magnitude of association between seedling vigour index and its component characters. Fifty rice genotypes were evaluated in completely randomized design with three replications. Correlation coefficient analysis of vigour index showed positive and significant association with total seedling length, root length, total seedling dry weight, root dry weight, shoot length, germination percentage and first leaf area under normal condition. Germination percentage, total seedling length, root length, shoot length and first leaf area showed strong and significant positive association with seedling vigour index under cold condition. Thus, these traits could play pivotal role in developing cold tolerant rice. Separation of correlation coefficients into direct and indirect effects of component traits for vigour index revealed that the traits total seedling length and root dry weight exerted maximum positive direct and indirect effect respectively on vigour under normal condition. Under cold stress the traits shoot length and root length exerted maximum positive direct and indirect effects respectively for vigour index. These characters, therefore, are required to be considered during selection for vigour improvement in rice under normal and cold condition in rice.

Key words: Cold stress, Correlation, Rice, Seedling vigour index, Path analysis.

INTRODUCTION

Rice (Oryza sativa L.) is the most important food crop, as over half of the world population consumes rice as their principal source of nourishment (Khush, 2005). Rice-growing areas consist of the tropics, subtropics, semi-arid tropics and temperate regions which requires a fairly high temperature ranging from 20°C to 40°C (Sridevi and Chellamuthu, 2015) for its growth. The standard temperature for rice seed germination is considered to be approximately 30°C and anything below 20°C results in a gradual decrease of germination rate. In India, rice is the principal food crop, contributing 40 per cent of total food grain production. It is estimated that the population is likely to increase to 138.89 crores by the year 2025. To meet these requirements of growing population, about 130 metric tonnes of rice will be required by 2025, against the current production of 94.01 metric tonnes of rice during 2010-11 (Anonymous, 2011). Even though rice production has been increasing at a steady pace since the adoption of high yielding rice cultivars, demand for rice continues to increase. Besides, many factors affecting rice production, high seedling vigour is essential for attaining maximum production. Hence, the varieties possessing high seed and seedling vigour trait associated with higher yield are the prime requisite for an efficient plant breeding program to meet the challenge of producing more rice from available land.

Low temperature (cold) is one of the main abiotic stresses in rice cultivation and improvement of Cold Tolerance in the Seedling Stage (CTSS) in rice is a difficult trait controlled by several genes (Dilday 1990 and Glaszmann and Khush 1990). Cold stress in rice delays germination and emergence, however, the successive stages of germination (i.e., growth of coleoptiles and radical) are the most vulnerable phases to cold spell (Yoshida, 1981).

Seedling vigour, is an important factor that reflects potential seed germination, seedling growth, seed longevity and tolerance to adversity (Sun et al. 2007) and is the ability of a seed to emerge rapidly from soil or water (Huang et al. 2004). Over the past 20 years, broad efforts have been made to get better cold tolerance in rice, which is a very multifaceted trait (Maruyama et al. 2014). Cold stress affects chlorophyll content (Kim et al. 2009) and can impair metabolism via cellular oxidative damage (Nakashima et al. 2007). On the other hand, rice also possesses strategies to cope with or acclimatize to cold stress. Under cold stress, contents of antioxidant species also augment to hunt ROS and protect rice plants against oxidative damage (Sato et al. 2011). Seeds with high vigor is important for rice production because it can not only significantly enhance seedling establishment (Luo et al. 2007), but also improves the capability to compete against weeds at seedling stage (Rao et al. 2007). Therefore, seedling vigor has been paid more

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attention, in respect to cultivation techniques and genetic analysis in recent years.

The association of plant characters and yield assumes special importance in the formulation of selection criteria. To make effective selection for early vigor, a thorough understanding of vigor indicating parameters, interrelationship among them is necessary. Correlation and path analysis establish the extent of association between the traits of interest and its attributes and brings out the relative importance of direct and indirect effects, giving an obvious understanding of their association with the interested traits (Babu et al. 2012). The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components. One component is the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable. The other component is the indirect effect (s) of a predictor variable on the response variable through the predictor variables (Dewey and Lu 1959). Considering the above facts a laboratory study was conducted to identify best performing rice genotypes under cold stress at seedling stage as high seed and seedling vigour are good indicators for a successful crop.

MATERIALS AND METHODS
An experiment was conducted in the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, to evaluate rice genotypes for cold tolerance based on seed and seedling parameters as per Cruz and Milach (2004). Fifty rice genotypes were taken and the experiment was laid out in completely randomized design with three replications each containing 25 seeds with two sets (normal condition and stressed condition). The seeds were kept in petri dish containing germination paper moistened with sterile distilled water and germination was allowed to proceed at 18 ± 1 °C (Chen et al. 2007) in growth chamber. After 28 days the germinated seedlings were taken and the seedling vigour traits were measured. Observations were recorded on eight physiological indices viz., germination percentage (%), first leaf area (cm²), total seedling length (cm), shoot length (cm), root length (cm), root dry weight (g), total seedling dry weight (g) and seedling vigour index. Seedling vigour index (SVI) was calculated by the method of Perry (1978).

Phenotypic and genotypic correlation coefficient analysis:
Phenotypic and genotypic correlation coefficients were computed from variance and covariance components based on the method described by Singh and Chaudhury (1996). The Pearson correlation test was applied for phenotypic and genotypic correlation coefficients respectively using SAS statistical package (2002).

Phenotypic and genotypic path coefficient analysis: The direct and indirect effect of component traits on yield and among themselves were estimated following the method suggested by Dewey and Lu (1959) given as follows.

\[ r_{ij} = \rho_{ij} + \sum \rho_{ik} \rho_{kj} \]

Where, 
\( r_{ij} \) = Mutual association between the independent trait (i) and dependent trait (j) as measured by the correlation coefficient. 
\( \rho_{ij} \) = Component of direct effects of the independent trait (i) on the dependent variable (j) as measured by the path coefficient and, 
\( \sum \rho_{ik} \rho_{kj} \) = Summation of components of indirect effect of a given independent trait (i) on the given dependent trait (j) via all other independent traits (k).

Residual effect estimated by the formula

\[ R^2 = \frac{1}{1-R^2} \]

Where, 
\( R^2 \) = \( \sum \rho_{ij} \)

Where, \( R^2 \) is the residual factor, \( \rho_{ij} \) is the direct effect of yield by ith trait and \( r_{ij} \) is the correlation of yield with the ith trait.

RESULTS AND DISCUSSION
The analysis of variance revealed highly significant differences among the genotypes for all the characters studied, indicating the existence of considerable genetic variation in the rice genotypes under study.

Correlation analysis under normal condition: The correlation estimates at genotypic level were moderate to strong in magnitude (Table 1). The correlation analysis

| Characters                      | Germination per cent | First leaf area | Shoot length | Root length | Total seedling length | Root dry weight | Total seedling dry weight | Seedling vigour index |
|--------------------------------|----------------------|----------------|--------------|-------------|-----------------------|----------------|--------------------------|----------------------|
| Germination per cent           | 1.000                |                |              |             |                       |                |                          |                      |
| First leaf area                | 0.040                | 1.000          |              |             |                       |                |                          |                      |
| Shoot length                   | 0.266**              | 0.382**        | 1.000        |             |                       |                |                          |                      |
| Root length                    | 0.348**              | 0.006          | 0.127        | 1.000       |                       |                |                          |                      |
| Total seedling length          | 0.412**              | 0.240**        | 0.708**      | 0.790**     | 1.000                 |                |                          |                      |
| Root dry weight                | 0.553**              | 0.081          | 0.260**      | 0.641**     | 0.617**               | 1.000          |                          |                      |
| Total seedling dry weight      | 0.511**              | 0.227**        | 0.511**      | 0.459**     | 0.643**               | 0.856**        | 1.000                     |                      |
| Seedling vigour index          | 0.661**              | 0.207**        | 0.674**      | 0.754**     | 0.953**               | 0.683**        | 0.691**                  | 1.000                |

** Significant at 1 per cent level.
revealed that seedling vigour index had significant positive
correlation with total seedling length (0.953), root
length (0.754), total seedling dry weight (0.691), root dry
weight (0.683), shoot length (0.674), germination percentage
(0.661) and first leaf area (0.674). Positive correlated result
indicated that increase of one trait will result in increase of
the correlated trait (Kampe et al, 2018). Thus direct selection
for seedling vigour index through the aforesaid characters
would be very effective in seedling vigour improvement in
rice. When considering the inter correlations the trait,
germination percentage had significant and strong positive
association with root dry weight (0.553), total seedling dry
weight (0.551). First leaf area portrayed low to moderate
association with shoot length (0.382), total seedling length
(0.240) and total seedling dry weight (0.227). The traits shoot
length and root length exhibited strong association with total
seedling length (0.708 and 0.790) and total seedling dry
weight (0.511 and 0.459). The trait root dry weight showed
moderate association (0.260) for shoot length and strong
association (0.641) for root length. Total seedling length
portrayed strong and positive correlation with seedling total
seedling dry weight (0.643) and root dry weight (0.617).
Similarly root dry weight showed strong association with
total seedling dry weight (0.856). Thus, indirect selection of
these characters would be expected to offer greater scope
for high seedling vigour under normal conditions.

**Correlation analysis under cold condition:** The genotypic
correlation coefficients among seedling vigour index traits are
presented in Table 2. Of these vigour related traits, germination
percentage (0.912), total seedling length (0.901), root
length (0.888), shoot length (0.880) and first leaf area
(0.749) showed strong and significant positive association
with seedling vigour index. Thus, these characters could be
considered for selection for cold tolerance. Inter correlations
between the traits showed that the trait, germination
percentage had significant and strong positive association
with total seedling dry weight (0.855), root length (0.848),
shoot length (0.829), first leaf area (0.731). First leaf area
portrayed strong association with total seedling length
(0.827) and shoot length (0.811). The trait shoot length
showed strong association with total seedling length
(0.983), root length (0.923) and moderate association with
total seedling dry weight (0.450) and root length exhibited
strong association with total seedling length (0.978) and
total seedling dry weight (0.465). Total seedling length exhibited
moderate association with total seedling dry weight (0.466)
and root dry weight (0.420). The trait root dry weight showed
strong association (0.933) with total seedling dry weight.
Thus, indirect selection of these characters would be
expected to offer greater scope for high seedling vigour under
cold conditions.

**Path coefficient analysis under normal condition:** The
Path coefficient analysis (Table 3) revealed that the

### Table 2: Genotypic correlation among morphological traits under cold condition.

| Characters            | Germination per cent | First leaf area | Shoot length | Root length | Total seedling length | Root dry weight | Total seedling dry weight | Seedling vigour index |
|-----------------------|----------------------|-----------------|--------------|-------------|-----------------------|-----------------|---------------------------|-----------------------|
| Germination per cent  | 1.000                |                 |              |             |                       |                 |                           |                       |
| First leaf area       | 0.731**              | 1.000           |              |             |                       |                 |                           |                       |
| Shoot length          | 0.829**              | 0.811**         | 1.000        |             |                       |                 |                           |                       |
| Root length           | 0.848**              | 0.811**         | 0.923**      | 1.000       |                       |                 |                           |                       |
| Total seedling length | 0.855**              | 0.827**         | 0.983**      | 0.978**     | 1.000                 |                 |                           |                       |
| Root dry weight       | 0.378**              | 0.289**         | 0.399**      | 0.426**     | 0.420**               | 1.000           |                           |                       |
| Total seedling dry weight | 0.398**              | 0.324**         | 0.450**      | 0.465**     | 0.466**               | 0.933**         | 1.000                     |                       |
| Seedling vigour index | 0.912**              | 0.749**         | 0.880**      | 0.888**     | 0.901**               | 0.268**         | 0.284**                   | 1.000                 |

** Significant at 1 per cent level.

### Table 3: Path analysis of morphological traits under normal condition.

| Characters            | Germination per cent | First leaf area | Shoot length | Root length | Total seedling length | Root dry weight | Total seedling dry weight | Seedling vigour index |
|-----------------------|----------------------|-----------------|--------------|-------------|-----------------------|-----------------|---------------------------|-----------------------|
| Germination per cent  | **0.3211**           | **0.0001**      | **-0.8667**  | **-1.3362** | 2.5537                | 0.5160          | -1.1479                   | 0.661                 |
| First leaf area       | **0.0127**           | **-0.0037**     | **-1.2415**  | -0.0209     | 1.4834                | 0.0755          | -0.5104                   | 0.207                 |
| Shoot length          | **0.0855**           | **-0.0014**     | **-3.2529**  | **-0.4875** | 4.3844                | 0.2429          | -1.4188                   | 0.674                 |
| Root length           | **0.1118**           | **0.0001**      | **-0.4134**  | **-3.8359** | 4.8947                | 0.5980          | -1.0315                   | 0.754                 |
| Total seedling length | **0.1324**           | **-0.0009**     | 2.3023       | **-3.0321** | **6.1924**            | 0.5757          | -1.4438                   | 0.953                 |
| Root dry weight       | **0.1774**           | **-0.0003**     | **-0.8463**  | **-2.4570** | 3.8184                | **0.9336**      | -1.9223                   | 0.683                 |
| Total seedling dry weight | **0.1640**           | **-0.0008**     | **-1.6630**  | **-1.7608** | 3.9788                | **0.7987**      | **-2.2471**               | 0.691                 |

Residual effect = 0.1599  Diagonal values (bold) indicate direct effects.
characters chosen for the study were very much appropriate as evident from the low amount of residual effect. The partitioning of correlation coefficient into direct effects showed that total seedling length (6.1924) exerted highest positive direct effect for seedling vigour index followed by root dry weight (0.9336) and germination percentage (0.3211). These characters, therefore, are required to be considered during selection for vigour improvement in rice. Direct positive effect of some characters indicated that selection of these traits is directly helpful for the improvement of our trait of interest (Kampe et al., 2018). The indirect effect of germination percentage revealed that the traits total seedling length (2.5537) followed by root dry weight (0.5160) exerted positive effect through these traits. These two traits total seedling length and root dry weight exerted indirect positive effects for first leaf area, shoot length and root length. This observation highlighted the importance of these two characters for controlling of seedling vigour index in rice. Therefore, the present investigation revealed that root length and shoot length were the major vigour determining traits in rice. Hence, these characters root length and shoot length should be considered during selection under cold condition in rice.

CONCLUSION

It is essential to know the degree of mutual association prevailing between vigour index and its component traits, which forms the basis for selecting desirable genotypes under extreme conditions. A study of correlation and path analysis will thus help in identifying suitable selection criteria for improving the trait of interest. Hence the present study was undertaken to determine the extent of correlation and path coefficients in some selected rice genotypes under normal and cold condition. Based on correlation analysis, total seedling length, root length, total seedling dry weight, root dry weight, shoot length, germination percentage and first leaf area displayed significant and positive association with vigour index under normal condition. Germination percentage, total seedling length, root length, shoot length and first leaf area showed strong and significant positive association with seedling vigour index under cold condition. Thus, these characters germination percentage, total seedling length, root length, shoot length, root length and first leaf area could be considered for selection for developing cold tolerant rice cultivars. Since, simple correlation does not partition correlation coefficients into cause and effect relationships of yield contributing traits, path coefficient analysis is employed to predict the exact figure of direct and indirect contribution of component traits on vigour index both under normal and cold conditions. The traits total seedling length and root dry weight exerted maximum positive direct and indirect effect on vigour under normal condition. Under cold stress the traits shoot length and root length exerted maximum positive direct and indirect effect for vigour index. These characters, therefore, are required to be considered during selection for vigour improvement in rice under normal and cold condition in rice.
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