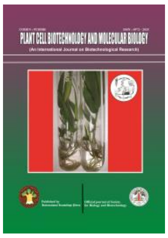

Plant Cell Biotechnology and Molecular Biology

Volume 25, Issue 9-10, Page 57-64, 2024; Article no.PCBMB.12307
ISSN: 0972-2025

Character Association and Path Coefficient Analysis for Early Seedling Vigour Traits in rice (*Oryza sativa* L.)

Rakshitha V. [a,b*], J. Suresh [a], C. Narendra Reddy [c] and Channappa Gireesh [b,d]

[a] Department of Genetics and Plant Breeding, College of Agriculture, PJTSAU, Hyderabad, Telangana, India.
[b] Indian Council of Agricultural Research (ICAR), Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, Telangana, India.
[c] Department of Entomology, College of Agriculture, PJTSAU, Hyderabad, Telangana, India.
[d] Indian Council of Agricultural Research (ICAR), Indian Institute of Seed Science (IISS), Regional Station, Bengaluru, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/pcbmb/2024/v25i9-108810

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12307

Original Research Article

Received: 02/06/2004
Accepted: 05/08/2024
Published: 08/08/2024

ABSTRACT

Early seedling vigour, a key trait in rice cultivation, significantly impacts plant establishment, growth and yield. The study applies path analysis to assess various rice traits and their direct and indirect contributions to early seedling vigour aiming to enhance breeding strategies for resilient rice varieties. A total of 168 rice genotypes from the 3K rice panel were evaluated for early seedling vigour traits under laboratory conditions. Key traits measured included germination percentage,

**Corresponding author: E-mail: rakshithaveerabhadrappa58533@gmail.com;*

Cite as: *V., Rakshitha, J. Suresh, C. Narendra Reddy, and Channappa Gireesh. 2024. "Character Association and Path Coefficient Analysis for Early Seedling Vigour Traits in Rice (Oryza Sativa L.)". PLANT CELL BIOTECHNOLOGY AND MOLECULAR BIOLOGY 25 (9-10):57-64. https://doi.org/10.56557/pcbmb/2024/v25i9-108810.*

seedling length, shoot length, root length, total fresh weight and total dry weight at 7 days after keeping for germination. Correlation studies showed germination percentage, seedling length, shoot length, root length, total fresh weight and total dry weight traits had significantly positive relationships with seedling vigour indices I and II. Path coefficient analysis identified positive direct effect on seedling vigour index I was exerted by germination percentage, seedling length, root length, shoot length and total dry weight and negative direct effect by total fresh weight. In case of Seedling vigour index II, positive direct effect was exerted via germination percentage, shoot length and total dry weight and negative direct effect via seedling length, root length and total fresh weight. Path results highlighted that, total dry weight as the most crucial trait with the highest positive effects on seedling vigour index II. Our findings indicate that selecting for these traits can effectively improve early seedling vigour in rice hybrids, aiding in the development of superior rice varieties for direct seeded condition.

Keywords: 3k RGP; early seedling vigour; correlation; path analysis; direct-seeded rice.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the main cereal for carbohydrate source across all Asian developing countries which provide about 23% of global caloric intake [1,2]. Rice is consumed as the primary source of food in the globe which provides food and livelihood security to nearly half (about 3.5 billion) of the world's population [3]. It is normally grown in the semiaquatic environments and transplanting has been the predominant method. The future threat to natural resources, rising labor shortages, declining arable lands, increasing prices of fertilizer and pesticide inputs, energy scarcity and changing climatic conditions are the major factors contributing to the decrease in rice production [4]. To overcome these constraints, the most promising strategy would be shifting from the conventional puddled transplanted rice system to direct-seeded rice technology [5]. This along with improvement in seedling vigour not only enhances the crop yield but can also improve the crop resilience against the changing climatic conditions and the biotic impediments to rice yields [6]. However, breeding for improvement in seedling vigour remains a challenge in rice research [7]. So, there is a need to transform traditional rice transplanting to a more sustainable approach, such as direct-seeded rice (DSR).

Early seedling vigour is a critical trait in DSR cultivation, influencing establishment, growth and yield potential. Understanding the genetic and physiological factors that underpin early seedling vigour can enhance breeding strategies aimed at developing resilient and high-performing rice varieties. Correlation coefficient is a statistical measure of degree (strength) and direction of relationship between two or more variables. The study of correlations may help the plant breeder to know how the improvement of one character will bring simultaneous improvement in other characters. These studies assess how various factors, such as germination rate, root development and seedling growth, correlate with overall plant health and productivity [8]. By analyzing these correlations, one can identify key traits that contribute to robust seedling vigour, thereby improving crop early establishment and yield stability.

Path analysis, a statistical technique used to describe the directed dependencies among a set of variables, is invaluable in understanding the complex relationships between different agronomic traits in rice. By partitioning the correlation coefficients into direct and indirect effects, path analysis helps identify key traits that directly influence yield and other important characteristics [9]. This method is particularly useful in rice breeding programs, where understanding these relationships can lead to the selection of superior genotypes with desirable traits. This study aims to apply path analysis to various rice traits to unravel their direct and indirect contributions to yield, providing insights for more effective breeding strategies.

2. MATERIALS AND METHODS

The experimental sample consisted of 168 rice genotypes from the 3k rice genome panel, sourced from the ICAR-Indian Institute of Rice Research in Rajendranagar, Hyderabad. These genotypes were tested for early seedling vigour traits using the paper towel method [10] under laboratory conditions. The seeds were pre washed and then transferred to paper towels for germination at a room temperature of 25 ^{0}C with a relative humidity of 75-80% as a standard procedure. The experiment was carried out in a completely randomized design with two replications. Observations were made on the 7th day for traits including germination percentage, seedling length, shoot length, root length, total fresh weight, total dry weight, seedling vigour index-I (SVI-I) and seedling vigour index-II (SVI-II).

Vigour indices are calculated using the following formulae:

SVI-I= Germination Percent × Seedling Length (cm)

SVI-II= Germination Percent × Seedling Dry Weight (g)

Statistical analyses for these traits were conducted using Singh and Chaudhary [11] for correlation coefficients and Dewey and Lu [12] for path analysis using R studio and SPSS statistical software.

3. RESULTS AND DISCUSSION

The comprehensive analysis of trait association and path analysis was performed for early seedling vigour traits using suitable statistical software to understand the relations among various vigour component traits. The outcomes of correlation study and path analysis are presented below.

3.1 Correlation Studies

Among the early seedling vigour traits studied (Table 1: Fig. 1), Seedling vigour index I (SVI-I) showed highest significant positive correlation with seedling length followed by total dry weight, total fresh weight, root length, shoot length and germination percentage. Similarly, Seedling vigour index II (SVI-II) had highest significant positive correlation with total dry weight followed by seedling length, total fresh weight, root length, germination percentage and shoot length. In case of both vigour indices seedling length, total fresh weight and total dry weight were the key traits. Similar results were reported earlier by Bharamappanavara et al. [13] in their correlation studies. Coming to inter trait association among other traits, seedling length had a highest significant positive correlation with SVI I followed by SVI II, total dry weight, total fresh weight, shoot length, root length and germination percentage. This could be due to the involvement of seedling length in estimation vigour index (SVI-I) and its influence of bringing out the high vigour. As seedling vigour refers to robust growth of the plant, thus seedling length having significant association with vigour indices is one of the vital factors. Total dry weight exhibited highest significant positive correlation with SVI II followed by SVI I, seedling length, total fresh weight, root length, shoot length and germination percentage. Many other studies focusing on early vigour such as Cui et al*.* [14] Bordoloi and Sarma [15] and Jan and Kashyap [16] have reported significant positive correlations among the traits discussed above. Total fresh weight displayed a highest significant positive correlation with total dry weight followed by SVI II, SVI I, seedling length, shoot length, root length and germination percentage. Our studies corroborate the earlier findings of Bharamappanavara et al. [13] who observed the positive correlations among seedling vigour traits studied through paper towel method. Root length exhibited a highest significant positive correlation with SVI I followed by seedling length, SVI II, total dry weight, total fresh weight, germination percentage and shoot length. Shoot length exhibited a highest significant positive correlation with seedling length followed by SVI I, total fresh weight, total dry weight, SVI II, germination percentage and root length. Germination percentage showed a highest significant positive correlation with SVI I, followed by SVI II, seedling length, total dry weight, root length, total fresh weight, and shoot length. Similar results were observed by Barik et al*.* [17] and Jan and Kashyap [16] in their studies. Barik et al. [17] investigated seedling vigour and its component traits under anaerobic conditions, revealing key trait associations that influence seedling vigour under flooding stress. Association results from the aforementioned study provides a comparative basis, linking their findings on anaerobic stress to the practical needs of direct-seeding techniques. This approach helps to contextualize our results within established research, bridging the gap between anaerobic germination studies and direct-seeding practices and guiding the development of more resilient rice varieties. The observed results also showed consistent, significantly positive associations among the studied traits, suggesting common genetic control. This is often might be due to genetic linkage, where traits controlled by closely linked genes are co-inherited or pleiotropy, where a single gene influences multiple traits. Shared physiological pathways, such as those regulating growth hormones, also contribute to these correlations by affecting multiple aspects of plant development simultaneously. These findings suggest that genetic factors influencing one trait can also affect others, revealing significant genetic correlations. This understanding is vital for deciphering the genetic mechanisms underlying early seedling vigour in rice. The consistent positive correlations indicate that these traits may collectively serve as effective indicators for evaluating seedling vigour, thereby assisting in the selection and improvement of rice varieties.

3.2 Path Coefficient Analysis

In this study, seedling vigour indices were treated as dependent variables, while germination percentage, seedling length, shoot length, root length, total fresh weight, and total dry weight served as independent variables. The residual effects of these independent variables, which have a minor impact on seedling vigour, are detailed in Tables 2 and 3.

Perusal of Table 2 revealed that highest direct effect on seedling vigour index I was exhibited by seedling length (0.338), root length (0.331), shoot length (0.306), germination percentage (0.151) and total dry weight (0.087). Positive direct effect of these traits on seedling vigour index I indicates their importance in determining this complex character and therefore should be given preference for the improvement of this trait. The total fresh weight (-0.049) showed direct negative effect. Similar findings were made by Jan and Kashyap [16] and Prasad et al. [18] in their studies. The same way goes too for indirect effects. Except total fresh weight the remaining traits exhibited positive indirect effects. The results obtained were in analogous to the findings of Patil et al. [19] Jan and Kashyap [16] Katiyar et al. [20] and Sadhana et al. [21].

Perusal of Table 3 revealed that highest direct effect on seedling vigour index II (SVI-II) was exhibited by total dry weight (0.961) followed by germination percentage (0.133) and shoot length (0.005). Positive direct effect of these traits on seedling vigour index II indicates their importance in determining this complex character and therefore should be given preference for the improvement of this trait. Jan and Kashyap [16] observed similar results in their study. The total fresh weight (-0.03), seedling length (-0.0025) and root length (-0.002) showed direct negative effect. The same way goes for indirect effects also. Total dry weight, germination percentage and shoot length exhibited indirect positive effects whereas total fresh weight, seedling length and root length the remaining traits exhibited negative indirect effects. Similar findings were made by Patil et al. [19] Jan and Kashyap [16] Katiyar et al. [20] in their studies.

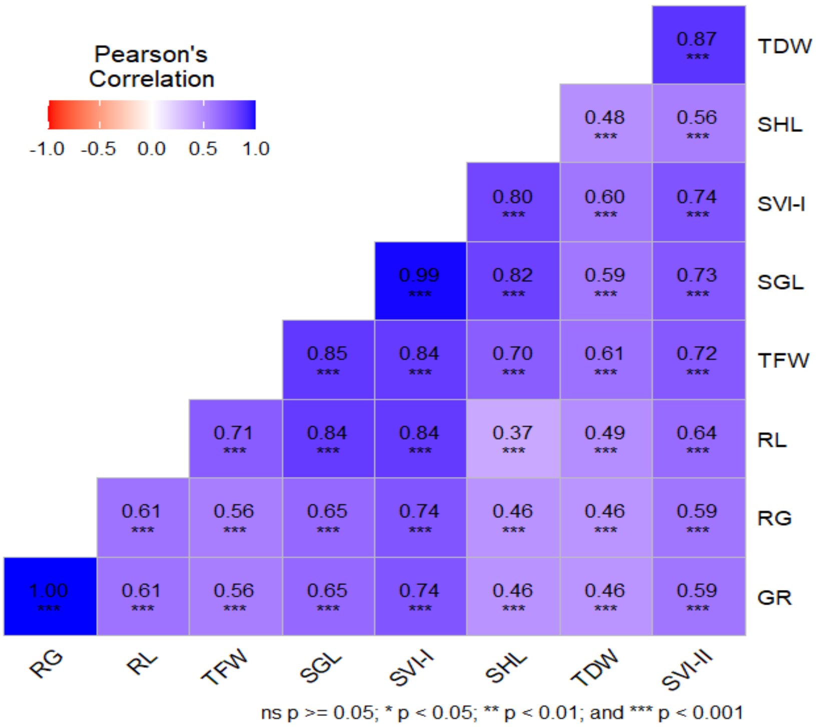

Fig. 1. Depiction of correlation among seedling vigour traits

Table 1. Genetic correlation among early seedling vigour traits at 7th day by using paper- towel method in rice

	Germination percentage	Seedling length	Root length	Shoot length	Total fresh weight	Total dry weight	Seedling vigour index-I	Seedling vigour index-II
Germination percentage	1	0.664**	0.627**	0.481**	0.576**	0.658**	0.76**	0.736**
Seedling length		1	0.848**	0.826**	0.866**	0.891**	1.006**	0.898**
Root length			1	0.402**	0.724**	0.793**	0.868**	0.805**
Shoot length				1	0.727**	0.698**	0.815**	0.696**
Total fresh weight					1	0.884**	0.876**	0.883**
Total dry weight						1	0.921**	1.005**
Seedling vigour index-I							1	0.915**
Seedling vigour index-II								1

**Significant at 5% level, **Significant at 1% level*

Table 2. Estimates of direct and indirect effects between seedling vigour index I and early seedling vigour traits

Traits	Germination percentage	Seedling length	Root Length	Shoot length	Total Fresh weight	Total dry weight	Seedling Vigour Index-I
Germination percentage	0.151	0.225	0.207	0.147	-0.028	0.058	0.76
Seedling length	0.1	0.338	0.281	0.252	-0.042	0.075	1.004
Root length	0.094	0.287	0.331	0.122	-0.036	0.063	0.862
Shoot length	0.072	0.279	0.132	0.306	-0.035	0.062	0.816
Total fresh weight	0.087	0.292	0.241	0.22	-0.049	0.077	0.868
Total dry weight	0.101	0.29	0.241	0.217	-0.043	0.087	0.892

Residual value: 0.27

**significant at 5% level, **significant at 1% level.*

Table 3. Estimates of direct and indirect effects between seedling vigour index II and early seedling vigour traits

Traits	Germination percentage	Seedling Length	Root length	Shoot length	Total Fresh weight	Total dry weight	Seedling Vigour Index-II
Germination percentage	0.133	-0.017	-0.001	0.002	-0.017	0.641	0.741
Seedling length	0.088	-0.025	-0.002	0.004	-0.026	0.825	0.864
Root length	0.083	-0.021	-0.002	0.002	-0.022	0.698	0.738
Shoot length	0.064	-0.021	-0.001	0.005	-0.021	0.681	0.707
Total fresh weight	0.076	-0.022	-0.002	0.003	-0.03	0.847	0.874
Total dry weight	0.088	-0.021	-0.002	0.003	-0.026	0.961	1.004

Residual value: 0.31

**Significant at 5% level, **significant at 1% level.*

Path analysis indicated that total dry weight was the most important character that had the maximum contribution to seedling vigour index II (SVI-II) as it exhibited a considerable positive direct effects and significant correlation coefficients on seedling vigour. It revealed total dry weight to be effective selection criteria for improvement of seedling vigour index II (SVI-II). Further, path analysis revealed the effectiveness of direct selection for seedling length, root length and shoot length towards improvement of early seedling vigour for development of rice varieties.

4. CONCLUSION

According to the findings, a consistent pattern of significantly positive associations among the studied traits was evident. This suggests the possibility of common genetic control influencing these traits. Such associations imply that genetic factors influencing one trait may concurrently affect others, indicating potential genetic correlations among them. The significant and positive correlations observed between seedling vigour index II (SVI-II) and traits such as germination percentage, seedling length, root length, shoot length, total fresh weight, and total dry weight indicate that direct selection based on these traits would be effective for improving early seedling vigour in rice hybrids. Total dry weight, in particular, emerged as a crucial trait with the highest direct and indirect positive effects on seedling vigour index II (SVI-II) and can be used as effective selection criteria for improving seedling vigour index II (SVI-II). Overall, the study highlights the importance of seedling vigour traits in implementing direct-seeded rice in water scarce areas.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

We extend our sincere gratitude for the financial support and expert guidance provided by the faculty at ICAR – IIRR and the College of Agriculture, Rajendranagar, Hyderabad.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Li SC, Chou TC, Shih CK. Effects of brown rice, rice bran, and polished rice on colon carcinogenesis in rats. Food Research International. 2011;44(1):209-216.
2. Pandit E, Pawar S, Barik SR, Mohanty SP, Meher J, Pradhan SK. Marker-assisted backcross breeding for improvement of submergence tolerance and grain yield in the popular rice variety 'Maudamani'. Agronomy. 2021;11(7):1263.
3. Samal R, Roy P, Sahoo A, Kar MK, Patra BC, Marndi BC, Gundimeda JNR. Morphological and molecular dissection of wild races from eastern India suggests distinct speciation between O. rufipogon and O. nivara populations. Scientific Reports. 2018;8(1):2773.
4. Singh N, Choudhury DR, Singh AK, Kumar S, Srinivasan K, Tyagi RK, Singh NK, Singh R. Comparison of SSR and SNP markers in estimation of genetic diversity and population structure of Indian rice varieties. PloS one. 2013;8(12):84136.
5. Chauhan BS, Abugho SB. Effects of water regime, nitrogen fertilization, and rice plant density on growth and reproduction of lowland weed Echinochloa crusgalli. Crop Protection. 2013;54: 142-147.
6. Mahender A, Anandan A, Pradhan SK. Early seedling vigour, an imperative trait for direct-seeded rice: an overview on physio-morphological parameters and molecular markers. Planta. 2015;241: 1027-1050.
7. Finch-Savage WE, Bassel GW. Seed vigour and crop establishment: extending performance beyond adaptation. Journal of Experimental Botany. 2016;67(3):567-591.
8. Bashir K, Xie L, Javeed H. Correlation studies for early seedling vigour traits in rice and their implications for breeding programs. Plant Breeding. 2015;134(6): 681-688.
9. Garson GD. Path analysis. Asheboro, NC: Statistical Associates Publishing; 2013.
10. Zhang ZH, Yu SB, Yu T, Huang Z, Zhu YG. Mapping quantitative trait loci (QTLs) for seedling-vigour using recombinant inbred lines of rice (*Oryza sativa* L.). Field Crops Research. 2005; 91(2-3):161-70.
11. Singh RK and Chaudhary BD. Biometrical methods in quantitative genetic analysis. Kalyani Publishers: New Delhi; 1995.
12. Dewey DR and Lu K. A correlation and path-coefficient analysis of components of

crested wheatgrass seed production 1. Agronomy journal. 1959;51(9):515-8.

13. Bharamappanavara M, Madhyavenkatapura AS, Appaiah MC, Patil BS, Vijjeswarapu A, Senguttuvel P, Madhav MS, Rathod S, Mondal TK, Ramappa L, Mathada UR. Genetic analysis of early seedling vigour in Oryza glaberrima accessions under laboratory and direct-seeded rice conditions. Cereal Research Communications. 2023;51(4): 991-1002.
14. Cui K, Peng S, Xing Y, Xu C, Yu S, Zhang Q. Molecular dissection of seedling-vigour and associated physiological traits in rice. Theoretical and Applied genetics. 2002; 105:745-53.
15. Bordoloi D, Sarma. Aerobic versus anaerobic germination performance of selected rice (*Oryza sativa* L.) genotypes with or without submergence tolerance. Journal of Experimental Biology and Agricultural Sciences. 2018;6(6):947-958.
16. Nusrat Jan and Subhash C Kashyap. Correlation and path analysis in rice (*Oryza sativa* L.) for seed and seed vigour traits. J Pharmacogn Phytochem 2019;8 (1):222-226.
17. Barik J, Kumar V, Lenka SK, Panda D. Genetic potentiality of lowland indigenous indica rice (*Oryza sativa* L.) landraces to anaerobic germination potential. Plant Physiology Reports. 2019; 24: 249-61.
18. Prasad GS, Sujatha M, Rao LVS, Chaitanya U, Patroti P. Character association and path analysis in rice (*Oryza sativa* L.) genotypes for cold tolerance. Helix. 2013;3:349-352.
19. Patil R, Diwan JR, Boranayaka MB, Dikshit S. Correlation and path coefficient analysis for seed and seedling characters for yield in rice (*Oryza sativa* L.). Research Journal of Agricultural Sciences. 2014;5(5):1064-1066.
20. Katiyar D, Srivastava KK, Prakash S, Kumar M, Gupta M. Study correlation coefficients and path analysis for yield and its component characters in rice (*Oryza sativa* L.). Journal of Pharmacognosy and Phytochemistry. 2019;8(1):1783-1787.
21. Sadhana P, Raju CD, Bhargava K, Rao LV, Kuna A. Studies on variability, correlation and path analysis for seedling vigour traits in rice (*Oryza sativa* L.). International Journal of Environment and Climate Change. 2022;12(10):121-130.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.ikprress.org/review-history/12307