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GENETIC VARIABILITY AND CORRELATION ANALYSIS AMONG GRAIN YIELD AND EARLY SEEDLING VIGOUR IN RICE

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Abstract

In the present study, 42 rice genotypes were evaluated for genetic variability, heritability, and trait associations for 13 traits to enhance resilience in direct-seeded conditions. Significant variation (ANOVA) was observed, with the widest range in seedling vigour index-I (1533.1-3708.8) and the narrowest in root-to-shoot ratio (1.13-2.55). High genotypic (GCV) and phenotypic (PCV) coefficients of variation, along with high heritability and genetic advance, were recorded for seedling vigour index-II (GCV: 25.06; PCV: 25.87), grain yield/plant (24.59; 25.39), germination index, seedling dry weight, shoot length, and root-to-shoot ratio, indicating strong genetic control and potential for phenotypic selection. Seedling vigour index-II (SVI-II) showed strong positive correlations with shoot dry weight (0.97**), shoot fresh weight (0.87**), and shoot height (0.95**), suggesting indirect selection of these traits could improve early vigour and yield in direct-seeded rice. The findings highlight traits with high heritability and genetic potential for breeding resilient genotypes.

Introduction

Rice (*Oryza sativa* L.) is the staple food for over half of the global population, especially in Asia, rice accounts for 90% of its production and consumption. Global rice cultivation spans over 165.25 million hectares, with India alone contributing around 46.28 million hectares. Despite world's rice productivity averaging 4.76 tons per hectare (Anonymous 2022-23), there is considerable regional variability, underscoring the need for ongoing research to improve yields, and ensure sustainability in the face of climate change. Traditional transplanting method of rice production is increasingly shifting towards direct seeding due to its lower costs and earlier maturity. However, direct seeding faces challenges like poor germination and seedling establishment. Thus, the present research focuses on identifying rice cultivars possessing high early seedling vigour.

Early seedling vigour is critical in direct-seeded rice systems as vigorous seedlings can outcompete weeds, better withstand stress, and establish more resilient root systems, leading to improved nutrient uptake and growth. Studying these traits helps identify genotypes with superior early growth performance, which is essential for improving overall productivity, ensuring stable yields.

The selection process is most effective when there is ample amount of variability in the base material. Hence, assessing variability and heritability is essential for effective artificial selection and understanding the variation in the breeding material (Roy and Shil 2020). The selection process is most effective when there is sufficient variability in the base material, making it important to evaluate the base material using genetic parameters such as range, phenotypic coefficient of variation (PCV), and genotypic coefficient of variation (GCV) (Debsharma *et al.* 2022, Saha *et al.* 2019). Despite variability, the efficiency of selection depends on heritability and selection intensity (Dudley and Moll 1969). Broad sense heritability estimates, combined with

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genetic advance as a percent of mean (GAM), offer insight into the heritable portion of traits, where high heritability coupled with high GAM suggests additive gene action and the potential for effective selection (Nwangburuka *et al.* 2012). Furthermore, understanding the association between early seedling vigour traits and grain yield is essential to improve rice production in direct-seeded environments. Selection based on yield-related traits is more effective (Grafius 1956), and a correlation study provides valuable insights into the relationships between grain yield and contributing traits. This study focuses on understanding variability, heritability, and association of early seedling vigour related with grain yield to support breeding programs aimed at developing rice varieties resilient to direct seeded conditions.

Material and Methods

The experimental material consisted of 42 rice genotypes, which were evaluated for early seedling vigour related traits at the Department of Genetics and Plant Breeding, Sri Venkateswara Agricultural College, ANGRAU, Andhra Pradesh, during 2020-21 to estimate the genetic parameters and association between traits considered in the study. The evaluation was conducted using the paper towel method, as per ISTA guidelines (2015), following a completely randomized experimental design. Observations were recorded on representative sample taken from randomly selected five plants in each replication for each entry. Observations were recorded on the First count of germination (%), Final count of germination (%), Shoot length (cm), Root length (cm), Seedling height (cm), Seedling fresh weight (mg), Seedling dry weight (mg) from ten randomly selected seedlings from each genotype in each replication for each entry. The Rate of germination (Ramadevi 1998), Germination index (Wang *et al.* 2010), and Seedling vigour indices (SVI-I and SVI-II) (Abdul-Baki and Anderson 1973) were calculated following standard procedures. Data on grain yield plant^{-1} was collected from field experiment laid at Wetland farm, Sri Venkateswara Agricultural College, ANGRAU, Andhra Pradesh, *Kharif* 2020-21 by following Randomized block design with three replications. The mean values of the data from these genotypes were subjected to analysis of variance (ANOVA) using variability package (Popat *et al.* 2020) in R-studio Rx643.6.2 and ANOVA was tested for significance. Genotypic and phenotypic variances were determined according to Singh and Chaudhary (1985) using MS-Excel programme. The genotypic coefficient of variation and phenotypic coefficient of variation were computed according to Burton and De vane (1953). Heritability Broad Sense (h^2_{bs}) was computed for each character as the ratio of genotypic variance to the total variance as suggested by Hanson *et al.* (1956). Genetic advance and genetic advance as percent of mean were estimated according to Johnson *et al.* (1955).

Karl Pearson's simple correlation coefficients for all the thirteen characters were estimated at phenotypic level and the heatmap of the correlation was made using function corrplot in R-studio Rx643.6.2. This heat map representation helps in visualizing data usilour variations. The colour intensity of the box indicates how strongly they are associated. The colour itself indicates the nature of the relationship positive or negative.

Results and Discussion

The analysis of variance for grain yield and early seedling vigour related traits among the 42 genotypes is presented in Table 1 and 2. The mean sum of squares due to genotypes was found to be significant for all the thirteen traits, indicating significant variation existed among the inbred lines chosen for the study. Variability among genotypes was measured for all 13 characters using range, mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability and genetic advance over mean. Results are displayed in Table 3.

Significant variability existed for all the traits, which is essential in any breeding programme Seedling vigour index-I showed the widest range (1533.1-3708.8), while root to shoot ratio had the narrowest (1.13-2.55) (Tiwari *et al*. 2019, Sudeepthi *et al*. 2020). All traits exhibited higher PCV than GCV, but the marginal difference indicates minimal environmental influence. Consequently, phenotypic selections for these traits will be readily expressed in the next generation.

Table 1. Analysis of variance for twelve early seedling vigour traits in rice (*Oryza sativa* L.).

Traits	df	FIRC	FINC	ROG	SOG	SFW	SDW	SL	RL	SH	RS	SVI-I	SVI-II
Genotypes	41	157.51**	102.01**	0.0018**	149.34**	353.00**	7.89**	11.87**	27.311**	55.53**	0.397**	650578.91**	83556.00**
Error	84	2.99	3.36	0.00016	1.33	6.68	0.18	0.25	0.25	0.16	0.01	3228.8	1757.00

**- Significant at 1% level of probability.

Table 2. Analysis of variance Grain Yield in rice (*Oryza sativa* L.).

Traits	df	YP
Replications	2	0.2
Genotypes	41	137.02**
Error	82	2.97

**-Significant at 1% level of probability.

Table 3. Genetic parameters with respect to yield and early seedling vigour related traits in rice (*Oryza sativa* L.) genotypes.

Sl. No.	Characters	Mean	Range	Variance		Coefficient of variation		Heritability (Broad sense) (%)	Genetic advance (%)	GA as percent of mean (%)
				Genotypic	Phenotypic	Genotypic (%)	Phenotypic (%)			
1	FIRC	87.55	74.33 - 98.33	54.15	57.29	8.4	8.64	94.51	14.37	16.42
2	FINC	91.07	78.33 - 99	34.57	38.11	6.46	6.77	90.72	11.25	12.35
3	ROG	96.03	89.77 - 100	5.38	7.103	2.42	2.78	75.8	0.04	4.33
4	SOG	33.13	21.55 - 48.33	49.32	50.68	21.19	21.48	97.33	14.27	43.08
5	SFW	65.22	48.34 - 92.58	121.35	128.37	16.89	17.37	94.53	21.52	33
6	SDW	7.38	5.34 - 11.9	2.7	2.89	22.26	23.03	93.44	3.19	43.24
7	SL	9.70	7.02 - 14.94	4.08	4.33	20.82	21.45	94.05	3.93	40.54
8	RL	16.49	11.06 - 23.31	9.49	9.74	18.68	18.92	97.4	6.11	37.03
9	SH	26.20	18.77 - 37.63	19.41	19.57	16.81	16.88	99.18	8.82	33.65
10	RS	1.74	1.13 - 2.55	0.13	0.15	21.08	22.64	90.71	0.7	40.29
11	SVI-I	2393.7	1533.1 - 3708.8	226897	230148	19.74	19.98	98.59	950.24	39.7
12	SVI-II	675.29	455.57 - 1165.8	28656	30528	25.06	25.87	93.87	329.52	48.8
13	YP	27.87	14.79 - 43.23	46.97	50.09	24.59	25.39	93.77	13.33	47.84

FIRC: First count of germination, FINC: Final count of germination, ROG: Rate of germination, SOG: Germination index, SFW: seedling fresh weight, SDW: Seedling dry weight, SL: Shoot length, RL: Root length, SH: Seedling height, RS: Root to shoot ratio, SVI-I: Seedling vigour index-I, SVI-II: Seedling vigour index-II and YP: Grain yield plant^{-1}.

The highest estimates of GCV and PCV (>20%) was registered for seedling vigour index-II (25.06, 25.87), grain yield plant^{-1} (24.59, 25.39), germination index (21.19, 21.48), root to shoot ratio (21.08, 22.64) and shoot length (20.82, 21.45) indicating strong genetic control and high selection potential (Table 3). Therefore, simple selection could be effective for further improvement of these traits. Whereas moderate GCV and PCV (10-20%) were observed for, seedling vigour index I (19.74, 19.98), root length (18.68, 18.92), seedling fresh weight (16.89, 17.37) and seedling height (16.81, 16.88). Low estimates of GCV and PCV were recorded for first count of germination (8.4, 8.64), final count of germination (6.46, 6.77) and rate of germination (2.42, 2.78). The moderate-to-high variability for most traits indicates significant selection opportunities, aligning with Barik *et al.* (2019) who reported similar potential for improving grain yield and seedling vigour.

Despite high genotypic (GCV) and phenotypic (PCV) variability, effective selection depends on the heritable portion of a trait, identified through broad-sense heritability and genetic advance over mean (GAM) (Rao and Rao, 2015). High heritability coupled with high GAM indicates a positive response to phenotypic selection (Antony *et al.* 2024). All thirteen traits exhibited high heritability (>0.60), with seedling height highest (0.99) followed by seedling vigour index-I (0.98) (Mishra *et al.* 2019). This confirms minimal environmental influence on these traits. Further, results of GAM revealed high values (>20%) for seedling vigour index-II followed by grain yield plant^{-1}, seedling dry weight, germination index, shoot length, root to shoot ratio, seedling vigour index-I, root length, seedling height and seedling fresh weight. These findings align with Sudeepthi *et al.* (2020) for most traits. First and final count of germination showed moderate GAM (10-20%). It also indicates that high heritability is not always associated with high GAM, as heritability does not always lead to high genetic gain. On Contrary, rate of germination recorded low GAM (<10%). Therefore, both heritability and GAM should be considered together to predict selection response (Tiwari et al. 2019).

Seedling vigour index-II followed by seedling dry weight, germination index, shoot length, root to shoot ratio, seedling vigour index-I, root length, seedling height and seedling fresh weight exhibited high broad-sense heritability along with high GAM (Chaitanya *et al.* 2018), as a result, phenotypic performance-based selection for these traits would be more successful. Therefore, traits that recorded higher estimates of genetic advance as per cent of the mean are to be given priority while deciding the selection strategies.

In the present study, high GCV and PCV coupled with high heritability and high genetic advance as per cent of mean was observed for germination index, seedling dry weight, shoot length, root to shoot ratio, seedling vigour index –II and grain yield plant^{-1} reflecting the predominance of additive gene effects, which enables trait improvement through selective breeding.

The information about the direction and magnitude of association of various quantitative traits helps in indirect selection for grain yield in the breeding programme, as the direct selection of a complex trait like grain yield is ineffective due to the influence of many genes and the environment (Grafius 1956). The early seedling vigour traits which show a strong association with grain yield and had high heritability could be used for indirect selection to improve grain yield under direct seeded conditions. The heat map representation of correlation coefficient among the thirteen traits including grain yield and early seedling vigour related traits displayed in Fig. 1, where the intensity of blue and red colour depicts the magnitude of negative and positive correlation among the traits, respectively. A perusal of these results revealed positive and significant association of seedling vigour index-II with all the traits included in the study expect root to shoot ratio. SVI-II also exhibited moderate positive correlation with Yield per Plant (YP) (0.32**) (Sudeepthi *et al.* 2020), suggesting that higher seedling vigour is associated with improved grain yield. The results of inter-correlation among early seedling vigour related traits showed a strong inter-correlation among the characters *viz*., first and final count of germination, rate of germination, seedling height, seedling vigour index-I and seedling vigour index-II correlated indicating a scope for simultaneous improvement of these traits through selection. Germination index showed positive correlation with all the traits except shoot length, where it was negatively correlated (Sudeepthi *et al*. 2020).

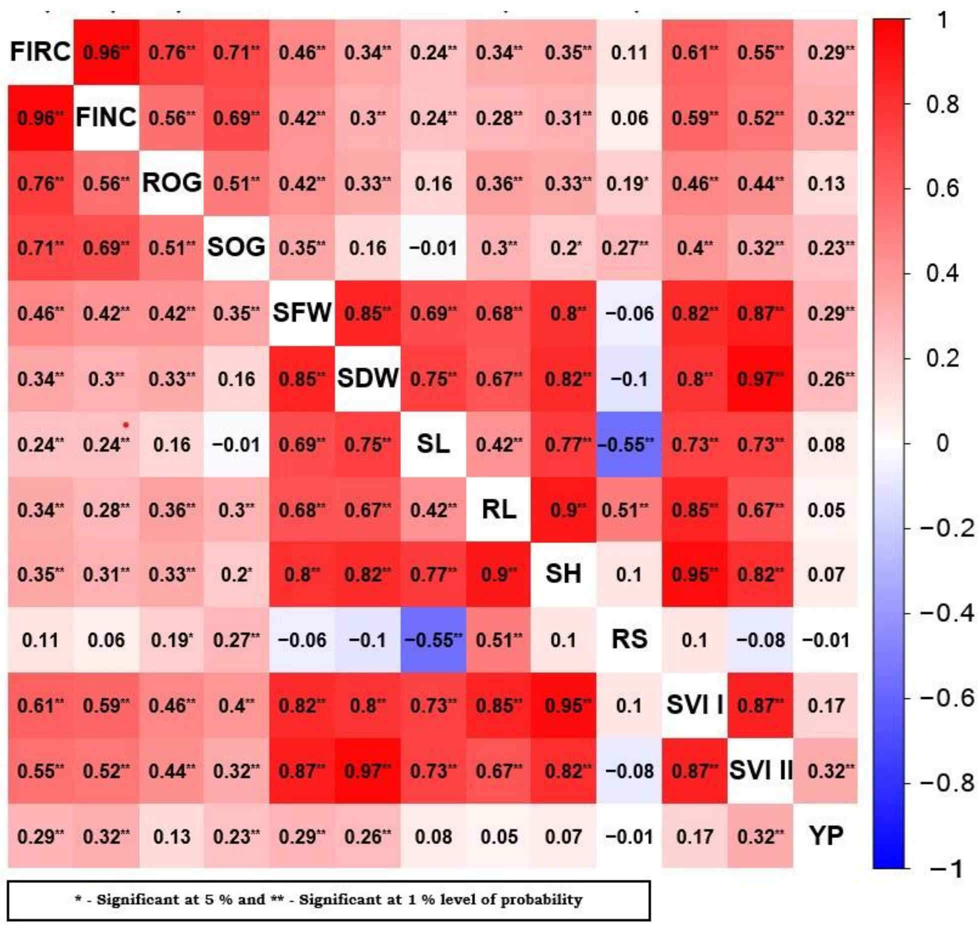

Fig. 1. Correlation of yield and early seedling vigour traits in rice.

FIRC: First count of germination, FINC: Final count of germination, ROG: Rate of germination, SOG: Germination index, SFW: seedling fresh weight, SDW: Seedling dry weight, SL: Shoot length, RL: Root length, SH: Seedling height, RS: Root to shoot ratio, SVI-I: Seedling vigour index-I, SVI-II: Seedling vigour index-II and YP: Grain yield plant^{-1}.

Based on these associations, it is evident that selecting genotypes with higher seedling dry weight, higher seedling vigour index-II, greater germination at both initial and final counts, higher seedling fresh weight, and a higher germination index, along with medium shoot and root length, moderate seedling height, and a balanced seedling vigour index-I, will contribute significantly to increased yield per plant. Together, these traits ensure vigorous early seedling establishment, critical to maximizing plant growth and productivity in direct-seeded systems.

This study concludes that significant genetic variability exists for yield and early seedling vigour traits. High heritability and genetic advance indicate phenotypic selection will be effective for seedling vigour indices, grain yield, and associated traits. Critically, seedling vigour index-II's strong positive correlation with grain yield demonstrates that improving these seedling traits directly enhances productivity under direct-seeded rice systems.

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