

Genetic Analysis of Key Traits for Sheath Blight Resistance and Yield Improvement in Rice (*Oryza sativa*)

ABSTRACT

Rice (*Oryza sativa*) is a staple crop for more than half of the global population, with significant production in India. However, rice production suffers yield losses of 25-30% due to diseases, particularly sheath blight (ShB), caused by *Rhizoctonia solani*. This study evaluated genetic variability, heritability, and genetic advance in ShB resistance and yield-related traits in 360 recombinant inbred lines (RILs) across two seasons at ICAR-IIRR, Hyderabad. Traits such as plant height, lesion height, relative lesion height, and panicle number showed high heritability and genetic advance, indicating their strong genetic influence and responsiveness to selection. These traits, especially relative lesion height, were identified as key indicators for breeding ShB resistance. In contrast, grain yield under inoculated conditions showed lower heritability, reflecting environmental effects and suggesting that indirect selection through stable, heritable traits may be more effective. This research offers a foundation for breeding high-yielding, disease-resistant rice cultivars, advancing sustainability in ShB-prone regions.

Key words: Rice, sheath blight, genetic variability, heritability, genetic advance.

1. INTRODUCTION

Rice (*Oryza sativa*) is one of the most important staple foods for more than half of world's population and an important integral part of Indian dietary. Cultivated rice belongs to the family Poaceae and about 20 species of the genus *Oryza* are recognized. Due to its adaptability and high demand, rice cultivation has expanded across various regions worldwide. In India, rice is primarily cultivated in the eastern and southern regions, covering approximately 45.15 million hectares, with an estimated annual production of 123.81 million tons (www.Indiastat.com, 2023-24) [1]. To meet the demands of a growing population, it is projected that rice production must increase by at least 40% by 2030 [2].

In India, rice production faces significant challenges due to diseases, resulting in an annual yield loss of approximately 25-30% [3]. Among these diseases, sheath blight (ShB), caused by the necrotrophic pathogen *Rhizoctonia solani* (Teleomorph: *Thanatephorus cucumeris*), is one of the most destructive threats to paddy [4]. This disease, also known as "Oriental sheath and leaf blight," occurs widely across India, with the severity of yield loss depending on the extent and progression of the infection. The *R. solani* anastomosis group AG1 IA is a primary causal agent of rice sheath blight. In severe cases, particularly when the infection reaches the plant's upper portions and panicles, yield losses from sheath blight can range from 30 to 40% [5]. Given the economic impact of this disease and the need for comprehensive studies on genetic variability in rice to support the development of an effective resistance breeding program, the present study was undertaken.

Understanding genetic variability in rice is essential for designing effective breeding programs aimed at enhancing resistance to sheath blight and other traits. The variability among genotypes, often evaluated through coefficients of variation, reveals the potential range of improvement within specific traits [6]. In addition to variability, insights into heritability and genetic advance provide a clearer picture of how consistently a trait can be passed on to progeny. Heritability, especially when paired with genetic

advance, offers more reliable predictions of selection gains than heritability alone. Estimates of genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, and genetic advance are invaluable tools for guiding future research on rice improvement [7]. Heritability is particularly critical for breeders, as it indicates how well a genotype's phenotype reflects its genetic potential, while genetic advance helps in applying effective selection pressure to achieve desired improvements.

2. MATERIAL AND METHODS

A total of 360 recombinant inbred lines (RILs) and five checks were evaluated during the dry season (DS) of 2022-23 and the wet season (WS) of 2023 at ICAR-IIRR, Hyderabad. The RILs were sown on raised beds and transplanted to the main field 27 days after sowing, with a spacing of 20 x 15 cm, using an augmented randomized complete block design (ARCB). RILs were planted only once while the checks were replicated in all five blocks. All recommended package of practices were followed to ensure optimal crop establishment. RILs were evaluated and observations were recorded on random three plants in each line for sheath blight disease and yield traits viz., days to 50% flowering (DFF), plant height (PH) (cm), lesion height (LH), relative lesion height (RLH), standard evaluation score (SES), tiller number (TN), panicle number (PN), panicle length (PL), grain yield un-inoculated (GY_u), grain yield inoculated (GY_i) and relative yield loss (RYL). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated according to the method elucidated by Burton, 1952 [8] and the estimates for variability were treated as per the categorization proposed by Sivasubramanian and Madhavamenon, 1973 [9]. Broad sense heritability (h²) and genetic advance mean (GAM) were calculated based on the approaches of Lush, 1940 [10] and Johnson *et al.*, 1955 [11].

The RILs were evaluated for sheath blight resistance using the standard Typha inoculation method, as described by Baktavatsalam *et al.*, 1978 [12]. Inoculation was carried out at the maximum tillering stage (40 days after transplanting). Disease severity was scored based on the relative lesion height (RLH) metric, following the International Rice Research Institute (IRRI) Standard Evaluation System (SES) for rice (2002) [13]. The RLH was calculated using the following formula:

$$RLH (\%) = \frac{\text{Lesionheight}}{\text{Plantheight}} \times 100$$

A standardized rice sheath blight grading chart, ranging from 0 to 9, was used to record the severity of symptoms based on lesion height and overall disease reaction: 0 indicates no symptoms (immune), 1 indicates 20% symptoms (resistant), 3 indicates 21-30% symptoms (moderately resistant), 5 indicates 31-45% symptoms (moderately susceptible), 7 indicates 46-65% symptoms (susceptible) and 9 indicates 66-100% symptomatic area or collapsed plants (highly susceptible).

3. RESULTS AND DISCUSSION

In the pursuit of enhancing rice productivity and disease resistance, particularly against sheath blight, understanding genetic variability is crucial for informed breeding strategies. Key genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) measure the extent of genetic and environmental influence on trait expression, respectively. High heritability combined with substantial genetic advance as a percentage of the mean (GAM) further highlights traits that are predominantly controlled by genetic factors and are responsive to selection [14]. These parameters collectively aid breeders in identifying traits that can reliably contribute to yield improvement and disease resilience, establishing a strong foundation for effective breeding programs focused on sustainable rice production.

In the present study, traits evaluated during the dry season demonstrated varying degrees of heritability and genetic advance, providing insights into their potential for selection. For instance, days to 50% flowering had high heritability (100%) with a moderate genetic advance (11.64%), suggesting that while this trait is highly heritable, gains through selection might be more modest, aligning with the findings of Paikomba *et al.*, 2014 [15]. Traits such as lesion height and plant height exhibited high heritability (86.43% and 92.74%, respectively) with substantial genetic advance (34.51% and 35.13%), indicating

that these traits are influenced by genetic factors and can be effectively improved through selection. This observation is consistent with the results reported by Prasad *et al.*, 2017 [16] for plant height. Relative lesion height, a critical indicator of sheath blight severity, also showed high heritability (90.57%) and high genetic advance (39.67%), suggesting that genetic improvements in resistance to sheath blight could be achieved. Traits with moderate heritability, such as the standard evaluation score, reflected some environmental influence, which could make direct selection for these traits slightly more challenging.

In the wet season, high heritability was observed for traits such as plant height (96.5%) and panicle length (97.01%). The genetic advance for these traits was also substantial, suggesting these are stable traits less influenced by environmental variability. These findings are in agreement with Tushara *et al.*, 2013 [17]. Relative lesion height demonstrated high GCV, PCV, heritability (84.21%), and genetic advance (42.16%), supporting its suitability as a selection criterion in breeding programs targeting sheath blight resistance. In contrast, grain yield un-inoculated and grain yield inoculated had lower heritability values, indicating a significant environmental influence. This lower heritability suggests that while yield is an important trait, direct selection based on observed yield alone may be less effective unless environmental conditions are controlled or optimized. The mean values and genetic parameters are presented in Table 1.

High heritability coupled with high genetic advance in traits like plant height, lesion height, relative lesion height, and panicle number across both seasons suggests that these traits could be prioritized in breeding programs aimed at improving resistance to sheath blight while also potentially enhancing yield. High genetic advance in these traits implies that gains through selection are feasible, which is especially relevant for disease resistance traits. The extremely high variability observed in relative yield loss, suggests substantial environmental and genetic interaction effects on yield loss due to sheath blight, underlining the complexity of this trait. Thus, indirect selection using more stable, high-heritability traits related to sheath blight resistance, such as relative lesion height and lesion height, may prove to be a more effective approach for managing yield stability under disease pressure.

Table1. Mean, variability, heritability and genetic advance as per cent of mean for yield and sheath blight disease traits in 360 RILs developed from ISM/Phougak

S. No.	Character	Mean	GCV%	PCV%	ECV%	Heritability (Broad Sense)	Genetic Advance as % of Mean at 5% level
1	DFFd	121.54	5.64	5.64	0.00	100.00	11.64
2	LHd	55.41	17.99	19.36	7.13	86.43	34.51
3	PHd	86.75	17.68	18.36	4.95	92.74	35.13
4	RLHd	72.51	20.20	21.23	6.52	90.57	39.67
5	SESd	8.18	9.69	12.98	8.64	55.71	14.92
6	TNd	13.18	19.02	22.81	12.60	69.49	32.70
7	PNd	11.63	21.98	23.23	7.52	89.52	42.90
8	PLd	20.50	11.94	12.70	4.32	88.41	23.16
9	Gyd	16.37	16.21	33.39	29.19	23.58	16.24
10	DFFw	97.41	6.78	6.78	0.00	100.00	13.98
11	LHw	62.94	15.75	16.96	6.28	86.31	30.19
12	PHw	146.73	15.37	15.65	2.93	96.50	31.15
13	RLHw	49.03	22.27	24.27	9.64	84.21	42.16
14	SESw	6.25	19.75	22.76	11.31	75.29	35.35
15	TNw	9.64	18.79	22.84	12.97	67.72	31.90
16	PNw	8.60	15.31	21.15	14.59	52.39	22.86
17	PLw	22.42	13.56	13.76	2.38	97.01	27.54
18	Gyw	10.05	32.07	54.04	43.49	35.22	39.26
19	GYw	4.59		76.22	79.80		
20	RYLw	0.26	6428.26	8602.37	5716.48	55.84	9909.87

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environment coefficient of variation, DFF-Days to 50% flowering, LH-Lesion height (cm), PH-Plant height (cm), RLH-

Relative Lesion Height (%), SES-Standard Evaluation Score, TN- Tiller number, PN- Panicle number, PL- Panicle length (cm), GYu- Grain yield under un-inoculated conditions (g), GYi- Grain yield under inoculated conditions (g), RYL-Relative Yield Loss (%), d-dry season and w-wet season.

4. CONCLUSION

This study underscores the potential of genetic variability as a foundation for enhancing sheath blight resistance and yield-related traits in rice. The observed high heritability and genetic advance in key traits such as lesion height, relative lesion height, plant height, and panicle number across both dry and wet seasons highlight their genetic stability and responsiveness to selection, making them prime candidates for breeding programs. Traits with moderate to low heritability, such as grain yield under inoculated conditions, suggest that yield improvement may benefit from indirect selection through associated stable traits with higher heritability. The substantial genetic advance in sheath blight-related traits, particularly lesion and relative lesion height, affirms the feasibility of improving disease resistance, which is crucial for sustaining productivity. Ultimately, this research provides a pathway for developing rice cultivars with enhanced disease resilience and stable yields, contributing to long-term sustainability in rice production systems, especially in disease-prone areas.

COMPETING INTERESTS

Authors have declared that no competing interests exist

REFERENCES

1. www.Indiastat.com, 2023-24.
2. Ashkani S, Rafii MY, Shabanimofrad M, Azadi A, Ghasemzadeh A, Azizi P. Allele mining strategies: principles and utilisation for blast resistance genes in rice (*Oryza sativa* L.). *Current Issues in Molecular Biology*. 2015;17(1):57-74.
3. Jha, AK, Singh, KM, Meena MS, Singh, RKP. Constraints of rainfed rice production in eastern India: An Overview. *SSRN Electronic Journal*. 2012;1-9.
4. Bhaktavatsalam G, Satyanarayana K, Reddy APK, John VT. Evaluation of sheath blight resistance in rice. *International Rice Research Notes*. 1978;3:9-10.
5. Burton GW. Quantitative inheritance in grasses. In: *Proceedings of the 6th International Grassland Congress*, Pennsylvania State College, USA. 1952;277-283.
6. Dey S, Badri J, Prakasam V, Bhadana VP, Eswari KB, Laha GS, Priyanka C, Rajkumar A, Ram T. Identification and agro-morphological characterization of rice genotypes resistant to sheath blight. *Australasian Plant Pathology*. 2016;45:145-153.
7. IRRI. Standard evaluation system for rice. International Rice Research Institute, Los Baños, Manila; 2002.
8. Jha AK, Singh KM, Meena MS, Singh RKP. Constraints of rainfed rice production in eastern India: An overview. *SSRN Electronic Journal*. 2012;1-9.
9. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybean. *Agronomy Journal*. 1955;47:314-318.
10. Khan MAR, Mahmud A, Islam MN, Ghosh UK, Hossain MS. Genetic variability and agronomic performances of rice genotypes in different growing seasons in Bangladesh. *Journal of Agriculture and Food Research*. 2023;14:100750.
11. Lush JL. Intra-sire correlation and regression of offspring on dams as a method of estimating heritability of characters. *Proceedings of the American Society of Animal Production*. 1940;33:293-301.
12. Paikhomba N, Arvind K, Chaurasia AK, Rai PK. Assessment of genetic parameters for yield and yield components in hybrid rice and parents. *Journal of Rice Research*. 2014;2:1-3.
13. Patel RRS, Sharma D, Das BK, Mondal S, Sahu PK, Vishwakarma G, Kumar V, Sao R, Khute IK. Study of coefficient of variation (GCV & PCV), heritability and genetic advance in advanced

- generation mutant line of rice (*Oryza sativa* L.). *The Pharma Innovation Journal*. 2021;SP-10(10):784-787.
14. Prasad RS, Suresh Babu B, Ram J, Rai PK. Evaluation of early mature elite rice (*Oryza sativa* L.) hybrids for yield and quality traits. *Journal of Pharmacognosy and Phytochemistry*. 2017;6(4):18-21.
 15. Sivasubramanian J, Madhavamenon. Genotypic and phenotypic variability in rice. *Madras Agricultural Journal*. 1973;12:15-16.
 16. Srinivas P, VedRatan, Reddy PN, Madhavi BG. In vitro evaluation of fungicides, biocontrol agents and plant extracts against rice sheath blight pathogen *Rhizoctonia solani*. *International Journal of Applied Biology and Pharmaceutical Technology*. 2013;5(1):121-126.
 17. Tushara M, Rao VS, Ahamed ML, Veni BK, Rao KL. Correlation of quantitative and qualitative characters with yield in medium and long-duration genotypes of rice. *The Andhra Agricultural Journal*. 2013;60(1):29-35.

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