Original Research Article

Exploring the Correlation between Morpho-Physiological Traits and Growth Attributes associated with Yield Characteristics in Rice (*Oryza sativa* L.)

ABSTRACT

This study aimed to identify the morpho-physiological and growth attributes, and yield associated with yield in rice genotypes. The experiment included 120 rice genotypes and 3 checks, conducted in an alpha lattice design with two replications at the Research Cum Instructional Farm in the Department of Plant Physiology, Indira Gandhi Krishi Vishawavidyalaya, Raipur, Chhattisgarh, during the two consecutive *Kharif* seasons of 2021-22 and 2022-23. Conventional spacing of 15 x 20 cm and recommended cultural practices were employed. The objective is to improve the overall efficiency and productivity of rice cultivation to meet the needs of a growing population. It is crucial to emphasize the comprehension and enhancement of the fundamental features associated with canopy structure and growth attributes. Improving these morpho-physiological traits is pivotal for boosting rice yield. By studying and refining the arrangement and growth of the rice plant's leaf canopy, the goal is to enhance the efficiency and productivity of rice cultivation. The results indicated that productive tillers (0.335**) and flag leaf area (0.213*) were positively correlated with higher yields. While leaf angles, specific leaf area, and days to panicle initiation showed negative correlations with yield. The leaf area index at flowering was positively correlated with specific leaf area (0.382***) but negatively with grain yield (-0.199*). Specific leaf weight was positively correlated with yield per hectare (0.178*). Understanding these relationships can guide the selection and breeding of rice genotypes with optimal traits for enhanced grain yield and crop performance.

Keywords: Rice, flag leaf area, leaf angle, specific leaf weight, yield attributes

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a semi-aquatic grass species cultivated globally. The crop is known as "dhanya" in India, where it represents "the subsistence of the human race". Panesar *et al*. (2016). It makes up about 30% of the land used for grain crops and 11% of all arable land on Earth. There is a projected 12% growth in the world's population, according to a recent study. Therefore, to fulfill the growing demand for rice, 500 million metric tonnes more rice must be produced, and productivity must rise by at least 13%. Al-daej *et al*., (2023). Yoshida (1981) states that one can increase rice yield by increasing biomass production, harvest index, or both. However, a growing body of research indicates that achieving higher rice yields mostly relies on biomass accumulation Zhang *et al*., (2009). Biomass production is dependent on leaf physiology and the canopy's capacity to block incident radiation. This capacity is determined by the leaf area index (LAI) and canopy architecture. Ikawa *et al*., (2018). It is well known that incident radiation is related to growth duration, while intercepted percent is dependent on canopy morphological characteristics such as leaf area, angle, and orientation [25-28]. Hirose, (2005) Lake and Sadras (2017). Yield is one of the most important and complex traits in rice. It is both regulated by genes known as quantitative trait loci and influenced by external environmental factors (Wang *et al*., 2012; Zeng *et al*., 2017; Zhang L. *et al*., 2017 Haider *et al*. (2023). The relationship between genotypes and phenotypes is crucial in all genomics-assisted selection methods. While recent advancements in rice genomic research have enabled comprehensive genotyping across the entire genome, phenotyping complex traits like biomass yield continues to pose challenges. This is due to the labor-intensive nature of phenotyping and the complexities involved in field management. Matsubara *et al*. (2016) Biomass yield varied across different environments for all recombinant inbred lines (RILs), the ranking of plant weights among selected RILs remained consistent with their respective genotypes across environments. This stability indicates that certain QTL alleles exert a reliable influence on biomass yield across diverse conditions, suggesting they possess inherent plasticity rather than showing significant genotype-environment interactions. Matsubara *et al*. (2018) In addition to regulating plant architecture, leaf angle one of the agronomic characteristics strongly associated with grain output is also necessary for achieving moderate leaf erectness, which raises rice yield. Wang and Li, (2011). The flag leaf plays a crucial role in grain yield, contributing approximately 45% through its significant involvement in photosynthetic activity and the synthesis of photo-assimilates translocated to the panicle. Mahesh *et al*. (2022). Yield variability was found in erect panicle recombinant inbred lines (EP RILs). It was observed that significant negative correlation between flag leaf length and yield specifically within the EP RILs. Interestingly, this correlation was not evident in the non-erect panicle recombinant lines included in their analysis Makino *et al*. (2021). Leaf erectness increases CO_2 diffusion efficiency and light capture, which raises photosynthetic efficiency. The lamina joint, which joins the leaf blade and leaf sheath in rice, establishes the leaf angle. Sakamoto *et al*., (2006). This requires a deep understanding of the factors influencing rice yield, particularly morpho-physiological traits, and growth attributes which play a crucial role in the plant's resource acquisition, growth efficiency, and grain production.

2. EXPERIMENTAL DETAILS

The experiment uses a two-replication alpha lattice design. The first trial nursery was planted on June 24th, 2021, and seedlings were transplanted in the main field on July 22nd, with each plot measuring 3.30x1.40 m and 140 hills per plot. A conventional spacing of (15 x 20 cm) was used when combined with suggested cultural treatments to produce a healthy, productive stand. The second trial nursery was planted on 24th June 2022, and seedlings were transplanted on 15th July with the same plot size and spacing and harvested based on their respective growth durations. The plants were randomly selected from each genotype. Each selected plant was tagged for identification. The experimental plots were inspected daily, and data were collected regularly. After collecting data on the morpho-physiological, growth parameter, and yield traits data were summarized through arithmetic means.

2.1 Data collection

The data collected were morpho-physiological and growth attributes such as plant height (PH), number of tiller/plant (NT), number of productive tiller/plant (NPT), flag leaf area (FLA), flag leaf angle (FLAn), leaf area index (LAI), leaf weight ratio (LWR), specific leaf weight (SLW), crop growth rate (CGR), net assimilation rate (NAR), spikelet fertility (SF), unfilled spikelet/panicle (UFSP), test weight (TW), yield per hectare (YPH) and harvest index (HI). Phenological characters were also evaluated which are days to panicle initiation, days to 50%

flowering, days to maturity. Plant height is measured in cm from the plant's base to the tip of its primary panicle at flowering and at the time of physiological maturity. The number of tillers that produce spikes and seeds is known as the productive tiller number, and it is often counted when the crop has reached maturity. Uppermost fully expanded leaf on the another tiller was selected for the estimation of flag leaf area at flowering stage. The length and maximum width of flag leaf were recorded at flowering stage. A factor (k) of 0.75 for flowering stage was used to calculate the flag leaf area. It was expressed as cm^2 (Palaniswamy and Gomez's 1972). The leaf angle was measured by marking the tip and collar of each leaf on paper against the main culm, which worked as a vertical line. A line was drawn between the two points, and an angle between the line and the vertical axis was measured with a protractor (Yoshida et al., 1976).

3. RESULTS AND DISCUSSION

3.1 Association between morpho-physiological, growth, and yield attributes of rice genotypes under irrigated condition

The correlation analysis was done between morpho-physiological and growth traits with grain yield. It was observed that productive tiller (0.335**) was strongly and positively correlated with yield per hectare and (0.224*) with harvest index. The flag leaf area had a significant positive correlation with grain yield (0.213*). The leaf angle of the flag leaf showed a highly significant and negative correlation with grain yield (-0.93***, -0.264**, -0.181*) and with harvest index (-0.678***, -0.193**) for flag leaf angle. Leaf area index at the flowering stage was highly significant and positively associated correlation with specific leaf area (0.382***) however it negatively correlated with grain yield (-0.199*). The leaf area ratio was highly significant and negatively correlated with yield per hectare (-0.223*). Specific leaf area recorded a significant and negative association with grain yield (-0.232*). However, the specific leaf weight had a highly significant and positive correlation with yield per hectare (0.178*). Crop growth rate between flowering to grain filling stage was found highly significant and negatively correlated with grain yield per hectare (-0.241**) while a highly significant and positive correlation with NAR (0.601***). (Table 1)

3.2 Association between phenological traits and yield attributes of rice genotypes under irrigated conditions

The association between phenological traits and yield attributes of rice genotypes is shown in (Table 2). Days to panicle initiation were strongly negatively correlated with harvest index (-0.356***) and grain yield per hectare (-0.309***). Similarly, days to 50% flowering were also highly and positively correlated with unfilled spikelets panicle^{-1} (0.327***), and days to physiological maturity were also strongly and positively correlated with grain yield per hectare (0.263***).

3.4 DISCUSSION

The study emphasizes the importance of understanding about plant morphology and canopy structure for optimizing rice yield. Correlation analysis revealed intricate relationship between morpho-physiological traits and yield parameters, providing insights for future crop improvement. Balancing plant architecture, optimizing tiller productivity, and efficient allocating resource are crucial for maximizing rice yield studied at Raipur plains, Chhattisgarh. The present study evaluated the correlation between morpho-physiological, growth, and yield attributes. Mohanan & Pavithran (2007) reported that the optimum number of tillers was more productive in economic yield. They also suggested the new plant type to replace conventional high tillering varieties for high yield. They also emphasized optimizing tillering, which is crucial for increasing yield. Jennings (2003) reported that the angle of the flag leaf was a significant factor in rice grain production. The products of photosynthesis determine the yield of grains, and crops may produce biomass more efficiently if leaves are distributed and arranged optimally. The angle of the flag leaf was a significant factor in rice grain production. The products of photosynthesis determine the yield of grains, and crops may produce biomass more efficiently if leaves are distributed and arranged optimally. An acceptable objective would seem to be increased light penetration into the crop plants structure along with morpho-physiological features that contribute to higher productivity. Huang *et al*. 2021 Mahesh *et al*., (2022) reported that the flag leaf and its penultimate leaves characters mostly contribute to catching high light intensity, directly influencing the grain yield. Although early flowering genotypes have a short period of vegetative growth, the reproductive and grain-filling stages have been reported to be similar for rice (Kropff, Van Laar & Matthews, 1994). An optimal LAI ensures efficient light interception and better grain yield. Mubarak et al. (2021) reported LAI had a strong negative correlation with PAR indicating that the canopy architecture with an improved light interception and utilization through the improved quantum yield efficiencies than the horizontal canopies. Specific leaf weight is an important characteristic in plant physiological processes. Bowes *et al*., (1972) reported that SLW, a measure of leaf thickness, had a high positive connection with leaf photosynthesis in numerous crops. The optimum LAI and maximum assimilation performed maximum crop growth rate. Takai *et al*. (2006) also stated that genotypes having higher CGR during the late reproductive period produced a greater number of spikelets per unit land area. The findings of the research showed that three factors affected grain yield intercepted light, the capacity of the plant to convert it to dry matter, and the partitioning and reallocation of photosynthate to grains.

4. CONCLUSION

The importance of traits such as tiller number, leaf area, and leaf angles in determining yield potential. However, the relationships between these traits and yield can vary significantly across different genotypes and environments. Therefore, elucidating these correlations in specific contexts can provide valuable insights for breeding programs aimed at improving rice yield. This study focuses on correlating morpho-physiological traits, growth patterns, and yield characteristics in various rice genotypes. By identifying the traits that significantly influence yield, we aim to provide a foundation for developing high-yielding rice varieties adapted to specific growing conditions. The findings of this study will contribute to the strategic selection and breeding of rice genotypes with enhanced yield potential and overall crop performance.

Table 1 Correlation analysis of morpho-physiological, growth parameters and yield attributes

	PH	NT	NPT	FLA	FLAn	LAI	LWR	SLW	CGR	NAR	SF	UFSP	TW	YPH	HI
PH	1														
NT	-0.111	1													
NPT	-0.082	0.733***	1												
FLA	0.092	-0.109	-0.017	1											
FLAn	0.015	-0.066	-0.294**	-0.163	1										
LAI	0.284**	0.049	-0.033	-0.268**	0.221*	1									
LWR	0.021	0.023	-0.027	-0.144	0.003	0.03	1								
SLW	0	-0.155	0.055	0.144	-0.349***	-0.23*	0.296**	1							
CGR	-0.026	0.108	-0.046	-0.022	0.311***	0.127	0.059	0.006	1						
NAR	0.008	0.075	0.021	0.008	0.202*	0.168	0.046	0.013	0.606***	1					
SF	-0.071	0.035	0.338***	0.17	-0.82***	-0.191*	0.035	0.395***	-0.244**	-0.181*	1				
UFSP	-0.02	0.035	-0.171	0.108	0.16	-0.022	-0.062	-0.209*	-0.086	-0.039	-0.377***	1			
TW	0.096	-0.007	-0.096	-0.067	-0.076	0.074	-0.027	0.09	0.059	-0.092	-0.046	0.047	1		
YPH	0.028	0.022	**0.335*** **	**0.213* **	**-0.93*** **	**-0.184* **	0.022	**0.454*** **	**-0.266** **	-0.171	**0.857*** **	**-0.289** **	0.064	1	
HI	0.015	0.135	**0.316*** **	**0.192* **	**-0.769*** **	-0.085	0.087	**0.31*** **	-0.128	-0.036	**0.75*** **	**-0.261** **	0.078	**0.803*** **	1

** Significant at 0.05; ** significant at 0.01 level of probability; plant height, NT- number of tiller/plant, NTP- number of productive tiller/plant, FLA- flag leaf area, FLAn- flag leaf angle, 2nd LAn- second leaf angle, 3rd LAn- third leaf angle, TDM flw- total dry matter at flowering, TDM- total dry matter at maturity, LAI- leaf area index, LAR-leaf area ratio, LWR-leaf weight ratio, SLA-specific leaf area, SLW- specific leaf weight, CGR-crop growth rate, NAR-net assimilation rate, SF- spikelet fertility, FSP- filled spikelet/panicle, UFSP-unfilled spikelet/panicle, TW-test weight, YPH-yield per hectare, HI-harvest index.*

Table 2 Correlation analysis between Phenological behavior and yield parameters

	DPI	D50%F	DM	FSP	UFSP	YPH	HI
DPI	1						
D50%F	0.281**	1					
DM	0.225*	0.837***	1				
FSP	0.006	0.044	0.172	1			
UFSP	0.152	0.327***	0.265	0.144	1		
YPH	-0.309***	0.064	0.263**	0.217*	-0.201*	1	
HI	-0.356***	-0.039	0.033	0.243**	-0.164	0.712***	1

* Significant at 0.05; ** significant at 0.01 level of probability *DPI- days to panicle initiation, D50%F- days to 50% flowering, DM- days to maturity, FSP- filled spikelet/panicle, UFSP- unfilled spikelet/panicle, YPH- yield per hectare, HI- harvest index*

Disclaimer (Artificial intelligence)

Option 1:

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.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

REFERENCES

1. Al-daej MI, Rezk AA, El-Malky MM, Shalaby TA, Ismail M. Comparative genetic diversity and marker-trait association using two DNA marker systems in rice (*Oryza sativa* L.). *Agronomy*. 2023;13 (2):329.

2. A.N.M. Mubarak, Musthapha Mufeeth, M.R. Roshana and A.D.N.T. Kumara. (2022) Influence of Canopy Architecture on the Light Interception, Photosynthetic and Biomass Productivity in Irrigated Elite Sri Lankan Rice Varieties The Journal of Agricultural Sciences - Sri Lanka Vol. 17, No 1, January 2022. Pp 148-160.

3. Bowes, G., Ogren, W.L. and Hageman, R.H. (1972), Light Saturation, Photosynthesis Rate, RuDP Carboxylase Activity, and Specific Leaf Weight in Soybeans Grown Under Different Light Intensities. *Crop Science*, 12: 77-79.

4. Guoqiang Huang, Heng Hu, Allison van de Meene, Jiao Zhang, Le Dong, Shuai Zheng, Fengli Zhang, Natalie S. Betts, Wanqi Liang, Malcolm J. Bennett, Staffan Persson, Dabing Zhang. (2021). AUXIN RESPONSE FACTOR 6 and 7 control the flag leaf angle in rice by regulating secondary cell wall biosynthesis of lamina joints. Plant Cell.

5. Haider MZ, Sami A, Shafiq M, Anwar W, Ali S, Ali Q, Muhammad S, Manzoor I, Shahid MA, Ali D and Alarifi S (2023) Genome-wide identification and in-silico expression analysis of carotenoid cleavage oxygenases gene family in Oryza sativa (rice) in response to abiotic stress. Front. Plant Sci. 14:1269995.

6. Hirose, T. (2005). Development of the Monsi-Saeki theory on canopy structure and function. Annals of Botany. 95(3), pp. 483–494.

7. Ikawa H, Chen CP, Sikma M, Yoshimoto M, Sakai H, Tokida T, Usui Y, Nakamura H, Ono K, Maruyama A, Watanabe T, Kuwagata T, Hasegawa T (2018) Increasing canopy photosynthesis in rice can be achieved without a large increase in water use–a model based on free-air CO_2 enrichment. *Glob Chang Biol* 24:1321–1341.

8. Jennings PR (2003). Plant type as a rice breeding objective. Crop Sci. 4:13-15.

9. Kropff, Van Laar & Matthews (1994) Kropff MJ, Van Laar LHH, Matthews RB. ORYZA1: an ecophysiological model for irrigated rice production. Los Baños, Philippines: International Rice Research Institute; 1994.

10. Lake L, Sadras V (2017) Associations between yield, intercepted radiation and radiation-use efficiency in chickpea. *Crop Pasture Sci* 68: 140–147.

11. Mahesh G. Chandra Mohan Y, Saida Naik D. and Narender Reddy S. Study on Flag Leaf and its Penultimate Leaves for their Association with Grain Yield in Rice (*Oryza Sativa L*.) Biological Forum – An International Journal 14(2): 270-274.

12. Matsubara K, Yamamoto E, Kobayashi N,Ishii T, Tanaka J, Tsunematsu H, et al. (2016) Improvement of Rice Biomass Yield through QTL-Based Selection. PLoS ONE 11(3): e0151830.

13. Matsubara K, Yonemaru JI, Kobayashi N, Ishii T, Yamamoto E, Mizobuchi R, Tsunematsu H, Yamamoto T, Kato H, Yano M. A follow-up study for biomass yield QTLs in rice. PLoS One. 2018 Oct 23;13(10):e0206054.

14. Mohanan & Pavithran (2007) Mohanan, K.V. and Pavithran, K. 2007. Chronology of tiller emergence and tiller orientation in rice (*Oryza sativa* L.). *Crop improvement Oryza* 44 (4):307-310.

15. Panesar PS, Kaur S. Rice: types and composition. Encyclopedia of Food and Health, Academic Press. 2016; *Oxford*:646-52.

16. Sakamoto, T., Morinaka, Y., Ohnishi, T., Sunohara, H., Fujioka, S., Ueguchi-Tanaka, M., et al. (2006). Erect leaves caused by brassinosteroid deficiency increase biomass production and grain yield in rice. *Nat. Biotechnol*. 24, 105–109.

17. Takai, Toshiyuki & Matsuura, Shoji & Nishio, Takahiro & Ohsumi, Akihiro & Tatsuhiko, Shiraiwa & Horie, Takeshi. (2006). Rice yield potential is close related to crop growth rate during late reproductive period. Field Crops Research -96. 328-335.

18. Wang, S., Wu, K., Yuan, Q., Liu, X., Liu, Z., Lin, X., et al. Control of grain size, shape, and quality by OsSPL16 in rice. (2012) *Nat. Genet*. 44, 950–954.

19. Wang, Y., and Li, J. (2011). Branching in rice. *Curr. Opin. Plant Biol*. 14, 94–99.

20. Yoshida S (1981) Fundamentals of Rice Crop Science. International Rice Research Institute, Los Banos.

21. Yuki Makino, Yoshihiro Hirooka, Koki Homma, Rintaro Kondo, Tian-Sheng Liu, Liang Tang, Tetsuya Nakazaki, Zheng-Jin Xu & Tatsuhiko Shiraiwa. (2022). Effect of flag leaf length of erect panicle rice on the canopy structure and biomass production after heading, Plant Production Science. 1:10

22. Zeng, D., Tian, Z., Rao, Y., Dong, G., Yang, Y., Huang, L., et al. Rational design of high-yield and superior-quality rice. (2017) *Nat. Plants* 3:17031.

23. Zhang H., Tan G., Yang L., Yang J., Zhang J., Zhao B. (2009). Hormones in the Grains and Roots in Relation to Post-anthesis Development of Inferior and Superior Spikelets in Japonica/ indica Hybrid Rice. *Plant Physiol. Biochem*. 47, 195–204.

24. Zhang, L., Yu, H., Ma, B., Liu, G., Wang, J., Wang, J., et al. A natural tandem array alleviates epigenetic repression of IPA1 and leads to superior yielding rice. (2017). *Nat. Commun*. 8:14789.

25. Preethi , V., V. Ravichandran, V. Babu Rajendra Prasad, K. Iyanar, and R. Karthikeyan. 2023. “Enhancing Morpho-Physiological and Yield Potential of Rice Using Nutrients and Plant Growth Regulators”. International Journal of Plant & Soil Science 35 (19):152-63. https://doi.org/10.9734/ijpss/2023/v35i193537.

26. Govardhani, A., SNCVL Pushpavalli, S. Vanisri, T. Nepolean, and A. Geetha. 2024. “Genetic Variability for Root and Shoot Morpho-Physiological Traits Contributing to Seedling Drought Stress Tolerance in Parental Lines of Pearl Millet”. Journal of Advances in Biology & Biotechnology 27 (6):24-35. https://doi.org/10.9734/jabb/2024/v27i6862.

27. Cirilo AG, Dardanelli J, Balzarini M, Andrade FH, Cantarero M, Luque S, Pedrol HM. Morpho-physiological traits associated with maize crop adaptations to environments differing in nitrogen availability. Field Crops Research. 2009 Aug 3;113(2):116-24

28. Rukmangada MS, Sumathy R, Kruthika HS, Naik VG. Mulberry (Morus spp.) growth analysis by morpho-physiological and biochemical components for crop productivity enhancement. Scientia Horticulturae. 2020 Jan 3;259:108819.