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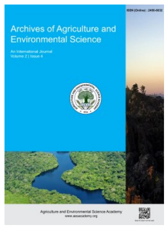

ORIGINAL RESEARCH ARTICLE

Evaluation of yield and agronomic traits of spring rice (*Oryza sativa* L.) genotypes in sub-tropical zone of Sunsari, Nepal

Bijay Mahato*, Anmol Khanal and Bikal Poudel

Nepal Polytechnic Institute (NPI), Purbanchal University (PU), Gothgaun, Morang, Nepal
*Corresponding author's E-mail: mahatobijay558@gmail.com

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ABSTRACT

Rice is a high-value economic crop and a primary food source for a large portion of the global population. Enhancing its potential yield is crucial to meet the growing food demands driven by population increase and changing climatic conditions. This research work was aimed to evaluate the phenological, morphological, and yield-contributing characters of seven genotypes of rice, a check variety (Chaite-5), under the prevailing spring season conditions to choose good genotypes with better productivity for potential cultivation in such agro-climatic regions. The experiment was conducted in spring season during the year 2024 under a randomized complete block design (RCBD) with three replications on the research farm. Phenological, morphological, and yield traits like yield, biomass production, harvest index, grains/spike, and sterility percentage were taken into consideration. Statistical analysis with correlation coefficients was carried out to ascertain the relationship between traits and grain yield. The results revealed significant ($p<0.05$) genetic variability among the genotypes. Among them, IR 17L 1420 was recorded with highest biomass and grain yield, while IR 16L 1619 exhibited the highest harvest index of rice. In contrast, the check variety Chaite-5 demonstrated lower productivity and higher sterility. Correlation analysis showed significant and positive relationships between grain yield and traits such as biomass, harvest index, and grains per spike of rice. These findings suggest that selecting genotypes with high biomass, superior harvest index, and low sterility rates could effectively enhance rice productivity. The study provides valuable insights for rice breeding programs and cultivar improvement under spring-season cultivation conditions.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world, which meets the nutritional requirements of humans in all parts of the world. It is a principal staple food crop that provides food for approximately 60% of the world's population as it is being manufactured seasonally and consumed annually (Sala *et al*., 2025). It is one of the most significant cereal crops and serves as the primary staple food for over half of the world's population (Shrestha *et al*., 2021a; Bastola *et al*., 2024). In Nepal, rice is the leading cereal crop in terms of cultivation area, total production, and consumption. It is considered a cornerstone of the national economy, playing a crucial role in contributing to the country's GDP. As the top crop in both yield and output, rice significantly influences the livelihoods and living standards of a large portion of the population (Tiwari *et al*., 2019). It is cultivated across diverse regions of Nepal, including the high hills (Jumla), mid-hills, and terai, covering approximately 1,473,474 hectares of land with 5,621,710 metric tons (mt) with an average productivity of 4.2 metric tons per hectare (MoALD, 2023).
Rice holds immense importance in Nepal's agricultural sector, being the most widely cultivated and consumed cereal crop in the country. It contributes significantly to the national economy, accounting for approximately 7% of the Gross Domestic

Product (GDP) and about 20% of the Agricultural Domestic Product (ADP) (Dhungel & Acharya, 2017). As a staple food, rice plays a central role in ensuring food and nutritional security and directly supports the livelihoods of a large portion of the population, particularly in rural areas. Given the dependence of a majority of Nepali households on agriculture, rice remains the most crucial sub-sector in the country's farming system (Bhatt *et al*., 2024). Historically, Nepal was a rice-exporting nation, but due to increasing domestic demand and stagnating production, the country now imports approximately one million tons of milled rice annually (Dhungana *et al*., 2022). This growing reliance on imports underscores the need for increased productivity and sustainability within the sector. Despite its significance, rice production in Nepal faces several persistent challenges. One of the major issues is the lack of self-sufficiency, as current production levels are insufficient to meet national consumption needs. A considerable portion of rice cultivation, approximately 44%, relies on rainfed conditions, including 39% in rainfed lowlands and 5% in uplands, while only 56% of the rice-growing area is irrigated (Tiwari *et al*., 2019). Even in areas classified as irrigated, water availability is often irregular and unreliable, resulting in yields that resemble those from rainfed systems. As a result, rice productivity remains low, with irrigated fields averaging around 3.5 tons per hectare and rainfed areas producing only 2.45 tons per hectare (Krupnik *et al*., 2021). These persistent challenges have contributed to significant knowledge gaps among rice farmers, limiting their capacity to enhance production and productivity. These barriers hinder the adoption of modern practices and technologies, which are essential for improving yield and achieving food security (Acharya *et al*., 2024). To overcome these issues, there is a pressing need for comprehensive scientific research focused on rice varietal selection and performance evaluation. Such research can generate valuable insights that empower farmers to make informed decisions and ensure the consistent availability of high-quality seeds. Since varietal choice is one of the most critical decisions rice farmers make each season, it directly affects the overall yield and economic returns of their farming operations. Therefore, advancing research and extension services in this area is vital for strengthening Nepal's rice production system and reducing dependency on imports (Joshi *et al*., 2020; Bastola *et al*., 2024).

High-quality seed plays a pivotal role in enhancing crop productivity, with the potential to increase yields by up to 25% while concurrently reducing production costs. Traditionally, plant breeding efforts have concentrated on maximizing grain output. However, with rising living standards, there has been a growing emphasis on improving the quality of rice in response to consumer demand (KC *et al*., 2021). Key agronomic traits such as plant height, number of tillers per hill, number of panicles per hill, panicle length, number of filled and unfilled grains per panicle, 100-grain weight, and total grain weight per panicle serve as critical yield determinants. A thorough evaluation of these traits is essential for the success of breeding programs aimed at yield improvement (Oladosu *et al*., 2018). These yield-contributing traits are often interrelated and demonstrate significant correlations with overall grain yield (Shrestha *et al*., 2020). For plant breeders, understanding the relationships among these traits and their impact on yield is fundamental for identifying superior genotypes and developing effective breeding strategies. Recognizing such associations enables the selection of ideal parental lines and the development of plant types with enhanced yield potential (Parajuli *et al*., 2022; Bastola *et al*., 2024). Given that grain yield is a complex quantitative trait influenced by environmental fluctuations, the selection of superior genotypes based on a comprehensive evaluation of yield components is critical for the advancement of rice breeding programs. The aim of this research was to thoroughly examine the phenological traits, growth characteristics, and yield components of different rice genotypes, offering a detailed insight into their adaptability and performance in the given environmental conditions. Identifying high-performing genotypes is especially valuable, as it helps farmers choose the most suitable varieties for cultivation. This, in turn, can lead to better crop yields, strengthened food security, and enhanced economic well-being for farming communities. By aligning varietal selection with local conditions, the study supports more effective and sustainable rice production practices.

MATERIALS AND METHODS

Experimental site

The experiment was done in a farmer's field at Ramdhuni-7, Sunsari, which is located at an altitude of 185 meters above sea level. Geographically, the experimental site is situated at 26° 44' 03.3'' N latitude and 87° 13' 12.2'' E longitude. The soil had a loamy structure with a pH of 5.5 and an organic matter content of 1.08%. Available nitrogen content was 0.06%, while phosphorus and potash were 30.05 and 46.6 kg/ha, respectively. The plant materials used for the experiment were sourced from the National Rice Research Program (NRRP), Dhanusha. Rice genotypes used in the study are characterized in Table 1.

Experimental details

Seven rice genotypes, along with a check variety (Chaite-5), were evaluated in a randomized complete block design with three replications during the spring season of 2024. The rice was transplanted on April 2, 2024. The plot size was maintained at 6 m², and the planting geometry was set at a 20 cm row-to-row and 15 cm plant-to-plant distance. Fertilizer and farmyard manure (FYM) were applied at the recommended rate of 120:40:30 NPK kg/ha and 10 t/ha, respectively. The full doses of P_2O_5 (DAP) and K_2O (MOP), along with half the dose of nitrogen (N) (urea), were applied as a basal dose. The remaining 50% of nitrogen fertilizer was split into two parts, with the first application made at the tillering stage and the second at the booting stage.

Table 1. List of rice genotypes used at Sunsari, Nepal.

Treatments	Genotypes
T1	IR 16L 1619
T2	IR 10L 152
T3	IR 16L 1831
T4	IR 10N 118
T5	IR 16L 1636
T6	IR 17A 1731
T7	IR 17L 1420
T8	CHAITE-5* (Check Variety)

Weather condition of the experimental site

The weather data from March to July shows significant seasonal variation in temperature, humidity, and precipitation. In March, the maximum temperature reached around 25°C, with a minimum of approximately 15°C. By April, temperatures rose to about 28°C during the day and 18°C at night. During the flowering period in May, temperatures further increased, with a maximum of about 32°C and a minimum of 22°C. In June, the maximum temperature peaked at 35°C, with a minimum of 25°C. By July, the maximum temperature rose to 38°C, and the minimum reached 28°C. Simultaneously, humidity and rainfall levels also showed substantial increases. Humidity rose from 60% in March to 80% in July, indicating a significant rise in atmospheric moisture. Rainfall followed a similar trend, increasing from 50 mm in March to 150 mm in July.

Collection of data

Observations were made on essential phenological, morphological, and yield-related traits. Phenological observations included days to 50% flowering, determined from transplanting to the date when half of the plants in a plot reached flowering, and days to maturity, noted when 80% of the plant population showed signs of physiological maturity such as straw coloration and reduced grain moisture. Morphological traits included plant height, measured from the soil surface to the tip of the panicle at harvest; panicle length, measured from the last node to the panicle tip; and the number of tillers per hill; all were recorded from five randomly selected hills. Yield-contributing traits included the number of filled and unfilled grains per panicle, number of grains per spike, and the 1000-seed weight, which was recorded using an electronic balance. Sterility percentage was calculated as the proportion of unfilled grains to the total number of grains. Biomass per hectare was estimated by converting the average biomass recorded per square meter to a hectare basis. The harvest index was calculated as the ratio of grain yield to the total above-ground dry matter, while grain yield (kg ha^{-1}) was adjusted to 14% moisture content using the standard formula recommended by Shrestha *et al*. (2021b).

$$\text{Grain yield (kg ha} - 1\text{) at 14\%MC} = \frac{(100 - \text{MC}) \times \text{net plot yield (kg)} \times 10000\ (\text{m2})}{(100 - 14) \times \text{net plot area (m2)}}$$

Where, MC is the moisture content in the percentage of the grains.

Statistical analysis

The data collected for various traits during the field study were initially organized and processed using Microsoft Excel (MS Excel 2016). The data were then analyzed using R-Studio (Version 1.4) to perform an analysis of variance (ANOVA). Correlation coefficients between different traits were calculated with the assistance of IBM SPSS 25 software.

RESULTS AND DISCUSSION

In this study, the performance of seven rice genotypes along with a check variety (Chaite-5) for key agronomic traits, including days to flowering (DF), days to maturity (DM), plant height (PH), panicle length (PL), and the number of tillers per hill (TPH) was studied. Significant variation was observed among genotypes for all traits, as indicated by the F-test values ($p < 0.01$ or $p < 0.001$) (Table 2). The earliest flowering genotype was IR 17A 1731 (50 days), whereas Chaite-5 had the longest duration to flowering (60.33 days). Similarly, Chaite-5 took the longest time to mature (85.67 days), while IR 17A 1731 matured the earliest (72.33 days), suggesting its suitability for short-duration cultivation. Early flowering varieties are generally preferred in short-season rice-growing environments as they allow early harvesting and reduce exposure to adverse climatic conditions. Ghimire *et al*. (2024) and Shrestha *et al*. (2021a) obtained similar results on days to 50% flowering and days to 50% maturity. Regarding plant height, IR 17L 1420 (139.34 cm) was the tallest, whereas IR 17A 1731 (104.75 cm) was the shortest. Panicle length varied significantly, with IR 17L 1420 having the longest (27.98 cm) and IR 17A 1731 the shortest (24.50 cm). Taller plants may have advantages in weed suppression but can be more susceptible to lodging, whereas shorter plants are generally preferred for their lodging resistance. The variability in plant height indicates the potential to select genotypes suited for different growing conditions and management practices (Devkota *et al*., 2023). A Significant difference in plant height was previously identified by Chaudhary *et al*. (2023) and panicle length by Tiwari *et al*. (2024).

Table 2. Varietal evaluation for different flowering, maturity, plant length (cm) and tillers number of different spring rice genotypes at, Sunsari, Nepal.

Genotypes	DF	DM	PH	PL	TPH
IR 16L 1636	56.67^{b}	74.67^{d}	120.92^{c}	27.35^{ab}	14.21^{b}
IR 16L 1619	54.33^{c}	73.67^{de}	109.67^{de}	24.96^{cd}	13.33^{c}
IR 10N 118	58.33^{ab}	77.33^{c}	112.84^{d}	26.94^{ab}	14.82^{a}
IR 17A 1731	50.0^{d}	72.33^{e}	104.75^{e}	24.50^{d}	9.5^{f}
IR 17L 1420	51.33^{d}	72.67^{de}	139.34^{a}	27.98^{a}	12.38^{e}
IR 10L 152	60.0^{a}	79.33^{c}	128.93^{b}	24.82^{cd}	12.78^{d}
IR 16L 1831	59.67^{a}	83.33^{b}	122.99^{bc}	26.22^{bc}	14.24^{b}
CHAITE – 5*	60.33^{a}	85.67^{a}	124.86^{bc}	25.86^{bcd}	8.26^{g}
Grand mean	56.33	77.37	120.54	26.08	12.44
SEM(+-)	0.41	0.2	1.44	0.3	0.008
LSD(0.05)	2.19	2.19	7.6	1.6	0.27
CV	2.22 %	1.61%	3.60%	3.50%	1.24%
F test	***	***	***	**	***

Note: **Significant at 1 percent level, *** significant at 0.1 percent level, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PL= Panicle length, TPH= number of tillers per hill.

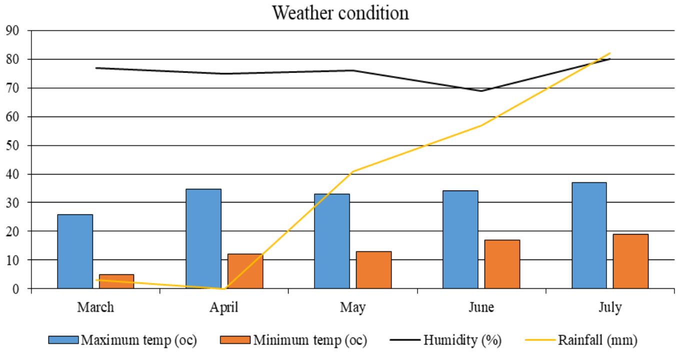

Figure 2. *Weather Conditions during the research period at Tarahara, Sunsari, Nepal. Source: Meteorological station of Regional Agriculture Research Station Tarahara, Sunsari.*

The number of tillers per hill (TPH), a crucial yield determinant, showed substantial differences, with IR 10N 118 (14.82) producing the highest tillers, whereas Chaite-5 recorded the lowest (8.26). A longer panicle and higher number of tillers often lead to higher grain yield due to an increased number of spikelets. A Significant difference in number of tillers per hill was previously reported by Jaiswal *et al.* (2024). Statistically, there was a highly significant difference filled grains per panicle, unfilled grains per panicle, thousand seed weight, sterility, grains per spike, biomass per hectare, harvest index, and grain yield per hectare between the genotypes (Table 3). The number of filled grains per panicle ranged from 386.8 (IR 10L 152) to 532.46 (IR 16L 1831). IR 16L 1831 recorded the highest number of filled grains (532.46), whereas IR 10L 152 had the lowest (386.8). A higher filled grains suggests superior sink strength, effective carbohydrate translocation, and better physiological adaptability to the growing conditions. Genotypes with a greater number of filled grains have a competitive advantage in maximizing yield potential under favorable conditions (Poudel *et al.*, 2024). Similar results on number of filled grains were previously recorded by Acharya *et al.* (2024).

Unfilled grains represent reproductive inefficiencies that can significantly impact grain yield. Chaite-5 exhibited the highest number of unfilled grains per panicle, (145.73), whereas IR 17A 1731 had the lowest (90.46), suggesting that Chaite-5 experienced a higher rate of pollen sterility, poor grain filling, or nutrient limitations. High number of unfilled grains per panicle; values are often associated with environmental stress factors, hormonal imbalances, or genetic constraints affecting spikelet fertility. Minimizing number of unfilled grains per panicle, through genetic improvement and agronomic management is crucial for enhancing yield stability (Panja *et al.*, 2022). Seed weight is a key yield component that influences grain quality and marketability. IR 16L 1636 exhibited the highest thousand seed weight (30.61 g), whereas Chaite-5 recorded the lowest (23.57 g). The variation in thousand seed weight suggests differences in endosperm development, assimilate partitioning, and genetic potential for grain filling. Higher thousand seed weight values are typically associated with improved starch accumulation, which enhances overall grain quality and productivity (Yan *et al.*, 2021). Likewise, Chaudhary *et al.* (2023) previously also reported significant difference in thousand seed weight.

Sterility is a major constraint in rice production, affecting grain-setting efficiency and final yield. The highest sterility percentage was observed in IR 10L 152 (25.46%), indicating reproductive challenges, while IR 17A 1731 exhibited the lowest sterility (16.20%). Sterility in rice can be influenced by genetic predisposition, environmental stress and pollen viability. The results were in accordance with that conducted by Poudel *et al.* (2023). Similarly, the number of grains per spike is a fundamental trait influencing yield potential. IR 17A 1731 recorded the highest grains per spike (131.26), whereas IR 16L 1831 had the lowest (122.87). A greater number of grains per spike value indicates a genotype's potential for high reproductive success and grain output per panicle. Genetic factors regulating floral development, panicle architecture, and carbohydrate allocation play a crucial role in determining number of grains per spike. Bhandari *et al.* (2020) also recorded highly significant variation among twelve genotypes of coarse rice in number of grains per spike.

Biomass production is a measure of a genotype's overall growth efficiency and resource utilization. IR 17L 1420 produced the highest biomass (9.66 t/ha), whereas IR 10N 118 produced the lowest (6.81 t/ha). Greater biomass accumulation tends to be associated with greater photosynthetic ability, efficient nutrient uptake, and enhanced physiological resistance (Yang *et al.*, 2018). The result was in accordance with that of Acharya *et al.* (2024). The harvest index is the proportion of total biomass

Table 3. Yield and yield attributing traits of different spring season rice genotypes at Sunsari, Nepal.

Genotypes	FG	UFG	TSW	ST	GPS	BM	HI	GY/ha
IR 16L 1636	519.4^{c}	106.53^{g}	30.61^{a}	17.07^{g}	128.46^{b}	8.66^{cd}	26.29^{b}	6.04^{b}
IR 16L 1619	525.06^{b}	123.93^{c}	24.00^{d}	19.13^{d}	130.6^{a}	7.67^{e}	35.34^{a}	5.87^{bc}
IR 10N 118	490.06^{e}	113.8^{f}	27.34^{c}	18.84^{e}	124.26^{d}	6.81^{f}	25.33^{b}	3.97^{e}
IR 17A 1731	473.26^{f}	90.46^{h}	29.97^{ab}	16.20^{h}	131.26^{a}	7.95^{e}	26.48^{b}	5.60^{bc}
IR 17L 1420	489.8^{e}	122.13^{d}	28.18^{c}	1.953^{c}	127.93^{bc}	9.66^{a}	21.36^{c}	6.56^{a}
IR 10L 152	386.8^{g}	132.2^{b}	27.92^{c}	25.46^{a}	124.46^{d}	8.18^{de}	17.51^{d}	5.00^{d}
IR 16L 1831	532.46^{a}	119.2^{e}	29.24^{b}	18.28^{f}	122.867^{e}	9.56^{ab}	19.49^{cd}	5.54^{c}
CHAITE – 5*	508.93^{d}	145.73^{a}	23.57^{d}	22.25^{b}	127.4^{c}	9.09^{bc}	18.52^{cd}	4.98^{d}
Grand mean	490.72	119.25	27.6	19.65	127.15	8.45	23.78	5.45
SEM(+-)	0.18	0.17	0.17	0.05	0.16	0.03	0.67	0.08
LSD(0.05)	0.95	0.94	0.9	0.28	0.86	0.56	3.53	0.45
CV	0.11%	0.45%	1.86	0.83%	0.38%	6.96%	8.47%	4.72%
F test	***	***	***	***	***	***	***	***

Note: *** significant at 0.1 percent level, FG= Number of filled grains per panicle, UFG= number of unfilled grains per panicle, TSW = thousand seed weight, ST=Sterility, GPS= Grains per spike, BM/ha=Biomass per hectare, HI= Harvest index and GY/Ha= Grain yield per hectare.

Table 4. Phenotypic correlation coefficients between agro-morphological characters of rice genotypes.

	DF	DM	PH	PL	TPH	FG	UFG	TSW	ST	GPS	BM	HI	GY
DF	1	.861**	0.217	-0.003	0.195	-0.087	0.635	-0.27	0.548	.759*	0.026	-.755*	-0.596
DM		1	0.248	-0.082	-0.197	0.051	0.676	-0.356	0.475	-0.647	0.307	-.86**	-0.477
PH			1	0.557	0.039	-0.217	0.554	0.025	0.548	-0.406	.715*	-0.327	0.322*
PL				1	0.406	0.376	0.019	0.246	-0.206	-0.257	0.363	-0.144	0.218*
TPH					1	0.123	-0.194	0.336	-0.167	-0.462	-0.222	0.12	-0.051
FG						1	-0.105	-0.139	-0.665	0.191	0.231	0.142	0.272*
UFG							1	-.742*	.809*	-0.365	0.297	-0.492	-0.182
TSW								1	-0.454	-0.115	0.143	0.122	0.246*
ST									1	-0.408	0.09	-0.437	-0.282
GPS										1	-0.128	.787*	0.513**
BM											1	-0.182	0.625**
HI												1	0.65**
GY													1

Note: *Significant at 5% level of significance and ** significant at 1% level of significance, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PL= Panicle length, TPH= number of tillers per hill, TW= Thousand seed weight, FG= Number of filled grains per panicle, UFG= number of unfilled grains per panicle, ST=Sterility, GPS= Grains per spike, BM= Biomass per hectare, HI= Harvest index and GY= Grain yield per hectare.

converted to economic yield. IR 16L 1619 recorded the highest harvest index (35.34%), and IR 10L 152 recorded the lowest (17.51%), showing inefficient biomass conversion. A high harvest index is always desirable for the sake of maximizing grain yield, as it shows an optimal balance between vegetative growth and reproductive allocation. The genotypic difference in harvest index shows varietal differences in source-sink relations, transport of photosynthetic, and physiological efficiency (Tiwari *et al.*, 2019). Similarly, Pandey *et al.* (2023) also reported significant differences in harvest index among different genotypes of rice.

Grain yield per hectare is the ultimate parameter for evaluating varietal performance under specified environmental conditions. IR 17L 1420 produced the maximum yield (6.56 t/ha), indicating its superior genetic potential, whereas IR 10N 118 yielded the least (3.97 t/ha). Yield performance is a multifactorial trait involving numerous factors like grain number, grain weight, sterility, and biomass production, whereas Chaite-5 (check) recorded a grain yield of 4.98 t/ha. Dhungana *et al.* (2022) also recorded significant variation in grain yield across rice genotypes, a finding that supports the work sustained by Acharya *et al.* (2024). Likewise, Mahato *et al.* (2024) also emphasized the core role played by different ages of seedlings and plant spacing in realizing optimum rice yield. Also, Shrestha *et al.* (2021b) also arrived at the same conclusion that the variation of grain yield among varieties was a function of varietal characteristics and interactions of their genotype with the environment.

Phenotypic correlation between agro-morphological traits of rice

The correlation analysis demonstrated that harvest index, biomass, and grains per spike exhibited significant and positive correlations with grain yield, indicating their critical role in enhancing yield potential (Table 4). Conversely, days to flowering, days to maturity, unfilled grains per panicle, and sterility percentage showed negative correlations with grain yield, suggesting that delayed maturity, higher sterility, and poor grain filling adversely affect productivity (Table 4). Plant height, panicle length, thousand seed weight, and filled grains per panicle exhibited weak to moderate positive correlations with grain yield, suggesting their partial influence on productivity. These findings emphasize the importance of selecting genotypes with higher harvest index, greater biomass accumulation, increased grain number per spike, and reduced sterility and unfilled grains to maximize rice yield potential. The present findings are consistent with previous studies, including those of (Shrestha *et al.*, 2021b), which reported a significant positive correlation of thousand grain weight and plant height with grain yield. Similarly, the observed positive association of harvest index with grain yield aligns with the findings of Pant *et al.* (2019). Furthermore, significant positive correlation between days to 50% flowering and days to maturity supports the results reported by Tiwari *et al.* (2024). A similar relationship between field grains per panicle has been documented by Khanal *et al.* (2020).

Conclusion

In conclusion, this study reveals considerable variation among rice genotypes for phenological, morphological, and yield-contributing traits. The findings suggest that IR 17L 1420 and IR 16L 1619 possess great potential as future cultivars due to their high yield and biomass production and harvest index, respectively. In contrast, Chaite-5 (check) showed lower productivity and higher sterility and is thus less suited to the test environmental conditions. Correlation analysis also reveals the supreme significance of harvest index, biomass, and grains per spike in enhancing yield potential, while delayed maturity, high sterility, and poor grain filling are negatively associated with grain yield. These results are valuable guidelines for rice breeders and agronomists in selecting and developing high-yielding rice varieties for comparable agro-climatic environments.

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DECLARATIONS

Author contribution statement

Conceptualization: B.M. and A.K.; Methodology: B.M.; Software and validation: B.M., and A.K.; Formal analysis and investigation: B.M.; Resources: A.K.; Data curation: B.M., B.P, and A.K.; Writing—original draft preparation: B.M.; Writing—review and editing: B.M.; Visualization: B.M.; Supervision: A.K.; Project administration: B.M.; Funding acquisition: B.M and A.K. All authors have read and agreed to the published version of the manuscript.

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