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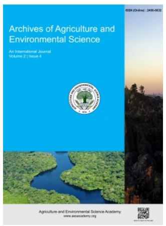

ORIGINAL RESEARCH ARTICLE

Agronomic performance and farmers' preferences of twelve spring rice genotypes under participatory approach at Kailali, Nepal

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ABSTRACT

The purpose of this paper was to assess the agronomic performance and farmers' preferences of spring rice genotypes in collaboration with farmers. This experiment was conducted from February to June, 2023 at Khaira, Bhajani Municipality in Farmer's Field School. The experiment was laid out in Randomized Complete Block Design (RCBD), with three replications, testing twelve rice varieties involving 37 small holder farmers. The individual plot size was 10m × 2m with plant spacing maintained at 20cm × 20cm. The data were analysed using the ANOVA technique in R-Studio software (version 4.0), and Fisher's Protected LSD test was applied for mean separation. Results revealed that yield and yield attributes along with days to maturity were statistically different among genotypes. Maximum grain yield was found in Chaite-5 (10.75 t/ha) followed by IR16L1831 (10.33 t/ha) which was statistically at par with genotype IR10L118 (10.07 t/ha), while the lowest yields were obtained in Chaite-4 (5.77 t/ha) followed by local check variety Chaini-Local (6.77 t/ha). The findings showed that SVIN-191 (139 days) and Hardinath-5 (138 days) had the highest duration to reach maturity. In contrast, the Chaini -Local variety had the shortest time to maturity, taking only 113 days, while Chaite-4 and IR10L152 required 119 and 122 days, respectively. On participatory varietal selection, the farmer preference score was found maximum in genotype IR10L152 (0.055) followed by a popular variety Chaite-5 (0.047) which signifies these genotypes have certain traits of farmer preference. Moreover, the preference for the genotype IR10L152 above the high-yielding variety Chaite-5 indicates that the farmers in Kailali took several desirable traits into consideration for rice variety selection rather than just high yield.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the major food crop for more than half of the world's population (Khadka *et al*., 2024). The Asia-Pacific region serves as a crucial hub for global rice production, as it accounts for over 90% of the world's paddy cultivation and consumption (Chaudhary *et al*., 2023). In 2020/21, Nepal produced a total of 5,550,878 metric tons of rice from 1,458,915 hectares of land (MOALD, 2021). As the most widely cultivated staple crop in the country, rice plays a pivotal role in ensuring food security, improving nutrition, and contributing significantly to the national GDP (MOALD, 2022). Rice contributes 11.30% to Nepal's national GDP (MOALD, 2022) and serves as the primary food crop for over 90% of the population, accounting for 56% of the country's total cereal consumption (Choudhary *et al*., 2022). Despite its importance, rice productivity remains limited to just 3.8 metric tons per hectare (MOALD, 2021). Rice imports in Nepal are rising sharply, with quantity and value increasing annually by 24.48% and 38.11%, respectively, while domestic production grows by less than 2% per year (Gairhe *et al*., 2021). To address this, the government focuses on boosting rice production through input subsidies and irrigation investments. Despite that, farmers in Nepal still face a significant yield gap of 50%, indicating a substantial difference between the potential crop yield that can be obtained from a given area under ideal conditions and the actual yield that is currently being achieved (National Rice Research Program NRRP, 2020).

A key factor contributing to this gap is the dominance of rainfed rice cultivation, which accounts for 92% of the total area during the rainy season, leaving only 8% of the land for rice cultivation in the spring season (Jaishi *et al*., 2020; Manni & Sharma, 2023). Spring rice, which has higher productivity compared to main-season rice, presents a promising solution. Promoting spring rice varieties can not only better utilize underused land during the off-season but also significantly increase overall rice productivity (Bhatt *et al*., 2024). Moreover, spring rice varieties are typically grown after the rainy season, allowing them to escape the impacts of floods that affect the main rice cropping season, thereby offering an alternative option for farmers in flood-prone areas (Subedi *et al*., 2018). However, the adoption of spring rice remains limited due to lack of farmer-preferred varieties. The absence of diverse and locally suitable options restricts farmers' willingness to transition to spring rice cultivation, highlighting the need for targeted breeding programs and farmer-inclusive approaches to develop and promote varieties that align with their preferences and agronomic requirements (Acharya *et al*., 2024). Unfortunately, the current rice breeding programs are not farmer-centric, and do not take into account the needs and preferences of local rice growers. This has obliged the farmers to grow and maintain the same varieties on their own until a better one is made available to them (Yadav *et al*., 2022). Thus, participatory varietal selection (PVS), a farmer centric breeding method is of utmost need for the present situation. PVS offers a rapid and efficient approach for diagnosing issues and promoting the sustainable adoption of technological advancements (Guèye, 2016). This method successfully addresses barriers that compel farmers to cultivate old, low-yielding traditional varieties by involving them in the identification and selection of plant varieties that align with their needs and preferences (De Santis *et al*., 2022). By allowing farmers to play an active role in the selection process, this approach seeks to increase the adoption of elite varieties and promote more efficient and effective plant breeding (Islam *et al*., 2008). With the increment of PVS and testing popular varieties systematically, adopting a liberal release system, and with the provision of easier access to new varieties seeds, farmers' adoption rate of varieties can be increased (Witcombe *et al*., 1996). Based on the gaps in existing literature and the potential benefits of PVS for spring rice, this research aims to conduct a preference study using PVS as a method to engage farmers in the rice breeding process. By doing so, the study seeks to contribute to the development of more farmer-centric breeding programs and the adoption of improved spring rice varieties that are better suited to the needs and preferences of local communities.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at *Naya Goreto* farmer field school implemented by Local Initiatives for Biodiversity, Research and Development (LI-BIRD) at Bhajani Municipality–03, Kailali, Nepal. The experiment was carried out from February to June, 2023. The experimental field was situated at 28.83° N latitude, 80.89°E longitude and at an altitude of 143 meters above sea level. During the experimental period, the temperature rose gradually, with the maximum temperature reaching from around 27°C to 42°C and the minimum temperature from approximately 15°C to 29°C. The relative humidity was highest (around 59.87%) during the initial phase of the experiment, while it was lowest (around 26%) during the month of April.

Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and twelve treatments. The total area of the experimental field was 595 m^2(35 m × 17 m) with individual plots of dimension 5 × 2 m^2. The spacing between each plot and replication was 1m. The local variety Chaini-Local, well-adapted and preferred by farmers, was used as a check variety to assess the performance. Hardinath-1, Chaite-4, and Chaite-5 were varieties recommended by the Government of Nepal for the spring season, while Hardinath-4 and Hardinath-5 were recommended for the main season. Genotypes IR10L152, IR16L1831, IR17L1481, IR10N118, IR16L1636 and SVIN 191 were provided by National Rice Research Program, Hardinath, Dhanusa, Nepal, for research purposes.

Agronomic practices

The seeds were first sorted by salt solution where heavier seeds, more likely to be viable, were separated from the lighter seeds. The viable seeds were then treated with (Bavistin 50) fungicide @ 2 grams per kilogram of seed to protect them from fungal diseases and afterward soaked in water for 24 hours and then sown in prepared nursery @25kg/ha. The seedlings were grown separately in dry nursery beds with an area of 1 m^2 each under the plastic polyhouse to protect seedlings from cold stress. Both the primary tillage and secondary tillage were done prior to transplanting of seedlings. The recommended dose of fertilizers @120:60:40 kg NPK/ha was applied along with well-decomposed FYM @ 6 tons/ha. Half dose of nitrogen and full dose of phosphorus and potash was applied as basal dose during transplanting while remaining half dose of nitrogen was applied as top dressing. The 40-days-old seedlings were transplanted at specific intervals of 20 cm × 20 cm in the main field. Water depth of 2 cm was maintained up to 7 days after transplanting (DAT) and 5cm was maintained throughout the crop period. A pre-emergence herbicide (Pretilachlor 50%EC) was applied within three DAT. Manual hand weeding was followed at every 7 days' interval. For control of yellow stem rice borer, Chlorpyrifos 50% EC @ 0.18 ml/L was sprayed at 80 DAT after observing the symptoms of white heads in some of the plants. From the centre of the plot, 1m² area was selected and was manually harvested then sun dried. After sun drying, manual threshing and winnowing were conducted to separate and clean the rice grains.

Data collection

The data were recorded from randomly selected ten plants. During each observation, several key parameters were recorded, including plant height, number of tillers per plant, panicle length, number of grains per panicle, sterile grains, biomass, grain weight, days to flowering and days to maturity. For height, vertical distance was measured from ground level of the plant to the longest leaf of the main tiller. Flowering was recorded from all the tillers in a randomly selected row of each plot, with observations made every alternate day. Maturity of crop was recorded, when the 60% of sample plants turned pale yellow colour and hard dough stage. Similarly, for selecting preferred variety, selection criteria were determined by farmers themselves with focus discussion in farmer field school. The criteria for selecting varieties were determined based on key factors such as the number of days to maturity, signs of pests and diseases, stem strength, leaf colour, and grain size. The most significant factor taken into account was days to maturity, with the main objective to skip potential risk of flood in Bhajani, Kailali. Participant farmers utilized the "Agro-ecological Situation Analysis" (AESA) form for systematically assessing various factors affecting preference, to make more informed decisions regarding the selection of rice varieties. Preference observation was carried out according to the guidelines set by Paris (2011). When most of the crops reached 80% maturity, farmers and researchers (officials and staff from School of Agriculture, Far-western University, Nepal and LIBIRD) were invited for varietal evaluation and selection. Respondents were asked to vote their two most and two least preferred genotypes based on criteria such as early maturity, weed infestation, pest infestation, maximum yield. Votes were tallied and the preference scores (PS) for each variety was then calculated from the formula:

$$\text{Preference score} = \frac{\text{Positive votes} - \text{Negative votes}}{\text{Total votes}}$$

Data analysis and techniques

Data tabulation was done in Microsoft Excel 2007. The tabulated data was then subjected to statistical analysis in R-Studio for Analysis of Variance (ANOVA). Treatment Means were compared with Duncan's multiple range tests at 5% of level of significance. Subsequently, the preferences of the participants were analysed in relation to the computed preference scores (PS).

RESULTS AND DISCUSSION

Phenological observations

The selected genotypes possessed a significant difference ($p<0.001$) for days to heading, flowering and maturity. Among the tested genotypes, Chaini-local took the shortest time to flower and reach maturity stage in 113 DAS, whereas, SVIN-191 took the longest duration to show up flowers taking 139.67 DAS to mature, as observed in Table 1. SVIN-191 showed late flowering at 116 DAS, followed by Hardinath-5 with 114 days which was at par with Hardinath-4. Likewise, IR10N118 was a moderate duration genotype with flowering at 102 DAS. Chaini-local, Chaite-4, and IR10L152 were quick to flower at 89 DAS, 95 DAS, and 95 DAS, respectively and hence identified as early maturing genotypes. But SVIN-191, Hardinath-4 and Hardinath -5 were late to flower, taking more than 138 days to mature, hence were identified as late maturing genotypes. The observed differences in heading, flowering and maturity are attributed to differences in plant genetics, as well as changes in temperature and humidity, which is in harmony with the study of (Gaballah *et al*., 2019; Puri *et al*., 2021, Chaudhary *et al*., 2023).

Biometric observation

The selected genotypes possessed a significant difference ($p<0.001$) for both plant height and tiller number at the time of harvest as shown in Table 2. Chaite-5 was superior in plant height with 105.82cm followed by Hardinath-5 (99.83 cm) which was statistically at par with IR10L152 (99.4 cm). Height of IR16L1636 was moderate with 93.77 cm which was statistically at par with IR16L1831 (93.56 cm). In contrast to these, the smallest height was observed in Chaine-local (74.13cm). Genotype IR16L1831 exhibits higher tiller count (19.07) at harvest, indicating its prolific tiller ability and it was statistically at par with IR10N118 and IR16L1636. But Chaini-local and IR10L152 were moderate in tillering, with tiller count being 16.9 and 16.15, respectively. The lowest number of tillers was observed in Hardinath-5 (14.59) followed by Chaite-5 (13.76). This finding suggests that both height and tillering were influenced by the genetic background of each variety and adaptive strategies reported aligning with the previous study that reported similar results regarding the impact of genetic factors (Ishaq *et al*., 2021; Wang *et al*., 2007). The taller plants observed in Chaite-5 could be attributed to genetic factors influencing internodal elongation and overall plant development. This characteristic may contribute to increased light interception and enhanced photosynthetic activity, positively impacting yield (Ghimire *et al*., 2023; Morales *et al*., 2020).

Yield attributing traits

The number of effective tillers/m^2, panicle length, number of grains per panicle, sterility percentage, and thousand grain weight were significantly influenced by different genotypes Table 3. The effective tiller count/m^2 was found to be the highest in IR16L1831, with 470.58 tillers/m^2 followed by IR10N118 and IR16L1636. Least number of effective tillers/m^2 was observed in Hardinath-5 (334) which was followed by Chaite-5 (344) and Hardinath-4. The panicles were statistically longest in Chaite-5 (26.53 cm) followed by IR10L118, IR16L1831 and IR16L1481 which were statistically at par with each other.

Table 1. Phenological observations of spring rice influenced by different genotypes.

Genotypes	Days to heading	Days to flowering	Days to maturity
IR10L1523	91.67^{gh}	97.33^{f}	122.67^{g}
Hardinath-4	109.33^{ab}	114.33^{b}	138.33^{ab}
SVIN 191	110.33^{a}	116.67^{a}	139.67^{a}
IR16L18315	95.33^{f}	110.63^{c}	130.33^{c}
IR17L1481	97.67^{e}	104.67^{d}	125.67^{ef}
IR10N118	99.67^{d}	102.33^{e}	124.67^{f}
Chaine-local1	85.33^{i}	89.67^{h}	113.33^{i}
Chaite-42	90^{h}	95^{g}	119.67^{h}
Chaite-5	102.67^{c}	109.67^{c}	131.67^{c}
IR16L16364	93.33^{g}	106.33^{cd}	128.33^{d}
Hardinath-5	107.67^{b}	114.67^{b}	138.67^{ab}
Hardinath -1	98.67^{de}	104.33^{d}	126.67^{de}
Sem (±)	0.37	0.37	0.37
F-test	***	***	***
CV (%)	0.65	0.62	0.51
Grand Mean	98.47	104.56	128.22

Note: *** significant at 0.001 level of significance, treatments mean followed by the same letter (s) within column are non–significantly different among each other at 5% level of significance.

Table 2. Plant height (cm) and tiller number of different spring rice genotypes during harvest.

Genotypes	Plant Height	Total Tiller Number
IR10L152	99.4^{b}	16.15^{a-c}
Hardinath-4	91.5^{de}	14.6^{bc}
SVIN 191	97.16^{bc}	14.31^{bc}
IR16L1831	93.57^{cd}	19.07^{a}
IR17L1481	98.17^{bc}	14.79^{bc}
IR10N118	91.48^{de}	19.06^{a}
Chaine-local	74.13^{g}	16.98^{ab}
Chaite-4	81.95^{f}	15.37^{bc}
Chaite-5	105.83^{a}	13.77^{bc}
IR16L1636	93.77^{cd}	18.71^{a}
Hardinath-5	99.83^{b}	13.39^{c}
Hardinath-1	88.21^{e}	14.78^{bc}
F-test	***	***
GrandMean	92.91	15.80
Sem (±)	1.02	0.64
CV (%)	1.89	7.01

Note: *** significant at 0.001 level of significance, treatments mean followed by the same letter (s) within column are non–significantly different among each other at 5% level of significance. CV= Coefficient of variation.

Table 3. Yield attributing traits of different spring rice genotypes.

Genotypes	Number of effective tillers/m^2	Panicle length (cm)	Number of grains per panicle	Sterility percentage (%)	Thousand grain weight (g)
IR10L152	403.83^{a-d}	24.64^{a-c}	189.17^{f}	16.37^{e}	24.33^{bc}
Hardinath-4	364.2^{cd}	24.1^{abc}	135.65^{i}	19.19^{c}	20.67^{de}
SVIN 191	357.87^{cd}	24.7^{a-c}	324.1^{c}	24.41^{a}	23.33^{b-d}
IR16L1831	470.58^{a}	25.38^{ab}	282.11^{d}	10.65^{h}	25.33^{ab}
IR17L1481	369.63^{cd}	25.33^{ab}	147.56^{h}	17.93^{d}	$_{22}$c-e
IR10N118	453^{ab}	25.53^{ab}	225.18^{e}	19.9^{c}	24.33^{bc}
Chaine-local	$_{419}$a-c	20.98^{d}	110.37^{j}	4.65^{j}	21.67^{c-e}
Chaite-4	388.33^{b-d}	22.77^{cd}	92.6^{l}	7.13^{i}	19.67^{e}
Chaite-5	344.17^{cd}	26.53^{a}	406.17^{a}	15.81^{e}	27.33^{a}
IR16L1636	464.58^{ab}	24.37^{a-c}	98.68^{k}	13.56^{g}	21d^{e}
Hardinath-5	334.63^{d}	24.7^{a-c}	347.93^{b}	14.72^{f}	24.33^{bc}
Hardinath-1	370.13^{cd}	24.15^{a-c}	157.35^{g}	22.8^{b}	22.33^{c-e}
Sem (±)	15.98	0.38	0.68	0.14	0.53
F-test	***	***	***	***	***
CV (%)	7.01	2.71	0.56	1.57	3.99
Grand Mean	395.00	24.43	209.74	15.59	23.03

Note: *** significant at 0.01 level of significance, treatments mean followed by the same letter (s) within column are non-significantly different among each other at 5% level of significance., CV= Coefficient of variation. The mean values are rounded off.

Statistically the shortest panicle was recorded in the local variety having shortest height i.e., Chaini-Local (20.98 cm), followed by Chaite-4 (22.76 cm). Statistically, grains per panicle was also found to be the highest on Chaite-5 (406.16) followed by Hardinath-5 (347.93), which was followed by SVIN 191 (324), IR16L1831 (282) and IR10N118 (225) respectively. However, statistically the lowest number of grains per panicle was recorded Chaite-4 (92.60) followed by IR16L1636 (98.68). Even a local variety, Chaini-Local produced higher grains per panicle (110.37) as compared to Chaite-4. The sterility percentage ranged from 24.40 to 4.64 with the highest observed in SVIN-191 followed by Hardinath-1 (22.79) and the lowest in Chaini-Local followed by Chaite-4 (7.12). The sterility percentage recorded in IR10N118 genotype (19.89) was statistically at par with Hardinath-4. Among the examined genotypes, the highest thousand grain weight was recorded in Chaite-5 at 27.33 grams, showcasing its distinction in producing larger and more substantial seeds. This was closely followed by IR16L1831, which reported thousand grain weights of 25.33 grams, making its position among the genotypes with larger seeds. Chaite -5 followed by IR16L1831 exhibits superior yield attributing traits, indicating its potential for high grain yield. In contrast, Chaite-4 exhibited the lowest value for thousand grain weight i.e. 19.99 grams, characterizing it as a genotype with smaller seeds. Genotypic differences in panicle number, panicle length, grains per panicle, and other yield-related traits demonstrate the diverse genetic makeup of the rice varieties studied (Ata-Ul-Karim *et al*., 2022; Demeke *et al*., 2023; Shanmugam *et al*., 2023).

Yield observation

Biomass and grain yield were significantly influenced by different genotypes Table 4. Biomass yield, grain yield and straw yield are the pivotal components that collectively shape the overall productivity and economic viability of rice crops (Li *et al*., 2023; Ouyang *et al*., 2022). The maximum biomass yields as well as grain yield were recorded in Chaite-5 (29.67 t/ha and 10.74 t/ha, respectively) which was followed by IR16L1831 while the lowest biomass and grain yield were recorded in Chaite-4 (15.99 t/ha and 5.77 t/ha, respectively), which was statistically at par with Chaini-Local. The significant variation in biomass yield among genotypes, with Chaite-5 exhibiting higher yield, aligns with the findings of Araus *et al*. (2022), suggesting that this genotype demonstrates greater efficiency in capturing solar radiation and converting it into organic matter through photosynthesis.IR16L1831 and Chaite-5 achieved an impressive grain yield of 10 t/ha, attributed to their genetic potential and the consistent water supply of lowland irrigated ecosystems, which supports optimal rice growth. Additionally, the favourable environment, proper fertilizer use, and timely pest control may have further contributed to the higher yield of Chaite-5. IR10L152 exhibited the highest harvest index of 0.43, indicating a superior ability to convert a larger proportion of biomass into grains. Following was IR10N118 with a harvest index of 0.40, which showed similar performance to Chaini-Local, Hardinath-1, and Hardinath-5. In contrast, the genotype IR16L1636 displayed the lowest harvest index of 0.32, indicating a lesser ability to convert biomass into grains efficiently. These findings align with the research which presents the significance of genetic makeup and environmental factors in determining the yield in rice crops (Kimani *et al*., 2013).

Table 4. Yield of spring rice influenced by different genotypes.

Genotypes	GY	BY	HI
IR10L152	9.55^{a-c}	22.13^{gh}	0.43^{a}
Hardinath-4	6.86^{de}	20.75^{h}	0.33^{cd}
SVIN 191	9.09^{bc}	26.09^{b-d}	0.35^{b-d}
IR16L1831	10.33^{ab}	26.79^{b}	0.39^{a-c}
IR17L1481	8.77^{bc}	23.96^{e-g}	0.37^{b-d}
IR10N118	10.07^{ab}	24.75^{c-e}	0.41^{ab}
Chaine-local	6.77^{e}	16.69^{i}	0.41^{ab}
Chaite-4	5.7^{7e}	15.99^{i}	0.36^{b-d}
Chaite-5	10.75^{a}	29.67^{a}	0.36^{b-d}
IR16L1636	8.38^{cd}	26.15^{bc}	0.32^{d}
Hardinath-5	9.49^{a-c}	24.2^{d-f}	0.39^{ab}
Hardinath-1	8.97^{bc}	22.28^{f-h}	0.40^{ab}
Sem (±)	0.31	0.37	0.01
F-test	***	***	***
CV (%)	0.31	2.78	5.45
Grand Mean	8.73	23.29	0.38

Note: *** significant at 0.01 level of significance, treatments mean followed by the same letter (s) within column are non-significantly different among each other at 5% level of significance. GY= Grain Yield (t/ha), BY = Biomass Yield(t/ha), HI=Harvest index CV= Coefficient of variation. The mean values are rounded off.

Table 5. Total preference score on participatory varietal selection.

Genotype	Positive votes	Negative votes	Preference score	Rank
IR10L152	13	6	0.0546875	I
Hardinath-4	2	0	0.015625	
SVIN 191	0	6	-0.046875	
IR16L1831	9	5	0.03125	II
IR17L1481	8	6	0.015625	
IR10N118	2	2	0	
Chaini-local	9	6	0.0234375	
Chaite-4	0	8	-0.0625	
Chaite-5	12	6	0.046875	III
IR16L1636	6	10	-0.03125	
Hardinath-5	0	6	-0.046875	
Hardinath-1	3	3	0	
Total	64	64		

Preference analysis

The Table 5 presented the preference scores of different spring rice genotypes based on participatory varietal selection. Among the genotypes, IR10L152 received the highest total preference score, followed by Chaite-5. Farmers preferred IR10L152 due to its traits like early maturity, robust grains, low sterility and resistance to insect-pests. Chaite-5 was also well-liked for having a higher number of tillers, more grains per panicle, and robust grains. On the other hand, Chaite-4 had the lowest preference score, which was due to fewer number of tillers, shorter panicles, low grain count per panicles, as well as being susceptible to pest and disease infestations despite its early maturity. Though Hardinath-5 had satisfactory grains per panicle and tillers/m^2, longer periods required for maturity resulted in less preference among the farmers. Among the studied 12 genotypes, there was moderate preference for the local variety Chaini-Local, likely due to its well-adapted nature to the local agro-climatic conditions and its long-standing presence in traditional farming practices. The variety may offer stable yields over different growing seasons, and farmers valued its taste, cooking qualities, and texture. Additionally, the ease of seed availability and accessibility could make it practical and a favoured choice among the farmers in the region.

Conclusion

Through this experiment, the farmers of Bhajani municipality, Kailali were able to actively engage in the identification and selection of rice genotypes which were in accordance with their need and preference. The yield was maximum in Chaite-5, IR16L1831, IR10N118 and IR10L152. Among these, the IR10L152 genotype stood out not only for its high yield but also for the factors like days to maturity, plant performance, stem strength and other yield components. This research recommends expanding rice selection criteria beyond yield, highlighting the promising pipeline genotype IR10L152. While not yet recommended for farmers, research stations are encouraged to test its adaptability across locations. To build upon these findings, it is recommended to conduct further comparative studies involving farmers in participatory breeding to identify specific traits of interest within IR10L152, exploring its stress tolerance, disease resistance and adaptability.

DECLARATIONS

Author's contribution

Conceptualization: NG.; Methodology: NG., SP., and RS.; Performed the experiments: NG., ST., and SL.; Formal Analysis and Investigation: NG. and RS.; Resources: NG. and SP.; Data Curation: NG., ST., and SL.; Writing—Original Draft Preparation: NG. and SP.; Writing—Review and Editing: RS., ST., SL., and BS.; Supervision: SP. and RS.; Coordination of Fieldwork: NG, SL. and ST.; Statistical Analysis: NG. and ST.; Farmer Interaction and Data Collection: NG., R.S., and BS.; Report Compilation: NG., and BS.

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Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

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