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RESEARCH

Evaluation of Rice Landraces for Yield and Related Traits Under Rainfed Conditions in Nepal

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Abstract

The primary staple crop in Nepal in terms of production and cultivated area is rice (*Oryza sativa* L.). This study evaluates the agronomic performance of fifteen genotypes of rice landraces under rainfed conditions in Krishnapur municipality, Kanchanpur, Nepal, during the rainy season of 2023. The experiment was conducted on an alpha lattice design with two replications. The study focused on yield and yield-related traits, including tiller per plant, plant height, panicle length, and grain length and width. ANOVA showed a significant variation among different genotypes for various traits. Rai Manuwa showed the highest tiller per plant (9), plant height (146 cm), panicle length (27.5 cm), and grain yield per plant (16.63 gm.), indicating greater drought adaptability. However, Sorali showed the lowest performance across most traits, indicating poor drought tolerance. The yield trait association analysis revealed a strong positive correlation between the total grain yield, average tiller per plant, and average panicle length. Therefore, yield could be increased by selecting these traits. Using the cluster analysis process, fifteen different genotypes of rice landraces were grouped into four groups. Genotypes in Cluster 2 (Rai Manuwa, Sarju) and Cluster 3 (Taichin) were identified as potential genotypes and tiller per plant, panicle length, and grain yield as potential traits for the breeding programs focused on improving drought tolerance.

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Statement of Sustainability: This study has assessed the performance of local landraces of rice under rainfed conditions in Nepal. Since climate change and its associated problems are worsening day by day, the identification of landraces of rice that can grow with superior performance in drought conditions is essential for rice farming. As per our objective, this study has revealed some promising local rice landraces with superior yield attributes under rainfed rice cultivation, which would be valuable input for rice farming in such rainfed conditions.

1. Introduction

Rice (*Oryza sativa L*) ranks first in Nepal in terms of area and production; it occupies an area of 1,477,378 ha with 5,130,625 tons production, and 3.472 tons/ha productivity. In Sudurpaschim province, the productivity of rice is 3.68 t/ha (MoALD, 2023). Nepal ranks 17th in rice production and 64th in rice productivity (Choudhary et al., 2022). Rice is cultivated in mainly three different ecological zones; terai occupies the first position of rice cultivation in terms of area, followed by mid-hill and high hill with a share of 68, 28, and 4%, respectively (Ghimire et al., 2015; Banjade et al., 2023). Rice grows in many regions in Nepal, including irrigated 51%, upland 9%, rainfed lowland 37%, flash floods, and deep water 3% (Yadav et al., 2023). Rice is a staple food for more than half of the world's population, providing more than 20% of the calories consumed worldwide, especially in East and South Asia, the Middle East, the West Indies, and Latin America (Khanal et al., 2024a). To fulfill the food demand for the growing global population, which is supposed to reach 10 billion by 2050, agricultural production must increase by approximately 70% (Chakraborti et al., 2023). Drought is a major problem in rice farming, where rainfall frequency and intensity have been reduced considerably, which may hurt the rice crop productivity (Banjade et al., 2024). Drought has affected many parts of the world in recent decades, and it has been increased by climate change (Khanal et al., 2024b). In addition, drought has a particularly detrimental impact on crop output and regional and global food security (Kang et al., 2021). Drought is a major abiotic stress that significantly reduces rice yields and affects 20% of Asia's rice-growing region (Perween et al., 2020).

Rainfed rice-growing areas comprise 45% of the total cultivated rice-growing area in the world, where drought in mild, moderate, or severe forms occurs in most years (Vikram et al., 2015). Water is essential for rice production, so drought is the limiting factor for water supply. There are various methods to overcome drought; one is direct-seeded rice (DSR), the best alternative (Kesh et al., 2022). The transplanting rice method (TPR) requires more labor and a labor shortage during main-season rice, resulting in a high labor cost (Bouman et al., 2005). In the transplanting rice method, nursery uprooting, hard pan formation, crust formation, and soil permeability increase yield loss in subsequent crops (Monaco et al., 2016). The DSR method of rice cultivation reduces the farmer's expenditure on cultivation and enhances the B: C ratio (Sharma et al., 2021). The distribution of water resources is not equally allocated, which results in rainfed rice farming and erratic rainfall patterns that decline rice production. In such a scenario, direct-seeded rice could be the first alternative method of rice cultivation (Romana et al., 2014). The positive aspect of the DSR method of rice cultivation is to conserve resources, which is crucial in the context of the limited resources available in the area (Singh et al., 2012). Rainfed rice cultivars may be extinct if they lack conservation programs. Conservation and further exploration of these varieties will be helpful for sustainable agriculture and food security (Newton et al., 2011). Finding landraces of rice that can produce the maximum yield under rainfed conditions can be the best asset for future rice breeding to develop drought-tolerant genotypes (Kumbhar et al., 2015).

Climate change adversely affects rainfall patterns, the biggest threat nowadays for rice cultivation. So, varieties resistant to or tolerating drought conditions are the best input materials for improved rice farming in western Nepal. This study aims to identify promising superiorly performing local rice landraces for the rainfed condition of Nepal that would be a great asset for the rainfed rice farming communities.

2. Materials and Methods

2.1. Experimental Site and Rice Genotypes

In 2023, an experiment was carried out using fifteen different rice types, including Mansuli, Churi, Taichin, Jhini, Askote, Hansraj, Sorali, Rato Basmati, Ratjare, Haria Chota, Thapa Chini, Raj Manuwa, Haldi Rato Dhan, and Radha-4 (control). The experiment was carried out in Krishnapur municipality-07, Kanchanpur, Nepal, located at latitude 28.796236 °N, longitude 80.524711 °E from June 2023 to October 2023, namely during the Kharif (monsoon) season. The details of the experimental site are presented in Figure 1.

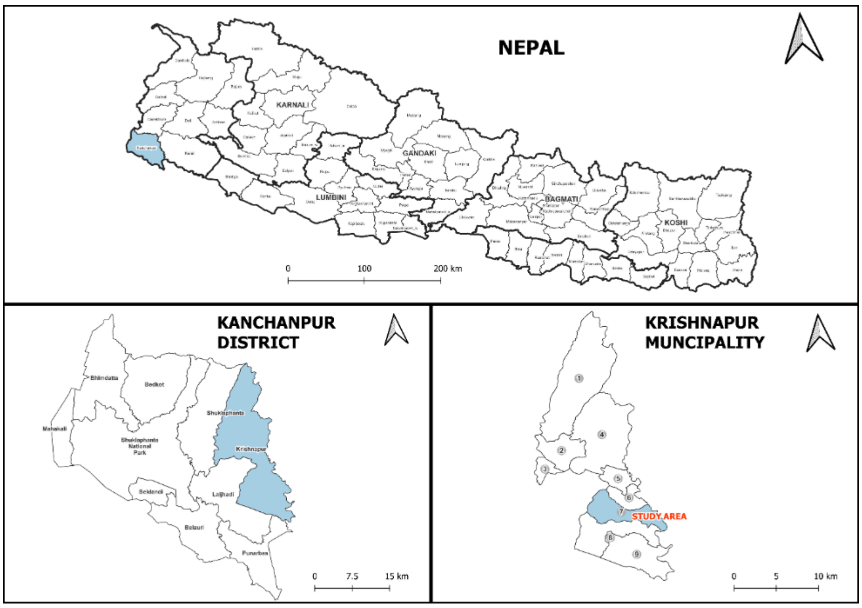

Figure 1. Map of the experimental site in Nepal.

2.2. Experimental Design and Agronomic Practices

The experiment was laid out using an alpha lattice design with two replications. Before plowing and leveling, pre-irrigation was conducted two days in advance to prepare the dry land. The seed sowing was carried out evenly using a hand and hoe in the pre-moistened seedbed, following the recommended seed rate of 80–100 kg/ha. Regarding high-density plantation, a seed rate of 40 grams per square meter was used for a plot size of 2 by 1.5 square meters with a spacing of 5 by 5 centimeters. Each experimental plot was uniformly fertilized with FYM during bed preparation at a rate of 2 kg per square meter, and the urea, DAP, and MOP of 12, 6, and 4 kg/ha were administered, respectively. DAP and MOP were applied at full basal dosages, whereas urea was applied in split doses. The first basal dose of 4 kg was administered along with DAP and MOP during bed preparation, and the remaining two equal split doses of urea of 4 kg were top dressed at two different periods, one at the tillering stage and another just before the blooming stage. For managing weeds, two hand weeding were done with the help of "Khurpi" after 30 days of sowing and another 45 days after sowing. No considerable irrigation was employed, as rice was cultivated in rainfed conditions. Neither fungicide nor insecticide was sprayed for controlling pests and insects. The climatic details of the study area are presented in Figure 2.

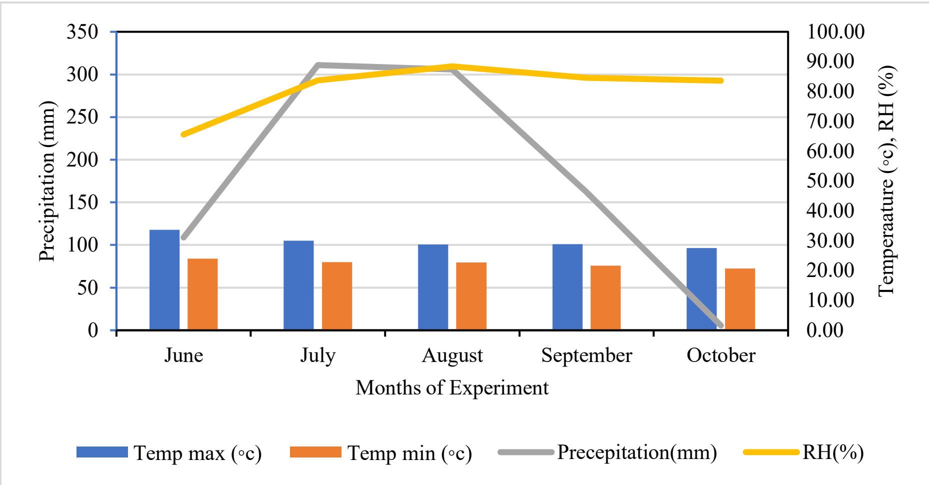

Figure 2. Agro-meteorological status during the study period.

2.3. Data Collection

Various agronomical data were collected, including tiller number per plant and average plant height acquired during the vegetative stage of the plant. After physiological maturity, each plot was harvested for the determination of yield contributing parameters like total plot yield, total grain yield per plant, and thousand-grain weight, along with other parameters like panicle length, number of primary branches per panicle, number of grains per primary branch, total grains per panicle, average grain length, and width, which were collected accordingly. A measuring scale measured the statistics for the height of the plant; a vernier caliper measured the grain's length and width, and a weighing balance determined the yield.

2.4. Statistical Analysis

All the data were subjected to statistical analysis separately using SAS version 3.81. Different tests were used for data analysis: PROC MIXED for ANOVA, PROC CORR for correlation and heatmap, and PROC CLUSTER for cluster gram. The difference among treatment means was compared using the least significant difference test at a 5% probability level.

3. Result and Discussion

3.1. Tillers Per Plant

The results of the ANOVA study demonstrated a statistically significant difference ($p \leq 0.05$) among the tested genotypes for the number of tillers per plant. Tiller per plant ranged from 3 to 9, with a mean value of 4.63. The variety with the highest number of tillers per plant was Rai Manuwa, with a count of 9. Taichi had the second-highest count with six tillers, while Askote had the lowest count of 3. Only five genotypes exhibited a higher number of tillers per plant than the average, whereas the remaining genotypes had a lower value than the average (Figure 3). This trait may lead to a higher panicle number and, eventually, a higher grain yield (Chang et al., 2020). This result is aligned with the previous findings, which have reported that tiller per plant varied significantly among genotypes (Shrestha et al., 2021).

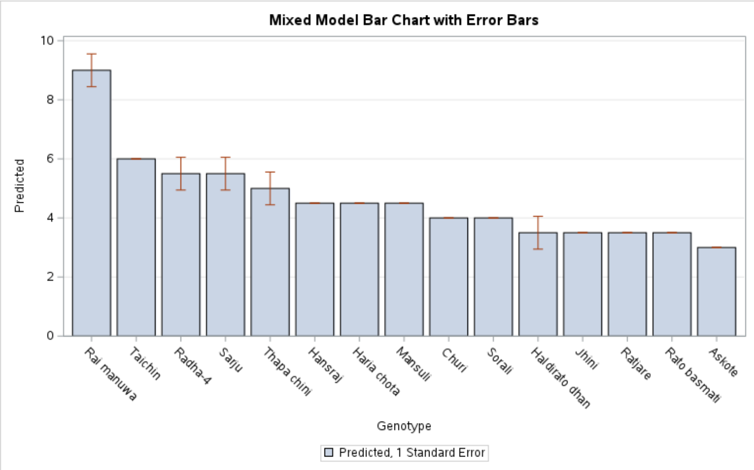

Figure 3. Mixed model bar chart with error bars for tillers number per plant.

3.2. Plant Height

There was a highly significant difference (p≤0.001) among different genotypes for plant height. The plant height varied from 73 cm to 146 cm, with a mean value of 112.4 cm. Rai Manuwa (146 cm.) displayed the longest plant height, which was statistically at par with Hansraj (133 cm.) and Ratjare (132 cm); similarly, the shortest plant height was displayed by Taichin (73 cm.), which is statistically similar to Radha-4 (78.5 cm.). Plant height varied across the genotypes: six showed a height over 120 cm, three were between the 110–120 cm range, and the remaining six were below 110 cm (Figure 4). Plant height is a crucial growth parameter for any crop since it determines or modifies characteristics contributing to yield, which determines grain production. The findings of this study are aligned with previous research, which has documented that high-yield rice varieties usually have higher plant height (Gautam et al., 2018).

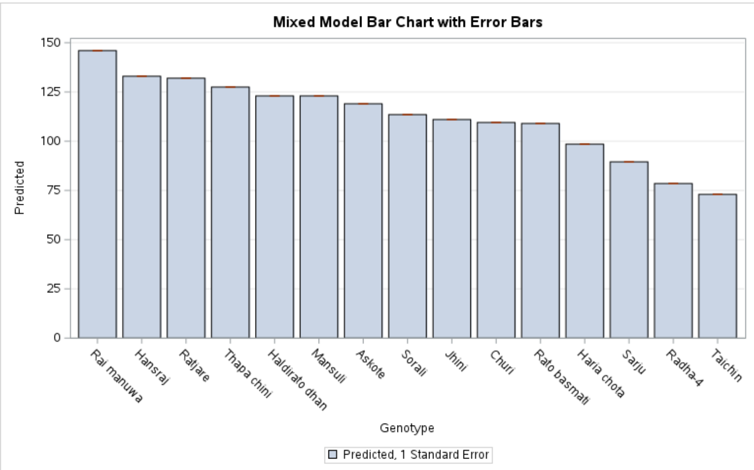

Figure 4. Mixed model bar charts with error bars for plant height.

3.3. Panicle Length

ANOVA showed a significant difference (p≤0.05) between different genotypes for panicle length. The panicle length ranged from 19 to 27.5 cm, with a mean value of 23.67 cm. The highest panicle length was found in Rai manuwa (27.5 cm.), which was statistically at par with Taichin (27.5 cm.), followed by Jhini (25 cm.), Sarju (25 cm.), and Mansuli (24.5 cm.). The lowest panicle length was recorded in Sorali (19 cm.). The frequency distribution showed that seven genotypes had panicle lengths greater than the mean, and eight genotypes had panicle lengths less than the mean (Figure 5). A similar result of panicle length ranging from 14.67 to 32.33 cm was also reported by Jasmin et al. (2024).

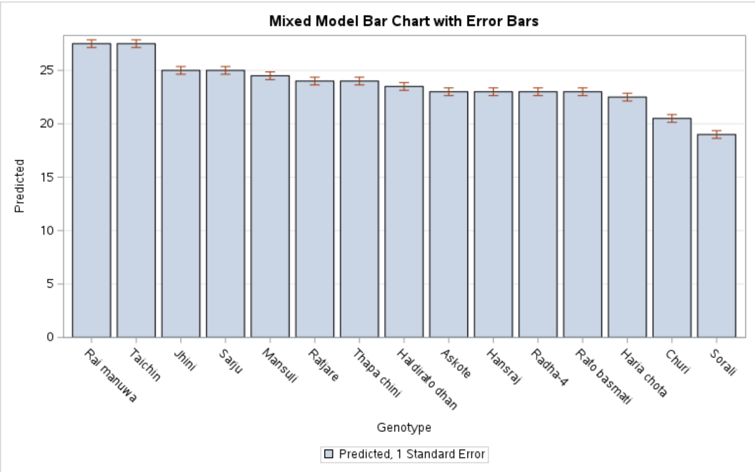

Figure 5. Mixed model bar charts with error bars for panicle length.

3.4. Grain Yield Per Plant

Grain yield per plant varied significantly ($p \leq 0.05$) between different genotypes of rice landraces. The grain yield per plant ranged from 0.96 to 16.625 gm, with an average value of 5.82 gm. The highest grain yield per plant was observed in Rai Manuwa, with a recorded weight of 16.63 grams. Taichin followed this with 8.255 grams, Jhini with 7.17 grams and Radha-4 with 6.68 grams. Furthermore, the Sorali variety exhibited the lowest grain yield per plant, measuring 0.96 grams. Out of the total genotypes, 8 had a grain yield that exceeded the mean value, while the remaining genotypes had a grain yield lower than the mean value (Figure 6). A study on genetic variation in upland rice landraces found that the genotypic coefficient of variation was highest for grain yield per plant, indicating that genetic variation substantially influences grain production (Gurung et al., 2018). Similar results of grain yield per plant were also reported by Crowell et al. (2016).

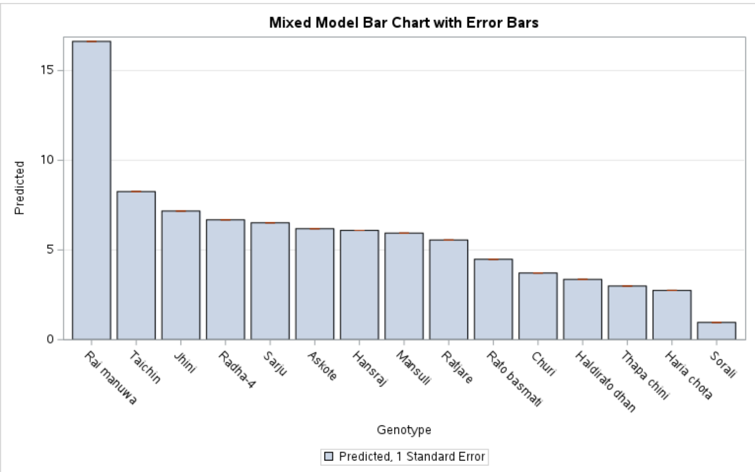

Figure 6. Mixed model bar charts with error bars for grain yield per plant.

3.5. Thousand Grain Weight

ANOVA showed a highly significant difference ($p \leq 0.001$) in thousand-grain weight for the genotype. The mean for the thousand-grain weight was found to be 19.87 gm. Churi (26.58 gm) had the highest thousand grain weight, followed by Radha-4 (24.86 gm) and Askote (22.62 gm). Sorali (15.66 gm) had the lowest thousand-grain weight, which is statistically similar to Ratjare (16.04 gm) (Figure 7). This result is aligned with the finding of Acharya et al. (2024), who reported that thousand-grain weight ranged from 18 to 26 gm. Roy et al. (2014) studied twelve rice varieties and found that thousand-grain weight, a major yield-determining component, is a hereditary trait least affected by the environment. This result is also consistent with the findings of Khatun et al. (2020).

3.6. Grain Length and Width

The mean grain length of genotypes was 0.83 mm. ANOVA found a non-significant variation in grain length. The maximum grain length was reported in Jhini (0.91 mm), and the lowest was measured in Sorali (0.635 mm). Eleven genotypes had grain lengths longer than the mean value, and four genotypes had less than the mean value (Figure 8). The average grain width was 0.21 mm. ANOVA showed that the tested genotypes did not vary significantly for grain width. The widest grains were found in Thapa Chini (0.23 mm), and the least wide ones were found in Sorali (0.19 mm). Three genotypes had grain widths the same as the mean value, two genotypes had grain widths less than 0.21 mm, and nine had grain widths greater than the mean value (Figure 9). Grain size and shape are critical for understanding genotypes' genetic and phenotypic structure since they can influence grain production and milling quality (Kishore et al., 2015). Ata-Ul-Karim et al. (2022) also reported a similar result of grain length ranging from 9.7 mm to 11.1 mm and grain width ranging from 2.3 mm to 2.7 mm.

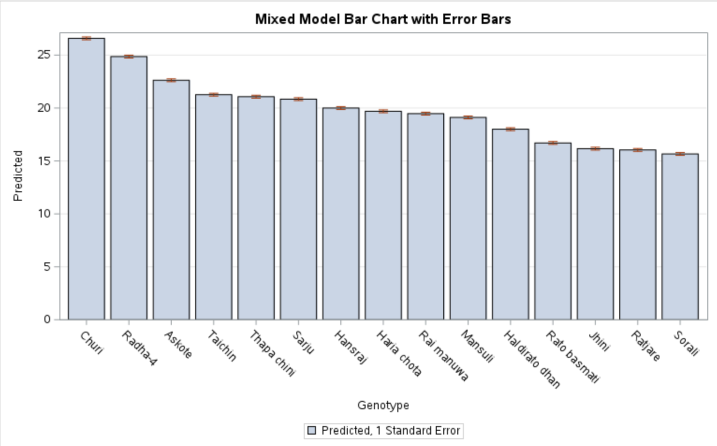

Figure 7. Mixed model bar charts with error bars for thousand-grain weight.

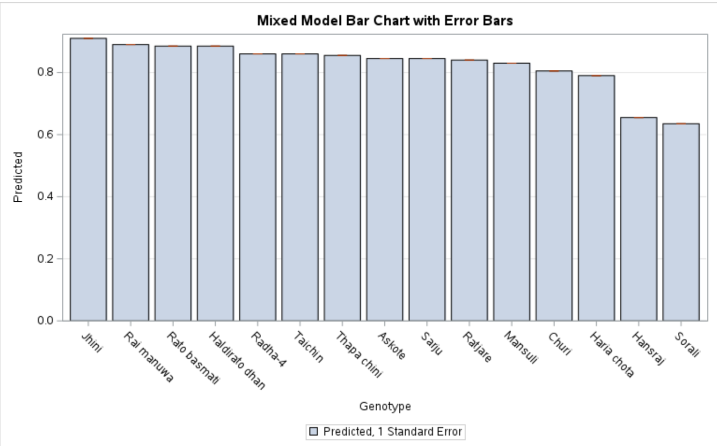

Figure 8. Mixed model bar charts with error bars for grain length.

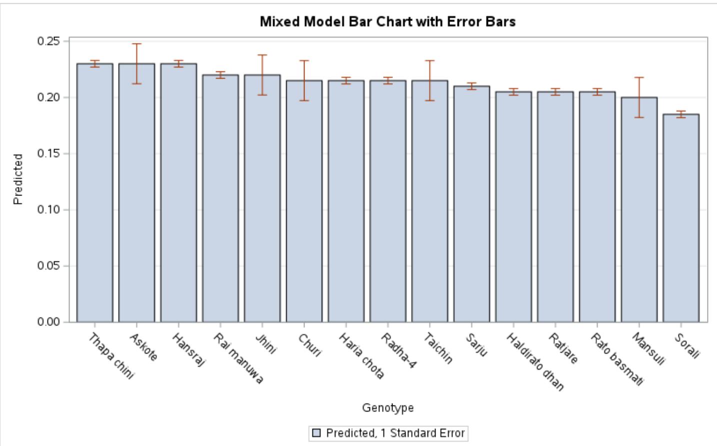

Figure 9. Mixed model bar charts with error bars for grain width.

3.7. Correlation Study

Total grain yield per plant showed a highly significant positive correlation with average tiller per plant (0.78***), followed by average panicle length (0.77***), indicating that grain per plant increased as number of panicles per plant increased and panicle length but showed non-significant positive correlation with average plant height (0.2), number of grains per primary branch in panicle (0.29), and negative correlation with days of 50% flowering (-0.22) as shown in Figure 10. Parimala et al. (2023) found a significant positive correlation between grain yield per plant and days to 50% flowering. Average panicle length significantly correlated with tiller per plant (0.6*). Total plot yield showed a non-significant positive correlation with tiller per plant (0.25), average panicle length (0.29), number of grains per primary branch (0.06), and primary branch per panicle (0.11). At the same time, there was a negative correlation with days of 50% flowering (-0.06). Vitrakoti et al. (2017) also reported a significant negative correlation with days to flowering and a non-significant positive correlation with panicle length. There was a non-significant positive correlation between grain yield and the number of primary branches per panicle and grain per primary branch, as reported by Karim et al. (2014). Thousand-grain weight showed a non-significant positive correlation with grain average length (0.06), width (0.34), and days of 50% flowering (0.17). In contrast, there was a negative correlation with the tiller per plant (-0.37), average panicle length (-0.25), and number of primary branches per panicle (-0.38). Martínez-Eixarch et al. (2015) reported a non-significant negative correlation with tiller per square meter. Similarly, Poudel et al. (2023) also reported the non-significant negative correlation of thousand-grain weight with panicle length.

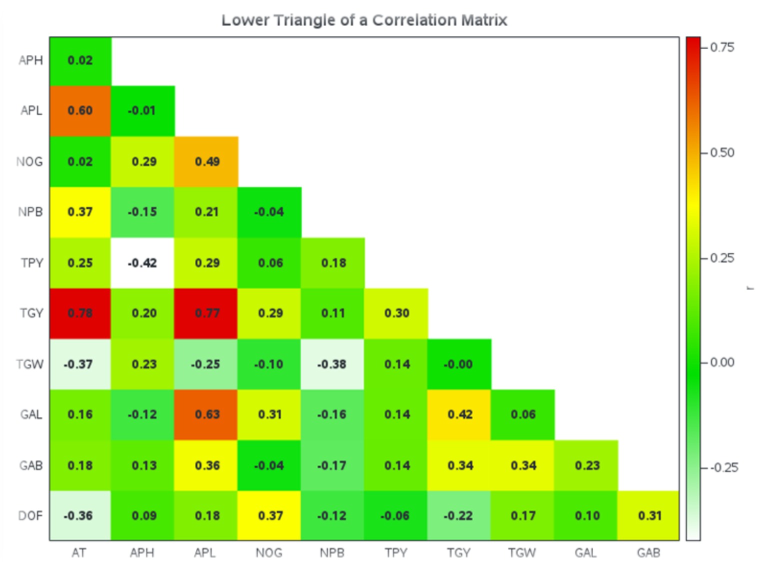

Figure 10. Correlation matrix among different traits for fifteen rice landraces (Note: AT: Average Tiller per Plant; APH: Average Plant Height; APL: Average Panicle Length; NOG: Number of Grains per Primary Branch in Panicle; NPB: Number of Primary branches per panicle; TPY: Grain Yield per Plot; TGY: Total Grain Yield per Plant; TGW: Thousand Grain Weight; GAL: Grain Length; GAB: Grain Width)

3.8. Cluster Analysis

Genotypes were clustered together based on various variables, including the number of tillers per plant, plant height, panicle length, number of grains per primary branch in the panicle, number of primary branches per panicle, total plot yield, total grain yield per plant, thousand-grain weight, the average length of grains, average width of grains, and days to 50% flowering as shown in Figure 11. The process of cluster analysis classified fifteen different genotypes of rice landraces into four distinct clusters. Cluster 1 comprised 11 genotypes, accounting for 73.33% of the total genotypes. It includes Mansuli, Rato Basmati, Haria Chota, Radha-4 (check), Haldirato Dhan, Askote, Hansraj, Ratjare, Jhini, Churi, and Thapa Chini. This cluster had moderate genotypes across all variables, except for days to 50% flowering, for which this cluster displayed a higher value. Cluster 2 consisted of 2 genotypes, representing 13.33% of total genotypes. It includes Sarju and Taichin. This cluster represents genotypes with the maximum number of primary branches per panicle and total plot yield. They have a moderate number of tillers per plant, average panicle length, total grain yield per plant, grain length, and grain width. However, they have the lowest plant height. Cluster 3 comprises one genotype, Rai Manuwa, representing 6.67% of the total genotypes. This cluster represents the genotype with the greatest tiller per plant, average plant height, panicle length, number of grains per primary panicle branch, total grain yield per plant, grain length, and width. Cluster 4 consisted of 1 genotype, Sorali, constituting 6.67% of the total genotypes. This cluster indicates the genotype with the lowest tiller per plant, the number of grains per primary panicle branch, total plot yield, total grain yield per plant, thousand-grain weight, grain length and width, and days to 50% flowering. Multiple authors reported the presence of variation among different genotypes, classifying them into different numbers of distinct clusters. Hasan et al. (2021) also divided six local rice varieties based on twelve agro-morphological traits. Tadesse Girma et al. (2018) grouped 64 rice genotypes based on seven yield and related traits.

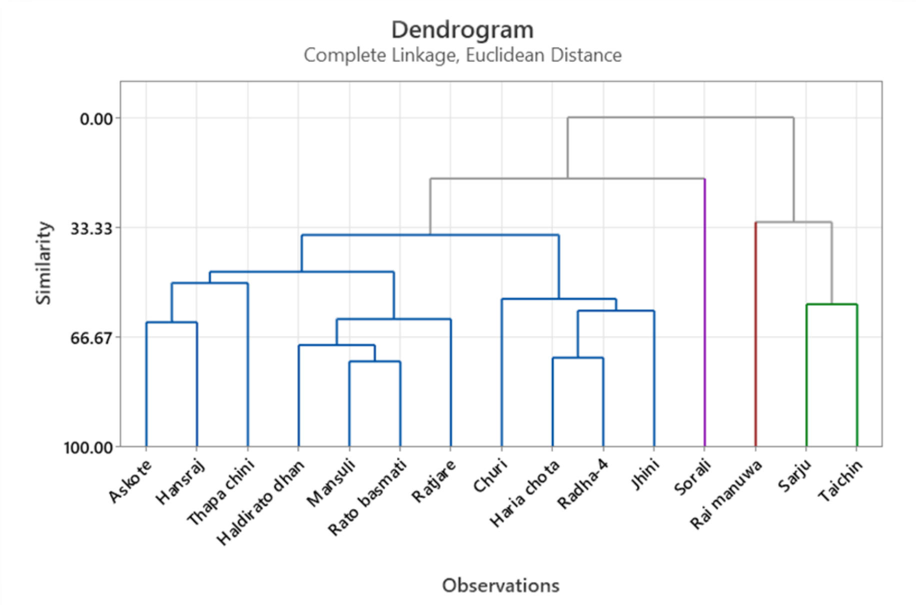

Figure 11. Dendrogram illustrating the similarity index among various rice landraces based on different yield and related traits.

4. Conclusion

Significant differences among various agronomic traits were observed in this study. Rai Manuwa exhibited the highest tiller per plant, plant height, grain yield per plant, and panicle length, suggesting a greater potential for drought tolerance. Sarju, Haria chota, and Radha-4 also showed excellent results, with a high yield per plot of 3.21 t/ha, 3.06 t/ha, and 3.06 t/ha, respectively. In contrast, Sorali performs poorly against almost all parameters, indicating poor performance under drought conditions. The correlation analysis showed that total grain yield per plant had a highly significant positive correlation with the average tiller per plant and panicle length. Rice varieties in Cluster 3 (Rai Manuwa) and Cluster 2 (Sarju and Taichin) could be considered for further breeding programs to develop drought-tolerant rice varieties. Conserving and utilizing these landraces in Nepal can help to achieve sustainable agriculture and food security. The study emphasizes the need for continued exploration and conservation of genetic diversity in rice to address the challenges of climate change and water scarcity.

Authors contribution: Conceptualization: Dipak Khanal, Bishnu Datta Pant, Adhiraj Kunwar; Data curation: Dipak Raj Bist, Arati Dhami, Dipesh Chand Yadav, Dhurba Banjade; Investigation: Bishnu Datta Pant, Adhiraj Kunwar; Methodology: Dipak Khanal, Bishnu Datta Pant, Adhiraj Kunwar, Narayan Prasad Belbase; Resources: Dipak Raj Bist, Arati Dhami, Dipesh Chand Yadav; Software: Dipak Khanal, Bishnu Datta Pant, Adhiraj Kunwar; Supervision: Dipak Khanal, Narayan Prasad Belbase, Dhurba Banjade; Validation: Dipak Khanal, Dhurba Banjade; Visualization: Dipak Khanal, Bishnu Datta Pant, Adhiraj Kunwar, Dipesh Chand Yadav; Writing – original draft: Dipak Khanal, Bishnu Datta Pant, Adhiraj Kunwar, Dipak Raj Bist, Arati Dhami; Writing – review & editing: Dipak Khanal, Dipesh Chand Yadav, Dhurba Banjade. All authors have read and agreed to the published version of the manuscript.

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Institutional/Ethical Approval: Not applicable.

Data Availability/Sharing: The datasets used and analyzed during the current study will be made available from the corresponding author upon a reasonable request.

Supplementary Information Availability: Not applicable.

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