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EVALUATION OF RICE (*ORYZA SATIVA* L.) GENOTYPES IN SPRING UNDER DIRECT SEEDED CULTIVATION IN JANAKPUR OF NEPAL

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ABSTRACT: Thirty rice genotypes, including twenty genotypes developed by the International Rice Research Institute (IRRI), four Nepali released varieties as national check and five other variants as international check varieties were selected for action research. Seeds were directly sown in alpha lattice design with two replications in the field of the National Rice Research Program, Hardinath, Dhanusha in March of 2023. The Primary objective of our research was to evaluate the adaptability, and stability of early maturing rice genotypes bred by IRRI. The secondary objective was to analyze the variation of yield-attributing parameters and drought tolerance among genotypes. The data for ten yield attributing parameters were recorded according to IRRI protocol. Analysis of variance revealed that most of the traits were significantly different for genotypes except flag leaf area, grain yield (GY) and panicle length. Genotypes IR132084-B-1327-2-1-B-15 (4.16 t/ha), IR13C149 (3.83 t/ha), IR13C149 (3.83 t/ha), IR 132084-B-1327-2-1-B-16 (3.5 t/ha), IR 127152-3-22-18-1-B-B (3.37 t/ha), and IR 132084-B-1327-2-1-B-16 (3.5 t/ha) were found to be superior for their performance based on GY. The genotypes IR13LT799 (23.75 g), IR 132084-B-1202- 1-3-B-3 (22.5 g), IR132084-B-1327-2-1-B-15 (23 g) IR13C149 (20 g), and IR 127152-3-22-18-1-B-B (18 g) were recorded to have the highest Thousand Grain Weight (TGW). GY was positively correlated with TGW, plant height and tiller per meter square. The highest broad sense heritability (0.77) was observed for GY followed by days to heading (0.72). Most of the phenotypic traits had significant positive correlation with GY revealing that selection pressure on such traits can improve economic yield.

Keywords: Drought, heritability, rice, variety, yield, genotypes, seeds,

Rice is one of the vital cereal crops globally, fulfilling the food demand of more than 3.5 billion people (Roychowdhury et al., 2012; Xu et al., 2021). *Oryza sativa* L. is the most widely cultivated species of rice among 20 genera of Oryza (Fageria, 2007). Globally, rice is cultivated in the area of 165 million hectares with an annual production of 787 megatons (FAO, 2022). On average over the past two decades, Asia shares 90.3% of the global production of Rice. Similarly, America, Africa and Europe share 5.2%, 3.9% and 0.6% of global rice production respectively. The average yield of Rice is 47,642 tones.ha^{-1} in 165,250,620 ha (FAOSTAT, 2023). In Nepal, rice is the prime staple food crop grown in an area of 1.49 million hectares, the production of rice is 5.62 million tones with an average national yield of 3.82 tones.ha^{-1} (CBS, 2021). The primary food crop in Nepal is rice, which provides a considerable portion of people's livelihoods and greatly boosts the nation's economy. In Nepal, mainly in the monsoon season, rice is cultivated due to the availability of irrigation facilities. Recent climate change has imposed drought conditions in most parts of the world (Farooq et al., 2023). The cultivation of rice is limited to the monsoon season in Nepal (Poudel et al., 2020). Spring rice is cultivated in those areas where irrigation facilities are available throughout the year (Subedi et al., 2018). In the spring season early, maturing varieties are suitable to escape monsoon rainfall in Nepal (Tiwari et al., 2019). The primary goal of rice breeding across the globe is to develop high-yielding rice genotypes to meet the global food demand (Xu et al., 2021). The demand for fine-grain rice constitutes one-fourth of total rice demand whereas the demand for coarse rice is projected to be 3.5 Mt by 2025 (Choudhary et al., 2022). Nepal exported rice worth $3439 but there was an import of 578767 tons of rice worth NRs 30.58 billion US $ 3128384690 in 2022 (NTIP, 2023; Trend Economy, 2023). Similarly, 166,486 tons of rice were imported in the first seven months of 2023. In the fiscal year 2019/20, there was an import of 1,722,879 metric tons worth NRs. 43,976.6 million (TKP, 2023).

Farmer prefers to cultivate legumes instead of spring rice as these crops need moderate soil moisture. The major problems associated with the decreased area are higher and increased cost of production due to crop weed competition, the lower yield of the genotypes, increased labor scarcity, slower mechanization, drought condition and lack of improved variety suitable for the region (Poudel et al., 2014). The surface water availability and groundwater table are decreasing day by day. The erratic rainfall patterns are increasing the problem during the cultivation of rice. Drought-resistant varieties which demand less water are very useful in the present scenario (Majumder et al., 2021). Drought is the major limitation for rice production in rainfed ecosystems leading to yield loss of 13–35% every year which affects 46 million hectares of rainfed lowland and 10 million ha of upland rice ecosystems in the Asian-Pacific region (Muthu et al., 2020). Among the areas under rice cultivation, more than 30% of the land is under rainfed ecosystems subject to severe drought or water-limited conditions (Sandhu et al., 2014). There is a need to increase rice production as the import of rice is increasing annually (Kattel et al., 2023; TKP, 2023). Only 19 crops from local landraces have been employed to generate 41 varieties, indicating the restricted utilization of local landraces. Landraces mostly underwent mass or pure line selection to improve their genetic makeup (K.C. et al., 2021). Recurrent selection breeding strategy within the elite population with the integration of modern tools and technologies can assist in boosting the genetic gains in IRRI's drought breeding program. The elite breeding panel identified in this study forms an easily available and highly enriched genetic resource for future recurrent selection programs to boost genetic gains (Khanna et al., 2022). There are several methods of planting rice. Among them, DSR can be used fully in those areas with water deficit conditions and low labor availability. There are a few constraints associated with Direct Seeded Rice (DSR), such as weed infestation, crop lodging and nutrient loss (Raut et al., 2020).

DSR in the spring season has been reported to be eco-friendly and sustainable on account of less methane emission which is a prominent greenhouse gas. Out of the 75 varieties of rice, 25 varieties that have been made public as of 2016 were created using IRRI germplasm (K.C. et al., 2021). In comparison to TPR, Methane emission decreased by 61.1% and 64% respectively in SRI and MSRI. Jain 2014 In lower land (Khet) the emission of CH_4 is significantly higher (102.29 µg CH_4 m^{-2} h^{-1}) than in lower land (*Bari*) (0.91 µg CH_4 m^{-2} h^{-1}). In the absence of puddling, the soil structure can be maintained, which leads to greater yields for succeeding crops as well. The average yield of DSR in dry and wet zones is 5 t/ha and 3.3 t/ha, respectively (Weerakoon et al., 2011). In Bangladesh, DSR is mainly practiced during the pre-monsoon in the rainfed uplands and also during the monsoon in rainfed rice (Shelley et al., 2016). Farmers ranked weed infestation, poor crop establishment, and reduced grain and straw yield in DDSR as the major problems (Dhakal et al., 2015). In the western terai of Nepal, there were comparable yields and lower production ($ 160 ha^{-1} in DSR as compared to TPR). In addition to this, water productivity was found to be greater by 4-18% leading to a net profit of $ 122–232 ha^{-1} (Devkota et al., 2019). In total 17 high-yielding, drought-tolerant rice varieties have been successfully developed and released throughout South Asia, Southeast Asia, and Africa as a result of the direct selection strategy for grain yield under drought conditions (Kumar et al., 2014). Utilizing conventional and molecular methods, the accumulation, preservation, characterization, tagging, mapping, and genetic improvement of Nepalese rice landraces can be strengthened (K.C. et al., 2021). It has been necessary to create rice varieties that are resistant to drought and use less fertilizer, as well as to give farmers, who are poor, marginalized, and vulnerable more options for rice types suited to stressful settings (Kharel et al., 2018). The goal of Nepal's rice breeding program is to create rice varieties with increased yield potential. Numerous rice varieties have been created and adapted in the nation's various agro-ecosystems (Joshi, 2014). The current initiatives of IRRI include breeding better rice varieties along with an improved farming system for market-driven product development for capacity building at different levels with the ultimate goal of strengthening the agri-food system (IRRI, 2023). The general objective of the research was to select early maturing, drought-tolerant genotypes of Rice. The specific objectives were to evaluate the rice genotypes for yield and yield attributing traits for their performance and to find out the correlation heritability of various traits of rice genotypes. Similarly, we intended to identify the high-yielding, disease and pest-resistant spring rice genotypes through DSR sowing.

2. MATERIALS AND METHODS

The field trial was conducted from March to July 2023 at the NARC research station i.e., National Rice Research Program, Hardinath, Dhanusha. NRRP is located in the Madhesh Province of Nepal (Figure 1).

(Source: Arc Map GIS, 2023)

2.1 Soil properties

A composite soil sample was taken from the experimental site after the land preparation from the field at different depths (0-30) cm. The soil was dried, grounded, and sieved through a 2 mm sieve and chemical and physical properties were analyzed in Soil Laboratorty, NRRP, Hardinath, and Dhanusha. The soil was sandy loam with slightly acidic pH, medium organic matter, and high in phosphorous content, medium in potassium and low in nitrogen content (Table 1). There was a medium presence of micronutrients.

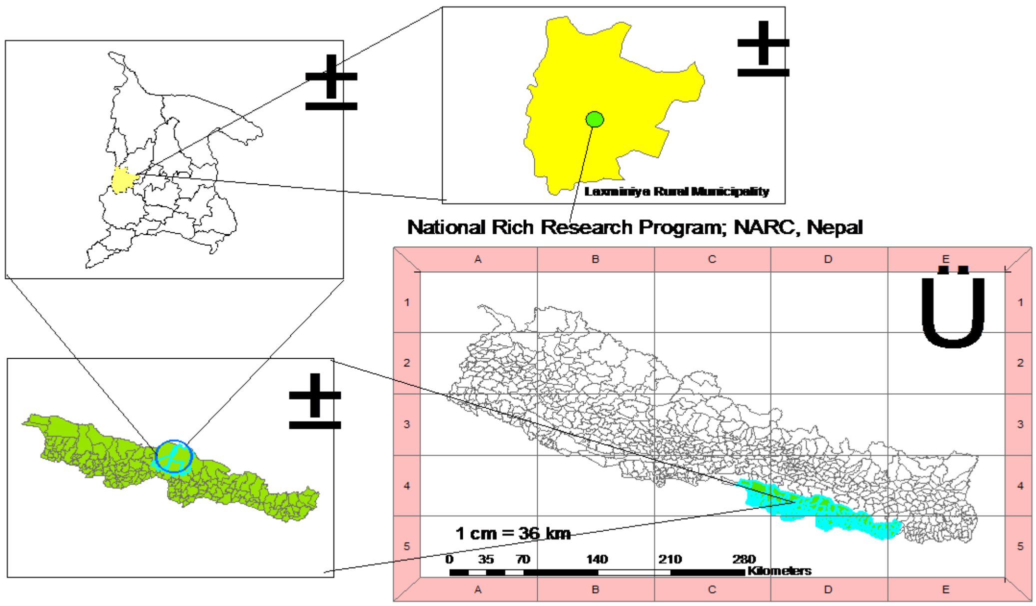
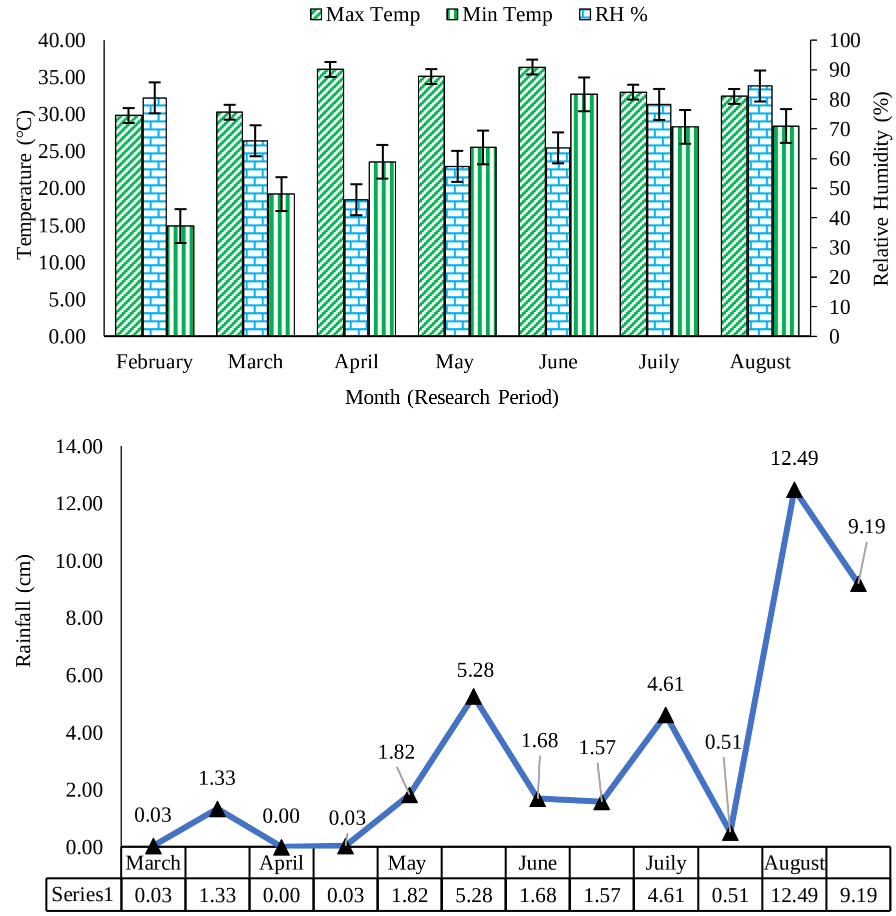


Figure 1. Map showing the location of the experimental site

Table-1: Soil properties at the experimental field, Hardinath, Dhanusha in spring, 2023-24

S.N.	Soil property	Content	Method
1.	Physical properties		
a.	Sand	47.78 %	Hydrometer
b.	Clay	11.85 %	
c.	Silt	40.37 %	
2.	Chemical properties		
a.	Soil pH value	6.55 (slightly acidic)	pH meter
b.	Soil organic matter (%)	1.16 (medium)	Walkey and Black method
c.	Total nitrogen content (%)	0.07 (low)	Micro-Kjeldahl method
d.	Available potassium (K_2O) (kg/ha)	135.04 (medium)	Modified Olsens bicarbonate method
e.	Available Phosphorus (P_2O_5) (kg/ha)	29.02 (high)	Flame photometer
f.	Boron (B) (ppm)	0.73 (medium)	
g.	Zinc (Zn) (ppm)	1.15 (medium)	
3.	Soil texture	Sandy loam	
4.	Soil type	Fluvial non-calcareous	

(Source: NRRP, NARC, 2023)



(Source: NRRP, 2023)

Figure-1.: Temperature, relative humidity, and Rainfall pattern at NRRP in research period 2023

Weather Data

Geographically, the station is located at 73 meters above mean sea level and lies at the latitude of 26°, 47’46.5’’N and longitude of 85°57’49.35’’E with a subtropical climate. The maximum temperature in summer is up to 44°C and the minimum temperature in winter is 4.8°C (Figure 2). The average annual rainfall is 1281 mm. Maximum precipitation occurs in July, and 80% of the total annual rainfall comes between June and September (Figure 2).

Plant material and Experimental layout

The seed of 21 genotypes 4 local check varieties and 5 international checks were made available by National Rice Research Program, NARC. The genotypes along with check varieties were tabulated along with plot arrangement. The plant materials used in the research were the genotypes provided by IRRI, Philippines to NRRP. Five international check varieties and four national check varieties were provided by NRRP, NARC. In terms of data connectivity across years for reliable estimates or predictions, Khanna et al. (2022) observed good data connectivity of genotypes with long-term checks (IR64, Swarna, Sahbhagi Dhan, IRRI 154) across the years. The experiment was laid out in an Alfa lattice design with 2 replications. There were 3 blocks within replication and 10 genotypes within each block. The genotypes were allotted randomly to the 30 plots in each replication. Seed was directly sown in 5 rows per plot line with row to row spacing of 25 cm in each plot area of 15m^2 (5m×3m) on March 17, 2023. (Figure 5). The row to row spacing was 30 cm. block to block spacing was 0.5 m and the space between two replications was 1 m (Figure 3).

Crop management

Land preparation was performed by ploughing two times followed by levelling. Chemical fertilizers were applied at the rate of 130:40:40 kg/ha of Nitrogen, Phosphorus, and Potassium respectively. The full dose of phosphorus and Potassium and half dose of Nitrogen were applied at the time of sowing. The remaining half dose of Nitrogen was applied at the booting stage. Two manual weeding were carried out at 25 Days After Sowing DAS and 60 DAS. The principal factors governing the nutrient dynamics in DSR are land preparation and water management (Farooq et al., 2011). The recommended level of Nitrogen in dry-DSR is 150-180 Kg/ha which is 40-70 Kg higher than that for TPR and wet-DSR. Phosphate and potassium are applied at the same rate for TPR and Wet-DSR i.e. 70 and 80 Kg/ha respectively (Lee et al., 2002; NSSRC, 2023). Pandey (2019) found that the application of 80 kg of Nitrogen improved the crop growth, grain yield and profitability of direct seeded rice under mid-western mid-hills in Nepal (Pandey et al., 2019). Similarly, a greater incidence of diseases was observed with a high amount of Nitrogen application (Lee et al., 2002).

Figure- 3: Direct line sowing of genotypes and flooding irrigation by submersible pump

The flooding method of irrigation was practiced once a fortnight with underground water from an electric-operated submersible pump (Figure 3). Precise water management is very important in dry drilled seeded rice, especially during the crop emergence phase (Balasubramanian & Hill, 2002; Kumar & Ladha, 2011). At present rice research has been shifted to the development of drought-tolerant genotypes. In the rainy season in terrain plain areas water logging is a major problem so submergence tolerant genotypes were devolved by inoculating the Sub-1 gene. Swarna Sub-1 variety released recently is submergence tolerant. Similarly, the introduction of the sub-1 gene in the Sambha Mansuli variety has helped to improve yield across Nepal (Joshi, 2014). The uniform spread of water in dry-DSR reduces the problem of submergence as well as drainage. Precise land levelling saves up to 25% of irrigation. The field should be saturated with water at the three-leaf stage which helps in adequate germination, effective seedling establishment, and plant growth (Kumar & Ladha, 2011). The field needs to be flooded one week earlier to avoid water stress during flowering (Bouman, 2007). Irrigation management during critical stages and foliar spray of Boron during flowering decreases the panicle sterility in DSR (Rehman et al., 2014). As per necessity, the insecticide Lambda-cyhalothrin was administered at the prescribed rate of 20 ml per 15 L knapsack sprayer. Halo sulfuron-methyl was sprayed at a0 mL per 15 L sprayer for broad-leaf weeds. The severity of rice blast increases under limited water conditions (Farooq et al., 2011).

Data collection

The data were recorded on individual plants and plot basis for fourteen quantitative traits at the appropriate growth stage of the crop according to the standard evaluation system (SES) for rice (IRRI, 1996). Data measurement was done according to the IRRI Protocol (Table 2). Five plants per genotype were tagged randomly for recording observation from each plot for all the quantitative traits except for germination, seed vigor and phenotypic acceptability scoring (Figure 4).

a. Canopy cover measurement using android application Canopeo

b. Periodic field monitoring

Figure-4: Periodic Field Monitoring and data collection

The whole plants from plots were taken into consideration for reproductive stage observations like days to heading, flowering and maturity, thousand-grain weight, and grain yield per hectare. The flag leaf (topmost leaf) of the five sampled plants was taken at the time of flowering and the area of the flag leaf was determined from K(L*W), where L is the leaf length, W is the maximum width of the leaf, and K is 0.73 for dry-season crops and 0.75 for wet-season crops. This method is unbiased; estimates should have no more than 5% error (Palaniswamy & Gomez, 1974; Shi et al., 2019).

Table- 2: IRRI protocol for data measurement

S.N	Data Parameters	Particulars
1.	10 DAS seedling emergence	Visual evaluation of the percentage of seedling emergence (%) (1: 81-100% of the plot has germinated 3: 61-80% of the plot has germinated 5: 41-60% of the plot has germinated 7: 21-40% of the plot has germinated 9: 0-20% of the plot has germinated)
2.	10 DAS early vegetative vigor	Visual evaluation of the greenness and business (1: Extra vigorous (very fast growing; plants at 5-6 leaf stage have 2 or more tillers in the majority of the population 3: Vigorous (fast-growing; plants at the 4-5 leaf stage have 1-2 tillers in the majority of the population) 5: Normal (plants at 4-5 leaf stage) 7: Weak (plants somewhat stunted; 3-4 leaves; thin population; no tiller formation) 9: Very weak (stunted growth; yellowing of leaves)
3.	Canopy cover at 30, 60 and 90 DAS (Figure 6)	Using Canopeo (fractional green canopy cover 0-100%); Canpeo is a mobile app available in the Play Store. In the absence of the Canopeo app, scale can be used (1: Highly vigorous plats providing 81-100% canopy cover 3: Vigorous plants providing 61-80% canopy cover 5: Normal growing plants providing 41-60% canopy cover 7: Less vigorous plants with slight stunting providing 21-40% canopy cover 9: Poorly growing and stunted plants providing less than 20% canopy cover)
4.	Heading Date	Days required for heading in >50% of the plot area
5.	Flowering date	Days required for heading in >80% of the plot area
6.	Plant height	Measure five random plants within the plot from soil to the tip of the tallest panicle; must range from 90 cm
7.	Cleaned thousand grain weight	Weight of cleaned seeds taken from plants from 50cm of the same row in a plot without getting the border and dried at 70 deg for 5 day
8.	Harvest date	Date of plant harvest
9.	Actual yield (g)	Actual plot yield after drying

10.	Phenotypic Acceptability (PAcp)	The score should reflect the overall acceptability of the variety in the site where it is being grown. PAcp scoring is done two weeks before harvest. (1: Excellent 3: Good 5: Fair 7: Poor 9: Unacceptable)

(Source: IRRI, 2002)

Statistical analysis

The observed data was entered in a Google spreadsheet. The recorded dates for heading, 80% flowering and maturity were converted to days from sowing and the yield parameters were converted to per hectare. Data processing was done using Microsoft Office Excel 2019. The data analysis was done by R Studio V.4.2.2 and PB tool software. Data collected on various growths, yield, and yield components were processed by using Excel 2019 and subjected to Analysis of Variance (ANOVA) by using the PB tool. The treatment means were compared by the Least Significant Difference (LSD) test at a 5% level (Gomez and Gomez, 1984). The collected data were subjected to the multivariable analysis done using the statistical software packages of Minitab version 14 (Mohammadi & Prasanna, 2003). The data was submitted to Average Linkage cluster analysis based on mean Euclidean distances and similarity index (Sneath and Sokal, 1973).

$$\text{Grain yield}\left(\frac{\text{kg}}{\text{ha}}\right)\text{at 12 \% moisture} = \frac{(100-\text{M}) \times \text{Plot yield(kg)}}{(100-12) \times \text{Neplotarea}(m^2)} \times 10000\ (m^2)$$

Where,

M is the grain moisture content in percentage

In addition, descriptive statistics such as mean, range, standard deviation and coefficient of variation (CV) were calculated for each trait. Mean comparisons were performed using Tukey's test using R studio. Correlation coefficients were analyzed using MS Excel to study the relationship between traits. In addition, descriptive statistics such as mean, range, standard deviation and coefficient of variation (CV) were calculated for each trait. Mean comparisons were performed using Tukey's test using R studio.

Correlation and heritability analysis

Correlation coefficients were analyzed using MS Excel to study the relationship between traits. The correlation of yield attributing and quantitative traits with grain yield described the inter-relationship among them. It merely indicates the intensity of the association. Phenotypic correlation reflects the observed relationship, while genotypic correlation underlines the true relationship among characters. Selection procedures could be varied depending on the relative contribution of each. The correlation indicates the overall association between characters due to linkage, pleiotropy and physiological association. For rational improvement of yield and its components, the understanding of correlation is very useful. A positive value of r shows that the changes of two variables are in the same direction, i.e. high values of one variable are associated with low values of the other variable. The correlation coefficient is independent of the unit of measurement. Its value lies between -1 and 1. It measures the degree and direction of association between two or more variables. Determining the correlation between different traits, particularly grain yield and its components and also determining causal relationships provide the breeders with the opportunity to select the most appropriate combination of components that will lead to greater yield (Moradi et al., 2010).

The heritability alone does not provide an idea about the expected gain in the next generation but combined with the estimates of genetic advance and the change in mean value between generations, it can give an idea of how much can the next generation gain from the present generation. Success in crop improvement generally depends on the magnitude of genetic variability and the extent to which the desirable character is heritable. Knowledge of the genetic association between grain yield and its components can help breeders improve the efficiency of selection (Ojha et al., 2019). Genetic parameters are vital to estimate the cause of variation among genotypes. The interaction of genotypes and environment is visualized by the calculation of genotypic variation, phenotypic variation, coefficient of variation, broad sense heritability etc. The genetic analysis of quantitative traits is a prerequisite for plant breeding programmes, which can lead to a systemic method of design and the appropriate planning of plant breeding strategies.

Table 3. Formulas for calculation of Phenotypic variance

S.N.	Heritability parameters	Formula	Variables
1	Phenotypic Variance	$\sigma^2_p = \sigma^2_g + \sigma^2_{ge} + \sigma^2_\varepsilon$	σ^2_p=Phenotypic variance, σ^2_g = genotypic variance, σ^2_{ge} =variance of G×E and σ^2_ε = error variance
2	Phenotypic coefficient of variation (PCV)	$PCV = (\sqrt{(\sigma\text{^}2\ P)}/X \times 100$	Where: σ^2_p = phenotypic variance; X= mean of the trait
3	Genotypic coefficient of variation (GCV)	$GCV = (\sqrt{(\sigma\text{^}2\ g)})/X \times 100$	Where; σ^2_g = genotypic variance; X = mean of the trait
4	Broad sense heritability	$h^2B = \frac{\sigma 2g}{\sigma 2P}$	Where: σ^2P=genotypic variance; σ^2g = phenotypic variance
5	Expected genetic advance	$GA = K*\sqrt{}\ (\sigma^2P)\times h^2b$	Where: K = constant that represents the selection intensity (when k is 5% the value is 2.06); $\sqrt{\sigma^2 p}$= standard deviation of phenotypic variance; h^2b = heritability in a broad sense

(Source: Ojha et al., 2019)

RESULTS AND DISCUSSION

The data analysis of phenotypic traits at the vegetative stage like plant height and leaf area, showed highly significant ($p<0.01$) results. Similarly evaluated rice genotypes were found highly significant for reproductive stage parameters like days to heading, thousand grain weight and grain yield.

3.1 Seedling emergence and vegetative vigour

The initial data at the germination phase was based on odd numeric scoring from 0 to 9. The results of emergence and vegetative vigour were satisfactory at 15 days after sowing (DAS). Thirty-six out of 60 plots had 81-100% seedling emergence 15 days after sowing (DAS) whereas 19 plots had 61-80% seedling emergence 15 DAS. Some of the genotypes with 81-100% seedling emergence were IR 132084-B-763-1-2-B-21, IR 132084-B-1456-1-2-B-3, IR 116713-B-B-50-1-B-B, IR 127152-2-11-14-1-B-B, IR 127152-2-11-22-1-B-B, IR 127152-3-22-18-1-B-B, IR 127153-2-3-14-1-B-B, IR 127153-2-3-5-1-B-B, and IR 127165-1-27-2-1-B-B (Table 4). Swain et al., (2014) reported that drought stress adversely affects seed germination and seedling growth. The speed of germination in plants is significantly influenced by barriers to water absorption in the hull and pericarp, and the genotype ranking remained stable over the years and water availability conditions (Chao et al., 2021). The major constraints for DSR in the South Asian region include rainfed culture, poor drainage, and slow economic growth (Pandey, 2002). None of the genotypes were fully vigorous at 15 DAS according to 0-9 scoring.

Some of the genotypes with weak vegetative vigor were IR 116713-B-B-50-1-B-B, IR 127152-2-11-14-1-B-B, IR 127152-2-11-22-1-B-B, IR 127153-2-3-5-1-B-B, IR 127165-1-27-2-1-B-B, IR 132084-B-1456-1-2-B-3, IR12C170, IR13C149, IR 132084-B-1327-2-1-B-18, IR 93945-27-1-2-1 etc (Table 4). The decrease in overall vigor is caused by dry soil and cold environmental conditions. Most of the other growth parameters among genotypes are significantly influenced by drought stress (Yehia & Katab, 2018). The inhibition of radicle emergence is mainly because of a decrease in the water potential gradient between the external environment and the seed and this impairs seedling height as a consequence (Sokoto, 2014). Genotypes exposed to a water deficit in the field germinated a little more slowly than grain from fields with a greater water supply. The management of field crop establishment and paddy germination in food processing is affected by genotypic diversity in vegetative vigor (Chao et al., 2021).

Table 4. Seedling emergence and seeding vigor of genotypes at 15 DAS

Seedling Emergence (%)	Genotype	Seedling early vegetative vigor	Genotype
81-100	IR 132084-B-763-1-2-B-21	Weak (plants somewhat stunted; 3-4 leaves; thin population; no tiller formation)	IR 116713-B-B-50-1-B-B
	IR 132084-B-1456-1-2-B-3		IR 127152-3-22-18-1-B-B
	IR 132084-B-1456-1-2-B-3		IR 127152-3-22-18-1-B-B
	IR 116713-B-B-50-1-B-B		IR 127153-2-3-14-1-B-B
	IR 127152-2-11-14-1-B-B		IR 127153-2-3-5-1-B-B
	IR 127152-2-11-22-1-B-B		IR 132084-B-1456-1-2-B-3
	IR 127152-3-22-18-1-B-B		IR 132084-B-763-1-2-B-21
	IR 127153-2-3-14-1-B-B		IR12C170

3.2 Canopy cover

At 30 DAS, 68.3% of plants were poorly growing and stunted plants provided less than 20% canopy cover while 28.3 % of plants were less vigorous plants with slight stunting providing 21-40% canopy cover. Only two plots had normal growing plants providing 41-60% canopy cover. At 60 DAS, 45% of plants had normal growing plants providing 41-60% canopy cover. While 20 plots had vigorous plants providing 61-80% canopy cover. Similarly, 10 plots had less vigorous plants with slight stunting providing 21-40% canopy cover and 2 plots had highly vigorous plats providing 81-100% canopy cover. At 90 DAS, 62% of plots had developed highly vigorous plants providing 81-100% canopy cover and 38% of plots had vigorous plants providing 61-80% canopy cover. IR 116713-B-B-50-1-B-B and IR 132084-B-1456-1-2-B-3 had normal growth providing 41-60% canopy cover at 30 and 60 DAS and vigorous growth providing 61-80% canopy cover. The genotype IR 127165-1-27-2-1-B-B had normal growing plants providing 41-60% canopy cover at 30 DAS while vigorous plants providing 61-80% canopy cover were observed at 60 and 90 DAS. Similarly, genotypes IR 116713-B-B-50-1-B-B and IR 132084-B-1456-1-2-B-3 had less vigorous plants with slight stunting providing 21-40% canopy cover at 30 DAS, vigorous plants providing 61-80% canopy cover was observed at 60 DAS and 90 DAS. The genotypes IR 127152-2-11-22-1-B-B, IR 132084-B-1202-1-3-B-3, IR13C149 and IR12C186 had Less vigorous plants with slightly stunted plants providing 21-40% canopy cover at 30 DAS while vigorous plants providing 61-80% canopy cover at 60 DAS and highly vigorous plats providing 81-100% canopy cover at 90 DAS (Figure 5).

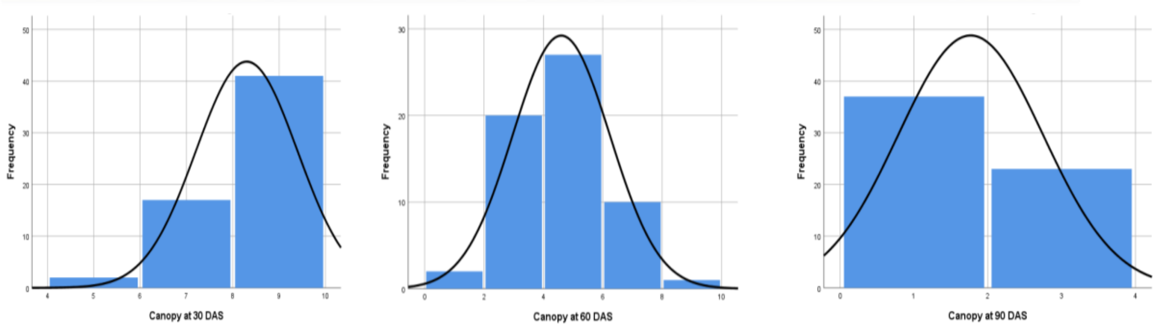


Figure-5: Canopy cover at 30 days interval after sowing

The three histogram curve at 30 days interval clearly shows a gradual increase in the canopy cover percentage of the plots of most of the genotypes. In the initial stage at 30 DAS, the most of genotypes had a score range between 7-9 i.e. most of the genotypes were less vigorous with slightly stunted plants providing only 21-40% canopy cover. Similarly, at 60 DAS the score was 5 i.e. most of the genotypes had normal growing plants providing 41-60% canopy cover in the plots. At 90 DAS the canopy score ranged from 1-3 i.e. most of the genotypes had highly vigorous plants providing 81-100% canopy cover in respective plots (Figure 5). The vegetation-based information derived from Canopeo index-weather data increasingly correlated with rice yield than the normalised difference vegetative index (NDVI) (Onwuchekwa-Henry et al., 2022). Canopy cover measured by Canopeo is a flexible and effective tool for marginal farmers with android phone access to younger generations. Ultimately Canopeo index-weather data can be used to identify and manage fertilizer and water supply to maximise productivity in the rice production system (Henry et al., 2022). The most important parameter for dry DSR is the early ground cover after yield for the reduction of weeds and drying of the soil. The pre-heading stage is the best stage for grain yield prediction with the Canopeo-driven vegetative index. The Canopeo index explains 65 % of the variability in the rice yield and the Canopeo index (Onwuchekwa-Henry et al., 2022). About 1800 species of weeds are reported in rice worldwide, of which 50 are prominent in DSR. The major weeds of Direct Seeded Rice are *Echinochloa spp., Ischaemum rugosum, Cyperus difformis,* and *Fimbristylis miliacea* (Rao et al., 2007). In general, Pendimethyline and Salicyclic Na (Nomani gold or Green level) are recommended for direct seeded conditions. Butachlor and Safener are effective against grassy weeds in transplanted rice. Pyrazosulfuron-ethyl at low doses is effective against sedges and broadleaf weeds, whereas mixing with surfactant is effective against broadleaf weeds (Subbaiah, 2008).

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Mean and analysis of variance

The existence of adequate genetic diversity among the studied genotypes was reflected by the analysis of variance of different parameters. Highly significant variation (p<0.001) was observed among the genotypes for plant height, days to heading and yield. Similarly, significant variation (p<0.01-0.001) was observed among genotypes for days to flowering while significant variation (P=0.05-0.01) was observed for days to maturity and thousand grain weight. The majority of characteristics, except for flag leaf area, grain per panicle, and panicle length, had significantly different variations between genotypes (Table 5). In general, ANOVA which showed differences among the genotypes (significant or highly significant) referred to the items of experimental design is differed and the comparison between them is valid. According to research, the most significant factors determining grain yield in rice were morphological parameters like plant height, panicle length, and grains per panicle. These traits might be employed as selection criteria in the breeding program of rice varieties to increase productivity (Poudel et al., 2023) Least significant difference by Tukey's test (means within each column with the same letter are not significantly different with LSD test p > 0.05), CV-coefficient of variation, SEm-standard error of the mean, PHT-plant height, TPM-tillers per meter square, LA-leaf area DTH-days to heading, DTF- days to flowering, DTM- days to maturity, PL- panicles length, GPP-grains per panicle, TGW- thousand-grain weight, GY- yield per hectare)

Table- 5: Mean comparison of phenotypic traits of rice genotypes at Hardinath, 2023-24

Genotype	PHT (cm)	TPM	LA (cm^{-2})	DTH (Days)	DTF (Days)	DTM (Days)	GPP	PL (cm)	TGW (g)	GY (ton/ha)
Hardinath-1	91.60^{c-e}	310^{e}	23.95	87^{i}	90^{i}	127^{k}	89	21.9	20^{a-f}	3.77^{c}
Hardinath-4	89.20^{c-e}	492.5^{a-c}	26.27	100^{d-g}	104^{c-g}	134^{j}	91	19.2	21^{a-e}	3.26^{g}
Hardinath-6	98.00^{b-e}	386^{b-e}	22.61	114^{a}	118^{a}	141^{a}	157	23.5	25.05^{a}	4.15^{b}
IR 116713-B-B-50-1-B-B	89.90^{c-e}	368^{b-e}	24.89	103^{b-d}	106^{c-e}	144^{a-e}	71	20.5	15.25^{ef}	2.60^{m}
IR 127152-2-11-14-1-B-B	116.90^{a}	446^{a-e}	29.85	94^{hi}	96^{g-i}	144^{a-e}	86	23.6	18.5^{a-f}	3.11^{ij}
IR 127152-2-11-22-1-B-B	99.70^{bc}	409.5^{b-e}	29.67	97^{d-h}	100^{d-h}	141^{d-i}	131	23.2	18.75^{a-f}	3.08^{ij}
IR 127152-3-22-18-1-B-B	96.80^{b-e}	494^{a-c}	35.86	95^{f-h}	99^{d-h}	143^{b-f}	98	21.2	18^{b-f}	3.37^{f}
IR127153-2-3-14-1-B-	94.50	394^{b-e}	27.47	99^{d-g}	105^{c-}	136^{ij}	85	21.5	18.75^{a-}	3.03^{j}

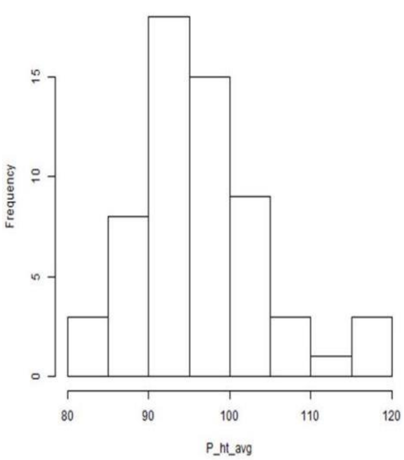
B	$^{b-e}$				^{f}				^{f}	
IR 127153-2-3-5-1-B-B	97.30^{b-e}	475^{a-d}	30.68	102^{b-d}	106^{c-e}	149^{a}	83	22.3	14^{f}	3.45^{e}
IR127165-1-27-2-1-B-B	99.70^{bc}	443^{a-e}	33.77	101^{c-f}	107^{cd}	143^{b-g}	83	19.4	19^{a-f}	2.72^{kl}
IR127165-1-27-9-1-B-B	90.60^{c-e}	572^{a}	31.29	101^{c-f}	105^{c-f}	147^{a-c}	122	24.1	19.5^{a-f}	3.15^{hi}
IR 132084-B-1202-1-3-B-16	99.10^{b-d}	521^{ab}	28.73	100^{d-g}	104^{c-g}	146^{a-d}	112	23.4	16^{d-f}	3.26^{g}
IR 132084-B-1202-1-3-B-3	97.70^{b-e}	388^{b-e}	35.34	99^{d-g}	104^{c-g}	148^{ab}	86	21.5	22.5^{a-d}	3.22^{gh}
IR132084-B-1327-2-1-B-15	92.30^{c-e}	572^{a}	25.29	100^{c-g}	104^{c-g}	145^{a-e}	70	27	23^{a-c}	4.16^{b}
IR 132084-B-1327-2-1-B-16	93.10^{b-e}	308^{e}	24.71	102^{b-d}	107^{cd}	143^{b-g}	112	20.9	17.5^{b-f}	3.5^{de}
IR 132084-B-1327-2-1-B-18	90.60^{c-e}	397^{b-e}	25.75	106^{bc}	110^{bc}	143^{b-g}	116	23	16.5^{c-f}	2.76^{k}
IR 132084-B-1456-1-2-B-3	96.60^{b-e}	314^{e}	27.91	107^{b}	110^{bc}	138^{g-j}	128	21.5	16^{d-f}	3.07^{ij}
IR 132084-B-763-1-2-B-21	88.80^{de}	324de	28.45	106^{bc}	115^{ab}	143^{b-g}	71	21.5	16^{d-f}	2.77^{k}
IR 93945-27-1-2-1	94.00^{b-e}	362^{c-e}	27.85	97^{d-h}	101^{d-g}	140^{e-i}	95	22.7	18^{b-f}	3.30^{fg}
IR 97198-47-2-2-2	95.60^{b-e}	438^{a-e}	30.3	89^{i}	97^{f-i}	144^{a-e}	95	22.7	16.75^{c-f}	2.67^{lm}
IR12C170	92.20^{c-e}	362^{c-e}	29.76	89^{i}	106^{c-e}	143^{b-g}	93	22.5	19.75^{a-f}	2.80^{k}
IR12C186	92.00^{c-e}	350^{c-e}	32.45	96^{gh}	98^{e-h}	144^{a-e}	112	22.6	16.5^{c-f}	2.66^{lm}
IR13C149	94.90^{b-e}	400^{b-e}	24.13	95^{e-h}	101^{d-g}	138^{f-j}	104	18.9	20^{a-f}	3.83^{c}
IR13LT799	99.80^{bc}	365^{c-e}	29	98^{d-h}	101^{d-g}	148^{ab}	109	22.7	23.75^{ab}	3.05^{j}
IR18A1316	87.30^{e}	407^{b-e}	22.98	98^{d-h}	103^{c-g}	142^{c-g}	79	21.3	20.5^{a-f}	3.08^{ij}
IRRI 154	103.40^{b}	376^{b-e}	29.59	99^{d-g}	103^{c-g}	146^{a-d}	92	27.3	16.5^{c-f}	3.50^{de}
IRRI 163	94.20^{b-e}	374^{b-e}	31.52	102^{c-g}	103^{c-g}	143^{b-g}	112	24	20.75^{a-f}	3.45^{e}
Sahbhagi Dhan	99.00^{b-d}	429^{a-e}	29.87	101^{c-g}	105^{c-f}	144^{a-e}	102	22	22.25^{a-d}	3.75^{c}
Sukkha Dan-6	112.70^{a}	390^{b-e}	29.16	98^{d-h}	101^{d-g}	147^{ab}	100	21.6	22.5^{a-d}	3.33^{a}
Vandana	103.20^{b}	438^{a-e}	29.61	89^{i}	93^{hi}	137^{hj}	108	23	14.5^{ef}	3.57^{d}
Grand Mean	96.36	410	28.62	99	101.53	142	98.4	22.4	18.9	3.27
Std.Dev	7.94	84.14	5.26	6.39	10.43	6.45	22.6	2.71	3.71	0.46
Significance	***	*	ns	***	**	*	ns	ns	*	***
F probability	<0.001	<0.05	<0.1	<0.001	<0.01	<0.05	<0.1	<0.01	<0.05	<0.001
SEm (± 0.05)	3.228	48.49	4.706	2.034	2.854	3.947	10.2	1.861	2.192	0.029
LSD (0.05)	9.09	129.85	12.11	5.21	7.03	8.69	28.65	4.59	5.74	0.08
CV (%)	4.58	15.37	20.54	6.46	10.2	3.21	14.	9.93	14.75	11.41

7	14

(Note: * significant at p ≤ 0.05, ** highly significant at p ≤ 0.01, ns: not significant at p > 0.05 LSD-

Plant height

Highly significant differences were observed among the studied genotypes for the grain per panicle. The value of plant height varied between 116.9 cm and 87.3 cm with mean value and standard deviation of 96.36 cm and 7.94 cm respectively The histogram showed that among 30 genotypes, more than 15 genotypes had plant height in the range of 90-100 cm. 15 genotypes had less than 90 cm plant height (Figure 6). The tallest height was observed in genotype IR 127152-2-11-14-1-B-B (116.9 cm) followed by national check Sukkha Dan-6 (112.70 cm). Some other genotypes in terms of plant height were IR 132084-B-1202-1-3-B-16 (99.10 cm), IR 127152-3-22-18-1-B-B (96.80 cm), and IR13C149 (94.90 cm) whereas the shortest height of plants was observed in genotype IR18A1316 (87.3 cm) followed by IR 132084-B-763-1-2-B-21 (88.80 cm) (Table 5).



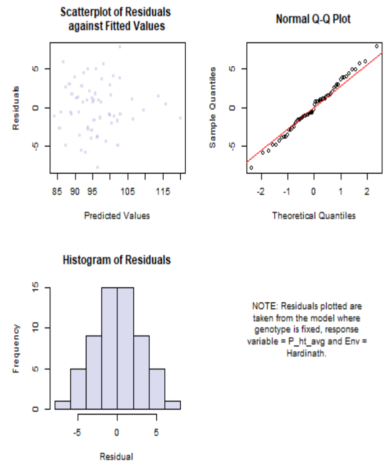


Figure- 6: Histogram showing plant height distribution among genotypes at 90 DAS

Plant height is an important growth parameter for cereal crops since it determines or alters yield contributing traits, which in turn gives grain production (Reddy & Redd, 1997; Shrestha et al., 2021). The height at the seedling stage and dry weight reduced in rice genotypes with the increase in water stress level (Islam et al., 2018). It is a complicated trait because of various genetically controlled elements, most of which are ruled by the genotype's genetic makeup. Plant height is directly affected by the number of internodes and length of internodes (Rahman et al., 2018).

Tillers per meter square

All evaluated rice genotypes were found significant (p<0.05) for tillers per meter square (TPM). The value of TPM varied between 572 and 310 with mean value and standard deviation of 410 and 84 respectively. The highest TPM was observed in genotype IR132084-B-1327-2-1-B-15 and IR127165-1-

27-9-1-B-B (572) while the least number of tillers was in Hardinath-1 (310). Among 30 genotypes, 15 genotypes had TPM in between 350-400 (Table 5). The diversity in the genetic makeup of the variety is the cause of the variability in the number of effective tillers per plant. Rice grain yield is heavily influenced by tillering ability. Reduced numbers of effective tillers result in fewer panicles, whereas too many tillers result in high tiller mortality, undersized panicles, poor grain filling, and reduced grain yield (Martinez-Eixarch et al., 2015). Productive tillers are one of the most important yield components, as the final yield is mostly determined by the number of panicles bearing tillers per unit area (Roy et al., 2014).

3.3.3 Flag leaf area

No significant differences were observed among the studied genotypes for the flag leaf area. The value of the flag leaf area varied between 35.86 cm^2 and 22.61 cm^2 with mean value and standard deviation of 96.36 cm and 7.94 cm respectively (Table 5). The flag leaf has an important role in rice yield by increasing grain weight by up to 40 per cent as it actively plays a physiological role during the grain-filling period. The higher plant density results in a reduction in both flag leaf area and flag leaf angle (Tari et al., 2009).

3.3.4 Days to heading

Highly significant differences (<0.01) were observed among the studied genotypes for the heading date. The value of the heading date varied between 114 days to 87 days with a mean value of 99 days. The longest heading days were observed in the national check variety Hardinath-6 114 days followed by genotype IR 132084-B-1456-1-2-B-3 (107 days) whereas the shortest heading day was found in the national check variety Hardinath-1 (87 days) followed by IR 97198-47-2-2-2, IR12C170, Vandana each with 89 DTH (Table 5). Some other genotypes with superior genotypes were IR 132084-B-1202-1-3-B-16 (100 days), IR13C149 and IR 127152-3-22-18-1-B-B 95 each with DTH of 95 days. Among 30 genotypes, 20 genotypes had 100 days to heading. Similarly, less than 10 genotypes had less than 95 days to heading (Table 5).

Heading date and yield are major determinants for the development of commercial rice varieties. Longer heading days result in a longer growth duration and a higher yield with a combination of longer panicle and culm length and lower panicle number (Fujino, 2020). Pleiotropic effects of the heading date genes on the development phase in panicles have been observed (Endo-Higashi & Izawa, 2011; Fujino & Ikegaya, 2020). Fujino, (2020) found that DTH limits the yield attributing traits rather than the genotypes for heading date.

Days to 50% flowering

A significant difference (<0.01) was observed among genotypes for days to flowering (DTF). The mean days to flowering (DTF) was 101.5 days with a standard deviation of 10 days. The longest DTF was found to be in national check variety Hardinath-6 (118 days) followed by IR 132084-B-1327-2-1-B-18 and IR 132084-B-1456-1-2-B-3 (110 days). The shortest DTF was found in Hardinath-1(90 days) followed by, IR13C149 (105 days) and IR 132084-B-1456-1-2-B-3 (107 days) (Figure 7; Table-5).

Figure-7: Flowering of genotype IR13C149 at 105 DAS

Flowering refers to the events between the opening and closing of the spikelet (floret) and it prolongs up to 1 to 2.5 hours. Generally, flowering begins upon panicle exertion or on the following day and is consequently considered synonymous with heading (Singh et al., 2017; Slaton, 2011). There is an inverse effect of days to flowering on the plant height and yield of rice grain i.e. genotypes with shorter days to flowering have higher plant height and yield. The maximum effect of days to flowering was seen at 80 DAS (Ranawake et al., 2014).

Days to maturity

The average days to maturity for genotypes was fond to be 142 days with a standard deviation of 6 days. Among genotypes, DTM was statically significant (<0.05). Genotype Hardinath-1 had the shortest DTM while genotype IR 127153-2-3-5-1-B-B had the longest DTM (Table 5). Days to maturity is an important trait for genotypes which is synonymous with days to heading since early heading genotypes mature early in around 30 days. Sabouri et al. (2009) have also reported variations in days to maturity in different genotypes of rice through QTL mapping. Tahir (2014) observed that the days to maturity of genotypes are relatively stable and less prone to varying environmental conditions. The benefits of DSR perceived by farmers included increased cropping intensity and productivity, the efficient use of early season rainfall and available soil nitrate, reduced water use (700-900 mm rainfall per crop), and lower risk of drought at maturity (Dhakal et al., 2015; Rao & Moody, 1994).

Grain per panicle

Genotypes were statistically non-significant for the grain per panicle. The value of grain per panicle varied between 155.96443 to 71.96248 with a mean value of 98.36. The highest grain per panicle was observed in national check variety Hardinath-6 (155.96) followed by genotype IR 132084-B-763-1-2-B-21 (71.96) whereas the lowest grain per panicle was found in IR 132084-B-763-1-2-B-21 (71.96) (Table 5). Among 30 genotypes, 20 genotypes had less than 100 grains per panicle, and rest 10 genotypes had up to 180 grains per panicle. The number of viable grains per panicle is one of the most critical yield-determining traits. Shrestha et al. (2021) found that full viable grains per panicle had a beneficial direct effect on rice yield.

Panicle length

Genotypes were statistically non-significant for the panicle length. The value of panicle length varied between 28.20 cm to 18.26 cm with a mean value of 22.39 cm. The longest panicle length was observed in international check variety IRRI154 (28.20) followed by genotype IR132084-B-1327-2-1-B-15 (27.90) whereas the shortest panicle length was found in IR13C149 (18.26 cm) (Table 5). The panicle length ranged from NR 11182-B-21 (21 cm) to NR 11196- B-3-3 (30.9 cm) (Subedi et al., 2018). The analysis of the variance of 150 genotypes revealed that Panicle length was significantly different along with other traits but genotypic and phenotypic coefficients of variation (GCV and PCV) were low for 50% flowering and panicle length (Prasad et al., 2013).

Thousand grain weight

The mean weight of a thousand grains was found to be 0.0189 kg. There was a significant difference (<0.05) among genotypes for TGW. Genotype IR 127153-2-3-5-1-B-B had the lowest TGW of 14 g and national check variety Hardinath-6 had the highest TGW of 25.05 g followed by IR13LT799 (23.75 g) (Table 5). The genotypes IR13LT799 (23.75 g), IR 132084-B-1202-1-3-B-3 (22.5 g), IR132084-B-1327-2-1-B-15 (23 g) IR13C149 (20 g), and IR 127152-3-22-18-1-B-B (18 g) were superior based on thousand grain weight (TGW). Environmental factors such as temperature, season time and soil fertility have also an effect on grain size and weight (Altaf et al., 2021).

Grain yield

The mean weight of grain yield per hectare was found to be 3.27 tons per hectare. There was a high significant difference (<0.01) among genotypes for grain yield per hectare. The genotypes IR132084-B-1327-2-1-B-15 (4.16 t/ha), IR13C149 (3.83 t/ha), IR 132084-B-1327-2-1-B-16 (3.5 t/ha), IR 127152-3-22-18-1-B-B (3.37 t/ha), and IR 132084-B-1202-1-3-B-16 (3.26 t/ha) performed better than the other genotypes based on major economic trait i.e. grain yield per hectare (Table 5).

The average yield of DSR in dry and wet zones is 5 t/ha and 3.3 t/ha, respectively (Weerakoon et al., 2011). The breeding values of the 200 genotypes formulating the core panel ranged between 2.37-4.62 t ha^{-1} (Khanna et al., 2022). Selection based on just yield may not be accurate, but selection via yield and its components is more efficient (El-Refaee et al., 2023). The average yield of rice from direct seeding was 3.3 t/ha whereas that from transplantation was 3.7 t/ha. The reduction in average yield for DSR was 10% as compared to TPR due to weed infestation (Qureshi et al., 2004). Grain yield as a major economic trait in Rice relies on several component characters that are mutually related. Minor changes in one of the components would bring change in complex characters. Therefore, these characters have to be analysed for their direct and indirect effects through other component character impacts on grain yield. The measurement of growth and yield metrics is a key component of rice breeding efforts for creating improved genotypes (Poudel et al., 2023). The identified stable genotypes; IR 92521-143-2-2-1, IR 97048-10-1-1-3, IR 91326-7-13-1-1, IR 91326-20-2-1-4, and IR 91328-43-6-2-1 may serve as novel breeding material for varietal development under aerobic system of rice cultivation (Sandhu et al., 2019). Collard et al., (2013) observed that there were substantial differences between the rice genotypes in terms of days to flowering, days to maturity, and grain yield. The maximum grain yield was obtained by genotype IR83381-B-B-137-1 (3851 kg ha^{-1}), followed by genotype IR83383-B-B-141-2 (3130 kg ha^{-1}). Plant breeders should choose genetically distinct individuals from the mean of a segregating population (Khanna et al., 2022). In the western terai of Nepal, there were comparable yields and lower production (\$ 160 ha^{-1} in DSR as compared to TPR). In addition to this, water productivity was found to be greater by 4-18% leading to a net profit of \$ 122–232 ha^{-1} (Devkota et al., 2019).

Pest and Disease observation

Leaf roller (*Cnaphalocroci medinalis*), Hispa (*Dicladispa armigera*), Stem borer (*Chilo* spp.) and yellow stem borer (*Scirpophaga incertulas* W.) were observed sparsely in genotypes IR 127165-1-27-9-1-110, IR 127152-3-22-18-1-B-B, IR 127152-2-11-22-1-B-B, IR 132084-B-1327-2-1-B-15 and IR 93945-27-1-2-1 (Figure 8.a,b). In South Asia warm and humid condition prevails which favors survival and proliferation of insect pests. The major insect pests of rice include Stem borer, Leaf folders, Brown planthoppers and Green leafhoppers. Similarly, in past damage by brown planthopper, rice bug, caseworm, leaf miner, hispa, stem borers (yellow, dark-headed and pink). Rice is grown in warm and humid environments of South Asia, favoring the survival and proliferation of insects. The key insect pests of rice in the region include stem borer, leaf folders, brown planthoppers and green leafhoppers and these insects are still the major pests of Rice in South Asia (Yadav et al., 2021). The management of insect pest and be done by integrated way including physical, biological and chemical methods. The use of Entomopathogenic fungi (EPF) like Green muscardine fungus (*Metarhizium* spp.), White muscardine fungus (*Beauveria* spp. and *Verticillium lecanii* is at research stage in Nepal (Sharma et al., 2023).

a. Gundhi bug (*Leptocorisa* sp.)

b. Rice stink bug (Halyomorpha halys)

c. Tiger beetle (*Cicindela* sp.)

d. Brown spot (*Bipolaris oryzae*) and False smut (*Ustilaginoidea virens*)

Figure-8: Rice insect pests (a & b), predator (c), and disease pathogen (d)

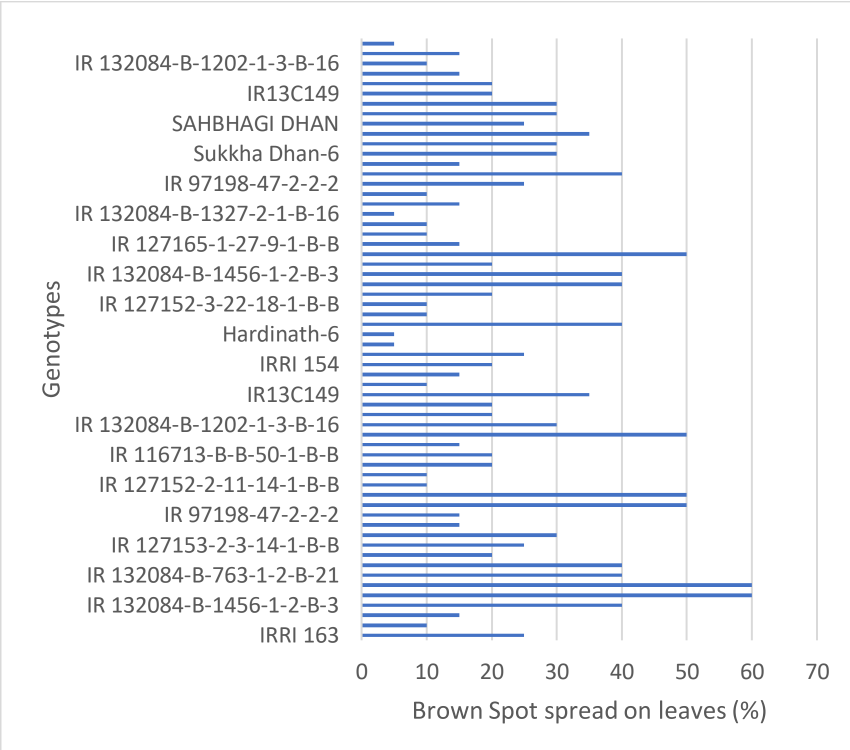


Figure- 9: Brown spot disease spread (%) in genotypes

Brown spot (*Bipolaris oryzae*) , Bacterial leaf blight (*Xanthomonas oryzae*), False smut (*Ustilaginoidea virens*) were major disease observed in research plots (Figure 8.d). In genotypes IR 132084-B-1327-2-1-B-18, IR12C170 and IR 127153-2-3-5-1-B-B half plot area was infected by Brown spot. Similarly, Bacterial leaf blight was seen in 60% IR12C186 and IR 127153-2-3 and 10-20% in IR 127153-2-3-5-1-B-B, IR 127152-3-22-18-1-B-B, IR 1320874-B-1327-2-1-B-16, IR13LT799, and IR13C149 (Figure 9).

In directly sown filed high plant density results in high humidity acelarating the occurance of several fungal diseases. Different species of *Pseudomonas* like *P. fluorescens*, *P. aeruginosa* and species of *Bacillus* like *B. subtilis*, *B. pumilus* are effective biocontrol agents against diseases like Rice blast, Brown spot, Bacterial blight and Sheath blight (Sharma et al., 2021). Along with direct damage by feeding, few insects transmit disease pathogens such as the Tungro virus leading to low rice yields. Fungal and bacterial pathogens enter through insect-damaged parts (Yadav et al., 2021; Sharma et al., 2023).

Phenotypic acceptability

The genotypes with excellent phenotypic score were IR18A1316, IR13LT799, IR 97198-47-2-2-2, IR 127152-2-11-14-1-B-B, IR 97198-47-2-2-2, IR 127152-2-11-14-1-B-B, IR18A1316, IR 127152-2-11-22-1-B-B, IR 132084-B-1327-2-1-B-15, IR 93945-27-1-2-1, IR 127152-2-11-14-1-B-B, IR 97198-47-2-2-2, IR13C149, IR12C186, IR 132084-B-1202-1-3-B-16, IR13LT799 and IR18A1316. Similarly, the genotypes IR13LT799, IR 127153-2-3-5-1-B-B, IR 116713-B-B-50-1-B-B, IR 127165-1-27-9-1-B-B, IR13C149, IR 132084-B-1327-2-1-B-16, IR 127152-3-22-18-1-B-B, IR 127152-2-11-22-1-B-B, IR 132084-B-1327-2-1-B-16, IR 127153-2-3-14-1-B-B etc. was scored as good during field level scoring two week before harvest.

Multiple studies have shown that Dry DSR can reduce up to 50% labor requirements for rice cultivation. More than 1000 genotypes of rice are introduced annually by IRRI for genetic and environmental evaluation (Joshi, 2014). The crop ideotype has changed over time. In conventional farming, biomass-determining traits were also considered along with economical yield as the dried straw has been major winter fodder for livestock. At present commercial rice growers even burn dry biomass in fields and only harvest grains. The varieties released by NRRP at present are adapted across Nepal. The Nepalese landraces occupy 10% of total rice areas whereas 9% of upland rice are local landraces (CDD, 2015). Improved donors with good grain type (medium to long slender) and improved plant type (medium height, higher numbers of tillers, lodging resistance), as well as tolerance to blast, are preferred for direct use in the breeding program (Kumar et al., 2014). Zainudin et al. (2014) observed that phenotypic acceptability characteristics are influenced by several factors such as tillering ability, plant height, plant recovery after water and drought stress, nutrient uptakes etc. These donors genotypes based on phenotypic evaluation include Basmati 370, PSBRc 80, Aus 257, IR77298-14-1-2, IR83614-1002-B-B, and IR83614-1005-

B-B (Kumar et al., 2014). In the evaluation of different rice genotypes in the cold climate the rice genotypes IR8225-9-3-2-3, PK3445-3-2, OM5627 and IR64 differed significantly concerning days to 50% flowering, days to maturity, plant height, thousand grain weight and paddy yield (t ha^{-1}) except panicle length and the number of tillers/hill (Ali & Rahman, 2014). On average B:C ratio was higher in the DDSR (2.00) as compared to the TPR (1.63) (Dhakal et al., 2015).Thus, it is necessary to increase the rate of genetic gain in rice and adopt new cultivation practices to ensure future food security (Peng et al., 2004; Li et al., 2018).

Estimation of heritability

In this study, broad sense heritability estimates ranged from 0.35 for TPM and 0.99 for yield (Table 6). Robonson et al. (1949) classified values as high (>0.60), moderate (0.30-0.60) and values less than 0.10 low. Accordingly, high heritability values were observed for PHT, HD, DTF, DTH and yield. Moderate heritability value was observed for GPP and TPM. There was a high influence of environment on the genotypic performance. Genotype × environment (G×E) showed substantial differences in the majority of yield-attributing traits. There was high heritability for the majority of the traits. Grain yield per hectare had the highest broad sense heritability (0.77), followed by days to heading (0.72) (Table 6).

Table -6: Estimation of heritability of traits in rice genotypes at Hardinath in Spring, 2023

Parameters	Environmental variance	Phenotypic variance	Genotypic variance	ECV	PCV	GCV	Heritability (h^2) Broad Sense	GAM
PH***	20.84	53.20	32.36	4.74	7.57	5.90	0.61	9.48
HD***	10.61	38.35	27.74	3.29	6.26	58.32	0.72	9.33
GPP***	207.86	508.77	300.91	14.66	17.64	22.93	0.59	27.94
DTF**	16.29	42.03	25.74	3.91	6.27	4.91	0.61	7.92
DTH**	10.61	38.35	27.74	3.29	6.26	5.32	0.72	9.33
TPM*	470..91	7200.19	2498.28	16.72	20.69	12.19	0.35	14.79
GY***	0.002	0.216	0.214	1.24	14.17	14.11	0.77	28.96

(Note: * significant at p ≤ 0.05, ** highly significant at p ≤ 0.01, ns: not significant at p > 0.05 LSD—honestly significant difference by Tukey's test (means within each column with same letter are not significantly different with LSD test p > 0.05), CV-coefficient of variation, ECV-Environmental Coefficient of Variance, GCV-Genotypic Coefficient of Variance, PCV-Phenotypic Coefficient of Variance, GAM-Genetic Advance as percentage of mean, DTF-days to flowering, DTH- days to heading, PH- plant height, GPP- number of filled grains per panicle, DTM- days to maturity, TGW-thousand-grain weight, TPM- tiller per square meter; GY- grain yield per hectare)

3.6 Correlation analysis

There was the highest correlation between grain production per hectare and TGW (0.387, followed by plant height (0.261) and tiller per square meter (0.140). The negative correlation between grain yield per hectare and days to flowering (-0.074) and days to heading (-0.006) was observed (Table 7). Poudel et al., (2020) observed that the number of filled grains per panicle, the thickness of the seed, and the weight of the thousand grains were strongly related to grain yield and needed to be considered for selection. Positive and substantial correlations between grain yield and plant height, effective tillers, panicle length, and grains per panicle were observed. The number of effective tillers and grain yield were found to be significantly (P 0.01) associated (r=0.23**). A positive and substantial correlation between plant height and panicle length was discovered (r=0.35**) (Poudel et al., 2023). Significant interaction was seen for the number of panicles and days to maturity and the correlation between tillers number hill-1 and panicle number hill-1 was highest (0.994**) (Kharel et al., 2018). The most significant factors determining grain output in rice were qualities including plant height, panicle length, and grains per panicle. These traits might be employed as selection criteria in the breeding program of rice varieties to increase productivity (Poudel et al., 2023). Zahid et al. (2005) reported that plant height has a negative correlation with yield positive relationship with grain quality. It is crucial to conduct multi-environmental yield trials to evaluate the rice lines' stability and adaptation to various settings before releasing a newly created variety for commercial cultivation (Sabri et al., 2020).

Table- 7: Correlation of traits among the rice genotypes at Hardinath in Spring, 2023

	DTH	PH	LA	PL	GPP	PA
DTH	1.00					
DTF	0.966					
PHT	-0.350	1.00				
LA	-0.078	0.105	1.00			
PL	0.065	0.063	0.049	1.00		
GPP	0.244	0.090	-0.045	0.273	1.00	
Pacp	0.733	-0.366	0.152	-0.096	0.194	1.00
TGW	0.170	-0.105	-0.139	0.077	0.086	0.092

DTM	0.699	-0.405	0.030	0.129	0.220	0.570	0.118	1.00		
TPM	-0.129	0.077	-0.022	0.200	-0.063	-0.207	0.217	-0.121	1.00	
GY	-0.006	0.261	-0.179	0.158	0.140	-0.132	0.387	-0.073	0.140	1.00

(Note: DTH- days to heading, PH-plant height, LA-leaf area, PL-panicles length, GPP-number of filled grains per panicle, DTM-days to maturity, PA-phenotypic acceptability, TGW-thousand-grain weight, TPM- tiller per square meter, GY- grain yield per hectare)

CONCLUSION

The genotypes showed significant differences and yield attributing parameters were comparable to the five national and four international check varieties. Selection for genotypes with higher thousand grain weight, and high plant height with shorter days to heading is a prerequisite for improving grain yield per hectare in rice. IR 132084-B-1202-1-3-B-16, IR132084-B-1327-2-1-B-15, IR 127152-3-22-18-1-B-B, and IR13C149 are the four genotypes that were found to be superior based on phenotypic evaluation at the vegetative and reproductive stages. These genotypes had higher phenotypic acceptability than other genotypes in comparison to check varieties. Genotype and environment interaction showed substantial differences in the majority of yield attributing traits with high heritability. The positive and significant correlation of most of the traits with yield showed that an increase in selection pressure on such traits could improve economic yield.

Recommendation

The high-yielding and drought-resistant genotypes can be utilized in a further breeding program for crop improvement through varietal release. Further research needs to be conducted to ensure yield stability of genotypes for different locations, over multiple growing seasons. More in depth molecular analysis of the genetic characteristics of high performing genotypes is needed to explore the underlying factors contributing to their performance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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