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Detection of superior rice genotypes through evaluating growth and yield parameters

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ABSTRACT

Rice (*Oryza sativa* L.) is the first staple crop in terms of area coverage for cultivation and production in Nepal. In rice breeding programs, developing superior genotypes depends on the evaluation of growth and yield parameters. Thus, to detect some of the primary superior genotypes, we evaluated the growth and yield parameters of 24 genotypes of rice in Rampur, Chitwan, Nepal. The rice varieties were planted in an alpha lattice design with three replications. The traits, such as plant height, number of tillers, number of effective tillers, length of panicles, number of panicles per square meter, and grain yield, were found to be highly significant (p=0.05). Sabitri (4.8 t ha^{-1}) and Makwanpur-1 (4.4 t ha^{-1}) were the two rice genotypes that yielded the most. Plant height, panicle length, and grains per panicle showed positive and significant (p=0.05) correlations with grain yield, showing potential genotypes for higher yield. We concluded that, among all 24 genotypes examined, the most promising varieties from a growth and yield perspective were Sabitri and Makwanpur-1.

Keywords: Correlation, panicle, rice, grain yield, tillers

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INTRODUCTION

Over half of the world's population is fed by one of the most important staple food crops, rice (*Oryza sativa* L.) (Ricepedia 2020, USDA 2020). Rice is the country's most important food crop, providing a significant portion of people's livelihoods and contributing the most to Nepal's economy of any commodity. In Nepal, it is cultivated on 1.49 million hectares, yielding a total of 5.61 million tons with an average productivity of 3.76 t ha1 of output (CBS 2018). The current average productivity of rice in Nepal is still lower compared to neighboring countries (Bishwajit et al 2013). Thus, studies are being carried out to examine rice germplasm with higher yield potential. Previously, many rice varieties had been developed and adapted in Nepal's various agro-ecosystems (Joshi 2017, Rana et al 2007). However, the development of superior rice genotypes in rain-fed environments is crucial for enhancing farmer livelihoods, but suitable varietal development for rain-fed environments has been rarely successful in Nepal (Adhikari et al 2015). The primary cause of low productivity in rice is related to poor knowledge of suitable germplasm, quality vigor seed, and purity needed for the intended location. Therefore, varietal trials in a particular area or location help in identifying and recommending the appropriate genotype, which contains both agromorphological and agronomical traits for various environments (Tiwari 2018). To determine the best genotype for a given area, generally, multi-location trials are carried out (Braun et al 2010). As such, trials demonstrate the adoptability of specific germplasm in specific agro-climatic conditions. Varietal trials can help increase output, productivity, and identify the best genotypes for higher yields (Joshi and Witcombe 2002).

About 74% of Nepal's paddy is grown in the Terai region, while 26% is grown in the hills and mountains (Pandey et al 2012), supporting nearly 50% of the country's total calorie requirement. Chitwan district, located in the inner Terai, is one of the most productive locations for high rice production due to its suitable agro-climatic conditions. However, there is still a substantial gap between the attainable yield and the farmer's yield even in the Chitwan district, which might be due to poor genotype selection. To find an adaptable and superior genotype, it is crucial to evaluate genotypes for yield and yield components (de Abeysiriwardena 2001). Considering such a gap, we performed an experiment with the aim of identifying superior rice genotypes for Chitwan and similar agro-climatic situations in Nepal.

MATERIALS AND METHODS

Experimental site

This experiment was carried out in the research field at Rampur, Chitwan, Nepal, located at 270° 65` north latitude, 840° 35` east longitude, and an altitude of 187 m above sea level. Before planting, soil samples were taken and analyzed from the experimental plots at a depth of 15-20 cm. The soil was found to be normally clay loam in texture, low in nitrogen (0.17%), low in phosphorus (29.07 kg ha^{-1}), low in potassium (102 kg ha^{-1}), medium organic carbon (4.3%), and acidic pH (4.7).

Meteorological Data

The climatic data during the experimental period is given in Table 1.

Table 1. Meteorological data of the experimental location in 2022

Months	Min. Temperature (°C)	Max. Temperature (°C)	Rainfall (mm)
June	18	34	599.9
July	18	29	943.7
August	17	30	888.9
September	16	30	490.4
October	13	29	149.3
November	9	26	23.7

Experimental design and crop management

The experimental plots and the wet seed bed were leveled and prepared using traditional practices. A raised nursery bed was constructed using the wet method of preparing nursery beds (2 m × 0.5 m). For 24 different genotypes, 24 different nursery beds with three replications of each were created following the alpha lattice design to evaluate the rice genotypes. The healthy seedlings, which were 21 days old at the time, were raised in the morning and transplanted that same day in the field after they had 3–4 leaves in June 2022.

The spacing between the rice plants was 20 cm by 15 cm. The plot had a 9-m^2 area. The fertilizers were applied using urea, dimmonium phosphate (DAP), and muriate of potash (MOP) at a rate of 100:60:40 $N:P_2O_5:K_2O$ [nitrogen (N), phosphorus (P_2O_5), and potassium

$(K_2O)]$ ha^{-1} (MOALD 2019). The full doses of P_2O_5 and K_2O, along with half of the dose of N, were applied as the base dose, and the remaining 50% of the nitrogenous fertilizer was divided into two halves. The first one was used during tillering, and the second one was used during booting.

Water supplied through the irrigation canal was used for irrigation. Weeding was done at 15–18 DAT and 40–45 DAT. When the last panicle grain reached the dough stage and the plant and panicle both turned yellow, this was considered physiological maturity. With the aid of a serrated sickle and by manually harvesting, 2-3 inches of the ground were left uncut. The National Rice Research Program, Hardinath, Dhanusha, Nepal, provided instructions on how to carry out cultivation practices.

Plant materials

The rice genotypes were obtained from National Agriculture Genetic Resource Centre (NAGRC), Khumaltar, Lalitpur, Nepal and National Rice Research Program, Hardinath, Dhanusha, Nepal. The list of rice genotypes used in this experiemnt is given in Table 2.

Table 2. List of rice genotypes used in the experiment at Rampur, Chitwan, Nepal in 2022

Treatments	Rice genotypes
T1	SV1N 307
T2	IR-161-1859
T3	IR 112208-B-BRGA-B-RGA-B-RGA-143 RGA
T4	NR-2198-1-1-1-2-1
T5	NR-2212-3-2-4-1-1
T6	IR-161-1743
T7	Makwanpur-1
T8	SV1N- 038
T9	SV1N-072
T10	IR-17L-1430
T11	IR-16L-1661
T12	IR-16A-3025
T13	Sabitri
T14	SV1N-358
T15	IR-17L-1365
T16	SV1N-372
T17	NR-2188-8-2-1-2-1
T18	NR-2189-11-4-1-2-1
T19	IR-16L-1801
T20	NR-2182-22-1-3-1-1-1
T21	Garima
T22	IR-16L-1657
T23	IR-16L-1755
T24	IR-16A-3708

Data collection and statistical analysis

Plant height, panicle length, number of tillers/plant, and grain yield were recorded. The grain yield at 12% moisture was calculated using the formula adopted by Shrestha et al (2020). Using Excel 2010 and Genstat 13.2, data gathered on various growths, yields, and yield components were processed and subjected to Analysis of Variance (ANOVA). The significance of the differences among the treatments of rice varieties was estimated with the help of Duncan's Multiple Range Test (DMRT) at a 5% level of probability.

RESULTS

Growth parameters

The effect of genotypes on plant height, number of tillers, number of effective tillers and panicle length were found significantly (P<0.5) different (Table 3). The plant height varied from 93cm to 131cm out of which the highest plant height was obtained in variety Makwanpur-1(131cm). The shortest height was found in IR 112208-B-BRGA-B-BRGA-B-RGA-143 RGA (93cm), which can be used in breeding program for the development of a lodging-resistant variety. Tillers per plant differ from 10 to 14 and effective tillers ranges from 5 to 12 where, maximum number of tillers (14) and effective tillers (12) per hill was found in variety NR 2182-22-1-3-1-1-1. Similarly, panicle length varied from 23 cm to 30 cm, where the longest panicle was found in Sabitri (30 cm) followed by NR 2189-1-1-1-2-1 (29 cm).

Table 3. Growth parameter of rice genotypes in the experiment at Rampur, Chitwan, Nepal in 2022

Genotypes	Plant height (cm)	Tillers (No./plant)	Effective tillers	Panicle length (cm)
SV1N 307	114^{cdefg}	11^{bcdef}	10^{abcd}	25^{efgh}
IR 16L 1859	105^{ij}	13^{ab}	11^{ab}	24^{fghi}
IR 112208-B-BRGA-B-RGA-B-RGA-143 RGA	93^{k}	13^{abcd}	11^{ab}	23^{hi}
NR 2189-1-1-1-2-1	122^{bc}	11^{bcdef}	8^{abcd}	29^{ab}
NR 2212-3-2-4-1-1	120^{cd}	11^{bcdef}	9^{abcd}	24^{fghi}
IR 16L 1743	102^{j}	13^{ab}	10^{abc}	25^{defg}
Makwanpur-1	131^{a}	11^{def}	8^{abcd}	26^{defg}
SV1N 038	109^{fghij}	11^{bcdef}	10^{abcd}	25^{efgh}
SV1N 072	114^{defg}	10^{ef}	9^{abcd}	27^{efgh}
IR 17L 1430	107^{ghij}	11^{cdef}	11^{ab}	27^{bcd}
IR 19L 1755	108^{fghij}	12^{abcdef}	10^{abcd}	23^{i}
IR 16A 3025	107^{ghij}	10^{ef}	11^{ab}	26^{defg}
Sabitri	129^{ab}	11^{cdef}	8^{abcd}	30^{a}
SV1N 358	112^{efghi}	12^{abcde}	7^{abcd}	29^{abc}
IR 17L 1365	108^{fghij}	12^{abcde}	11^{ab}	25^{defg}
SV1N 372	107^{fghij}	12^{abcdef}	7^{bcd}	24^{ghi}
NR 2188-8-2-1-2-1	115^{cdef}	10^{f}	5^{cd}	24^{gh}
NR 2189-11-4-1-2-1	120^{cde}	13^{abc}	5^{d}	25^{defg}
IR 16L 1801	106^{ghij}	11^{def}	10^{abcd}	26^{def}
NR 2182-22-1-3-1-1-1	114^{defgh}	14^{a}	12^{a}	25^{efgh}
Garima	118^{cde}	11^{def}	10^{abc}	24^{fghi}
IR 16L 1657	106^{hij}	12^{abcde}	9^{abcd}	25^{efgh}
IR 16L 1755	121^{bcd}	11^{bcdef}	11^{ab}	25^{efghi}
IR 16A 3708	113^{defghi}	12^{bcdef}	9^{abcd}	29^{abc}
Grand mean	112	12	9	26
F-test	***	**	*	***
LSD (0.05)	8.22	2	4.91	2.24
CV %	4.43	10.16	31.29	5.24

Mean followed by the same letter(s) in a column do not differ at 5 % level of significance by DMRT, CV: Coefficient of variation, LSD: Least significant difference, *P<0.5; **P<0.01, ***P<0.001

Yield and yield parameters

The outcome demonstrated that genotypes had significant effects on grain yield and panicles per square meter (Table 4). The panicle per square meter differs from 264 to 343, where the highest number (343) of panicles per square meter were found in rice genotype NR 2212-3-2-

4-1-1. (343). While grains per panicle ranged from 124 to 163 and thousand grain weight varied from 21 g to 31 g, out of which, Sabitri produced the most filled grains per panicle (163) and SV1N 072 produced the highest thousand grain weight (31 g). The analysis of variance revealed that the different rice genotypes had no significant effect on grain weight and panicle size (Table 4). At 12% moisture content, the grain yield was calculated, which varied from 2.9 to 4.8 t ha^{-1} with Sabitri producing the highest grain yield (4.8 t ha^{-1}), followed by Makwanpur-1 (4.4 t ha^{-1}) (Table 4).

Table 4. Grain yield and yield contributing parameters of rice genotypes in experiment at Rampur, Chitwan, Nepal in 2022

S.N.	Genotype	Grain yield (t ha^{-1})	Panicle m^{-2}	Thousand grain weight (g)	Grains $panicle^{-1}$
1.	SV1N 307	3.8^{abcde}	291^{abc}	24	134
2.	IR 16L 1859	3.7^{abcde}	320^{abc}	24	133
3.	IR 111208-B-BRGA-B-RGA-B RGA-143 RGA	3.2^{cde}	305^{abc}	28	124
4.	NR 2189-1-1-1-2-1	3.7^{abcde}	314^{abc}	27	151
5.	NR 2212-3-2-4-1-1	3.1^{de}	343^{a}	27	145
6.	IR 16L 1743	3.5^{cde}	264^{bc}	25	141
7.	MAKWANPUR-1	4.4^{ab}	283^{abc}	26	162
8.	SV1N 038	2.9^{e}	322^{ab}	29	149
9.	SV1N 072	3.6^{bcde}	275^{bc}	31	145
10.	IR 17L 1430	3.3^{cde}	296^{abc}	25	148
11.	IR 19L 1755	3.6^{bcde}	277^{bc}	24	148
12.	IR 16A 3025	3.4^{cde}	272^{bc}	28	156
13.	Sabitri	4.8^{a}	280^{ab}	27	163
14.	SV1N 358	3.6^{bcde}	300^{abc}	24	144
15.	IR 17L 1365	3^{de}	301^{abc}	27	138
16.	SV1N 372	2.9^{de}	300^{abc}	29	138
17.	NR 2188-8-2-1-2-1	3.1^{de}	274^{bc}	24	126
18.	NR 2189-11-4-1-2-1	3.8^{abcd}	282^{abc}	21	139
19.	IR 16L 1801	4.1^{abc}	275^{bc}	23	138
20	NR 2182-22-1-3-1-1-1	3.7^{abcde}	300^{abc}	24	132
21.	Garima	3.4^{cde}	296^{abc}	27	142
22.	IR 16L 1657	3.1^{de}	270^{bc}	28	124
23.	IR 16L 1755	3.2^{cde}	274^{bc}	27	131
24.	IR 16A 3708	3.5^{bcde}	281^{abc}	25	159
	Grand mean	3.5	290	26	142
	F-test	*	***	ns	ns
	LSD (0.05)	0.92	28	6.05	30.5
	CV%	15.9	12.7	14	15

Mean followed by the same letter(s) in a column do not differ at 5 % level of significance by DMRT, CV: Coefficient of variation, LSD: Least significant difference, *P<0.5; ***P<0.001, ns: Non significant.

Correlation

The plant height, effective tillers, panicle length, and grains per panicle showed positive and significant correlaton with grain yield (Table 5). Grain yield and no. of effective tiller m^{-2} were found to be significantly (P<0,01 level) correlated (r=0.23**). The panicle length and plant height were found to be positively and significantly correlated (r=0.35**) (Table 5). These findings demonstrated that any improvement in these traits will increase rice grain yield. These findings suggested that traits like plant height, panicle length, and grains per panicle were the most important yield components affecting grain yield in rice, and these could be used as selection criteria in the breeding program of rice varieties for yield improvement.

Table 5. Estimates of correlation coefficients between grain yield and yield attributing tratis at Rampur, Chitwan in 2022

Traits	PH	ET	PL	GP	GY	PA	TGW
PH	1	-0.29**	0.35**	0.24**	0.41**	-0.07*	-0.05
ET		1	-0.04	-0.03	-0.23**	0.06	0.25**
PL			1	0.33**	0.31**	-0.07*	0.04
GP				1	0.15*	-0.07*	0.17*
GY					1	-0.04	-0.11*
PA						1	-0.03
TGW							1

PH: Plant height (cm), ET: No. of effective tiller per m^2, PL: Panicle length (cm), GP: Grains per panicle, GY: Grain yield (t ha^{-1}), PA: Panicle per m^2, TGW: Thousand seed weight (g). *Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The present experiment performed to conduct superior genotypes for Chitwan districts agro-ecological condition using the 24 genotypes (Table 2) showed that Sabitri followed by Makwanpur 1 were the most promising genotypes based on growth and yield parameters (Table 4). The grain yield of Sabitri genotype was 4.8 and that of Makwanpur 1 was 4.4 t ha^{-1}. The yield ranges of both genotypes are within the range reported earlier in several studies such as Dhungana et al (2020) and Krishi Diary (2021). The yields of these genotypes were related with values observed in grains per panicles (Table 4). The experiment by Kabir (2004) also observed that varietal differences cause variation in the plant, panicles and grains per panicle.

Around 30 to 40 days after transplanting of rice varieties, the maximum tiller usually reached at the highest (Lal et al 2017). Ghosh (2001) also demonstrated that improved rice varieties performed better than cultivars in terms of panicle length. A substantial variation in panicle length, panicle type, and grain weight per panicle was also discovered in the experiment carried out by Daiz (2000). Mondal (2005) showed that improved rice varieties possess more effective tillers per hill, filled grains per panicle, and grain yield per hectare, Effective tillers planted per hill are associated with higher productivity of rice. Nuruzzaman (2000) also explained that the plant height had a strong negative correlation with maximum tiller number. These all findings observed were almost similar in the present experiment suggesting that genotypes growth observed in the present study were at par with previous studies.

The findings of Shriname and Muley (2003) showed that the number of filled grains per panicle positively influenced the grain yield of paddy. Jianchang (2006) showed that high-yielding rice varieties had a higher filled-grain percentage. Dutta (2002) discovered that the yield was influenced by the quantity of filled grains per panicle. A study by Howlader et al (2017) suggests that genetic makeup may have contributed to substantial variation in thousand grain weight. Khush (1997) suggested that thousand grain weight is a crucial yield-attributing genetic traits those are known to be least affected by the environment.

According to Oad (2002), the plant height, leaf area index, thousand grain weight, panicle length, and growth rate were associated with agronomical and physiological factors that affect rice grain yield. Najeeb et al (2018) and Tester and Langridge (2010) suggested that when choosing rice varieties for commercial cultivation, all of above mentioned traits must be considered to be taken into account. Such primary data can also be useful for choosing rice varieties for future breeding programs. With these information plant breeders can build their breeding materials and use selection strategies in the future with the help of the information on variation for the traits among the studied rice varieties.

Various rice varieties such as Mansuli, Sabitri, Makwanpur-1, Ghaiya 2, Radha 7, Radhakrishna 9, Loktantra, Mithila, Hardinath etc. are the released cultivar for terai and inner terai of Nepal. Many of these varieties are majorly used for cultivation in Chitwan district. The productivity of these rice varieties ranges from 3.5 t ha^{-1} to 4.8 t ha^{-1} (Krishi Diary 2021). As plant height of Makwanpur-1 and Sabitri has higher plant height compared to other genotypes which suggest that these varieties should have higher biomass. Thus, it is likely that these superior germplasm would not only enhance the grain production, but can also contributing to higher fodder production to livestock. These facts indicated that these varieties should be adopted and preferred well by small holder farmers. In the experiment the grain yield of Sabitri and Makwanpur-1 genotypes were high, because it is site specific superior germplasm (Joshi 2006) but not due to differences in management factors such as nursery management, soil, fertilizer, irrigation, photoperiod, disease etc.

CONCLUSION

Rice plays a very important role in the food security of Nepal. Therefore, one of the most important studies in rice varietal development is the detection of superior rice genotypes. It would be advantageous to grow Sabitri and Makawanpur-1 in Chitwan areas and in similar agro-ecological conditions.

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Authors' Contributions

AP and MS Chaudhary were involved in conducting the experiments, analysis, data interpretation, and drafting of the manuscript. AA guided the experiment, data analysis and interpretation. JS was involved in critical revision of the manuscript. All authors listed have made a substantial, direct and intellectual contribution to the study, and approved it for publication.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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