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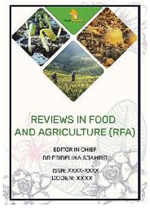

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RESEARCH ARTICLE

ASSESSMENT OF VARIABILITY AND HERITABILITY OF 49 RICE LANDRACES OF NEPAL

Sujan Subedi[a*], Sarika Gawali[b], Sujan Lamichhane[c], Bibek Regmi[c], Dibash Ghimire[c], Raju Kharel[a]

[a] Department of Genetics and Plant Breeding, Agriculture and Forestry University, PO Box 13712 Bharatpur 44200, Bharatpur Metropolitan City, Bharatpur, Chitwan, Nepal.
[b] Department of Agronomy, Agriculture and Forestry University, PO Box 13712 Bharatpur 44200
[c] Faculty of Agriculture Agriculture and Forestry University, PO Box 13712 Bharatpur 44200
**Corresponding Author Email: suzan.subedi.54@gmail.com*

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ABSTRACT

Nepal possesses a wide diversity of rice landraces in all rice-growing areas from low to high altitudes. Characterization, evaluation, and diversity studies are essential to provide information for plant breeding programs. An experiment was conducted in 49 landraces of rice by alpha-lattice design with three replications, seven blocks per replication, and seven plots per block in a field experiment at Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal. Of the 31 qualitative characters evaluated, polymorphism was detected in 30, whereas all the studied 18 quantitative traits showed highly significant differences. The maximum grain yield was recorded by Jagaha (4964.11kg/ha). Most of the traits showed high heritability (>60%), along with high GAM ensuring the dominance of the genetic components in the variations seen between landraces. The higher PCV compared to GCV indicates that there is an influence of environment in every character we studied. This study concludes that there was a lot of variation among rice accessions, which is crucial for breeding programs or genetic research. The findings of this study are useful for using the genotypes under examination in the next breeding programs.

KEYWORDS

Genetic advance, Heritability, Landraces, Phenotype, Variability

1. INTRODUCTION

Rice (Oryza sativa, 2n=24), a member of the Poaceae family, serves as a staple food for more than 60% of the world's population (Singh and Singh, 2011). This shows rice is the most essential strategic crop for global food and nutrition security in this regard. Being the most important staple food of Nepal, Rice supplies about 40% of the food calorie intake and contributes nearly 20% to the Agricultural Gross Domestic Product (AGDP) and almost 13.6% to AGDP (MoALD 2022). In Nepal, rice is grown in 1,477,378 ha with a total production of 5,130,625 metric tons with a productivity of 3.79 mt/ha in the country (MoALD, 2022). A group researcher claim that Nepal's National Agriculture Genetic Resources Centre (NAGRC) is maintaining around 2500 rice landraces, 150 of which are fragrant (Joshi et al., 2021). Rice accounts for 62.1% area of the total area under cereal crops in the country. It accounts for one-third of the country's cropped area. In Nepal, around 1,700 rice landraces are ranging in altitude from 60 to 3,050 meters (K.C. et al., 2021). Oryza nivara, Oryza Rufipogan, Oryza Granulata, and Oryza Oficinalis are wild rice species found in Nepal (Gupta et al., 2013). Rice is grown in a variety of agro-climatic zones throughout Nepal, ranging from the terai (50 masl) to the mid-hills and high mountains valley (3050 masl) in Jumla (the highest altitude of rice growing location in the world). The rice landrace diversity was greatest at the mid-hill site (Kaski). Rice diversity was higher in favorable conditions than in less favorable ones (Bajracharya et al., 2010).

Rice landraces are the reservoir of genetic potential and several resistant genes for biotic and abiotic stresses, whereas the modern varieties are devoid of such quality (Tiwari et al., 2018). Crop genetic resources are a key component of long-term agricultural development because they can be utilized to create crop varieties that can adapt to a variety of environmental situations. Nepal is the source and diversification hub for Asian rice with several landraces still existing. Genetic variability parameters are key foundations for the genetic evolution of the characteristic since they provide information on the degree of variation in the population. Despite the great diversity of rice that exists, foreign germplasm is frequently utilized as parents in rice breeding operations, and around 95% of Nepal's varietal development is based on foreign rice germplasm (Joshi, 2017).

Although Nepal has many regionally adapted rice genotypes, their usage in developing improved cultivars is minimal. A group of researchers say farmers continue to develop a variety of rice landraces with a wide range of natural adaptations to endure abiotic and biotic stress, as well as high tillering capacity, good grain quality, and adaptability to disadvantaged places (Joshi et al., 2019). It is critical to diversify the genetic base of this vital crop by introducing genes from various sources. As a result, untapped germplasm must be collected, exploited, and evaluated. It was an attempt to characterize a set of rice germplasm accessions for various morphological and agronomic parameters, as well as to detect the diversity present in the collection in this context. Keeping in view the importance of aforesaid aspects, the present study was undertaken with the objective of characterizing and evaluating the rice landrace of Nepal collection using agro-morphological traits, analyzing & understanding the genetic variation and agro-morphological diversity, and estimating heritability and association for quantitative traits in rice landraces to aid effective selection for breeding program.

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2. Materials and Methods

2.1 Selection of site

The whole field experiment was conducted on the Agriculture and Forestry University (AFU) research farm, Rampur, Chitwan, Nepal. The precise location of the experimental site was 27.74625^0 Northern latitude, 84.48427^0 Eastern latitude, and at an altitude of 229.2 meters above sea level.

The physical and chemical properties of soil of the experimental field analyzed in the laboratory of Soil Science Division, Khumaltar, Lalitpur is mentioned in Table 1.

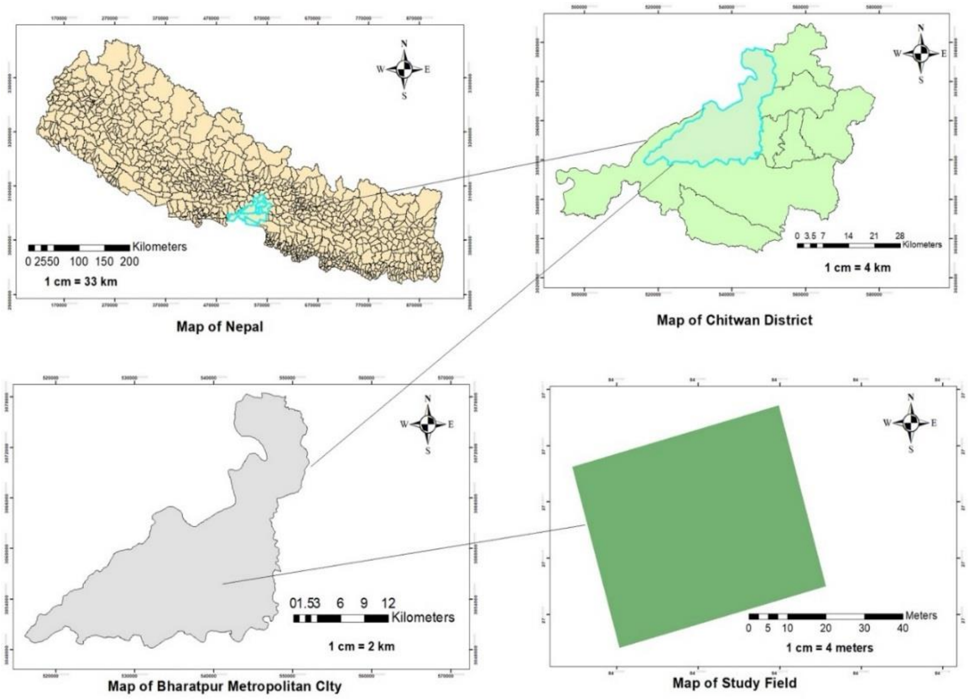

Table 1: Physical and chemical properties of the soil of the experimental field				
S.N.	**Soil properties**	**Contents**	**Category**	**Methods**
1	Physical properties			Hygrometer
	Sand %	67.80%		
	Silt %	24.70%		
	Clay %	7.50%		
2	Texture		Sandy loam	
3	Chemical properties			
	soil pH	6.6	Neutral	Beckman Glass E;ectrode pH meter
	Soil organic matter %	2.3	Low	Walkey and Black method
	Nitroogen %	0.116	Medium	Micro-Kjeldahl method
	Phosphorus (Kg/ha)	34.25	Medium	Modified Olsens Bicarbonate method
	Potassium (kg/ha)	241.41	Medium	Flame photometer method

2.2 Experimental Design and Data Collection

The field trials were conducted under irrigated transplanting conditions. Twenty-eight-day-old seedlings were subsequently transplanted into the field in alpha-lattice with three replications. Each replication had seven blocks, and each block contained Seven landraces of (1.5m*1.5m) 2.25 m^2 each. Crop geometry was 20 cm between rows and 20 cm between plants within rows. Each replication was spaced by 1 m and block by 0.5m. Transplanting of 2 seedlings per hill in 7 rows was done in each plot.

A recommended fertilizer dose of 100:30:30 kg N:P: K was applied. As a basal dose, the full dosages of potassium, phosphorus, and nitrogen were administered. Two splits of the remaining nitrogen dosage were administered, one at the tillering and panicle initiation stages. Thirty days after transplanting, the first weeding was completed, and sixty days after the second was completed. Irrigation was done on a regular basis up until the heading stage. Standard agronomic techniques were implemented for good crop growth.

Thirty-one qualitative characteristics and Eighteen Quantitative traits were identified for the assessment of variability by the descriptor developed by Biodiversity International, IBPGR, WARDA, and IRRI (2007). Details about the Qualitative characters along with their descriptor and evaluation stage of Nepalese rice landraces are displayed in Table 3. Similarly, Quantitative characters along with the procedure and evaluation phase are shown in Table 4.

2.3 Statistical Analysis

Data entry and processing were carried out using MS Excel 2019. For the quantitative traits the Analysis of Variance was performed using the F test and in order to group the accessions, the LSD test was used. Statistical significance was set at 5 % (<0.05). The data were subjected to the following analyses with the help of standard statistical procedures.

The estimation of various genetic parameters based on the results of ANOVA particularly focusing on the partitioning of variance into genotypic and phenotypic components, as well as calculating coefficients of variation, heritability, and expected genetic advance for further analysis, in the context of plant breeding or genetic studies.

Genotypic and phenotypic variances (VG and VP) were estimated according to (Bernardo, 2002).

Genotypic variance (V_g) = $(MSG - MSE)/r$

Phenotypic variance (V_p) = $VG + (MSE/r)$

Where MSG is the means squared of genotype,

MSE is the means squared of the residual (error),

r is the number of replications.

The Genotypic Coefficient of Variance (GCV) and Phenotypic Coefficient of

Variance (PCV) were computed according to the methods suggested (Burton and Devane, 1953).

GCV (%) = *(σg/x) × 100*

PCV (%) = *(σp/x) ×100*

Where σg is the genotypic standard deviation

x is the trait mean

σp is the phonotypic standard deviation

The PCV and GCV values were categorized as low, moderate, and high indicated by as follows (Sivasubramanjan and Menon, 1973):

0 – 10 %: Low

10 – 20 %: Moderate

>20 % : High

Heritability(h2), Genetic advance in the absolute unit (GA), and percent of the mean (GAM), assuming the selection of a superior 5% of the genotypes was estimated in accordance with the methods illustrated (Johnson et al., 1955):

$h^2 = (V_g/V_p) \times 100$

GA = $h^2 \times \sigma P \times K$,

Where, GA= Genetic Advance

K is a selection differential, which at the selection intensity of 5% is 2.06.

σp is the phonotypic standard deviation

h^2 = Broad sense heritability

Genetic advance as percentage of mean = *(GA/Trait mean) × 100*

The **heritability percentage** is categorized as low, moderate, and high followed as follows (Robinson et al., 1949):

Low : 0 – 0.30

Moderate: 0.30 – 0.60

High: more than 0.60

The GA as a percent of the mean was categorized as low, moderate, and high as suggested by as follows (Johnson et al., 1955):

Low : 0 - 10 %

Moderate:10 -20 %

High: above 20 %

2.4 Shannon-Diversity Index

According to Shannon's formula from 1948, the Shannon index was computed. Mathematically,

$$\sum_{i=1}^{s} pi\ ln\ pi$$

Where, H`= Shanon-Weiner index

Pi = Proportion of traits

Pi = (P_trait / P_total) x 100

Where:

Pi is the proportion of the population bearing the given trait,

P_trait is the number of individuals in the population possessing the specific trait,

P_total is the total number of individuals in the population

2.5 Simpson Diversity Index

The Simpson's Diversity Index was developed by Edward H. Simpson, a British statistician, in 1949. This index evaluates diversity by considering both the variety of species present and their relative distribution. It indicates higher diversity when there is high species richness and evenness.

$$D=1-\frac{\Sigma n(n-1)}{N(N-1)}$$

Where,

n = the number of individuals displaying one trait

N = the total number of all individuals

The value of *D* ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

2.6 Evenness

The term "species evenness" describes how closely spaced out each species is in an ecosystem. It can be mathematically defined as a diversity index, a biodiversity metric that expresses how numerically equal the community is. The evenness was computed using Magurran's formula (Magurran's, 2004). Mathematically,

Evenness (E) = H`/ ln(S)

Where *S denotes the total number of variation cases*

Table 2: List of rice landraces of Nepal collected from Community Seed Bank, Nawalpur of Nepal

1	Anjan	18	Jagaha	35	Rajala
2	Bagadi	19	Jarneli	36	Rambela
3	Bakuli Anadi	20	Jhinuwa	37	Rato Anadi
4	Balamsar	21	Jhuppe	38	Sabitri
5	Basmati	22	Jumeli Jadan	39	Satha
6	Batasar	23	Kalo Basmati	40	Sete
7	Buladitar	24	Koipur	41	Seto Parewa Pwakh
8	Bulahi Anadi	25	Lakil Sawa	42	Seto Satha
9	Chameli	26	Lalchan	43	Sikiyan
10	Chameli1	27	Lalka Basmati	44	Simjara
11	Chyanna	28	Madhukar	45	Sohawat
12	Gauriya	29	Magar Anadi	46	Thapa Chini
13	Gheupuri	30	Mansura	47	Tilaki
14	Godara	31	Mithai Dhan	48	Vaman Chini
15	Gokulachan	32	Nakhisaro	49	Video Anadi
16	Gopal	33	Phul Bisj		
17	Gude	34	Rahimnuwa		

Table 3: Qualitative characters along with their descriptor and evaluation phase of Nepalese rice landraces

Qualitative traits	Descriptors	Evaluation Stage
Basal leaf sheath color	Green, green with a purple line, light purple, purple	Late Vegetative
Leaf blade (Green color)	pale green, green, dark green, purple tips, purple margins , purple blotch	Late Vegetative
Leaf blade (Anthocyanin coloration)	Absent, Present	Late Vegetative
Leaf sheath (Anthocyanin)	Absent, Medium, Weak, Strong	Late Vegetative
Leaf blade (Distribution of anthocyanin)	Absent,Blotches only,Margin Only, Tips only, Uniform	Late Vegetative
Leaf blade (Pubescens)	Glaborous, Intermediate, Pubescent	Late Vegetative
leaf blade attitude	Drooping, Erect	Late Vegetative
Auricle color	Whitish, Yellowish green, Purple, Purple lines	Late Vegetative
Collar color	Green,Light green, Purple, absent	Late Vegetative
Shape of ligule	2-cleft, Absent, Turncate, acute	Late Vegetative
Color of ligule	Whitish, Yellowish green, Purple lines ,Absent	Late Vegetative
Flag leaf (Attitude of blade)	Drooping, Erect, Horizontal, Intermediate, Semi erect	Early Reproductive
Culm kneeing ability	Absent, Present	At Maturity
Culm habit (Angle)	Erect, Intermediate, Procumbent, Semi-erect, Spreading	At Maturity
Awns (Colors of awns)	Absent, White, Purple, Red, Straw, Gold,	At Maturity
Awns (Distribution of awns)	Absent, Tips only, Whole length, Upper-quarter only, upper half, upper three-quarter	Flowering to maturity
Lemma (Color of Apiculus)	Straw, Whitish, Black, Brown, Purple, Purple apex, White	At Maturity
Lemma and Palea color	Brown Furrows, Brown Tawny, Gold and gold furrows, Yellowish green,	At Maturity
Lemma (anthocyanin coloration below Apiculus)	Very weak, Weak, Medium, Strong	At Maturity
Spikelet (Color of stigma)	Light Purple, Whitish, Purple, Light green	At Flowering
Sterile lemma color	Straw, White, Purple, Dark Purple, Brown	At Maturity
Flag leaf (Attitude of the blade) (Late)	Descending, Drooping, Horizontal, Intermediate	After Heading
Culm (Anthocyanin coloration of nodes)	Absent, Purple, Light purple, Dark purple	After Flowering
Culm (underlying node color)	Absent, Purple lines, Dark purple, Light purple, Purple	After Flowering
Culm (Internode anthocyanin)	Absent, Present	After Flowering
Culm (Underlying internode coloration)	Absent, Purple lines, Dark purple, Light purple, Purple	After Flowering
Culm lodging resistance	Strong, Weak, Very Weak, Intermediate	Flowering to maturity
Panicle (Exsertion)	Open, Partly exserted, Moderately well exserted, well exserted	Near maturity
Panicle (Attitude of the main axis)	Erect, Slightly Drooping, Strongly drooping, upright	At Maturity
Panicle (Attitude of branches)	Semi-compact, open, Compact	Near maturity
Panicle (Secondary branching)	Light, absent, strong, medium	Near maturity

Table 4: Quantitative characters along with procedure and evaluation phase of Nepalese rice landraces

Traits	Process	Stage
Leaf length of blade (LLB)	Measured in cm from the topmost leaf blade below the flag leaf on the main culm (n = 5).	Late vegetative
Leaf width of blade (LWB)	Width is measured at the widest portion of the blade on the leaf below the flag leaf (n = 5).	Late vegetative
Leaf length of ligule (LLL)	Ligule length is measured in millimeters from the base of the collar to the tip n=5	Late vegetative
Flag leaf Length (FLL)	The length of the topmost leaf from the main culm is measured in cm, n=5	At Flowering Period
Flag leaf width (FLW)	The breadth of the topmost leaf from the main culm is measured in cm, n=5	At Flowering Period
Total number of Tillers (NT)	Total numbers of tillers are counted, n=5	35 DAT
Culm Diameter (CD)	Data are taken in mm from the outer diameter of the culms (n = 5) measured at the midportion of the Culm	At Flowering Period
Net Effective Tillers (NET)	Tillers moving into heading are counted n=5	After heading
Days to Flowering (DTF)	Days from Transplanting to flowering are recorded	At 50% flowering
Days to Physiological maturity (DTPM)	Days from Transplanting to maturity are recorded	At 50% maturity

Table 4(Cont.): Quantitative characters along with procedure and evaluation phase of Nepalese rice landraces		
Traits	**Traits**	**Traits**
Panicle length (PL)	measured in centimeters from the base to the tip of the panicle n=5	Near maturity
Culm Length (CL)	Culm length is measured in centimeters from ground level to the base of Panicle n=5	After Heading
Grain Length (GL)	The measurement involved determining the distance from the bottom of the lowest glume to the end (apiculus) of the fertile lemma or palea, whichever extended farther. For cultivars with awns, the measurement was taken to a similar point as the apiculus tip (excluding the awn).	After harvest
Grain Width (GW)	The width of the fertile lemma and palea at their broadest point was recorded.	After harvest
Filled Grains per panicle (FGPP)	The number of fertile grains of the sampled plant is counted	After harvest
Unfilled Grains per panicle (UGPP)	The number of sterile grains of the sampled plant is counted	After harvest
Thousand grain weight (TGW)	The weight of thousand sterile grains is measured	After harvest
Grain yield (GY)	Grain yield is calculated in kg/ha	After harvest

3. Results

3.1 Evaluation of Diversity Measures

Table 5 shows the diversity indices of qualitative characters among the rice landraces under study. The richness of character for a trait has been evaluated using the Shannon-Weiner index. The high value of this index indicates a more diversified population for that trait. The highest values of the Shannon-Weiner index were observed for the lemma (apiculus color) and lemma and plea color (1.2), each showing five characters followed by the culm habit and lemma anthocyanin coloration below apiculus (1.13) which showed four characters each. The minimum value was found to be 0 in the shape of a ligule followed by Basal leaf sheath color and leaf sheath anthocyanin (0.1). These two traits showed only two types of characters.

The Simpson diversity index was developed to calculate the likelihood that any two landraces selected from noticeably large communities have distinct characteristics for a trait. The value of the Simpson diversity index was found to be maximum for culm habit (0.66), followed by lemma and palea color (0.63). The probability of obtaining two separate characters for a trait under random selection increases with increasing Simpson index value. The lowest value was found in to be culm anthocyanin coloration (0.07) which indicates the dominance of a single character of a trait.

The characters were evenly distributed in trait Auricle color (0.99), where two characters whitish and yellowish green were present in almost equal proportion followed by culm kneeing ability (0.86) and leaf blade color (0.83). The minimum evenness was observed in shape of ligule (0) where all landrace showed 2- cleft shape. This trait was followed by basal leaf sheath color (0.14), panicle attitude (0.18), and leaf blade anthocyanin distribution (0.18).

Table 5: Diversity indices of qualitative traits of rice landraces of Nepal			
Qualitative traits	**Simpson`s Diversity Index**	**Shanon Weiner Index**	**Evenness**
Basal leaf sheath color	0.04	0.1	0.14
Leaf blade (Green color)	0.58	0.92	0.83
Leaf blade (Anthocyanin coloration)	0.08	0.17	0.25
Leaf blade (Distribution of anthocyanin)	0.08	0.2	0.18
Leaf-sheath (Anthocyanin)	0.04	0.1	0.09
Leaf blade (Pubescens)	0.56	0.89	0.81
leaf blade attitude	0.08	0.17	0.25
Auricle color	0.51	0.69	0.99
Collar color	0.08	0.17	0.25
Shape of ligule	0	0	0
Color of ligule	0.12	0.23	0.33
Flag leaf (Attitude of blade)	0.08	0.17	0.25
Culm kneeing ability	0.42	0.6	0.86
Culm habit (Angle)	0.66	1.13	0.81
Awns (Colors of awns)	0.23	0.45	0.41
Awns (Distribution of awns)	0.26	0.47	0.43
Lemma (Color of Apiculus)	0.59	1.2	0.67
Lemma and Palea color	0.63	1.2	0.75
Lemma (anthocyanin coloration below Apiculus)	0.62	1.13	0.82
Spikelet (Color of stigma)	0.08	0.17	0.25
Sterile lemma color	0.42	0.86	0.53
Flag leaf (Attitude of blade) (Late)	0.56	1.05	0.76

Table 5 (Cont.): Diversity indices of qualitative traits of rice landraces of Nepal			
Qualitative traits	**Qualitative traits**	**Qualitative traits**	**Qualitative traits**
Culm (Anthocyanin coloration of nodes)	0.25	0.41	0.59
Culm (underlying node color)	0.26	0.52	0.38
Culm (Internode anthocyanin)	0.22	0.37	0.54
Culm (Underlying internode coloration)	0.23	0.52	0.33
Culm lodging resistance (Culm strength)	0.46	0.79	0.72
Panicle (Exsertion)	0.23	0.5	0.56
Panicle (Attitude of main axis)	0.08	0.3	0.18
Panicle (Attitude of branches)	0.28	0.51	0.46
Panicle (Secondary branching)	0.47	0.89	0.64

Table 6: Analysis of variance for quantitative characteristics in rice landraces of Nepal

Characters	**Mean sum of squares of the source of variation**			
	Replication df=2	**Treatment df=48**	**Rep: Block df=18**	**Error df=78**
LLB	30.01	110.26***	47.36	37.7
LWB	0.18322*	0.12592***	0.05173	0.04372
FLL	165.49**	77.59***	49.29*	27.38
FLW	0.07685	0.10038***	0.04582	0.03007
NT	101.09***	19.06***	8.56	6.27
CD	0.3337	0.5968***	0.3111	0.2578
CL	13.5	967.1***	28	45
NET	4.202	6.647***	0.997	1.713
DTF	119.57***	310.79***	10.24	6.08
DTPM	32.9***	627.7***	3.9	2.9
PL	2.566	19.853***	5.442	4.527
GL	0.561	4.27***	0.284	0.416
GW	0.02529	0.30984***	0.08981	0.11518
FGPP	3190*	2956***	303	810
UGPP	475.1*	275.3**	153.1	127.7
TGW	11.08	54.78***	11.21	12.33
GY	2083585**	2919793***	614261**	276468

*=significant at 5%, **= significant at <1%, ***=significant at <0.1% LLB=leaf length of blade, LWB= leaf width of blade, LLL= leaf length of ligule, FLL= flag leaf length, FLW= flag leaf width, CD= culm diameter, DTF= days to flowering, CL= culm length, NT= Number of tillers, NET= Net effective tiller, DTPM= days to physiological maturity, PL= panicle length, GL= grain length, GW= grain width, FGPP= number of filled grains per panicle, UGPP= number of unfilled grains per panicle, TGW= thousand grain weight, GY= grain yield

3.2 The Estimation of Genetic Parameter

3.2.1 Phenotypic and genotypic coefficient of variation (PCV and GCV)

Table 6 shows the GCV and PCV values for quantitative traits. High GCV value (>20%) was observed for filled grains/panicle (24.10), unfilled grains/panicle (28.76), grain weight/panicle (29.81), and grain yield (36.35). Traits with moderate GCV values were leaf width of the penultimate leaf (14.05), flag leaf length (10.41), flag leaf width (11.01), net effective tillers (12.39), days to flowering (12.62), days to physiological maturity (14.76), culm length (15.18), grain length (12.96) and thousand-grain weight (17.89). However, the leaf length of the pen ultimate leaf (9.79), culm diameter (8.75), panicle length (8.77) and grain weight (8.47) displayed low (<10%) GCV value. Similarly, a high estimate of PCV was observed for the number of filled grains/panicle (28.28), unfilled grains/panicle (39.28), weight/Panicle (33.40), thousand-grain weight (20.32) and net plot yield (38.21). Moderate PCV was seen in leaf length penultimate leaf (12.07), leaf width of penultimate leaf (17.39), flag leaf length (12.94), flag leaf width (13.16), leaf length of ligule (16.0), culm length (15.54), culm diameter (11.62), days to flowering (12.75), days to physiological maturity (14.79), and grain length (13.64) and grain width (10.69) and low PCV was observed for panicle length (9.99).

3.2.2 Broad sense heritability (H 2) and genetic advance (GA)

Many of the traits in the current study showed high heritability (>60 percent). penultimate leaf length (0.66), penultimate leaf width (0.65), ligule length (0.75), flag leaf (0.65), flag leaf width (0.70), panicle (0.77), culm diameter (0.95), grain yield (0.91), thousand-grain weight (0.77), grain length (0.90), grain width (0.63), grain weight/panicle (0.80) and filled grains per panicle (0.73) were traits with high heritability. Moderate heritability was observed for culm diameter (0.57) and unfilled grains per panicle (0.54). Estimates of genetic advance as a percentage of the mean (GAM) in our study ranged from 13.56 to 71.11 percent. Number of filled grains per panicle (42.21%), number of unfilled grains per panicle (43.29%), grain weight per panicle (54.71%), thousand-grain weight (32.37%), net plot yield (71.11%), leaf width of the penultimate leaf (23.34%), length of ligule (24.63%), net effective tiller (21.95%), days to flowering (25.70%), days to physiological maturity (30.27%), culm length (25.30%) and grain length (25.30%). Penultimate leaf length (16.33%), flag leaf length (17.22%), flag leaf width (18.95%), culm diameter (13.56%), panicle length (15.85%), and grain (13.80 %) width were traits with moderate GAM. No genotypes with low GAM were observed.

Table 7: Estimate of genetic parameters of quantitative traits in rice landraces in Nepal

Traits	**Range**		**GM**	**GCV(%)**	**PCV(%)**	**H2(%)**	**GA(%)**	**GAM(%)**
	Maximum	**Minimum**						
LLB (cm)	62.57	39.63	50.24	9.79	12.07	0.66	8.2	16.33
LWB (cm)	1.51	0.76	1.18	14.05	17.39	0.65	0.27	23.34
LLL (cm)	2.97	1.45	2.15	13.84	16	0.75	0.53	24.63
FLL (cm)	49.32	31.16	39.3	10.41	12.94	0.65	6.77	17.22
FLW (cm)	1.82	0.88	1.39	11.01	13.16	0.7	0.26	18.95
NT	21.79	9.36	13.27	15.56	18.99	0.67	3.48	26.21
CD (mm)	4.59	2.63	3.84	8.75	11.62	0.57	0.52	13.56

Table 7 (Cont.): Estimate of genetic parameters of quantitative traits in rice landraces in Nepal

Traits	Range		GM	GCV(%)	PCV(%)	H2(%)	GA(%)	GAM(%)
	Maximum	Minimum						
NET	13.17	7	10.35	12.39	14.38	0.74	2.27	21.95
DTF	104	60.67	79.84	12.62	12.75	0.98	20.52	25.7
DTPM	118	74.33	97.8	14.76	14.79	1	29.6	30.27
PL (cm)	30.98	18.42	25.76	8.77	9.99	0.77	4.08	15.85
CL (cm)	157.96	58.96	115.5	15.18	15.54	0.95	35.2	30.47
GL (mm)	11.02	5.76	8.75	12.96	13.64	0.9	2.21	25.3
GW (mm)	3.54	2.32	3.01	8.47	10.69	0.63	0.42	13.8
FGPP	158.93	46.13	111	24.1	28.28	0.73	46.85	42.21
UGPP	41.07	5.6	24.39	28.76	39.28	0.54	10.56	43.29
TGW	34.09	14.3	21.03	17.89	20.32	0.77	6.81	32.37

4. Discussion

4.1 Variation in qualitative characters

Qualitative traits are used as morphological markers to distinguish between different landraces because they are less influenced by environmental changes (Raut, 2003). When conducting a DUS test, these factors are crucial (distinctiveness, uniformity, and stability). By using the DUS test for varietal characterization, it will be possible to determine a variety's uniqueness. Polymorphism was found in all qualitative traits studied except ligule shape. Lemma and palea color (intensity of green color), lemma and palea color, basal leaf-sheath color, attitude of panicle axis and branches, and leaf blade pubescence all showed high polymorphism. The traits leaf blade color, lemma and palea color, apiculus color, and lemma and palea pubescence showed the most variation among accessions in studies conducted to characterize 32 aromatic rice accessions of the Badshah Bhog group from IGKV, Raipur, Chhattisgarh germplasm (Sarawgi, 2008). Leaf blade color, leaf attitude, stigma color, node and internode color, collar color, auricle color, and other qualitative characters in our study also demonstrated polymorphism. A group researchers investigated the distinctiveness of 65 farmer's varieties and found variation in the anthocyanin coloration of leaves, nodes, internodes, ligules, lemma, and paleas as well as the attitude of flag leaves, panicles, panicle branches, and leaf senescence (Rao et al., 2013). Twelve out of fourteen qualitative traits were found to be polymorphic (Feng et al., 2007). 146 accessions of upland rice (Oryza sativa L.) were studied by using qualitative and quantitative agro-morphological descriptors and twelve of the fourteen qualitative characters that were examined showed polymorphism (Nascimento et al., 2011). Breeders and researchers will find the enormous variability present in the genotypes we studied to be very helpful in future breeding programs.

4.2 Genetic parameters

For all the studied characters, it was observed that the magnitude of the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV), though there were only slight differences, suggesting that these characters were less influenced by the environment. For the characters, the grain yield, unfilled grains per panicle, thousand-grain weight, and filled grains per panicle showed the highest PCV and GCV estimates. This suggests that the genotypes chosen for study have a diverse genetic background and that there may be scope for genetic improvement using direct selection for these traits. High PCV and GCV were found for thousand-grain weight, grain yield, and number of grains/panicles (Parikh et al., 2011). The traits width of the penultimate and flag leaf, culm diameter, culm length, number of tillers, number of effective tillers, grain length, days to flowering, and days to physiological maturity all had moderate PCV and GCV values.

The same kinds of results were also noted by (Dhurai et al., 2014; Sheera et al., 2021; Stephen Forson, 2015). Lower estimates of PCV and GCV were found for flowering days, panicle length, and grain length. Low PCV and GCV were also noted for panicle length, culm diameter, and grain width (Vanisree et al., 2013). The coefficient of variability is a measure of the degree of genetic diversity among a character's genotypes. However, it does not specify how much of this variability is inherited and how much is not. The proportion of variability that could be passed from parents to children is indicated by the estimate of heritability (Visscher et al., 2008). Except for the leaf length and width of the penultimate leaf, the length of the flag leaf, the grain weight of the culm, and the number of unfilled grains per panicle, all the traits examined in our experiment showed high heritability (>70 percent) in the broad sense.

Days to flowering, panicle length, productive tillers, plant height, days to flowering, grain yield, thousand grain weight, and other eleven traits were studied for heritability by who observed high heritability for all the traits (Kumar et al., 2013). All the studied characters have high broad sense heritability, which may indicate that the environment had little effect on how the genotypes expressed the phenotype (Visscher et al., 2008). Panse stated, the heritability of a trait may be high but the genetic advance may be minimal if it is controlled by non-additive gene action (Panse, 1954). High heritability (above 60%) and high genetic advance as a percent of mean (above 20%), even though it is governed by additive gene action, offer good potential for further development. Heritability estimate along with expected genetic advance may give more reliable information (Govindaraj, 2011). Most of the traits in our study exhibit high heritability along with high genetic advance as a percentage of mean (GAM), that include Leaf length and width of penultimate leaf, Days to flowering and physiological maturity, Culm length, Grain Length, filled grains per panicle, thousand grain weight and grain yield. We can conclude that there is a high proportion of additive gene action for these traits because most of the traits had high genetic advance as a percentage of mean along with high heritability. Mass selection and other breeding techniques based on progeny testing could be used to improve these kinds of character traits. The same outcomes were also attained (Kumar et al., 2013; Singh et al., 2011; Idris, 2012). The overall findings showed that the material under study contains enough genetic diversity.

5. Conclusion

In our study, Polymorphism was found in all qualitative traits studied except ligule shape. The eighteen traits studied by the landraces of rice were significantly different among them, according to an analysis of variance. This suggests that there is a lot of room for selecting genotypes with improved, superior yield-attributing traits. Genetic parameters such as phenotypic and genotypic coefficients of variation revealed that the environment had less impact on the characteristics under study. Response to direct selection may therefore be useful in enhancing these traits. The higher PCV and GCV estimates suggest that the genotypes chosen for study have a diverse genetic background and that there may be scope for genetic improvement using direct selection for these traits. Except for Culm diameter and Unfilled grains per panicle, all the traits investigated in our experiment exhibited high heritability (>60 percent) in the broad sense. Given that most of the traits exhibit high heritability and high genetic advance as a percentage of the mean (GAM), we can infer that these traits are primarily the result of additive gene action. A significant amount of diversity was found in the set of genotypes under study, as revealed by UPGMA clustering and principal component analysis of genotypes based on quantitative traits. The findings of this study could greatly increase genetic variation for rice improvement and aid in the selection of the most diverse cultivars. Therefore, the tested landraces contained several potential yield-related characters; those landraces that possessed the desired yield-related traits could then be used in rice breeding programs to create new superior varieties with high yield potential.

Recommendations for Further Research

The present study found significant variability for quantitative and qualitative traits, which suggests different genetic backgrounds and can be used for effective and strong rice improvement programs. Additionally, research should be conducted on how these rice landraces respond to various biotic and abiotic challenges, as well as grain quality evaluation, cooking and nutritional quality evaluation, hybridization, micronutrient identification and integration and molecular characterization.

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Conflict of 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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