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Heritability, correlation, genotypic and phenotypic coefficient of variance, and path coefficient analysis of pipeline spring rice genotypes in western hills of Nepal

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Abstract

A participatory varietal trial on spring rice (*Oryza sativa* L.) was conducted at farmer's field of Dhamilikuwa, Lamjung with an objective to find out high yielding spring rice genotypes of farmer's interests with study of variability, heritability, GCV, PCV, preference score and character association between yield and yield attributes during spring season 2017. Seven spring rice genotypes were laid out in randomized complete block design (RCBD) with three replications. Preference score was determined by CGIAR model using positive votes, negative votes and total votes casted. Analysis of variance revealed that yield and yield attributes were statistically different among genotypes. Phenotypic coefficients of variance were higher than genotypic coefficients of variance in all the characters studied. A joint consideration of high heritability in broad sense and high genetic advance as percentage of mean found in flag leaf area, grain yield and test weight could be explained by additive gene action whereas high heritability in broad sense and moderate/low genetic advance as percentage of mean found in plant height, maturity days, heading days, and chlorophyll could be explained by non-additive gene action. Grain yield of spring rice was significantly correlated with flag leaf area ($r = 0.799^{**}$), fertility percentage ($r = 0.697^{**}$), effective tillers ($r = 0.665^{*}$), panicle length ($r = 0.587^{*}$) and leaf chlorophyll content ($r = 0.579^{*}$). Selection based on these attributes is very important key for crop improvement through suitable breeding program. On path analysis, flag leaf area has highest positive direct effect on yield followed by test weight, panicle length, and heading days.

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Introduction

Rice (*Oryza sativa* L.) is one of the pivotal staple cereal crops feeding more than 3.5 billion people worldwide (IRRI, 2017). *Oryza sativa* L. belongs to Family Poaceae, Sub-family Oryzoideae, tribe Oryzae with chromosome number 24 i.e. 2n = 24 (Grist, 1986). Rice ranks third most staple crop after maize and wheat in world in terms of production (NGS, 2017). Its annual production in world was 741.4 million ton with yield of 4.55 t/ha (FAOSTAT, 2017). It ranks first important staple crop of Nepal which is followed by maize, wheat, millet and barley. It accounts for one-fifth of total agricultural GDP of the country. Nepal is rich in rice genetic resources with 1,700 rice landraces growing from 60 to 3,050 m altitude (Mallick, 1981). Rice production, production area and productivity in Nepal during fiscal year 2015/2016 was 5.23 million metric ton, 1.55 million ha & 3.36 metric ton/ha (MoAD, 2017).

Food insecurity has grown as a major problem to focus in recent scenario of Nepal. In addition, rapid population growth has increased daily food demand (Basnet, 2008). Furthermore, in recent decade's climate change and natural calamities like drought, flood, pest infestation and fluctuation in rainfall pattern are extra risk factors to have food secured condition (Bhandari, 2015). In order to meet the highest growing insists for rice grain, development of high yielding genotypes with enviable agronomic traits for miscellaneous ecosystem is therefore a requisite. However, grain yield is a complex trait, proscribed by various genes, environmentally influenced and determined by the magnitude and nature of their genetic variability in which they grow (Singh *et al.*, 2000). Use of adaptable and high yielding variety is one of key factor in achieving rice sufficiency (Christian, 2015).

Correlation coefficient helps to find the relative contribution of component characters towards yield (Panse, 1957). Character association of component qualities with yield and among themselves is very essential. The relationships between rice component and yield have been premeditated widely at phenotypic level.

Thus, yield components have influence on ultimate yield both directly and indirectly (Tukey, 1954). Splitting of total correlation into direct and indirect effects, therefore, would provide a more meaningful interpretation of such association. Path coefficient, which is a standard partial regression coefficient, specifies the cause and effect relationship and measures the relative importance of each variable (Wright, 1921). Therefore, correlation in combination with path coefficient analysis will be an important tool to find out the association and quantify the direct and indirect influence of one character upon another (Dewey and Lu, 1959).

Inappropriate genotypic/varietal evaluation and selection of our country had led to the less development of variety with high yield potential. Improvement of spring rice genotypes by study of the genetic variability, heritability, and character association between yield traits help in rice breeding for development of best spring rice varieties.

Materials and method

Study site

The experiment was carried out at farmer's field of Rinas Municiplity-6, Dhamilikuwa, Lamjung, Nepal situated at 28.09°N latitude, 84.47°E longitude and altitude of 607 m above mean sea level.

Research layout and planting material

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Seven upland rice genotypes (Table 1) obtained from Regional Agriculture Research Council, Lumle were used in this study. The experimental material was planted in three blocks. Each block consisted of eight genotypes randomized and replicated within each block of size 14 x 21 m^2. Twenty seven days old seedlings were transplanted 20 cm apart between rows and 20 cm within the row. All necessary precautions were taken to maintain uniform plant population in each treatment per replication. All the recommended packages of practices were followed along with necessary prophylactic plant protection measures to raise a good crop.

Collection and statistical interpretation of data

Preference analysis through casting votes was conducted when most variety reached around 80% maturity following Paris *et al.* (2011). Observations were recorded and the data was subjected to statistical analysis. Statistical analyses for the yield and yield attributes were done through F-test in R 3.1.1. The phenotypic and genotypic variance components and coefficients of phenotypic and genotypic of variation to compare the variation among traits were calculated by the methods suggested by Lush (1940) and Chaudhary and Prasad (1968). Heritability in broad sense for all characters was computed using the formula given by Falconer (1996). Genotypic and phenotypic coefficient of correlation between two characters was determined by using variance and covariance components suggested by Weber and Moorthy (1952).

Results and discussion

Mean performance and analysis of variance

Mean values and significant levels of yield and yield attributing traits of pipeline spring rice genotypes are presented in Table 2. Significant results were observed for the traits effective tillers, chlorophyll content, heading days, maturity days, flag leaf area, plant height, harvest index, test weight and grain yield which indicates the existence of sufficient genetic variability.

Table 1. Genotypes used in research.

Entry No.	Treatments
1	Dhamilikuwa local (local check)
2	Hardinath-1
3	IR 09N-503
4	IR 09N-538
5	NR 2168-65-1-1-1-1-1
6	OM2574
7	PK 19333-9-9-1-1-5-5-4-1

Genotypic and phenotypic coefficient of variation

Genotypic coefficient of variability (GCV) was found maximum in flag leaf area (21.74) followed by effective tiller (21.94) and grain yield (22.41). Whereas, moderate genotypic coefficient of variability (GCV) was found in test weight (16.41) and straw yield (14.47). Low genotypic coefficient of variability (GCV) was found in panicle length (9.79), chlorophyll content (7.32), plant height (6.87), heading days (5.20), maturity days (4.50)and spikelet fertility (4.28).Phenotypic coefficient of variability (PCV) was found maximum in effective tiller (32.58) followed by spikelet fertility (29.47), grain yield (29.47), flag leaf area (29.47) and straw yield (24.23). Medium phenotypic coefficient of variability (PCV) was recorded for test weight (19.42), panicle length (14.97) and chlorophyll content (10.62) whereas low PCV was found in plant height (7.73), maturity days (5.36) and heading days (4.56).

The current study suggests that phenotypic variance (Vp) and phenotypic coefficient variance (PCV) were higher than theirs corresponding genotypic variance (Vg) and genotypic coefficient of variance (GCV) respectively for all the characters studies, indicating that the expression of these characters was influenced by environment. Similar results were reported by Dutta *et al.* (2013); Singh *et al.* (2014) and Tuhina-Khatun *et al.* (2015) in rice. It is interesting to note that this difference was low for heading days, maturity days, chlorophyll, panicle length, and flag leaf area, indicating that these characters were less influenced by environment. It also suggests that selection based on these characters would be effective for future crossing. Analogous results were also found by Prajapati *et. al.* (2011) and Singh *et al.* (2014).

Table 2. Mean square from analysis of variance of spring rice genotypes at Dhamilikuwa, Lamjung, 2017.

Source of variation	*Genotype*	*Replication*	*Error*
Character	Df 6	2	12
Effective tiller	11.33*	6.675	2.966
Chlorophyll content at 60 DAT	17.524*	1.354	4.714
Heading days	48.19***	3.48	0.98
Maturity days	73.8***	1	0.59
Flag leaf area	139.14***	1.65	8.1
Panicle length	3.175	8.046	4.348
Fertility percentage	139.81	8.69	228.63
Plant height	147.3***	19.19	11.89
Harvest index	153.98*	0.3	5.74
Test weight	46.15***	6.48	5.43
Grain yield	2.2604 **	0.183	0.3192

Sig. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Heritability (Board sense heritability)

High heritability estimates for days to maturity (0.98), days to heading (0.94),flag leaf area (0.86), plant height (0.79), test weight (0.71) and grain yield (0.67) indicated a high response to selection in these traits. While moderate heritability was found in trait chlorophyll content at sixty days after transplanting (0.48), effective tiller (0.45), panicle length (0.43), straw yield (0.38) and low heritability with spikelet fertility (0.02)as presented in Table 5.

In consistence with these result, high heritability estimate were recorded for grain yield, plant height and days to heading (Al-Tabbal *et al.*, 2012; Dutta *et al.*, 2013; Rafii *et al.*, 2014). High values of heritability in broad sense indicate character is less influenced by environmental effects.

Table 3. Estimates of Phenotypic (σ^2p) and Genotypic (σ^2g) Variance, Phenotypic coefficient of variability (PCV) and Genotypic coefficient of variability (GCV), Broad sense heritability (H^2_{bs}), Expected genetic advances (GA) and Genetic advance as percent of mean (GAM).

Character	*Mean*	*σ^2 g*	*σ^2 p*	*Coefficient of variation*		*H^2_{bs} (Broad sense)*	*GA*	*GAM*
				GCV	PCV			
GY	3.70	0.65	0.97	21.74	26.56	0.67	1.36	36.64
SY	10.38	2.26	5.89	14.47	23.37	0.38	1.92	18.45
TW	22.44	13.57	19.00	16.41	19.42	0.71	6.41	28.58
SF	28.88	1.53	72.47	4.28	29.47	0.02	0.37	1.28
FLA	29.49	43.68	51.05	22.41	24.23	0.86	12.59	42.70
HD	76.24	15.74	16.72	5.20	5.36	0.94	7.93	10.40
MD	109.71	24.40	24.99	4.50	4.56	0.98	10.06	9.17
PH	97.74	45.14	57.03	6.87	7.73	0.79	12.31	12.60
ET	7.61	2.79	6.15	21.94	32.58	0.45	2.32	30.44
CH	28.23	4.27	8.98	7.32	10.62	0.48	2.93	10.40
PL	20.73	4.12	9.63	9.79	14.97	0.43	2.74	13.20

TW= Test weight (1000 grain weight), FP= Fertility percentage, FLA= Flag Leaf Area, HD= Heading days, MD=Maturity Days, PH=Plant height, ET=Effective Tiller, CH=Chlorophyll at 60 days after transplanting, PL= Panicle Length, GY=Grain Yield ton per Ha.

Genetic advance and genetic advance as percentage of mean

Heritability in broad sense and the genetic advance are also important selection parameters. It is more useful as a selection tool when considered jointly with heritability. Genetic advance was found maximum in flag leaf area (12.59) followed by plant height (12.31), maturity days (10.06), heading days (7.93), test weight (6.41), chlorophyll content (2.93), panicle length (2.74), effective tiller(2.32), straw yield (1.92), grain yield (1.36) and spikelet fertility (0.37). High genetic advance as percentage of mean was found in flag leaf area (42.70), grain yield (36.64), and test weight (28.58) with high heritability in broad sense. These results could be explained by additive gene action and their selection may be done in early generations. Similar findings have been reported by Wolie *et al.* (2013), Ogunbayo *et al.* (2014) in rice and Reza *et al.* (2015) in wheat.Whereas, medium genetic advance mean was found in straw yield (18.45), panicle length (13.20) plant height (12.60), chlorophyll (10.40) and heading days (10.40).

Table 4. Estimates of phenotypic and genotypic correlation coefficients between yield and yield component characters.

	TW	SF	FLA	HD	MD	PH	ET	CH	PL	GY
TW	1									
SF	.764*	1								
FLA	.345	.699	1							
HD	-.300	-.407	-.253	1						
MD	-.283	-.350	-.202	.895**	1					
PH	-.129	-.259	.083	-.058	-.137	1				
ET	.814**	.840*	.552	.062	.098	-.195	1			
CH	.842**	.835*	.465	-.496	-.441	-.353	.635	1		
PL	.640	.742	.525	.067	.120	-.144	.753	.732	1	
GY	.433	.697**	.799**	.003	.087	-.474	.665*	.579*	.58*	1

TW= Test weight (1000 grain weight), FP= Fertility percentage, FLA= Flag Leaf Area, HD= Heading days, MD=Maturity Days, PH=Plant height, ET=Effective Tiller, CH=Chlorophyll at 60 days after transplanting, PL= Panicle Length, GY=Grain Yield ton per Ha. *Correlation is significant at the 0.05 level (2 tailed) and** Correlation is significant at the 0.01 level (2 tailed).

Correlation between grain yield and yield component characters

The phenotypic correlation coefficients among yield and yield attributes are presented in Table 4. The result revealed that grain yield of spring rice was significantly correlated with flag leaf area (r =0.799**), fertility percentage (r= 0.697**), effective tillers (r =0.665*), panicle length (r = 0.587*) and leaf chlorophyll content (r = 0.579*). The result was in unison with Roy *et al.* (1995) and Reddy *et al.* (1997) in term of effective tillers, and Hairmansi *et al.* (2009) in term of spikelet fertility. Similarly, Khaliq *et al.* (2004), Akhtar and Chaudhary (2006) and Saleem *et al.* (2006) reported the significant positive association between yield and panicle length. Grain yield was found negatively correlated with plant height (r = -0.474); moderate positive correlation with test weight (r =0.433) and low degree of positive correlation with maturity days(r =0.087) and heading days (0.003). Ray *et al.* (1993), Paul and Sharma (1997) and Balan *et al.* (1999) reported positive correlation between test weight and grain yield per hill. According to Tahir *et al.*, 1988 and Zahid *et al.*, (2006), tallness in rice reduces the paddy yield due to high accumulation of photosynthates in vegetative parts as compared to reproductive parts (i.e. seed formation and grain filling) and lodging susceptibility. However, in contrast with the result, De and Surya (1988) and Dilruba *et al.* (2014) presented the positive correlation between plant height and yield per plant.

Correlation among character

The result revealed that test weight has positive correlation with chlorophyll content at 60 days after transplanting (r = .842**), effective tiller (r = .814**), and spikelet fertility (r = .764*).Test weight is negatively correlated with plant height (r = -.129), maturity days (r = -.283) and heading days (r = -.300). The spikelet fertility has strong positive correlation with effective tiller (r = .840*) and chlorophyll content at 60 days after transplanting (r = .835*). It has high degree of positive correlation with panicle length (r = .742) and flag leaf area(r= .699) also. Spikelet fertility has negative correlation with plant height (r =-.259), maturity days (r =-.350) and heading days (r = -.407).The association of panicle length with 1000-grain weight was found in positive direction. Similar positive correlation between panicle length and days to maturity was also observed by Chaubey and Singh (1994).

Table 5. Path coefficient analysis showing direct (diagonal bold) and indirect effect of various traits in grain yield of spring rice genotypes at Dhamilikuwa, Lamjung, 2017.

	TW	*FP*	*FLA*	*HD*	*MD*	*PH*	*ET*	*CH*	*PL*
Via TW	0.765	0.585	0.264	-0.230	-0.217	-0.099	0.623	0.644	0.490
Via FP	-0.306	-0.401	-0.280	0.163	0.140	0.104	-0.337	-0.335	-0.298
Via FLA	0.393	0.795	1.138	-0.288	-0.230	0.094	0.628	0.529	0.597
Via HD	-0.001	-0.001	-0.001	0.002	0.002	0.000	0.000	-0.001	0.000
Via MD	0.003	0.004	0.002	-0.009	-0.010	0.001	-0.001	0.005	-0.001
Via PH	0.103	0.207	-0.066	0.046	0.109	-0.798	0.156	0.282	0.115
Via ET	-0.213	-0.219	-0.144	-0.016	-0.026	0.051	-0.261	-0.166	-0.197
Via CH	-0.529	-0.524	-0.292	0.311	0.277	0.222	-0.399	-0.628	-0.460
Via PL	0.217	0.252	0.178	0.023	0.041	-0.049	0.256	0.249	0.340

TW= Test weight (1000 grain weight), FP= Fertility percentage, FLA= Flag Leaf Area, HD= Heading days, MD=Maturity Days, PH=Plant height, ET=Effective Tiller, CH=Chlorophyll at 60 days after transplanting, PL= Panicle Length, GY=Grain Yield ton per Ha.

Days to maturity was found strongly correlated with heading days (r = .895**) and negatively correlated with chlorophyll content (r= -.496) and plant height (r = -.137). Similarly, Choudhary and Das, (1998) presented positive and significant association between days to heading and days to maturity.

Path coefficient analysis between grain yield and other traits

Path coefficient analysis (Table 5) revealed that flag leaf area has highest positive direct effect on yield followed by test weight, panicle length, and heading days. Similar result was obtained in Akhtar *et al.* (2011). However, the results were in contrary with Yolanda and Das (1995) and Zahid *et al.* (2006) who reported that fertility percentage has highest positive direct effect. Negative direct effect was found highest on plant height followed by Chlorophyll contents at sixty days of transplanting and effective tillers. Similar result was found in Akhtar *et al.* (2011). Positive highest indirect effect was found highest on fertility percentage via flag leaf area followed by chlorophyll via test weight and effective tiller via flag leaf area. Similarly negative highest indirect effect was found on test weight and fertility percentage via chlorophyll.

Conclusion

Analysis of variance revealed that yield and yield attributes were statistically different among genotypes. Phenotypic coefficients of variance were higher than genotypic coefficients of variance in all the characters studied, indicating that the expression of these characters was influenced by environment.

High heritability in broad sense estimates were obtained for days to maturity (0.98), days to heading (0.94), flag leaf area (0.86), plant height (0.79), test weight (0.71) and grain yield (0.67) suggesting that these traits were primarily under genetic control. A joint consideration of high heritability in broad sense and high genetic advance as percentage of mean found in flag leaf area, grain yield and test weight could be explained by additive gene action whereas high heritability in broad sense and moderate/low genetic advance as percentage of mean found in plant height, maturity days, heading days, test weight and chlorophyllcould be explained by non-additive gene action. Grain yield of spring rice was significantly correlated with flag leaf area ($r = 0.799^{**}$), fertility percentage ($r = 0.697^{**}$), effective tillers ($r = 0.665^{*}$), panicle length ($r = 0.587^{*}$) and leaf chlorophyll content ($r = 0.579^{*}$). Selection based on these attributes is very important key for crop improvement through suitable breeding program. On path analysis flag leaf area has highest positive direct effect on yield followed by test weight, panicle length, and heading days and could be used as an assortment criteria for hybridization pros.

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