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ORIGINAL RESEARCH ARTICLE





Correlation coefficient and path analysis of yield and yield attributing characters of rice (*Oryza sativa* L.) genotypes under reproductive drought stress in the Terai region of Nepal

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ARTICLE HISTORY	ABSTRACT
Received: 07 October 2022 Revised received: 17 December 2022 Accepted: 20 December 2022	An experimental trial of nine rice genotypes was conducted in the Agronomy field of the Insti- tute of Agriculture and Animal Science (IAAS) Paklihawa Campus under a randomized block design layout with three replications from July to November of 2022. The aim was to study genetic variability and analyze the character association of yield and yield-attributing compo-
Keywords	nents in rice genotypes and their direct and indirect effect on grain yield under reproductive drought stress conditions. Observations on days to flowering (50%), plant height, panicle
Direct effect Grain yield Indirect effect Stress	length, panicle weight, number of grains/panicles, effective panicle/m ² , grain yield, and 1000 kernel weight were recorded. Grain yield showed a highly positive significant correlation with effective panicle/m ² (0.713^{**}), followed by plant height (0.347) and panicle length (0.289). The path coefficient analysis of different traits revealed the highest positive direct effect of the effective panicle per m ² (0.748963), followed by panicle length (0.24145) and plant height (0.227505). The highest negative direct effect was shown by the number of grains per panicle (- 0.31218). The experimental results revealed that the selection of trait-effective panicle per square meter would be most beneficial for the improvement of yield in rice genotypes facilitating selection and plant breeding programs.

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INTRODUCTION

In the case of growing area, production, and consumption, rice occupies the top number as a major cereal crop in Nepal. The contribution of rice to Nepal's economy is so beneficial and is also said to be the backbone of the country's GDP. It ranks first in terms of production and productivity which helps to exert a big impact on the majority of people's quality of life (Tiwari *et al.*, 2019). It is one of the most prominent staple foods in the world, feeding at least 63% of people on the earth and providing 20% of the average global population's calories and 30% of the population in Asia (Shrestha *et al.*, 2018). More than 90% of the rice produced worldwide is produced in the continent of Asia while

China(214 MT) and India(172 MT) are rated 1st and 2nd, respectively, in terms of global output (Pokhrel *et al.*, 2021). 20% of the world's dietary energy is derived from rice, compared to 19 and 5% from wheat and maize respectively, which claims that the most vital crop for global food and nutrition security is rice (Gadal *et al.*, 2019). According to several research, Nepal is home to about 2000 different rice landraces that are thought to be cultivated between 60 and 3050 meters above sea level (Tiwari *et al.*, 2019). By 2030, the world is predicted to have to produce 60% more rice than it did in 1995 to cope with the problem of food security and poverty (K. *et al.*, 2014).

The most cost-effective and effective strategies to reduce the yield gap between rice and the growing global population are to



improve existing varieties and to generate high-yielding cultivars which support to order to increase in the variety, through breeding operations (Shrestha *et al.*, 2018). Examining the relationships between quantitative characteristics is crucial for determining if it would be possible to jointly pick two or more qualities as opposed to choosing the secondary features as genetic bonuses for the core traits under discussion (Saleh *et al.*, 2020). A successful breeding program requires an understanding, research and selection of the genetic variability of potential yield-contributing traits, their interactions, and how the yield is related to these factors. Additionally, the selection was based on knowledge of heritability, which determines the degree of a trait's capacity to be passed on to the next generation.

Participatory Varietal Selection (PVS), that was launched at the Lumle Agriculture Center in 1989-1990, seems to be an effective strategy because it evaluates, confirms, and promotes new rice cultivars while taking into account the socio-technological context of the end-users and highlights their preferences (Kosanke, 2019). The PVS technique has been using indigenous knowledge to accelerate the adoption of emerging types of rice genotypes (Aristya et al., 2021). Drought stress is significant due to main five factors: its unpredictable nature, manner of occurrence, severity, length, and timing (Abarshahr et al., 2011). One of the key issues limiting rice output is water stress, which is especially pronounced during the reproductive stage that leads to substantial production decreases and irreversible damage (Pant et al., 2019). Both the vegetative and reproductive stages of rice are when it is most vulnerable to drought stress (Bunnag and Pongthai, 2013). Grain yield is one of the variability characteristics which is influenced by numerous variables. The selection of features that would enhance a complicated property as yield would benefit from correlation analysis and path coefficient analysis, which divides the correlation coefficients into their direct and indirect impacts (Cyprien et al., 2011).

Correlation explains the degree of association between the variables, while, path coefficient analysis, a statistical method, has been used to organize and present the causal links between predictor variables and response variables through the use of a path diagram based on experimental data (Samonte *et al.*, 1998). The extent of the relationship between yield and its constituents is established by correlation and path analysis, that accounts to provide clear knowledge of their relationship to grain production (K. *et al.*, 2014). Breeders will be able to create effective selection criteria for desired genotypes in early segregating populations with the use of the information by using correlation and path analysis on the relative direct and indirect contributions of each component trait to yield (Kiani and Nematzadeh, 2012).

The results of the current study showed that the genotypic correlation coefficients were greater than the phenotypic correlation coefficients, indicating that genetic factors were responsible for the observed correlations between the various features (Manjunatha *et al.*, 2018). The yield-attributing character associated with higher improvement in yield plays a crucial role in the selection of better genotypes. Through such research, we can enhance the breeding program for the selection of suitable genotypes.

MATERIALS AND METHODS

Site description and experimental material

The field experiment was conducted at the Institute of Agriculture and Animal Science Paklihawa, Rupandehi, Nepal. It is geographically located with an altitude of 100 masl, latitude 27°30' N, 83°27' E, and 79 m above sea level. Nine different types of rice genotypes were collected from National Wheat Research Program (NWRP), Bhairahawa as shown in Table 1. Source of these genotypes was National Rice Research Centre, Hardinath.

Experimental design

The evaluation of different genotypes in the experimental site was carried out using a Randomized Complete Block design as shown in Figure 1. Three replications are prepared. Each replication consists nine plots. The plot size was $5m \times 2m$.

Table 1. List of rice genotypes sown in the experimental field.

S. N.	Genotypes	
1	IR17L1408	
2	IR16L1831	
3	IR16L1704	
4	IR16L1713	
5	IR17L1323	
6	Vandana	
7	Sukhdhan 3	
8	IR16L1801	
9	IR17L1387	



Figure 1. Randomized Complete Block Design Layout of the experimental field consisting of the nine rice genotypes arranged in three replications

	Max. Temp. (°C)	Min. Temp (°C)	Avg. Temp. °C	Relative Humidity (%)
June	28.5	20	24.2	63
July	29.1	21	25	78
August	29.03	20.6	24.8	81
September	28.5	19.7	24.1	80
October	26.4	14.9	20.6	72
November	25	11	18	70

	Table 2. Agro-meterolo	gical information	of Bhairahwa, Ru	pandehi from the	month of June to November
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Source: Local, National, & Global Daily Weather Forecast | AccuWeather and World Weather Averages | Weather-2-Visit (weather2visit.com).

Land preparation and fertilizer application weeding

Nursery bed was prepared and seeds were sowed in 7th of June, 2022. After 4-5 weeks the seedlings were uprooted and planted in the field which had already been prepared i.e., transplanting was done. Spacing was maintained $20 \text{cm} \times 20 \text{ cm}$. No. of seeds / hill was made 2-3. Compost manure at the rate of 5 ton/ha and the individual plots was fertilized with a recommended dose of 100:40:30 kg NPK/ ha. At basal dose, 50:40:30 NPK kg/ha was applied while the remaining was top dressed i.e. First at 20-25days from emergence and second at 40-60 days from emergence. First weeding was done between 20 days after germination. Second weeding was done 40 days after weeding. Harvesting was done in 2nd November, 2022.

Agro-metrological data

Weather data was recorded in IAAS Paklihawa, Bhairahawa during the experimental period (7th June 2022 to 2nd November 2022), as shown in the Table 2.

Traits that are studied

Ten sample plants were selected randomly from each plot to collect data. Yield-attributing traits like Days to 50% flowering (DTF), Plant height (PH), Panicle length (PL), Panicle weight (PW), and Number of grains per panicle (NGPP) were noted. The mean $1m^2$ area was taken from each plot which represents the respective plot. Then, Effective Panicle per m² area (EP/m²), Grain Yield (GY), and 1000 grain weight (TGW) were recorded.

Statistical analysis

Microsoft Office Excel 2010 was used for data entry and processing. Data were analyzed via IBM SPSS Statistics 25 to compute Pearson's correlation among variables at 5% and 1%. Path coefficient was obtained using Excel to find out the direct and indirect effects of parameters in relation to the grain yield.

RESULTS AND DISCUSSION

Correlation between grain yield and other traits

The correlation coefficient analysis is commonly used to determine the nature and intensity of the relationship between two parameters, including grain yields, and has shown promise for simultaneously improving the connected traits through selec-

tion. Days to 50% flowering, plant height, panicle length, panicle weight, number of grains per panicle, effective panicle per meter square, and thousands of grain weight were all separately calculated for different rice genotypes as part of extensive phenotypic research on the relationship between rice yield and yield components. In Table 3, the outcomes are displayed. Effective panicle/m² and grain yield had a high, direct, and significant association (r = 0.713^{**}). Another study discovered a considerably strong positive correlation between effective panicle/m2 (Singh et al., 2006). A small but significant association between plant height and panicle length with grain yield was discovered (r=0.347 and r=0.289, respectively) similarly, a weak but significant association between days to 50% flowering (r=0.051) and the positive insignificant association between the number of grains per panicle (r=0.003) was recorded. Earlier study by (Sangaré et al., 2017) revealed a similar finding for plant height and days to 50% flowering with grain yield. Our result showed a low but significant relationship between panicle length and grain yield under drought stress (r= 0.289), this conclusion was further validated by Panja et al. (2017).

In contrast, the research we have conducted does not support the idea by Augustina et al. (2013) that panicle length and grain yield are negatively correlated. Additionally, the scientist discovered a weak and positive correlation between plant height and grain yield as well as a weakly significant correlation between days to 50% heading and grain yield, all of which are similar to our findings (Rasel et al., 2018). However, there was a slight and substantial negative significant correlation between panicle weight (r=-0.096) and thousand-grain weight (r=-0.192) with grain yield. Our results contradict previous reports that claimed there was a positive and significant correlation between panicle weight and grain yield (Akinwale et al., 2011). Previous researchers had similar results when they looked at the relationship between grain yield and thousand-grain weight (Fiyaz et al., 2011). Our result showed a negative and significant association between grain yield and thousand-grain weight, however, conflicted with the earlier findings by (Islam et al., 2016).

It has been discovered that one of the aforementioned features directly influenced grain yield by slightly increasing or decreasing it. Characteristics that have a positive direct effect and a positive significant correlation coefficient with grain yield are typically found to affect grain yield favorably and require careful consideration when choosing cases (Prince *et al.*, 2015).

5	6	7

Parameters	DTF (50%)	PH	PL	PW	NGPP	EP/m ²	TGW	GY
DTF (50%)	1	-0.358	0.268	0.303	-0.160	-0.178	0.137	0.051
PH	-0.358	1	.404*	-0.195	0.130	0.185	0.062	0.347
PL	0.268	.404*	1	.419*	0.360	-0.039	-0.043	0.289
PW	0.303	-0.195	.419*	1	.532**	-0.243	-0.109	-0.096
NGPP	-0.160	0.130	0.360	.532**	1	0.129	506**	0.003
EP/m ²	-0.178	0.185	-0.039	-0.243	0.129	1	-0.365	.713**
TGW	0.137	0.062	-0.043	-0.109	506**	-0.365	1	-0.192
GY	0.051	0.347	0.289	-0.096	0.003	.713**	-0.192	1

 Table 3. Correlation analysis among grain yield and its components of PVS rice genotypes in drought condition at Paklihawa,

 Bhairahwa Rupandehi in 2021.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

DTF (50%): days to 50% flowering; PH (cm): plant height; PL (cm): panicle length; PW (gm): panicle weight; NGPP: number of grain per panicle; EP/m²: effective panicle per meter square; TGW (gm): thousands grain weight; GY(Kg/ha): grain yield.

When breeding complex qualities like yield for environmental stressors like drought, the correlation between the traits under stress circumstances is a key consideration (Hairmansis *et al.*, 2010). According to our studies, days to 50% flowering plant height, panicle length, and effective panicle per square meter, all have significantly and positively correlated with grain yield whereas the number of grains per panicle was a positive and insignificant association with grain yield. On the other hand, panicle weight and thousand-grain weight showed negative but significant associations with grain yield, suggesting that simultaneously selecting these characteristics would increase grain yield.

Correlation between characters

Days to (50%) flowering: Days to 50% flowerings showed a weak positive association with panicle weight(r=0.303) followed by panicle length(r=0.268) and thousand-grain weight (r=0.137). Similarly, weak negative association with plant height (r=-0.358) followed by effective panicle per square meter (r=-0.178) and several grains per panicle (r=-0.160) which showed a low negative correlation with days to 50% flowering. Our findings had contradicted with previous findings by Singh *et al.* (2006).

Plant height (cm): Plant height was found moderate significant positive association with panicle length ($r=0.404^*$), low to weak positive correlation with effective panicle per square meter (r=0.185), number of grains per panicle(r=0.130), and thousand-grain weight(r=0.062) respectively. And, a low negative correlation with days to 50% flowering(r=-0.358) as well as with panicle weight (r=-0.195). A similar result was reported by Singh *et al.* (2006) for panicle length, the number of grains per panicle, and days to 50% flowering and contradicts our findings for effective panicle per meter square and thousand-grain weight.

Panicle length (cm): Panicle length was found moderate significant positive association with panicle weight ($r=0.419^*$), as well as with plant height ($r=0.404^*$), with low positive significant correlation with the number of grains per panicle (r=0.360), and with days to 50% flowering (r=0.268). While the weak negative

correlation with thousand-grain weight (r=-0.043) and with effective panicle per square meter(r=-0.039) respectively. Our findings for the number of grains per panicle, thousand-grain weight, effective panicle per meter square, panicle weight, and plant height were in accordance with earlier researchers where-as contradicting for days to 50% flowering (Sabesan *et al.*, 2009).

Panicle weight (gram): Panicle weight was found to positive and strong significant association with NGPP ($r=0.532^{**}$), a moderate significant association with panicle length, and a weak association between panicle weight and days to 50% flowering (r=0.303). While, low to weak association with effective panicle per square meter (r=-0.243), plant height (r=-0.195), and thousand-grain weight (r=-0.109) respectively. Panicle weight and other traits showed a significant and positive correlation with panicle length which was similar to our findings but thousandgrain weight and days to 50% flowering were contradict our findings (Majeed *et al.*, 2011).

Number of grains per panicle (gram): Strong, positive, and significant association with panicle weight ($r=0.532^{**}$) and a considerably weak association with panicle length(r=0.360), effective panicle per square meter (r=0.129), and, plant height (r=0.130) respectively. And, a strong negative significant association with thousand-grain weight ($r=-0.506^{**}$) and a weak negative but significant association with days to 50% flowering(r=-0.160).

Effective panicle per square meter (EP/m2): Plant height (r=0.185) and the number of grains per panicle (r= 0.129) showed weak positive and significant associations with effective panicle per square meter. Whereas, thousand-grain weight (r=-0.365), panicle weight (r=-0.243), days to 50% flowering (r=-0.178) and panicle length (r=-0.039) showed low to a weak and negative association with effective panicle per meter square respectively.

Thousand-grain weight (gram): Days to 50% flowering (r=0.137) and plant height (r=0.062) showed a weak and significant association with thousand-grain weight. While strong and

	DTF (50%)	PH	PL	PW	NGPP	EP/m ²	TGW	GY
DTF (50%)	0.115797	-0.04142	0.030984	0.0351	-0.01856	-0.02059	0.0159	0.051
PH	-0.08137	0.227505	0.091912	-0.0444	0.029573	0.042082	0.014027	0.347
PL	0.064605	0.097546	0.24145	0.101168	0.086947	-0.00938	-0.01047	0.289
PW	0.045742	-0.02945	0.06323	0.150907	0.080283	-0.03661	-0.01646	-0.096
NGPP	0.050036	-0.04058	-0.11242	-0.16608	-0.31218	-0.04031	0.157963	0.003
EP/m ²	-0.13318	0.138536	-0.02908	-0.18172	0.096708	0.748963	-0.27374	0.713
TGW	-0.01084	-0.00487	0.003422	0.008608	0.039939	0.028848	-0.07893	-0.192
GY	0.050794	0.347275	0.289497	-0.09642	0.002709	0.713002	-0.19171	

 Table 4. Path coefficient analysis among grain yield and its components of PVS rice genotypes in drought condition at Paklihawa,

 Bhairahwa Rupandehi in 2021.

DTF (50%): days to 50% flowering; PH (cm): plant height; PL (cm): panicle length; PW (gm): panicle weight; NGPP: number of grain per panicle; EP/m²: effective panicle per meter square; TGW (gm): thousands grain weight; GY(Kg/ha): grain yield.

negative significant association with the number of grains per panicle (r=-0.506) followed by effective panicle per square meter (r=-0.365) and low to weak but significant association with panicle weight (r=-0.109) and panicle length (r=-0.043) respectively. Karim *et al.* (2014) reported that thousand-grain weight exhibited a positive significant association with the number of grains per panicle, effective panicle per m2, which supports our findings but weak negative significant association with plant height and days to 50% flowering, which contradicted from our findings.

Path coefficient analysis: Path coefficient analysis reveals the direct indirect effects exerted by the said parameters upon others. The values on main diagonal represents the direct effect, while the remaining values indicate indirect effects. As per the path coefficient analysis conducted on the yield and yield-attributing components of PVS rice genotype on drought stress condition, following direct and indirect effects as displayed by Table 4 were obtained. All yield-attributing features, excluding the number of grains per panicle and the weight of the thousand kernels, exhibited a positive and direct effect on grain yield, with effective panicle per m2 showing the highest positive and direct relationship with grain yield.

Direct effects (positive and negative) via studied traits: The results of path analysis showed the highest positive and strong direct effects on grain yield was exerted by effective panicle per meter square (0.748963) followed by panicle length (0.24145). This results matched with Cyprien et al. (2011) and Ratna et al. (2015). The positive direct effect on grain yield was also exhibited by plant height (0.227505) followed by mild positive panicle weight (0.150), and plant height (0.138536). 1000 - grain weight (0.15) also contributed positive direct effect on grain yield. The same result with plant height was also founded by Saleh et al. (2020) and Sowmiya and Venkatesan (2017), similar finding with panicle length was also supported by result of Solomon and Wegary (2016). But in contrary, Ratna et al. (2015) and Saleh et al. (2020) concluded that thousand grain weight showed highest positive direct effects on grain yield. The same result with panicle weight was also founded by Cyprien et al. (2011). The result of 1000 - grain weight agreed with Agahi et al. (2007). The result of NGPS didn't match with Agahi et al. (2007) as they

found this trait as important criteria in selection of breeding programs while similar result was matched with Solomon and Wegary (2016). In the case of Days to 50% flowering, the similar result was matched with finding of Abdul Fiyaz *et al.* (2011). The highest negative direct effects were shown by no. of grain per panicle (-0.31218). similarly, the Days to Flowering (50%) (-0.133198), panicle weight (-0.18172), and thousand kernel weight also shows negative direct effects on grain yield. In the case of thousand kernel weight same result was also obtained by Sowmiya and Venkatesan (2017), while Chikkadevaiah *et al.* (2002) and Kumar (2014) concluded that this traits as important trait for drought tolerance in breeding programs.

Indirect effects (positive and negative) via studied traits: The salient indirect effects findings of study are summarized below:

- The indirect effect of days to flowering on grain yield was negative via plant height (-0.04142), number of grains per spike, and effective panicle per meter square (-0.02059). The finding matched the results of Chikkadevaiah *et al.* (2002).
- The indirect effect of plant height on grain yield via studied traits were all negative via each of days to footing and panicle weight (-0.0444), while positive via panicle length (0.091912), no. of grain per spike (0.029573), effective panicle per meter square (0.042082) and thousand kernel weight (0.014027). In the case of Days to 50% flowering, the result matched with Chikkadevaiah *et al.* (2002).
- The indirect effect of panicle length on grain yield via was negative via effective panicle per meter square (-0.00938) and thousand-grain weight (-0.01047)(Solomon and Wegary, 2016), while neglective positive via plant height (0.097546) and no. of grain per spike (0.085947), positive and medium via panicle weight (0.101168). Here, the result agreed with Days to 50% flowering, while thousand-grain weight didn't match the finding (Agahi et al., 2007).
- The indirect effect of panicle weight on grain yield was neglected and negative via effective panicle per meter square (-0.03661) and thousand-grain weight (-0.01646), while positive via DTF (0.045742), panicle length (0.06323) and NGPP (0.080283).
- The indirect effect of NGPP on grain yield was negative via

plant height (-0.04058), panicle length (-0.11242), panicle weight (-0.16608), and effective panicle per meter square (-0.04031) and positive mild via thousand-grain weight (0.157963). The result matched with the findings of Agahi *et al.* (2007) but results on thousand grain weight didn't match with Solomon and Wegary (2016).

- The indirect effects of EP/m² on grain yield were negative with studied traits via DTF (-0.13318), panicle length (-0.02908), panicle weight (-0.18172), and thousand-grain weight (-0.27374), mild positive via plant height (0.138536) and via NGPP 0.096708). But the finding didn't show similar results with Abdul Fiyaz *et al.* (2011).
- The indirect effect of TGW (gm) on grain yield with studied traits was negative via DTF (-0.01084), and plant height (-0.00487), while positive and neglected via panicle length (0.003422), panicle weight (0.008608), NGPP (0.039939) and EP/m² (0.028848). The similar results were found by Abdul Fiyaz et al. (2011).

Conclusion

The study revealed that a positive and highly significant correlation was found between the grain yield and effective panicle per m^2 , followed by significant relation to plant height and panicle length. Except for the number of grains per panicle and thousand kernel weight, all other traits showed a positive and direct effect on the grain yield, whereas effective panicle per m^2 exhibited the highest positive and direct effect on grain yield. Panicle weight and plant height also possess higher values for positive and direct effects. These results might help in exploring the potentiality for the selection of these traits for the improvement program in plant breeding among all the rice genotypes studied, as the improvement in these traits will simultaneously lead to the improvement of yield in rice varieties.

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Conflict of interests

Authors have not declared any conflict of interest.

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