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Association Analysis and Correlation Studies in Upland Rice (*Oryza sativa*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A total of 53 advanced breeding lines derived from 12 distinct crosses of upland rice germplasm were evaluated during Kharif 2018 at Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh. Grain yield showed significant positive correlation with no. of

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tillers per plant, no. of panicles per tiller, spikelets per panicle, biological yield, harvest index and test weight. Harvest index showed highly significant positive correlation with grain yield at both phenotypic and genotypic level. Moderate PCV and GCV was observed for number of tillers per plant followed by flag leaf length, seed yield per plant, harvest index, number of panicles per plant, test weight and panicle length. Genetic advance as per cent of mean was highest for number of tillers per plant, followed by flag leaf length, seed yield per plant, no. of panicles per plant, harvest index and test weight. Moderate genetic advance as per cent of mean was recorded for biological yield per plant, number of spikelets per plant, flag leaf width and plant height. High heritability coupled with high genetic advance as percent of mean in the present set of rice genotypes was recorded for plant height and harvest index. So, selection for these traits could lead to improvements in rice yield and productivity.

Keywords: Rice; agriculture; germplasm; upland rice.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is one of the most important food crops in world. Rice belongs to the genus Oryza of family Graminae (Poaceae). The genus includes 24 species out of which 22 are wild and two *viz*., *Oryza sativa* and *Oryza glaberrima* are cultivated. The basic chromosomes number (n) of the genus *Oryza sativa* is 12 (2n=24). Rice is most common crop of the continents cultivated under four different land types *viz*., irrigated (57%), rainfed lowland (37%), upland (9%) and deep water (3%)" (Aishwarya et al., 2024). "Rice, one of the most important crops of the world, has the evolutionary particularity of being semiaquatic and water requirement is quite higher *i.e*. 2500 litres to produce 1 kg of grain" (Ghoochani et al.,2017), and is expected that "rice production will be decreased due to water stress in many Asian countries affecting more than 19 million ha. This higher water requirement is probably due to large area of lowland irrigated rice. Thus it is necessary to opt for varieties requiring limited water" (Matsumoto et al., 2014) to sustain food security. "Variability occurs when there are differences in the genetic makeup of individuals in a plant population or due to changes in the environment. When there is a lot of genetic variation in the breeding material, selection becomes more effective" (Sumanth et al., 2017). Heritability refers to how much of a trait is passed down to the next generation, while genetic advance shows the difference between the average values of the selected population and the original one. Combining heritability estimates with genetic advance gives a more accurate prediction of genetic improvement through selection. With this, the present investigation was taken up with the objective to study different variability parameters which helps in raising the production of rice in various environments.

2. MATERIALS AND METHODS

The experimental material comprised of 53 advanced breeding lines derived from 12 distinct crosses of upland rice germplasm. This study was conducted at the Field Experimentation Centre of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh, India, during the kharif season of 2018. The experimental design employed a randomized block design with three replications under irrigated conditions. Each plot measured 2 x 5 m², with row spacing of 15 cm and plant spacing of 10 cm within rows. Standard agronomic practices were strictly adhered throughout the growing period to ensure optimal crop development. Data were collected from 10 randomly selected plants for thirteen biometric traits, including plant height, number of tillers per hill, number of panicles per hill, panicle length, flag leaf length, flag leaf width, number of spikelets per panicle, biological yield per hill, harvest index, test weight and grain yield per hill in each replication. Additionally, days to 50% flowering and days to maturity were recorded on plot basis. Data collected for all traits was analyzed for analysis of variance, employing the formula recommended by (Panse & Sukhatme,1978). Additionally, various components of variance, including phenotypic, genotypic and environmental variance, were estimated. Genetic parameters such as the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad-sense heritability and genetic advance as a percentage of the mean were calculated using the appropriate statistical methods. Data was analysed using R software.

3. RESULTS AND DISCUSSION

The results obtained from the present study, along with the relevant discussion, have been summarized under the following headings.

3.1 Analysis of Variance

The analysis of variance for different characters is presented in (Table 1). The mean sum of squares due to genotypes (treatments) showed significant difference for all 13 characters under study at 1% level of significance, suggesting the presence of sufficient variability among the genotypes. This indicates that there is an ample scope for selection of promising lines from the present gene pool for yield and its components. The presence of large amount of variability might be due to diverse source of materials taken as well as environmental influence affecting the phenotypes. These findings are in accordance with the findings of Chaudhary and Motiramani (2003) and Singh *et al*. (2006).

3.2 Variability Parameters

Variability parameters were estimated for all the 13 characters and the results obtained were presented in the Table 2.

"The estimates of genotypic and phenotypic variances revealed moderate range of phenotypic variance for the characters like spikelets per panicle followed by plant height, harvest index, flag leaf length, biological yield and test weight. Whereas lower range of phenotypic variance was observed in flag leaf width, grain yield per plant, No. of tillers per plant, No. of panicles per plant, days to 50% flowering, days to maturity. The studies on GCV and PCV revealed high PCV (Phenotypic coefficient of variation) over GCV (Genotypic coefficient of variation) explaining the effect of environment on expression of these traits. This higher PCV over GCV as observed for all the characters may due to higher degree of interaction of genotypes with the environment" (Kavitha and Reddy, 2002).

Moderate PCV and GCV was observed for number of tillers per plant (17.88% and 17.80%) followed by flag leaf length (17.65 and 17.51), seed yield per plant (16.38% and 16.26%), harvest index (15.69% and 15.63%), number of panicles per plant (15.71% and 15.65%), test weight (13.70% and 13.60%) and panicle length (12.64 and 12.55%). Lowest magnitude of PCV and GCV was recorded for days to 50% flowering (2.47% and 1.67%), days to maturity (9.25% and 9.01%), plant height (7.07% and 6.85%), flag leaf width (8.47% and 8.35%), number of spikelets per panicle (2.12% and 1.02%) and biological yield (10.00 and 9.83). Chaubey and Singh (1994), Nayak *et al.,* (2002), Medhi *et al*., (2004) and Vivek *et al*., (2004) also reported high phenotypic coefficient of variation values for number of tillers per plant.

Table 1. Analysis of variance for 13 characters studied in upland rice

S.No.	Characters	Mean Sum of Squares		
		Replications (df = 2)	Treatments (df = 52)	Error (df = 104)
1	Days to 50% Flowering	0.02	7.82**	2.19
2	Plant Height	3.76	180.07**	3.94
3	Tillers/ plant	0.007	3.30**	0.01
4	Panicles/ plant	0.008	2.24**	0.006
5	Panicle length	0.087	24.32**	0.12
6	Flag Leaf Length	0.41	79.14**	0.42
7	Flag Leaf Width	0.001	0.03**	0.003
8	Spikelet's/ panicle	1.02	408.14**	6.92
9	Biological yield/ hill	3.31	7.50**	3.95
10	Harvest index	0.02	16.12**	0.18
11	Days to maturity	0.12	124.83**	0.33
12	Test Weight	0.34	15.29**	0.07
13	Seed Yield/ plant	0.07	7.37**	0.03

Table 2. Variability parameters for 13 characters studied in upland rice

S.No.	Characters	VG	VP	GCV (%)	PCV (%)	h^2 (bs) (%)	GA	GA as %of mean
1	Days to 50% Flowering	1.88	4.07	1.67	2.47	46	1.91	2.34
2	Plant height	58.92	62.86	6.85	7.07	94	15.31	13.66
3	No of tiller/ plant	1.10	1.11	17.80	17.88	99	2.15	36.49
4	No of panicles/ plant	0.75	0.75	15.65	15.71	99	1.77	32.11
5	Panicle length	8.07	8.19	12.55	12.64	98	5.81	25.65
6	Flag leaf length	26.24	26.66	17.51	17.65	98	10.47	35.79
7	Flag leaf width	0.01	0.01	8.35	8.47	97	0.20	16.97
8	Days to maturity	133.74	140.67	9.01	9.25	95	23.23	18.11
9	No of spikelets / panicle	1.18	5.14	1.02	2.12	23	1.08	1.01
10	Biological yield	5.31	5.50	9.83	10.00	97	4.67	19.90
11	Harvest index	41.50	41.83	15.63	15.69	99	13.22	32.06
12	Test weight	5.07	5.15	13.60	13.70	99	4.69	27.81
13	Seed yield / plant	2.45	2.48	16.26	16.38	99	3.20	33.25

Relatively low magnitudinal differences were observed between genotypic coefficient of variation and phenotypic coefficient of variation for number of panicles per plant, number of tillers per plant, panicle length, flag leaf length, flag leaf width, harvest index, test weight and grain yield per plant indicating less environmental influence in the expression of these attributes. Relatively high differences between genotypic coefficient of variation and phenotypic coefficient of variation were observed for no. of spikelets per panicle, plant height and days to 50% flowering. These findings suggested that greater influence of the environment in the expression of these traits Mohammad *et al*. (2002) reported high magnitudinal differences between phenotypic coefficient of variation and genotypic coefficient of variation for days to maturity and plant height, "whereas environmental coefficient of variation contributed more in the expression of these characters. These PCV, GCV values alone are not helpful in determining the heritable portion of variation" (Falconer, 1996).

In the present study, high heritability values were recorded for almost all the characters. Seed yield per plant, test weight, harvest index, number of tillers per plant, number of panicles per plant, panicle length, flag leaf length, flag leaf width, biological yield per plant, plant height showed high heritability estimates indicating the least influence of environment on these characters. Heritability estimates are generally influenced by the type of genetic material, sample size, method of sampling, conduct of experiment, method of calculation and effect of linkage etc. Therefore their scope is restricted. Thus, heritability values coupled with genetic advance would be more reliable and useful in predicting the gain under selection than heritability estimates alone.

High heritability coupled with high genetic advance as percent of mean in the present set of rice genotypes was recorded for plant height (94% and 13.66), harvest index (99% and 32.06) indicating predominance of additive gene effects and the possibilities of effective selection for the improvement of these characters. High heritability associated with moderate genetic advance was observed for flag leaf length (98% and 35.79) suggesting greater role of non-additive gene action in their inheritance. Heterosis breeding could be used to improve these characters. Genetic advance as per cent of mean was highest for number of tillers per plant (36.49%), followed by flag leaf length (35.79%), seed yield per plant (33.25), no. of panicles per plant (32.11%), harvest index (32.06%) and test weight (27.81%). Moderate genetic advance as per cent of mean was recorded for biological yield per plant (19.90%), number of spikelets per plant (18.11%), flag leaf width (16.97%) and plant height (13.66%). Lower genetic advance as percent of mean was observed for days to 50% flowering (2.34%) and No. of spikelets per panicle (1.01).

4. CORRELATION

The correlation coefficient is a measure of the degree of association and relationship between two variables. It is important in plant breeding as it can be used for indirect selection. The study of the correlation between different characters may help the plant breeder to know how the improvement of one character will bring simultaneous changes in other characters. Degree of correlation is categorized as weak (0-0.3), moderate (0.3-0.7) and strong (0.7-1.0). The phenotypic correlation between grain yield and yield attributing traits of 53 rice genotypes is presented in Fig. 1.

Grain yield showed significant positive correlation with no. of tillers per plant, no. of panicles per tiller, spikelets per panicle, biological yield, harvest index and test weight. Harvest index showed highly significant positive correlation with grain yield at both phenotypic and genotypic level. The characters viz., days to 50 % flowering expressed significant positive association with days to maturity (0.32), while it showed negative significant association with plant height (-0.10), flag leaf length (-0.03) and biological yield (-0.03). This implies that plants which flower later tend to be shorter, have shorter flag leaves and produce less overall biomass. Therefore, if high yield is a priority, it's important to carefully balance early flowering with other traits to prevent a reduction in plant size and biomass production. Similar kind of results reported by (Hasan et al.,2013) for spikelet fertility, (Priyanka et al.,2016) for harvest index and (Sakthivel.,2001).

Positive and significant correlation was observed between No. of tillers per plant and panicles per tiller (0.82), spikelets per panicle (0.64), biological yield (0.24), harvest Index (0.65), test weight (0.61), grain yield (0.74). This correlation is important for achieving higher grain yield. No. of tillers per plant and the number of panicles per primary tiller are both important for achieving high grain yields. (Golam et al., 2015) reported a

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	
Days to 50% flowering (1)	1.00													
Plant height (2)	-0.10	1.00												
No. of tillers/plant (3)	0.09	-0.08	1.00											-100%
No. of panicles/tiller (4)	0.24	-0.15	0.83**	1.00										-80%
Panicle length (5)	0.01	0.05	-0.02	-0.02	1.00									-60%
Flag leaf length (6)	-0.03	0.10	-0.07	-0.08	0.77**	1.00								-40%
Flag leaf width (7)	0.11	0.02	-0.05	0.00	0.12	0.02	1.00							-20%
No. of spikelets/panicle (8)	0.11	0.07	0.64**	0.46**	0.26	0.08	0.01	1.00						100%
Days to maturity (9)	0.32*	-0.12	0.22	0.32*	-0.11	-0.31*	0.20	0.39**	1.00					80%
Biological yield (10)	-0.03	-0.07	0.25	0.25	-0.20	-0.16	-0.07	0.06	0.01	1.00				60%
Harvest index (11)	0.21	0.01	0.66**	0.52**	0.29*	0.11	0.06	0.75**	0.31*	-0.20	1.00			40%
Test weight (12)	0.09	0.00	0.61**	0.45**	0.17	-0.07	-0.05	0.75**	0.33*	0.03	0.73**	1.00		20%
Grain yield/ plant (13)	0.16	-0.02	0.75**	0.62**	0.19	0.02	0.06	0.76**	0.31*	0.35*	0.85**	0.75**	1.00	0%

Fig. 1. Correlation matrix for 13 traits studied in upland rice

strong association between total tillers per plant and productive tillers per plant. More tillers per plant and panicles per tiller are linked to higher rice yield. Similarly, having more primary tillers per square meter and more panicle-bearing tillers per plant leads to higher grain yield.

It was observed that number of panicles per tiller exhibited significant positive genotypic association with spikelets per panicle (0.46), days to maturity (0.32), harvest index (0.52), test weight (0.45), grain yield per plant (0.62). Increasing the number of spikelets per panicle is a main approach to increase grain yields. The number of spikelets per panicle, which affects rice yield, is determined by how spikelets form and degenerate.

Panicle length showed significant positive correlation with flag leaf length (0.77), spikelets per panicle (0.26) and harvest index (0.29) whereas negative correlation with biological yield (-0.19). Earlier researchers, (Patel et al., 2014) for biomass, (Ramanjaneyulu et al., 2014) for harvest index reported similar results. This correlation is associated with higher grain yield.

Flag leaf length is negatively correlated with days to maturity (-0.31), biological yield (-0.15). Shorter flag leaves may be associated with earlier maturity and higher yields. Spikelets per panicle showed positive correlation with days to maturity (0.39), harvest index (0.75), test weight (0.75) and grain yield per plant (0.76). When a plant has more spikelets per panicle, it generally takes longer to mature, has a higher harvest index, greater test weight, and produces a larger grain yield, showing a positive link between spikelets and these yield factors.

Days to maturity showed positive significant correlation with harvest index (0.31), test weight (0.33), grain yield per plant (0.31). This indicates that as the crop takes longer to mature, it generally produces a higher proportion of grain relative to harvest index, test weight and grain yield per plant. A longer maturity period gives the plant more time to gather nutrients and grow larger grains, leading to a higher test weight and grain yield. This extra time also helps the plant better allocate resources to grain production, increasing the harvest index. The trait, harvest index was found to possess positive and significant association with test weight (0.73) and grain yield per plant (0.84).

From the study it was concluded that the traits number of total tillers per plant, number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility and 1000 grain weight are very crucial for higher yields, as they exhibited significant positive correlation with grain yield per plant.

5. CONCLUSION

No. of tillers per plant, No. of panicles per tiller, No. of spikelets per panicle, No. of panicles per tiller and days to maturity exhibited significant positive correlation with grain yield per plant. Moderate PCV and GCV was observed for number of tillers per plant, flag leaf length, grain yield per plant, harvest index, number of panicles per plant, test weight. On the other hand test weight, harvest index, number of tillers per plant, number of panicles per plant, panicle length, flag leaf length, flag leaf width, number of spikelets per panicle, biological yield per plant, plant height showed high heritability. High heritability coupled with high genetic advance as percent of mean was recorded for plant height, harvest index. Hence selection for these traits could lead to improvements in rice yield and productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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