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Assessment of genetic variability and correlation studies in direct seeded aerobic rice ecosystem

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Abstract
Rice, being the staple food, is consumed in a huge quantity, which demands for its higher production. In order to satisfy the food security needs of the expanding global population, rice producers are adopting the promising "Direct Seeded Aerobic Rice" technology, which promises to save water. The current study is aimed at exploring the variability present amongst the test genotypes and uncovering the correlation among different yields and yield-attributing traits. 96 genotypes under study manifested moderate GCV and PCV and narrow differences between GCV and PCV for all the six traits *viz*., days to fifty per cent flowering (DFF), plant height (PH), panicle length (PL), spikelet fertility (SF), productive tillers (PT) and single plant yield (SPY). These traits were least influenced by the environment. In the present study, all the traits except productive tiller showed high heritability, genetic advance, and genetic advance over mean, indicating high variation among the genotypes and additive gene effects. Single plant yield as well as expressed high heritability, and genetic advance over mean. The study also indicated that four traits, *viz*., PT, PL, PH and SF showed a positive significant correlation with SPY. However, DFF had a significant negative correlation with SPY. Hence, these traits can be improved by simple phenotypic selection, which can be further used for selection programmes. Overall, 26 genotypes were chosen as the most promising lines for future breeding programmes under aerobic field conditions.

Keywords: Direct seeded aerobic rice, augmented randomised complete block design, variation and correlation

Introduction
Rice is an important staple food crop that feeds more than half of the world's population. The energy needs of rice farmers in Asia account for a good proportion of their total energy consumption, and the demand for rice will rise by 38% over the next 30 years. The amount of water needed to produce 1 kg of rice is between 4500 and 5000 litres (Bouman, 2009) [2]. Water is now very scarce for agriculture around the world, and water supplies are being used up quickly. At the same time, increasing fresh water resource costs are a threat to the sustainability of irrigated rice systems. By 2025, (Tuong and Bouman, 2003) [3] predicted that 22 million hectares of Asia's irrigated rice may experience "economic water scarcity" and 17 million ha may experience "physical water scarcity" Rice cultivation under the traditionally flooded conditions won't be practicable in the upcoming days, requiring the application of certain water management strategies that will help cut down on irrigation water usage (Bouman, 2001) [4]. Rice grown aerobically is the option that is most practical among the alternatives. With a focus on high yields, it involves producing rice in aerobic soil, free from flooding and puddles, and with the help of different inputs like supplemental irrigation and fertilisers (Wang *et al*, 2002) [24]. When compared to the irrigated lowland approach, this technique for cultivating rice uses roughly 73 per cent and 56 per cent less water for crop development and soil preparation, respectively (Castaneda *et al*, 2005) [4].
The yield obtained through this form of cultivation is much lower than that obtained through a lowland system due to the reduced water availability. But given that consumer demand for rice keeps rising along with population growth, this is unsustainable. The choice of suitable cultivars is a key factor for the success of aerobic rice production (Wang *et al*, 2002) [24]. The characteristics of upland rice (drought tolerance) and current high-yielding rice cultivars of the irrigated ecosystem should be combined in aerobic rice (Lafitte *et al*. 2002: Atlin *et al*. 2006) [2].
When compared to lowland rice breeding, the aerobic rice breeding programme is incredibly small and was only recently systematically started in a very small number of research

institutions worldwide, including IRRI (International Rice Research Institute, Philippines), NRRI (National Rice Research Institute, Cuttack), and UAS (University of Agricultural Sciences), Bengaluru. Despite the fact that many varieties were created for aerobic farming, the yields were 20–30% lower than those of types grown under flood-like conditions (Farooq *et al*. 2009; Prasad *et al*. 2011) [8]. Currently, only a few number of productive aerobic rice cultivars with high production potential and wide biotic and abiotic stress tolerance are grown. However, more cultivars that have a lower yield penalty still need to be developed for the aerobic ecosystem.

So far, more than 18 rice varieties have been released for cultivation under aerobic conditions. DRRH4, the world's first hybrid released by CVRC, recently posed hope for hybrid rice technology in water limited conditions.

In this respect, the current study was conducted to examine the genetic variation among 96 rice genotypes for morphological and yield component qualities using heritability, genetic advance and correlation studies.

Materials and Methods

The experiment was carried out in the Department of Hybrid Rice at the Indian Institute of Rice Research (IIRR) in Rajendranagar, Hyderabad. During *Kharif* (2021). A total of 96 genotypes were studied using an improved augmented randomised complete block design (ARCBD). The experimental area contains a total of five blocks. Prior to determining the genotypes in each block, the six checks were initially randomised. Each block was given a total of 24 entries, which included 18 genotypes and 6 checks. Each genotype was grown in a length of 1 m with a plant-to-plant distance of 15 cm and a row-to-row distance of 20 cm. The genotype list provided in the study (Table-1). Field was irrigated immediately after sowing to ensure proper germination and subsequently irrigation was given once at 5-7 interval. To maintain aerobic condition, the plots were kept without standing water throughout crop season. Recommended cultural operations and plant protection measures were taken to ensure uniform and healthy crop stand. Data was recorded on three randomly selected plants on 6 morphological parameters *viz*., days to 50% flowering, plant height, panicle length, productive tillers, spikelet fertility, and single plant yield.

Table 1: List of Genotypes used for the study under Aerobic condition

SI. No	Genotypes	SI. No	Genotypes	SI. No	Genotypes	SI. No	Genotypes
1	CHECK-1	25	NVK-19	49	NVK-43	73	NVK-67
2	CHECK-2	26	NVK-20	50	NVK-44	74	NVK-68
3	CHECK-3	27	NVK-21	51	NVK-45	75	NVK-69
4	CHECK-4	28	NVK-22	52	NVK-46	76	NVK-70
5	CHECK-5	29	NVK-23	53	NVK-47	77	NVK-71
6	CHECK-6	30	NVK-24	54	NVK-48	78	NVK-72
7	NVK-1	31	NVK-25	55	NVK-49	79	NVK-73
8	NVK-2	32	NVK-26	56	NVK-50	80	NVK-74
9	NVK-3	33	NVK-27	57	NVK-51	81	NVK-75
10	NVK-4	34	NVK-28	58	NVK-52	82	NVK-76
11	NVK-5	35	NVK-29	59	NVK-53	83	NVK-77
12	NVK-6	36	NVK-30	60	NVK-54	84	NVK-78
13	NVK-7	37	NVK-31	61	NVK-55	85	NVK-79
14	NVK-8	38	NVK-32	62	NVK-56	86	NVK-80
15	NVK-9	39	NVK-33	63	NVK-57	87	NVK-81
16	NVK-10	40	NVK-34	64	NVK-58	88	NVK-82
17	NVK-11	41	NVK-35	65	NVK-59	89	NVK-83
18	NVK-12	42	NVK-36	66	NVK-60	90	NVK-84
19	NVK-13	43	NVK-37	67	NVK-61	91	NVK-85
20	NVK-14	44	NVK-38	68	NVK-62	92	NVK-86
21	NVK-15	45	NVK-39	69	NVK-63	93	NVK-87
22	NVK-16	46	NVK-40	70	NVK-64	94	NVK-88
23	NVK-17	47	NVK-41	71	NVK-65	95	NVK-89
24	NVK-18	48	NVK-42	72	NVK-66	96	NVK-90

Statistical analysis

Using R software, analysis of variance (ANOVA) and basic Pearson correlation coefficients were calculated using mean values for all traits. To determine if the correlation coefficients are significant or not, the correlation coefficients were compared to the table values (Fisher and Yates, 1963) at (n-2) degrees of freedom at the 5% and 1% levels. The genotypic and phenotypic coefficients of variation were applied to the mean data after each character's computation, as outlined by Burton (1952), while the estimates of heritability and genetic advance were obtained as per the procedures outlined by Burton and Devane (1953), and Johnson *et al*. (1955), respectively.

Results and Discussion

Analysis of variance

All of the variables that contribute to yield showed highly significant differences, showing that the genotypes under study had enough variation (Table-2). Under aerobic conditions, the varied germplasms known as accessions led to the development of numerous germplasm lines with higher yields.

Table 2: Analysis of variance for 6 different rice genotypes (mean sum of squares) an Aerobic condition (n=96)

Source	Df	DFF	PH	PL	PT	SF	SPY
Block (ignoring Treatments)	4	52.35 **	134.09 **	4.5 **	3.55 ns	144.99 **	15.64 **
Treatment (eliminating Blocks)	95	61.49 **	153.71 **	6.57 **	6.17 **	168.03 **	27.11 **
Treatment: Check	5	10.77 **	601.31 **	35.19 **	51.59 **	117.94 **	73.75 **
Treatment: Test and Test vs. Check	90	64.3 **	128.84 **	4.98 **	3.65 *	170.82 **	24.52 **
Block (eliminating Treatments)	4	1.62 ns	21.35 ns	0.19 ns	1.34 ns	3.21 ns	0.58 ns
Standard error difference		1.16	5.45	0.68	1.6	1.95	1.01
Critical difference		2.41	11.37	1.42	3.35	4.06	2.11
Coefficient of variation		1.24	5.34	2.71	13.3	2.01	6.01

Significant values are as follows: * Significant at 5%, ** Significant at 1%, and *** Significant at 0.1 percent.
Df: Degrees of freedom; DFF: Days to 50% flowering; PH: Plant height (cm); PL: Panicle length (cm); SF: Spikelet fertility; SPY: Single plant yield (g)

Mean performance of aerobic rice genotypes

The mean values of the six characters across 96 rice genotypes are explained below (Table-3). The single plant yield had a range of variance of 3.61g to 24.04g, with an average of 13.13g. The average number of productive tillers per plant was 9.76, with a range of 5.14 to 17.56. The range of plant heights was 58.82 cm to 112.24 cm, with an average of 84.6 cm. The average panicle length was 21.29 cm, with the lowest panicle length was 14.46 cm and the highest panicle length was 27.52 cm. For days to 50% flowering, the range varied from 71.97 days to 95.47 days, with an average of 80.6 days. The average spikelet fertility was 79.59 per cent, with the lowest spikelet fertility value being 43.2 per cent and the greatest spikelet fertility value being 97.92 per cent.

The average performance of the 96 genotypes included in the study showed that no single genotype of rice was superior for all the traits examined. All of the observations among the tested 96 genotypes showed highly significant variations between the genotypes.

When genotype is regarded a treatment, the analysis of variance data revealed highly significant variance (at 0.1 per-cent) attributable to treatment, demonstrating the inherent genetic differences between the genotypes. These genotypes showed significant genetic variation in a number of component characters, indicating that these characters had been well selected.

Table 4: Under aerobic conditions, GCV, PCV, and other genetic characteristics of all the genotypes used for the study (n=96)

Aerobic	SPY	PT	PH	PL	DFF	SF
Mean	13.13	9.76	84.6	21.29	80.6	79.59
Std. Error	0.43	0.18	1.17	0.23	0.73	1.2
Std. Deviation	4.23	1.8	11.42	2.29	7.13	11.73
Min	3.61	5.14	58.82	14.46	71.97	43.2
Max	24.04	17.56	112.24	27.52	95.47	97.92
GV	15.66	0.58	92.91	4.9	50.3	134.9
EV	0.73	1.84	21.24	0.33	0.96	2.71
GCV	30.13	7.81	11.39	10.4	8.8	14.59
GCV. category	High	medium	Medium	Medium	Low	Medium
PCV	30.83	15.94	12.63	10.74	8.88	14.74
PCV. category	High	Medium	Medium	Medium	Low	Medium
h^2	95.53	24.01	81.4	93.63	98.13	98.03
hBS. category	High	Low	High	High	High	High
GA	17.98	0.77	17.94	14.42	14.49	23.72
Skewness	0.32 ns	1.53 **	0.2 ns	0.06 ns	0.4 ns	-1 **
Kurtosis	2.87 ns	8.27 **	2.94 ns	3.33 ns	1.95 **	3.85 ns

GCV - Genotypic coefficient of variation; PCV – Phenotypic coefficient of variation; h^2 – Heritability; GA – Genetic advance; SPY – Single plant yield (g); PT – Productive tillers; PH – Plant height (cm); PL – Panicle length (cm); DFF – Days to fifty percent flowering: SF – Spikelet fertility (%).

Variability, heritability (h^2), genetic advance (GA)

The development of a plant characteristic is greatly influenced by genetic diversity and heritability. Prior knowledge of population variability estimates and the heritable elements of the trait are helpful tools in any breeding programme. It would be more challenging to try to enhance a character through selection unless a significant amount of the variation is heritable.

Breeding would benefit from knowledge of the character's heritability as well as its phenotypic and genotypic coefficient of variation. In order to compare the variability seen across various traits, the coefficient of variation expressed at the phenotypic and genotypic levels was used. The variability parameters, including mean, minimum, maximum, standard error, standard deviation, estimations of genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), environmental co-efficient of variation (ECV), heritability (h2), and genetic advance over mean with respect to yield and yield associated traits (Fig-1 and Fig-2), are briefly discussed below.

The characteristics examined in this study had PCV and GCV values that varied from the highest to the most moderate. The highest PCV and GCV values for single plant yield were observed. These results were consistent with Nath and Kole (2021); Ajmera *et al*. (2017) [1], along with moderate values for the number of productive tillers, plant height, panicle length, and spikelet fertility, are then supported by Parimala and Devi (2019) [15]; and Sandeep *et al*. (2018) [18]. Many of these traits had moderate GCV, PCV and ECV suggested that these traits are under the relatively greater influence of genetic factors and relatively less influence of the environment. All variables, with the exception of productive tillers, have strong heritability in a broad sense and genetic advance, and this finding is supported by Singh *et al.* (2011) and Mohan *et al.* (2012) [13]. Hence, these characters can be relied upon and simple selection can be practiced for further improvement.

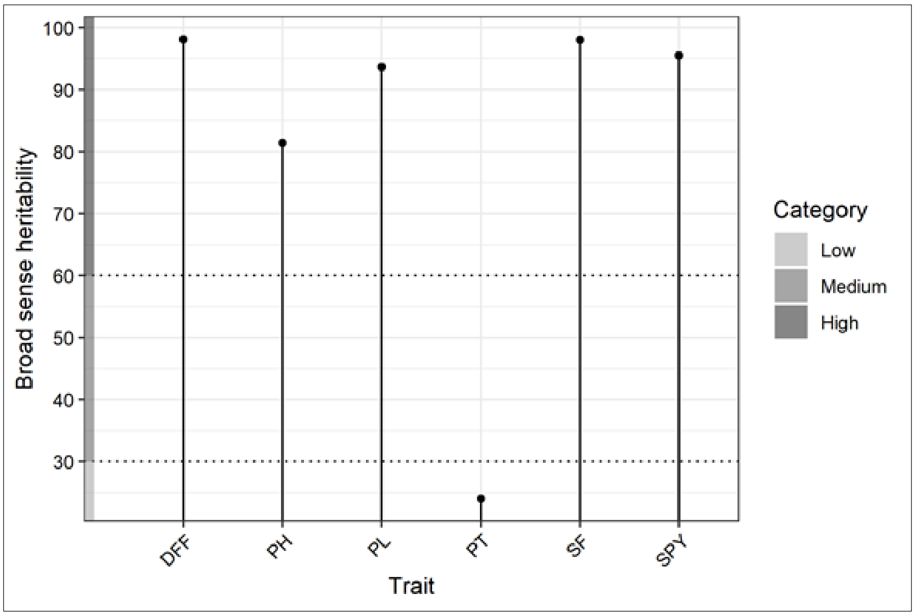

Fig 1: Heritability (h^2) for different traits in rice genotypes under aerobic condition (n=96)

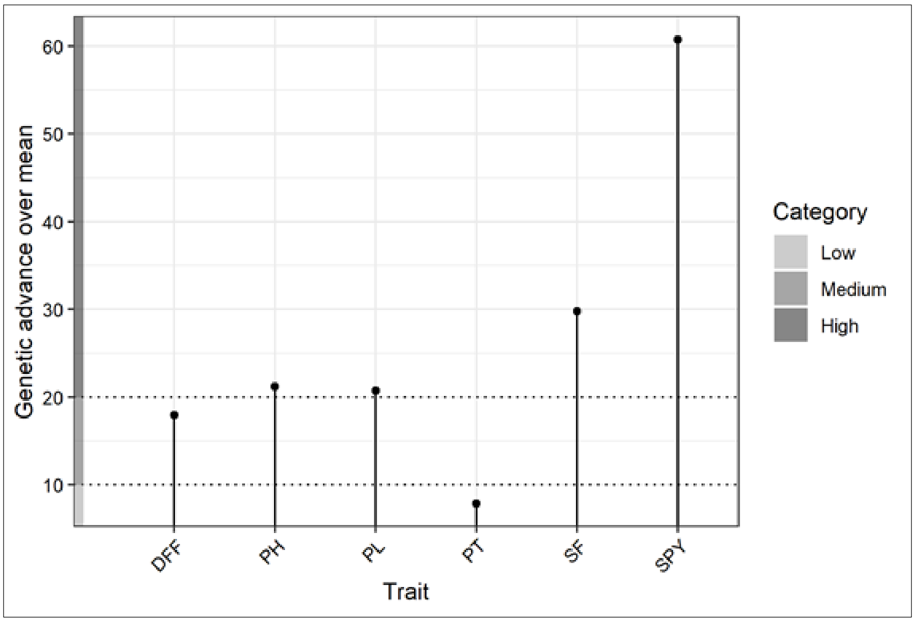

Fig 2: Genetic advance over mean for different traits in rice genotypes under aerobic condition (n=96)

Correlation studies

The indirect selection of a complicated trait paired with a simple trait is greatly influenced by the study of the relationships between various traits. The correlation helps in identifying the potential for increasing yield through indirect selection of its highly associated component traits. The data for phenotypic correlations from the current investigation are shown in (Fig-3) and discussed more below.

Plant height, the number of productive tillers, and panicle length all have a positive relationship with single plant yield that is highly significant. The findings of (Raju *et al.* 2004; Shashidhar *et al.* 2005; Nagesh *et al.* 2012) [16, 19], were in conformity with this result. Compared to days to 50% flowering, single plant yield showed a strong negative correlation. Similar findings for days to 50% flowering were reported by (Gunasekaran *et al.* 2017; Srivastava *et al.* 2017). Productive tillers exhibit a highly significant positive correlation with spikelet fertility and single plant yield. The results are supported by (Lakshmi *et al.* 2020; Srivastava *et al.* 2017; Sudeepthi *et al.* 2020a). Productive tillers show a significant negative correlation with days to 50% flowering, and the results are verified with (Kishore *et al.* 2015). Panicle length is highly significant positive correlation with plant height. (Kishore *et al.* 2015; Sameera *et al.* 2016) both confirmed that panicle length is highly correlated with plant height. Panicle length is significant negative correlation with days to 50% flowering. This result was in conformity with the reports by (Devi *et al.* 2017; Gunasekaran *et al*. 2017) [7].

For the yield and its related traits under aerobic conditions, all 96 of the selected germplasm lines shown substantial variance. The estimated genetic variability parameters in the genotypes revealed a presence of a small difference between PCV and GCV for all the analysed traits, indicating the least influence of environment on the expression of these traits. Most traits, with the exception of days to 50% flowering, showed a significant positive correlation with grain yield. Correlation study shows that these features can both be improved simultaneously. Overall, the results of the current field experiment demonstrated high heritability and significant genetic advance for the most of the characters, indicating the presence of additive gene effects and significant variation. Consequently, phenotypic selection might be helpful in enhancing these features. Overall, 26 genotypes were identified as the most promising lines under aerobic field conditions and can be used in future breeding programmes.

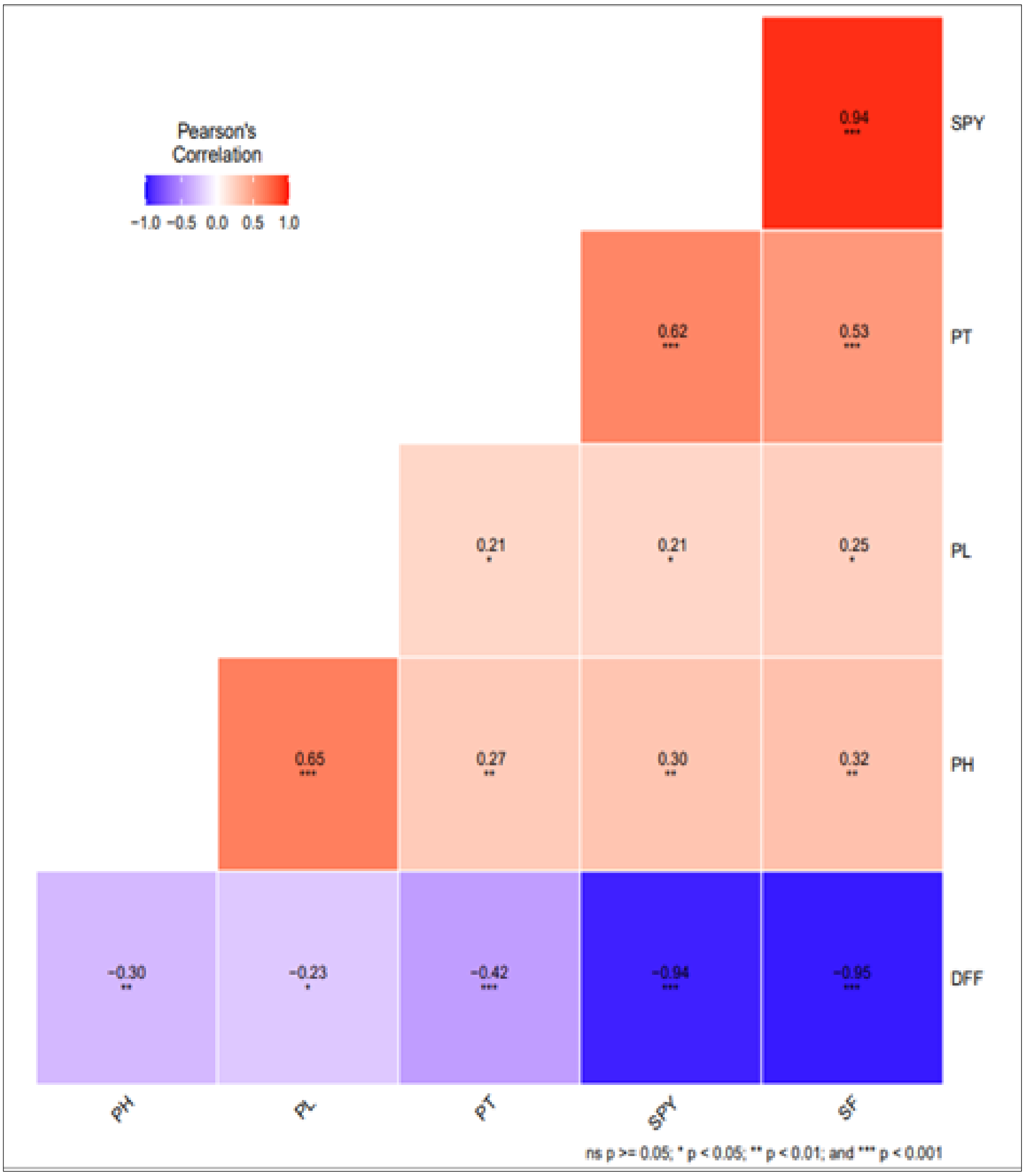

Fig 3: Estimates of the coefficient of correlation for different features for 96 aerobic rice genotypes

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