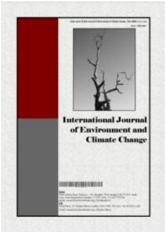

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Genetic Variability, Heritability and Genetic Advance Studies on Yield, Its Components, Quality Traits and Gall Midge Incidence in Rice (*Oryza sativa* L.)

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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

Twenty-eight lines including 18 F1 plants, 9 parents, and one commercial were studied for estimation of genetic variability, heritability, and genetic advance at Agricultural Research Station, Kunaram. Analysis of variance revealed highly significant differences among the genotypes for all the traits studied indicating the presence of a considerable amount of variability among the genotypes for yield and its components, quality traits and gall midge incidence. PCV values for the number of productive tillers per plant were significantly greater than GCV indicating highly sensitive to environmental changes. The GCV and PCV were high for the percentage of gall midge incidence, the number of productive tillers per plant, the number of filled grains per panicle, and grain yield per plant, whereas, low for hulling percentage, head rice recovery, milling percentage, and kernel length. Additive gene action was predominant for Gall midge incidence, number of productive tillers per plant, number of filled grains per panicle, grain yield per plant and grain weight per 1000 grains as they registered high heritability coupled with high genetic advance values.

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Keywords: Gall midge; genetic variability; genetic advance; heritability; rice.

1. INTRODUCTION

Rice is an important staple cereal crop for half of the people of the world and is cultivated in an area of 164.19 million ha with 756.74 million tons of paddy production and 4.61 t/ha productivity [1]. About 90% of rice is produced and consumed in Asia [2]. Rice is the main food in India providing 43% of the country's total daily calorie needs for more than 70 % of its people and ranks second in terms of production and has the greatest area dedicated to rice cultivation. Approximately 124.00 million tons of rice is produced annually in India in an area of 46 million hectares, with a yield of more than 2.5 tons of milled rice per hectare [3]. More than half of the rice in the nation is produced by the states of West Bengal, Uttar Pradesh, Andhra Pradesh, Telangana, and Punjab. The primary crop grown widely in Telangana State throughout both the *kharif* and *rabi* seasons is rice, which is grown in all of the districts. In 2019–20, the rice crop was being produced on a land area of 31.93 lakh ha, yielding 1.03 lakh tons of rice at a productivity of 3516 kg/ha [4]. When compared to other nations, these productivity levels are poor. In light of this, there is a pressing need to boost the state's output and productivity in order to meet the rising demand from the expanding population by utilizing the existing genetic variation in rice germplasm.

The rice gall midge *Orseolia oryzae* (Wood-Mason) is considered to be one of the most destructive pests after borers and plant hoppers [5] in the world. A vast majority of high-yielding rice varieties are prone to gall midge attack, but few of the cultivars and landraces are immune to it [5]. In India, it is rated as the third most important pest of rice in terms of spread, severity of the damage and yield loss [6]. The high vulnerability of existing popular varieties to gall midge attack is the result of narrow genetic variability and less diversified parents used in breeding. Thus, a critical analysis of the genetic variability is a prerequisite for initiating any crop improvement programme. The major problem is the high incidence of gall midge (Biotype 3) during kharif under early as well as late planting conditions in some parts of Telangana. The Asian rice gall midge, *O. oryzae* is one of the important insect pests in northern Telangana. More recently, gall midge incidence has increased in almost all the rice growing states of India which results in considerable yield losses as affected tillers bear no panicles or grains. In contrast, the maggots fail to induce gall formation on the resistant varieties and perish in 2-4 days after hatching. Hence, breeding for gall midge resistant varieties has been an important strategy with higher yield [7].

Genetic variability is a measure of the tendency of individual genotypes in a population to vary from one another. Genetic variability is essential in crops to enhance the traits and to adapt to environmental changes in the success of any plant breeding programme. Genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV) are crucial in detecting the amount of variability present in the germplasm. The passage of genetic information for qualities from parents to offspring is measured *via* heritability estimation. High heritability values suggest that the variables being studied are heritable and are more resistant to environmental impact in their expression. Genetic variation and heritability estimates give a good idea of the efficiency of selection [8].

Genetic advance is a helpful sign of development that can be anticipated after working out choices based on the relevant population. Heritability combined with genetic advancement might result in a more trustworthy index of greater selection value. Estimates of heritability and genetic progress [9] will aid in understanding the type of gene action that is affecting the trait desired. Selection for traits with high heritability and high genetic progress results in the accumulation of more additive genes. It might increase their potential for future performance enhancements.

2. MATERIAL AND METHODS

In the present investigation, six lines (KNM 118, JGL 24423, PR 126, KNM 7660, KNM 11549 and IRRI 179) and three testers (JGL 11727, IBT MRR 24 and WGL 1119) were used to produce 18 F_1 crosses in a Line x Tester mating fashion during *rabi* 2020-21 (Table 1). All 18 crosses along with their nine parents and check consisted of 28 rice genotypes in the experimental material. The seed of 28 lines was raised on nursery beds and 25 days old seedlings of each entry were transplanted under an irrigated system with three replications in a randomized block design (RBD) design during *Kharif* 2021 at Agricultural Research Station, Kunaram by adopting spacing of 20 x 15 cm between the rows and within the row. An established bundle of agronomical techniques was used to raise a good crop. Data was recorded on five random plants for each entry in each replication for days to 50 % flowering (DFF), plant height (PH) (cm), panicle length (PL) (cm), number of productive tillers per m^2 (NPT), number of grains per panicle (NG), 1000-grain weight (TW), grain yield (GY) and gall midge incidence (GI). Data was also recorded for quality traits such as hulling percentage (HP), milling percentage (MP), head rice recovery (HRR), kernel length (KL), kernel breadth (KB) and kernel L/B ratio (KR). The plants were selected from the middle rows to minimize error due to the border effect. The mean data after computing for each trait were subjected to analysis of variance [10], genotypic coefficient of variation (GCV), phenotypic coefficients of variation (PCV) following the formula suggested by [11], heritability (h^2) in the broad sense as suggested by [12] and genetic advance [13] following standard procedures.

Gall midge incidence was recorded on a hill basis 45 days after planting during *Kharif* 2021 season. The occurrence of silver shoots in randomly selected 10 plants was recorded (Standard Evaluation System for Rice (IRRI, 2002). For scoring the gall midge incidence the total number of tillers and the total number of tillers with silver shoot were recorded and the per cent tiller infestation was calculated as follows.

$$\textbf{Percent silver shoot} = \frac{\textbf{Number of infested tillers}}{\textbf{Total number of tillers}} \textbf{ x 100}$$

Table 1. Salient features of parents and check utilized for the research programme

S. No	Genotype	Source	Salient features
	Lines		
1	KNM 118	Agricultural Research Station, Kunaram	Short duration (120-125 days), long slender rice variety with resistance to leaf blast and moderately resistant to neck blast.
2	JGL 24423	Regional Agricultural Research Institute, Polasa, Jagtial	Short duration (120-125 days), long bold rice variety with resistance to leaf blast and moderately resistant to neck blast.
3	PR 126	Punjab Agricultural University, Ludhiana, Punjab	Short duration (120 days), long slender rice variety.
4	KNM 7660	Agricultural Research Station, Kunaram	Short duration (120 days), long slender rice variety with BPH tolerance.
5	KNM 11549	Agricultural Research Station, Kunaram	Short duration (120 days) long slender rice variety.
6	IRRI 179	International Rice Research Institute, Philippines	Short duration (120 days) long slender rice variety.
	Testers		
1	WGL 1119	Regional Agricultural Research Institute, Warangal.	Short duration (120 days) medium slender rice variety with gall midge resistance.
2	JGL 11727	Regional Agricultural Research Institute, Polasa, Jagtial	Medium duration (140 days) medium slender rice variety with gall midge resistance.
3	IBT MRR 24	Institute of Biotechnology, Rajendranagar, Hyderabad	Early duration (120 days) long slender rice variety with gall midge resistance.
	Checks		
1	MTU 1010	Regional Agricultural Research Institute, Maruteru, Andhra Pradesh.	Short duration (120 days), long slender rice variety with blast tolerance.

3. RESULTS AND DISCUSSION

In the present study, analysis of variance (Table 2) revealed that there is a highly significant difference existed among 28 genotypes including six lines, three testers, 18 crosses, and one check considering all agro-morphological traits indicating the presence of the wide range of variability among the genotypes. It was observed in the present study that there were inherent genetic differences among the genotypes with respect to morphological traits considered during analysis. Consequently, there is a large amount of space for selection to boost production.

The mean performance of parents, crosses, and checks recorded on 14 characters is presented in Table 3. The general mean for days to 50 per cent flowering was 82.32 days with a range of 69.67 to 97.67 days. The observed range of days to 50 per cent flowering for lines was from 80.67 days for KNM118 to 92.33 days for KNM 11549, whereas for testers it ranged from 79.33 days for IBTMRR 24 to 97.66 days for JGL 11727. Further among crosses, days to 50 per cent flowering recorded were maximum for KNM11549 X WGL1119 (91.00 days) and minimum for KNM7660 X IBT MRR 24 (69.67 days). Plant height ranged from 74.53 (PR 126) to 93.35 cm (IRRI 179) for lines and 72.26 (WGL 1119) to 104.85 cm (JGL 11727) for testers, while in F_1 crosses it ranged from 83.68 (PR 126 X JGL 11727) to 113.19 cm (IRRI 179 X IBT MRR 24). The data further revealed that the crosses were taller (98.81 cm) than the lines (82.19 cm). Among the lines, PR 126 (74.53 cm) was the shortest one whereas IRRI 179 (93.35 cm) was the tallest one. However, among testers JGL 11727 and WGL1119 recorded maximum (104.85 cm) and minimum (72.26 cm) values respectively. Among the crosses, PR 126 X JGL 11727 (83.68 cm) was the shortest genotype while IRRI 179 X IBT MRR 24 (113.19 cm) was the tallest genotype followed by KNM 11549 X WGL 1119 (110.27 cm) and IRRI 179 X WGL 1119 (107.75 cm) and the check MTU 1010 was with 92.68 cm. The general mean recorded for panicle length was 25.00 cm with a range of 20.40 to 30.90 cm. The crosses recorded a greater average panicle length (25.99 cm) in comparison with lines (22.74 cm) and testers (23.92 cm). A perusal of mean values revealed that among lines IRRI 179 had the longest panicle (24.83 cm), whereas PR 126 had the shortest panicle (20.67 cm), and the testers JGL 11727 (30.90 cm) and IBT MRR 24 (20.40 cm) recorded maximum and minimum values respectively. Among the crosses length of panicles varied from 23.20 cm for cross PR 126 X WGL 1119 to 28.53 cm for cross KNM7660 X JGL 11727 and check with MTU1010 recorded Panicle length of 24.13 cm.

Table 2. Analysis of variance for yield, its components, gall midge incidence and quality traits in rice

Character	Mean sum of squares		
	Replications (d.f = 2)	Treatments (d.f= 27)	Error (d.f = 54)
Days to 50 % flowering	9.89	158.40**	3.28
Plant height (cm)	4.74	378.47**	10.59
Panicle length (cm)	2.45	20.06**	1.06
No. of productive tillers per plant	4.18	29.90**	2.20
1000- grain weight (g)	1.39	34.73**	0.45
No. of filled grains per Panicle	414.53	7063.65**	212.05
Grain yield per plant (g)	2.79	73.28**	1.85
Incidence of gall midge (%)	282.40**	2522.14**	22.48
Hulling (%)	2.20	10.65**	3.69
Milling (%)	7.32	40.84**	5.00
Head rice recovery (%)	5.57	28.73**	3.79
Kernel length (mm)	0.046	0.82**	0.02
Kernel breadth (mm)	0.00	0.17**	0.01
Kernel L/B ratio	0.024	0.76**	0.05

**Significance at 5% level; **Significance at 1% level*

Table 3. Mean performance for yield, its components, gall midge incidence and quality traits in rice

Entry	DFF	PHT	PL	NPT	TW	NFG	GYP	GI	HP	MP	HRR	KL	KB	LBR
KNM 118	85.67	81.75	20.83	9.8	24.53	97.6	16.03	41.4	79.73	70.57	65.1	6.76	1.73	3.91
IRRI 179	91.33	93.35	24.83	5.57	23.63	132.2	23.73	63.37	80.37	73	61.73	7.16	1.76	4.08
JGL 24423	90.33	82.01	24.53	10.83	24.83	137.8	20.1	36.73	75.87	65.43	54.17	6.62	2.29	2.88
PR 126	91	74.53	20.67	2.83	20.67	138.87	16.67	81.97	79.53	73.2	62.93	6.53	1.7	3.83
KNM 11549	92.33	85.72	23.27	2.87	24.5	120.2	19.6	80.77	79.83	69	59.07	6.41	1.88	3.41
KNM 7660	80.67	75.79	22.3	3.63	24.53	112.93	19.2	78.33	82.57	74.47	67.57	6.82	2.09	3.26
JGL 11727	97.67	104.85	30.9	11.73	16.87	253.87	25.8	27.27	79.93	68.97	65.43	6.31	1.7	3.73
WGL 1119	90.33	72.26	20.47	11.13	15.27	147.73	24.83	3.83	79.17	64.67	59.23	5.45	1.55	3.52
IBT MRR 24	79.33	77.93	20.4	14	17.9	110.07	16.43	3.87	75.67	60.37	56.6	6.36	1.6	3.97
KNM 118 X JGL11727	76.67	99.98	27	5.53	15.3	297.8	23.37	71.57	78.97	68.53	59.17	5.54	1.76	3.16
KNM 118 X WGL 1119	72.67	90.79	25.63	8.43	20.7	224.8	26.7	25.27	82.27	74.97	60.7	6.2	1.82	3.42
KNM 118 X IBT MRR 24	87.33	103.68	25.7	5.63	25	196.07	24.4	72.33	81.9	69.27	64.33	5.83	2.39	2.44
IRRI 179 X JGL11727	84.67	98.45	25.57	5.23	24.53	197.6	23.23	73.73	79.83	72.4	59.9	6.8	2.35	2.9
IRRI 179 X WGL 1119	85.33	107.75	25.53	7.73	24.4	184.73	28.7	58.47	81.5	69.27	61.07	5.82	2.31	2.52
IRRI 179 X IBT MRR 24	77.33	113.19	27.97	10.47	24.47	185.27	31.07	0	79.83	72.67	60.87	7.26	1.76	4.14
JGL 24423 X JGL11727	78	97.28	27.53	7.47	23.8	201.07	23.7	56.77	79.27	71.77	58.97	6.61	2.13	3.16
JGL 24423 X WGL 1119	75	95.77	25.93	7.63	21.23	187.2	16.43	24.4	78.3	70.73	65.17	5.97	2.14	2.79
JGL 24423 X IBT MRR 24	76.67	100.99	27.27	10.8	24.57	182.8	22.3	0	77.4	70.7	61.73	6.31	1.68	3.76
PR 126 X JGL11727	76.33	83.68	23.3	3.23	22.47	168	15.67	77.63	80.23	72.67	58.3	6.94	1.76	3.96
PR 126 X WGL 1119	76	87.89	23.2	7.7	15.1	248.73	24.57	60.53	83.53	75.77	63.23	5.42	1.91	2.85
PR 126 X IBT MRR 24	80	89.68	25	9.23	24.27	179.2	21.93	27.67	80.83	75.27	62.1	7.12	1.71	4.17
KNM 11549 X JGL11727	89	103.8	25.23	5.67	24.97	172.13	24.4	68.27	81.9	77.17	64.67	6.42	1.61	3.99
KNM 11549 X WGL 1119	91	110.27	26.47	6.17	28.17	193.2	30.2	68.07	80.87	74.87	60.37	6.94	2.12	3.32
KNM 11549 X IBT MRR 24	76.67	100.94	28	10.77	24.43	185.8	30.43	0	82.13	69.93	64.17	6.96	1.99	3.52
KNM 7660 X JGL11727	79.67	105.27	28.53	7	22.07	250	30.2	54.2	80.37	67.73	62.73	7.13	1.76	4.06
KNM 7660 X WGL 1119	73	96.75	25.07	14.57	20.6	190.27	30.47	0	82	74.03	60.97	6.32	2.07	3.05
KNM 7660 X IBT MRR 24	69.67	92.46	24.8	8.77	23.7	125.27	20.07	21.83	78.03	69.43	56.27	6.83	1.83	3.73

MTU 1010	81.33	92.68	24.13	7.07	22.93	139.47	16.53	51.47	80.1	70.1	63.53	6.73	1.87	3.6
Mean	**82.32**	**93.55**	**25**	**7.91**	**22.34**	**177.17**	**23.1**	**43.92**	**80.07**	**70.96**	**61.43**	**6.48**	**1.9**	**3.47**
Range Lowest	69.67	72.26	20.4	2.83	15.1	97.6	15.67	0	75.67	60.37	54.17	5.42	1.55	2.44
Range Highest	97.67	113.19	30.9	14.57	28.17	297.8	31.07	81.97	83.53	77.17	67.57	7.26	2.39	4.17

DFF: Days to 50% lowering; PHT:Plant height; PL:Panicle length; NPT:Number of productive tillers per plant; TW:Test grain weight; NFG:Number of filled grains per panicle; GYP:Grain yield per plant; GI:Gallmidge incidence; HP:Hulling Percentage; MP:Milling Percentage; HRR:Head rice recovery; KL:Kernel length; KB:Kernel Breadth; LBR: Length breadth ratio

The number of productive tillers ranged from 2.83 to 14.57 with a general mean of 7.91. The average number of productive tillers per plant was higher for testers (12.29) followed by crosses (7.89) and lines (5.92). Mean productive tillers per plant in the lines ranged from 2.83 for PR 126 to 10.83 for JGL 24423 and 14.00 for IBT MRR 24 to 11.13 for WGL 1119 in testers. Among the crosses, it varied from 3.23 for cross PR 126 to 14.57 for cross KNM7660 X WGL 1119 and in the case of check MTU 1010 with 7.07. The 1000- grain weight ranged from 20.67 (PR 126) to 24.83 g (JGL 24423) in lines and from 15.27 (WGL 1119) to 17.90 g (IBT MRR 24) in testers with an overall mean of 23.78 g in lines and 16.68 g in testers. The mean performance for 1000- grain weight was higher for lines (23.78 g) in comparison with crosses and testers. Further among crosses, cross KNM11549 X WGL 1119 recorded higher (28.17 g), while PR 126 X WGL 1119 recorded a lower (15.10 g) value. The mean 1000- grain weight for check MTU 1010 recorded was 22.93 g. This character with a general mean of 22.34 g. The average number of filled grains per panicle was observed to be 123.27 for lines, 170.56 for testers, and 198.33 in crosses. Among the lines, PR 126 and JGL 24423 recorded maximum (138.87 and 137.80) and minimum for KNM 118 (97.60) per se performance, while the testers JGL 11727 and IBT MRR 24 recorded maximum (253.87) and minimum (110.07) values respectively. Further among crosses, the cross KNM118 X JGL11727 exhibited greater per se performance (297.80), while cross KNM7660 X IBT MRR 24 recorded lesser per se performance (125.27) respectively for the trait. In the case of check, the average number of filled grains per panicle was 139.47. Most of the crosses recorded high mean values for grain yield per plant than the parents and checks studied. The average grain yield per plant in the lines ranged from16.03 g (KNM118) to 23.73 g (IRRI 179) and in testers; it varied from 16.43 g (IBT MRR 24) to 25.80 g (JGL 11727). The crosses IRRI 179 X IBT MRR 24 (31.07 g), KNM7660 X WGL 1119 (30.47 g), KNM 11549 X IBT MRR 24 (30.43 g), KNM 7660 X JGL 11727 (30.20 g), KNM 11549 X WGL 1119 (30.20 g), and IRRI 179 X WGL 1119 (28.70 g), recorded high grain yield per plant compared to check MTU 1010 (16.53 g). The average means of lines and testers revealed that crosses registered superior performance than parents with respect to all the traits studied. Further, the crosses in general were tall and high yielding than their parents. The general mean for gall midge incidence was 43.92 per cent with a range of 0 to 81.97 per cent. The lines recorded a mean value of 63.76 per cent with a range of 36.70 (JGL 24423) to 81.97 per cent (PR 126) while, testers recorded a mean value of 11.66 per cent with a range of 3.83 (WGL 1119) to 27.26 per cent (JGL 11727). The mean of crosses was 42.26 per cent with a range of 0.00 per cent (KNM11549 X IBT MRR 24, JGL 24423 X IBT MRR 24, IRRI 179 X IBT MRR 24 and KNM 7660 X WGL 1119) to 77.63 per cent (PR 126 X JGL 11727). The check recorded a mean incidence of 51.47 per cent. In terms of hulling percentage, the range was observed from 75.67 per cent to 83.53 per cent with an overall mean of 80.07 per cent. The mean hulling percentage in lines ranged from 75.87 per cent (JGL 24423) to 82.57 per cent (KNM 7660) and in testers, it ranged from 75.67 per cent (IBT MRR 24) to 79.93 per cent (JGL 11727). Among the crosses, the cross PR 126 X WGL 1119 recorded maximum of 83.53 per cent followed by KNM 118 X WGL 119 (82.27 per cent), KNM 11549 X IBT MRR 24 (82.13 per cent) and KNM 7660 X WGL 1119 (82.00 per cent) and the cross JGL24423 X IBT MRR 24 recorded a minimum (77.40 per cent). The check MTU 1010 recorded an average hulling percentage value of 80.1 per cent for this trait. In terms of milling percentage, the range was observed from 60.37 per cent to 77.17 per cent with an overall mean of 70.96 per cent. The mean milling percentage in lines ranged from 65.43 per cent (JGL 24423) to 74.47 per cent (KNM 7660) and in testers, it ranged from 60.37 per cent (IBT MRR 24) to 68.97 per cent (JGL 11727). Among crosses, the milling percentage ranged from 67.73 per cent (KNM 7660 X JGL 11727) to 77.17 per cent (KNM11549 X JGL 11727) and check MTU 1010 recorded an average milling percentage of 70.1 per cent. In terms of head rice recovery percentage, the range observed was 54.17 per cent to 67.57 per cent with an overall mean of 61.43 per cent. The mean head rice recovery percentage in lines ranged from 54.17 per cent (JGL 24423) to 67.57 per cent (KNM 7660) and in testers, it ranged from 56.60 per cent (IBT MRR 24) to 65.43 per cent (JGL 11727). Among crosses, the cross JGL 24423 X WGL 1119 recorded a maximum of 65.17 per cent followed by KNM11549 X JGL 11727 (64.67 per cent), KNM 118 X IBT MRR 24 (64.33 per cent) and the cross KNM 7660 X IBT MRR 24 recorded a minimum value of (56.27 per cent). The check recorded an average head rice recovery value of 63.53 per cent. The general mean for kernel length was 6.48 mm with a range of 5.42 mm to 7.26 mm. The lines recorded a mean of 6.72 mm with a range of

6.41 (KNM 11549) to 7.16 mm (IRRI 179) and the testers recorded a 6.04 mm mean value with a range from 5.45 mm (WGL 1119) to 6.36 mm (IBT MRR 24). The mean of crosses was 6.47 mm with a range of 5.42 mm (PR 126 X WGL 1119) to 7.26 mm (IRRI 179 X IBT MRR 24). The check recorded an average kernel length of 6.73 mm. The general mean for kernel breadth was 1.90 mm with a range of 1.55 mm to 2.39 mm. The lines recorded a mean of 1.91 mm with a range of 1.70 mm (PR 126) to 2.29 mm (JGL 24423) and the testers recorded a 1.61 mm mean value with a range from 1.55 mm (WGL 1119) to 1.70 mm (JGL 11727). The mean of crosses was 1.95 mm with a range of 1.61 mm (KNM 11549 X JGL 11727) to 2.39 mm (KNM 118 X IBT MRR 24). The check recorded an average kernel breadth of 1.87 mm. The general mean for kernel L/B ratio was 3.47 with a range of 2.44 to 4.17. The lines recorded a mean of 3.56 with a range of 2.88 (JGL 24423) to 4.08 (IRRI 179) and the testers recorded a 3.74 mean value with a range from 3.52 (WGL 1119) to 3.97 (IBT MRR 24). The mean of crosses was 3.39 with a range of 2.44 (KNM 118 X IBT MRR 24) to 4.17 (PR126 X IBT MRR 24). The check recorded an average kernel L/B value of 3.6.

Phenotypic and genotypic coefficient of variations (Table 4) showed that PCV values were higher than GCV values for all the traits indicating that environmental factors play a role in how these traits are expressed. The results of this study provided confirmation with Toshimenla and Changkija [14], Vanisree et al. [15], Tuhina et al. [16], Savitha and Usha Kumari [17], Bhinda et al. [18], Siddi et al. [19], Sreedhar Siddi and Anil Deva [20], Srinivas et al. [21] and Subhas Chandra Roy and Pankaj Shil [22]. The GCV was found to be less than PCV for all the traits except for the number of productive tillers per plant. The observation that PCV values for the number of productive tillers per plant were significantly greater than GCV indicates that there is a significant environmental influence and predominance of non-additive gene effects, whereas for remaining characters there were small differences, indicating a significant genetic influence. Contrary to this, Subhas Chandra Roy and Pankaj Shil [22] reported that the difference between the values of GCV and PCV was higher for flag leaf length, number of grains per panicle, and active tillering.

The percentage of gall midge incidence, the number of productive tillers per plant, the number of filled grains per panicle, and grain yield per plant showed higher phenotypic and genotypic coefficients of variation indicating the presence of a high degree of variation for these traits among the genotypes which could be improved through selection in a desirable direction. These results are in agreement with the findings obtained by Thippaswamy et al. [23] and Siddi et al. [19] for Gall midge incidence, Mohan et al. [24] and Subhas Chandra Roy and Pankaj Shil [22] for the number of filled grains per panicle, Allam et al. [25], Ajmera et al. [26] and Ram et al. [27] for grain yield. Ajmera et al. [26] and Siddi et al. [19] reported the same for the number of productive tillers.

Moderate levels of PCV and GCV for 1000 grain weight, kernel L/B ratio, kernel breadth, plant height, and panicle length indicated the considerable level of variability in these traits and suggested the possibility of improving these traits through selection. These results are in confirmation with Ahmed et al. [28] and Das [29] for 1000-grain weight. In contrary to this, Mohan et al. [24] and Srinivas et al. [30] reported high GCV and high PCV values for 1000 grain weight. Dhanwani et al. [31] and Ajmera et al. [26] reached similar conclusions in their reports. For Plant height, moderate levels of PCV and GCV were observed, and these results are contrary to Dhanwani et al. [31] who showed high GCV and PCV values. Akinwale et al. [9], Sangram Kumar et al. [32] and Siddi et al. [19] reported low levels of PCV and GCV for plant height. Whereas, low levels of PCV and GCV were observed for hulling percentage, head rice recovery, milling percentage, kernel length, and days to 50% flowering suggesting less variability among the genotypes for these traits. Similar reports were concluded by Akinwale et al. [9], Sangram Kumar et al. [32] and Das [29]. Days to 50% flowering, milling percentage, kernel length, head rice recovery and hulling percentage all showed low PCV and GCV values, indicating that these variables varied less amongst the genotypes under investigation.

Characteristics passed down from parents to their offspring are measured by a trait's heritability. Estimates of heritability aid plant breeders in selecting elite genotypes from a wide genetic population; as a result, previous knowledge of the heritability of the traits is a requirement for the selection procedure. High genetic advance and high heritability point to additivity as the dominant factor. The predominance of dominance and interallelic interactions causes high heritability and little genetic advancement. In situations where low heritability estimates are recorded, the environmental effect is regarded as being more pronounced. These values were therefore calculated in F_1 crosses and displayed in Table 4. According to Johnson et al. [33], heritability is classified as low (below 30%), medium (30% - 60%) and high (above 60%); and genetic advance (as percentage of mean) is classified as low (<10%), moderate (10% - 20%) and high (>20%). In the current study, heritability (in the broad sense) was observed for all the characters studied, and values are high for all the traits, including gall midge incidence, 1000-grain weight, days to 50% flowering, kernel length, grain yield per plant, plant height, number of filled grains per panicle, panicle length, kernel L/B ratio, number of productive tillers per plant, kernel breadth, milling percentage and head rice recovery and facilitates selection process. Estimates of both genetic advance and heritability should be taken into account in order to reach more trustworthy conclusions of complete practical importance. Since heritability does not always indicate genetic gain, therefore heritability estimate coupled with genetic advance is more effective for selection.

In this study, the genetic advance estimate was high for gall midge incidence, number of productive tillers per plant, grain yield per plant, number of filled grains per panicle, 1000-grain weight, kernel L/B ratio, plant height, and kernel breadth, and moderate for panicle length, days to 50% flowering and kernel length. While there has been a little genetic advance in the milling percentage, head rice recovery and hulling percentage.

Gall midge incidence, number of productive tillers per plant, number of filled grains per panicle, grain yield per plant, and grain weight per 1000 grains had strong heritability along with high genetic advance estimates indicating that these traits were less influenced by the environmental fluctuations and, governed by additive gene action and can be easily selected through phenotypic selection. Days to 50% flowering, panicle length, and kernel length had high heritability and moderate genetic advance. Low estimates of both parameters were found for hulling percentage indicating that non-additive genes may play a role in the inheritance of this trait and that breeding for heterosis or recurrent selection is preferable in order to improve such kind of trait. These results are in accordance with the findings of Srinivas et al. [30] and Sreedhar Siddi and Anil Deva [20].

Table 4. Genetic variability components for yield, its components, gall midge incidence and quality traits in rice

Character	General Mean	Range Lowest	Range Highest	GCV	PCV	h^2(Broad sense)	GA in % over mean
Days to 50% flowering	82.32	69.67	97.67	8.74	9.008	94.00	17.45
Plant height (cm)	93.55	72.26	113.19	11.84	12.34	92.10	23.39
Panicle length (cm)	25.00	20.40	30.90	10.07	10.88	85.60	19.19
No of Productive tillers/Plant	7.91	2.83	14.57	38.42	42.75	80.80	71.11
1000 grain weight (g)	22.34	15.10	28.17	15.13	15.43	96.20	30.566
No of filled grains/ Panicle	177.17	97.60	297.80	26.98	28.19	91.50	53.155
Grain Yield (g)	23.10	15.67	31.07	21.13	21.93	92.80	41.916
Gall midge incidence (%)	43.92	0.00	81.97	65.72	66.61	97.40	133.602
Hulling (%)	80.07	75.67	83.53	1.90	3.06	38.60	2.437
Milling (%)	70.96	60.37	77.17	4.871	5.802	70.50	8.423
Head Rice Recovery (%)	61.43	54.17	67.57	4.694	5.664	68.70	8.013
Kernel length (mm)	6.48	5.42	7.26	8.011	8.298	93.20	15.933
Kernel breadth (mm)	1.90	1.55	2.39	12.21	13.953	76.60	22.01
kernel LB ratio	3.47	2.44	4.17	14.111	15.508	82.80	26.449

4. CONCLUSION

Based on the above-mentioned findings, it is inferred that the material contains a wide range of genetic variations in which the gall midge incidence, the number of productive tillers per plant, the number of filled grains per panicle and grain yield per plant showed the high PCV and GCV indicating the presence of a high degree of variation for these traits among the genotypes which could be improved through selection in the desirable direction. The character number of productive tillers per plant revealed that the degree of difference between the genotypic and phenotypic coefficients of variation was large difference indicating that there is a significant environmental influence and predominance of non-additive gene effects, whereas for the remaining characters there were small differences, indicate a significant genetic influence. Gall midge incidence, number of productive tillers per plant, number of filled grains per panicle, grain yield per plant, and grain weight per 1000 grains had strong heritability along with high genetic advance estimates. Traits with high heritability and high genetic advance could be used as a powerful tool in the selection, which are responsible for additive genes and less influenced by the environment. For the purpose of creating high-yielding, gall midge-resistant rice varieties, plant features like the number of productive tillers per plant, number of filled grains per panicle, grain yield per plant and 1000 grain weight along with gall midge tolerance should indeed receive more focus in future breeding programmes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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