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Research Article

Genetic variability, heritability and genetic advance of yield and lodging-related traits in rice (*Oryza sativa* L.)

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Abstract
This study was conducted to determine the PCV and GCV, heritability (bs) and genetic gain in lodging resistance and lodging-related traits among selected high yielding rice varieties of Kerala. Results revealed the presence of large genotypic differences in yield, lodging and related traits and difference between PCV and GCV among all the selected genotypes. Both PCV and GCV were highest for seed yield per plant followed by panicle weight and tillers plant^{-1}. Heritability was high and ranged from (99.81 %) potassium content to (91.43 %) panicle weight. The genetic advance as per cent of mean estimates was high for all the traits and highest for lodging per cent (84.83 %). The high estimates of genetic advance indicating that, the selection for characters *viz*., internodal length, culm wall thickness, lodging perc ent, seed yield per plant, silicon and potassium content will be effective for further improving overall lodging resistance.

Keywords
Lodging resistance, internode length, rice, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance

INTRODUCTION

Rice is a staple food for more than half of the global population and it provides 15 % of per capita protein and 21% of global human per capita energy. Traditionally rice cultivation is well suited and occupied a prime position in Kerala's agriculture as the wet and humid tropical climate condition is well supportive. The high amount of rainfall and strong wind especially in coastal areas reduce the grain yield due to lodging of plants. The green revolution paved the way for higher grain yield through the introduction of semi-dwarf varieties which were having strong culm that ensures lodging resistance. It's also recorded that photosynthesis is reduced by 60-80 % due to lodging (Hitaka, 1969) and every 2 % increase in lodging reduces 1 % grain yield (Setter *et al*., 1997). Severe lodging prevents the transport of water, nutrients, and assimilates through the xylem and phloem, resulting in a reduction in assimilates for grain filling. High moisture levels in a lodged plant community may be favourable for fungal growth and disease development which, affects grain quality and appearance.

The grains of lodged plants may also germinate on the panicle, especially in cultivars with weak seed dormancy. As a result, lodging causes great losses in both grain quantity and quality. Furthermore, it also causes difficulties in harvest operations, increases demand for grain drying, and consequently results in increased production cost. The development of semi-dwarf rice and wheat varieties by introducing the sd-1 gene in the early 1960s represented the greatest success in improving lodging resistance and yield potential of cereal crops. Lodging resistance can also be improved by harnessing the gene from the wild relatives (Keerthiraj *et al*., 2020). Resistance to lodging has been improved by reducing the plant height with the gene *sd-1*. Among morphological traits, stem diameter and culm wall thickness have direct contribution to lodging resistance and the breaking strength of the culm. Basal internode length and the cross-sectional area of the culm majorly determine straw strength (Yang *et al*., 2000).

Resistance to lodging which is a complex trait mainly includes interactions between many agro-morphological traits. Many recent studies in rice cultivars mainly focussed on the relation between the lodging related traits such as, lodging resistance and height of plant (Yang *et al.,* 2000), type of panicle (Ma *et al.,* 2004), upper plant weight (Islam *et al.,* 2007), diameter and length of basal internode (Wan and Ma, 2003), silicon content (Ma and Yamaji, 2006), lignin content, cellulose content, rate of nitrogen application and yield (Yang *et al.,* 2009). The objectives of this study were to determine genotypic variation in lodging resistance and lodging-related morphological traits and to identify the key morphological traits associated with lodging resistance.

MATERIALS AND METHODS

Twenty-one high yielding varieties of rice as presented in **Table1**. formed the experimental material for this study. The genotypes were raised in experimental field of Agricultural Research Station, Mannuthy, in randomized block design with two replications. The seedlings were raised in nursery and transplanted to the main field at 31st May of 2018. The plot size was 5 m x 2 m and the spacing was 20 x 15 cm. with a spacing of 40 cm. between the blocks in a replication and spacing of 1m between replications. General agronomic practice was carried out as per recommendations given in package of practices, KAU (2016). Observations including qualitative, quantitative and biochemical parameters were recorded. Percentage of lodging was determined as per cent ratio of plants lodged at maturity stage to the total number of plants in a block as per IRRI, 2014 standard evaluation system (SES) under the natural conditions and culm strength was first measured after heading by gently pushing the tillers back and forth a few times holding at basal of culm. This test gave some indication of culm stiffness and resilience.

Table 1. Salient features of twenty-one varieties of rice used in the study

Sl. No.	Variety/ Line	Salient features	Duration	Source
1	Aathira	Suited for I and II crop seasons and also for hilly tracts, Semi-tall, non-lodging, moderate resistance to brown plant hopper, blast and blight diseases.	120-130 days	RARS, Pattambi
2	Akshaya	Tall, long duration, non-lodging. Moderately resistant to stem borer, leaf folder and blast disease. Tolerant to high temperature and moisture stress	145-150 days	RARS, Pattambi
3	Aiswarya	Resistant to Brown plant hopper, blast and blight diseases. Suitable for modern cultivation and for first and II crop seasons.	120-125 days	RARS, Pattambi
4	Gouri	Non-lodging, medium tall, moderately resistant to sheath blight.	115-120 days	RRS, Moncompu
5	Harsha	Moderate resistant to blast and moisture stress. Suitable for direct seeding in rainfed lowlands.	105-110 days	RARS, Pattambi
6	Jyothi	Moderately tolerant to brown plant hopper and blast, susceptible to sheath blight, suitable for direct seeding, transplanting and special systems of *Kole* and Kuttanad.	110-115 days	RARS, Pattambi
7	Kairali	Moderately resistant to blast, blight, gall midge and leaf folder. Can be cultivated in all the three seasons.	110-115 days	RARS, Pattambi
8	Kanchana	Suitable for *Kole* and Kuttanad regions. Resistant to blight, blast, stem borer and gall midge. Suitable for all seasons.	105-110 days	RARS, Pattambi
9	Karishma	Dwarf, medium tillering, resistant to BPH and medium resistant to GM..	115-120 days	RRS, Moncompu
10	Karuna	Multiple resistant, tolerant to iron toxicity, good response to low fertilizer regimes, susceptible to brown spot. Specific to II crop season.	140-145 days	RARS, Pattambi
11	Kunjukunju Varna	Photo-insensitive, moderately tolerant to gall fly, leaf folder, whorl maggot and stem borer. Leaf sheath and apicules are purple pigmented.	110-115 days	RARS, Pattambi
12	Mangala Mahsuri	Multiple resistant, tolerant to iron toxicity and waterlogging. Good response to low fertilizers regimes.	140-145 days	RARS, Pattambi
13	Manupriya	Suitable for *Kole* lands. Tolerant to sheath blight, brown spot, blast, stem borer and gall midge. Suitable for all seasons.	105-110 days	Agricultural Research Station (ARS), Mannuthy
14	Prathyasa	Non-lodging, semi-tall variety, photo-insensitive, suitable for Kuttanad. Moderately resistant to gall midge, BPH, sheath blight and sheath rot.	100-110 days	RRS, Moncompu
15	Ponmani	Resistant to brown plant hopper and high yield potential.	155-160 days	RARS, Pattambi
16	Pournami	Semi tall, medium tillering, moderately resistant to sheath blight, sheath rot, lakshmi disease, BPH and gall midge. Non-lodging, tolerant to high temperature.	115-120 days	RRS, Moncompu
17	Samyuktha	Suitable for Koottummundakan system of cultivation with Makaram in Central zone.	112-117 days	RARS, Pattambi
18	Swetha	Suitable for black cotton soils of Chittoor taluk as a transplanted II crop.	135-140 days	RARS, Pattambi
19	Uma	Dwarf, medium tillering, non-lodging, resistant to brown plant hopper and GM Biotype-5.	115-120 days	RARS, Pattambi
20	Vaishak	Suitable for direct seeding during *kharif* season in the uplands. Tolerant to moisture stress and resistant to blue beetle.	120-125 days	RARS, Pattambi
21	Varsha	Suitable for direct seeding in rainfed lowlands. Moderate resistant to blue beetle.	110-115 days	RARS, Pattambi

Final observation at maturity was made to record standing position of plants based on Standard Evaluation System-International Rice Research Institute (SES-IRRI, 2014). Observation recorded for traits days to fifty per cent flowering, plant height, flag leaf width, flag leaf length, tillers per plant, internodal length, culm diameter, culm wall thickness, days to maturity, panicle length, panicles per plant, panicle weight, seeds per panicle, test weight, silicon content, potassium content, seed yield per plant, and lodging per cent. Silicon content in plant sample (culm) was estimated by digestion of sample in micro-digester with HNO3, HF and H2O2 acids and determined by using ICP-OES. Potassium content in plant sample (culm) was estimated by digesting the sample with diacid mixture of HNO3 and HClO4 in the ratio of 9:4 and determined by using the Flame-photometer (Jackson, 1958).

RESULTS AND DISCUSSION

Results of analysis of variance showed the presence of highly significant genetic variations among the genotypes for all the characters under study (**Table 2**).

Lodging percentage Uma reported the lowest i.e. 8.82 per cent and Samyuktha with 45.65 per cent was the highest and mean value for the lodging character was 26.14 per cent. Lodging related traits *viz*., plant height varied from 95.9 cm. for Kunju Kunju Varna to 160.30 cm. for Vaisakh with a mean performance of 121.7 cm. Internodal length (4th inter node from the top) was recorded the lowest in Pournami with 9.02 cm. and the highest in Aathira with 18.27 cm and mean performance of 12.35 cm. Culm diameter reported the lowest in Kanchana 6.01 mm. and Mangala Mahsuri (red) with 9.5 mm. was the highest and mean performance was 7.59 mm. Culm wall thickness recorded among the 21 rice genotypes varied from 0.57 mm. for Aathira to 1.63 mm. for Mangala Mahsuri, with a mean performance of 0.87 mm.

Yield per plant among the 21 genotypes, Kunju Kunju Varna reported the lowest yield 29.27 g. per plant and the highest was 76.57 g. per plant for Uma and mean value was 51.75 g. per plant. Yield related traits viz., the number of panicles was reported least for Swetha, with 5.9 panicles per plant and the highest was 12.5 the numbers of panicles for Uma and mean performance among the genotypes was 8.92 panicles per plant. Number of seeds per panicle ranged from 166.4 in Kanchana to 272.6 in Ponmani with a mean performance of 223.17 seeds per panicle. Test weight varied from 19.48 g. for Mangala Mahsuri to 30.01 g. for Vaisakh, with a mean value of 25.43 g. Swetha reported the lowest silicon content with 0.14 % and Uma with 0.51 % was the highest and mean performance was 0.32 %. Potassium content was reported least for Ponmani with 0.75 per cent and the highest was 2.39 per cent in Kunju Kunju Varna, with a mean performance of 1.49 per cent.

Table 2. Analysis of variance calculated for different quantitative and biochemical characters among 21 rice genotypes

Source	df	Mean sum of squares								
		Days to 50 per cent flowering	Plant height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Tillers per plant (no.)	Internodal length (cm)	Culm diameter (mm)	Culm wall thickness (mm)	Days to maturity
Replication	1	2.9	17.101*	1.44	0	1.101*	0.07	0.017	0	3.43
Treatment	20	275.945**	778.823**	102.155**	0.179**	6.914**	15.229**	1.585**	0.11**	414.179**
Error	20	2.7	2.5	0.47	0	0.1	0.094	0.015	0	2.68

*Significant at 5% ; **significant at 1%

(......contd)

Source	df	Mean sum of squares								
		Panicles per plant (no.)	Lodging %	Panicle length (cm)	Panicle weight (g)	Seeds per panicle (no.)	Test weight (g)	Seed yield per plant (g)	Silicon content (%)	Potassium content (%)
Replication	1	3.429*	1.3	0.768*	0	195.437*	0.003	9.571	0	0.004*
Treatment	20	5.22**	236.95**	17.584**	2.613**	2247.037**	16.568**	305.52**	0.02**	0.47**
Error	20	0.2	2	0.08	0.12	15	0.125	10.66	0	0

*Significant at 5% ; **significant at 1%

Coefficient of variation provides a relative measure of variance among different traits under study. In general, the estimates phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) indicating the effect of environment on expression of genotype (**Table 3**). The difference between PCV and GCV were least for silicon and potassium content followed by plant height and panicle length (0.05 %) and days to maturity (0.08 %). The difference was less than one per cent indicating comparatively less influence of environment on the expression of all characters. Phenotypic coefficient of variation ranged from 11.36

per cent to 41.82 per cent for test weight and lodging per cent respectively. Test weight, culm diameter, days to maturity, panicle length, days to fifty per cent flowering, panicle weight, seeds per panicle, plant height, flag leaf width, panicles per plant and flag leaf length recorded moderate PCV with 10-20%. Tillers per plant, Internodal length, seed yield per plant, culm wall thickness, silicon content, potassium content and lodging per cent have shown high PCV with above 20%. Genotypic coefficient of variation ranged from 11.28 per cent to 41.47 per cent for test weight and lodging per cent respectively. Test weight, culm diameter, days to maturity, panicle length, days to fifty per cent flowering, panicle weight, seeds per panicle, plant height, panicles per plant, flag leaf width, tillers per plant and flag leaf length recorded moderate GCV with 10-20%. Internodal length, seed yield per plant, culm wall thickness, silicon content, potassium content and lodging % have shown high GCV. The results are in consonance with Sameera *et al*., (2015).

Table 3. Variability and genetic parameters for eighteen characters estimated from 21 rice genotypes

Characters	Range		Mean	CV	CD at 5%	SE(m)	Coefficient of variation (%)	
	Min.	Max.					GCV	PCV
Days to 50 % flowering	79.50	122.50	93.45	1.768	3.471	1.169	12.51	12.63
Plant height (cm)	95.90	160.30	121.70	1.3	3.324	1.119	16.19	16.24
Flag leaf length (cm)	26.38	52.21	35.85	1.919	1.445	0.486	19.89	19.98
Flag leaf width (cm)	1.22	2.49	1.66	2.428	0.085	0.029	17.90	18.10
Tillers per plant (no.)	6.00	13.00	9.37	3.772	0.743	0.25	19.66	20.02
Internodal length (cm)	9.02	18.27	12.35	2.485	0.645	0.217	22.28	22.41
Culm diameter (mm)	6.01	9.50	7.59	1.613	0.257	0.087	11.68	11.79
Culm wall thickness (mm)	0.57	1.63	0.87	3.195	0.058	0.02	26.98	27.22
Days to maturity	106.50	157.50	122.29	1.338	3.438	1.157	11.73	11.81
Panicles per plant (no.)	5.90	12.50	8.92	4.708	0.883	0.297	17.79	18.41
Lodging %	8.22	45.65	26.14	5.4	2.965	0.998	41.47	41.82
Panicle length (cm)	17.48	29.72	24.67	1.141	0.591	0.199	11.99	12.05
Panicle weight (g)	6.46	9.79	8.06	4.237	0.717	0.241	13.86	14.50
Seeds per panicle (no.)	166.40	272.60	223.17	1.749	8.201	2.76	14.97	15.07
Test weight (g)	19.48	30.01	25.43	1.39	0.743	0.25	11.28	11.36
Seed yield per plant (g)	29.27	76.57	51.75	6.309	6.859	2.309	23.46	24.29
Silicon content (%)	0.14	0.51	0.32	6.007	0.041	0.014	30.84	30.84
Potassium content (%)	0.75	2.39	1.49	1.441	0.045	0.015	32.59	32.59

Moderate PCV and GCV estimates in Test weight, days to maturity, panicle length, days to fifty per cent flowering and panicle weight were also reported by Padmaja *et al*., (2008). High PCV and GCV for internodal length, culm diameter, culm wall thickness and lodging per cent, indicating the presence of ample variability among the rice genotypes and the possibility of improvement through selection. Similar findings in case of internodal length, culm wall thickness and lodging per cent were reported by Sabesan *et al*., (2009), Pal and Sabesan, (2010) and Karthikeyan *et al*., (2010).

Heritability ranged from 91.43 per cent in panicle weight to 99.81 per cent in potassium content followed by plant height (99.36 %), panicle length (99.11 %) and flag leaf length (99.08 %). Among 21 rice genotypes, heritability for all the characters was high (**Table 4**).

High heritability for test weight, days to maturity, panicle weight, seeds per panicle, plant height, panicles per plant, flag leaf width, tillers per plant, flag leaf length was also reported by Padmaja *et al.,* (2008). Manjunatha and Kumara (2019) have also reported high heritability for day's number to 50 per cent flowering. Pal and Sabesan (2010) have also reported high heritability for internodal length, culm diameter, culm wall thickness and lodging per cent. High heritability for tillers per plant, panicles per plant, seeds per panicle and seed yield per plant was also reported by Jayasudha and Sharma, (2010), Fiyaz *et al*., (2011) and Anyaoha *et al*., (2018).

Even though high heritability for a character indicates the effectiveness of selection on the basis of phenotypic performance, it cannot be considered as the amount of genetic progress that can be made from selecting the best individual among the population. Panse and Sukatme (1954) reported that a high heritability value for character does not necessarily lead to a high genetic gain. If the heritability is mainly due to non-additive genetic effects (dominance and epistasis) the expected genetic gain would be low and when it is chiefly due to additive effects, a high genetic gain would be expected. Hence estimation of genetic advance as percentage mean can serve as an indication in this regard. According to Johnson *et al*.,

Table 4. Estimation of broad sense heritability and genetic advance for eighteen characters estimated from 21 rice genotypes

Characters	Heritability broad sense (%)	Genetic advance (%)
Days to 50 % flowering	98.04	25.55
Plant height (cm)	99.36	33.29
Flag leaf length (cm)	99.08	40.85
Flag leaf width (cm)	97.79	36.52
Tillers per plant (no.)	96.45	39.83
Internodal length (cm)	98.77	45.67
Culm diameter (mm)	98.13	23.86
Culm wall thickness (mm)	98.20	55.15
Days to maturity	98.71	24.04
Panicles per Plant (no.)	93.44	35.49
Lodging %	98.33	84.83
Panicle length (cm)	99.11	24.63
Panicle weight (g)	91.43	27.35
Seeds per panicle (no.)	98.65	30.67
Test weight (g)	98.50	23.09
Seed yield per plant (g)	93.26	46.74
Silicon content (%)	96.24	63.62
Potassium content (%)	99.81	67.23

The genetic advance as per cent of mean estimates varied between 23.09 per cent to 84.83 per cent for test weight and lodging per cent respectively. In respect of the individual traits, the genetic advance is test weight (23.09 %), culm diameter (23.86 %), days to maturity (24.04 %), panicle length (24.63 %), days to 50 per cent flowering (25.55 %), panicle weight (27.35 %), seeds per panicle (30.67 %), plant height (33.29 %), panicles per plant (35.49 %), flag leaf width (36.52 %), tillers per plant (39.83 %), flag leaf length (40.85 %), internodal length (45.67 %), seed yield per plant (46.74 %), culm wall thickness (55.15 %), silicon content (63.62 %), potassium content (67.23 %) and lodging per cent (84.83 %).

All characters under the study showed moderate to high estimates of genetic advance, indicating that the selection for these characters will be effective for further improvement. Padmaja *et al.,* (2008) also reported high genetic advance for test weight, days to maturity, panicle weight, seeds per panicle, plant height, panicles per plant, flag leaf width, tillers per plant and flag leaf length. Manjunatha and Kumara (2019) also reported the high genetic advance for days number to 50 per cent flowering.

High genetic advance for tillers per plant, panicles per plant, seeds per panicle and seed yield per plant were also reported by Anyaoha *et al*., (2018). High genetic advance for internodal length, culm diameter, culm wall thickness and lodging per cent was also reported by Pal and Sabesan (2010), Sameera *et al*., (2015) and Sudeepthi *et al*., 2020.

In conclusion, the present study identified the presence of adequate genetic variability, heritability and genetic advance indicated that the study needs an interrelationship between yield and other traits including lodging among 21 tested genotypes. Hence, the information generated from this study, high PCV and GCV estimates were recorded for seed yield per plant and lodging per cent. High heritability coupled with high genetic advance as per cent of mean indicating the influence of additive gene action in the expression of trait were observed for seed yield per plant, lodging per cent and related traits viz., plant height, internodal length, culm diameter, culm wall thickness and seeds per panicle. Substantial improvement in the expression of these characters over base population can be expected through simple selection.

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