Appraisal of MAGIC lines of Rice (*Oryza sativa* L.) for genetic variability, character association and path analysis studies

Abstract

An investigation was carried out to estimate genetic parameters, assess association and path coefficient analysis among growth, yield and yield attributes in Multiparent Advanced Generation Intercross (MAGIC) lines of Rice (*Oryza sativa* L.). A total of 100 MAGIC lines along with seven checks were evaluated in augmented design during summer2022 at ZAHRS, KSNUAHS, Shivamogga. Analysis of variance revealed significant differences among the advanced lines for all the traits under study. The variability studies among the lines revealed a higher GCV, PCV, heritability and GAM for majority of traits. The correlation and path coefficient analysis revealed that traits tillers per plant, productive tillers per plant, panicle length, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility, test weight and L/B ratio were positively associated with yield.Selection of lines with higher filled grains per panicle would be effective for yield improvement program along with the higher percentages of productive tillers per plant, panicle length and spikelet fertility.

Keywords: Variance, Heritability, Genetic advance, MAGIC and Augmented.

Introduction

Rice (*Oryza sativa* L.) is one of the world's most important cereal food crops and is used synonymous to food in significant parts of Asia, where it has shaped their diet, economic life and culture. It is the primary source of food and protein with an enormous nutritional and economic impact. It is the crucial dietary and food security source of many Asian countries. The two most populous nations namely China and India are the largest producers and consumers of rice (FAOSTAT 2018). Globally, rice covers an area of about 167.10 million hectares, with production of about 782.00 million tonnes and productivity of 4.67 tonnes per hectare (Annon., 2018). In India, it is cultivated across an area of 45.00 million ha and production of about 117.90 million tonnes with productivity of 3.87 tonnes per hectare with 23 per cent of total world rice production and 45 per cent of the total Indian food grain production (Annon., 2019-20). In Karnataka, it is grown in an area of 1.40 million hectares with a production of 3.78 million tonnes and productivity of 2.70 tonnes per hectare (Annon., 2019). Assessment of variability for grain yield and yield attributes is essential for the successful yield improvement through breeding. Further, grain yield depends on various component characters and knowledge of correlation with yield and among yield component traits in addition to identification of the direct and indirect effects of the traits on yield would help in effective yield improvement. The present investigation was undertaken in this context to elucidate information on variability, heritability, genetic advance, character associations and path coefficients in promising rice genotypes.

Material and Methods

Experimental material for the present investigation comprised of 100 MAGIC lines of rice developed at Zonal Agricultural and Horticultural Research Station (ZAHRS), Shivamogga. The experiment was laid out in augmented design with five blocks and each block having 27 genotypes (20 MAGIC lines and 7 checks) to evaluate the advanced lines during summer 2022. Twenty-one days old seedlings were transplanted manually into the main field with single seedling per hill and with the spacing of 20 × 15 cm. The recommended package of practices was followed to maintain a healthy and good crop stand. Five plants were randomly selected from each line and observations were recorded in each treatmentdays to 50 per cent flowering, days to maturity, plant height (cm), panicle length (cm), number of tillers per plant, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility (%), test weight (g), L/B ratio,grain yield (Kg/ha). However, days to 50 per cent flowering and maturity was recorded on plot basis. The data collected was subjected to standard statistical procedures.Analysis of variance for 12 characters was done following the augmented design as suggested by (Federer *et al.*1975).Correlation was worked out using the formulae suggested by Falconer (1964). Partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Analysis was done using WINDOSTAT software (Version 9.2) and R 4.0 software.

Result and discussion

An obligatory requirement of a fruitful breeding program is the presence of genetic variability in the population. It will be a key component for isolating favourable and promising genotypes. The analysis of variance was carried out for all the growth, yield and yield attributing traits in 100 MAGIC lines along with seven parents as checks. The results unveiled notable variations among the advanced lines across all examined traits, suggesting a considerable degree of genetic variability. This underscores the appropriateness of the selected materials for the study, as illustrated in Table 1. This observation was reinforced by the broader range exhibited by all characters, highlighting the presence of extreme genotypes suitable for selection. The genetic variability parameters *viz.*, mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance as per cent of mean (GAM) for all the twelve traits are depicted in Table 2.

Results revealed that maximum range of variability for the trait number of filled grains per panicle (106.10-443.72)while minimum range (2.75-5.09) was recorded for the length/breadth ratio. Higher PCV, compared to GCV were recorded for all the traits studied in the present investigation, indicating the influence of the environment. Similar findings were reported earlier by Tiwari*et al.* (2019). High phenotypic and genotypic coefficients of variation (>20%) was recorded for number of spikelets per panicle, number of filled grains per panicle and grain yield per plant. Similar results were reported earlier by Niharika *et al.* (2022). Further, moderate estimates (10-20%) of PCV and GCV were observed for traits number of tillers plant, number of productive tillers plant, spikelet fertility and length/breadth ratio. These results are in accordance with the findings of Gnaneswari *et al.* (2023)for the number of tillers plant and Williams *et al.* (2021) for spikelet fertility and length/breadth ratio. In contrast, low (<10%) estimates of genotypic and phenotypic coefficients of variation were observed in the present study for days to 50% flowering, days to maturity and test weight, indicating low variability for these characters in the present experimentalmaterial and therefore little scope for the improvement of these traits. Similar findings were reported earlier by Kulsum *et al*. (2022).

In the present study, heritability estimates for the varioustraits studied ranged from (66.28) panicle length to (97.64) days to maturity. High estimates of heritability (>60%)

Table 1: Analysis of variance for yield and its component characters in rice advanced lines of MF_6 generation

Source	Df	Mean sum of square					
		DFF	DM	PH	NT	NPT	PL
Block (eliminating Treatments)	4	0.19 ns	1.04 ns	1.2 ns	1.94 ns	1 ns	1.32 ns
Treatment (eliminating Blocks)	106	42.25 **	43.57 **	202.11 **	15.82 **	12.02 **	8.23 **
Treatment: Test	99	32.08 **	35.67 **	157.07 **	13.39 **	10.56 **	7.87 **
Treatment: Check	6	288.39 **	254.25 **	1192.28 **	76.44 **	50.82 **	17.89 **
Treatment: Test vs. Check	1	0.99 ns	1.01 ns	1065.88 **	106.72 **	4.79 ns	9.71 ns
Residuals	24	0.99	0.84	38.01	2.05	2.19	2.65
CV %	0.92	0.67	5.02	2.44	9.89	7.59	7.29

DFF = Days to 50 per cent flowering
DM = Days to maturity
PH = Plant height
NT = Number of tillers plant^{-1}
NPT = Number of productive tillers plant^{-1}
PL = Panicle length

Table 1: Continued…

Source	Df	Mean sum of square					
		NSP	**NFG**	**SF**	**LB**	**TW**	**GY**
Block (eliminating Treatments)	4	307.55 ns	655.46 ns	21.29 ns	0.0019 ns	1.35 ns	53.29 ns
Treatment (eliminating Blocks)	106	5123.81 **	3590.4 **	38.33 **	0.27 **	8.19 **	111.72 **
Treatment: Test	99	4088.15 **	3217.53 **	39.47 **	0.16 **	4.27 **	84.23 **
Treatment: Check	6	21131.07 **	12667.52 **	106.83 **	2.21 **	69.59 **	564.46 **
Treatment: Test vs. Check	1	27223.69 **	8500.5 **	6.65 ns	0.05 *	34.4 **	321.18 **
Residuals	24	396.45	494.6	13.66	0.01	1.42	24.55
CV %	0.92	11.09	6.61	4.38	8.14	0.92	6.85

TW = **Test weight**
NSP = Number of spikelets panicle^{-1}
NFG = Number of filled grains panicle^{-1}
PF = Spikelet fertility
GY = Grain yield plant^{-1}
LB = Length/Breadth ratio

Table 2: Estimation of genetic parameters for growth, yield and yield related characters

Sl. No.	Traits	Mean± SE_m	Range		Coefficient of variation		h^2 bs (%)	GAM (%)
			Min	Max	PCV (%)	GCV (%)		
1	**Days to 50 % flowering (days)**	108.00 ± 0.56	95.00	126.00	5.24	5.16	96.93	10.48
2	**Days to maturity (days)**	137.49 ± 0.58	124.00	154.00	4.34	4.29	97.64	8.75
3	**Plant height (cm)**	124.05 ± 1.22	91.00	176.00	10.10	8.80	75.80	15.80
4	**Number of tillers plant^{-1}**	20.51 ± 0.37	12.26	28.00	17.84	16.42	84.70	31.18
5	**Number of productive tillers plant^{-1}**	18.11 ± 0.31	11.43	26.43	17.94	15.97	79.25	29.33
6	**Panicle length (cm)**	24.79 ± 0.27	20.33	31.33	11.33	9.22	66.28	15.49
7	**Number of spikelets panicle^{-1}**	268.48 ± 6.19	154.60	563.24	23.82	22.63	90.30	44.37
8	**Number of filled grains panicle^{-1}**	228.31 ± 5.48	106.10	443.72	24.84	22.86	84.63	43.38
9	**Spikelet fertility (%)**	84.51 ± 0.63	63.78	98.85	12.81	10.46	66.74	17.63
10	**Length / Breadth ratio (cm)**	3.77 ± 0.04	2.75	5.09	10.48	10.19	94.55	20.45
11	**Test weight (g)**	16.12 ± 0.63	11.06	25.50	7.43	6.01	65.39	10.03
12	**Grain yield plant^{-1} (g)**	43.94 ± 0.90	22.40	65.80	20.87	17.57	70.86	39.92

were recorded for all the traits studied. A perusal of the results on genetic advance as per cent of mean revealed high values (>20%) for number of tillers per plant, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, length/breadth ratio and grain yield per plant. Further, moderate estimates (10-20%) of genetic advance as per cent of mean were observed for days to 50% flowering, plant height, panicle length, spikelet fertilityand test weight. In their study, Sudeepthi *et al.* (2020) noted moderate GAM for traits such as days to 50 per cent flowering, panicle length, and spikelet fertility. Additionally, they reported a high GAM for the number of productive tillers per plant, the number of filled grains per panicle, and grain yield. In contrast, high GAM was observed for spikelet fertility and length breadth ratio by Gnaneswari *et al.* (2023). Comparable outcomes were noted in studies conducted by Mahamadali*et al.* (2020), Williams *et al.* (2021) and Singh *et al.* (2022).

High heritability coupled with high genetic advance as per cent of mean was recorded for number of tillers per plant, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, length/breadth ratio and grain yield per plant indicating that heritability observed was due to additive gene effects and therefore the selection would be effective for these traits. However, days to 50% flowering, plant height, panicle length, spikelet fertility and test weight had recorded a high heritability coupled with moderate genetic advance as per cent of mean indicating the role of additive and non-additive gene effects for the characters. Further, the information on genetic variation along with heritability and genetic advance estimates has been reported to give a better idea about the efficiency of selection (Burton, 1953). In the present study, high GCV and PCV coupled with a high heritability and high genetic advance as per cent of meanwas observed for the number of spikelets per panicle and number of filled grains per panicle indicating the pre-ponderance of an additive gene action and therefore the scope for improvement of the trait through selection.

Character associations for yield and yield component traits were studied in the present investigation and the results are presented in Table 3. A perusal of these results revealed a positive and significant association of grain yield per plant with number of tillers per plant (r = 0.56), number of productive tillers per plant (r = 0.69), panicle length (r = 0.58), total number of spikelet’s per panicle (r = 0.78), number of filled grains per panicle (r = 0.84), spikelet fertility (r = 0.38) and length breadth ratio (r = 0.25). Similar results were reported by Niharika *et al.* (2022). In contrast, a non-significant negative association of grain yield per

Table 3: Phenotypic correlation among growth, yield and yield related characters of MAGIC lines of rice

Traits	DFF	DM	PH	NT	NPT	PL	NSP	NFG	SF	L/B	TW	GY/P
DFF	**1**	0.97**	0.39	0.12	0.11	-0.13	0.09	0.01	-0.31	-0.04	-0.26	-0.09
DM		**1**	0.35	0.10	0.08	-0.17	0.06	-0.01	-0.28	-0.06	-0.24	-0.12
PH			**1**	-0.08	-0.03	-0.10	-0.05	-0.08	-0.08	-0.09	-0.11	-0.16
NT				**1**	0.88**	0.28	0.39	0.42**	0.22	0.15	0.05	0.56**
NPT					**1**	0.36	0.51**	0.55**	0.25	0.22	0.02	0.69**
PL						**1**	0.55**	0.58**	0.21	0.21	0.24	0.58**
SP							**1**	0.97**	0.04	0.32	0.01	0.78**
NFG								**1**	0.27	0.36	0.09	0.84**
PF									**1**	0.22	0.30	0.38*
L/B										**1**	-0.13	0.25*
TW											**1**	0.18
GY/P												**1**

DFF = Days to 50 per cent flowering

DM = Days to maturity

PH = Plant height (cm)

NT = Number of tillers plant^{-1}

NPT = Number of productive tillers plant^{-1}

PL = Panicle length (cm)

NSP = Number of spikelets panicle^{-1}

NFG = Number of filled grains panicle^{-1}

SF = Spikelet fertility (%)

L/B = Length/Breadth ratio

TW = Test weight (g)

GY = Grain yield plant $^{-1}$ (g)

plant was found with days to 50 per cent flowering (r = -0.09), days to maturity (r = -0.12) and plant height (r = -0.15). Studies on inter-character associations for the yield component traits revealed significant and positive association of days to 50 % flowering with days to maturity; number tillers per plant with number of productive tillers per plant and number of filled grains per panicle; number of productive tillers per plant with the number of spikelets per panicle and number of filled grains per panicle; panicle length with the number of spikelets per panicle and number of filled grains per panicle in the present investigation, indicating a scope for simultaneous improvement of these traits through selection. Similar results were observed by Mahamadali*et al.* (2020), Buelah *et al.* (2022) Edukondalu *et al.* (2017) and Manivelan*et al.* (2022).

Path Coefficient Analysis serves as an effective method for discerning both the direct and indirect factors contributing to associations. It critically assesses the specific forces influencing a given correlation and gauges the relative significance of each causal factor. Consequently, this investigation delved into the study of direct and indirect effects of traits on the grain yield per plant, and the ensuing results are outlined in Table 4. An examination of these findings disclosed a minimal residual effect (0.4171), signifying that the variables investigated in this experiment elucidated approximately 58.29% of the variability in grain yield per plant. Consequently, it suggests that factors beyond those examined in this study also play a role in influencing grain yield per plant.

A detailed analysis of the direct and indirect effects also revealed a high (>0.3) positive direct effect for the number of productive tillers per plant (0.362) and number of filled grains per panicle (0.385), in addition to significant and positive association with grain yield per plant. High direct effects of the traits therefore appear to be the main factor for their association with grain yield per plant. Hence, the traits should be considered as an important selection criteria in all rice improvement programmes and direct selection for the traits is recommended for yield improvement. The results are in conformity with the findings of Edukondalu *et al.* (2017). Further, days to 50% flowering, number of spikelets per panicle and spikelet fertility had recorded low to moderate positive direct effects on grain yield per plant. These findings are in agreement with Niharika *et al.* (2022) for days to 50% flowering and spikelet fertility. However, association of days to 50% flowering, number of spikelets per panicle and spikelet fertility was noticed to be positive with grain yield per plant indicating indirect effects to be the cause of correlation and hence, the need for

Table 4: Path coefficient analysis of growth, yield and yield related characters in MAGIC lines of rice

Traits	DFF	DM	PH	NT	NPT	PL	SP	NFG	SF	L/B	TW	R values
DFF	**0.171**	-0.224	-0.029	-0.006	0.038	-0.009	0.020	0.003	-0.049	0.004	-0.013	**-0.094**
DM	0.165	**-0.232**	-0.026	-0.006	0.028	-0.012	0.014	-0.004	-0.044	0.005	-0.012	**-0.122**
PH	0.066	-0.080	**-0.075**	0.004	-0.011	-0.007	-0.012	-0.029	-0.013	0.008	-0.005	**-0.155**
NT	0.020	-0.024	0.006	**-0.054**	0.320	0.020	0.085	0.160	0.034	-0.013	0.002	**0.556**
NPT	0.018	-0.018	0.002	-0.048	**0.362**	0.026	0.112	0.210	0.039	-0.018	0.001	**0.686**
PL	-0.022	0.040	0.008	-0.015	0.132	**0.071**	0.120	0.222	0.034	-0.017	0.012	**0.582**
NSP	0.015	-0.015	0.004	-0.021	0.184	0.039	**0.220**	0.373	0.006	-0.027	0.001	**0.779**
NFG	0.001	0.002	0.006	-0.022	0.197	0.041	0.213	**0.385**	0.044	-0.030	0.004	**0.841**
PF	-0.053	0.065	0.006	-0.012	0.089	0.015	0.008	0.106	**0.159**	-0.018	0.015	**0.379**
L/B	-0.007	0.015	0.007	-0.008	0.078	0.015	0.071	0.137	0.034	**-0.083**	-0.006	**0.252**
TW	-0.045	0.055	0.008	-0.003	0.006	0.017	0.002	0.033	0.048	0.011	**0.048**	**0.181**

DFF = Days to 50 per cent flowering

DM = Days to maturity

PH = Plant height (cm)

NT = Number of tillers plant^{-1}

NPT = Number of productive tillers plant^{-1}

PL = Panicle length (cm)

NSP = Number of spikelets panicle^{-1}

NFG = Number of filled grains panicle^{-1}

SF = Spikelet fertility (%)

L/B = Length/Breadth ratio

TW = Test weight (g)

GY = Grain yield plant^{-1} (g)

consideration of indirect causal factors during selections for yield improvement through these traits.

Conclusion

Based on the results obtained in this study, it is suggested that the selection process prioritize traits such as days to 50 per cent flowering, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, panicle length, spikelet fertility, and test weight. These traits exhibited a direct positive influence on grain yield, with a special emphasis on the number of filled grains per panicle, which appeared to be the most influential. The high positive direct effect of the number of filled grains per panicle, as well as the indirect effects of the number of productive tillers per plant, number of spikelets per panicle, panicle length, spikelet fertility, and test weight through the number of filled grains per panicle, emerged as vital contributing factors to grain yield per plant and can be effectively utilized in the selection process.

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