# 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 Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), heritability and Genetic Advance as Percent of Mean (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 length/breadth 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 stands as the principal source of sustenance and protein, wielding a substantial influence on both nutritional and economic fronts. For numerous Asian nations, it serves as a pivotal pillar for dietary requirements and food security. Notably, China and India, the world's most populous nations, emerge as the primary contributors to rice production and consumption (FAOSTAT 2018). On a global scale, rice cultivation spans approximately 167.10 million hectares, yielding a total production of around 782.00 million tonnes and boasting a productivity rate of 4.67 tonnes per hectare (Anonymous., 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" (Anonymous.,

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" (Anonymous., 2019). Evaluating the variability of grain yield and its attributes is crucial for successful yield enhancement through breeding. Additionally, understanding the interplay between grain yield and its component characters, as well as recognizing correlations among these traits, is essential. This knowledge, coupled with the identification of both direct and indirect effects of these traits on yield, is instrumental in facilitating effective yield improvement. In the current study, we conducted an investigation to shed light on variability, heritability, genetic advance, character associations, and path coefficients in promising rice genotypes within this context.

## Material and Methods

The experimental materials utilized in the current study consisted 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 $20 \times 15$ 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 treatment days 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), length/breadth 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.

The results showed that the trait with the widest range of variability was the number of filled grains per panicle (ranging from 106.10 to 443.72), while the trait with the smallest range was the length/breadth ratio (ranging from 2.75 to 5.09). "In this study, higher Phenotypic Coefficient of Variation (PCV) values, in comparison to Genotypic Coefficient of Variation (GCV), were observed for all studied traits, indicating the significant influence of environmental factors". Tiwari et al. (2019). "Notably, traits such as the number of spikelets per panicle, number of filled grains per panicle and grain yield per plant exhibited high levels of both GCV and PCV (>20%)", Niharika *et al.* (2022). Furthermore, moderate estimates (10-20%) of PCV and GCV were noted for traits such as the number of tillers per plant, number of productive tillers per 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 per plant and Williams *et al.* (2021) for spikelet fertility and length/breadth ratio. Conversely, the current study revealed low (<10%) estimates of genotypic and phenotypic coefficients of variation for days to 50% flowering, days to maturity and test weight. These findings suggest limited variability in these traits within the experimental material, indicating minimal potential for improvement in these specific characteristics. Similar results were previously documented by Kulsum et al. (2022).

**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 |
| **NT** | = | Number of tillers plant$^{-1}$ | **NPT** | = | Number of productive tillers plant$^{-1}$ |

**PH** = Plant height

**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 | | h² 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 |

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

"Traits such as the 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 exhibited high heritability along with a substantial genetic advance as a percentage of the mean. This suggests that the observed heritability is primarily attributed to additive gene effects, indicating the potential effectiveness of selection for these traits. Conversely, traits like days to 50% flowering, plant height, panicle length, spikelet fertility, and test weight demonstrated high heritability accompanied by moderate genetic advance as a percentage of the mean, pointing towards a combination of additive and non-additive gene effects.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).Notably, in the current investigation, traits such as the number of spikelets per panicle and number of filled grains per panicle displayed high genetic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) alongside high heritability and genetic advance, indicating a predominant additive gene action. This suggests a promising opportunity for trait improvement through selective breeding.

Associations among yield and yield component traits and the findings are detailed in Table 3. A thorough examination of these results unveiled a notable positive correlation between grain yield per plant and the number of tillers per plant(r = 0.56), number of

**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 | **NPT** | = | Number of productive tillers plant[-1] | |
| **DM** | = | Days to maturity | **PL** | = | Panicle length (cm) | |
| **PH** | = | Plant height (cm) | **NSP** | = | Number of spikelets panicle[-1] | |
| **NT** | = | Number of tillers plant[-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) |

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 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.

An in-depth examination of both direct and indirect effects revealed a notably high (>0.3) positive direct impact for the number of productive tillers per plant (0.362) and the number of filled grains per panicle (0.385). These traits also exhibited a significant and positive association with grain yield per plant. The substantial direct effects of these traits appear to be the primary contributing factor to their correlation with grain yield per plant. Consequently, these traits should be regarded as crucial selection criteria in all rice improvement programs, and direct selection for these traits is recommended for enhancing yield. These findings align with the results reported by Edukondalu *et al.* (2017).Moreover, days to 50% flowering, number of spikelets per panicle, and spikelet fertility demonstrated low to moderate positive direct effects on grain yield per plant. These outcomes are

**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 | **NPT** | = | Number of productive tillers plant[-1] | |
| **DM** | = | Days to maturity | **PL** | = | Panicle length (cm) | |
| **PH** | = | Plant height (cm) | **NSP** | = | Number of spikelets panicle[-1] | |
| **NT** | = | Number of tillers plant[-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)

consistent with the findings of Niharika et al. (2022) for days to 50% flowering and spikelet fertility.However, the positive association of days to 50% flowering, number of spikelets per panicle, and spikelet fertility with grain yield per plant indicates that indirect effects may be influencing the correlation. Therefore, it is crucial to consider 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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