Correlation Studies on Yield and Yield Contributing Traits in Rice (*Oryza sativa* L.)

Ally Mwichande Russinga1, 3*, A. Srividhya2, V.L.N. Reddy1 and P. Latha2

1Department of Genetics and Plant Breeding, S.V. Agricultural College, ANGRAU, India
2Regional Agricultural Research Station, Tirupati, ANGRAU, India
3Tanzania Agricultural Research Institute (TARI), Ifakara Center, Ifakara, Tanzania

*Corresponding Author E-mail: arussinga@yahoo.com

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ABSTRACT

The rice genotype panel comprised of 30 varieties which includes indica group, landraces, improved varieties, interspecific derivatives (*Oryza glaberrima* × *Oryza sativa*), aromatic and japonica rice etc. were evaluated for yield and yield contributing traits, during kharif 2019. ANOVA test showed highly significant variation for the twelve traits under study. The correlation analysis showed a total of 28 significant associations between 12 yield and yield-related traits measured under study. Very high significant positive correlation in the present study was detected between number of filled grains per panicle (FG) and total grain number per panicle (GN) \( r^2 = 0.948^{**} \) followed by grain length (GL) and grain length to width ratio (GLW) \( r^2 = 0.799^{**} \) while, very high significant negative correlation was detected between grain width (GW) and grain length to width ratio (GLW) \( r^2 = -0.847^{**} \) followed by number of chaffy grains per panicle (CG) and spikelet fertility (SF) \( r^2 = -0.832^{**} \). This indicates the effect of selections for strongly associated traits are dependent and worked in directional manner either in positive direction or in negative direction. Therefore, a breeder should be well understood the effect of a trait on prior handling with a trait improvement breeding programme.

**Keywords:** Rice (*Oryza sativa* L.), Yield components, Correlation coefficients, Quantitative traits

INTRODUCTION

Rice (*Oryza sativa* L.) is a major staple food in the world, especially in the developing countries of Asia. In Africa, it is the most rapidly growing food source and, according to a conservative estimate, about 30 million tons more rice will be needed by 2035 (Kim et al., 2016). Rice occupies pivotal place in Indian Agriculture. In order to meet the domestic demand of the increasing population the present day production of 107.40 million tons (Thorat et al., 2019) of milled rice has to be increased to 125 million tons by the year 2030. Within existing agricultural lands, the genetic improvement of yield potential in rice could be the ideal way to increase yield.

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The improvement of yield of food crops in general and rice in particular, is a permanent concern due to the consistent demand projection in lieu of rapid increase of global human population and also due to the decrease of arable land and water resources. Grain yield in rice can be improved by targeting diverse yield contributing traits viz., plant height, number of tillers, number of productive tillers per plant, number of grains per panicle, and grain weight. Among these, the most reliable traits are number of panicles, grains per panicle and grain weight (Anh et al., 2015). Grain Weight is measured as the 1000-grain weight (TGW). Grain size of rice is determined by grain length (GL), grain width (GW), grain thickness (GT) and grain length to width ratio (GL/GW). GL/GW is the major determinant of grain appearance quality and grain weight of rice (Xing and Zhang, 2010).

Economic product of rice is the grain yield, which exhibits complex genetics as it is influenced by various yield contributing characters and the environment. In general, increased number of fertile panicles is the single most important yield component associated with rice yield, number of spikelets/panicle; percent filled grains/panicle are also of secondary and tertiary importance (Ratna et al., 2015). Another trait directly related to panicle is panicle density which chiefly affects the yield potential. These yield contributing components are interrelated with each other showing a complex chain of relationship and also highly influenced by the environmental conditions (Prasad et al., 2001).

Breeding strategy in rice mainly depends upon the degree of associated characters as well as its magnitude and nature of variation (Anis et al., 2016 and Prasad et al., 2001). Therefore, information about the yield contributing traits is of immense importance to the plant breeders for the development of improved varieties/lines of rice with increased yield potential.

Furthermore, the grain yield is a complex character dependent on many component characters and it responds poorly to the direct selection (Thorat et al., 2019). For the improvement of grain yield, the knowledge on the association between grain yield and its component characters will be helpful. The present study was, therefore, undertaken to understand the association among grain yield and its component characters in rice.

**MATERIALS AND METHODS**

In the present study, a core set of 30 rice genotypes were chosen based on their yield component trait diversity under different subgroups (japonica, indica and aromatic) from around 250 genotypes available at the Department of Genetics and Plant Breeding, S.V. Agricultural College, Tirupati. The panel comprises of landraces, improved varieties, interspecific derivatives (Oryza glaberrima × Oryza sativa), aromatic and japonica rice etc were used for correlation analysis of yield contributing traits (Supplementary Table 1).

The experiment was carried out at Wetland Farm, S.V. Agricultural College, Tirupati, ANGRAU during Kharif, 2019. The experiment was laid out in three replications in Randomized Block Design (RBD) with spacing of 20 cm × 15 cm and 2 rows of 4 m length for each genotype. The agronomic management was done as per the standard recommendations. The phenotypic data was recorded for the twelve yield contributing traits from 5 plants per replication per genotype. The productive tillers(PT), plant height(PH), panicle length(PL), filled grains(FG), chaffy grains(CG), number of total grains(GN), percentage of spikelet fertility(SF), grain length(GL), grain width(GW), ratio of grain length-to-grain width(GR), 1000-grain weight(TGW) and grain yield per plant(GY), were evaluated.

For each trait, means of the replicates were used in the data analyses. Statistical analysis: The data with respect to yield and yield-related traits were subjected to analysis of variance to determine the significant differences among genotypes for all the characters evaluated by the OPSTAT program. Pearson’s Correlation analysis between character pairs was computed at probability levels of $P<0.05$ and $P<0.01$ in Microsoft Excel using trait average for the trait pairs among genotypes. Significance of
correlation coefficients (r) at p = 0.05 or 0.01 is indicated by * or **, respectively.

RESULTS AND DISCUSSION
Mean performance of individual genotype for each trait and its analysis of variance was given in Table 1. Grain yield per plant the genotype’s mean observed was of 18.66 g with a range of 7.90 g to 32.71 g. Similar results reported by Anh et al. (2018) and Anh et al. (2015). The analysis of variance of all traits of 30 rice genotypes showed highly significant difference among the genotypes (Table 2). This is in agreement with work of Shahriar et al., 2014.

Correlation between different character pairs occur because of either linkage or pleiotropy. Correlation studies provide information on the nature and extent of association between any two characters. From this it would be possible to bring about genetic up-gradation in one trait by the selection of the other trait of a pair. Pearson’s Correlation analysis between character pairs was conducted for all traits using diverse genotypes (Table 3).

The correlation analysis showed 28 significant associations between all traits measured under study. Significant positive correlations were observed between trait pairs, panicle length (PL) and plant height (PH) \((r^2=0.589**)\), panicle length and grain length (GL) \((r^2=0.643**)\), panicle length and grain length to width ratio (GR) \((r^2=0.527**)\). Ratna et al. (2015) and Anis et al. (2016) also reported that plant height was significantly and positively correlated with panicle length.

Plant height (PH) had significant positive associations with number of filled grains per panicle (FG) \((r^2=0.546**)\), total grain number per panicle (GN) \((r^2=0.391*)\), spikelet fertility (SF) \((r^2=0.519**)\) and with grain yield per plant (YP) \((r^2=0.485**)\).

Number of filled grains per panicle (FG) has significant association with total grains number per panicle (GN) \((r^2=0.948**)\) and grain yield per plant (GY) \((r^2=0.948**)\), whereas number of chaffy grains per panicle (CG) had positive association with total grains number per panicle (GN) \((r^2=0.578**)\), grain length to width ratio (GR) \((r^2=0.378*)\). Eidikohnaki et al. (2013), Haider et al. (2012), Kiani and Nematzadeh (2012), Seyoum et al. (2012), Akinwale et al. (2011), Akhtar et al. (2011) and Shanthi et al. (2011) also reported the positive association of grain yield with filled grains/panicle.

Further, positively significant associations were found between the trait pairs, total grains number per panicle (GN) and grain yield per plant (YP) \((r^2=0.578**)\), spikelet fertility (SF) and grain width (GW) \((r^2=0.455**)\), spikelet fertility and grain yield per plant \((r^2=0.316*)\), grain length (GL) and grain length to width ratio (GR) \((r^2=0.799**)\), grain width and 1000-grain weight (TGW) \((r^2=0.670**)\) (Table 4.3). Similar positive correlation observed between grains number (GN) and grain yield (YP) reported by Thorat et al. (2019) and Swamy et al. (2014).

Significant negative correlations were found between trait pairs, number of productive tillers per plant (PT) and FG \((r^2=-0.331*)\), number of productive tillers per plant and total grains number per panicle (GN) \((r^2=-0.356*)\). Number of filled grains per panicle with 1000-grain weight (TGW) \((r^2=-0.325*)\), number of chaffy grains per panicle (CG) with spikelet fertility (SF) \((r^2=-0.832**)\), with grain width \((r^2=-0.481**)\), and with 1000-grain weight \((r^2=-0.461**)\) had significant negative correlations.

As assumed, negative associations also found between the total grains number per panicle (GN) and 1000-grain weight (TGW) \((r^2=-0.430**)\), spikelet fertility (SF) and grain length (GL) \((r^2=-0.382*), spikelet fertility (SF) and grain length to width ratio (GR) \((r^2=-0.407*)\), grain length (GL) and grain width (GW) \((r^2=-0.423**), grain width (GW) and grain length to width ratio (GR) \((r^2=-0.847**), and lastly grain length to width ratio (GR) and 1000-grain weight (TGW) \((r^2=-0.424**)\). Very high significant positive correlation in the present study was detected
between number of filled grains per panicle (FN) and total grains number per panicle (GN) \((r^2=0.948**)\) followed by grain length (GL) and grain length to width ratio (GR) \((r^2=0.799**)\) while, very high significant negative correlation was detected between grain width (GW) and grain length to width ratio (GR) \((r^2 = -0.847**)\) followed by number of chaffy grains per panicle (CG) and spikelet fertility (SF) \((r^2 = -0.832**)\) (Table 3).

Li et al. (2019) reported that plant height, filled grain number/panicle, 1000-grain weight, plant height, panicle length, grains per panicle, seed setting rate and low seed length/width ratio have positive association on high grain yield.

Thorat et al. (2019) evaluated the nature and extent of correlations among yield and yield attributing characters in rice, the results revealed that grain yield per plant to be positively and significantly associated with productive tillers per plant \((r^2 = 0.849**)\), panicle length \((r^2 = 0.978**)\), total spikelets per panicle \((r^2 = 0.806**)\) and fertile spikelets per panicle \((r^2 = 0.979**)\).

Similar analyses of two rice populations by Swamy et al. (2014), were estimated the correlations between the trait pairs. Eighteen correlations in population 1 and 22 correlations in population 2 were found to be significant, and these were observed between plant height and number of spikelets per plant \((r^2 = -0.173**)\) in population 2, plant height and number of filled grains \((r^2 = 0.394**)\) in population 1, plant height and yield per plant \((r^2 = 0.405**)\) in population 1, number of spikelets per plant \((r^2 = 0.998**\) and \(r^2 = 0.960**)\) in population 1 and 2, respectively, number of spikelets per plant and yield per plant \((r^2 = 0.869**\) and \(r^2 = 0.554**)\) in population land 2, respectively and number of filled grains and yield per plant \((r^2 = 0.855**\) and \(r^2 = 0.551**)\) in population land 2, respectively.

The present study, as many of earlier reports, proved that almost all the traits are interdependent and associated with multitude of traits. Hence, selections for a trait either affect gain or loss of the other. Being rice is marketed mostly based on region preference/consumer preference, it is quite obvious to keep always in mind of a breeder that the effect of selected trait on the grain quality traits.

**Table 1: Per se Performance of the 30 rice genotypes for grain yield and its related traits and their ANOVA (P-value)**

| S.No. | Genotype       | PT(%) | PL(cm) | PH(cm) | FG  | CG  | GN   | SF(%) | GL(mm) | GW(mm) | GR   | TGW(g) | YP(g) |
|-------|----------------|-------|--------|--------|-----|-----|------|-------|--------|--------|------|--------|-------|
| 1     | AbhayA         | 10.60 | 25.27  | 120.80 | 123.43 | 16.38 | 139.82 | 89.00  | 8.71   | 2.41   | 3.61 | 22.58  | 22.18 |
| 2     | Aditya         | 10.60 | 21.93  | 81.20  | 58.58  | 11.60 | 70.18  | 84.00  | 8.81   | 2.77   | 3.18 | 24.69  | 7.90  |
| 3     | AMO            | 11.58 | 24.07  | 101.60 | 158.73 | 34.00 | 192.73 | 83.00  | 8.16   | 2.55   | 3.21 | 21.40  | 25.49 |
| 4     | Anjali         | 6.80  | 26.33  | 113.60 | 78.53  | 12.67 | 91.20  | 86.00  | 8.03   | 3.02   | 2.66 | 24.34  | 8.48  |
| 5     | Azucena        | 15.00 | 26.13  | 98.42  | 125.58 | 23.92 | 149.50 | 84.00  | 10.41  | 2.91   | 3.57 | 27.71  | 29.47 |
| 6     | Badshahbog     | 10.33 | 28.73  | 118.87 | 147.27 | 29.87 | 177.13 | 83.00  | 10.03  | 2.41   | 4.16 | 21.74  | 21.42 |
| 7     | Burma Black    | 7.02  | 28.33  | 175.33 | 190.47 | 18.33 | 208.80 | 91.00  | 9.57   | 3.49   | 2.74 | 28.71  | 28.14 |
| 8     | Daddiga        | 7.20  | 23.60  | 128.73 | 180.17 | 21.67 | 201.83 | 89.00  | 7.36   | 3.31   | 2.22 | 24.65  | 19.03 |
| 9     | Disang         | 11.47 | 23.93  | 95.80  | 86.85  | 15.88 | 102.73 | 85.00  | 8.09   | 2.58   | 3.14 | 24.43  | 10.22 |
| 10    | Haryana        | 8.93  | 22.07  | 87.87  | 137.60 | 29.87 | 167.47 | 82.00  | 8.48   | 2.17   | 3.91 | 15.00  | 16.64 |
| 11    | HIM799         | 15.00 | 25.87  | 106.60 | 103.00 | 41.00 | 144.00 | 72.00  | 9.00   | 2.55   | 3.54 | 30.03  | 19.68 |
| 12    | Kesari         | 15.53 | 21.13  | 97.60  | 148.80 | 16.67 | 165.47 | 90.14  | 8.14   | 2.53   | 3.22 | 18.54  | 29.93 |
| 13    | Krishna        | 8.13  | 24.20  | 101.40 | 175.27 | 51.07 | 226.33 | 78.00  | 8.57   | 2.16   | 3.98 | 15.94  | 20.08 |
| 14    | Lait           | 7.67  | 23.13  | 95.13  | 106.87 | 25.87 | 132.73 | 80.00  | 9.14   | 2.59   | 3.53 | 22.27  | 11.03 |
| 15    | Mrunalini      | 10.87 | 28.73  | 130.47 | 189.49 | 49.89 | 259.37 | 79.00  | 9.44   | 2.39   | 3.95 | 22.57  | 32.71 |
| 16    | NL1            | 10.67 | 22.87  | 82.47  | 78.87  | 34.87 | 113.73 | 69.00  | 9.80   | 2.45   | 3.99 | 22.78  | 13.59 |
| 17    | NL16           | 9.87  | 25.67  | 109.20 | 101.55 | 28.80 | 130.35 | 78.00  | 9.75   | 2.52   | 3.87 | 26.21  | 19.91 |
| 18    | NL3            | 10.53 | 26.13  | 92.67  | 89.25  | 29.50 | 118.75 | 76.00  | 10.36  | 2.68   | 3.87 | 25.35  | 10.74 |
| 19    | NL9 Numali     | 11.00 | 26.07  | 82.33  | 75.00  | 27.00 | 102.20 | 74.00  | 10.11  | 2.52   | 4.01 | 26.15  | 14.27 |
| 20    | Numali         | 7.00  | 24.33  | 129.60 | 221.63 | 30.58 | 252.22 | 88.00  | 8.14   | 2.81   | 2.90 | 21.23  | 22.39 |

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Table 2: Analysis of Variance (ANOVA) for yield and yield contributing traits

| S.No | Trait | Replication Df=2 | Treatment Df=29 | Error Df=58 | F ratio | P value |
|------|-------|------------------|-----------------|-------------|---------|---------|
| 1    | PT    | 39.39632         | 29.29591        | 8.00406     | 3.6601  | 0.00**  |
| 2    | PL(cm) | 3.612            | 18.81945        | 2.14305     | 8.7817  | 0.00**  |
| 3    | PH(cm) | 0.728007         | 1392.645        | 46.8082     | 29.7522 | 0.00**  |
| 4    | FG    | 201.3338         | 5260.321        | 395.7462    | 13.2922 | 0.00**  |
| 5    | CG    | 73.17824         | 752.1923        | 145.615     | 5.1656  | 0.00**  |
| 6    | GN    | 56.29593         | 7037.815        | 606.5634    | 11.6028 | 0.00**  |
| 7    | SF(%) | 0.7054           | 1.8652          | 0.4094      | 4.5565  | 0.00**  |
| 8    | GL(mm) | 0.036743         | 2.791779        | 0.104347    | 26.7548 | 0.00**  |
| 9    | GW(mm) | 0.000724         | 0.39802         | 0.007573    | 52.5597 | 0.00**  |
| 10   | GR    | 0.00772          | 1.940174        | 0.083727    | 23.1727 | 0.00**  |
| 11   | TGW(g) | 20.0928          | 42.55748        | 10.28684    | 4.1371  | 0.00**  |
| 12   | YP(g) | 25.9534          | 130.6254        | 27.3448     | 4.777   | 0.00**  |

PT, Number of productive per plant; PL, Panicle length; PH, Plant height; FG, Number of filled grains per panicle; CG, Number of chalky grains per panicle; GN, Total grains number per panicle; GL, Grain length (mm); GW, Grain width (mm); GL/GW, Grain length to width ratio; TGW,1000-grain weight; YP, Yield per plant; CD, Critical difference; SD, Standard Deviation; SE, Standard error; Coefficient of variation.

Trait means, range, critical difference, standard deviation, standard error, coefficient of variation and ANOVA (P-Value), were done with ANOVA and Microsoft Excel Programme.

ANNOVA Table (ANOVA):

| Trait | Mean | Range | C.D. | S.D. | S.E. | C.V. |
|-------|------|-------|------|------|------|------|
| TGW   | 1000 | 100   | 20   | 20   | 20   | 20   |
| GL/GW | 5    | 5     | 5    | 5    | 5    | 5    |
| GL    | 5    | 5     | 5    | 5    | 5    | 5    |
| GW    | 5    | 5     | 5    | 5    | 5    | 5    |

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Table 3: Correlation coefficients for yield and its related traits observed between trait pairs

| Trait | PT | PL(cm) | PH(cm) | FG | CG | GN | SF(%) | GL(mm) | GW(mm) | GR | TGW(g) | YP(g) |
|-------|-----------------|---------|--------|-----|----|-----|-------|--------|--------|-----|--------|-------|
| PT    | 1.000           |         |        |     |    |     |       |        |        |     |        |       |
| PL(cm) | -0.028          | 1.000   |        |     |    |     |       |        |        |     |        |       |
| PH(cm) | -0.129          | 0.589** | 1.000  |     |    |     |       |        |        |     |        |       |
| FG    | -0.331*         | 0.121   | 0.546** | 1.000|     |     |       |        |        |     |        |       |
| CG    | -0.224          | 0.076   | -0.223 | 0.288| 1.000|     |       |        |        |     |        |       |
| GN    | -0.356*         | 0.128   | 0.391* | 0.948**| 0.578**| 1.000|       |        |        |     |        |       |
| SF(%) | 0.103           | -0.044  | 0.519** | 0.236| -0.832**| -0.075| 1.000 |       |        |     |        |       |
| GL(mm) | 0.099          | 0.643** | 0.039  | -0.164| 0.216  | -0.068| -0.382*| 1.000 |       |     |        |       |
| GW(mm) | -0.011         | -0.183  | 0.298  | -0.327| -0.481**| -0.182| 0.455**| -0.423**| 1.000|     |        |       |
| GL/GW | 0.047           | 0.527** | -0.031 | 0.001 | 0.378* | 0.126 | -0.407**| 0.799**| -0.847**| 1.000|     |        |       |
| TGW(g) | 0.170           | 0.197   | 0.192  | 0.325* | -0.461**| 0.430**| 0.213  | 0.060  | 0.670**| -0.424**| 1.000|     |        |       |
| YP(g)  | 0.204           | 0.273   | 0.485**| 0.671**| 0.020  | 0.578**| 0.316* | 0.086  | 0.058  | 0.031  | 0.080 | 1.000|     |        |       |

PT, Number of productive per plant; PL, Panicle length; PH, Plant height; FG, Number of filled grains per panicle; CG, Number of chaffy grains per panicle; GN, Total grains number per panicle, GL, Grain length; GW, Grain width; GL/GW, Grain length to width ratio; TGW,1000-grain weight and YP, Yield per plant.

Supplementary Table 1: List of rice genotypes used in the study

| S.No. | Genotype             | Subspecies/Group |
|-------|----------------------|------------------|
| 1     | Abhaya               | Indica           |
| 2     | Aditya               | Indica           |
| 3     | AMO                  | Indica           |
| 4     | Anjali               | Indica           |
| 5     | Azucena              | Aromatic, Japonica|
| 6     | Badshahbog           | Indica           |
| 7     | Burma Black          | Indica/Landrace  |
| 8     | Daddiga              | Indica           |
| 9     | Disang               | Indica           |
| 10    | Haryana Basmati      | Aromatic, Indica |
| 11    | HIM 799              | Indica           |
| 12    | Kesari               | Indica           |
| 13    | Krishna              | Indica           |
| 14    | Luit                 | Indica           |
| 15    | Mrunalini            | Indica           |
| 16    | NL 1 (Nerica line 1) | Og/os            |
| 17    | NL 16 (Nerica line 16) | Og/os           |
| 18    | NL 3 (Nerica line 3) | Og/os            |
| 19    | NL 9 (Nerica line 9) | Og/os            |
| 20    | Numali               | Indica           |
| 21    | Pant Sugandh Dhan 15 | Aromatic, Indica |
| 22    | Pathariya            | Indica           |
| 23    | RPBio 248            | Indica/Indica wild |
| 24    | SannaJajula          | Indica           |
| 25    | Savithri             | Indica           |
| 26    | Sharbati             | Indica           |
| 27    | Solumpiket           | Indica           |
| 28    | Taramati             | Aromatic, Indica |
| 29    | TKM 6                | Indica           |
| 30    | WAB450-24-32-P18-HB  | Og/os            |

Og/Os: Oryza glaberrima/Oryza sativa

CONCLUSION

From results on character associations for grain yield and yield components, it can be concluded that selection of genotypes based on correlation analysis enhances simultaneous improvement of several yield and grain quality.

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contributing traits in rice. This can be attributed further to the pleiotropic effect of a gene and/or involvement of common regulator factors (positive/negative gene regulation) at associated yield contributing traits, which might result in either positive or negative relationships. Thus, it is worthy to notice effect of selected/desired yield contributing trait(s) on grain quality, as ultimately the marketing of developed rice is highly influenced by the grain quality alone in rice.

**Conflicts of Interest**
The authors declare no conflicts of interest

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