Definition of selection criterion using correlation and path coefficient analysis in rice (*Oryza sativa* L.) genotypes

Maysoun M. Saleh¹, Khaled F. M. Salem²,³* and Abdelmoaty B. Elabd⁴

Abstract

**Background and objective:** Investigation on genetic variability and correlation study between yield and its components of genotypes on rice may increase the opportunity to exploit its potential which will help meet the demand of high grain yield and nutrition supply. The current study aimed to determine correlation and path coefficients between twenty-two Egyptian and exotic rice genotypes to establish selection criteria which might help to develop genotypes for high yielding.

**Materials and methods:** Twenty-two Egyptian and exotic rice genotypes were evaluated through seven agronomic traits. Agronomic data were collected during the two successive rice growing seasons, 2017 and 2018. The matrix of phenotypic correlations was estimated and analyzed into direct and indirect effects through path coefficient analysis.

**Results:** Results showed that grain yield per plant had a high positive and significant correlation ($p \leq 0.01$) with panicle number per plant, full grain number per panicle, and 1000 grain weight, 0.791**, 0.670**, and0.766**, respectively. As expected, there was a negative correlation ($p \leq 0.05$) between days to heading and panicle number per plant ($r = -0.496^*$) and with1000 grain weight ($r = -0.433^*$). Path coefficient analysis showed that despite high positive and significant correlation ($p \leq 0.01$) between grain yield per plant and many variables, a small number of these correlations was verified to have a relationship of cause and effect. Variables with positive and significant correlation and with a high direct effect on grain yield per plant were 1000 grain weight (0.5107 direct effects) followed by panicle number per plant (0.4003), and full grain number per panicle (0.3028).

**Conclusion:** The three traits (1000 grain weight, panicle number per plant, and full grain number per panicle) are the most important variables for use in grain yield per plant assessment programs as selection indices because they have positive and significant correlations and direct and/or indirect effect on the correlation value of the increased rice grain yield production. Hence, for increasing grain yield, the direct selection of genotypes based on positively correlated traits will be more fruitful while planning any rice breeding program to achieve higher grain yield in rice.

**Keywords:** Rice (*Oryza sativa* L.), Correlation, Grain yield, Path coefficient, Selection
Introduction

Rice (Oryza sativa L.) is an important staple food worldwide. About half of the world’s population depends on rice for their survival. Considering the growing population, the primary goal of plant breeders will always be towards improving grain yield in the strategic food crops. It has been estimated that the world will have to produce 60% more rice by 2030 compared with that of 1995. Therefore, increased rice production plays a very important role in food security and poverty alleviation. Rice is considered as an essential and stable food for about 66% of people worldwide, providing almost 20% of energy (Wogu et al., 2011). In Egypt, it has an area of 0.445 M ha in the production area of 4280 metric tons and productivity of 9.6 ton/ha. Examining the relationship between quantitative traits is an important task of assessing the feasibility of a joint selection of two or more traits instead of selecting the secondary traits as genetic gains for primary traits under consideration (Ezeaku and Muhammad, 2006). Path analysis is a statistical tool that has been used to organize and present causal relationships between prediction variables and response variables through a path chart based on experimental results (Samonte et al., 1998, Esmail, 2001). Yield and its component traits are complex traits associated with the number of traits of the component that are interrelated (Ikeda et al., 2013, Zhou et al., 2018). Often this is dependent on its relationship to the grain yield, which makes the relationship ineffective. Singh et al. (1985) mentioned that loading the path parameter helps in segmenting the correlation into direct and indirect effects. Therefore, path analysis is needed that dividing the correlation coefficient into its direct and indirect effect components has been extensively studied (Sürek and Beşer, 2003). Plant breeders used agricultural path analysis to help identify useful features as selection criteria for improving crop yields (Milligan et al., 1990). The objective of this study was to (i) discover association among different agronomic traits in Egyptian and exotic rice genotypes for developing new cultivars, (ii) assess the direct and indirect effects of some agronomic traits on grain yield of rice, (iii) define selection criteria for grain yield improvement, and (iv) save time and resources during selection processes.

Material and methods

Plant material

Twenty-two genotypes of rice (Oryza sativa L.) which originated from different countries were used in this study (Table 1). Seeds were provided by the International Rice Research Institute (IRRI), Los Banos, Philippines; USDA, ARS; National Small Grains Collection, USA; and Agriculture Research Center (ARC), Giza, Egypt.

| No | Genotype name | Origin | Seed sources | Subspecies group |
|----|---------------|--------|--------------|-----------------|
| 1  | IR 20         | Philippines | IRRI         | Indica          |
| 2  | IR 22         | Philippines | IRRI         | Indica          |
| 3  | IR 24         | Philippines | IRRI         | Indica          |
| 4  | IR 50         | Philippines | IRRI         | Indica          |
| 5  | IR 64         | Philippines | IRRI         | Indica          |
| 6  | IR 74         | Philippines | IRRI         | Indica          |
| 7  | Bala          | India    | IRRI         | Indica          |
| 8  | IET 1444      | India    | IRRI         | Indica          |
| 9  | Arabi         | Egypt    | USDA, USA    | Japonica        |
| 10 | Agarmy M1     | Egypt    | USDA, USA    | Japonica        |
| 11 | Nahda         | Egypt    | USDA, USA    | Japonica        |
| 12 | Yabani M1     | Egypt    | USDA, USA    | Japonica        |
| 13 | Yabani M7     | Egypt    | USDA, USA    | Japonica        |
| 14 | Yabani 15     | Egypt    | USDA, USA    | Japonica        |
| 15 | Yabani ilulu  | Egypt    | USDA, USA    | Japonica        |
| 16 | Giza 14       | Egypt    | USDA, USA    | Japonica        |
| 17 | Giza 171      | Egypt    | ARC, Egypt   | Japonica        |
| 18 | Giza 172      | Egypt    | ARC, Egypt   | Japonica        |
| 19 | Giza 177      | Egypt    | ARC, Egypt   | Japonica        |
| 20 | Giza 178      | Egypt    | ARC, Egypt   | Indica/ Japonica|
| 21 | Giza 181      | Egypt    | ARC, Egypt   | Indica          |
| 22 | Gz 1386-5-4   | Egypt    | ARC, Egypt   | Indica          |

Field experiments

This investigation was carried out at the experimental farm of the Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh Governorate, Egypt, during the two successive rice growing seasons, 2017 and 2018. The seeds of the twenty-two rice genotypes were grown in the nursery and transplanted 30 days after sowing in a row. The experiment was arranged in randomized complete block design (RCBD), with three replicates. Each replicate consisted of a single row, 5-m long, with 20 cm between rows and comprised 25 hills each of a single plant. Recommended cultural rice practices were applied as usual for the ordinary rice field in the area. At maturity, ten guarded plants were selected at random for subsequent measurements as follows (IRRI 1980), days to heading (DTH), plant height (cm) (PH), panicle length (cm) (PL), panicle number per plant (PNP), full-grain number per panicle (FGNP), 1000 grain weight (g) (TGW), and grain yield per plant (g) (GYP). The data were recorded on an individual plant basis for each genotype.

Statistical analysis

Simple phenotypic correlation coefficients were calculated using the SPSS version 15 (IBM Corporation,
2010) as $r_{p12} = \frac{COV_{p12}}{\sigma_{p1} \times \sigma_{p2}}$, where, $COV_{p12}$ is phenotypic covariance between the variables $X_1$ and $X_2$, the phenotypic standard deviation of the variable $X_1$ and is the phenotypic standard deviation of the variable $X_2$. Direct and indirect path coefficients were calculated using GenStat 12, J Nelder (2009), as described by Singh and Chudhary (1977) as $r_{yi} = P_{yi} + \sum_{i' = 1}^{k} r_{yi}P_{yi'}$ for $i \neq 1$.

where $r_{yi}$ is the correlation coefficient between the $i$th causal variable ($X_i$) and effect variable ($y$), $r_{yi'}$ is the correlation coefficient between the $i$th and $i'$th causal variables, $P_{yi}$ is the path coefficient (direct effect) of the $i$th causal variable ($X_i$), $\langle X_i \rangle$, $r_{yi}$, $P_{yi}$ is the indirect effect of the $i$th causal variable via the $i'$th causal variable. The strength of direct and indirect effect values was scaled according to Lenka and Mishra (1973) as follows: very strong (more than 1), strong (0.3–0.9), medium (0.2–0.29), weak (0.1–0.19), neglected (less than 0.1).

### Results

#### Correlation

The study of the association between grain yield and its component traits helps to reveal their importance in rice breeding programs. The results of the correlation analysis showed a significant and negative correlation between days to heading and panicle number per plant ($r = -0.496^{*}$) and with 1000 grain weight ($r = -0.433^{*}$) (Table 2) (Fig. 1). Correlation between panicle length and full-grain number per panicle was significant and positive ($r = 0.435^{*}$) (Table 2) (Fig. 1). Results revealed a highly significant and positive correlation between panicle number per plant and each of the full grain number per panicle ($r = 0.606^{**}$) and 1000 grain weight ($r = 0.543^{**}$) (Table 2) (Fig. 1). Grain yield per plant had a positive highly significant correlation with each of the

| Traits                  | DTH | PH  | PL   | PNP | FGNP | TGW | GYP |
|-------------------------|-----|-----|------|-----|------|-----|-----|
| DTH                     | 1   |     |      |     |      |     |     |
| PH                      | -0.008 | 1   |      |     |      |     |     |
| PL                      | -0.097 | -0.244 | 1   |     |      |     |     |
| PNP                     | -0.496* | -0.239 | 0.292 | 1   |      |     |     |
| FGNP                    | -0.327 | -0.115 | 0.435* | 0.606** | 1   |     |     |
| TGW                     | -0.433* | 0.095 | 0.174 | 0.543** | 0.296 | 1   |     |
| GYP                     | -0.366 | -0.051 | 0.382 | 0.791** | 0.670** | 0.766** | 1   |

DTH days to heading, PH plant height, PL panicle length, PNP panicle number per plant, FGNP full-grain number per panicle, TGW 1000 grain weight, GYP grain yield per plant.

*Significance at $p \leq 0.05$ level of probability; ** significance at $p \leq 0.01$ level of probability

For the development of new rice cultivars with the greater genetic potential to increase grain yield is the ultimate objective by implementing continuous selection, improving, maintaining, and enhancing other related grain yield components. Our results suggest that full-grain number and panicle number per plant and with 1000 grain weight are important yield-related traits and could be considered as selection criteria to increase rice grain yield.

#### Path coefficient analysis

Results of path analysis showed that the direct effect of studied traits on grain yield was always positive, strong for each of the 1000 grain weight ($0.5107$), panicle number per plant ($0.4003$), and full grain number per panicle ($0.3028$) while weak for days to heading ($0.1597$) and neglected for each of plant height ($0.0501$) and panicle length ($0.0726$) (Table 3).

The indirect effect of days to heading on grain yield was negative via other studied traits and neglected via each of plant height ($-0.0004$), panicle length ($-0.0070$), full grains number per panicle ($-0.0990$), while weak via panicle number per plant ($-0.0990$) and medium via 1000 grain weight ($-0.2209$) (Table 3).

The indirect effect of plant height on grain yield via studied traits was all neglected, negative via each of the days to heading ($-0.0013$), panicle length ($-0.0177$), panicle number per plant ($-0.0957$) and full grain number per panicle ($-0.0349$), while positive via 1000 grain weight ($0.0483$) (Table 3).

The indirect effect of panicle length on grain yield via each of the days to heading and plant height was neglected and negative ($-0.0155$, $-0.0122$) respectively, but neglected and positive via 1000 grain weight ($0.0887$), and it was positive and weak via both of panicle number per plant ($0.1169$) and full grain number per panicle ($0.1319$) (Table 3).

The indirect effect of panicle number per plant on grain yield was neglected and negative via each of the days to heading ($-0.0792$) and plant height ($-0.0120$) and also neglected but positive via panicle length ($0.0212$), whereas it was positive and weak via full grain number per panicle ($0.1834$) and positive and medium via 1000 grain weight ($0.2773$) (Table 3).

The indirect effect of full grain number per plant on grain yield was also neglected and negative via each of the days to heading ($-0.0522$) and plant height ($-0.0058$), neglected positive via panicle length ($0.0316$), positive and medium via panicle number per plant ($0.2424$), and positive and weak via 1000 grain weight ($0.1510$) (Table 3).
The indirect effect of 1000 grain weight on grain yield was negatively neglected via days to heading (−0.0691), also neglected but positive via each of the plant height (0.0047) and panicle length (0.0126) and also full grain number per panicle (0.0895), whereas it was medium and positive via panicle number per plant (0.2173) (Table 3).

Discussion
The correlation among traits under study indicated that the short period to heading will provide more time to increase the number of panicle per plant and 1000 grain weight, and full-grain number per panicle will be improved by increasing of panicle length or panicle number per plant, as well as any increase in panicle number per plant will cause an increase in 1000 grain weight which leads to improvement of the final grain yield which was correlated positively to yield traits. These results agree with the results of Kumar et al. (2011), Khush (2013), Karim et al. (2014), Kumar et al. (2017), Lakshmi et al. (2017), Bhutta et al. (2019), Chhangte and Devi, (2019), and Panda et al. (2019). Current knowledge about trait relationships helps in the appropriate selection process due to the increased share of crop improvement (Gonçalves et al., 2017).

Breeding programs aim to increase rice production by using more genetic types and applying effective selection methods to increase yield through yield traits. Identifying the relationship between yield and yield traits via correlation analysis is an essential step (Akhtar et al., 2011), but dividing the influence of traits into direct and indirect effects by path analysis is more essential for the selection of yield traits (Ahmadi-zadeh et al., 2011, Dhavaleshvar et al., 2019).

The total effect in path analysis represents correlation value between targeted trait and grain yield, the direct

![Fig. 1 Association between grain yield and its components characters in 22 Egyptian and exotic rice genotypes](image)

**Table 3** Path coefficient analysis among grain yield and its components of 22 Egyptian and exotic rice genotypes

| Traits  | DTH  | PH   | PL   | PNP  | FGNP  | TGW  | r value |
|---------|------|------|------|------|-------|------|--------|
| DTH     | 0.1597 | −0.0004 | −0.0070 | −0.1984 | −0.0990 | −0.2209 | −0.366 |
| PH      | −0.0013 | 0.0501 | −0.0177 | −0.0957 | −0.0349 | 0.0483 | −0.051 |
| PL      | −0.0155 | −0.0122 | 0.0726 | 0.1169 | 0.1319 | 0.0887 | 0.382 |
| PNP     | −0.0792 | −0.0120 | 0.0212 | 0.4003 | 0.1834 | 0.2773 | 0.791 |
| FGNP    | −0.0522 | −0.0058 | 0.0316 | 0.2424 | 0.3028 | 0.1510 | 0.670 |
| TGW     | −0.0691 | 0.0047 | 0.0126 | 0.2173 | 0.0895 | 0.5107 | 0.766 |

Underlined numbers indicate a direct effect while not underlined show an indirect effect.

*DTH days to heading, PH plant height, PL panicle length, PNP panicle number per plant, FGNP full-grain number per panicle, TGW 1000 grain weight, r value correlation with grain yield per plant*
effect of days to heading reflects the real relationship with grain yield, while the indirect effect of days to heading via other traits especially 1000 grain weight then panicle number per plant were the causes of the negative correlation. The same result was indicated for plant height, in which the direct effect was positive and equal to the negative correlation because of its indirect effects on grain yield via other studied traits. Although the direct effect of panicle length was neglected, its indirect effects via panicle number per plant and full-grain number per panicle were the reason for the strong and positive total effect. Our results are in agreement with the results of Herawati et al. (2019) which indicated that direct effect of plant height was positive and neglected (0.06), the direct effect of panicle length was positive and neglected, and the direct effect of full-grain number per panicle was positive and strong (0.4); these agree with Chhangte and Devi (2019) who found that the direct effect of 1000 grain weight on grain yield was positive and strong, the total effect of panicle number per plant was positive and high (0.68), and indirect effect on grain yield via plant height was negative, while positive and weak via the grain number per panicle (0.11).

The positive total effect of panicle number per plant was mainly due to the strong and positive direct effect of panicle number per plant which indicated that this trait could be the selection criteria for improvement of grain yield of rice, with similar results for full-grain number per panicles and 1000 grain weight which their direct effects reflected about half or more of the total effect on grain yield, in addition to their indirect effects via panicle number per plant, and for that these three traits (1000 grain weight, panicle number per plant, and full-grain number per panicle) are considered as important indices to increase grain yield. These agree with the findings of other researchers (Haimansis et al., 2013, Sarwar et al., 2015). Harish et al. (2019) study resulted that the indirect effect of plant height on grain yield via each of the panicle length and grain per panicle was negative and neglected, and indirect effect of panicle length via plant height was negative and neglected, while the indirect effect of grain per panicle via panicle length was positive on grain yield.

Our results of path analysis are in agreement with the findings of Bhutta et al. (2019), who revealed that the indirect effect of panicle length via plant height on grain yield was negative and neglected, and the direct effect of plant height on grain yield was positive and neglected as well as an indirect effect of plant height via panicle length was negative, and with Babu et al. (2012), who defined a positive and neglected direct effect of plant height on grain yield, as well as with Panda et al. (2019) who indicated that the direct effect of panicle length on grain yield is positive and neglected (0.08) and the direct effect of 1000 grain weight was positive on grain yield, with other scientists (Harish et al., 2019, Mohammad et al., 2013).

In the present study, the rice genotypes had sufficient genetic variability for all studied traits. A significant negative association was found between days to heading and both of panicle number per plant and 1000 grain weight; panicle length and full-grain number per panicle were significantly positively associated. A highly significant and positive association was found between panicle number per plant and each of full grain number per panicle and 1000 grain weight; a highly significant association was found between grain yield per plant and three traits (panicle number per plant, full-grain number per panicle, and 1000 grain weight). Enhanced attention in the breeding program on 1000 grain weight, panicle number per plant, and full-grain number per panicle as selection criteria is crucial to improve rice grain yield.

Conclusion
Our results obtained from twenty-two rice genotypes over 2 years showed that grain yield per plant was significantly and positively correlated with panicle number per plant, full-grain number per panicle, and 1000 grain weight. Path coefficient analysis indicated that the direct positive effects of the three traits were associated with positive and positive correlations with the grain yield per plant. Therefore, the characteristics of 1000 grain weight, panicle number per plant, and full-grain number per panicle can be used as selection criteria to improve rice grain yield in rice breeding program.

Abbreviations
RRTC: Rice Research and Training Center, Sakha, Kafir El-Sheikh Governorate, Egypt; RCBD: Randomized complete block design; ANOVA: Analysis of variances

Acknowledgements
Sincere gratitude goes to Genebanks of International Rice Research Institute (IRRI), Los Banos, Philippines; USDA, ARS; National Small Grains Collections, USA; and Agriculture Research Center (ARC), Giza, Egypt for providing rice seeds. The authors are grateful to Genetic Resources Department, General Commission for Scientific Agricultural Research, Damascus, Syria; Plant Biotechnology Department, Genetic Engineering and Biotechnology Research Institute (GEBRI), University of Sadat City, Sadat City, P.O. Box 79, Egypt; Department of Biology, College of Science and Humanities, Shaqra University, Qwaieah, Saudi Arabia; and Rice Research Section, Field Crops Research Institute, Agriculture Research Center (ARC), Giza, Egypt for their efforts.

Significance statement
The study represented useful important traits, i.e., 1000 grain weight, panicle number per plant, and full-grain number per panicle for use in grain yield per plant assessment breeding programs as selection indices.

Authors’ contributions
MAMS contributed to the design, data analysis, and writing up the manuscript. KFMS contributed to the design, performance field experiments, data analysis, writing the manuscript, and following up the publication with the journal (correspondence). ABA contributed to the design, performance of
the field experiment, data analysis, and writing the manuscript. The authors read and approved the final version of the manuscript.

Funding
This work did not have any funding support.

Availability of data and materials
All data generated or analyzed during this study already exist in this published article.

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

Author details
1 Genetic Resources Department, General Commission for Scientific Agricultural Research (GCSAR), Damascus, Syria. 2 Plant Biotechnology Department, Genetic Engineering and Biotechnology Research Institute (GEBRI), University of Sadat City, P.O. Box 79, Sadat City, Egypt. 3 Department of Biology, College of Science and Humanities Studies, Shaqra University, Qwaiieah, Saudi Arabia. *Rice Research Section, Field Crops Research Institute, Agriculture Research Center (ARC), Giza, Egypt.

Received: 14 April 2020 Accepted: 17 August 2020
Published online: 28 August 2020

References
Ahmadnavazdeh M, Noli A, Shabzai H, Aharizad S (2011) Correlated response of morpho-physiological traits of yield grain in durum wheat under normal irrigation and drought stress conditions in greenhouse. Afr J Biotechnol 10: 19771–19779

Akhtar N, Nazir MF, Rabnaewaz A, Mahmood T, Safdar ME, Asif M, Rehman A (2011) Estimation of heritability, correlation and path coefficient analysis in fine grain rice (Oryza sativa L.). J Anim Plant Sci 21:660–664

Babu VR, Sheya K, Dangki KS, Usharani G, Shankar AS (2012) Correlation and path analysis studies in popular rice hybrids of India. Int J Sci Res 2:1

Bhatta MA, Munir S, Qureshi MK, Shahzad AN, Aslam K, Manzoor H, Shabir G (2019) Correlation and path analysis of morphological parameters contributing to yield in rice (Oryza sativa) under drought stress. Pak J Bot 51: 73–80

Changte L, Devi TR (2019) Correlation and path analysis studies in aromatic rice germplasm of north-east region of India. Pharm Innov J 8:1

Dhavalekshvar M, Malleshappa C, Dushyanth-Kumar BM (2019) Variability, correlation and path analysis studies of yield and yield attributing traits in advanced breeding lines of rice (Oryza sativa L.). Int J Pure App Biosci 7:267–273

Esmail RM (2001) Correlation and path coefficient analysis of some quantitative traits with grain yield in bread wheat (Triticum aestivum L.). Bull Natl Res Cent 26(3):395–408

Ezeaku IK, Mohammed SG (2006) Character association and path analysis in grain sorghum. Afr J Biotechnol 5:337–340

GenStat 12, J Nelder (2009) Statistical software: laws of agricultural trust. VSN international

Gonzáles DDL, Barelli MAA, Oliveira TCD, Santos PRJD, Silva CRD, Poletine JP, Neves LG (2017) Genetic correlation and path analysis of common bean collected from Caceres Mato Grosso state, Brazil. Ciênc Rural 47(8):1–7

Hairamansis A, Kustianto B, Suwarno S (2013) Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. Indones J Agric Sci 11:11–15

Harish D, Gowda TH, Pradeep P (2019) Correlation and path analysis for yield and yield component traits in rice (Oryza sativa L.) genotypes in hill zone. Int J Pure App Biosci 7:358–363

Herawati R, Ainiopri M (2019) Correlations and path analysis to determine the selection characters for developing new type of upland rice. Bio Sci Res 16: 1492–1499

IBM Corporation (2010) IBM SPSS statistics for windows, version 15.0 IBM Corp, Armonk, NY. http://www-01.ibm.com/software/analytics/spss/products/statistics/ (accessed 15 Nov 2009)

Ikeda M, Miura K, Aya K, Kitanou H, Matsuoka M (2013) Genes offering the potential for designing yield-related traits in rice. Curr Opinion Plant Biol 16: 213–220

IRRI (1980) Minimum list of descriptors and descriptor-states for rice Oryza sativa L. in IRRI, descriptor for rice Oryza sativa L. IRRI, Manila, Philippines.

Karim D, Siddique MNA, Sarkar U, Hasan MZ, Sultana J (2014) Phenotypic and genotypic correlation co-efficient of quantitative characters and character association of aromatic rice. J Bios Agric Res 1:34–46

Khush GS (2013) Strategies for increasing the yield potential of cereals: case of rice as an example. Plant Breed 132:433–436

Kumar SU, Bhuvaneswari S, Devi EL, Sharma SK, Ansari MA, Singh IM, Singh YR, Prakash NA (2017) Estimation of genetic variability, correlation and path analysis in short duration rice genotypes of Manipur. J Agric Search 4:112–118

Kumar Y, Singh BN, Verma OP, Tripathi S, Dwived DK (2011) Correlation and path coefficient analysis in scented rice. Environ Ecol 29(3B):1550–1556

Lakshmi L, Rao MB, Raju CS, Reddy SN (2017) Variability, correlation and path analysis in advanced generation of aromatic rice. Int J Curr Microbiol Appl Sci 6:1798–1806

Lenka D, Mist B (1973) Path coefficient analysis of yield in rice varieties. Indian J Agr Sci 43:376–379

Milligan SB, Gravios KA, Bischoff KP, Martin FA (1990) Crop effect on genetic relationship among sugarcane traits. Crop Sci 30:927–931

Mohammad N, Kumar P, Singh S, Tewari S (2013) Character association and path coefficient analysis for productivity traits in basmati rice (Oryza sativa L.). Panntagar J Res 11:332–336

Panda GH, Pandey ID, Tripathy SK (2019) Correlation of characters and path analysis among different traits of CMS lines and maintainers. Int J Curr Microbiol Appl Sci 8:609–614

Samonte SOBP, Wilson LT, McClung AM (1998) Path analysis of yield and yield-related traits of fifteen diverse rice genotypes. Crop Sci 38:1130–1136

Sarwar G, Harun-Ur-Rashid M, Parveen S, Hossain MS (2015) Correlation and path coefficient analysis for agro-morphological important traits in Aman rice genotypes (Oryza sativa L.). Adv Biore 6:40–47

Singh BK, Chaudhary BD (1977) Biometrical methods in quantitative genetics analysis. Kalyani Publishers, Ludhiana, New Delhi, India

Singh PK, Chaudhary SD (1985) Biometrical methods in quantitative genetics analysis. Khalnay New Delhi, India

Sürek H, Beşir N (2003) Correlation and path coefficient analysis for some yield-related traits of rice (Oryza sativa L.) under thrice conditions. Turk J Agric For 27:77–83

Wogu MD, Omoruyi MI, Odeh HO, Guobadia JN (2011) Microbial load in ready-to-eat rice sold in Benin City. J Microbiol Antimicrob 3:29

Zhou Y, Tao Y, Yuan Y, Zhang Y, Miao J, Zhang R, Yi C, Gong Z, Yang Z, Liang G (2018) Characterization of a novel quantitative trait locus, GRN4-J, for grain number and yield in rice (O. sativa L.). Theor Appl Genet 131(3):637–648

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.