RESEARCH

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

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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**, and 0.766**, 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 with 1000 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

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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.

Table 1 Genotype names, origin, seed sources, and types of rice genotypes used in this study

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	Agamy 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 lulu	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 (days) (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,

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[2010](#)) as $r_{p1.2} = \frac{Cov_{p1.2}}{\sigma_{p1} \times \sigma_{p2}}$, where, $COV_{p1.2}$ is phenotypic covariance between the variables X_1 and $\underline{X}_2$, 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 Gen-Stat 12, J Nelder ([2009](#)), as described by Singh and Chudhary ([1977](#)) as $r_{yi} = P_{yi} + \sum\limits_{\substack{i'=1 \\ i' \neq 1}}^{k} r_{ii'} P_{yi'}$ for $i \neq 1$,

where r_{yi} is the correlation coefficient between the ith causal variable (X_i) and effect variable (y), $r_{ii'}$ is the correlation coefficient between the ith and i'th causal variables, P_{yi} is the path coefficient (direct effect) of the ith causal variable (X_i), (X_i), $r_{ii'} P_{yi}$ is the indirect effect of the ith 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

panicle number per plant ($r = 0.791^{**}$) (Table [2](#)) (Fig. [1](#)), full-grain number per panicle ($r = 0.670^{**}$), and 1000 grain weight ($r = 0.766^{**}$) (Table [2](#)) (Fig. [1](#)).

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](#)).

Table 2 Pearson phenotypic correlation for grain yield and its component characters in 22 Egyptian and exotic rice genotypes

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
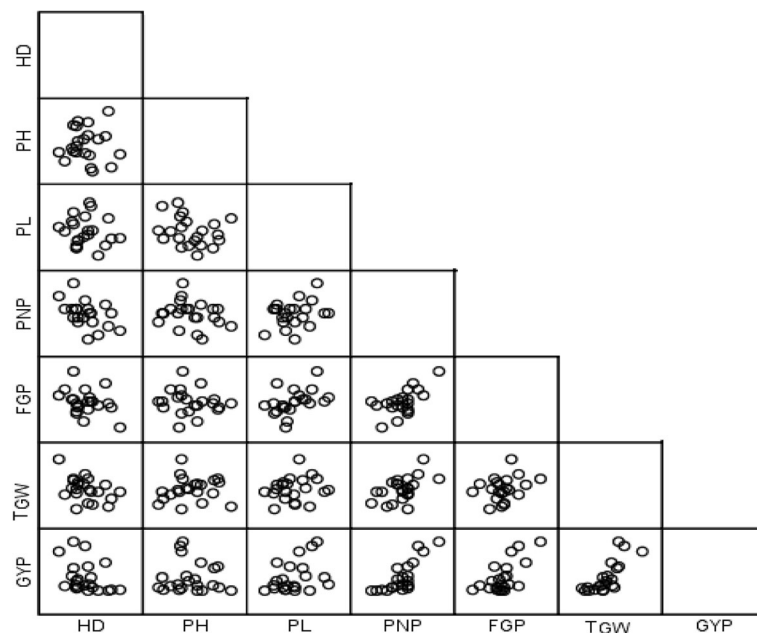
Fig. 1 Association between grain yield and its components characters in 22 Egyptian and exotic rice genotypes

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 (Ahmadizadeh et al., 2011, Dhavaleshvar et al., 2019).

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

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

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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 (Hairmansis 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.

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