Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 2723-2728
Received: 07-11-2017
Accepted: 08-12-2017

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Correlation and path analysis of yield determinants and micronutrient content in rice (*Oryza sativa* L.)

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Abstract
The study of relationship between different traits has great importance in the selection of a complex trait associated with a simple trait as it helps to determine the nature, direction (negative or positive) and magnitude of association between nutritive characters. Correlation and path coefficient analysis among fourteen rice genotypes was conducted and genotypes were evaluated for different traits during *kharif* season of 2014. Grain yield per plant manifested significantly positive correlation with number of productive tillers (0.54) and number of tillers (0.54). Highest positive direct effect on yield was shown by total number of tillers. Based on path analysis, total number of tillers had highest direct positive effect, selection based on total number of tillers for grain yield per plant would be the most effective strategy. Therefore, it could be concluded that these characters would be most suitable for indirect selection in rice improvement program that aims at increasing grain yield along with their iron and zinc content. No direct positive or negative effect of zinc and iron content in different parts of rice grain on grain yield was found.

Keywords: correlation analysis, path analysis, grain yield, zincs content, iron content, rice

Introduction
Rice, being a relatively cheap, high energy and starchy food is more preferred by the people of developing countries due to its affordability and abundant availability. Improvement in the micronutrient content of rice would aid in combating the problem of malnutrition among the target population as it is a staple food in many underdeveloped and developing countries. The cost of rice is artificially kept low due to extensive and elaborate government intervention in the form of price support, subsidy. It has been reported that rice significantly lack some of the micronutrients such as Fe, Zn, Ca, Mg, Cu, I and Se etc., which are important for human beings for their proper growth and development (Banerjee and Chandel, 2011) [2]. The existence of a negative relationship between irrigation and iron and zinc uptake (Scagel *et al*., 2012) [12] and a similar negative relationship between phosphorus and iron and zinc uptake (Saha *et al*., 2013) [11] also lead to lower the accumulation of these micronutrients in the cereal grains. Since the edible parts of the cereals are poor in iron and zinc, thus heavy dependence of people from developing countries on these foods results in the development of large-scale iron and zinc malnutrition. To alleviate iron and zinc deficiency, it is required to increase iron and zinc concentration in the endosperm to 8 and 30 mg kg-1, respectively. The relationship between yield and yield components may be negative or positive but it is the net result of direct effect of that particular trait and indirect effects via other traits. Hence, it is necessary to determine the path-coefficients which partitions the observed correlation into direct and indirect effects and also reveals the cause and effect relationship existing between yield and their related traits. Therefore it is necessary to understand the relationship between grain iron and zinc content with the other morphological traits.

Material and Methods
The present experiment was conducted at the field allotted to aerobic rice/biotechnology rice research laboratory, Department of Plant Biotechnology, University of Agricultural Sciences, GKVK campus, Bangalore, India during *Kharif*-2014 in order to study the association between and effect of different morphological and quality traits on grain yield. The genotypes were sown in rows spaced at 30 cm apart with intra-row spacing of 15 cm with three replications each. The recommended dose of fertilizer *i.e.* nitrogen 100 Kg, phosphorus 50 Kg and potassium 50 Kg along with 5 tone of FYM per hectare was applied. Study of physico-chemical properties of soil at the experimental site showed the presence of 0.74 ppm Zn (estimated using DTPA, diethylenetriamine penta acetic acid extractable method), a pH of 6.1 and 7.4 g kg^{-1} of organic carbon.

Panicle length, percentage spikelet fertility, days to first flowering, hundred grain weight, days to 50 % flowering, days to maturity, shoot dry weight. Zinc and Iron content in different parts of rice grain i.e., brown rice (after removing husk), white rice (obtained after polishing of brown rice) and cooked rice (obtained after cooking of white rice) of genotypes was estimated using XRF at ICRISAT, Hyderabad and MSSRF, Chennai.

To estimate the degree of association between the traits studied, correlation was computed by using the formula given by Webber and Moorthy (1952) [16]. Path-coefficient analysis was carried out using phenotypic correlation values of different characters as suggested by Wright (1921) [17] and as illustrated by Dewey and Lu (1959) [5]. It was carried out to know the direct and indirect effect of the morphological traits and grain Zn content on grain yield. Standard path-coefficients which are the standardized partial regression coefficients were obtained using statistical software package Genres 1.

Results and Discussion

Correlation studies

The study of genetic potentiality of yield attributing traits and their association among themselves and with the target variable plays important role in effective selection for isolating productive genotypes. The results of the correlation analysis are presented in Table 01. Grain yield per plant manifested significantly positive correlation with number of productive tillers (0.54) and number of tillers (0.54) but it showed negative association with shoot dry weight (0.38), days to first flowering (0.47), days to fifty per cent flowering (0.51), days to maturity (0.51), white rice iron and zinc (0.48 & 0.50 respectively) and cooked rice iron and zinc (0.23 & 0.40 respectively).

Plant height has shown significant positive effect on panicle length (0.64), but showed negative effect on total number of tillers (0.29), number of productive tillers (0.36) and cooked rice iron (0.22). Total number of tillers showed significant positive effect on number of productive tillers (0.925) but showed negative effect on panicle length (0.36), hundred grain weight (0.37), biomass (0.04), zinc content in brown rice (0.17), iron content in white rice (0.39), zinc content in white rice (0.40) and zinc content in cooked rice (0.31). It also showed significant negative effect on water uptake after cooking (0.55).

Number of productive tillers showed negative effect on panicle length (0.36), hundred grain weight (0.37), shoot dry weight (0.14), zinc content in brown rice (0.11), zinc content in white rice (0.43), zinc content in cooked rice (0.34) and iron content in white rice (0.36). NPT also showed positive effect on days to first flowering (0.15) and days to fifty percent flowering (0.13).

Number of productive tillers and number of total tillers had significant positive effect on grain yield which can be effectively utilized in selection. These findings are supported by previous reports of Bekele *et al*., 2013; Nagesh *et al*., 2012; Raju *et al*., 2004; Chakraborti *et al*., 2009) [3, 8, 9, 4] indicating that number of tillers can act as selection criteria simultaneously to increase grain yield per plant. These findings are supported by previous reports (Yuan *et al*., 2011; Yaqoob *et al*., 2012; Anuradha *et al*., 2012) [15, 14, 1].

Shoot dry weight showed positive effect on days to first flowering (0.33), days to fifty per cent flowering (0.47) and days to maturity (0.41) but showed negative effect on hundred grain weight (0.16). It has also showed positive effect on brown rice iron and zinc (0.32 & 0.46 respectively).

Panicle length showed significant positive effect on kernel length before cooking (0.53) and hundred grain weight (0.68) but showed negative effect on zinc and iron content in brown rice (0.10 and 0.38 respectively).

Hundred grain weight has significant negative effect on cooked rice iron (0.61) and positive effect on grain yield per plant (0.41). It also showed negative effect on days to first flowering (0.33), days to fifty per cent flowering (0.35), days to maturity (0.33) and percentage spikelet fertility (0.15) while it showed positive effect on zinc content in brown rice (0.03), zinc content in white rice (0.18) and zinc content in cooked rice (0.17).

The time taken for first flowering showed significant positive effect on days for 50 % flowering (0.97), days to maturity (0.97), zinc content in brown rice (0.67), zinc content in white rice (0.55) and zinc content in cooked rice (0.56) but showed negative effect on percentage spikelet fertility (0.53).

Days for 50 % flowering showed significant positive effect on days to maturity (0.98), brown rice zinc content (0.74), zinc content in white rice (0.62) and zinc content in cooked rice (0.61) while as it showed positive effect on brown and white rice iron content (0.30 and 0.19 respectively). It also showed negative effect on percentage spikelet fertility (0.53).

Days to maturity showed significant positive effect on zinc content in brown rice (0.719), zinc content in white and cooked rice (0.58 and 0.57 respectively) but showed significant negative effect on percentage spikelet fertility (0.55) and positive effect on iron content in brown rice (0.30), iron content in white rice (0.20) and iron content in cooked rice (0.40). Percentage spikelet fertility showed significant negative effect on zinc content in brown rice (0.65), negative effect on zinc content in white rice (0.52) and zinc content in cooked rice (0.43) and positive effect on iron content in brown and white rice (0.04 and 0.19 respectively).

Iron content in brown rice does not show any significant effect on the traits studied. Zinc content in brown rice exhibited significant positive effect on days to first flowering (0.67), days for 50 % flowering (0.74) and days to maturity (0.71) but showed significant negative effect on percentage spikelet fertility (0.65). Iron content in white rice does not have significant effect on any of traits studied. Iron content in different parts of white and brown rice does not show any significant effect on grain yield.

Zinc content in white rice showed significant positive effect on zinc content in brown rice (0.89), days to first flowering (0.55), days to fifty per cent flowering (0.62) and days to maturity (0.58), however it was observed to show negative effect on number of productive tillers (0.43), number of tillers (0.40), percentage spikelet fertility (0.52) and brown rice iron (0.18).

Iron content in cooked rice showed significantly negative effect on hundred grain weight (0.61), plant height (0.22), panicle length (0.31) and white rice zinc (0.14). Zinc content in cooked rice showed significant positive effect on white rice zinc (0.96) zinc content in brown rice (0.87). days to first flowering (0.56), days to fifty per cent flowering (0.61) and days to maturity (0.57) but showed negative effect on number of tillers (0.31), number of productive tillers (0.34), percentage spikelet fertility (0.43), iron content in brown rice (0.27) and iron content in cooked rice (0.12).

Kernel length before cooking showed significant positive effect on panicle length (0.53) but showed negative effect on white rice iron and zinc (0.19 and 0.13 respectively) and brown rice iron and zinc (0.32 and 0.05 respectively).

Kernel length after cooking showed significant positive effect on kernel length before cooking (0.53) but showed negative effect on brown rice iron and zinc (0.33 and 0.14 respectively) and iron content in white and cooked rice (0.28 and 0.38 respectively).
Water uptake after cooking showed significant positive effect on water uptake before cooking (0.59), zinc content in white and cooked rice (0.58 and 0.56 respectively) and also showed significant negative effect on number of productive tillers (0.63) and number of tillers (0.55). Volume expansion showed significant negative effect on water uptake before cooking (0.63) but showed negative effect on kernel length before and after cooking (0.34 and 0.13 respectively). Elongation ratio showed significant negative effect on kernel length before cooking (0.85) but showed positive effect on water uptake after cooking (0.24) and volume expansion (0.39). It has also showed negative effect on kernel length after cooking (0.10) and water uptake before cooking (0.14).

Path-coefficient analysis

The path-coefficient analysis was carried out to discern direct and indirect effects of yield attributing traits on grain yield. Results are presented in Table 2 and 3. The relationship between yield and yield components may be negative or positive but it is the net result of direct effect of that particular trait and indirect effects via other traits. Hence, it is necessary to determine the path-coefficients which partition the observed correlation into direct and indirect effects and also reveals the cause and effect relationship exists between yield and their related traits.
Highest positive direct effect on yield was shown by total number of tillers (0.53). Thus, choosing total number of tillers for yield will be best for selection process. Kalita and Upadhaya (2001) [7], Rajeshwari and Nadarajan (2004) [10] and Suman *et al*. (2005) [13] also reported high positive direct effect of number of productive tillers per plant on grain yield. Habib (2005) [6] and Suman *et al*. (2005) [13] also reported high positive direct effect of panicle length on grain yield.
Hundred grain weight had lowest positive direct effect of 0.02 on grain yield per plant. Among the characters under study, days to maturity has highest negative direct effect on grain yield (0.46), while percentage spikelet fertility has lowest direct negative effect on grain yield (0.07). Among the selected genotypes, water uptake before cooking had the highest positive indirect effect of 0.79 *via.* volume expansion towards grain yield whereas, number of tillers had lowest positive indirect effect of 0.0004 *via.* Iron content in brown rice towards grain yield.
Among the characters under study, water uptake before cooking had highest negative indirect effect of 0.76 *via.* water uptake after cooking towards grain yield whereas iron content in brown rice had lowest negative indirect effect of -0.0002 *via.* number of tillers towards grain yield.

Conclusion

The present study revealed that traits such as number of productive tillers, 100 grain weight, biomass of plant and plant height exhibited positive association with grain yield per plant and nutritional quality and therefore, would prove effective to enhance yield potential. Zinc and Iron content in brown rice exhibited direct negative effect on yield suggesting that quality parameter should be associated with yield. As total number of tillers had highest direct positive effect, selection based on total number of tillers for grain yield per plant would be the most effective strategy. As there is not much direct positive or negative effect of zinc and iron content in different parts of rice grain on grain yield, simultaneous selection has to be made to obtain genotype with higher grain zinc and iron content and higher grain yield per plant.

Table 1: Estimates of genotypic correlation coefficients for various characters in rice genotypes

Characters	PH	NPT	NT	SDW	PL	HGW	DFF	DFPF	DM	PSF	BRF	BRZ	WRF	WRZ	CRF	CRZ	KLBC	KLAC	WUBC	WUAC	VEXP	ER	GYPP
PH	1.00																						
NPT	-0.36	1.00																					
NT	-0.29	.925**	1.00																				
SDW	0.48	-0.14	0.04	1.00																			
PL	.642*	-0.36	-0.28	0.13	1.00																		
HGW	0.27	-0.37	-0.37	-0.16	.682**	1.00																	
DFF	-0.14	0.15	0.02	0.33	-0.38	-0.33	1.00																
DFPF	-0.03	0.13	0.04	0.47	-0.38	-0.35	.976**	1.00															
DTM	-0.08	0.16	0.06	0.41	-0.38	-0.33	.972**	.983**	1.00														
PSF	0.28	0.01	0.20	0.00	0.36	-0.15	-0.53	-0.53	-.557*	1.00													
BRF	-0.10	0.05	0.04	0.32	-0.38	-0.32	0.25	0.30	0.30	0.04	1.00												
BRZ	0.13	-0.11	-0.17	0.46	-0.10	0.03	.673**	.740**	.719**	-.659*	-0.04	1.00											
WRF	0.50	-0.36	-0.39	0.08	0.14	-0.22	0.16	0.19	0.20	0.19	0.10	0.11	1.00										
WRZ	0.29	-0.43	-0.40	0.50	0.09	0.18	.557*	.624*	.584*	-0.52	-0.18	.892**	0.22	1.00									
CRF	-0.22	0.49	0.51	0.26	-0.31	-.613*	0.34	0.34	0.40	0.08	0.08	0.02	0.06	-0.14	1.00								
CRZ	0.32	-0.34	-0.31	0.43	0.18	0.17	.562*	.612*	.579*	-0.43	-0.27	.878**	0.28	.969**	-0.12	1.00							
KLBC	-0.08	0.18	0.03	-0.29	.538*	0.43	0.07	-0.06	0.02	-0.03	-0.32	-0.05	-0.19	-0.13	0.10	0.00	1.00						
KLAC	-0.11	-0.45	-0.43	-0.25	0.52	0.46	-0.28	-0.38	-0.39	0.17	-0.33	-0.14	-0.28	0.01	-0.38	0.05	.533*	1.00					
WUBC	0.32	-0.52	-0.51	0.09	0.52	0.49	-0.14	-0.10	-0.09	-0.05	-0.24	0.05	0.21	0.31	-0.15	0.28	0.22	0.37	1.00				
WUAC	0.49	-.631*	-.555*	0.28	0.47	0.31	-0.21	-0.12	-0.17	-0.07	-0.49	0.40	0.20	.585*	-0.26	.569*	-0.06	0.40	.598*	1.00			
VEXP	0.10	0.05	0.11	0.14	-0.20	-0.32	-0.04	0.00	-0.04	0.01	-0.21	0.31	-0.03	0.17	0.00	0.20	-0.34	-0.13	-.638*	0.23	1.00		
ER	-0.04	-0.44	-0.30	0.13	-0.43	-0.42	-0.25	-0.17	-0.23	0.14	0.23	-0.11	0.16	0.02	-0.17	-0.10	-.850**	-0.10	-0.14	0.24	0.39	1.00	
GYPP	-0.08	.549*	.543*	-0.38	0.28	0.41	-0.47	-0.51	-0.51	0.14	-0.34	-0.40	-0.50	-0.48	-0.23	-0.40	0.35	0.03	-0.16	-0.30	-0.10	-0.49	1.00

PH=Plant height NPT=Number of productive tillers NT=Total number of tillers SDW=Shoot dry Weight PL=Panicle length HGW=Hundred grain weight

DFF=Days to first flowering DFPF=Days for 50 % flowering DM=Days to maturity PSF=Percentage spikelet fertility BRF= Fe content in brown rice BRZ= Zn content in brown rice

WRF= Fe content in white rice WRZ= Zn content in white rice CRF= Fe content in cooked rice CRZ= Zn content in cooked rice KLBC=kernel length before cooking KLAC= Kernel length after cooking

WUBC= water uptake before cooking WUAC=water uptake after cooking VEXP=volume expansion ER= Elongation ratio

Table 2: Estimates of direct and indirect effects of yield components on grain yield at phenotypic level in selected rice genotypes.

TRAITS	PH	NPT	NT	SDW	PL	HGW	DFF	DFPF	DM	PSF
PH	-0.21	0.11	-0.18	0.12	0.02	0.00	0.03	-0.00	0.02	-0.02
NPT	0.08	-0.28	0.57	-0.04	-0.01	-0.01	-0.03	0.02	-0.07	-0.00
NT	0.07	-0.27	0.59	0.01	-0.01	-0.01	-0.00	0.00	-0.02	-0.02
SDW	-0.12	0.06	0.04	0.21	0.00	-0.00	-0.09	0.08	-0.23	-0.00
PL	-0.15	0.12	-0.23	0.03	0.03	0.02	0.11	-0.07	0.21	-0.03
HGW	-0.06	0.12	-0.24	-0.05	0.03	0.02	0.07	-0.05	0.18	0.01
DFF	0.03	-0.04	0.01	0.08	-0.01	-0.00	-0.23	0.15	-0.47	0.04
DFPF	0.00	-0.04	0.01	0.12	-0.01	-0.00	-0.23	0.15	-0.47	0.04
DM	0.01	-0.05	0.03	0.11	-0.01	-0.00	-0.23	0.16	-0.46	0.05
PSF	-0.07	-0.01	0.17	0.00	0.01	-0.00	0.14	-0.09	0.29	-0.07
BRF	0.02	-0.01	0.00	0.08	-0.01	-0.00	-0.05	0.05	-0.16	-0.00

BRZ	-0.03	0.04	-0.11	0.12	-0.00	0.00	-0.16	0.13	-0.36	0.06
WRF	-0.11	0.11	-0.24	0.02	0.00	-0.00	-0.04	0.03	-0.09	-0.01
WRZ	-0.06	0.13	-0.24	0.12	0.00	0.00	-0.13	0.10	-0.28	0.04
CRF	0.05	-0.15	0.32	0.06	-0.01	-0.01	-0.08	0.05	-0.19	-0.00
CRZ	-0.07	0.10	-0.19	0.10	0.00	0.00	-0.13	0.10	-0.27	0.03
KLBC	0.02	-0.05	0.02	-0.07	0.02	0.01	-0.01	-0.01	-0.00	0.00
KLAC	0.02	0.13	-0.27	-0.06	0.02	0.01	0.06	-0.06	0.18	-0.01
WUBC	-0.07	0.16	-0.31	0.02	0.02	0.01	0.03	-0.02	0.05	0.00
WUAC	-0.11	0.19	-0.35	0.07	0.01	0.00	0.05	-0.02	0.08	0.00
VEXP	-0.02	-0.01	0.02	0.04	-0.00	-0.00	0.00	0.00	0.01	-0.00
ER	0.01	0.13	-0.19	0.03	-0.01	-0.01	0.05	-0.02	0.11	-0.01
GY	-0.77	0.49	-0.77	1.12	0.08	0.03	-0.87	0.68	-1.94	0.10

PH=Plant height
NPT=Number of productive tillers
NT=Total number of tillers
SDW=Shoot dry Weight
PL=Panicle length
HGW=Hundred grain weight
DFF=Days to first flowering
DFPF=Days for 50 % flowering
DM=Days to maturity
PSF =Percentage spikelet fertility

Table 3: Estimates of direct and indirect effects of different traits on grain yield at phenotypic level in selected rice genotypes

Traits	BRF	BRZ	WRF	WRZ	CRF	CRZ	KLBC	KLAC	WUBC	WUAC	VEXP	ER
PH	0.03	-0.03	-0.09	-0.10	0.12	0.16	-0.07	0.11	-0.41	0.43	-0.11	-0.01
NPT	-0.00	0.03	0.07	0.15	-0.30	-0.17	0.17	0.45	0.69	-0.59	-0.04	-0.10
NT	-0.00	0.04	0.08	0.14	-0.31	-0.15	0.02	0.44	0.65	-0.52	-0.09	-0.07
SDW	-0.12	-0.11	-0.02	-0.19	-0.16	0.24	-0.32	0.29	-0.11	0.27	-0.18	0.03
PL	0.16	0.01	-0.03	-0.03	0.20	0.10	0.60	-0.58	-0.73	0.47	0.23	-0.11
HGW	0.11	-0.00	0.04	-0.06	0.39	0.09	0.46	-0.51	-0.69	0.29	0.40	-0.10
DFF	-0.07	-0.15	-0.03	-0.20	-0.20	0.28	0.06	0.29	0.20	-0.19	0.02	-0.05
DFPF	-0.09	-0.17	-0.04	-0.23	-0.20	0.30	-0.06	0.39	0.15	-0.11	-0.01	-0.04
DM	-0.11	-0.16	-0.04	-0.21	-0.24	0.29	0.01	0.39	0.13	-0.15	0.02	-0.05
PSF	-0.02	0.16	-0.04	0.21	-0.04	-0.23	-0.03	-0.17	0.06	-0.07	-0.01	0.03
BRF	-0.32	0.02	-0.02	0.06	-0.06	-0.14	-0.34	0.36	0.34	-0.48	0.24	0.05
BRZ	0.03	-0.21	-0.02	-0.32	-0.02	0.44	-0.05	0.14	-0.06	0.35	-0.33	-0.02
WRF	-0.03	-0.02	-0.19	-0.07	-0.03	0.13	-0.18	0.27	-0.27	0.17	0.03	0.03
WRZ	0.06	-0.19	-0.04	-0.35	0.08	0.47	-0.13	-0.00	-0.39	0.52	-0.19	0.00
CRF	-0.03	-0.00	-0.01	0.05	-0.58	-0.06	0.09	0.38	0.20	-0.22	-0.01	-0.04
CRZ	0.09	-0.19	-0.05	-0.34	0.07	0.48	-0.00	-0.05	-0.35	0.50	-0.21	-0.02
KLBC	0.11	0.01	0.03	0.04	-0.05	-0.00	0.98	-0.53	-0.27	-0.05	0.36	-0.19
KLAC	0.12	0.03	0.05	-0.00	0.22	0.02	0.53	-0.97	-0.47	0.35	0.13	-0.02
WUBC	0.08	-0.01	-0.04	-0.11	0.09	0.13	0.21	-0.36	-1.25	0.52	0.67	-0.03
WUAC	0.17	-0.08	-0.04	-0.21	0.15	0.28	-0.05	-0.40	-0.76	0.87	-0.23	0.05
VEXP	0.07	-0.06	0.00	-0.06	-0.00	0.10	-0.33	0.12	0.79	0.19	-1.06	0.09
ER	-0.08	0.02	-0.03	-0.00	0.10	-0.04	-0.83	0.10	0.16	0.20	-0.42	0.22
R value	0.16	-1.06	-0.46	-1.83	-0.77	2.72	0.74	0.16	-2.39	2.75	-0.79	-0.35
Residual effect	= 0.2115597											

BRF= Fe content in brown rice
BRZ= Zn content in brown rice
WRF= Fe content in white rice
WRZ= Zn content in white rice
CRF= Fe content in cooked rice
CRZ= Zn content in cooked rice
KLBC=kernel length before cooking
KLAC= Kernel length after cooking
WUBC= water uptake before cooking
WUAC=water uptake after cooking
VEXP=volume expansion
ER= Elongation ratio

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