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Path coefficient analysis studies in Iron and Zinc containing rice varieties

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Abstract
The objective of this study was to estimate the direct and indirect effects of iron and zinc on grain yield in eleven rice genotypes. Path coefficient analyses were estimated at phenotypic levels to resolve the direct and indirect effects of different characters on grain yield. Path coefficient analysis revealed that Biological yield, harvest index and spikelet fertility exhibited highest positive direct effect on grain yield *via* grain yield Per Plant. Spikelet fertility and Polished Zinc seed exhibited positive and high indirect effect on grain yield per plant *via* Harvest index.

Keywords: rice, correlation, iron, zinc, path analysis

Introduction
Cereals are the most significant source of calories to humans. Rice, wheat and maize offer 23%, 17% and 10% calories globally. It is known as the grain of life and is synonymous with food for Asians as it supplies majority of starch, protein and micronutrient requirements. Rice nutrient content varies depending on the cultivar and production conditions in addition to the processing method (Rohman *et al.* 2014) [18]. Rice has been adapted to tropical, sub-tropical and temperate climates (Lafitte, 2004) [8]. Abiotic stresses such as drought, salinity, flooding or problem soils limit crop production worldwide.
Mineral elements are found in crops as chemical compounds and have an important role in human nutrition. Iron deficiency causes a range of health problems in humans, including poor pregnancy-related complications, brain damage in infants, chronic hypoxia and reduced work performance (Goto and Yoshihara 2001) [4]. Zinc (Zn) deficiency is also a most common nutrient problem for rice next to nitrogen and phosphorus.
Correlation analysis between different minerals contents have shown significant positive associations between the contents of K and Mg, Ca and Na and Mg, Fe, Zn, Mn and Cu, whereas Cu and K contents were negatively correlated (Jiang *et al*. 2007) [5]. The aim of this study was to estimate the direct and indirect effects of iron and zinc levels in grain rice genotypes through path coefficient analysis.

Materials and Methods
The experiment was carried out at the Experimental field and Green house, Department of Plant Molecular Biology and Genetic Engineering, N.D. University of Agriculture and Technology, Faizabad (U.P.) during Kharif season. The plant materials used in the research work included Shusk Samrat, Barani Deep, Narendra Usar Dhan 3, Narendra Usar Dhan 2, Swarna sub 1, Jalmagna, NDR 359, Sarjoo-52 and Kalanamak and two $F_{1(s)}$ namely NDR-359 × Kalanamak, NDR-359 × Barani Deep made in background of NDR 359. Taken Data on Days to 50% flowering, Days to Maturity, Plant height, Flag leaf Area, Panicle bearing tillers per plants, Number of spikelets per panicle, Grain per panicle Spikelet fertility (%), Test weight (g), Biological yield (g), Harvest index (%), Unpolished Zinc (ppm), Polished Zinc (ppm), Unpolished Iron (ppm), Polished Iron (ppm), Grain yield (g) were recorded. Estimation of Iron and zinc content of grain samples were estimated by Atomic Absorption Spectrophotometer. It was carried out using 9:4 mixture of HNO_3: $HClO_4$. One gram ground sample material was placed in 100 ml volumetric flask. To this, 10 ml of acid mixture was added and the content of the flask was mixed by swirling. The flask was placed on low heat hot plate in a digestion chamber. Then, the flask was heated at higher temperature until the production of red NO_2 fumes ceases. The contents were further evaporated until the volume was reduced to about 3 to 5 ml but not to dryness. The completion of digestion was confirmed when the liquid became colorless. After cooling the flask, 20 ml of deionized H_2O was added

and volume was made up with deionized water and the solution was filtered through whatman filter paper. Aliquotes of this solution were used for the determination of iron and zinc. The direct and indirect effects of individual characters on grain yield were estimated in table-1.

Results and Discussion

Path-coefficient analysis was carried out according to Dewey and Lu (1959) [2]. A study was envisaged on character association, to assess the relationships among yield and its components and to have an insight into the causes for higher yield in hybrids and varieties. This Path analysis reveals the stable associations among the traits for use in future selections by plant breeders.

Days to 50% flowering

Days to 50% flowering showed very low direct effect on grain yield *via* grain yield Per Plant. It had negative indirect effect on grain yield via harvest index. The direct negative effect of days to 50 per cent flowering on grain yield per plant was reported by Yadav *et al.* (2010), Pankaj Garge *et al*. (2010), Rajamadhan *et al*. (2011) [14] and Ravindra Babu *et al*. (2012) [16].

Days to Maturity

Days to maturity exhibited indirect effect on grain yield via biological yield. It had negative indirect effect on grain yield *via* Harvest index.

Plant height

Plant height Showed indirect effect on grain yield via biological yield. Similar results were reported by Mulugeta Seyoum *et al*. (2012), Pandey *et al*. (2012) and Yadav *et al*. (2012).

Flag leaf area

Flag leaf area had indirect effect on grain yield via biological yield.

Panicle bearing tillers per plants

This trait had negative indirect effect on grain yield via biological yield. It also exhibited negative indirect effect on grain yield *via* Harvest index. Similar results were found for number of productive tillers per plant by Monalisa *et al.* (2006), Panwar *et al.* (2007) and Kole *et al.* (2008); [9, 12, 6]

Number of spikelets per panicle

This trait exhibited negative indirect effect on grain yield via biological yield. It had positive and high indirect effect on grain yield per plant *via* spikelet fertility.

Grain per panicle

Grain per panicle exhibited negative indirect effect on grain yield via biological yield. It had positive and high indirect effect on grain yield per plant *via* spikelet fertility. Simmilar result was reported by Yadav *et al.* (2010). Similar results were found for number of grains per panicle by Choudhury and Das (1998), Yoga meenakshi *et al.* (2004) and Panwar *et al.* (2007) [12].

Spikelet fertility (%)

The direct contribution of this character to grain yield was positive and very high in addition to its significant association with grain yield per plant. It had negative indirect effect on grain yield via biological yield. These characters have also been identified as major direct contributors towards grain yield by Rangare *et al.* (2012) [15]; Krishnamurthy and Kumar, 2012 [7] and Reddy *et al.* (2013) [17].

Test weight (g)

Test weight showed Positive indirect effect on grain yield via biological yield while it had negative indirect effect on grain yield *via* Harvest index. The results reported by Panwar *et al.* (2007), Sathish Chandra *et al.* (2009), Nandeshwar *et al.* (2010), Bhadru *et al.* (2012) [12, 19, 11, 1] also indicated that 1000 seed weight plays greater role for higher grain yield per plant.

Biological yield (g)

This trait showed highest positive direct effect on grain yield *via* grain yield Per Plant. It also exhibited negative indirect effect *via* spikelet fertility. These findings were also corroborated by Kole *et al.* (2008) [6].

Harvest index (%)

Highest positive direct effect on grain yield *via* grain yield Per Plant exhibited by this trait compared to other trait except biological and spikelets fertility. It had also negative indirect effect on grain yield via biological yield. Similar findings were also observed by Kole *et al.* (2008) [6].

Unpolished Zinc (ppm)

It exhibited indirect effect on grain yield via biological yield. Grain zinc content had direct positive influence on grain yield. The similar results were reported by Nagesh *et al.* (2012) [10] and Rajamadhan *et al.* (2011) [14]

Polished Zinc (ppm)

This trait exhibited indirect effect on grain yield via biological yield. It had negative indirect effect *via* spikelet fertility.

Unpolished Iron (ppm)

Unpolished iron exhibited negative indirect effect on grain yield via biological yield. It had negative indirect effect on grain yield *via* Harvest index. Grain iron content had direct negative influence on grain yield. The similar results were reported by nagesh *et al.* (2012) [10] and Rajamadhan *et al.* (2011) [14].

Polished Iron (ppm)

Polished iron exhibited negative indirect effect on grain yield *via* Harvest index also *via* spikelet fertility.

Conclusion

The path coefficient analysis indicated that biological yield, harvest index and spikelet fertility had maximum direct effect on grain yield. Plant height, days to 50% flowering, days to maturity, flag leaf area, unpolished zinc seed, test weight and polished zinc seed exerted very positive indirect effect on grain yield via biological yield. Path analysis revealed selection of more number of productive tillers per plant, more number of grains per panicle and high test weight will be useful in increasing the grain yield.

Table 1: Direct and indirect effect (phenotypic correlation) of 15 characters on grain yield per plant in rice

S. No	Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle bearing tillers/plant	Flag leaf area (cm^2)	Spike lets/panicle	Grains/ panicle	Spikelet fertility (%)	Test weight (g)	Biological yield (g)	Harvest index	Unpolished seed (Zn)	Polished seed (Zn)	Unpolished seed (Fe)	Polished seed (Fe)	Grain yield/ plant (g)
1.	Days to 50% flowering	0.0218	0.0214	0.0134	-0.0009	0.0158	0.0028	0.0017	-0.0048	0.0062	0.0101	-0.0107	0.0008	-0.0029	-0.0020	0.0045	0.0418
2.	Days to maturity	0.0384	0.0390	0.0232	-0.0032	0.0291	0.0044	0.0027	-0.0077	0.0104	0.0195	-0.0171	0.0002	-0.0062	-0.0037	0.0065	0.1038
3.	Plant height (cm)	-0.0070	-0.0068	-0.0115	0.0038	-0.0064	0.0053	0.0064	0.0071	-0.0078	-0.0072	0.0032	-0.0037	-0.0023	0.0032	-0.0027	0.2897
4.	Panicle bearing tillers/plant	0.0001	0.0002	0.0008	-0.0025	0.0008	-0.0013	-0.0012	0.0001	-0.0002	0.0013	0.0009	0.0000	0.0000	-0.0005	-0.0012	-0.6359
5.	Flag leaf area (cm^2)	-0.0062	-0.0064	-0.0048	0.0028	-0.0086	-0.0021	-0.0015	0.0020	-0.0011	-0.0028	0.0010	0.0018	0.0029	0.0001	-0.0028	0.1794
6.	Spike lets/ panicle	0.2155	0.1920	-0.7804	0.9161	0.4094	-1.6955	1.6537	0.4317	-0.6586	-0.8098	-0.2205	-0.6570	-0.8074	0.5243	0.7606	-0.4348
7.	Grains/ panicle	-0.1444	-0.1301	1.0385	-0.8980	-0.3314	-1.8114	-1.8572	-0.8559	0.8231	0.9128	0.1220	0.6897	0.9356	-0.6682	-0.5601	-0.4020
8.	Spikelet fertility (%)	-0.0934	-0.0836	-0.2613	-0.0137	-0.0968	0.1073	0.1942	0.4213	-0.1578	-0.1040	0.1167	-0.0222	-0.1131	0.1334	-0.1936	0.0040
9.	Test weight (g)	-0.0116	-0.0109	-0.0276	-0.0033	-0.0050	0.0158	0.0180	0.0152	-0.0407	-0.0106	0.0102	-0.0113	0.0001	-0.0083	-0.0141	0.0204
10.	Biological yield (g)	0.3558	0.3831	0.4829	-0.4091	0.2544	-0.3669	-0.3776	-0.1897	0.1993	0.7683	-0.0100	0.2010	0.1540	-0.3209	-0.1889	0.7569
11.	Harvest index	-0.3214	-0.2873	-0.1806	-0.2396	-0.0736	-0.0851	-0.0430	0.1811	-0.1647	-0.0085	0.6540	-0.0292	0.0781	-0.1348	-0.1867	0.6420
12.	Unpolished seed (Zn)	0.0002	0.0000	0.0021	-0.0001	-0.0014	-0.0026	-0.0025	-0.0004	0.0019	0.0017	-0.0003	0.0067	0.0049	-0.0040	-0.0013	0.1686
13.	Polished seed (Zn)	-0.0033	-0.0039	0.0050	0.0002	-0.0084	-0.0118	-0.0124	-0.0066	-0.0001	0.0049	0.0029	0.0181	0.0247	-0.0195	-0.0057	0.2343
14.	Unpolished seed (Fe)	-0.0038	-0.0040	-0.0115	0.0090	-0.0005	0.0128	0.0149	0.0131	0.0084	-0.0173	-0.0086	-0.0251	-0.0328	0.0415	0.0064	-0.4585
15.	Polished seed (Fe)	0.0012	0.0009	0.0014	0.0026	0.0019	0.0025	0.0017	-0.0026	0.0020	-0.0014	-0.0016	-0.0011	-0.0013	0.0009	0.0057	-0.3735

Residual effect = 0.0300, Bold value showed direct effect on grain yield of rice

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