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Association studies between resistance to brown spot disease and yield related traits in rice

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Abstract
Cochliobolus miyabeanus (Anamorph: *Bipolaris oryzae* (Breda de Haan) Shoemaker, 1959 (Synonyms: *Helminthosporium oryzae*) is the causal organism for brown spot disease in rice and is responsible for significant economic losses as it results in loss of both grain quality and yield. Though, it is a minor disease in most of the parts of the world but the historical famines like Krishna Godaveri Delta famine and Bengal famines and huge crop losses in a number of incidences as in Guyana and Nigeria renders. It as a potential threat to rice crop and adverted the requirement of efficient, sustainable and economical strategies to cope with the pathogen. In this context, availability of resistant sources against the pathogen is a noteworthy alternative for disease management. Keeping this in view the present investigation was undertaken to study association between resistance to brown spot disease and yield related traits in rice via correlation and path analysis to identify high yielding resistant lines for brown spot disease in rice. In this study disease resistance expressed in terms of AUDPC (Area under the disease Progress Curve) showed negative correlation with yield and yield attributing traits and direct negative effect on yield. Thus, AUDPC could be used as a selection parameter of developing improved cultivars with higher grain yield and lower susceptibility towards the brown spot pathogen.

Keywords: Rice, AUDPC, correlation, *Bipolaris oryzae*

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food crop for more than half of the global population [1]. Average daily intake of rice provides 20-80 percent of dietary energy and 12-17 percent dietary proteins for Asians. It is a semi-aquatic annual grass native to tropical Asia. In India it has the largest area under cultivation and highest production among grain crop. In India rice is cultivated over an area of 43.19 million hectares producing 115.63 million tons of grains with average productivity of 26.77 Q /ha (3rd Adv. Est. 2018-19, Annual Report, DAC&FW). A well-managed crop with adequate irrigation, nutrient and crop health management yield average 2-3 t/ha. However, its yield potential is adversely affected by diseases, insect-pest and weeds. Among these, fungal diseases especially brown spot is a serious threat to the standing crop in context of rice production and productivity. The disease is caused by *Cochliobolus miyabeanus* [2] (Anamorph: *Bipolaris oryzae* (Breda de Haan) Shoemaker, 1959 (Synonyms: *Helminthosporium oryzae*) and is responsible for significant economic losses as it results in loss of both grain quality and yield. The pathogen infects the coleoptiles (causing blighting), leaves (forming oval, dark brown to purplish-brown spots ultimately killing the leaf) and even the seeds which are badly damaged at the flowering to milk stages than at the soft dough or mature stages [3]. The disease is of great importance on ground of economic significance as well as historical context and reported to be associated with two major epidemics in India, the first in 1918–19, in the Krishna Godavari delta and the second, the Great Bengal Famine during 1942 [4]. These epidemics were a results of heavy crop loss upto 90% [4, 5] in associated area due to large scale devastation by the pathogen in absence of suitable management practises. Among a number of alternatives, use of resistant sources against the pathogen is considered to be most sustainable and economical method of disease management. However, it is often reported that the field resistance in commercial varieties of a crop is not durable and liable for breakdown on account of fast evolving pathogen like *Cochliobolus miyabeanus*. To cope with this, it is imperative that the resistant sources should be diverse and should be strategically employed to prevent the speedy spread of pathogen or to trap it in limited cropped area. In this regard, the available germplasm resources should be screened against the pathogen and evaluated for higher yield characteristics to identify high yielding resistance lines that could be used in future breeding

programmes. Yield being a complex trait is governed by a large number of genes and it depends on plant genotype and its interaction with environment [6]. The influence of each trait on yield could be known through correlation studies with a view to determine the extent and nature of relationships prevailing among yield and yield attributing traits [7]. Path analysis is a multivariate analysis, which deals with a closed system of variables, which are linearly related. This method is employed to disentangle the direct and indirect influences of components of grain yield. The path coefficient quantifies the inter relationship among different components and their direct and indirect effect on grain yield. Information on association of characters, direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process. Correlation and path analysis establish the extent of association between yield and other variables bring out relative importance of their direct and indirect effects, thus giving an obvious understanding of their association with grain yield. Keeping these in view, the present investigation is carried out with the objective of studying the associations between resistance to brown spot disease and yield attributing characters in rice.

Materials and Methods
The present experiment was carried out at Rice Research Farm, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar on 300 genotypes of rice along with three check varieties namely Rasi (resistant check), IR-64 (moderately resistant check) and Pankaj (susceptible check) in augmented design. The experimental plot was subdivided into 12 blocks with replicated checks and unreplicated test genotypes. Thirty days old seedlings were transplanted 20cm apart between rows and 15cm within the row. All the recommended package of practices was followed along with necessary prophylactic plant protection measures to raise a good crop. The fungal suspension was used for spraying the crop for artificial inoculation in controlled conditions while in field the susceptible check was used as infector row. Moreover, the experimental location is a hotspot for brown spot infection. Disease scoring was done visually on individual plants following Standard Evaluation System for Rice (SES), 2013 for brown spot. Data on yield and yield attributing traits were recorded and subjected to statistical analysis for studying the association between disease resistance and yield. The genotypic and phenotypic correlation coefficients between variables under study was calculated using the formula as suggested by Johnson *et.al.* (1955) [8]. Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959) [9].

Results and Discussion
Correlation Analysis
Association between two or more traits in terms of degree and direction can be defined by correlation. In the present study genotypic (above diagonal) and phenotypic (below diagonal) correlation among different characters was studied and their correlation matrix is presented in table 4.1. AUDPC showed significant and positive genotypic and phenotypic correlation with days to 50% flowering (0.93 & 0.80), days to physiological maturity (0.96 & 0.83), plant height (0.87 & 0.65) while significant but negative correlation with panicle length (0.95 & 0.80) number of effective tillers per plant (0.67 & 0.51), number of grains per panicle (0.73 & 0.57), test weight (0.89 & 0.73) and yield (0.48 & 0.37).

Table 1: Estimates of Genotypic and Phenotypic Correlation co-efficient between yield and its related trait

Traits	Days to fifty percent flowering	Days to physiological maturity	Plant height (cm)	Panicle length (cm)	Effective tillers per plant	Grains per panicle	Test weight (g)	AUDPC	Grain yield per plant (g)
Days to fifty percent flowering	1.00	0.99***	0.92***	0.88***	-0.52***	-0.59***	-0.85***	0.93***	-0.31**
Days to physiological maturity	0.99***	1.00	0.92***	0.91***	-0.57***	-0.65***	-0.88***	0.96***	-0.37**
Plant height (cm)	0.80 ***	0.80***	1.00	0.83***	-0.47***	-0.48***	-0.76***	0.87***	-0.22**
Panicle length (cm)	0.78***	0.82***	0.71***	1.00	0.62***	-0.68***	-0.83***	-0.95***	0.43***
Effective tillers per plant	-0.43***	-0.46***	-0.34**	0.52***	1.00	0.85***	0.80***	-0.67***	0.90***
Grains per panicle	-0.52***	-0.57***	-0.40***	-0.57***	0.65***	1.00	0.88***	-0.73***	0.92***
Test weight (g)	-0.72***	-0.75***	-0.57***	-0.71***	0.60***	0.70***	1.00	-0.89***	0.72***
AUDPC	0.80***	0.83***	0.65***	-0.80***	-0.51***	-0.57***	-0.73***	1.00	-0.48***
Grain yield per plant (g)	-0.27**	-0.32**	-0.19**	0.37**	0.79***	0.83***	0.65***	-0.37**	1.00

*, **, ***: Significant at 5%, 1% and 0.1% probability levels, respectively.

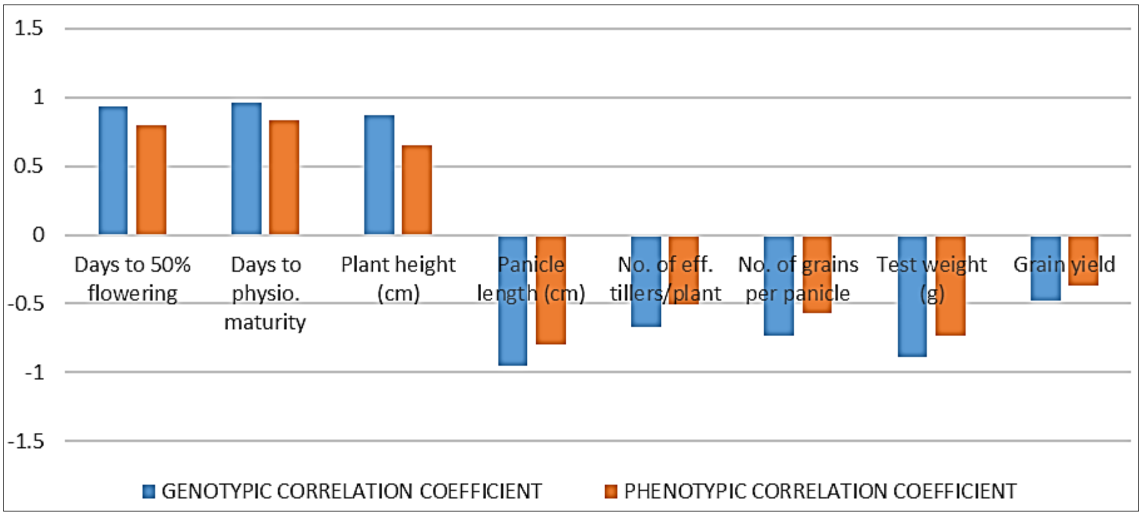

Fig 1: Correlation of disease resistance (in terms of AUDPC) with other morphological triats under study

Path analysis

Phenotypic Path Matrix

In phenotypic path matrix (table 4.2) highest direct positive effect on grain yield was shown by number of grains per panicle (0.59) followed by number of effective tillers per plant (0.45; similar to Singh *et al.*, 2018) [10], test weight (0.36) and days to 50% flowering (0.05) while the highest direct negative effect was shown by days to physiological maturity (-0.36) followed by AUDPC (-0.13), panicle length (-0.09) and plant height (-0.013; similar to Kumar *et al.*, 2018) [11]. The highest positive indirect effect was shown by number of grains per panicle (similar to Prakash *et al.*, 2018) [12]. via test weight (0.42) while the lowest positive indirect effect was shown by days to 50% flowering via number of effective tillers per plant (0.02). Further, the highest negative indirect effect on grain yield was shown by days to physiological maturity via days to 50% flowering (-0.35) while the lowest negative indirect effect was shown by plant height via number of effective tillers per plant (-0.004).

Table 2: Estimates of Phenotypic(P) and Genotypic (G)matrix of direct and indirect effects on grain yield per plant

Traits		Days to fifty percent flowering	Days to physiological maturity	Plant height (cm)	Panicle length (cm)	Effective tillers per plant	Grains per panicle	Test weight (g)	AUDPC	Correlation with Grain yield per plant (g)
Days to fifty percent flowering	P	0.05	0.05	0.04	0.04	0.02	0.03	0.04	0.04	-0.27
	G	4.10	4.08	3.78	3.61	2.15	2.44	3.47	3.84	-0.31
Days to physiological maturity	P	-0.35	-0.36	-0.28	-0.29	-0.16	-0.20	-0.27	-0.29	-0.32
	G	-5.74	-5.76	-5.31	-5.24	-3.27	-3.76	-5.07	-5.52	-0.37
Plant height (cm)	P	-0.01	-0.01	-0.013	-0.01	-0.004	-0.005	-0.007	-0.008	-0.19
	G	-0.19	-0.19	-0.21	-0.17	-0.10	-0.10	-0.16	-0.18	-0.22
Panicle length (cm)	P	-0.07	-0.08	-0.07	-0.09	-0.05	-0.05	-0.07	-0.07	0.37
	G	-0.16	-0.17	-0.15	-0.18	-0.11	-0.12	-0.15	-0.17	0.43
Effective tillers per plant	P	0.19	0.20	0.15	0.23	0.45	0.29	0.27	0.23	0.79
	G	0.10	0.11	0.09	0.12	0.19	0.16	0.15	0.13	0.90
Grains per panicle	P	0.30	0.34	0.24	0.34	0.38	0.59	0.42	0.34	0.83
	G	0.62	0.67	0.49	0.70	0.88	1.04	0.91	0.75	0.92
Test weight (g)	P	0.26	0.27	0.21	0.26	0.22	0.25	0.36	0.26	0.65
	G	0.49	0.51	0.44	0.48	0.46	0.51	0.57	0.51	0.72
AUDPC	P	-0.10	-0.11	-0.08	-0.10	-0.07	-0.07	-0.09	-0.13	-0.37
	G	-0.39	-0.40	-0.36	-0.39	-0.28	-0.30	-0.37	-0.41	-0.48

Bold diagonal values indicates the direct effect; R^2 P = 0.8989 RESIDUAL EFFECT = 0.3179; R^2 G = 1.0061 RESIDUAL EFFECT =0.0781

Genotypic Path Matrix

Genotypic path matrix (table 4.2) showed highest direct positive effect was shown by days to 50% flowering (4.10; similar to Ratna *et al.*, 2015) [13] followed by number of grains per panicle (1.04), test weight (0.57) and number of effective tillers per plant (0.19) while days to physiological maturity (-5.76), AUDPC (-0.41), plant height (-0.21) and panicle length (-0.18) showed direct negative effect. Bhadru *et al.*, (2011) [14] and Chandra *et al.*, (2009) [15] reported positive direct effect of days to 50% flowering and Eidi kohnaki *et al.*, (2013) [16] and Kiani and Nematzadeh (2012) [17] found the positive direct effect and significant positive correlation coefficient between productive tillers/plant and grain yield/plant which also supported the present finding. Thus, number of grains per panicle and test weight were identified as major contributors toward yield enhancement and can be used as a major selection in direct selection for identifying high yielding resistant lines. The highest positive indirect effect on yield (similar to Jaiswal *et al.*, 2019) [7]) was shown by days to 50% flowering via days to physiological maturity (4.08) while the lowest positive indirect effect on yield was shown by number of effective tillers per plant via plant height (0.09). The highest indirect negative effect was shown by days to physiological maturity via days to 50% flowering (-5.74) while the lowest indirect negative effect was shown by panicle length via number of effective tillers per plant (-0.11).

Conclusion

In this study, disease resistance expressed in terms of AUDPC showed negative correlation with yield and yield attributing traits. Further it showed direct negative effect on yield. It also showed indirect negative effect on yield via other traits under study. Thus, AUDPC could be used as a selection parameter of developing improved cultivars with higher grain yield and lower susceptibility towards the brown spot pathogen. The salient findings of this study establishes a negative association between AUDPC and yield. Hence, a line with lower AUDPC value would be expected to be resistant to the pathogen and have higher yield.

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Competing interests

Authors have declared that no competing interests exist.

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