Plant Archives Vol. 24, No. 2, 2024 pp. 1967-1973 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.282

CORRELATION AND PATH ANALYSIS OF ASSOCIATION AMONG YIELD AND YIELD CONTRIBUTING TRAITS UNDER AEROBIC CONDITION IN F_2 POPULATION OF RICE

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(Date of Receiving-01-06-2024; Date of Acceptance-15-08-2024)

ABSTRACT

The present investigation was conducted to assess association between grain yield and yield component traits in F_2 population of 236 lines of cross involving DRR Dhan 60 × Pusa 44 (NIL) to establish a selection criterion for developing superior genotypes. Correlation studiesrevealed positive and significant association of grain yield with the yield component traits, namely, number of tillers per plant, number of productive tillers per plant and thousand grain weight indicating scope for their simultaneous improvement with grain yield per plant. While DFF shows negative and significant correlation with yield. High direct effects (0.30-0.99) were noticed for number of productive tillers per plant, spikelets per panicle and spikelet sterility on grain yield per plant. These traits had also recorded positive and significant association with grain yield per plant, indicating the effectiveness of direct phenotypic selection for the trait in improvement of grain yield per plant.

Key words : Path coefficient, Correlation analysis, Selection, Rice.

Introduction

Over half of the world's population depends on rice (*Oryza sativa* L.), which is one of the most staple foods and an excellent source for all generations (Bouman, 2007). Additionally, it is a good source of calories, providing between 50–80% of a person's daily caloric intake (Seck *et al.*, 2012; Futakuchi *et al.*, 2013). Abiotic and biotic factors have a negative impact on the productivity of rice-growing regions worldwide. Environmental stressors are thought to be the cause of around 200 million tonnes of rice loss annually (Moonmoon and Islam, 2017). A number of factors, such as the water deficita significant consideration given the scarcity of water in many regions worldwide control the amount of rice produced (Nirubana *et al.*, 2019). Another way of growing rice is essential due to the depletion of water resources and work force scarcity in agriculture. This necessitates a shift in cultivation practice from transplanted to direct-seeded rice (DSR).

Because DSR can cut methane emissions, save labour costs by up to 11–66%, save water by up to 35–54%, and boost farmers' net profits, it is a promising substitute technology for sustainable rice cultivation (Chakraborty *et al.*, 2017). The technique of starting a rice crop from seeds placed directly in the field as opposed to transplanting is known as "direct-seeding." Following the completion of germination and seedling establishment, the crop may be successively flooded and water regimes can be maintained, much like with transplanted rice. Alternatively, the crop can continue to be rainfed, with conditions in the upper layers of soil varying between aerobic and nonaerobic. Direct seeding is the oldest method of rice establishment and prior to the late 1950s, direct seeding was the major method used in developing countries (Grigg, 1974).

The ideal generation for imposing selection is one that exhibits significant levels of segregation and recombination (Thirugnanakumar *et al*., 2011). A crucial component is the degree of connection between the qualities, particularly for complicated and economically significant variables like yield. A statistical tool for determining the strength of the association between two or more variables is the correlation coefficient. The examination of path coefficients aids in the creation of suitable breeding protocols for the evolution of genotypes with high yields. Research on the relationship between yield and genotype components in rice may make it easier to realise the crop's potential and assist satisfy the need for a high grain yield and a supply of nutritious food. In order to determine if it would be feasible to pick two or more features jointly rather than choosing the secondary traits as genetic gains for the primary traits under discussion, it is crucial to examine the link between the quantitative traits. Using a route chart based on experimental data, path analysis is a statistical technique that has been used to arrange and display causal links between response and prediction variables (Samonte *et al*., 1998; Esmail, 2001).

The complicated qualities linked with the quantity of connected traits of each component make up yield and its component traits (Ikeda *et al*., 2013; Zhou *et al*., 2018). Often this is dependent on its relationship to the grain yield, which makes the relationship ineffective. According to Singh *et al*. (1985), loading the route parameter facilitates the division of the correlation into direct and indirect effects. Thus, route analysis which has been thoroughly studied is required to split the correlation coefficient into its direct and indirect impact components. Agricultural path analysis was employed by plant breeders to determine beneficial traits that might be utilised as selection criteria to increase crop yields (Milligan *et al*., 1990). The objective of the current investigation was to ascertain correlation and path coefficients in rice F_2 segregating generation of a cross involving DRR Dhan 60 × Pusa 44 (NIL) under DSR conditions to create selection criteria that might aid in the development of high producing genotypes.

Materials and Methods

The present investigation was carried out at Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad. The crossing was performed between DRR Dhan 60 (Recurrent parent) and Pusa 44(NIL) (Donor parent) which is having herbicide tolerance to imazythapyr during *Rabi*, 2021-22 at crossing block in IIRR.A total of 236 F_2 segregants of DRR Dhan 60 × Pusa 44 (NIL) were raised during *Kharif*, 2023 Recommended agronomic practices were followed throughout the crop growth period.

Data was recorded in all the segregants for Days to 50% flowering, Plant height (cm), Number of tillers per plant, Flag leaf length (cm), Flag leaf width (cm), Number of panicles per plant, Panicle length (cm), Number of spikelets per panicle, Number of filled grains per panicle, Number of chaffy grains per panicle, Spikelet fertility (%), Spikelet sterility (%),1000-grain weight (gm) and

Table 1 : Details of the parents of the intra-specific cross studied in the present investigation.

S. no.	Parent	Details
1.	DRR Dhan 60 (Improved sambhamahsuri × Kasalath)	DRR Dhan 60 is released from Indian Institute of Rice Research (ICAR-IIRR). It is having medium slender grain type with the duration of 120-125 days yielding 4.8 – 5.19 tonnes/ha and it is having BLB resistance (*xa5, xa13* and *Xa21*) and low P tolerance due to presence of *Pup 1* QTLdeveloped through marker assisted selection.
2.	Pusa 44 (NIL)	It is a Near isogenic line of PUSA44 (a high yielding short duration variety and possess resistance to blast (*Pi 54*) and bacterial leaf blight having long bold grains) developed with a gene *AHAS* (Aceto hydroxy acid synthase) leading to herbicide (imazethapyr) tolerance.

Table 2 : Details of gene specific markers used for hybridity confirmation in the present study.

Molecular Markers	Linked gene	Primer sequence	Chromosome Location	Reference
RM 6844	*AHAS*	F: AGTCCAAGAAAGGCACGAGAGG R:CTGCATCGAAGAAGAAGAAGAAGC	2	Shoba *et al*. (2017)
Pi 54 MAS	*Pi 54*	F: CAATCTCCAAAGTTTTCAGG R: GCTTCAATCACTGCTAGACC	11	Ramkumar *et al.* (2015)

Grain yield per plant (gm). Correlation coefficients were calculated using the formula given by Singh and Choudhary (1977). The direct and indirect effects of different components on grain yield were estimated by path coefficient analysis as suggested by Dewey and Lu (1959). 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). The R software version 4.4.1 was used for all statistical analysis and for illustrating the association plot.

Results and Discussion

Correlation studies provide an effective basis of phenotypic selection in plant populations, whereas Path Coefficient analysis evaluates the participation of each component to the resultant variable directly as well as indirectly (Chamundeswari *et al.*, 2014). The results on character associations between yield and yield components are presented in Table 3 and Fig. 1. A perusal of these results revealed positive and significant association ($p \leq 0.01$) of grain yield with the yield component traits, namely, number of tillers per plant (r=0.95***), number of productive tillers per plant (r=0.97***) and thousand grain weight (r=0.36***) indicating scope for their simultaneous improvement with grain yield per plant. The results are in agreement with the reports of Fathima *et al.* (2021) and Kishore *et al.* (2015) for productive tillers per plant and thousand grain weight. Further positive and significant correlation of number of tillers per plant (r=0.32***) and number of productive tillers per plant (r=0.33***) and also these two traits with thousand grain weight. Panicle length showed positive and significant correlation with number of spikelets per panicle (0.76***), number of filled grains per panicle (r=0.74***), spikelet fertility (r=0.41***). The same result was observed by Shankar *et al.* (2016), Gopikannan and Ganesh (2013) and Lakshmi *et al.* (2017). Days to first flowering had negative and significant inter correlation with number of tillers per plant (r=-0.38***), number of productive tillers per plant (r=-0.37***) and grain yield per plant (r=-0.38***). According to the association between the variables under investigation, a short heading period will provide plants more opportunity to produce more panicles per plant and thousand 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. These results agree with the results of Kumar *et al.* (2011), Karim *et al.* (2014), Kumar *et al.* (2017), Bhutta

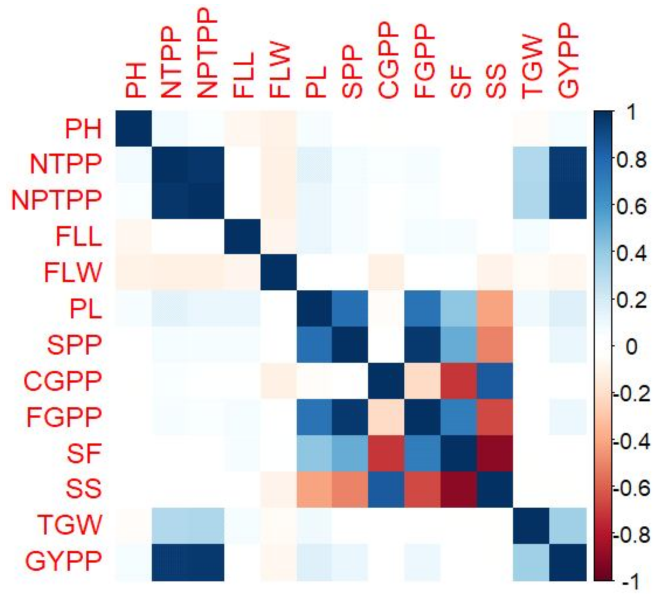

Fig. 1 : Correlation matrix of yield components for grain yield and yield components in F_2 derivatives of DRR Dhan 60 × Pusa 44 (NIL) intra-specific cross.

et al. (2019) and Panda *et al.* (2019). The increasing share of crop improvements owing to current understanding about trait correlations aids in the optimal selection procedure (Goncalves *et al.*, 2017), which was correlated positively to yield traits. Panicle length with spikelet sterility (-0.41***) also showed negative and significant correlation. Similar results were reported by Shankar *et al.* (2016) and Priyanka *et al.* (2019). Such negative correlations are inferred to occur when one component gets advantage over the other, primarily due to competition for a common possibility, such as nutrient supply. Hence, balanced selection needs to be adopted while effecting simultaneous improvement for these traits (Sameera and Srinivas, 2016) (Table 3, 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. The results of my investigation suggest that number of tillers per plant, number of productive tillers per plant and 1000 grain weight are important yield-related traits and could be considered as selection criteria to increase rice grain yield.

The total effect in path analysis represents correlation value between targeted trait and grain yield, the direct effect of days to heading reflects the real relationship with grain yield. The results on path analysis of yield component traits on grain yield per plant are presented in Table 5. A perusal of the results revealed a residual effect of 0.059 indicating that variables studied in the present investigation explained about 94.10 of variability for grain

Table 3 : Genotypic correlation coefficient among the grain yield and yield characters in F_2 generation.

	DFF	PH	NTPP	NPTPP	FLL	FLW	PL	SPP	CGPP	FGPP	SF	SS	TGW	GYPP
DFF	**1*** **	0.01	-0.38***	-0.37***	0.11	0.05	-0.1	-0.11	0.01	-0.12	-0.13	0.07	-0.19**	-0.38***
PH		**1*** **	0.09	0.06	-0.07	-0.1	0.06	0.01	-0.03	0.01	0.02	-0.01	-0.05	0.07
NTPP			**1*** **	0.98***	0.01	-0.11	0.14	0.08	0.05	0.06	-0.01	0.01	0.32***	0.95***
NPTPP				**1*** **	-0.01	-0.11	0.11	0.07	0.03	0.05	-0.01	0.01	0.33***	0.97***
FLL					**1*** **	-0.09	0.11	0.06	0.03	0.07	0.07	-0.02	0.08	-0.01
FLW						**1*** **	0.02	0.01	-0.11	0.01	0.04	-0.1	-0.06	-0.08
PL							**1*** **	0.76***	-0.05	0.74***	0.41***	-0.41***	0.1	0.16
SPP								**1*** **	-0.01	0.97***	0.51***	-0.5***	0.02	0.11
CGPP									**1*** **	-0.22	-0.71***	0.85***	-0.01	0.02
FGPP										**1*** **	0.71***	-0.66***	0.01	0.1
SF											**1*** **	-0.9***	-0.02	0.02
SS												**1*** **	-0.02	-0.03
TGW													**1*** **	0.36***
GYPP														**1*** **

***significant at 0.1 % level, ** significant at 1% level.

DFF- Days to 50% flowering, **PH**-Plant height, **NTPP**-No of tillers per plant, **NPTPP**-No of productive tillers per plant, **FLL**-Flag leaf length, **FLW**-Flag leaf width, **PL**- Panicle length, **SPP**-Spikelet's per panicle, **CGPP**-Chaffy grains per panicle, **FGPP**-Filled grains per panicle, **SF**-Spikelet fertility, **SS**-Spikelet sterility, **TGW**-Thousand grain weight, **GYPP**-Grain yield per plant.

yield per plant and therefore other attributes, besides the characters studied are contributing for grain yield per plant. This can be attributed to the fact that analysis in this study was carried out with a F_2 population, which was an early generation, segregating population.

Results of path analysis showed that the direct effect of studied traits on grain yield was positive, strong for most of the traits *viz.*, number of productive tillers per plant (0.9692), spikelets per panicle (0.7377) and neglected via each trait thousand grain weight (0.0410), plant height (0.0133), flag leaf width (0.0249), panicle length (0.0331), while negative and neglected for each of days to 50% flowering (-0.0138) and filled grains per panicle (-0.6871). These results are in accordance with the inferences of Kishore *et al.* (2015), Priyanka *et al.* (2019) and Lakshmi *et al.* (2017). These traits had also recorded positive and significant association with grain yield per plant, indicating the effectiveness of direct phenotypic selection for the trait in improvement of grain yield per plant. Although, filled grains per panicle exhibited high negative direct effect, its positive correlation and indirect causal factors are to be considered simultaneously for selection to improve yield (Table 4).

The indirect effect of days to 50% flowering on grain yield was negative via other studied traits and strong via number of productive tillers per plant (-0.3586) and neglected via each of flag leaf length (-0.0002), panicle length (-0.0033), spikelets per panicle (-0.0812), thousand grain weight (-0.0078), while positive and neglected via each of plant height (0.0001), number of tillers per plant (0.0098), flag leaf width (0.0012), filled grains number per panicle (0.0825) (Table 4). Here, the indirect effect of days to 50% flowering via other traits especially number of productive tillers per plant the n number of spikelets per panicle were the causes of the negative correlation with the grain yield per plant.

The indirect effect of plant height on grain yield via studied traits was all neglected, negative via each of the days to 50% flowering (-0.0001), number of tillers per plant (-0.0023) and number of filled grain per panicle (-0.0069), thousand grain weight (-0.0021). While positive and neglected via panicle length (0.0020), number of productive tillers per plant (0.0582) (Table 4). Plant height showed positive and non-significant correlation with grain

Table 4 : Path coefficients of the yield and yield contributing traits on single plant yield in F_2 generation.

	DFF	PH	NTPP	NPTPP	FLL	FLW	PL	SPP	CGPP	FGPP	SF	SS	TGW	GYPP
DFF	**-0.0138**	0.0001	0.0098	-0.3586	-0.0002	0.0012	-0.0033	-0.0812	0.0001	0.0825	-0.0373	0.0285	-0.0078	**-0.38*****
PH	-0.0001	**0.0133**	-0.0023	0.0582	0.0001	-0.0025	0.0020	0.0000	0.0087	-0.0069	0.0057	-0.0041	-0.0021	**0.0700**
NTPP	0.0052	0.0012	**-0.0259**	0.9498	0.0001	-0.0027	0.0046	0.0590	-0.0144	-0.0412	-0.0029	0.0041	0.0131	**0.95*****
NPTPP	0.0051	0.0008	-0.0253	**0.9692**	0.0000	-0.0027	0.0036	0.0516	-0.0087	-0.0344	-0.0029	0.0001	0.0135	**0.97*****
FLL	-0.0015	-0.0009	0.0001	-0.0097	**-0.0020**	-0.0022	0.0036	0.0443	-0.0087	-0.0481	0.0201	-0.0081	0.0033	**-0.0100**
FLW	-0.0007	-0.0013	0.0028	-0.1066	0.0002	**0.0249**	0.0007	0.0001	0.0318	0.0000	0.0115	-0.0407	-0.0025	**-0.0800**
PL	0.0014	0.0008	-0.0036	0.1066	-0.0002	0.0005	**0.0331**	0.5607	0.0144	-0.5084	0.1175	-0.1669	0.0041	**0.1600**
SPP	0.0015	0.0001	-0.0021	0.0678	-0.0001	0.0001	0.0252	**0.7377**	0.0029	-0.6665	0.1462	-0.2035	0.0008	**0.1100**
CGPP	0.0001	-0.0004	-0.0013	0.0291	-0.0001	-0.0027	-0.0017	-0.0074	**-0.2887**	0.1512	-0.2035	0.3460	-0.0004	**0.0200**
FGPP	0.0017	0.0001	-0.0016	0.0485	-0.0001	0.0001	0.0245	0.7156	0.0635	**-0.6871**	0.2035	-0.2686	0.0001	**0.1000**
SF	0.0018	0.0003	0.0003	-0.0097	-0.0001	0.0010	0.0136	0.3762	0.2050	-0.4878	**0.2867**	-0.3663	-0.0008	**0.0200**
SS	-0.0010	-0.0001	-0.0003	0.0001	0.0001	-0.0025	-0.0136	-0.3689	-0.2454	0.4535	-0.2580	**0.4070**	-0.0008	**-0.0300**
TGW	0.0026	-0.0007	-0.0083	0.3198	-0.0002	-0.0015	0.0033	0.0148	0.0029	0.0001	-0.0057	-0.0081	**0.0410**	**0.36*****

Residual effect:0.0599; The values in the diagonal box (bold) are direct effects

DFF- Days to 50% flowering, **PH**-Plant height, **NTPP**-No of tillers per plant, **NPTPP**-No of productive tillers per plant, **FLL**-Flag leaf length, **FLW**-Flag leaf width, **PL**- Panicle length, **SPP**-Spikelet's per panicle, **CGPP**-Chaffy grains per panicle, **FGPP**-Filled grains per panicle, **SF**-Spikelet fertility, **SS**-Spikelet sterility, **TGW**-Thousand grain weight, **GYPP**- grain yield per plant.

yield mainly due to number of productive tillers per plant. These results are in agreement with the results of Herawati *et al*. (2019), which indicated that direct effect of plant height was positive and neglected (0.0133).

The indirect effect of panicle length on grain yield via each of the days to 50% flowering and plant height was neglected and positive (0.0014, 0.0008) respectively, but neglected and positive via thousand grain weight (0.0041) and it was positive and weak via both of number of productive tillers per plant (0.1066), while strong and negative via number of filled grain per panicle (-0.5084) (Table 4). The direct effect of panicle length was neglected, mainly due to its strong negative indirect effect via number of filled grains per panicle is sole reason for the weak and positive total effect. Similar results were reported by Harish *et al*. (2019)

The indirect effect of number of productive tillers per plant on grain yield was neglected and negative via number of filled grain per panicle (-0.0344) and also neglected, but positive via panicle length (0.0036), thousand grain weight (0.0135), plant height (0.0008), days to 50% flowering (0.0051), panicle length (0.0036) (Table 4). 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, which their direct effects reflected about half or more of the total effect on grain yield, in addition to their indirect effects via days to 50% flowering and panicle length.

The indirect effect of number of filled grain per panicle on grain yield was all neglected and positive via each of the days to 50% flowering (0.0017), plant height (0.0001), panicle length (0.0245), number of productive tillers per plant (0.0485), thousand grain weight (0.0001) (Table 4). These results are in agreement with Hairmansis *et al*. (2013) and Sarwar *et al*. (2015)

The indirect effect of thousand grain weight on grain yield was negatively neglected via plant height (-0.0007), also neglected but positive via each of the days to 50% flowering (0.0026), panicle length (0.0033) and also number of filled grain per panicle (0.0001), whereas it was medium and positive via number of productive tillers per plant (0.3198) (Table 4). These are in agreement with results reported by Harish *et al*. (2019).

Indirect effects are inferred to be the cause of

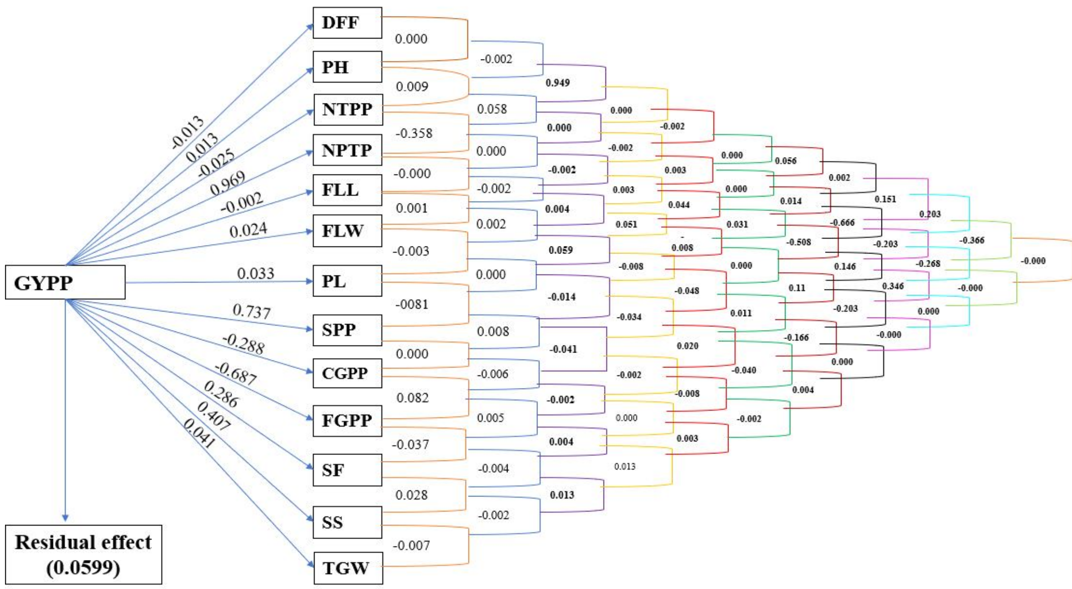

Fig. 2 : Path diagram for yield and yield contributing traits.

correlation with grain yield per plant for all the above traits, indicating the need for consideration of the indirect causal factors also simultaneously for selection aimed at improvement of grain yield. Number of productive tillers per plant, number of tillers per plant had high positive indirect with grain yield per plant. Panicle length had high positive indirect with spikelets per panicle. Spikelets per panicle had positive indirect with filled grains per panicle. Thousand grain weight showed high positive indirect effect with number of productive tillers per plant. Similar results were reported by Priyanka *et al*. (2019) and Revathi *et al*. (2016).

Hence selection based on productive tillers per plant and spikelets per panicle would be most effective for grain yield improvement in this population as these two traits exerted the highest positive direct effect on grain yield.

Conclusion

The three traits *viz*., number of tillers per plant, number of productive tillers per plant and thousand grain weight 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. Among these traits, number of productive tillers per plant recorded high positive direct effect coupled with significant and positive correlation with grain yield per plant. Hence, the trait, number of productive tillers per plant is identified as effective selection criterion for effecting grain yield improvement. 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.

Acknowledgement

The financial support provided in the form of UGC JRF and SRF Fellowships by the Department of Higher Education, Ministry of Education, New Delhi, Government of India, through NTA reference No: 220510411256. Dated: 15th December, 2022 to the first and corresponding author, for pursuing full time Doctoral research (Ph. D.) program of Acharya N G Ranga Agricultural University, Lam, Guntur, at S.V. Agricultural College, Tirupathi, Andhra Pradesh and ICAR – IIRR, Hyderabad, Telangana, India is acknowledged.

References

Bhutta, M.A., Munir S.A.N.A., Qureshi M.K., Shahzad A.N., Aslam Kashif, Manzoor H. and Shabir G. (2019). Correlation and path analysis of morphological parameters contributing to yield in rice (*Oryza sativa*) under drought stress. *Pak J Bot.*, **51(1)**, 73-80.

Bouman, B. (2007). Rice: feeding the billions. In: Molden, D. (ed). Water for food, water for life: A comprehensive assessment of water management in agriculture, 1st edn. Earthscan/ International Water Management Institute, London, pp 515–549.

Chakraborty, Debashis *et al*. (2017). A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production. *Scientific Reports*, **7.1**, 9342.

Chamundeswari, N., Satyanarayana P.V., Manasa Y., Umasundari P., Ravikumar B., Girijarani M. and Vishnuvardhan K. (2014). Correlation and path analysis for yield and quality traits in direct seeded rice (*Oryza sativa* L.). *Life Sci. Int. Res. J.*, **1(1)**, 2347-8691.

Dewey, D.I. and Lu K.H. (1959). A Correlation and Path-Coefficient

Analysis of Components of Crested Wheatgrass Seed Production. *Agron. J*., **51**, 515-518.

Esmail, R.M. (2001). Correlation and path coefficient analysis of some quantitative traits with grain yield in bread wheat (*Triticum aestivum* L.).

Fathima, M.A., Geetha S., Amudha K. and Uma D. (2021). Genetic variability, frequency distribution and association analysis in ADT (R) 48 x Kavuni derived F_2 population of rice (*Oryza sativa* L.). *Elect. J. Plant Breed*., **12(3)**, 659-666.

Futakuchi, K., Manful J. and Sakurai T. (2013). Improving grain quality of locally produced rice in Africa. In : *Realizing Africa's rice promise* (pp. 311-323).

Goncalves, D.D.L., Barelli M.A.A., Oliveira T.C.D., Santos P.R.J. D., Silva C.R.D., Poletine J.P. and Neves L.G. (2017). Genetic correlation and path analysis of common bean collected from Caceres Mato Grosso State, Brazil. *Ciencia Rural*, **47**, e20160815.

Gopikannan, M. and Ganesh S.K. (2013). Inter-Relationship and Path Analysis in Rice (*Oryza sativa* L.) under Sodicity. *Indian J. Sci. Technol.,* **6(9)**, 5223 – 5227.

Grigg, D.E. (1974). 'The Agricultural Systems of the World: An Evolutionary Approach. Cambridge University Press, Cambridge, U.K.

Hairmansis, A., Kustianto B. and Suwarno S. (2010). Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. *Indonesian J. Agricult. Sci*., **11(1)**, 11-15.

Herawati, R. (2019). Genetic Analysis of Grain Yield of F_4 Populations for Developing New Type of Upland Rice. *SABRAO J. Breed. Gen*., **51(1)**.

Ikeda, M., Miura K., Aya K., Kitano H. and Matsuoka M. (2013). Genes offering the potential for designing yield-related traits in rice. *Curr. Opin. Plant Biol*., **16(2)**, 213-220.

Karim, D., Siddique M.N.A., Sarkar U., Hasnat Z. and Sultana J. (2014). Phenotypic and genotypic correlation co-efficient of quantitative characters and character association of aromatic rice. *J. Biosci. Agricult. Res.*, **1(1)**, 34-46.

Kishore, N.S., Srinivas T., Nagabhushanam U., Pallavi M. and Sameera S.K. (2015). Genetic variability, correlation and path analysis for yield and yield components in promising rice (*Oryza sativa* L.) genotypes. *SAARC J. Agricult*., **13(1)**, 99-108.

Kumar, Sudhir, Bhuvaneswari S., Devi E.L., Sharma S.K., Ansari M.A., Singh I.M. and Prakash Narendra (2017). Estimation of genetic variability, correlation and path analysis in short duration rice genotypes of Manipur. *J. Agri Search*, **4(2)**, 112-118.

Kumar, Y.K., Singh B.N., Verma O.P., Shweta Tripathi S.T. and Dwivedi D.K. (2011). Correlation and path coefficient analysis in scented rice (*Oryza sativa* L.) under sodicity.

Lakshmi, L., Brahmeswara Rao M.V., Surender Raju Ch. and Narender Reddy S. (2017). Variability, Correlation and Path Analysis in Advanced Generation of Aromatic Rice. *Int. J. Curr. Microbiol. Appl. Sci*., **6(7)**, 1798-1806.

Lenka, D. and Misra B. (1973). *Path-coefficient analysis of yield in rice varieties*.

Milligan, S.B., Gravois K.A., Bischoff K.P. and Martin F.A. (1990). Crop effects on genetic relationships among sugarcane traits. *Crop Sci.*, **30(4)**, 927-931.

Moonmoon, S. and Islam M.T. (2017). Effect of drought stress at different growth stages on yield and yield components of six rice (*Oryza sativa* L.) genotypes. *Fundamental and Applied Agriculture*, **2(3)**, 285-289.

Nirubana, V., Vanniarajan C., Aananthi N., Banumathy S., Thiyageshwari S. and Ramalingam J. (2019). Variability and frequency distribution studies in F_2 segregating population of rice with phosphorous starvation tolerance Gene (OsPSTOL 1) introgressed. *Int J Curr Microbiol App Sci*., **8(9)**, 2620-2628.

Panda, G.H., Pandey I.D. and Tripthy S.K. (2019). Correlation of characters and path analysis among different traits of CMS lines and maintainers. *Int J Curr Microbiol App Sci.*, **8**, 609-614.

Priyanka, A.R., Gnanamalar R.P., Banumathy S., Senthil N. and Hemalatha G. (2019). Genetic variability and frequency distribution studies in F_2 segregating generation of rice. *Elect. J. Plant Breed*., **10(3)**, 988-994.

Ramkumar, G., Rao S.K., Mohan M.K., Sudarshan I., Sivaranjani A.K.P and Krishna (2015). Development and validation of functional marker targeting an In Del in the major rice blast disease resistance gene Pi54 (PIKH). *Molecular Breeding*, **27**, 129-135.

Revathi, S., Sakthivel K., Manonmani S., Umadevi M., Ushakumari R. and Robin S. (2016). Genetics of wide compatible gene and variability studies in rice (*Oryza sativa* L.). *J. Genetics*, **95(2)**.

Sameera, S.K., Srinivas T., Rajesh A.P., Jayalakshmi V. and Nirmala P.J. (2016). Variability and path co-efficient for yield and yield components in rice. *Bangladesh J. Agricult. Res*., **41(2)**, 259-271.

Samonte, S.O., Wilson L.T. and McClung A.M. (1998). Path analyses of yield and yield related traits of fifteen diverse rice genotypes. *Crop Science*, **38(5)**, 1130-1136.PB.

Sarwar, G., Harun-Ur-Rashid M., Parveen S. and Hossain M.S. (2015). Correlation and Path Coefficient Analysis for Agro-morphological important traits in Aman rice Genotypes (*Oryza sativa* L.). *Adv. Biores.*, **6(4)**.

Seck, P.A., Diagne A., Mohanty S. and Wopereis M.C. (2012). Crops that feed the world 7: Rice. *Food Security*, **4**, 7-24.

Shankar, H.P.P., Krishna Veni B., Dayal Prasad Babu J. and Srinivasa Rao V. (2016). Assessment of Genetic Variability and Association studies in Dry Direct Sown Rice (*Oryza sativa* L.). *J. Rice Res.*, **9(2)**.

Shoba, D., Raveendran M., Manonmani S., Utharasu S., Dhivyapriya D. and Subhasini G. (2017). Development and genetic characterization of a novel herbicide (Imazethapyr) tolerant mutant in rice (*Oryza sativa* L.). *Rice*, **10**, 1-12.

Singh, R.K. and Chaudhary B.D. (1977c). Biometrical methods in quantitative genetic analysis. *Kalyani Publishers*, New Delhi. p. 57-58.

Thirugnanakumar, S., Narasimman R., Anandan A. and Senthil Kumar N. (2011). Studies of genetics of yield and yield component characters in F_2 and F_3 generations of rice (*Oryza sativa* L.). *Afr. J. Biotechnol*., **10(41)**, 87-7997.

Zhou, Y., Tao Y., Yuan Y., Zhang Y., Miao J., Zhang R. and Liang G. (2018). Characterisation of a novel quantitative trait locus, GN4-1, for grain number and yield in rice (*Oryza sativa* L.). *Theoret. Appl. Gen*., **131**, 637-648.