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Trait Association Studies to Determine Selection Indices in F_5 Segregating Populations of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment consisted of 38 promising F_5 breeding lines developed and evaluated for correlation coefficient, path coefficient and selection indices studies with four check varieties *viz*., NVSR-2435, Sardar, Lalkada Gold and GR-18 in RBD with three replications during *kharif*-2023 at RRRS, Vyara, Gujarat. Genotypic correlation analysis revealed that grain yield per plant appeared to be positively and significantly correlated with productive tillers per plant, plant height, panicle length, straw yield per plant and 100 grain weight, which suggested that these characters can be improved simultaneously towards higher grain yield per plant by direct selection. Genotypic path analysis revealed that positive and direct effects on grain yield per plant were exhibited by days to maturity, productive tillers per plant, panicle length, 100 grain weight and straw yield per plant. Among these traits, panicle length, productive tillers per plant, 100 grain weight and straw yield per plant exhibited direct effect along with highly significant and positive association with grain yield per plant. Therefore, selection for such traits may be considered as most important yield attributing characters. The negligible residual effect of 0.037 was observed in path analysis, indicates that the model explained large proportion of variance. Thirty-one selection indices were constructed in all possible combinations of grain yield per plant (X_1) along with four components *viz*., productive tiller per plant (X_2), panicle length (X_3), 100 grain weight (X_4) and straw yield per plant (X_5) through equal weight method. Among all the selection indices, the relative efficiency (%) and expected genetic advance (GA) was noted maximum with four characters selection index (I_{1245}) compared to grain yield per plant (I_1).

Keywords: Correlation; path coefficient; selection indices; rice.

1. INTRODUCTION

Rice is the world's most important staple cereal crop. Rice has 24 species belonging to the tribe *Oryzeae*, sub family *Oryzoidae* and family *Poaceae* (*Gramineae*). The tribe has 11 genera, of which genus *Oryza* is the only one with cultivated species *viz*., *O. sativa* and *O. glaberrima*. Cultivated varieties of *O. sativa* were grouped into three types or ecographic races *viz*., indica, japonica and javanica (tropical japonica). Rice is the primary source of food and calories for more than half of the world's population. In Asia, where 60 % of the earth's people live, 90 % of the world's rice is grown and more than 3 billion Asians obtain 35-75 % of their calories from rice and its products [1]. It provides 20 *per cent* of the calories and 15 *per cent* of protein consumed by the world's population [2].

Yield is complex character and it is composed of several traits which were affect the yield directly as well as indirectly. So, knowledge of association of yield with traits is necessary. Correlation co-efficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. Several researchers have studied the relationship between yield and its main economic components in segregating rice populations [3, 4 and 5]. When attempts are made to establish correlation, it is essential to calculate the co-efficient of correlation between the character of interest with regard to type of variability *viz*., genotypic, phenotypic and environmental [6]. We will choose one character and take care of the other automatically if there is a significant association between a set of acceptable traits. Selection may cause genetic slippage and restrict genetic advancement if undesirable and desirable traits have an unfavourable association. Direction and magnitude of correlation between yield and yield contributing characters must be considered for selection of superior genotypes from diverse genetic population but correlation does not provide information about direct and indirect effects of independent variable on dependent one. Thus, this path coefficient analysis is essential.

Path co-efficient analysis was given by Wright [7] is standardized as partial regression co-efficient, which helps in partitioning the correlation co-efficient into direct and indirect effects of independent variables on dependent variable. One variable is measured by one's direct impact on another. Hence, it will help to illuminate the innate nature of the observed associations and influence a degree of confidence in selection scheme adopted for a given situation. Direct selection of yield is not reliable because it is affected by the environment. Therefore, it is necessary to identify the character attributes that can influence yield.

For exploitation of yield potential in rice through allowing the selection of superior genotypes is done by formulating an appropriate ‘selection index’ or ‘score’. For construction of the selection indices, the characters which had desirable correlation as well as high and positive direct effects on grain yield per plant were considered. In doing so, one should have thorough knowledge of the variability existing in the plant material used, association among the characters along with the cause of association between those characters [8].

2. MATERIALS AND METHODS

The present experiment was carried out at Regional Rice Research Station, Navsari Agricultural University, Vyara, Gujarat during *kharif* 2021 to *kharif* 2023.

For the study of correlation coefficient, path coefficient and selection indices, breeding lines were developed from four crosses *viz*., Lalkada Gold × GR-18, NVSR-2435 × Sardar, Maudamani × NVSR-2435 and Swarna Sub-1 × NVSR-2435 during *kharif*-2021. Detail characteristics of parental material utilized for crossing presented in Table 1. Total 38 promising F_5 breeding lines, 18 breeding lines (23KDSBF$_5$-1 to 23KDSBF$_5$-18) derived from NVSR-2435 × Sardar and 20 breeding lines (23KDSBF$_5$-19 to 23KDSBF$_5$-38) derived from Lalkada Gold × GR-18 (Table 2). No promising material identified from crosses *viz*., Maudamani × NVSR-2435 and Swarna Sub-1 × NVSR-2435 due to late flowering of F_4 progenies in July-2023 resulted in bird damage.

All 42 breeding lines were analyzed in randomized block design (RBD) with three replications. Each row was comprised of fifteen plants at a spacing of 20 cm and 15 cm between the plants within row. The crop was well grown by providing all plant protection measures and basic agronomic. Total ten quantitative traits *i.e*., days to 50 % flowering (DFF), days to maturity (DM), plant height (cm) (PH), panicle length (cm) (PL), grains per panicle (GPP), productive tillers per plant (PTPP), 100 grain weight (g) (100GW), straw yield per plant (g) (SYPP), grain yield per plant (g) (GYPP) and harvest index (%) (HI) were studied. Five randomly chosen plants from each progeny and replication were observed and their means were used for biometrical analysis. However, DFF and DM were evaluated on a population basis.

Analysis of correlation co-efficient was done as suggested by Panse and Sukhatme [9]. Path analysis was calculated by using the method suggested by Wright [7] and Dewey and Lu [10]. In selection indices, relative efficiency and expected genetic advance were calculated by the formula suggested by Robinson et al. [11].

3. RESULTS AND DISCUSSION

Genotypic Correlation Coefficient Analysis: This association studies indicated that GYPP was positive and significant correlated with ETPP (0.595), PH (0.330), PL (0.316), 100GW (0.458) and SYPP (0.747), which suggested that these characters can be improved simultaneously with GYPP by direct selection. GYPP was observed to be positive and non-significant correlated with DFF (0217), DM (0.224), GPP (0.284) and HI (0.101), suggested less significance of these traits for improvement (Table 3).

Significant and positive association of GYPP with ETPP and SYPP were observed by Dinkar et al. [12] and Kujur et al. [13]. While significant and positive association of GYPP with PH, PL and 100GW were observed by Singh et al. [14]. Non-significant and positive association of GYPP with DFF, DM and GPP were observed by Edukondalu et al. [15]. Positive and non-significant association of GYPP with HI was observed by Dutta et al. [16] and Farheen et al. [17].

PH had positive and significant association with DFF and DM, indicates possibilities of simultaneous improvement of these traits. PL was positively and significantly associated with GPP. PH was significantly and positively correlated with PL. This suggested that increasing PH and PL may result in increase of GPP.

GPP and HI were positively and significantly associated with PL. So, while selecting for long panicle, PL can be improved simultaneously GPP and HI. 100GW was significantly and negatively correlated with PL. So, 100GW can’t be improved simultaneously with PL.

PTPP, 100GW and SYPP was significantly and positively associated with each other. This indicates that such traits can be improved simultaneously.

Table 1. Salient features of parents *viz*., Lalkada Gold, GR-18, NVSR-2435, Sardar, Maudamani and Swarna Sub-1 used in the present study

Particulars	Lalkada Gold	GR-18	NVSR-2435	Sardar	Maudamani	Swarna Sub-1
Parentage / pedigree	IR-28 / LALKADA	GAR-13 / JGJ-3828	GAR-13 / JAYA	GURJARI / JAYA	(DANDI / NAVIN) / DANDI	SWARNA / IR49830 (Sub-1 donor)
Days to flowering	88-90	78-80	110-112	84-86	108-117	120-125
Plant height (cm)	105-115	120-130	120-126	110-115	109-119	85-90
Panicle length (cm)	21-24	25-28	22.5-26.5	20-24	22.1-26.1	26.0
Productive tillers per plant	6-8	5-8	5-8	8-10	5-8	10-12
Grains per panicle	140-170	210-240	226-253	220-250	119-146	150-180
Grain type	Long slender	Medium slender	Medium slender	Long bold	Short bold	Medium slender
Grain yield (kg/ha)	4000-4500	5400-5800	5500-6000	5500-6000	6000-8000	5000-5500

Table 2. Details procedure of development of F_5 breeding lines

Generation	Season	Procedure followed
Crossing	*Kharif*-2021	• Cross successfully made for all the four crosses
F_1	*Rabi* 2021-2022	• Space planted under polythene cover at 20 cm × 15 cm • Hybridity confirmed with SSR markers • True F_1 plants were harvested from each cross
F_2	Summer - *Kharif* 2022	• F_2 population of each cross direct seeded under narrow spacing at 10 cm row to row spacing • Bulk harvested each cross
F_3	*Kharif*-2022 - *Rabi* 2022-23	• F_3 population of each cross space planted at 20 cm × 15 cm • 50 individual plant selection (IPS) made from each cross
F_4	Summer 2023	• 50 F_4 progenies of each cross space planted at 20 cm × 15 cm • 38 promising IPS made from two crosses *viz*., Lalkada Gold × GR-18 and NVSR-2435 × Sardar
F_5	*Kharif* 2023 (Evaluation)	• F_5 breeding lines evaluated under randomized block design

Table 3. Genotypic correlation coefficients of grain yield per plant with other characters in F_5 breeding lines of rice

Character	DFF	DM	PH	PL	PTPP	GPP	100 GW	SYPP	HI	GYPP
DFF	**1.000**									
DM	0.998**	**1.000**								
PH	0.504**	0.510**	**1.000**							
PL	0.307*	0.278	0.350*	**1.000**						
PTPP	-0.140	-0.137	-0.035	-0.200	**1.000**					
GPP	0.181	0.162	0.211	0.932**	-0.272	**1.000**				
100 GW	0.110	0.133	0.049	-0.512**	0.670**	-0.545**	**1.000**			
SYPP	0.295	0.309*	0.328*	-0.067	0.536**	0.001	0.468**	**1.000**		
HI	-0.154	-0.174	-0.031	0.533**	-0.104	0.302	-0.096	-0.573**	**1.000**	
GYPP	0.217	0.224	0.330*	0.316*	0.595**	0.284	0.458**	0.747**	0.101	**1.000**

*** - Significant at 1% level of probability, * - Significant at 5.0 % level of probability*

DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); PL: Panicle length (cm); PTPP: Productive tillers per plant; GPP: Grain per panicle; 100 GW: 100 grain weight (g); SYPP: Straw yield per plant (g); HI: Harvest index (%); GYPP: Grain yield per plant (g)

Table 4. Genotypic path coefficient analysis of component characters towards grain yield per plant in F_5 breeding lines of rice

Character	DFF	DM	PH	PL	PTPP	GPP	100 GW	SYPP	HI	Correlation with grain yield per plant
DFF	**-5.184**	5.032	-0.086	0.299	-0.004	-0.081	0.022	0.272	-0.052	**0.217**
DM	-5.176	**5.040**	-0.087	0.271	-0.004	-0.072	0.027	0.285	-0.059	**0.224**
PH	-2.615	2.568	**-0.172**	0.341	-0.001	-0.094	0.010	0.302	-0.011	**0.330***
PL	-1.591	1.399	-0.060	**0.975**	-0.006	-0.415	-0.105	-0.062	0.181	**0.316***
PTPP	0.727	-0.69	0.006	-0.195	**0.029**	0.121	0.138	0.494	-0.035	**0.595****
GPP	-0.941	0.814	-0.036	0.908	-0.008	**-0.446**	-0.112	0.001	0.102	**0.284**
100 GW	-0.568	0.668	-0.008	-0.499	0.019	0.243	**0.205**	0.432	-0.032	**0.458****
SYPP	-1.527	1.555	-0.056	-0.065	0.015	0.001	0.096	**0.923**	-0.194	**0.747****
HI	0.797	-0.874	0.005	0.520	-0.003	-0.134	-0.020	-0.528	**0.339**	**0.101**

*** - Significant at 1.0 per cent level of probability, * - significant at 5.0 per cent level of probability, Residual = 0.037, Bold diagonal figures are the direct effects*

DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); PL: Panicle length (cm)
PTPP: Productive tillers per plant; GPP: Grain per panicle; 100 GW: 100 grain weight (g); SYPP: Straw yield per plant (g)
HI: Harvest index (%); GYPP: Grain yield per plant (g)

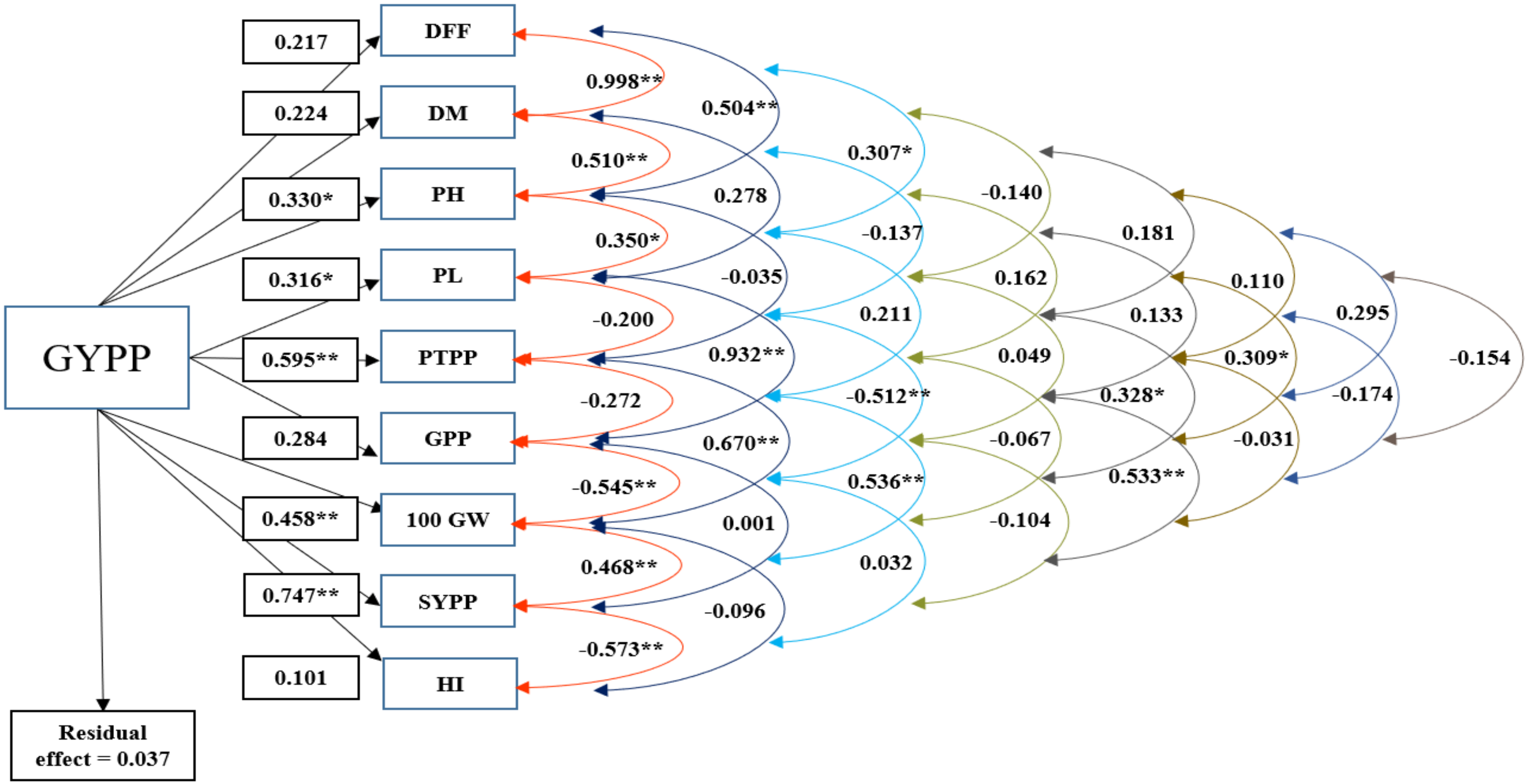

Fig. 1. Genotypic path diagram for grain yield per plant

Where,

DFF:	Days to 50% flowering	DM:	Days to maturity	PH:	Plant height (cm)	PL:	Panicle length (cm)
PTPP:	Productive tillers per plant	GPP:	Grain per panicle	100 GW:	100 grain weight (g)	SYPP:	Straw yield per plant (g)
HI:	Harvest index (%)	GYPP:	Grain yield per plant (g)				

Table 5. Selection indices with expected genetic advance (GA) in yield and relative efficiency (%) with the use of equal weight (W_1) method in rice

Sr. No.	Indices	Character combinations	GA	RE (%)
1	I_1	$I=0.403X_1$	3.62	100.00
2	I_2	$I=0.350X_2$	0.95	26.17
3	I_3	$I=0.223X_3$	1.06	29.21
4	I_4	$I=0.669X_4$	0.65	17.81
5	$\mathbf{I_5}$	$\mathbf{I=0.635X_5}$	**9.51**	**262.25**
6	I_{12}	$I=0.433X_1+0.202X_2$	4.25	117.32
7	I_{13}	$I=0.444X_1 +0.360X_3$	4.42	121.91
8	I_{14}	$I=0.373X_1+1.958X_4$	4.26	117.60
9	$\mathbf{I_{15}}$	$\mathbf{I=0.317X_1+0.754X_5}$	**13.11**	**361.83**
10	I_{23}	$I=0.281X_2+0.204X_3$	1.18	32.67
11	I_{24}	$I=0.326X_2+1.304X_4$	1.74	48.03
12	I_{25}	$I=0.116X_2+0.672X_5$	10.19	281.25
13	I_{34}	$I=0.177X_3+-0.138X_4$	0.88	24.23
14	I_{35}	$I=0.050X_3+0.627X_5$	9.39	259.02
15	I_{45}	$I=2.308X_4+0.606X_5$	10.02	276.51
16	I_{123}	$I=0.516X_1+-0.02X_2+0.32X_3$	4.92	135.84
17	I_{124}	$I=0.401X_1+0.093X_2+2.719X_4$	5.15	142.04
18	$\mathbf{I_{125}}$	$\mathbf{I=0.393X_1+-0.243X_2+0.793X_5}$	**13.85**	**381.99**
19	I_{134}	$I=0.435X_1+0.366X_3+1.172X_4$	4.68	129.20
20	I_{135}	$I=0.399X_1+0.178X_3+0.715X_5$	13.15	362.87
21	I_{145}	$I=0.286X_1+3.259X_4+0.715X_5$	13.74	379.05
22	I_{234}	$I=0.341X_2+0.186X_3+0.492X_4$	1.35	37.35
23	I_{235}	$I=0.022X_2+0.012X_3+0.671X_5$	10.07	277.84
24	I_{245}	$I=-0.011X_2+3.071X_4+0.637X_5$	10.85	299.35
25	I_{345}	$I=0.062X_3+1.336X_4+0.618X_5$	9.75	269.05
26	I_{1234}	$I=0.491X_1+-0.061X_2+0.357X_3+1.986X_4$	5.39	148.76
27	I_{1235}	$I=0.520X_1+-0.510X_2+0.104X_3+0.761X_5$	13.91	383.73
28	$\mathbf{I_{1245}}$	$\mathbf{I=0.381X_1+-0.425X_2+4.146X_4+0.744X_5}$	**14.62**	**403.43**
29	I_{1345}	$I=0.378X_1+0.236X_3+2.407X_4+0.690X_5$	13.61	375.52
30	I_{2345}	$I=-0.029X_2+0.054X_3+2.098X_4+0.650X_5$	10.53	290.52
31	$\mathbf{I_{12345}}$	$\mathbf{I=0.503X_1+-0.607X_2+0.194X_3+3.311X_4+ 0.723X_5}$	**14.49**	**399.65**

Where,

X_1 = Grain yield per plant (g) *X_2 = Productive tillers per plant* *X_3 = Panicle length (cm)*
X_4 = 100 grain weight (g) *X_5 = Straw yield per plant (g)*

Genotypic Path Coefficient Analysis: The overall genotypic path coefficient analysis revealed that highest positive and direct effects on GYPP was exhibited by DM (5.040), PL (0.975), SYPP (0.923), HI (0.339), 100GW (0.205) and PTPP (0.029). Therefore, selection for these traits in F_5 and further generations would be useful to bring about improvement in rice. The highest negative direct effect on GYPP was recorded by DFF (-5.184), GPP (-0.446) and PH (-0.172) indicating less significance of these characters in selection for higher grain yield (Table 4 and Fig. 1).

Positive direct effect on GYPP was exhibited by DM, PL, SYPP, HI, 100GW and SYPP was observed by Dinkar et al. [12]. Negative direct effect on GYPP by DFF was observed by Yadav et al. [18] and Moukoumbi et al. [19]. Negative direct effect on GYPP by GPP and PH was observed by Edukondalu et al. [15], Acharya et al. [20] and Belete et al. [21].

PTPP, PL, 100GW and SYPP exhibited direct effect on grain yield per plant along with positive and significant association with GYPP. Hence, these may be considered as most important yield attributing characters. The negligible residual effect (0.037) was observed in path coefficient analysis, which indicates that the model explains large proportion of variance.

Selection Indices: In this context, the GYPP (X1) along with four characters *viz*., PTPP (X2), PL (X3), 100GW (X4) and SYPP (X5) were identified and considered. When selection was based on two or more characters then the expected relative efficiency and genetic advance assessed for different indices increased considerably. Thirty-one selection indices were constructed in all possible combinations of the five yield contributing characters including GYPP by using equal weight method (Table 5).

The expected genetic advance (GA) and relative efficiency (%) was noted maximum with four characters selection index (I_{1245}), a function involving GYPP, PYPP, 100GW and SYPP (X1+X2+X4+X5) was recorded 14.62 g GA and 403.43% RE value followed by five characters selection index (I_{12345}), a function involving GYPP, PTPP, PL, 100GW and SYPP (X1+X2+X3+X4+X5) was recorded 14.49 g GA and 399.65% RE; three characters selection index (I_{125}), a function involving GYPP, PTPP and SYPP (X1+X2+X5) was recorded 13.85 g GA and 381.99% RE; two characters selection index (I_{15}), a function involving GYPP and SYPP (X1+X5) was recorded 13.11 g GA and 361.83% RE and one characters selection index (I_5), a function involving SYPP (X5) was recorded 9.51 g GA and 262.25% RE compared to GYPP (X1) with 3.62 g GA and 100.00% RE (Table 4). Maximum efficiency of straw yield was also observed by Raghuwanshi et al. [22] in groundnut. While, best selection index including straw yield per plant was observed by Fazl et al. [23] in rice, Kumar et al. [24] in sorghum, Shah et al. [25] in wheat, Chandrashekhar and Shailaja [26] and Htwe et al. [27] in rice.

Further, when each character was added at the same time, the relative efficiency of the subsequent index increased gradually. However, five components-based index showed lower efficiency than four components-based indices due to negative correlation of panicle length with grain yield per plant.

4. CONCLUSION

Genotypic correlation analysis revealed that grain yield per plant appeared to be significant and positive association with productive tillers per plant, plant height, panicle length, 100 grain weight and straw yield per plant, which suggested that direct selection for these characters can be improved simultaneously towards higher grain yield per plant. Genotypic path coefficient analysis revealed that positive and direct effects on grain yield per plant were exhibited by days to maturity, panicle length, productive tillers per plant, 100 grain weight and straw yield per plant. Among these traits, panicle length, productive tillers per plant, 100 grain weight and straw yield per plant exhibited direct effect along with highly significant and positive association with grain yield per plant. Therefore, selection for such traits may be considered as most important yield attributing characters. In selection indices, the grain yield per plant (X1) along with four components *viz*., productive tiller per plant (X2), panicle length (X3), 100 grain weight (X4) and straw yield per plant (X5) were identified and considered. The expected genetic advance (GA) and relative efficiency (%) was noted maximum with four characters selection index (I_{1245}) followed by five characters selection index (I_{12345}), three characters selection index (I_{125}), two characters selection index (I_{15}) and straw yield per plant (one character) selection index (I_5) compared to grain yield per plant (I_1).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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