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Study of genetic variability and trait associations in F_2 Population of YH3 x AKDRMS 21-54 intra-specific cross of rice

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Abstract
The present experiment was conducted to study the variability and trait associations in a F_2 population derived from the cross, YH3 x AKDRMS 21-54. A high level variability in the form of high phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) coupled with high heritability and genetic advance as % of mean was noticed for the traits filled grains per panicle, total grains per panicle, spikelet fertility (%) and test weight. Significant and positive correlation of grain yield per plant was noticed with productive tillers per plant, filled grains per panicle and total grains per panicle indicating a scope for simultaneous improvement of these traits enhancing grain yield per plant. Filled grains per panicle also recorded high positive direct effect on grain yield per plant coupled with significant and positive association, indicating the effectiveness of direct phenotypic selection for the trait for effecting significant grain yield improvement.

Keywords: Variability, heritability, F_2 generation, genetic advance, correlation analysis, path analysis, rice

Introduction
Rice is the staple food for more than 100 countries of the world and is the primary source of nourishment for almost 70% of the people. It is the crucial for the dietary and food security source of many Asian countries (Kumar *et al*, 2020) [15]. India ranks second world-wide in the production of rice, with a share of 22% of the total world rice production. In spite of significant improvement in rice production and productivity, which was achieved through green revolution, plateaus in yield levels are limiting the efforts for increasing production to meet the demands of the ever-growing population, especially in developing and under developed countries. The estimated Indian population by 2050 has been reported to threaten food security of India (Fathima *et al*, 2021) [8]. Hence, guaranteeing food security in future is a big challenging task, particularly, for rice breeders in India as rice is pivotal for food and nutritional security in the country. Rice varieties with elevated productivity levels and suitable agronomic features are required for breaking the yield barriers for which hybridization has been identified as an important plant breeding tool for creation of desired variability and achieving of high productivity levels. Further, selection in segregating generations need to be focussed for obtaining a better yielding plants for which variability with respect to yield and its related traits is of prime importance and identification of effective selection criteria for yield improvement is required. Assessment of variability for grain yield and yield attributes is therefore essential for successful improvement through breeding. However, grain yield depends on various component characters. Hence, the knowledge of association among yield and yield components would help in the formulation of effective breeding programs. In addition, path coefficient analysis aids in the effective partitioning of correlation coefficient into measures of direct and indirect effects, thus helping the plant breeder to ascertain the real components for selection of superior genotypes. The present study is an attempt in this direction to elucidate information on variability, heritability, genetic advance, character associations and path coefficients of grain yield and yield component characters to aid in the identification of effective selection criteria for grain yield improvement in segregating generation of rice.

Material and Methods

The present investigation was carried out at Agricultural College, Bapatla Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India and ICAR-Indian Institute of Rice Research, Hyderabad, India. Genetically pure seeds of YH3 and AKDRMS 21-54 (Table 1) were obtained from ICAR-IIRR and the parents were raised in crossing block at Agricultural College Farm, Bapatla, and Andhra Pradesh during *Rab*i 2019-20. YH3 parent was used as the female parent, while AKDRMS 21-54 was used as the male parent. Hybridization of the parents was effected using standard emasculation and pollination procedures and the crossing chamber facility available at Agricultural Research Station, Bapatla was utilized for the purpose. The crossed seeds were used to raise the F_1 generation during *Kharif* 2020 at Agricultural College Farm, Bapatla. Hybridity of the F_1's was confirmed using gene linked markers, which are detailed in Table 2. Seed from the identified true F_1 plants were harvested and forwarded to the F_2 generation and a population of 300 sergeants along with the parents were sown in raised nursery bed and were transplanted in main field 20 days after sowing at a spacing of 20 x 15 cm during *Rabi* 2020-21 at Agricultural College Farm, Bapatla. All recommended agronomic practices and crop protection measures were adopted during the crop growth period for raising a healthy crop. Twelve traits, namely, days to 50% flowering (days), shoot length (cm), plant height (cm), productive tillers per plant, flag leaf length (cm), flag leaf width (cm), panicle length (cm), filled grains per panicle, total grains per panicle, grain yield per plant spikelet fertility (%) and test weight (g) were recorded in every individual F_2 plant.

The genetic variability parameters, namely, Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were calculated using the formula given by Mirza *et al.* (2011) [18], Heritability was calculated using the formula given by Allard *(*1960) [3] and genetic advance as percentage of mean was calculated by adopting the formula given by Johnson *et al.* (1955) [11]. Correlation coefficients were calculated using the formula given by Singh and Choudhary (1977) [28]. The direct and indirect effects of different components on grain yield were estimated by path coefficient analysis as suggested by Dewey and Lu (1959) [7]. The R software version 1.4.1717 was used for illustrating the association plot and SPSS16.0 software was used to depict frequency distribution in the form of a histogram for the traits studied.

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

S. No.	Parent	Details	Average grain yield (t/ha)
1	YH3 (MTU1121 x Kasalath) Female parent	Sri Druthi (MTU 1121) released from Regional Agricultural Research Station, Maruteru of Acharya N G Ranga Agricultural University, Guntur, Andhra Pradesh during 2015 as short duration, medium slender, high yielding variety with tolerance to BPH for *Rabi* season was improved at PJTSAU, ICAR-IIRR and ANGRAU as YH3 for tolerance to low soil phosphorous possessing *Pup1* gene through Marker Assisted Backcross Breeding.	6.0
2	AKDRMS 21-54 (Akshayadhan x ISM) x (Akshayadhan x Tetep) Male Parent	Improved Akshayadhan resistant to BLB and Blast with *Xa21* and *Pi54*genes	4.5

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

Molecular Markers	Linked gene	Primer sequence	Chromosome Location	Reference
pTA248	Xa21	F: AGACGCGGGAAGGGTGGTTCCCGGA	11	Ronald *et al.* (1992) [23]
		R: AGACGCGGGTAATCGAAAGATGAAA		
Pi 54 MAS	Pi 54	F: CAATCTCCAAAGTTTTCAGG	11	Ramkumar *et al.* (2011) [22]
		R: GCTTCAATCACTGCTAGACC		
K20-2	Pup1	F: CTGGACTTGACCCCAATGTA	12	Chin *et al.* (2010) [6]
		R: TCTGATGGAGTGTTCGGAGT		

Results and Discussion

The results on variability and other genetic parameters for grain yield and yield component traits studied in the present investigation are presented in Table 3 and Fig. 1-3. A perusal of the results on mean performance and range of the yield component traits studied in the present investigation (Table 3 and Fig. 1) revealed maximum range for total grains per panicle followed by filled grains per panicle and plant height, while minimum range was noticed for flag leaf width. Grain yield per plant was noticed to range from 27.16 g to 54.44 g with a mean of 37.57 g per plant. Similar variation in F_2 for grain yields per plant were reported earlier by Khandappagol *et al.* (2019) [12], in their studies in a F_2 population of two crosses involving traditional varieties of rice. The test weight in the present study ranged from 17.87 g to 35.35 g. The results are also in agreement with the reports of Khandappagol *et al.* (2019) [12]. Flag leaf length and width, in the present study, were also noticed to range from 16.8 cm to 52.32 cm with an average of 31.31 cm and 0.94 cm to 2.11 cm with a mean of 1.40 cm, respectively. Similar range for flag leaf length and width were reported earlier by Bakya *et al.* (2020) [4]. Panicle length in the F_2 population studied was noticed to range from 17.64 cm to 36.17 cm with a mean value of 25.38 cm. The results are in conformity with the reports of Priyanka *et al.* (2019) [21].

The results on genotypic (GCV) and phenotypic (PCV) coefficients of variation are presented in Table 3 and Fig. 2. An analysis of these results revealed higher PCV value, compared to GCV value for all traits studied, indicating the effect of environment. Among the traits, spikelet fertility (%) recorded greater difference between phenotypic and genotypic coefficients of variation, compared to other traits, indicating higher influence of environment on the trait, resulting in low heritability values for the trait, However, total and filled grains per panicle had recorded minimum variation between GCV and PCV values, indicating lesser influence of environment resulting in high heritability values (≥ 95 percent). The observations are in agreement with the inferences of Priyanka *et al.* (2019) [21]. The results also revealed high genotypic and phenotypic coefficient of variation for number of filled grains per panicle, total grains per panicle and test weight. These results are in agreement with the findings of Krishna *et al.* (2021) [14] for number of filled grains per panicle; Bhargava *et al.* (2021) [5] for total grains per panicle; Harijan *et al.* (2021) [9] for test weight. In contrast, moderate genotypic and phenotypic coefficients of variation were recorded for productive tillers per plant, flag leaf width, and panicle length and grain yield per plant in the present study. These results are in agreement with the reports of Madhavilatha *et al.* (2005) [17] for productive tillers per plant and panicle length; Bakya *et al.* (2020) [4] for flag leaf width; and Sameera *et al.* (2014) [24] for grain yield per plant. Further, moderate genotypic and high phenotypic coefficient of variation were observed for flag leaf length, similar to the findings of Harijan *et al.* (2021) [9]. The results also revealed low genotypic and moderate phenotypic coefficient of variation for days to 50% flowering and shoot length, whereas low genotypic and phenotypic coefficients of variation were recorded for plant height and spikelet fertility. The findings are in conformity with the reports of Kishore *et al.* (2015) [13] for plant height and Sudeepthi *et al.* (2020) [32] for spikelet fertility.

High heritability (>60%) and high genetic advance as % of mean (>20) was observed for productive tillers per plant, flag leaf length, flag leaf width, panicle length, number of filled grains per panicle, total grains per panicle and test weight (Table 3 and Fig 3). These results are in agreement with the observations of Fathima *et al.* (2021) [8] for productive tillers per plant and panicle length; Bakya *et al.* (2020) [4] for flag leaf length and width; Lakshmi *et al.* (2021) [16] for number of filled grains per panicle and total grains per panicle; and Hema *et al.* (2019) [10] for test weight. However, high heritability coupled with moderate genetic advance as % of mean was observed for days to 50% flowering, shoot length, plant height and grain yield per plant. The findings are in agreement with the reports of Kumar *et al*. (2020) [15] for days to 50% flowering; Priya *et al*. (2017) [20] for plant height; and Bakya *et al.* (2020) [4] for grain yield per plant.

High GCV and high PCV coupled with high heritability and high genetic advance as % of mean was recorded for of number of filled grains per panicle, total grains per panicle and test weight, suggesting the predominance of additive type of gene action. Hence, direct phenotypic selection would be effective for improvement of these traits even in early generations. Similar findings were reported earlier by Ali *et al.* (2018) [2] for filled grains per panicle; Bhargava *et al.* (2021) [5] for total grains per panicle; and Harijan *et al.* (2021) [9] for test weight.

The results on character associations between yield and yield components are presented in Table 4 and Fig. 4. A perusal of these results revealed positive and significant association of grain yield with the yield component traits, namely, productive tillers per plant, filled grains per panicle and total grains per panicle, indicating scope for their simultaneous improvement with grain yield per plant. The results are in agreement with the reports of Fathima *et al.* (2021) [8] for productive tillers per plant, filled grains per panicle and total grains per panicle. Further, positive and significant associations were also noticed for days to% flowering with flag leaf width and test weight; shoot length with plant height, productive tillers per plant, flag leaf length, flag leaf width, panicle length, filled grains per panicle and test weight; plant height with productive tillers per plant, panicle length, filled grains per panicle, test weight and flag leaf width; productive tillers per plant with panicle length and test and flag leaf width; flag leaf width with panicle length, filled grains per panicle, total grains per panicle and test weight; panicle length with filled grains per panicle, total grains per and test weight; and filled grains per panicle with total grains per panicle and spikelet fertility; and total grains per panicle with spikelet fertility, indicating a scope for simultaneous improvement of these traits. The findings are in broad agreement with the reports of Priyanka *et al*. (2019) [21], Singh *et al*. (2020) [20] and Bhargava *et al*. (2021) [33].

Negative and significant association of flag leaf length with grain yield per plant was recorded in the present study. Further, negative and significant associations were also noticed for spikelet fertility with flag leaf widthand productive tillers per plant (Abhialsh *et al*. 2018) [1]; test weight with filled grains per panicle (Subbulakshmi and Muthuswamy, 2018) [31], spikelet fertility and total grains per panicle (Bhargava *et al*. 2021) [5], similar to the findings of earlier workers. 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) [25].

The results on path analysis of yield component traits on grain yield per plant are presented in Table 5 and Fig. 5. A perusal of the results revealed a residual effect of 0.279 indicating that variables studied in the present investigation explained about 72.10% of variability for grain 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. Low direct effects (0.10-0.19) were noticed for shoot length and productive tillers per plant, along with non-significant to significant associations with grain yield per plant. The results are in agreement with the findings of Sowjanya and Hittalmani (2017) [30] for productive tillers per plant. Further, high negative direct effect coupled with significant positive correlation was observed for total grains per panicle. The findings are in agreement with the reports of Singh *et al.* (2020) [29]. Further, spikelet fertility, panicle length and flag leaf length had recorded moderate (0.20 - 0.29) to low and negative direct effects, whereas test weight, flag leaf width, plant height and days to 50% flowering had recorded negligible negative direct effects in the present study. The results are in agreement with the findings of Fathima *et al.* (2021) [8] for test weight; Seneega *et al.* (2019) [27] for plant height; and Muthuramu and Ragavan *et al.* (2020) [19] for days to 50% flowering. These traits had also recorded non-significant association with grain yield per plant. Indirect effects are inferred to be the cause of 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. In contrast, high positive direct effect (0.30-0.99) of filled grains per panicle was recorded in the present study on grain yield per plant. The findings are in agreement with the reports of Sameera *et al*. (2016) [26]. The trait 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.

Table 3: Variability parameters in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

S. No.	Character	Mean	Range		Coefficient of variation		Heritability (%)	Genetic advance as % of mean
			Minimum	Maximum	GCV (%)	PCV (%)		
1	Days to 50% flowering	90.08	67.118	119.15	8.876	11.121	63.700	14.594
2	Shoot length (cm)	82.98	62.323	105.899	8.13	10.139	64.300	13.431
3	Plant Height (cm)	106.04	80.05	137.121	7.852	9.925	62.600	12.796
4	Productive tillers per Plant	11.09	7.232	20.31	17.475	18.758	86.800	33.536
5	Flag leaf length (cm)	31.31	16.8	52.32	19.977	21.302	87.900	38.593
6	Flag leaf width (cm)	1.40	0.94	2.11	13.978	15.477	81.600	26.007
7	Panicle length (cm)	25.38	17.64	36.17	13.077	14.349	83.100	24.552
8	Filled grains per panicle (No.)	193.12	78.94	425.55	35.684	36.466	95.800	71.933
9	Total grains per panicle (No.)	216.00	91.89	467.67	33.479	34.240	95.600	67.433
10	Spikelet Fertility (%)	89.09	67.24	99.30	4.214	7.320	33.100	4.998
11	Test Weight (g)	25.35	17.87	35.35	26.115	27.282	91.600	51.496
12	Grain yield per plant (g)	37.57	27.61	54.44	10.637	12.372	73.900	18.839

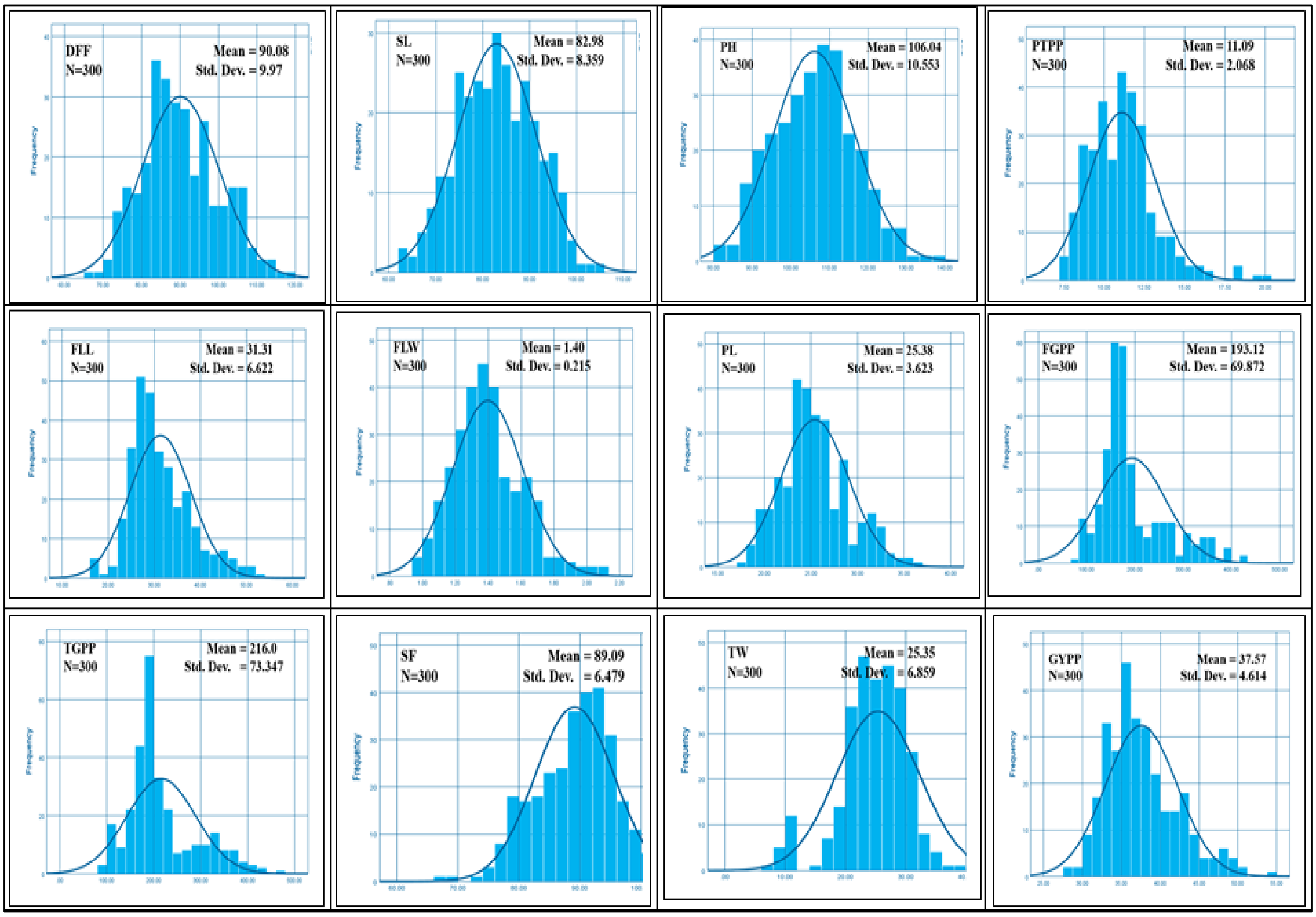
Table 4: Correlation coefficients for grain yield and yield components in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

Traits	Shoot length	Plant Height	Productive tillers per Plant	Flag leaf length	Flag leaf width	Panicle Length	Filled grains per panicle	Total grains per panicle	Spikelet Fertility	Test Weight	Grain yield per plant
Days to 50% flowering	0.0517	0.0056	0.0941	-0.0633	0.1197*	-0.0023	-0.0480	-0.0322	-0.1128	0.1247*	-0.0011
Shoot length		0.9069 **	0.2650**	0.0263	0.6036**	0.7462**	0.4178**	0.4354	0.0115	0.4238**	0.0546
Plant Height			0.2507**	-0.0205	0.5742**	0.7008**	0.2893**	0.3090	-0.0357	0.4988**	0.0084
Productive tillers per Plant				0.1058	0.2183**	0.2408**	0.0368	0.0606	- 0.1713**	0.4303**	0.1264*
Flag leaf length					-0.0517	-0.0129	-0.0415	-0.0485	0.0621	0.0486	-0.1318*
Flag leaf width						0.7216**	0.4690**	0.5150**	- 0.1835**	0.3543**	0.0569
Panicle length							0.6892**	0.7271**	-0.0455	0.3409**	0.0897
Filled grains per panicle								0.9871**	0.3083**	-0.1869**	0.1948**
Total grains per panicle									0.1594**	-0.1435**	0.2103**
Spikelet Fertility										-0.2737**	-0.0756
Test Weight											-0.0966

Table 5: Direct and indirect effects for yield component traits in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

Traits	Days to 50% flowering	Shoot Length	Plant Height	Productive tillers per Plant	Flag leaf length	Flag leaf width	Panicle Length	Filled grains per panicle	Total grains per panicle	Spikelet Fertility	Test Weight	Grain yield per plant
Days to 50% flowering	-0.0183	-0.0009	-0.0001	-0.0017	0.0012	-0.0022	0.0000	0.0009	0.0006	0.0021	-0.0023	-0.0011
Shoot length	0.0078	0.1508	0.1367	0.0399	0.0040	0.0910	0.1125	0.0630	0.0656	0.0017	0.0639	0.0546
Plant Height	-0.0004	-0.0620	-0.0684	-0.0171	0.0014	-0.0393	-0.0479	-0.0198	-0.0211	0.0024	-0.0341	0.0084
Productive tillers per Plant	0.0158	0.0445	0.0421	0.1680	0.0178	0.0367	0.0405	0.0062	0.0102	-0.0288	0.0723	0.1264
Flag leaf length	0.0082	-0.0034	0.0027	-0.0137	-0.1293	0.0067	0.0017	0.0054	0.0063	-0.0080	-0.0063	-0.1318
Flag leaf width	-0.0088	-0.0446	-0.0424	-0.0161	0.0038	-0.0738	-0.0533	-0.0346	-0.0380	0.0135	-0.0262	0.0569
Panicle length	0.0004	-0.1205	-0.1132	-0.0389	0.0021	-0.1165	-0.1615	-0.1113	-0.1174	0.0074	-0.0551	0.0897
Filled grains per panicle	-0.0426	0.3707	0.2566	0.0327	-0.0368	0.4161	0.6115	0.8872	0.8758	0.2735	-0.1659	0.1948
Total grains per panicle	0.0174	-0.2355	-0.1672	-0.0328	0.0262	-0.2786	-0.3933	-0.5340	-0.5409	-0.0862	0.0776	0.2103
Spikelet Fertility	0.0316	-0.0032	0.0100	0.0479	-0.0174	0.0513	0.0127	-0.0863	-0.0446	-0.2798	0.0766	-0.0756
Test Weight	-0.0121	-0.0412	-0.0485	-0.0418	-0.0047	-0.0344	-0.0331	0.0182	0.0139	0.0266	-0.0972	-0.0966

Residual effect = 0.279; Diagonal and bold indicates the direct effects



DFF- Days to 50% flowering, SL- Shoot length, PH - Plant height, PTPP- Productive tillers per plant, FLL - Flag leaf length, FLW - Flag leaf width,
PL- Panicle length, FGPP- Filled grains per panicle, TGPP- Total spikelet's per panicle, SF- Spikelet fertility, TW- Test weight, GYPP- Grain yield per plant

Fig 1: Frequency distribution for biometrical traits in F2 generation of YH3 x AKDRMS 21-54 intra-specific cross

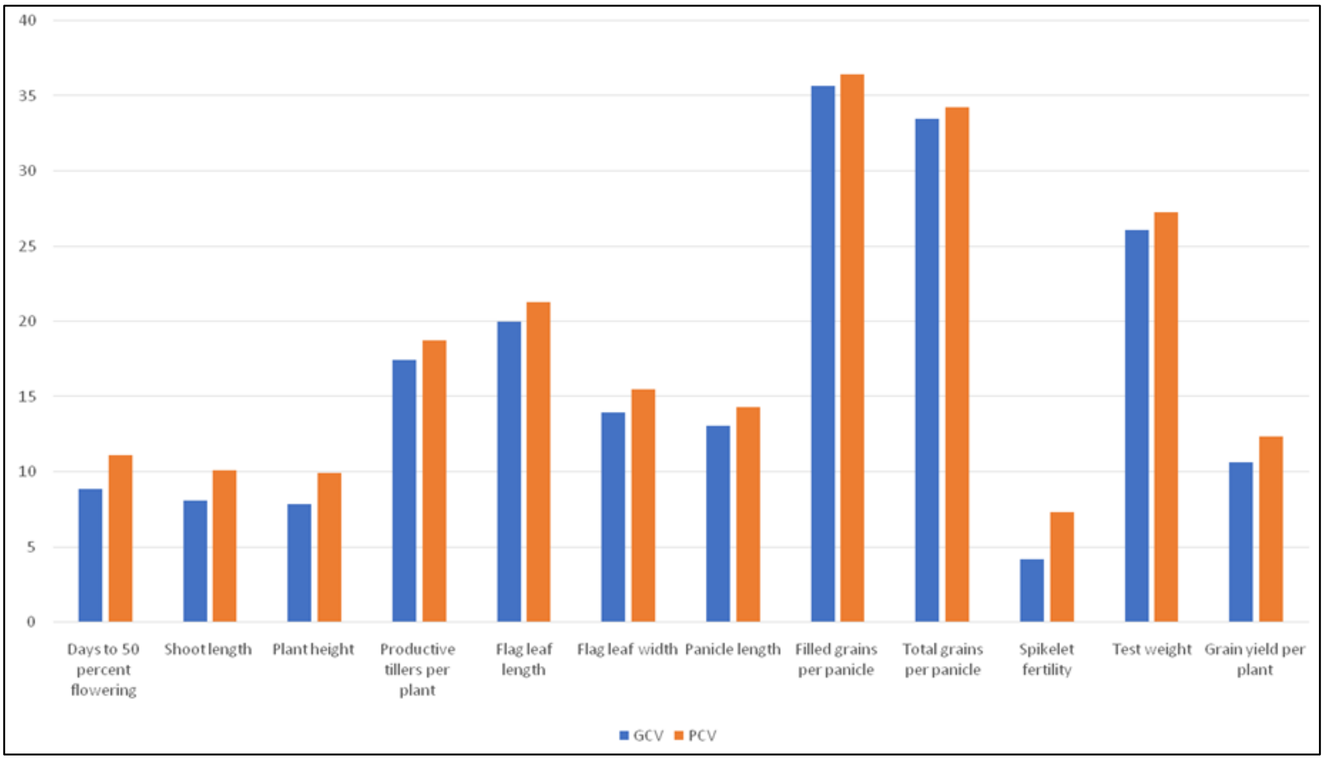


Fig 2: Genotypic and Phenotypic coefficients of variation for grain yield and yield components in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

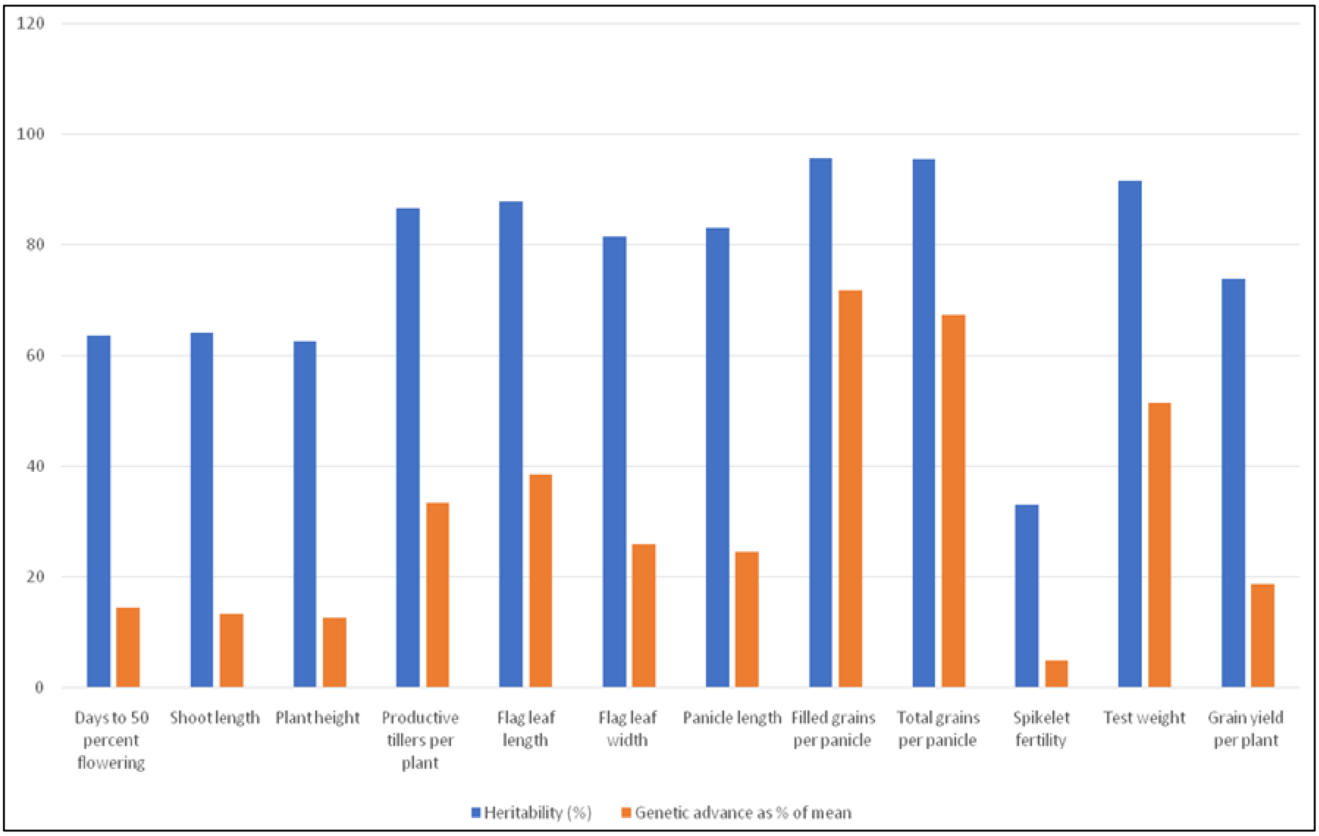


Fig 3: Heritability and genetic advance as % mean for yield and yield component traits in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

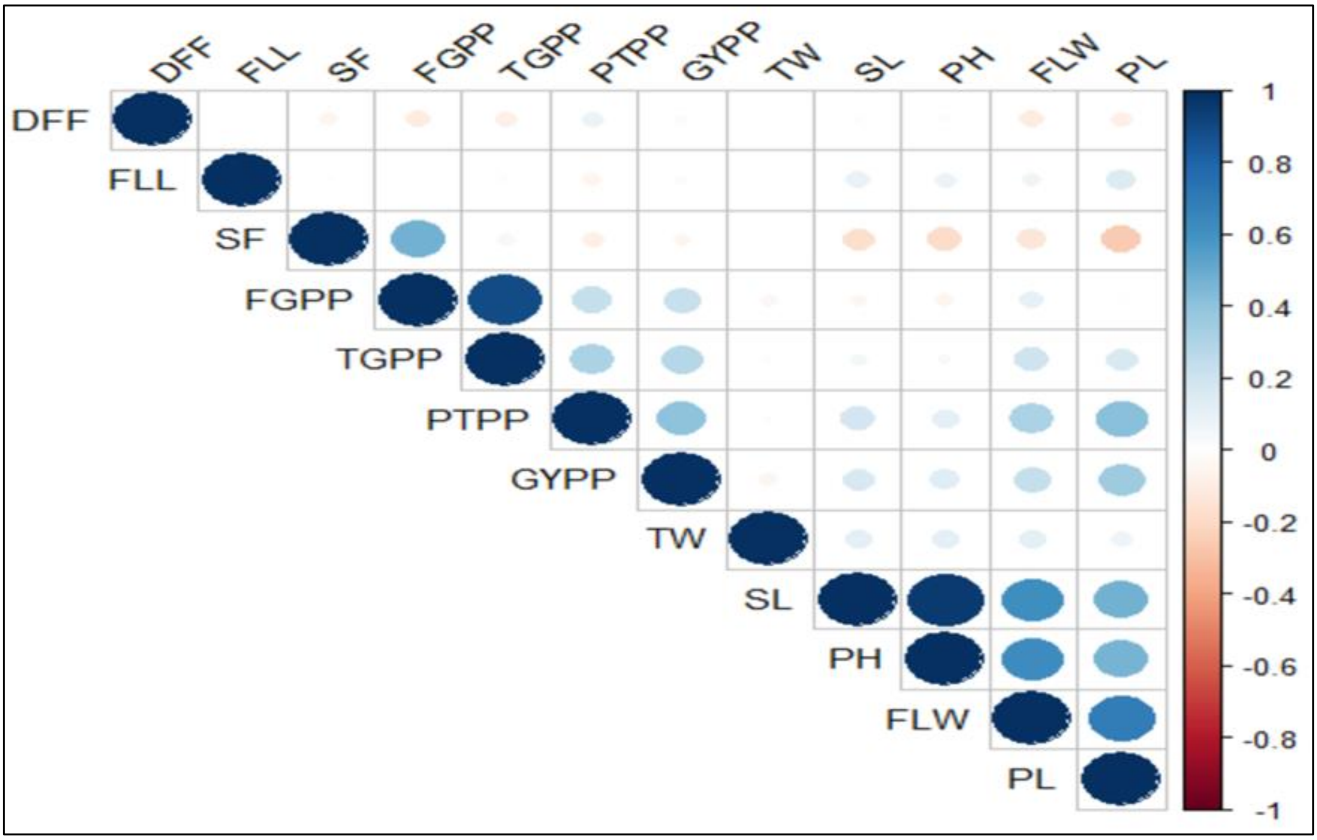


Fig 4: Correlation matrix of yield components for grain yield and yield components in F2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

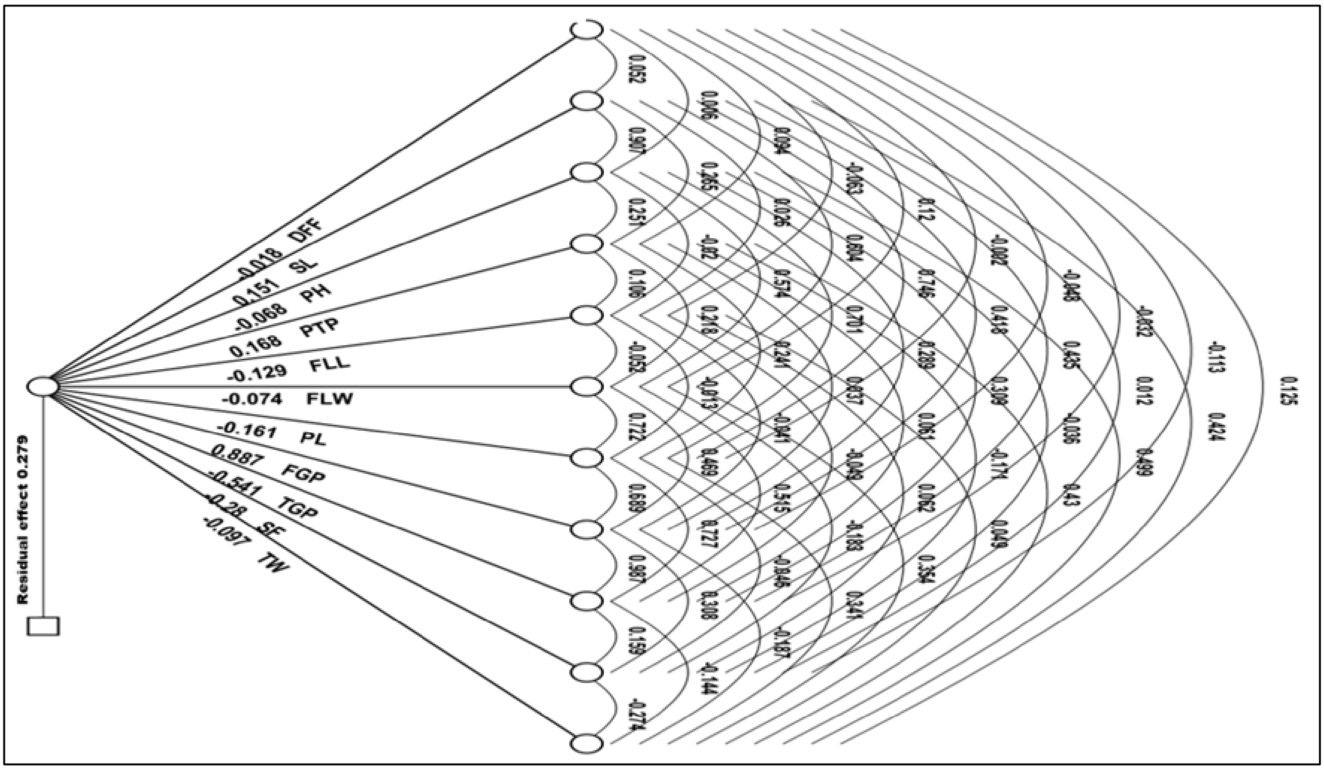


Fig 5: Path diagram of yield components for grain yield per plant in F_2 derivatives of YH3 x AKDRMS 21-54 intra-specific cross

Conclusion

The outcome of the current study indicated high GCV, PCV, heritability and genetic advance as % of mean for number of filled grains per panicle, total grains per panicle and test weight indicating the effectiveness of direct selection for improvement of these traits. Among these traits, filled grains per panicle recorded high positive direct effect coupled with significant and positive correlation with grain yield per plant. Hence, the trait, filled grains per panicle is identified as effective selection criterion for effecting grain yield improvement.

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