Received: 09 Mar 2022 | Revised: 11 May 2022 | Accepted: 13 May 2022

Electronic Journal of Plant Breeding

Research Article

Genetic studies on F_3 population of bread wheat [*Triticum aestivum* L.] for yield and its components traits

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Abstract
The F_3 population of 22 wheat genotypes for 14 traits was evaluated at Agriculture Research Farm, Lovely Professional University, Punjab, during *rabi,* 2020-21. ANOVA revealed highly significant variation among all the traits studied. According to GCV and PCV grain yield per plant, harvest index, ear weight, test-weight, the number of productive tillers per plant and the number of grains per ear were found to be high (>20). High heritability (>60) and GA% (>20) of mean were observed for grain yield per plant, biological yield per plant, test-weight, the number of ears per plant, the number of productive tillers per plant, the number of grains per ear, the number of spikelets per ear, ear weight, harvest index. The number of productive tillers per plant, biological yield per plant and harvest index exhibited a significant positive correlation and path direct with grain yield per plant. Thus, the above mentioned traits are additive genetic control and direct selection in wheat has good potential for improvement in grain yield.

Keywords: Wheat, segregation population, genetic variability, correlation, path analysis.

INTRODUCTION

Wheat is an allohexaploid (2n = 6x = 42, AABBDD). *T. aestivum*, or common bread wheat, is the most important species, accounting for more than 90% of the total wheat area in the country. According to the FAO's Annual Report 2021, wheat production in 2021/22 was 775.4 million tons and in India it is 103.9 million tons. To maintain wheat's high productivity level, genetic variability in nature or created through crop breeding is extremely valuable (Khan *et al*., 2017). The relationship between yield and its components is also necessary for a breeder to judge the superiority of direct and indirect selection. The amount of phenotype passed down to the next generation determines an individual's breeding value (Chowdhry *et al.,*1994). In the current study, heritability, genetic variability, and genetic advance for various yield characters were investigated in an F_3 segregating population using path analysis to estimate the direct and indirect effects of various characters on grain yield.

MATERIALS AND METHODS

Experiment was carried out at Lovely Professional University (LPU), Research Farm in Punjab during the *rabi*, 2020-2021.The study involved 22 F_3 segregating populations of wheat raised in a randomized complete block design with three replications. Twenty two F_3 populations **(Table 1)** were chosen for the experiment from the 11 crosses of the F_2 generation. These F_3 genotypes were sown with 22.5 x 3 cm spacing with a plot size of 400 m^2. The initial objective of making the crosses was the varietal development and 22 F_3 populations were selected on the

Table 1. List of wheat genotypes in F_3 generation

S.NO.	CROSSES	S.NO.	CROSSES
1	DBW- 90 X PBW-343	7	DBW-90 X MP-3336
2	WH- 703 X PBW-343	8	DBW- 107 X MP-3336
3	RUJ-4037 X PBW-343	9	RUJ-4037 X MP-3336
4	PBW-110 X PBW-343	10	DBW- 88 X MP-3336
5	DBW-107 X PBW-343	11	PBW- 677 X MP-3336
6	PBW-677 X PBW- 343		

basis of phenotypic screening for the traits *viz*., days to 50% heading, days to maturity, plant height, the number of productive tillers per plant, ear length etc.

In each replication, observations were taken on yield and yield-attributing characters. Except for the days to 50% heading and days to maturity, which were recorded on a plot-by-plot basis, five randomly selected competitive plants were tagged in each plot to record the observations. Days to 50% flowering, plant height, the number of productive tillers per plant, the number of spikelets per ear, ear length, ear weight, the number of ears per plant, the number of grains per ear, test-weight, biological yield per plant, harvest index, chlorophyll content and grain yield per plant were recorded.

The analysis of variance was done as per Panse and Sukhatme (1961) and heritability values were calculated as suggested by Robinson (1949) and the percentage was classified as low (0-30 %), moderate (30-60 %) and high (> 60 %) using Hanson *et al*. (1956). According to Johnson *et al*. (1955), the genetic advance was measured in absolute units (GA) and as a percentage of the mean (GAM), implying selection superiority of 5% of genotypes, and was classified as low (0-10 %), moderate (10-20 %), and high (>20 %). Burton (1952) formula was used to calculate the PCV and GCV in per cent, which was then classified as low (0–10 %), moderate (10–20 %), or high (> 20 %). Miller *et al*. (1958), proposed calculating genotypic correlations using variance and co-variances. Path coefficient analysis was carried out in accordance with recommendations by Dewey and Lu (1959). R software (Rstudio) with package variability was used to compute the data.

RESULTS AND DISCUSSION

The mean sum of squares (MSS) due to genotypes were highly significant for all characters at 1% and 5% levels of significance, indicating the presence of variability for all traits among the segregating population in **Table 2**. Similar findings were made by Devesh *et al*. (2021). There was no significant variation in replication, indicating that environmental error was less effective, providing breeders with an excellent opportunity to identify accessions with high scores for desirable characteristics in order to improve breeding programs. Mean performances of 22 wheat genotypes.

Table 2. Analysis of variance for grain yield and its components in wheat

		Mean sum of squares							
Source of variation	D.F	Days to 50% heading	Days to maturity	Plant height	Number of productive tillers per plant	Number of spikelets per ear	Ear length	Ear weight	Number of ears per plant
Replication	2	0.18	57.51	51.31	1.99	0.94	0.03	0.01	0.03
Genotypes	21	30.27**	51.06**	208.89**	25.64**	13.47**	1.83**	1.46**	22.73**
Error	42	14.15	3.89	14.20	0.71	0.54	0.04	0.08	0.48

		Mean sum of squares					
Source of variation	D.F	Number of grains per ear	Test-weight	Biological yield per plant	Harvest index	Chlorophyll content	Grain yield per plant
Replication	2	0.52	9.05	10.81	4.04	11.32	10.23
Genotypes	21	139.03**	973.58**	1820.49**	125.73**	12.67**	161.95**
Error	42	4.06	18.28	10.71	7.45	5.92	3.64

** Significant at 1 % level

The genotypes derived from DBW 107 x PBW 343 and DBW 90 x MP 3336 had early mean performance for days to 50% flowering (87.54 days) and days to maturity (141.12 days), respectively **(Table 3 & Fig.1)**. Because dwarfness is important in wheat, RUJ 4037 X MP 3336 with a plant height of (73.67 cm) is considered the best. High mean performance genotypes considered were: PBW 677 x PBW 343 for the number of productive tillers per plant (21.98), DBW 107 x PBW 343 for the number of spikelets per ear (21.91), PBW 110 x PBW 343 for ear length (13.29 cm), PBW 110 x PBW 343 for ear weight (4.93 g), PBW 677 x PBW 343 for the number of ears per plant (20.77), DBW 107 x MP 3336 for the number of grains per ear (67.39), PBW 677 x MP 3336 for test-weight (53.89 g), DBW 107 x PBW 343 for biological yield per plant (151.42 g), DBW 107 x MP 3336 for harvest index (26.45), RUJ 4037 x PBW 343 for chlorophyll content (51.83) and DBW 107 x PBW 343 for grain yield per plant (50.47). A similar range of mean values was observed by Jan *et al*. (2015).

Table 4 displays the variability parameters phenotypic variance, genotypic variance, PCV, GCV, broad sense heritability H(bs), genetic advance [GA], and GA as a percentage of the mean. High PCV than GCV indicates that the environment has an influence on the characters studied. Grain yield per plant had the highest PCV and GCV, followed by harvest index, ear weight, test-weight, the number of productive tillers per plant, and the number of grains per ear. A high GCV and PCV, according to Salesh *et al*. (2010), indicates that environmental influences have less impact on the expression of such characteristics, implying that there is a greater opportunity to improve them through selective breeding. GCV and PCV levels were found to be moderate for the number of spikelets per ear, ears per plant, and grains per ear. Because environmental influences on phenotypic expression are minimal in traits with moderate PCV and GCV, hereditary factors have a greater influence. As a result, these characteristics are amenable to further improvement through selection. Avinashe (2015) observed low PCV and GCV and were observed for days to 50% flowering, days to maturity and chlorophyll content. Similar results were observed by Reddy (2019) in wheat genotypes for days to maturity and days to 50% heading.

Johnson *et al*. (1955) proposed that combining H (bs) estimates with the GA per cent mean was a more effective way of estimating the impact of selecting the best genotypes. High heritability combined with high genetic advance ensures that heritability is due to additive gene effects, and early generation selection for the traits under study may be effective (Devesh *et al*., 2021). Grain yield per plant, biological yield per plant, test-weight, the number of ears per plant, the number of productive tillers per plant, the number of grains per ear, the number of spikelets per ear, ear weight, and harvest index all had high heritability and GA per cent mean **(Table 4).** These traits have a high selective value and are influenced by additive gene action. Wheat crop improvement benefits from the selection of these characters. Santosh *et al*. (2019) obtained comparable results, with high H (bs) and GA for plant height, the number of productive tillers per plant, ear length, test-weight, biological yield per plant and grain yield per plant. The results obtained are similar to those reported by Singh *et al*. (2013) for biological yield, harvest index and grain yield per ha. Fellahi *et al*. (2018) reported the same high values for days to heading, days to maturity and test weight and plant height and ear length were found to have moderate H (bs) and GA. This could be because the environment appears to have a

Table 3. Selection of better genotype based on mean values

S. No.	Character	Genotype
1	Days to 50% heading	DBW 107 X PBW 343
2	Days to maturity	DBW 90 X MP 3336
3	Plant height (cm)	RUJ 4037 X MP 3336
4	Number of productive tillers per plant	PBW 677 X PBW 343
5	Number of spikelets per ear	DBW 107 X PBW 343
6	Ear length (cm)	PBW 110 X PBW 343
7	Ear weight (g)	PBW 110 X PBW 343
8	Number of ears per plant	PBW 677 X PBW 343
9	Number of grains per ear	DBW 107 X MP 3336
10	Test weight (g)	PBW 677 X MP 3336
11	Biological yield per plant (g)	DBW 107 X PBW 343
12	Harvest index (%)	DBW 107 X MP 3336
13	Chlorophyll content (%)	RUJ 4037 X PBW 343
14	Grain yield per plant (g)	DBW 107 X PBW 343

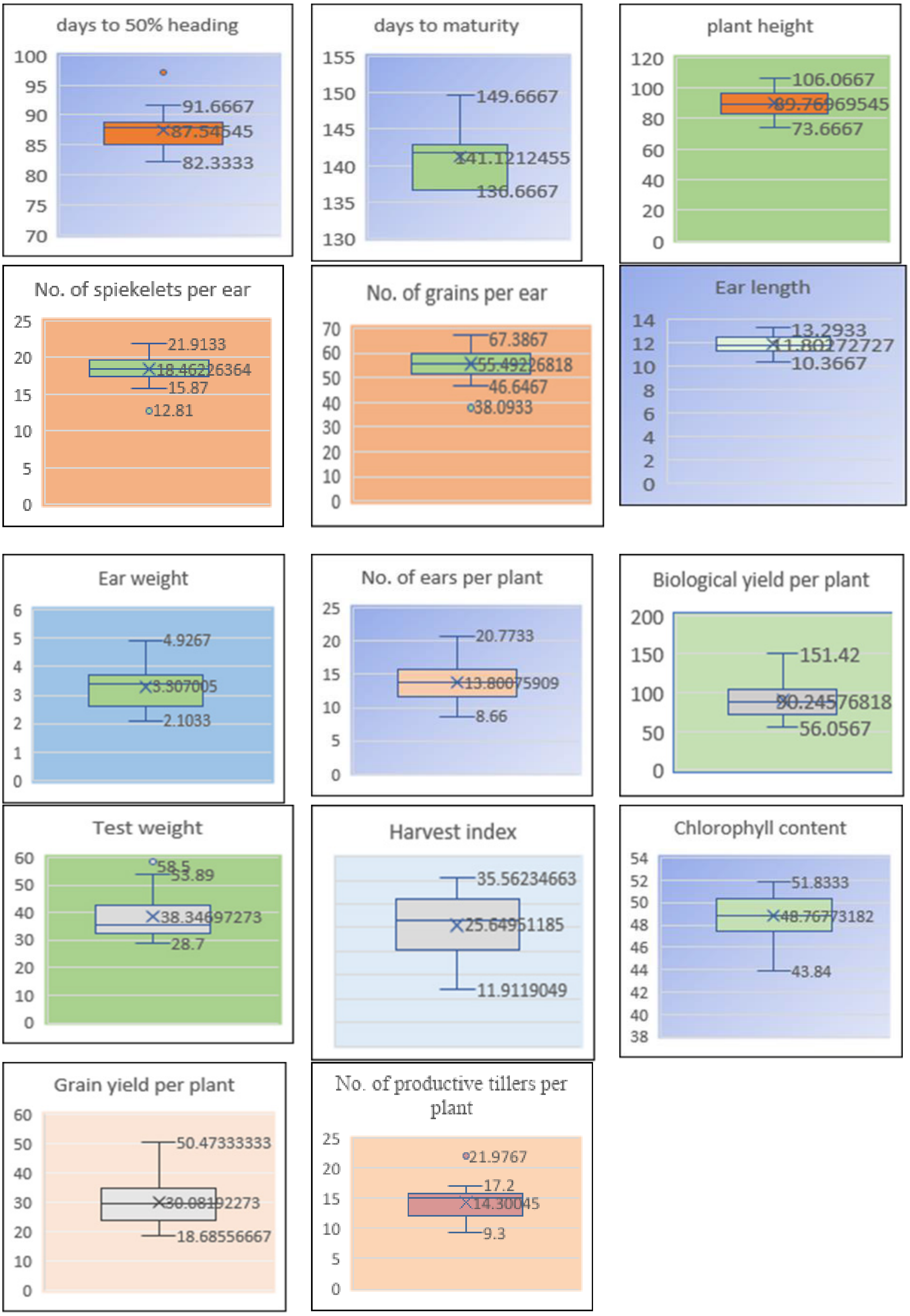

Fig. 1. Box plot showing mean and range for all the characters under study

Table 4. Genetic variability parameters for grain yield and its components in Wheat

Characters	Range		Mean	GCV%	PCV%	Heritability (bs) %	Genetic advance	GA % mean
	Minimum	Maximum						
Days to 50% heading	82.33	91.66	87.54	2.64	5.04	27.52	2.50	2.86
Days to maturity	136.66	149.66	141.12	2.80	3.13	80.14	7.31	5.18
Plant height (cm)	73.66	106.06	89.76	8.97	9.90	82.05	15.03	16.74
Number of productive tillers per plant	9.3	21.97	14.30	20.15	21.00	92.07	5.69	39.84
Number of spikelets per ear	12.81	21.91	18.46	11.24	11.93	88.76	4.02	21.82
Ear length (cm)	10.36	13.29	11.80	6.54	6.76	93.60	1.53	13.04
Ear weight (g)	2.10	4.92	3.31	20.48	22.25	84.70	1.28	38.83
Number of ears per plant	8.66	20.77	13.80	19.73	20.36	93.86	5.43	39.38
Test-weight (g)	28.7	53.89	38.34	20.93	21.12	94.57	16.38	42.73
Number of grains per ear	38.09	67.38	55.49	12.08	12.62	91.71	13.23	23.84
Biological yield per plant (g)	56.05	151.42	90.24	27.21	27.45	98.26	50.15	55.57
Harvest index (%)	11.91	35.56	25.64	24.47	26.69	84.09	11.86	46.24
Chlorophyll content (%)	43.84	51.83	48.76	3.07	5.86	27.55	1.62	3.32
Grain yield per plant (g)	18.68	50.47	30.08	32.55	33.65	93.53	14.47	64.84

Table 5. Genotypic and phenotypic correlation of quantitative traits in Bread Wheat

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	G	1.00	-0.03	-0.21	0.05	-0.18	0.14	-0.01	0.02	-0.16	0.07	0.17	-0.17	-0.42**	0.08
	P	1.000	-0.16	-0.30*	0.08	-0.22	0.12	0.09	0.01	-0.29*	0.06	0.36**	-0.19	-0.45**	0.10
X2	G		1.00	0.27*	-0.25*	0.03	-0.02	0.36**	-0.19	0.09	0.55**	-0.01	0.55**	0.12	0.42**
	P		1.000	0.34**	-0.29*	0.05	-0.04	0.48**	-0.19	0.08	0.62**	-0.02	0.70**	0.33**	0.47**
X3	G			1.00	-0.28*	0.26*	0.36**	0.10	-0.15	0.29*	0.30*	0.24	-0.09	0.32**	0.08
	P			1.000	-0.33**	0.26*	0.41**	0.14	-0.16	0.31*	0.34**	0.26*	-0.13	0.59**	0.07
X4	G				1.00	-0.27*	-0.07	-0.56**	0.85**	-0.36**	-0.13	0.43**	-0.07	0.05	0.36**
	P				1.000	-0.31*	-0.06	-0.61**	0.88**	-0.38**	-0.13	0.45**	-0.09	0.17	0.38**
X5	G					1.00	0.03	0.19	-0.21	0.95**	0.11	0.12	-0.06	-0.10	-0.02
	P					1.000	0.02	0.22	-0.22	0.98**	0.10	0.13	-0.11	-0.28*	-0.00
X6	G						1.00	0.25*	-0.02	0.09	0.17	0.31*	-0.08	0.05	0.17
	P						1.000	0.27*	-0.00	0.09	0.16	0.32**	-0.07	0.16	0.17
X7	G							1.00	-0.57**	0.26*	0.47**	-0.04	0.33**	0.01	0.15
	P							1.000	-0.63**	0.28*	0.51**	-0.05	0.39**	-0.13	0.17
X8	G								1.00	-0.29*	-0.14	0.48**	-0.21	0.00	0.27*
	P								1.000	-0.29*	-0.14	0.49**	-0.21	0.04	0.29*
X9	G									1.00	0.16	0.08	-0.08	-0.12	-0.03
	P									1.000	0.15	0.08	-0.10	-0.28*	-0.02
X10	G										1.00	0.28*	0.15	0.08	0.38**
	P										1.000	0.28*	0.17	0.20	0.39**
X11	G											1.00	-0.29*	-0.02	0.59**
	P											1.000	-0.31*	-0.03	0.61**
X12	G												1.00	0.18	0.50**
	P												1.000	0.10	0.52*
X13	G													1.00	0.05
	P													1.000	0.06

X1-Days to 50% heading, X2-Days to maturity, X3-Plant height, X4-Number of productive tillers per plant, X5-Number of spikelets per ear, X6-ear length, X7-Ear weight, X8-Number of ears per plant, X9-Number of grains per ear, X10- Test weight, X11-biological yield per plant, X12-Harvest index, X13-chlorophyll content, X14-Grain yield per plant.

* significant at 5% and ** significant at 1% level

greater impact on the expression of the characteristics, limiting the potential for selective improvement due to the presence of non-additive (dominant and/or epistatic) modes of gene action. Fellahi *et al*. (2018) observed moderate estimates for spike length, the number of spikelets per plant, grains per spike and harvest index. Low heritability and GA were observed for days to 50% flowering and chlorophyll content. Santosh *et al.* (2019) discovered that the days to 50% heading, days to maturity, and chlorophyll content all had low H (bs) and GA.

Days to maturity, the number of productive tillers per plant, the number of ears per plant, the number of grains per ear, biological yield per plant and harvest index all have a significant positive correlation with grain yield **(Table 5)**. Verma *et al*. (2019) observed comparable output with the number of ears per plant and biological yield per plant. Kumar *et al*. (2020) found a positive relationship between the number of tillers per plant, spike length, test weight and the number of grains per spike and grain yield per plant.

Path coefficient analysis was done using the Lenka and Mishra (1973) scale with grain yield per plant as the dependent trait. Among the thirteen characters, six have a direct positive effect on grain yield per plant, namely the number of productive tillers per plant, the number of spikelets per ear, the ear length, the number of grains per ear, the biological yield per plant and the harvest index, while the others have a direct negative effect **(Table 6).**These characteristics should be considered when selecting the next generation of wheat for the wheat improvement program. According to Baraskar *et al*. (2015) days to 50% flowering, days to maturity, plant height, ear weight, the number of ears per plant, test weight and chlorophyll content all had a negative direct effect on grain yield per plant. Tiwari *et al*. (2017), Dhanda *et al*. (2018), Rajaneesh *et al*. (2019), Reddy (2019), Reddy *et al*. (2022) and Devesh *et al*. (2021) observed similar results with positive effects of the number of grains per ear, the number of spikelets per ear and harvest index on grain yield.

The 22 wheat genotypes studied had a high degree of genetic variation based on the analysis of variance for all characteristics. Based on grain yield per plant, harvest index, ear weight, test-weight and the number of productive tillers per plant and grains per ear, high (>20 %) values of GCV and PCV were found for the attributes *viz*., grain yield per plant, biological yield per plant, test-weight, the number of ears per plant, the number of productive tillers per plant, the number of grains per ear, the number of spikelets per ear, ear weight, harvest index have high heritability (>60 %) and GA per cent (>20 %) of mean. This study found a favourable association between the number of productive tillers and yield, as well as an increase in ears grains per ear, biological yield and harvest index. It was shown that these features should be taken into account while selecting wheat varieties for increased productivity.

Table 6.Genotypic path coefficient on grain yield per plant in wheat

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	Genotypic correlation for grain yield per plant
X1	**-0.271**	0.016	0.007	0.008	-0.023	0.009	-0.027	-0.004	0.078	0.015	0.365	-0.168	0.100	0.08
X2	0.045	**-0.096**	-0.007	-0.025	0.005	-0.003	-0.137	0.055	-0.022	0.147	-0.022	0.609	-0.074	0.42**
X3	0.084	-0.032	**-0.022**	-0.028	0.027	0.028	-0.041	0.046	-0.082	0.080	0.265	-0.120	-0.131	0.08
X4	-0.024	0.028	0.007	**0.084**	-0.032	-0.005	0.174	-0.254	0.102	-0.032	0.453	-0.082	-0.039	0.36**
X5	0.061	-0.005	-0.006	-0.027	**0.103**	0.002	-0.064	0.065	-0.258	0.025	0.130	-0.097	0.063	-0.02
X6	-0.035	0.004	-0.009	-0.006	0.002	**0.068**	-0.078	0.002	-0.024	0.038	0.319	-0.065	-0.037	0.17
X7	-0.026	-0.046	-0.003	-0.052	0.023	0.019	**-0.284**	0.183	-0.075	0.121	-0.054	0.338	0.029	0.15
X8	-0.004	0.018	0.004	0.074	-0.023	0.000	0.181	**-0.287**	0.078	-0.034	0.494	-0.191	-0.011	0.27*
X9	0.080	-0.008	-0.007	-0.033	0.101	0.006	-0.081	0.085	**-0.263**	0.036	0.087	-0.091	0.063	-0.03
X10	-0.017	-0.061	-0.007	-0.011	0.011	0.011	-0.148	0.041	-0.040	**0.234**	0.279	0.152	-0.045	0.38**
X11	-0.100	0.002	-0.006	0.039	0.013	0.022	0.016	-0.143	-0.023	0.066	**0.990**	-0.269	0.008	0.59**
X12	0.053	-0.068	0.003	-0.008	-0.012	-0.005	-0.111	0.063	0.028	0.041	-0.307	**0.867**	-0.024	0.50**
X13	0.124	-0.032	-0.013	0.015	-0.029	0.011	0.038	-0.014	0.075	0.048	-0.035	0.095	**-0.220**	0.05

RESIDUAL EFFECT= 0.02104

X1-Days to 50% heading, X2-Days to maturity, X3-Plant height, X4-Number of productive tillers per plant, X5-Number of spikelets per ear, X6-ear length, X7-Ear weight, X8-Number of ears per plant, X9-Number of grains per ear, X10- Test weight, X11-biological yield per plant, X12-Harvest index, X13-chlorophyll content

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