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Research Article

Correlation and path coefficient analysis for yield, yield components and quality traits in wheat

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Abstract
Sixty advanced lines of wheat were procured from Wheat Improvement Project, JNKVV, Jabalpur. All these lines were evaluated at Seed Breeding Farm, Department of Genetics and Plant Breeding, College of Agriculture, Jabalpur. The experiment was conducted during *Rabi* 2016-17 in randomized complete block design with three replications. Correlation and path analysis was performed for 19 traits of wheat. Grain yield/plant showed a significant positive correlation with the biological yield/plant, plant height, hectolitre weight, harvest index and thousand-grain weight. In path analysis, grain yield/plant exhibited the highest positive direct effect *via* biological yield/ plant followed by harvest index, whereas wet gluten per cent exhibited a low positive direct effect. However, a negligible negative direct effect was obtained by the number of spikelets/spike and plant height. Correlation and path coefficient analysis indicated that the biological yield/plant, harvest index and thousand-grain weight are more important traits for wheat improvement.

Key words
Wheat, Correlation, Path analysis, Yield, Quality

INTRODUCTION

Wheat is a self-pollinated crop of family Gramineae. It is the world's second most important staple food crop for more than 35 per cent of the world's population next to rice. Extreme and high adaptation of this crop accompanied by its consumption pattern in human nutrition, has made it one of the most important cereal crops in the world. It is a rich source of carbohydrate and provides about 20 per cent of the food resources of the world (Farzi and Shekari, 2010). There are seventeen different species, out of which only three *i.e.*,*Triticum aestivum, Triticum durum* and *Triticum dicoccum* are cultivated in the world. *Triticum aestivum* (bread wheat) is occupying more than 90 per cent area followed by *Triticum durum* (9 to 10%) with a very limited area of wheat under *Triticumdicoccum.*

Due to high adaptation to varied environments, wheat is cultivated in almost all the states of India. The recorded production of wheat in the year 2019 was 102.19m. t. and the highest productivity of 35.07qt/ha (Annual Report 2019, ICAR-IIWBR). Madhya Pradesh ranked third in wheat production in the country with 10.23m. ha of area, 16m. t. of production and 3298kg /ha of productivity.

The correlation coefficient analysis is a statistical measure that is used to find out the degree and the direction of the relationship between two or more variables. It measures the mutual relationship between various plant traits and determines the component traits on which selection can be used for genetic improvement in yield while path coefficient analysis is useful to measure the inter-association among yield components and determine the importance of them for contributing to grain yield. Breeding and identification of high yielding wheat lines of good quality is a prime objective of wheat improvement.

MATERIALS AND METHODS

Sixty advanced lines (NIVT: National initial varietal trial; PYT: Preliminary yield trial and released varieties) of wheat (10 *Triticumdurum* and 50 *Triticumaestivum*) respectively presented in **Table 1** were procured from Wheat Improvement Project, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh. All these lines were grown in three replications by using randomized complete block design (RCBD) during *Rabi* 2016-17 at Seed Breeding Farm, Department of Genetics and Plant Breeding, College of Agriculture, Jabalpur. Each plot consisted of two rows of 2.5 m in length and 20 cm apart. The observations were recorded on five randomly selected competitive plants from each plot and replication for nineteen traits. The protein content of each genotype was estimated by the micro-Kjeldahl method (Markham, 1942). Quantity of wet gluten per cent was estimated using an automatic gluten washer. Sedimentation value

Table 1. List of wheat genotypes with their pedigree

S. No.	Genotypes	Pedigree	S. No.	Genotypes	Pedigree
1.	N5B 801	GW 1333	31.	PYT 86	20SAWSN48/4CHOI7STAR//WEAVER13/STAR
2.	N5B 803	HI 8789	32.	PYT 100	K9107/UP2425
3.	N5B 804	NIDW 1063	33.	PYT 64	15-KBSN198/UP2425
4.	N5B 805	MPO 1321	34.	PYT 33	35IBWSN249/DBW-17
5.	N5B 806	HI 8793	35.	PYT 44	SEGPSN83/DBW-17
6.	N5B 807	HI 8792	36.	PYT 56	15KBSN16/DBW-16
7.	N5B 808	GW 1335	37.	PYT 31	35IBWSN249/DBW-17
8.	N5B 809	NIDW 1053	38.	PYT 85	CMH832517/46GPSN6
9.	N5B 810	RKD 302	39.	PYT 88	BABA×12PR1//R9946/R9883
10.	N5B 811	UAS 462	40.	PYT 70	AGA12CMH79A5B2//RAJ3777/3/PBW502
11.	GW 366	DL 802-3/GW 232	41.	PYT 13	ROX-1/ACSuarrosa224//OPATA/3/HD2177
12.	Lok 1	S 308/S 331 or SONALIKA/CHOTI-LERMA	42.	PYT 89	BABA×/2PRI//R9946R9883
13.	JW 3173	HI 1011 WH 965-1	43.	$PYTT_3$24	35IBWSN159/DBW17
14.	MP 4010	ANGOSTURA 88	44.	PYT 6	Chen/ac SQ. HromsBC×1/3KA42/4/DBW17
15.	GW 322	GW 173/GW 196	45.	PYT 91	20SAWSN23/105AWYST-27
16.	MP 1106	HUW 334	46.	PYT 19	AGA/2 CMH79A582//RAJ-3777/3 PBW502
17.	MP 1201	CMH82A.1294/2*KAUZ//MUNIA/CHTO/3/MILAN	47.	PYT 87	BABA×2*PR_1//R9946/R9883
18.	GW 173	TW 275-7-6-1/Lok-1	48.	PYT 32	IBWSN249/DBW17
19.	MP 3288	DOVE/BUC/DL 788-2	49.	PYT 69	4EGPSN/109/4EGPSN85
20.	JW 3269	EGPSN-EC-1425319	50.	PYT 98	PR846/R9883//PBW402
21.	HI 1544	HINDI 62/BOBWHITE/CPAN2099	51.	PYT 18	CHEN/AE sq(trans)//BCN/3/KA/2/4DBW1
22.	WH 147	(E.4870 x C-303) x (S.339 x V1	52.	PYT 9	NIAW1917
23.	JW 3020	C 306/CB, SPRING(BW84)	53.	PYT 62	15KBSN98/UP2425
24.	MP 1142	169-90C369/CBRD//SW89.1862	54.	PYT 1	DBW16
25.	MP 3336	HD2402/GW173	55.	PYT 3	XING82.2661/2*KAUZ//20SAWSN70
26.	JW 3211	SKAUZ/2/FCT	56.	PYT 10	Croc-1/Ae.Squarrosa(224)//OP ATA/3/HD2177
27.	MP 1202	POCIS/3/KAUZ82.BOW//KAUZ	57.	PYT 66	MS-1770/MS/1900
28.	GW 273	CPAN 2084/VW 205	58.	PYT 68	MSI770/MS/900
29.	JW 17	HUW 334	59.	PYT 45	DBW/7PBW-343
30.	MP 3382	CHOIX/STAR/3/H.E1/3*CNO79//2*S.ERI/4/GW273	60.	PYT 20	35IBWSN159*2/DBW17/3/Alter84/Ae squarrosa (229)//Seri

measures the quality of proteins and is based on the fact that gluten protein absorbs water and swells considerably when treated with lactic acid in the presence of Sodium Dodecyl Sulphate (SDS). The hectolitre weight of the samples was measured using a hectolitre machine developed by DWR-Karnal, which gives the weight in terms of kg/hectolitre. Canopy temperature was recorded by the CTD instrument at grain filling stage by Infra Red Thermometer (Model LT 300 Sixth Sense). Chlorophyll content was estimated on 4th leaf from the top (fully expended leaflet) with the help of chlorophyll meter (SPAD-502 plus). Readings measured in 3 plants per plot at grain filling stages and chlorophyll content is expressed in terms of SPAD units.

The recorded observations were subjected to analysis of variance (ANOVA) as suggested by Burton, (1952). Correlation coefficient analysis was estimated as suggested by Miller *et al.* (1958) and path coefficient analysis as suggested by Wright (1921, 1934) and elaborated by Dewey and Lu (1959). Data analysis was performed by statistical software WINDOSTAT Version 9.2 at the Department of Genetics and Plant Breeding, College of Agriculture, Jabalpur.

RESULTS AND DISCUSSION

Variation within the germplasm of any crop provides an opportunity for plant breeders to develop new and improved cultivars with desirable traits in that crop. In the present study, the analysis of variance (**Table 2**) showed the presence of sufficient genetic variability among all the genotypes. Correlation and path analysis determines the nature of relationships among the traits and plays an important role during the selection of desirable parents for hybridization in wheat improvement programme. The *per se* performance of all the lines across traits is depicted in **Table 3**.

The estimates of genotypic and phenotypic correlation coefficients of different traits of wheat are mentioned in **Table 4**. At genotypic and phenotypic level, days to 50 per cent heading exhibited a positive significant association with spike length (0.448, 0.347) but, a negative significant association with thousand-grain weight (-0.359, -320), canopy temperature (0.325, -0.295), peduncle length(-0.303, -0.272), plant height (-0.289, -0.265) and biological yield /plant (-0.195, -0.161). Days to maturity showed a significant negative correlation at both level with plant height (-0.437, -0.261). Plant height showed a significant positive association with biological yield/ plant (0.670, 0.559), thousand-grain weight (0.627, 0.606), peduncle length (0.507, 0.456), grain yield/plant (0.464, 0.324) and canopy temperature (0.353, 0.316). Similar associations were also reported by Kashif and Khaliq (2004) for thousand-grain weight and grain yield/plant. But plant height showed a negative significant association with harvest index (-0.638, -0.414), chlorophyll content (-0.276, -0.220) and spike length (-0.197, 0.153). The number of tillers/plant had a highly significant positive association with number of spikes/plant (0.996, 0.954) but, significant negative association with thousand-grain weight (-0.225, -0.149) and spike length (-0.148). The number of spikes/plant showed a significant negative association with spike length (-0.174, -0.148). Spike length showed a significant positive correlation with harvest index (0.583, 0.304), the number of spikelets/spike (0.065, 0.490), the number of grains/ spike (0.457, 0.452) at both genotypic and phenotypic level but, at genotypic level a significant negative correlation with biological yield/plant(-0.250) and a significant positive correlation with biological yield/plant(0.152) while, it showed a significant negative association with thousand-grain weight (-0.314, -0.236) at both levels. Peduncle length showed a significant positive association with biological yield/plant (0.391, 0.318), thousand-grain weight (0.360, 0.326), canopy

Table 2. Analysis of variance (ANOVA)of nineteen traits of wheat

Source of variation	d.f.	Mean sum of squares									
		DH	DM	PH	NTPP	NSPP	SL	PL	NSPS	NGPS	TGW
Replication	2	5.90	1.43	5.06	2.65	4.78	3.95	3.31	2.22	4.67	3.12
Treatment	59	60.25**	9.31**	202.27**	4.51**	4.24**	4.70**	52.64**	9.86**	80.00**	171.33**
Error	118	2.57	3.26	3.29	1.31	1.39	0.79	2.54	1.15	4.39	1.58

Source of variation	d.f.	Mean sum of squares								
		CT	CC	PP	WGP	HLW	SDS	BYPP	HI	GYPP
Replication	2	0.33	4.89	6.52	31.71	7.33	2.77	5.01	1.29	1.90
Treatment	59	4.93**	20.04**	1.47**	16.53**	20.62**	116.97**	34.40**	10.21**	4.42**
Error	118	0.39	2.88	0.40	3.17	2.26	4.79	3.48	2.94	1.01

****Significant at 1% level of significance**

DH - Days to 50% heading, DM - Days to maturity, PH - Plant height, NTPP - Number of tillers plant^{-1}, NSPP - Number of spikes plant^{-1}, SL - Spike length, PL - Peduncle length, NSPS - Number of spikelets spike^{-1}, NGPS - Number of grains spike^{-1}, TGW -Thousand-grain weight, CT - Canopy temperature, CC - Chlorophyll content, PP - Protein%, WGP - Wet gluten%, HLW - Hectolitre weight, SDS - Sedimentation value, BYPP - Biological yield plant, HI - Harvest index and GYPP - Grain yield plant^{-1}.

temperature (0.276, 0.216), grain yield/ plant (0.261, 0.179) whereas, a significant negative association with harvest index (-0.365, -0.230). The number of spikelets/ spike showed a highly significant positive association with the number of grains/ spike (0.988, 0.946). The number of grains/ spike was not showing a significant association with any character. Significant positive association of thousand-grain weight with biological yield/plant (0.432, 0.371), canopy temperature (0.408, 0.356), grain yield/ plant (0.283, 0.204), but a significant negative association with harvest index (-0.433, -0.288); Rajpoot *et al*. (2015) also observed a positive association between Thousand-grain weight and grain yield/ plant. Canopy temperature showed a significant positive association with biological yield /plant (0.321, 0.232) but, a significant negative association with harvest index (-296, -0.168). Biological yield/plant had a highly significant positive association with grain yield/plant (0.905, 0.850) at both levels, Desheva, *et al*.(2016) and Phougat,*et al*. (2017) have also reported similar correlation. Biological yield/plant showed a significant negative association with harvest index (-0.597, -0.313). Harvest index showed a negative association with grain yield/plant (-0.204) at genotypic level but a significant positive association with grain yield /plant (0.229) at phenotypic level.

Table 3. *Per se* performance of all the lines of wheat across the traits

S. No.	Genotypes	DH	DM	PH	NTPP	NSPP	SL	PL	NSPS	NGPS	TGW	CT	CC	PP	WGP	HLW	SDS	BYPP	HI	GYPP
1.	N5B801	62.33	118.67	123.83	9.63	8.70	8.17	20.10	17.67	49.80	55.13	27.47	40.63	12.98	29.88	75.97	43.17	42.27	38.42	16.27
2.	N5B803	68.33	119.00	126.43	8.73	7.80	7.90	28.40	17.13	47.30	53.57	24.67	46.37	13.03	30.37	74.92	44.34	42.10	35.56	14.97
3.	N5B804	69.67	121.00	114.04	10.80	9.07	8.00	20.90	16.23	45.10	42.63	26.13	42.10	11.92	29.74	71.93	41.00	34.70	37.11	12.87
4.	N5B805	69.33	121.33	92.40	7.80	6.60	8.80	9.63	17.60	48.83	41.83	24.93	50.50	12.01	30.83	70.05	43.11	30.23	38.52	11.63
5.	N5B806	64.33	119.67	122.27	8.87	7.53	7.30	21.03	17.17	48.23	59.77	25.90	49.90	12.06	31.66	79.71	53.30	43.00	36.83	15.83
6.	N5B807	63.33	121.67	115.53	7.13	6.10	10.27	8.30	18.40	50.83	58.23	23.70	50.87	12.24	29.92	77.97	41.97	38.97	38.69	15.10
7.	N5B808	62.00	118.00	111.93	8.07	6.77	9.87	24.83	18.77	53.03	69.67	27.47	48.60	11.32	26.20	79.37	44.13	42.20	39.39	16.63
8.	N5B809	75.00	121.67	103.70	6.57	5.27	7.40	13.13	16.83	47.57	56.10	26.00	52.43	12.81	26.63	76.45	39.64	36.97	35.75	13.23
9.	N5B810	70.67	120.67	100.93	7.80	6.80	7.97	18.90	18.43	50.20	51.27	26.80	55.07	12.98	27.99	76.06	38.87	33.97	39.22	13.33
10.	N5B811	69.67	119.67	128.40	9.07	7.93	10.27	17.20	20.13	56.03	60.60	25.73	48.53	13.87	31.56	78.30	51.35	39.47	38.10	15.07
11.	GW336	66.00	122.33	103.37	9.70	8.43	9.43	13.50	18.40	51.93	50.03	24.90	48.17	13.70	33.06	71.82	41.89	34.33	42.55	14.63
12.	LOK1	64.33	120.00	107.13	8.73	7.48	9.73	14.80	17.90	50.07	50.00	25.83	50.00	12.05	33.66	72.17	40.50	30.83	41.07	12.67
13.	JW3173	73.33	123.33	102.20	6.63	5.97	11.40	11.10	16.40	44.87	40.03	26.07	45.33	12.94	33.48	68.23	39.98	32.90	42.28	13.90
14.	MP4010	64.67	120.67	99.13	8.40	7.47	8.70	13.83	15.67	43.73	41.80	24.30	44.47	13.54	32.35	71.73	52.87	36.10	39.25	14.17
15.	GW322	68.00	119.67	102.27	9.53	8.53	9.33	16.80	16.43	46.03	38.70	23.73	48.03	11.91	33.53	70.42	54.77	30.80	40.77	12.53
16.	MP1106	64.00	120.33	100.73	7.27	6.03	7.80	19.70	15.13	43.63	50.53	24.70	45.23	12.52	34.58	72.39	42.63	30.80	40.98	12.60
17.	MP1201	69.67	120.67	109.67	10.20	9.10	9.03	17.43	15.63	43.63	42.20	23.90	46.10	12.75	33.57	69.61	52.47	32.13	41.66	13.40
18.	GW173	61.67	119.67	83.87	10.33	8.83	6.93	14.17	13.87	38.80	43.37	25.43	50.37	14.15	34.02	72.76	54.93	33.03	41.22	13.63
19.	MP3288	69.67	118.33	100.93	9.93	8.17	8.07	9.50	15.13	44.70	44.13	24.00	44.43	13.30	32.13	73.10	42.28	34.00	39.01	13.27
20.	TW3269	66.33	119.67	111.77	8.57	7.60	11.07	11.37	16.40	44.93	48.20	23.83	45.97	12.00	29.66	71.46	50.86	32.37	41.00	13.27
21.	HI1544	63.00	120.33	99.97	9.20	7.73	9.40	9.77	16.43	46.03	45.59	26.27	49.97	12.59	28.39	75.93	35.40	32.40	42.61	13.80
22.	WH147	65.67	119.00	99.23	10.83	9.60	7.47	18.33	18.47	52.13	42.53	25.27	46.83	13.42	30.97	75.61	41.58	30.13	42.83	12.90
23.	JW3020	66.33	120.00	98.47	7.57	6.40	9.80	13.67	16.83	44.63	51.30	24.33	47.83	13.61	30.47	74.91	51.07	32.33	40.98	13.27
24.	MP1142	67.00	119.67	107.13	9.80	8.73	8.60	18.63	16.17	43.10	49.30	21.97	48.43	12.38	28.24	74.62	37.09	38.37	38.98	14.97
25.	MP3336	62.00	119.00	97.47	11.03	9.47	8.53	16.20	16.40	45.93	39.43	23.50	51.53	12.58	32.62	73.33	44.65	34.43	40.64	14.00
26.	JW3211	71.67	122.00	100.80	9.13	8.07	10.47	13.40	20.50	58.23	55.73	23.00	50.63	12.63	31.11	77.44	41.69	30.20	42.89	12.97
27.	MP1202	72.67	122.33	104.30	10.50	9.00	9.93	11.00	16.37	45.20	58.93	23.50	44.57	13.11	30.20	72.74	44.29	33.50	40.67	13.63
28.	GW273	65.00	120.33	99.67	7.73	6.33	8.83	13.87	14.77	41.03	38.60	24.83	47.37	12.72	32.16	74.17	53.88	31.67	39.86	12.60
29.	JW17	71.67	123.00	110.27	9.17	7.57	10.33	18.50	14.83	40.63	52.00	23.90	45.53	13.42	32.29	69.84	57.77	31.87	40.14	12.80
30.	MP3382	61.00	120.33	104.53	8.97	7.57	9.70	18.03	18.17	50.33	40.63	23.17	50.27	13.72	33.52	73.81	55.31	30.43	42.57	12.97
31.	PYT86	73.67	120.00	100.37	9.37	8.07	10.37	14.97	15.37	42.93	41.37	22.87	45.83	13.21	30.66	69.72	54.36	33.87	41.35	14.03

32.	PYT100	72.67	123.00	91.87	11.13	10.10	8.83	11.27	17.17	48.23	34.40	24.17	50.97	13.32	33.54	69.59	55.70	35.47	42.60	15.10
33.	PYT64	73.67	118.33	99.17	9.27	7.93	9.43	10.33	17.77	47.46	34.67	23.83	48.33	14.69	35.15	72.78	51.27	36.20	41.88	15.17
34.	PYT33	70.00	119.33	100.93	9.57	8.60	9.37	15.87	18.77	53.03	36.47	24.33	48.13	13.90	34.69	75.22	59.94	35.37	38.82	13.73
35.	PYT44	67.00	117.00	100.60	8.97	8.13	10.67	21.53	17.20	48.33	43.97	23.13	48.83	13.97	33.47	72.46	55.40	32.50	41.10	13.37
36.	PYT56	65.33	119.00	106.73	8.63	7.47	10.13	20.30	18.47	51.50	41.57	24.27	48.43	13.48	30.86	73.78	43.10	38.53	40.07	15.43
37.	PYT31	73.33	119.33	99.27	6.60	5.80	10.80	14.50	15.97	44.87	37.53	24.97	50.73	13.61	33.71	71.25	48.05	40.30	42.61	17.17
38.	PYT85	75.00	121.67	104.60	11.00	9.97	11.70	12.50	21.60	60.93	38.97	24.97	43.90	12.53	28.27	70.63	55.41	35.63	41.63	14.83
39.	PYT88	73.67	115.67	96.23	9.00	7.07	10.57	12.40	17.47	47.10	35.83	24.00	47.80	13.98	32.03	71.44	50.27	32.13	40.45	13.00
40.	PYT70	76.00	119.33	99.53	10.10	8.93	10.90	16.90	17.93	50.30	37.27	23.60	47.83	12.87	30.97	73.23	49.97	34.50	40.37	13.93
41.	PYT13	72.00	120.67	98.07	8.83	7.20	11.30	10.80	20.33	57.37	37.17	23.30	46.00	12.23	32.36	70.81	60.64	35.60	40.34	14.37
42.	PYT89	75.00	121.33	98.77	8.17	6.90	11.23	11.97	19.93	55.93	41.07	20.70	45.50	13.72	30.53	74.12	51.99	38.43	42.23	16.23
43.	PYTT324	77.00	119.33	96.87	8.30	6.97	11.27	14.93	20.60	57.60	37.80	24.53	49.50	13.25	27.89	71.74	52.54	30.73	39.16	12.03
44.	PYT6	72.67	120.67	94.87	10.07	8.80	11.13	10.43	19.00	50.80	36.43	22.83	48.83	12.65	30.44	70.79	53.28	32.80	40.70	13.33
45.	PYT91	77.00	116.67	95.63	7.43	6.13	10.63	19.77	17.13	48.13	41.43	23.97	44.90	12.34	26.96	74.49	45.57	32.07	41.12	13.17
46.	PYT19	70.67	125.00	98.60	8.77	7.70	10.60	11.27	17.80	50.67	49.30	24.73	51.67	12.02	32.15	74.92	42.57	30.33	39.06	11.83
47.	PYT87	72.67	118.33	100.27	7.90	6.57	11.37	13.50	21.03	58.17	40.97	24.83	47.33	14.23	32.13	69.20	52.50	30.73	42.97	13.20
48.	PYT32	71.00	119.00	99.40	10.03	9.10	9.37	12.10	14.73	40.93	39.93	21.80	46.47	12.34	32.90	73.31	48.90	30.97	39.38	12.20
49.	PYT69	66.33	120.00	98.53	7.13	5.70	10.33	10.60	20.80	57.87	41.70	24.67	45.90	13.84	34.19	73.83	57.45	31.13	43.67	13.60
50.	PYT98	76.33	119.67	98.00	9.33	8.03	11.07	13.33	18.17	51.23	36.17	22.50	50.00	13.21	34.57	69.20	45.80	30.17	39.07	11.77
51.	PYT18	66.33	118.33	98.53	8.33	7.13	10.90	21.37	19.27	53.23	47.53	23.70	46.23	12.86	37.98	73.46	37.61	33.03	42.72	14.10
52.	PYT9	70.33	116.67	96.17	7.17	6.10	10.20	16.80	16.20	44.83	42.47	24.00	47.30	13.27	33.60	71.72	55.16	30.37	41.94	12.73
53.	PYT62	72.67	118.00	96.10	7.47	6.50	9.57	9.63	17.13	46.80	44.03	22.97	48.83	12.85	28.75	72.70	52.66	30.37	40.36	12.27
54.	PYT1	77.33	122.33	98.87	9.37	7.80	9.90	11.00	13.27	37.27	42.73	25.20	47.50	13.80	30.22	72.25	51.68	33.90	42.73	14.50
55.	PYT3	72.00	122.67	100.43	9.10	8.00	10.83	15.70	16.67	47.27	47.47	23.70	47.97	13.33	29.11	74.48	45.06	33.63	42.39	14.27
56.	PYT10	74.67	120.33	96.03	8.07	6.83	8.83	10.57	16.03	43.83	41.33	23.57	46.00	13.08	28.56	74.40	45.75	32.40	41.50	13.43
57.	PYT66	71.33	121.67	99.90	9.40	8.33	10.83	16.30	19.43	54.30	41.97	24.07	50.90	12.77	30.02	72.85	45.57	34.10	42.47	14.50
58.	PYT68	71.33	120.67	97.20	6.17	5.10	10.10	12.27	18.07	51.57	48.50	23.97	48.60	12.23	29.55	74.66	45.90	32.53	42.09	13.70
59.	PYT45	64.33	122.33	97.63	8.97	7.77	12.20	11.40	18.47	52.13	34.87	24.53	47.83	12.35	30.03	67.85	44.27	33.83	41.48	14.03
60.	PYT20	72.00	120.33	96.00	7.07	5.83	10.83	16.33	17.47	49.13	44.37	23.77	50.33	12.70	31.37	73.19	45.35	30.60	43.01	13.17
	Mean	**69.52**	**120.14**	**102.29**	**8.80**	**5.58**	**9.76**	**14.94**	**17.46**	**48.67**	**44.85**	**24.31**	**47.90**	**12.98**	**31.35**	**73.11**	**47.99**	**33.98**	**40.64**	**13.48**
	Range	61.00	115.67	83.87	6.17	5.10	6.93	8.30	13.27	37.27	34.40	20.70	40.63	11.32	26.20	67.85	35.40	30.13	35.57	11.63
		77.33	125.00	128.40	11.13	10.10	12.20	28.40	21.60	60.93	69.67	27.47	55.07	14.69	37.98	79.71	60.64	43.00	43.67	17.17
	C.D. (5%)	2.60	2.92	2.93	1.85	1.91	1.44	2.58	1.74	3.39	2.04	1.02	2.75	1.02	2.88	2.43	3.54	3.02	2.77	1.63
	C.D. (1%)	3.43	3.87	3.88	2.45	2.53	1.90	3.41	2.30	4.48	2.69	1.35	3.63	1.35	3.81	3.22	4.68	3.99	3.67	2.15

DH - Days to 50% heading, DM - Days to maturity, PH - Plant height, NTPP - Number of tillers plant^{-1}, NSPP - Number of spikes plant^{-1}, SL - Spike length, PL - Peduncle length, NSPS - Number of spikelets spike^{-1}, NGPS - Number of grains spike^{-1}, TGW - Thousand-grain weight, CT - Canopy temperature, CC - Chlorophyll content, PP - Protein%, WGP - Wet gluten%, HLW - Hectolitre weight, SDS - Sedimentation value, BYPP - Biological yield plant^{-1}, HI - Harvest index and GYPP - Grain yield plant^{-1}.

Days to 50 per cent heading exhibited a significant positive association at phenotypic level with hectolitre weight (0.269) but at genotypic level it showed a significant negative association with hectolitre weight (-0.341), at both level days to 50 per cent heading showed a significant positive association sedimentation value (0.183, 0.172) while, it showed a significant negative association wet gluten per cent (-0.210, -0.151). Plant height showed a significant positive correlation with hectolitre weight (0.457, 0.374) but, significant negative correlation with wet gluten per cent (-0.188, -0.147). Spike length showed a significant positive correlation with sedimentation value (0.223, 0.186) but significant negative correlation with hectolitre weight (-0.442, -0.291). Peduncle length was significantly positive associated with hectolitre weight (0.325, 0.267). Thousand-grain weight was highly significant positive correlated with hectolitre weight (0.729, 0.615) but, significant negative correlation with sedimentation value (-0.395, -0.356) and protein per cent (-0.351, -0.237). Canopy temperature showed a significant positive

Table 4. Genotypic and phenotypic correlation coefficients among different traits of wheat

Traits		DM	PH	NTPP	NSPP	SL	PL	NSPS	NGPS	TGW	CT	CC	PP	WGP	HLW	SDS	BYPP	HI	GYPP
DH	G	0.138	-0.289	-0.086	-0.089	0.448	-0.303	0.112	0.098	-0.359	-0.325	-0.040	0.216	-0.210	-0.341	0.183	-0.195	0.104	-0.165
	P	0.058	-0.265**	-0.056	-0.068	0.347**	-0.272**	0.110	0.101	-0.320**	-0.295**	-0.040	0.140	-0.151*	0.269**	0.172*	-0.161*	0.048	-0.126
DM	G		-0.023	0.143	0.187	0.060	-0.437	-0.047	-0.020	0.142	0.045	0.134	-0.309	-0.088	-0.164	-0.169	-0.019	0.067	0.024
	P		0.005	0.033	0.047	0.140	-0.261**	0.018	0.052	0.075	0.063	0.138	-0.082	-0.082	-0.101	-0.105	-0.094	0.084	-0.044
PH	G			0.082	0.126	-0.197	0.507	0.095	0.091	0.627	0.353	-0.276	-0.246	-0.188	0.457	-0.151	0.670	-0.638	0.464
	P			0.049	0.069	-0.153*	0.456**	0.089	0.086	0.606**	0.316**	-0.220**	-0.143	-0.147*	0.374**	-0.144	0.559**	-0.414**	0.324**
NTPP	G				0.996	-0.184	0.094	-0.047	-0.039	-0.225	-0.121	-0.210	0.065	0.100	-0.193	0.136	0.051	0.023	0.084
	P				0.954**	-0.180*	0.043	-0.080	-0.063	-0.149*	-0.113	-0.142	0.047	0.111	-0.098	0.080	0.027	-0.081	-0.013
NSPP	G					-0.174	0.128	-0.038	-0.029	-0.222	-0.134	-0.202	0.047	0.124	-0.188	0.128	0.083	0.016	0.118
	P					-0.148*	0.068	-0.056	-0.043	-0.135	-0.116	-0.119	0.024	0.105	-0.100	0.068	0.061	-0.061	0.032
SL	G						-0.323	0.465	0.457	-0.314	-0.403	-0.082	0.085	0.035	-0.442	0.223	-0.250	0.583	0.010
	P						-0.208	0.490**	0.452**	-0.236**	-0.281**	-0.004	-0.030	-0.015	-0.291**	0.186*	0.152*	0.304**	0.025
PL	G							-0.012	0.003	0.360	0.276	-0.120	-0.118	-0.014	0.325	-0.113	0.391	-0.365	0.261
	P							-0.011	-0.006	0.326**	0.216**	-0.090	-0.084	-0.008	0.267**	-0.107	0.318**	-0.230**	0.179*
NSPS	G								0.988	0.011	-0.013	0.139	0.048	-0.088	0.150	0.045	0.089	0.183	0.194
	P								0.946**	0.012	0.008	0.109	-0.019	-0.092	0.117	0.060	0.056	0.050	0.081
NGPS	G									0.024	0.012	0.112	0.000	-0.092	0.160	0.029	0.084	0.139	0.167
	P									0.030	0.034	0.116	-0.037	-0.069	0.136	0.044	0.068	0.098	0.118
TGW	G										0.408	0.069	-0.351	-0.368	0.729	-0.395	0.432	-0.433	0.283
	P										0.356**	0.045	-0.237**	-0.290	0.615**	-0.356**	0.371**	-0.288**	0.204**
CT	G											0.044	-0.152	-0.227	0.309	-0.305	0.321	-0.296	0.225
	P											0.022	-0.111	-0.163*	0.201**	-0.237**	0.232**	-0.168*	0.135
CC	G												-0.055	-0.035	0.251	-0.142	-0.099	-0.017	-0.125
	P												0.002	-0.037	0.194**	-0.141	-0.075	0.013	-0.066
PP	G													0.424	-0.123	0.470	-0.007	0.404	0.204
	P													0.312**	-0.174*	0.245**	-0.063	0.201**	0.047
WGP	G														-0.404	0.328	-0.275	0.355	-0.153
	P														-0.270**	0.214**	0.183*	0.208**	-0.072
HLW	G															-0.314	0.485	-0.414	0.355
	P															-0.233**	0.388**	-0.242**	0.251**
SDS	G																-0.083	0.162	-0.013
	P																-0.078	0.095	-0.024
BYPP	G																	-0.597	0.905
	P																	-0.313**	0.850**
HI	G																		-0.204
	P																		0.229**

*, ** indicates the level of significance at 5% and 1% respectively

DH - Days to 50% heading, DM - Days to maturity, PH - Plant height, NTPP - Number of tillers plant^{-1}, NSPP - Number of spikes plant^{-1}, SL - Spike length, PL - Peduncle length, NSPS - Number of spikelets spike^{-1}, NGPS - Number of grains spike^{-1}, TGW - Thousand-grain weight, CT - Canopy temperature, CC - Chlorophyll content, PP - Protein%, WGP - Wet gluten%, HLW - Hectolitre weight, SDS - Sedimentation value, BYPP - Biological yield plant^{-1}, HI - Harvest index, GYPP - Grain yield plant^{-1}, G - Genotypic correlation and P - Phenotypic correlation.

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Table 5. Path analysis of various independent traits of wheat on grain yield

Traits	DH	DM	PH	NTPP	NSPP	SL	PL	NSPS	NGPS	TGW	CT	CC	PP	WGP	HLW	SDS	BYPP	HI	GYPP
DH	**-0.029**	-0.004	0.008	0.003	0.003	-0.013	0.009	-0.003	-0.003	0.010	0.009	0.001	-0.006	0.006	0.010	-0.005	0.006	-0.003	-0.165
DM	0.003	**0.022**	-0.001	0.003	0.004	0.001	-0.010	-0.001	-0.001	0.003	0.001	0.003	-0.007	-0.002	-0.004	-0.004	0.000	0.002	0.025
PH	0.023	0.002	**-0.078**	-0.007	-0.010	0.015	-0.040	-0.007	-0.007	-0.049	-0.028	0.022	0.019	0.015	-0.036	0.012	-0.053	0.050	0.464
NTPP	-0.006	0.009	0.005	**0.064**	0.064	-0.012	0.006	-0.003	-0.003	-0.014	-0.008	-0.013	0.004	0.006	-0.012	0.009	0.003	0.002	0.084
NSPP	0.003	-0.006	-0.004	-0.031	**-0.031**	0.005	-0.004	0.001	0.001	0.007	0.004	0.006	-0.002	-0.004	0.006	-0.004	-0.003	-0.001	0.119
SL	0.044	0.006	-0.020	-0.018	-0.017	**0.099**	-0.032	0.046	0.045	-0.031	-0.040	-0.008	0.008	0.004	-0.044	0.022	-0.025	0.058	0.010
PL	0.000	0.000	0.000	0.000	0.000	0.000	**-0.001**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.261
NSPS	-0.010	0.004	-0.009	0.004	0.004	-0.043	0.001	**-0.092**	-0.093	-0.001	0.001	-0.013	-0.005	0.008	-0.014	-0.004	-0.008	-0.017	0.195
NGPS	0.006	-0.001	0.006	-0.003	-0.002	0.030	0.000	0.067	**0.066**	0.002	0.001	0.007	0.000	-0.006	0.011	0.002	0.006	0.009	0.168
TGW	-0.003	0.001	0.005	-0.002	-0.002	-0.003	0.003	0.000	0.000	**0.008**	0.003	0.001	-0.003	-0.003	0.006	-0.003	0.003	-0.003	0.283
CT	-0.004	0.001	0.004	-0.002	-0.017	-0.005	0.003	0.000	0.000	0.005	**0.012**	0.001	-0.002	-0.003	0.004	-0.004	0.004	-0.004	0.225
CC	0.000	-0.001	0.002	0.001	0.001	0.001	0.001	-0.001	-0.001	0.000	0.000	**-0.006**	0.000	0.000	-0.002	0.001	0.001	0.000	-0.125
PP	0.010	-0.014	-0.011	0.003	0.002	0.004	-0.005	0.002	0.000	-0.016	-0.007	-0.003	**0.045**	0.019	-0.006	0.021	0.000	0.018	0.204
WGP	-0.001	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	0.000	-0.001	-0.001	0.000	0.002	**0.004**	-0.002	0.001	-0.001	0.001	-0.154
HLW	-0.005	-0.002	0.007	-0.003	-0.003	-0.006	0.005	0.002	0.002	0.010	0.004	0.004	-0.002	-0.006	**0.014**	-0.005	0.007	-0.006	0.355
SDS	-0.004	0.003	0.003	-0.003	-0.003	-0.004	0.002	-0.001	-0.001	0.008	0.006	0.003	-0.009	-0.007	0.006	**-0.020**	0.002	-0.003	-0.014
BYPP	-0.238	-0.023	0.814	0.063	0.102	-0.304	0.476	0.109	0.103	0.526	0.391	-0.121	-0.010	-0.335	0.590	-0.102	**1.215**	-0.726	0.906
HI	0.044	0.028	-0.267	0.010	0.007	0.244	-0.153	0.077	0.058	-0.182	-0.124	-0.007	0.169	0.149	-0.173	0.068	-0.250	**0.419**	-0.204

RESIDUAL EFFECT = 0.0213

Note: Diagonal bold figures are the direct effects and the off diagonals are indirect effects

DH - Days to 50% heading, DM - Days to maturity, PH - Plant height, NTPP - Number of tillers plant^{-1}, NSPP - Number of spikes plant^{-1}, SL - Spike length, PL - Peduncle length, NSPS - Number of spikelets spike^{-1}, NGPS - Number of grains spike^{-1}, TGW - Thousand-grain weight, CT - Canopy temperature, CC - Chlorophyll content, PP - Protein%, WGP - Wet gluten%, HLW - Hectolitre weight, SDS - Sedimentation value, BYPP - Biological yield plant^{-1}, HI - Harvest index and GYPP - Grain yield plant^{-1}.

correlation with hectolitre weight (0.309, 0.201) but, significant negative correlation with sedimentation value (-0.305, -0.237) and wet gluten per cent (-0.227, -0.163). Chlorophyll content was significantly positive correlated with hectolitre weight (0.251, 0.194). Protein per cent showed a significant positive correlation with sedimentation value (0.470, 245), wet gluten per cent (0.424, 0.312), harvest index (0.404, 0.201) but, significant negative correlation with hectolitre weight (-0.123, -0.174). Wet gluten per cent showed a significant positive correlation with harvest index (0.355, 0.208), sedimentation value (0.328, 0.214) but, at genotypic level wet gluten per cent showed a significant negative correlation with biological yield/plant (-0.275) and at phenotypic level it showed a significant positive correlation with biological yield/plant (0.183) while significant negative correlation with hectolitre weight (-0.404, -0.270) at both levels. Hectolitre weight showed a significant positive correlation with biological yield/plant (0.485, 0.388), grain yield/plant (0.355, 0.251) but significant negative correlation with harvest index (-0.414, -0.242) and sedimentation value (-0.314, -0.233). Meles,*et al.*(2017) also reported a significant positive association between hectolitre weight and grain yield / plant.

Path coefficient analysis was carried out by taking grain yield/plant as a dependent variable and the path coefficients were measured as per the scale given by Lenka and Mishra (1973). The grain yield/plant exhibited the highest positive direct effect *via* biological yield/plant (1.215) followed by harvest index (0.419) whereas, spike length (0.098) exhibited a low positive direct effect **(Table 5)**. However, a negligible negative direct effect was obtained by the number of spikelets/spike (-0.092). All the other traits recorded either negligible positive or negative direct effect on grain yield/plant. In this experiment biological yield/plant and harvest index had a positive direct effect on grain yield/plant. Direct selection for these traits may be rewarding and these traits should be given importance while practising selection aimed at improvement of grain yield in wheat. The highest positive direct effect on grain yield/plant *via.,* biological yield/plant and harvest index were also reported by Singh and Dwivedi (2002); Singh *et al*. (2003); Majumder *et al*. (2008); Avinashe *et al*. (2015); Kumari *et al*. (2017) and Phougat *et al*. (2017).

The number of tillers/plant had a positive indirect effect *via* the number of spikes/plant (0.0644) and sedimentation

value (0.0087); the number of grains/plant showed a positive indirect effect *via* the number of spikes/plant (0.0665), spike length (0.0300) and hectolitre weight (0.0105);biological yield/plant exhibited maximum positive indirect effect *via* plant height (0.8144), hectolitre weight (0.5904), thousand-grain weight (0.5257), peduncle length (0.4757), canopy temperature (0.3905), the number of spikelets/ spike (0.1089), the number of grains/ spike (0.1028) and the number of spikes/ plant (0.1019); whereas, it exhibited a negative indirect effect *via* harvest index (-0.7257), wet gluten per cent (-0.3345), spike length (-0.3042), days to 50 per cent heading (-0.2378), chlorophyll content (-0.1214) and sedimentation value (-0.1017). Harvest index showed a positive indirect effect *via* spike length (0.2443), protein per cent (0.1693) and wet gluten per cent (0.1488). The majority of the indirect effects of the remaining traits *via* other traits were negligible and of little importance. Residual effect 0.0213 at genotypic level, showed that the traits included in the path analysis explained 97.8 per cent of the variability in grain yield.

The majority of indirect effects of various independent traits *via* other traits were extremely low of either sign or magnitude. There were only a few characters which had higher to moderate positive indirect effects. Biological yield/plant had a positive indirect effect on grain yield/ plant *via* plant height, hectolitre weight, thousand-grain weight, peduncle length, canopy temperature, the number of spikelets/spike, the number of grains/spike and the number of spikes/plant. Hence these indirect effects should also be kept in mind while selection for better yield.

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