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Ajay Jaiswal
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Sharad Tiwari
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

RS Shukla
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Vinod Kumar
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Suneeta Pandey
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Manoranjan Biswal
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Sanjay Kumar Singh
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Vinod Kumar
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Genetic analysis of hybrid wheat under timely and late sown conditions

Ajay Jaiswal, Sharad Tiwari, RS Shukla, Vinod Kumar, Suneeta Pandey, Manoranjan Biswal and Sanjay Kumar Singh

Abstract
An experiment was conducted to determine the genetic variability, heritability, genetic advance and character association for yield and its component traits in 68 hybrid wheat including 10 cms lines, 5 restorer lines and 3 best checks under timely and late sown conditions. Significant genotypic differences were observed for all the traits in both the environments. The high magnitude of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was recorded for number of grains per ear, harvest index, biological yield per plant, thousand grain weight, spike weight, number of spikes per plant and number of effective tillers per plant under timely and late sown condition. The traits grain yield per plant, number spikelets per spike, number of grains per ear, harvest index, biological yield per plant, thousand grain weight, spike weight, number of spikes per plant, number of effective tillers per plant and spike length reported as high heritable coupled with high genetic advance in both the environments. Grain yield showed positive and significant correlation with grains per ear, harvest index, biological yield per plant, thousand grain weight, spike weight, number of spikes per plant, number of spiklets per spike and number of effective tillers per plant but negative correlation and significant was recorded for days to 50% flowering, days to maturity and plant height under timely and late sown condition. Harvest index had highest positive direct effect on seed yield followed by biological yield per plant under both the environments, indicating that these were main contributors for enhancing the grain yield per plant.

Keywords: Genetic variability, correlation coefficient, heritability, genetic advance, wheat

Introduction

Wheat (*Triticum aestivum* L., 2n=6x=42) belongs to the genus “Triticum” of family- Poaceae has been a staple food of the major civilizations for 8000 years (Kumar *et al.*, 2021; Getachew *et al.*, 2017) [18, 9]. It is grown in temperate, irrigated to dry and high rainfall areas and in warm, humid to dry and cold environments. Wheat ranks second in world crop production and is a staple food for over 41% of the world's population in more than 40 countries, so it is known as “King of cereals”. India is the second-largest wheat producer in the world, with a production level of 109.52 million tones (Goyal *et al.*, 2020) [12]. Madhya Pradesh is the second-largest producer state of wheat with an area, production, and productivity of 6.69 million hectares, 17.58 million tonnes, and 2627 kg/ha, respectively (Anonymous, 2020-21). Madhya Pradesh wheat is known for its quality and sale at high premium rate in the market due to its good chapati making quality (Goyal *et al.*, 2020) [12]. Wheat production is affected by several environmental factors responsible for yield losses over world including India. Environmental stresses affect negatively plant growth, productivity, reproductive phases, and survival. Environmental stress may result from abiotic and biotic factors. High temperature is affected about 65 to 70 mha in the World (Reynolds *et al.*, 1994) [25], around 13.5 mha area in India (Joshi *et al.*, 2007) [16]. The influence of high temperatures on growth and development of wheat and other crops is well documented (Wheeler, *et al.*, 2000) [30]. Heat decreases leaf photosynthetic rate, increase embryo abortion, lesser grain number, and decrease filling duration of grains resulting in lower grain yield (Prasad *et al.*, 2006) [24]. When experienced during the reproductive phase, high temperatures induce the loss of both grain weight and number (Hays *et al.*, 2007) [13]. In order to raise the yield potential of the crop, genetic variability in the available germplasm is a prerequisite in breeding program to effectively utilize the superior genotypes (Goyal and Bisen, 2017) [10]. The assessment of genetic parameters like genotypic and phenotypic variability, genotypic and phenotypic coefficient of variation, heritability and genetic advance are significant for the effective selection and improvement of breeding population.

The present study therefore was conducted to estimate magnitude of phenotypic and genotypic variability, heritability, genetic advance, correlation coefficient and path analysis with the aim to utilize the genetic information gained for the developing superior wheat genotypes.

Methods and Materials

The experimental materials comprised of 68 wheat hybrids including 10 CMS lines, 5 restorer lines and 3 checks which were raised under timely (E1) and late sown condition (E2) during *Rabi* season, 2020-21 in a randomized block design with three replications at research area under, Seed Breeding Farm, Department of Plant Breeding and Genetics, College of Agriculture, JNKVV, Jabalpur (MP). The plot size was 2.5x 0.80 m with row to row spacing of 20 cm. JNKVV, Jabalpur is located in global geographical position between 23.207°N and 79.954°E in Kymore Plateau and Satpura Hills of Madhya Pradesh. Observations for all the traits were recorded by taking five plants per plot. The data were recorded for days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, number of spike per plant, number of spikelets per spike, spike length, spike weight, number of grains per ear, thousand grain weight, biological yield per plant, harvest Index (%), grain yield per plant. Analysis of variance for the observations recorded on different characters was carried out as per the standard procedure of Fisher (1930) [8]. Genotypic and phenotypic coefficients of variation were estimated according to Burton (1952) [5]. Heritability in broad sense and Genetic advance were worked out as per the procedures of Johnson *et al.,* (1955) [15]. Coefficients of correlation were estimated by using formula suggested by Miller *et al*., (1958) [20] and path coefficient analysis as per Dewey and Lu (1959) [7]. The statistical tools INDOSTAT were utilized for data analysis.

Results and Discussion

Analysis of variance

The mean sum of squares for different traits under study has been presented in table 1. The results indicated that mean sum of squares due to genotype were significant for all the morphological and physiological characters studied under both timely and late sown conditions indicating thereby the prevalence of enough genetic variability in the materials under study for selection and improvement. Therefore, further analysis of data is appropriate for computation of correlation coefficient analysis. Similar results were also recorded by Nukasani *et al.,* (2013) [22].

Variability parameters

The result of mean, range, genotypic coefficient of variation (GCV), Phenotypic Coefficient of Variation (PCV), heritability (broad sense), and expected genetic advance have been presented in table 2. This revealed sufficient range of variation among genotypes for each character.

GCV and PCV

A perusal of table 2 revealed that phenotypic coefficients of variance (PCV) was higher than genotypic coefficients of variance (GCV) for all the characters under study but the difference was relatively small indicating that these characters were less influenced by the environment. Under timely sown condition number of grains per ear depicted high PCV and GCV, respectively followed by harvest index, biological yield per plant, thousand grain weight, spike weight, number of spikes per plant and number of effective tillers per plant, whereas, under late sown condition number of grains per ear, biological yield per plant, spike weight, thousand grain weight, harvest index %, number of spikes per plant, number of effective tillers per plant showed highest value of PCV and GCV. Similar results were obtained by Bhushan *et al.,* (2013) [4] for grain yield and productive tiller per plant. Veeresha and Naik (2016) [29], Jain and Kashyap (2013) [14] and Nukasani *et al.,* (2013) [22] for number of productive tillers per meter and grain yield. Moderate PCV and GCV were obtained for plant height, number of spiklets per spike, spike length and 1000-grain weight under timely and late sown condition. Similar results were reported by Nukasani *et al.,* (2013) [22] reported moderate PCV and GCV for plant height and 1000-grain weight. Lowest PCV and GCV were obtained for days to maturity under timely and late sown condition. Similar results were reported by Bhushal *et al.,* (2017) for days to heading, days to anthesis and days to physiological maturity, by Bhushan *et al.* (2013) [4] and Goyal *et al.,* (2019) [11] for days to heading and days to maturity.

Heritability and genetic advance

The genetic parameter heritability determines the extent of genetic control of a given trait and its transmission to progeny and, hence has bearing on the selection efficiency of trait concerned. Johnson *et al.,* (1955) [15] advocated that for selection to be effective, heritability and genetic advance should be considered together. Under timely sown condition High estimates of heritability coupled with high genetic advance were recorded for days to heading, plant height, grain yield per plant, spike weight & biological yield per plant, number of grains per ear, harvest index, number of spike per plant, number of effective tillers per plant, thousand grain weight, number spikelets per spike and spike length whereas, under late sown condition high estimates of heritability and genetic advance have been observed for days to heading, grain yield per plant, biological yield per plant, plant height, spike weight, thousand grain weight, harvest index, number of grains per ear, number of spike per plant, number of effective tillers per plant, spike length. The high heritability and genetic advance are attributed due to additive gene action with least environment influence which would result in effective selection for these traits. Similar results were also recorded by Nukasani *et al.,* (2013) [22] for tillers per meter and grain yield per meter, by Singh *et al.,* (2012) [26] for tillers per plot and grain yield and by Veeresha and Naik (2016) [29] for number of productive tillers per meter and grain yield. Contrary to this Kumar *et al*., (2014) [17] observed moderate heritability for number of tillers per meter and grain yield. High heritability with moderate genetic advance was observed for days to maturity under timely and late sown condition. Contrary results were obtained by Jain and Kashyap (2013) [14], Bhushan *et al.,* (2013) [4] and Kumar *et al.,* (2014) [17] for 1000-grain weight.

Correlation coefficient analysis

Yield, a complex polygenic trait has a large number of other contributing component traits. Correlation analysis reveals the relationship of dependent variable yield with its independent variables, thus association of various traits would determine their relative significance to improve yield. The results of correlation coefficient at phenotypic and genotypic level among different traits were studied and have been presented in table 3. In almost all the characters the magnitude of genotypic correlation coefficients was found higher than phenotypic correlation coefficients, thus indicating a good extent of strong inherent association between different characters. Grain yield showed positive and significant correlation with number of grains per ear, harvest index, biological yield per plant, thousand grain weight, spike weight, number of spikes per plant, number of spiklets per spike and number of effective tillers per plant, but correlated negatively with days to 50% flowering, days to maturity and plant height under timely and late sown condition. Similar results were reported by Nukasani *et al.*, (2013) [22] for tillers per meter and grain weight per spike, by Arya *et al.*, (2005) [2] for effective tillers per plant and by Singh *et al.*, (2012) [26] for 1000 grain weight. Days to heading had positive and significant phenotypic correlation with days to anthesis, days to maturity, plant height under both the conditions.

Table 1: Analysis of variance for yield and yield attributing traits under timely sown (E1) and late sown (E2) conditions

Source of variation	D.F.	Envi.	Mean sum of square												
			DH	DM	PH	NETPP	NSPP	NSPS	SL	SW	NGPE	TGW	BYPP	HI	GYPP
Replication	2	E1	5.03	7.60	8.66	3.63	2.29	4.35	0.74	0.02	4.46	2.42	1.90	2.91	1.12
		E2	6.94	18.56	3.06	1.60	1.18	20.42	1.92	0.01	25.21	0.35	0.37	0.79	0.07
Treatment	67	E1	152.74**	129.19**	416.28**	48.02**	45.84**	21.80**	7.72**	2.19**	253.67**	122.96**	289.78**	322.82**	95.64**
		E2	137.11**	132.58**	412.72**	38.94**	38.23**	22.69**	7.46**	2.05**	244.09**	159.93**	309.04**	333.31**	69.56**
Error	134	E1	0.25	0.73	1.26	1.24	0.98	1.32	0.55	0.02	4.27	3.43	3.68	6.15	0.53
		E2	0.55	1.15	4.33	1.48	1.29	2.63	0.67	0.02	7.95	2.37	2.82	5.15	0.36

DH: Days to 50% Flowering (days); DM: Days to Maturity (days); PH: Plant height (cm); NETPP: Number of effective tillers per plant; NSPP: Number of Spike per plant; NSPS: Number of Spikelets per spike; SL: Spike length (cm); SW: Spike weight (g); NGPE: Number of grains per ear; TGW: Thousand grain weight (g); BYPP: Biological yield per plant (g); HI: Harvest Index (%); GYPP: Grain yield per plant (g)

Table 2: Genetic parameters for yield and yield attributing traits under timely sown (E1) and late sown (E2) conditions

Characters	Mean		PCV (%)		GCV (%)		h2 (bs)		GA% of Mean	
	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2
DH	63.873	60.520	11.190	11.216	11.162	11.148	99.5	98.8	22.936	22.828
DM	123.716	122.157	05.334	05.489	05.289	05.418	98.3	97.4	10.804	11.017
PH	88.574	83.238	13.340	14.223	13.279	14.002	99.1	96.9	27.231	28.395
NETPP	16.691	14.176	24.584	26.367	23.658	24.928	92.6	89.4	46.900	48.550
NSPP	15.098	13.039	26.442	28.291	25.611	26.911	93.8	90.5	51.102	52.731
NSPS	18.225	15.397	15.668	19.831	14.335	16.796	83.7	71.7	27.019	29.304
SL	09.444	09.111	18.176	18.805	16.361	16.514	81.0	77.1	30.335	29.875
SW	02.786	02.517	31.080	33.250	30.497	32.644	96.3	96.4	61.647	66.109
NGPE	39.120	34.637	23.899	26.878	23.307	25.614	95.1	90.8	46.824	50.285
TGW	43.186	40.840	15.233	18.142	14.616	17.744	92.1	95.7	28.890	35.751
BYPP	41.771	35.584	23.826	28.783	23.378	28.393	96.3	97.3	47.225	57.695
HI	37.381	37.259	28.274	28.725	27.485	28.071	94.5	95.5	55.038	56.508
GYPP	15.601	13.063	36.394	37.054	36.090	36.765	98.3	98.4	73.725	75.144

DH: Days to 50% Flowering (days); DM: Days to Maturity (days); PH: Plant height (cm); NETPP: Number of effective tillers per plant; NSPP: Number of Spike per plant; NSPS: Number of Spikelets per spike; SL: Spike length (cm); SW: Spike weight (g); NGPE: Number of grains per ear; TGW: Thousand grain weight (g); BYPP: Biological yield per plant (g); HI: Harvest Index (%); GYPP: Grain yield per plant (g)

Table 3: Phenotypic correlation coefficient for various traits under timely (E1) and late sown (E2) condition.

Characters	Env	DH	DM	PH	NETPP	NSPP	NSPS	SL	SW	NGPE	TGW	BYPP	HI	GYPP
DH	E1	1.0000	-0.0863	0.2916**	0.1146	0.0548	0.2184**	0.2219**	0.1943**	0.0211	0.0880	0.0465	-0.02204	0.0406
	E2	1.0000	-0.1426*	0.1714*	0.1160	0.1002	0.1994**	0.2707**	0.1818**	0.0100	0.0451	0.0164	-0.01103	0.0320
DM	E1		1.0000	0.1016	0.1440*	0.1639*	0.2230**	0.2417**	0.1076	0.0039	-0.1504*	-0.0936	0.0337	-0.0388
	E2		1.0000	0.1911**	0.1393*	0.1803**	0.1858**	0.2132**	0.1300	0.0296	-0.1116	0.0052	-0.0157	-0.0190
PH	E1			1.0000	0.2152**	0.2237**	0.4543**	0.5292**	0.0762	0.1209	0.0670	0.2039**	-0.2219**	-0.0327
	E2			1.0000	0.1405*	0.2091**	0.3625**	0.5650**	0.0686	0.1026	0.0369	0.2192**	-0.2979**	-0.0560
NETPP	E1				1.0000	0.8812**	0.1979**	0.0870	0.6410**	0.2354**	0.2774**	0.3723**	0.2572**	0.4467**
	E2				1.0000	0.8861**	0.2406**	0.1007	0.6277**	0.2276**	0.2677**	0.3183**	0.2023**	0.4009**
NSPP	E1					1.0000	0.2258**	0.1134	0.6080**	0.2853**	0.3194**	0.4467**	0.2303**	0.4781**
	E2					1.0000	0.3453**	0.1591*	0.6192**	0.2948**	0.3189**	0.4202**	0.1347	0.4585**
NSPS	E1						1.0000	0.5642**	0.2870**	0.3388**	0.0407	0.3916**	-0.0738	0.2390**
	E2						1.0000	0.4128**	0.4237**	0.2969**	0.0772	0.4566**	-0.1047	0.3243**
SL	E1							1.0000	0.0105	0.2372**	-0.0162	0.1309	-0.0951	0.0405
	E2							1.0000	0.1105	0.0967	-0.0528	0.1538*	-0.2148**	-0.0085
SW	E1								1.0000	0.3854**	0.4428**	0.4927**	0.3101**	0.5646**
	E2								1.0000	0.3945**	0.4219**	0.4731**	0.3133**	0.6090**
NGPE	E1									1.0000	0.4589**	0.6213**	0.4773**	0.7676**
	E2									1.0000	0.5208**	0.6194**	0.3241**	0.7298**
TGW	E1										1.0000	0.3703**	0.4726**	0.5746**
	E2										1.0000	0.3647**	0.4304**	0.5830**

BYPP	E1											1.0000	-0.0130	0.6731**
	E2											1.0000	-0.1805**	0.6834**
HI	E1												1.0000	0.71114**
	E2												1.0000	0.5666**

DH: Days to 50% Flowering (days); DM: Days to Maturity (days); PH: Plant height (cm); NETPP: Number of effective tillers per plant; NSPP: Number of Spike per plant; NSPS: Number of Spikelets per spike; SL: Spike length (cm); SW: Spike weight (g); NGPE: Number of grains per ear; TGW: Thousand grain weight (g); BYPP: Biological yield per plant (g); HI: Harvest Index (%); GYPP: Grain yield per plant (g)

Table 4: Direct (diagonal) and indirect path effects of different characters on grain under timely (E2) and late sown (E2) condition

Traits	Envi.	DH	DM	PH	NETPP	NSPP	NSPS	SL	SW	NGPE	TGW	BYPP	HI	GYPP
DH	E1	0.0257	-0.0023	0.0075	0.0030	0.0014	0.0062	0.0064	0.0051	0.0004	0.0023	0.0012	-0.0005	0.0412
	E2	0.0202	-0.0029	0.0035	0.0025	0.0021	0.0047	0.0064	0.0038	0.0003	0.0010	0.0003	-0.0002	0.0335
DM	E1	0.0013	-0.0148	-0.0015	-0.0022	-0.0025	-0.0037	-0.0041	-0.0017	-0.0001	0.0023	0.0014	-0.0005	-0.0394
	E2	0.0039	-0.0271	-0.0053	-0.0041	-0.0053	-0.0065	-0.0067	-0.0037	-0.0007	0.0031	-0.0002	0.0004	-0.0160
PH	E1	-0.0140	-0.0049	-0.0477	-0.0109	-0.0112	-0.0237	-0.0280	-0.0037	-0.0059	-0.0033	-0.0100	0.0111	-0.0338
	E2	-0.0105	-0.0117	-0.0599	-0.0093	-0.0133	-0.0266	-0.0393	-0.0041	-0.0066	-0.0021	-0.0137	0.0186	-0.0567
NETPP	E1	-0.0007	-0.0009	-0.0013	-0.0058	-0.0053	-0.0012	-0.0006	-0.0040	-0.0014	-0.0018	-0.0023	-0.0016	0.4645
	E2	-0.0181	-0.0223	-0.0231	-0.1482	-0.1350	-0.0382	-0.0198	0.1012	-0.0350	-0.0423	-0.0497	-0.0325	0.4242
NSPP	E1	0.0016	0.0048	0.0065	0.0250	0.0277	0.0067	0.0037	0.0179	0.0084	0.0094	0.0131	0.0064	0.4910
	E2	0.0197	0.0366	0.0416	0.1708	0.1874	0.0753	0.0382	0.1242	0.0601	0.0639	0.0831	0.0266	0.4831
NSPS	E1	0.0081	0.0083	0.0164	0.0068	0.0080	0.0331	0.0222	0.0105	0.0126	0.0017	0.0144	-0.0028	0.2594
	E2	0.0099	0.0100	0.0187	0.0109	0.0169	0.0422	0.0256	0.0216	0.0149	0.0038	0.0228	-0.0053	0.3874
SL	E1	0.0067	0.0074	0.0159	0.0027	0.0036	0.0181	0.0270	0.0002	0.0078	-0.0007	0.0041	-0.0030	0.0460
	E2	0.0090	0.0070	0.0187	0.0038	0.0058	0.0173	0.0285	0.0034	0.0044	-0.0021	0.0049	-0.0072	-0.0192
SW	E1	-0.0017	-0.0010	-0.0007	-0.0060	-0.0057	-0.0028	-0.0001	-0.0088	-0.0035	-0.0041	-0.0045	-0.0029	0.5848
	E2	-0.0056	-0.0040	-0.0020	-0.0203	-0.0197	-0.0152	-0.0036	-0.0297	-0.0126	0.0129	-0.0145	-0.0095	0.6214
NGPE	E1	-0.0002	0.0000	-0.0017	-0.0035	-0.0043	-0.0053	-0.0041	-0.0056	-0.0141	-0.0069	-0.0092	-0.0071	0.7930
	E2	-0.0003	-0.0007	-0.0028	-0.0061	-0.0083	-0.0091	-0.0040	-0.0110	-0.0258	-0.0146	-0.0172	-0.0091	0.7769
TGW	E1	-0.0026	0.0044	-0.0019	-0.0087	-0.0096	-0.0014	0.0007	-0.0132	-0.0139	-0.0284	-0.0108	-0.0147	0.6050
	E2	-0.0019	0.0045	-0.0014	-0.0112	-0.0134	-0.0035	0.0029	-0.0171	-0.0222	-0.0393	-0.0146	-0.0172	0.5859
BYPP	E1	0.0324	-0.0655	0.1428	0.2655	0.3214	0.2954	0.1038	0.3478	0.4409	0.2592	0.6791	0.0125	0.6899
	E2	0.0136	0.0046	0.1863	0.2727	0.3604	0.4401	0.1410	0.3971	0.5400	0.3023	0.8126	-0.1346	0.6910
HI	E1	-0.0151	0.0251	-0.1680	0.1986	0.1673	-0.0620	-0.0809	0.2404	0.3619	0.3752	0.0133	0.7228	0.7196
	E2	-0.0063	-0.0100	-0.2310	0.1629	0.1053	-0.0932	-0.1885	0.2380	0.2603	0.3252	-0.1229	0.7424	0.5725

DH: Days to 50% Flowering (days); DM: Days to Maturity (days); PH: Plant height (cm); NETPP: Number of effective tillers per plant; NSPP: Number of Spike per plant; NSPS: Number of Spikelets per spike; SL: Spike length (cm); SW: Spike weight (g); NGPE: Number of grains per ear; TGW: Thousand grain weight (g); BYPP: Biological yield per plant (g); HI: Harvest Index (%); GYPP: Grain yield per plant (g)

Path coefficient analysis

Since correlation studies alone are not sufficient to make picture of association analysis very clear, hence the assessment of real contribution of an individual character towards seed yield per plant becomes essential. Path coefficient provides a clear and more realistic picture of a complex situation that exists at correlation level. It measures the direct as well as indirect effect of one variable on the dependent variable through the other traits. The path coefficient analysis was done on genotypic correlations and results have been presented in table 4. A critical perusal of path coefficient analysis in which diagonal values is direct effects revealed that harvest index had highest positive direct effect on seed yield followed by biological yield per plant. Under late sown condition biological yield per plant had a highest positive direct effect on seed yield followed by harvest index, number of spiklets per spike and number of spike per plant. These results are in agreement with the findings of Choudhary *et al.*, (2020) [6]; Mohammad *et al.*, (2011); Phougat *et al.*, (2017) [23]; Singh *et al.*, (2012) [26] and Singh *et al.*, (2002) [28] for harvest index and biological yield/plant; Singh *et al.*, (2003) [27] for biological yield/plant; Majumder *et al.*, (2008) [19] for harvest index.

The negative direct effect was recorded for number of effective tillers per plant under late sown condition. Contrary to these results Nukasani *et al.*, (2013) [22] reported negative direct effect on grain yield although the magnitudes are very small. Residual factor value was found 0.1445 and 0.1646 under timely and late sown condition respectively indicated that there are some other factors influencing the grain yield, which were not being included in the study. From the results obtained in the present study, it can be concluded that biological yield per plant, harvest index, number of spiklets per spike and number of spike per plant, in order, were the most important traits supporting grain yield in wheat. Therefore, more emphasis should be given on these traits while making selection for high yielding genotypes in wheat.

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