



## Research Article

# Variability, Correlation and Path Coefficient Analysis for Agro-morphological Traits in Wheat Genotypes (*Triticum aestivum* L.) under Normal and Heat Stress Conditions

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### Abstract

Assessment of variability and traits association in crop help to enhance selection efficiency. Therefore, the present investigation entitled “Variability, Correlation and Path Coefficient Analysis for Agro-morphological Traits in Wheat Genotypes (*Triticum aestivum* L.) under Normal and Heat Stress Conditions” was carried out during winter season of 2019/2020 at Institute of Agriculture and Animal Science (IAAS), Bhairahawa, Nepal to identify traits that highly contribute to grain yield and suitable for its further improvement. The experiment was laid out following alpha lattice design with two replications. The twenty genotypes of wheat were sown in two different environments viz., irrigated and heat stress in November 29, 2019 and December 25, 2019 respectively. It was found that under normal condition, moderate GCV and PCV were recorded in SW, TGW, NGPS, and WGPS. Under heatstress condition, high GCV and PCV were observed in GY. High heritability and high GAM were observed in TGW & GY, NGPS, WGPS, TGW under normal and heat stress condition respectively. Under normal condition SW exhibited positive correlation and high positive direct effect on GY at genetic level and WGPS at phenotypic level. And under heat stress condition SW exhibited positive correlation and high positive direct effect on GY. Whereas, at phenotypic level, WGPS and PH exhibited high positive direct effect on grain yield. Hence it is clear that spike weight and weight of grains per spike are important traits for grain yield improvement.

**Keywords:** Genetic advance; Heat stress; Heritability; Path analysis; Wheat

## Introduction

*Triticum aestivum*, commonly known as wheat, is a cereal grass placed in family Poaceae. Wheat (*Triticum aestivum*) is the largest food crop to cover the earth's surface (218.54 million hectares in 2017) and the second largest crop after maize in terms of the production (771.71 million tons in 2017) in the world (FAO, 2018). Globally about 30% of the cereal producing area is represented by wheat (Cossani &

Reynolds 2012). Given the growing world population, wheat productivity is expected to reach 3.5 tons per hectare by 2033. However, the demand for wheat is rising and it is expected that by 2050 the requirement of wheat would be 60% higher than the present year (FAO, 2018). Therefore, to meet the food demand of increasing population,

improvement in crop production and productivity is the demand of 21st century (Poudel & Poudel, 2020).

Wheat is the most important cereal crop cultivated in Nepal after rice and maize and is ranked at 3rd position both in terms of area and productivity. It occupies 21.7% of total cereal crop area and contributes 19.7% of the total cereal production in the country. Presently, area under cultivation, production and productivity of wheat is 7,06,843 hectares, 1.95 million metric tons and 2.757 tons/ha respectively (MoAD, 2016). The productivity of wheat in Nepal is almost constant ranging from 1.9 to 2.5t/ha and is very low compared to highest wheat growing nations like New Zealand and Ireland and compared with other Asiatic countrylike Bangladesh.

Wheat is grown in tropical and sub-tropical region of the world which experiences various abiotic stresses. Adverse environmental stress significantly reduces crop production (Rahaie *et al.*, 2013). The major abiotic stresses include heat, drought, salinity cold, chemical and water excess. However, heat is the main abiotic stresses affecting the wheat production worldwide (Lesk *et al.*, 2016; Liu *et al.*, 2016). Wheat is a mesophytic plant so for cultivation of wheat, temperature range is relatively narrow and ranges from 10-15°C during sowing and 21-26°C during the ripening period though, there are varieties of wheat that can even grow at 35°C. With every passing year, there is change in rainfall patterns, increase in Carbon dioxide and other Greenhouse Gases concentration along with decrease in annual precipitation (Flato *et al.*, 2013). The period 1980 to 2015 has been the warmest period of the 1400-year duration; global temperature has risen to about 0.85°C during this period. One of the consequences of climate change will be reduced crop yield and it is believed to be the major risk in the realm of agriculture (Sonia *et al.*, 2019). Among all the crops, the production of the wheat will be highly reduced due to rise in temperature.

The wheat improvement programs in Nepal follow conventional approach of selection in high production environments and thus modern varieties are not specifically tested for stress conditions. In order to minimize the production losses due to abiotic stress, future wheat varieties must have enhanced adaptability to stress, because due to the changing global climate abiotic stress episodes are expected to become more frequent and severe. Numerous high yielding varieties that have been suggested in the past are presently losing their yield capacity because of changes in different edaphic and ecological conditions. Therefore, continuous determination of high yielding varieties that can adapt to changing ecological condition is important (Tahir *et al.*, 2009).

The genetic variability of crop and selection skill of plant breeder play important role for the success of plant breeding programs. The phenotypic and genotypic coefficients of

variation are helpful for identifying the magnitude of variability in the breeding populations, whereas assessment of heritability provides index of transmissibility of traits. Heritability is the ratio of variation due to differences between genotypes to the total phenotypic variation for a character in a population. Genetic advance estimates Improvement in the mean genotypic value of selected plants over the parental population. Combine estimation of Heritability and genetic advance gives more accurate result in predicting the genetic gain under selection. Variability, genetic diversity, expected genetic advances and heritability of the characters are fundamental for genetic improvement of the character (Adhikari *et al.*, 2018). The heritability alone does not provide precise information in identifying traits for selection. Heritability provides an idea to the extent of genetic control for expression of a particular trait and the reliability of phenotype in predicting its breeding value (Tazeen *et al.*, 2009). High heritability indicates less environmental influence in the observed variation (Mohanty, 2003). It also gives an estimate of genetic advance a breeder can expect from selection applied to a population and help in deciding on a crop breeding method to choose (Gatti *et al.*, 2005). Genetic advance is an important parameter that helps the plant breeder in selection programme as genetic advance estimates the degree of gain in a trait obtained under a given selection pressure (Hamdi *et al.*, 2003). Heritability estimates along with predicted genetic advance is more suitable (Johnson *et al.*, 1955). High heritability and high genetic advance for a given trait indicates that it is governed by additive gene action and, therefore, provides the most effective condition for selection (Tazeen *et al.*, 2009).

Grain yield in wheat is a complex trait and is the result of various contributing factors affecting yield directly or indirectly. Thus, the plant breeder is naturally interested in exploring the extent and type of association of such traits (Zafarnaderi *et al.*, 2013). Correlation coefficient is an important statistical method, which can help wheat breeders in selection for higher yields. The grain yield and yield attributes of wheat are affected highly by the type of genotype and the environment in which it grows. Therefore, when producing new cultivars by breeding, the breeders study the relationship between yield and yield components. To improve the grain yield, study of direct and indirect effects of yield components provides the basis for its successful breeding programs. Although correlation estimates are useful in identifying the components of complex trait such as yield, they do not provide a clear picture of the relative importance of direct and indirect effect of each of the component characteristics of this trait. Therefore, correlation along with path analysis is a logical step. The present study is therefore aimed to assess the variability, correlation and path analysis of yield and yield attributing traits among the wheat genotypes under normal and heat stress conditions.

## Materials and Methods

### Plant Materials

A set of twenty wheat genotypes were obtained from National Wheat Research Program (NWRP), Bhairahawa, Nepal. The complete sets of genotypes with their entry names are presented in the Table 1.

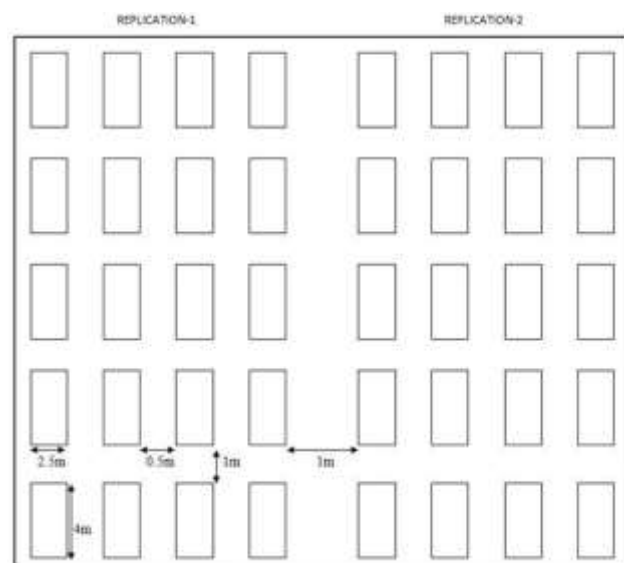
**Table 1:** List of genotypes used for the field experiment

S.N.	Genotypes	Source
1	Bhirkuti	NWRP, Bhairahawa
2	BL4407	NWRP, Bhairahawa
3	BL4669	NWRP, Bhairahawa
4	BL4919	NWRP, Bhairahawa
5	Gautam	NWRP, Bhairahawa
6	NL1179	NWRP, Bhairahawa
7	NL1346	NWRP, Bhairahawa
8	NL1350	NWRP, Bhairahawa
9	NL1368	NWRP, Bhairahawa
10	NL1369	NWRP, Bhairahawa
11	NL1376	NWRP, Bhairahawa
12	NL1381	NWRP, Bhairahawa
13	NL1384	NWRP, Bhairahawa
14	NL1386	NWRP, Bhairahawa
15	NL1387	NWRP, Bhairahawa
16	NL1404	NWRP, Bhairahawa
17	NL1412	NWRP, Bhairahawa
18	NL1413	NWRP, Bhairahawa
19	NL1417	NWRP, Bhairahawa
20	NL1420	NWRP, Bhairahawa

Source: NWRP, Bhairahawa

### Field Experimentation

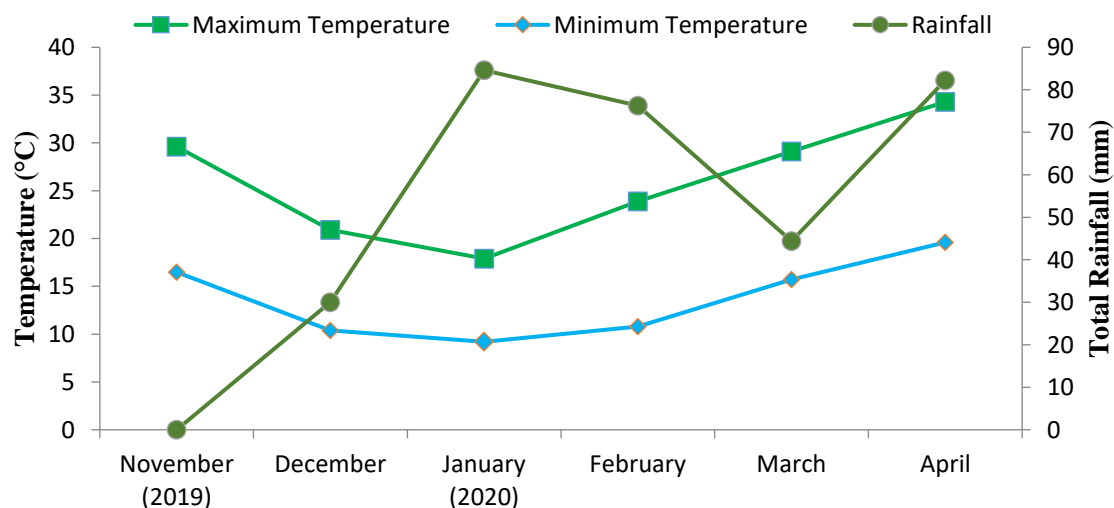
The field experiment was conducted at Bhairahawa, Rupandehi, Nepal. Geographic location of the research site is 27°30' N and 83°27' E and at the altitude of 79 meters above the sea level. This site has a humid sub-tropical climate where summers are hot and winters are cold with total annual rainfall as 1725.3mm. The field experiment was conducted following Alpha Lattice design (Fig. 1) with five blocks and the block size of 4 plots, replicated twice under normal and late sowing mediated heat stress conditions. Each genotype was planted in a plot size of 10m<sup>2</sup> (4m×2.5m). Each plot was provided with rows with spacing of 25 cm between the rows and there was continuous sowing as in line sowing method. There was gap of 0.5 meter between two plot and 1 meter gap between two replications.



**Fig. 1:** Experiment layout of the field in alpha lattice design

### Weather Condition

The maximum and minimum temperature and total rainfall during the crop growth period (November 2019 to April 2020) is presented in Fig. 2.



**Fig. 2:** Weather data of experimental site during crop growing period.

**Field Preparation, Sowing and Crop Management**

The field was prepared by using tractor for deep ploughing followed by two harrowing with disc and with one manual leveling. The line sowing was done on 29<sup>th</sup> November 2019 for irrigated condition and 25<sup>th</sup> December 2019 for heat stress condition at the seed rate of 100kg/ha. Late sowing wheat varieties faces severe temperature stress during its anthesis period.

**Fertilizer Dose**

Compost manure at the rate of 5ton/ha and the individual plots was fertilized with recommended dose of 100:50:25 kg NPK/ha. All the phosphorus, potash and half dose of nitrogen were applied before sowing. The remaining dose of nitrogen was applied in two split doses: a quarter at 30 DAS and the last dose at 70 DAS. One manual weeding was done during heading stage of plants. Irrigation was given for two times in each environment (Table 2). The remaining water requirement was fulfilled by natural rainfall.

**Table 2:** Irrigation scheduling in wheat in normal and heat stress environments.

	Normal condition	Heat stress condition
1 <sup>st</sup> irrigation	December 26, 2019	February 5, 2020
2 <sup>nd</sup> irrigation	February 9, 2020	February 20, 2020

**Harvesting and Threshing**

Harvesting was done manually by using serrate edges sickles when the grains were dried enough, and awns color had turned to straw color. Harvesting of 1m<sup>2</sup> of each plot were kept in different tagged plastic bags whereas total

yield of plot was harvested ignoring first row from sides of the plot and also packed in another plastic bag. Harvested wheat was threshed on the floor by beating with sticks and hands.

**Observations Recorded**

The yield and yield attributing traits like days to booting (DTB), days to heading (DTH), days to maturity (DTM), plant height (PH), spike length (SL), spikelets per spike (SPS), spike weight (SW), weight of grains per spike (WGPS), number of grains per spike (NGPS), grain yield (GY) and thousands grain weight (TGW) were recorded. Twenty wheat genotypes were assessed for biometrical analysis namely, genetic variability, heritability (broad sense), genetic advance as percent of mean, character association and cause and effect analysis.

**Statistical Analysis**

Data entry and processing was carried out using Microsoft Office Excel 2010. Analysis of variance of all the parameters and estimation of means was done by using R3.5.0 a software package for alpha lattice design by ADEL-R (CIMMYT, Mexico). Correlation and path coefficient analysis was done by using SPSS and Excel.

**Results and Discussions**

The analysis of variance revealed the presence of significant difference among wheat genotypes for most of the traits under normal and heat stress conditions, which indicates the existence of considerable genetic variability among treatments under study (Table 3). Thus, there is plenty of area and scope for improvement of different quantitative and qualitative traits through selection.

**Table 3:** Mean sum of squares for different quantitative characters of twenty wheat genotypes under study.

Traits	Mean sum of squares							
	Replication (df=1)		Treatment (df=19)		Block (within replication, df=8)		Error (df=11)	
	Normal	Heat stress	Normal	Heat stress	Normal	Heat stress	Normal	Heat stress
DTB	0.9	4.9	11.1834**	7.3719**	1.073	0.5209	0.7742	0.3576
DTH	4.9	4.9	9.1179**	7.1251**	1.8549	0.5596	1.2055	0.3294
DTM	2.025	0.625	4.598*	4.244**	0.3859	0.7202	1.308	0.6467
PH	7.225	19.6	27.5542**	24.3013**	2.8819	2.3906	5.2018	5.3886
SL	0.0063	0.0022	1.0157**	1.2255**	0.063	0.1417	0.1168	0.1226
SPS	0.016	0	1.2651NS	1.2582**	0.2502	0.1777	0.2675	0.2753
SW	0.0004	0.027	0.251*	0.1866*	0.0631	0.041	0.0673	0.0652
NGPS	0.289	21.904	62.2603*	110.1472*	15.9633	28.0392	22.5622	23.082
WGPS	0.0122	0.0436	0.1479NS	0.1619*	0.0407	0.0576	0.0615	0.0404
GY	289850.6	411278.4	227060.9NS	604118.4**	129528.2	58989.6	137835.1	109888.9
TGW	7.396	10.404	43.171**	32.3666**	17.0091	1.8876	7.0847	2.5287

\*significant at 0.05 level of significance, \*\* significant at 0.01 level of significance, NS: statistically not significant

**Variability, Heritability and Genetic Advance****Normal Condition**

Genotypic coefficient of variation (GCV) was lower than phenotypic coefficient of variation under both normal and heat stress conditions, signifying the impact of environment on the expression of these traits (Gaikwad et al., 2011). The variation observed in the characters studied in the present investigation were classified as, low (less than 10%), moderate (10-20%) and high (more than 20 %) phenotypic and genotypic coefficients of variation. None of the traits showed high GCV and PCV (Table 4). Moderate GCV and PCV were recorded in SW, TGW, NGPS, and WGPS. Moderate GCV and PCV for these traits indicating still there is possibility of improvement of genotypes through selection. Low GCV and PCV were observed DTM, DTH, DTB, PH, SL, SPS, and GY, Indicating the need of variability either by hybridization or mutation followed by selection. High difference between PCV & GCV was recorded in WGPS indicating high environmental effect in expression of this trait (Ogbonna and Ubi, 2005).

Heritability is classified as low (less than 30%), moderate (30-60%) and high (more than 60%), & Genetic advance as a percent of mean is classified as low (less than 10%), moderate (10-20%) and high (more than 20%). High heritability was observed in DTB, SL, DTH, TGW, PH, and SPS. Moderate heritability was observed in WGPS, NGPS, DTM and SW. Low heritability was recorded in GY.

Selection of GY will be in ineffective (high environmental effect) for its further improvement. High heritability was observed in DTB but GAM found to be low indicating that this trait may be governed by non-additive gene so, direct selection is not beneficial. Thus, high heritability doesn't always indicate a high genetic gain. So, high heritability with high genetic advance is suitable condition for selection. As high heritability coupled with high GA is likely to accumulate more additive gene leading to further improvement of their performance. Among the traits under study, none of the traits had high GAM. However, among these traits higher value of GAM was recorded in SW and TGW whose heritability is moderate and high respectively. Thus, selection of these traits is beneficial over other traits. Low heritability and low GAM was recorded in GY, indicating slow progress through selection of this trait.

**Heat Stress Condition**

High GCV and PCV were observed in GY which suggests the presence of sufficient variability in the germplasm, predominance of additive gene action and high transmissibility of this character. Similar result of high PCV and GCV was reported by Santosh & Jaiswal (2019). Therefore, direct selection will be rewarding depending upon this trait (Pal et al., 2016). NGPS and WGPS exhibited high PCV but moderate GCV (Table 5). Moderate GCV and PCV were recorded in SW and TGW. Low GCV and PCV were observed DTM, DTH, DTB, PH, SL and SPS. High difference between PCV & GCV was recorded in SW.

**Table 4:** Estimation of variability, heritability and genetic advance for yield and yield component of wheat genotypes under Normal condition.

Traits	$\sigma^2g$	$\sigma^2p$	Mean	GCV	PCV	H	GA	GAM
DTB	5.20	5.98	80.75	2.83	3.03	87.05	4.38	5.43
DTH	3.96	5.16	84.90	2.34	2.68	76.65	3.59	4.23
DTM	1.65	2.95	124.13	1.03	1.38	55.71	1.97	1.59
PH	11.18	16.38	93.23	3.59	4.34	68.24	5.69	6.10
SL	0.45	0.57	10.47	6.40	7.19	79.37	1.23	11.75
SPS	0.50	0.77	18.09	3.90	4.84	65.09	1.17	6.49
SW	0.09	0.16	2.38	12.71	16.73	57.71	0.47	19.89
NGPS	19.85	42.41	44.08	10.11	14.78	46.80	6.28	14.25
WGPS	0.04	0.10	1.79	11.63	18.11	41.26	0.28	15.39
GY	44612.88	182447.99	4322.13	4.89	9.88	24.45	215.16	4.98
TGW	18.04	25.13	38.14	11.14	13.14	71.81	7.41	19.44

**Table 5:** Estimation of variability, heritability and genetic advance for yield and yield component of wheat genotypes under Heat stress condition.

Traits	$\sigma^2g$	$\sigma^2p$	Mean	GCV	PCV	H	GA	GAM
DTB	3.51	3.86	70.30	2.66	2.80	90.75	3.68	5.23
DTH	3.40	3.73	73.65	2.50	2.62	91.16	3.63	4.92
DTM	1.80	2.45	107.33	1.25	1.46	73.55	2.37	2.21
PH	9.46	14.84	79.05	3.89	4.87	63.70	5.06	6.40
SL	0.55	0.67	10.02	7.41	8.19	81.81	1.38	13.81
SPS	0.49	0.77	17.87	3.92	4.90	64.10	1.16	6.47
SW	0.06	0.13	1.99	12.40	17.86	48.21	0.35	17.74
NGPS	43.53	66.61	38.21	17.27	21.36	65.35	10.99	28.76
WGPS	0.06	0.10	1.51	16.29	21.02	60.06	0.39	26.01
GY	247114.77	357003.66	2265.60	21.94	26.37	69.22	851.98	37.61
TGW	14.92	17.45	32.39	11.92	12.90	85.51	7.36	22.72

High heritability was observed all traits under study except SW which exhibited moderate heritability. Bhanu *et al.* (2018) also reported similar result for DTM and DTH. High heritability and High GAM were observed in GY, NGPS, WGPS and TGW, which reveals that these traits will be fruitful for their further improvement. High GAM for GY and TGW was also reported by Bhanu *et al.* (2018). Low GAM was observed DTM, DTH, DTB, PH and SPS. Moderate GAM was observed in SL and SW.

#### **Traits Association**

The study of inter-relationship among various characters in the form of correlation is, in fact, one of very important aspects in selection programme for the breeder to make an effective selection based on the correlated and uncorrelated response. The phenotypic correlation includes a genotypic and environmental effect, which provides information which provides information characters. The phenotypic correlations were normally of genetic and environmental interaction which provides information about the association between the two characters. Genotypic correlation is provided a measure of genetic association between the characters and normally used in selection. While environmental as well as genetic architecture of a genotype plays a great role in achieving higher yield combined with better quality.

Knowledge of correlation alone is often misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one. Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects. Thus, Path coefficient analysis provides actual information on contribution of characters and thus forms the basis for selection to improve the yield. If only if the trait has positive (or negative) correlation and high positive (or negative) direct effect on GY then correlation explains the true relationship.

#### **Normal Condition**

##### **Correlation**

The correlation and path coefficient analysis of wheat genotypes at genetic and phenotypic levels under normal condition is presented in Table 6 and Table 7 respectively. There is higher magnitude of correlation at the genotypic level in most cases as compared with the corresponding phenotypic level which clearly indicated the presence of inherent genetic relationships among various characters and it also indicate that association among these characters was largely under genetic control. Similar conclusion was obtained by Tripathi *et al.* (2015). There is significant positive correlation of plant height with grain yield at genetic level. None of the traits showed significant

correlation with grain yield at phenotypic level. DTH, SW, NGPS, WGPS and TGW showed positive correlation with grain yield at both levels. Similar results of positive association of seed yield t with number of 1000 grains weight and number of grains / spikes were observed by (AbdulHamid *et al.*, 2017). At phenotypic level highest positive correlation was observed between plant height and grain yield. DTB, DTM, SL and SPS showed negative correlation with grain yield at both levels.

#### **Path Coefficient Analysis**

##### **Path Analysis at Genetic Level**

SW, NGPS, TGW, PH exhibited positive correlation and positive direct effect on GY. Similar results of positive direct effect on grain yield were reported by Nagar *et al.* (2018) for PH. SW exhibited high positive direct effect on grain yield and the positive correlation of SW and grain yield is mainly due to direct effect of SW on grain yield. However, the positive correlation of NGPS, TGW and PH with GY is mainly due to the indirect effect of SW via these traits rather than their direct effect. SW showed high positive indirect effect on grain yield via WGPS, TGW, SL, NGPS, PH and negative indirect effect via DTB, DTH, DTM and SPS. NGPS, TGW and PH observed to have low indirect effect via other traits, when compared with SW. High positive direct effect is exhibited by DTB but its correlation with GY is -ve. So, a restricted selection model is to be followed to nullify the undesirable indirect effect in order to make use of direct effect (Ghimire *et al.*, 2020). As the direct effect of DTH is highly negative but the correlation with GY is observed to be positive. This may be due to counter-balancing by positive indirect effect of other traits via DTH. The negative direct effect and correlation on grain yield was observed in DTM and SL.

##### **Path Analysis at Phenotypic Level**

WGPS, DTH and PH exhibited positive correlation and positive direct effect on GY. WGPS exhibited high positive direct effect on grain yield and the positive correlation of WGPS and grain yield is mainly due to direct effect of WGPS on grain yield. However, the positive correlation of PH with GY is mainly due to the indirect effect of WGPS via PH rather than due to direct effect of PH. Also, the positive correlation of DTH with GY is mainly due to indirect effect of SW via DTH. WGPS showed high positive indirect effect on grain yield via PH, SL, SW, NGPS and TGW and negative indirect effect via DTB, DTH, DTM and SPS. DTH and PH observed to have low indirect effect via other traits, when compared with WGPS. Positive direct effect is exhibited by SL and DTM but their correlation with GY is -ve. The direct effect of SW, NGPS and TGW are negative but their correlation with GY is observed to be positive. The negative direct effect and correlation on grain yield was observed in DTB.

**Table 6:** Correlation and path coefficient analysis of wheat genotypes at genetic level under normal condition.

	DTB	DTH	DTM	PH	SL	SPS	SW	NGPS	WGPS	TGW
<b>DTB</b>	<b>6.69</b>	6.52	5.76	-2.08	-4.24	1.61	-5.53	-4.52	-6.19	-3.50
<b>DTH</b>	-4.68	<b>-4.81</b>	-4.49	0.70	3.44	-0.64	3.22	2.61	3.56	2.60
<b>DTM</b>	-1.33	-1.44	<b>-1.55</b>	0.88	0.99	-0.70	1.03	1.17	1.31	0.59
<b>PH</b>	-0.02	-0.01	-0.04	<b>0.08</b>	0.03	-0.04	0.04	0.04	0.05	0.04
<b>SL</b>	2.79	3.15	2.82	-1.41	<b>-4.40</b>	-0.23	-3.33	-1.62	-2.95	-3.57
<b>SPS</b>	0.19	0.11	0.36	-0.40	0.04	<b>0.79</b>	-0.13	-0.46	-0.28	-0.08
<b>SW</b>	-4.51	-3.65	-3.63	2.61	4.13	-0.89	<b>5.45</b>	3.07	5.36	4.58
<b>NGPS</b>	-1.21	-0.97	-1.35	0.98	0.66	-1.04	1.01	<b>1.79</b>	1.29	0.17
<b>WGPS</b>	2.69	2.15	2.46	-1.67	-1.95	1.01	-2.85	-2.09	<b>-2.90</b>	-2.17
<b>TGW</b>	-0.81	-0.84	-0.59	0.85	1.26	-0.15	1.30	0.14	1.16	<b>1.55</b>
<b>Genotypic correlation with GY</b>	<b>-0.21</b>	<b>0.20</b>	<b>-0.26</b>	<b>0.53*</b>	<b>-0.04</b>	<b>-0.29</b>	<b>0.21</b>	<b>0.14</b>	<b>0.40</b>	<b>0.21</b>

**Table 7:** Correlation and path coefficient analysis of wheat genotypes at phenotypic level under normal condition

	DTB	DTH	DTM	PH	SL	SPS	SW	NGPS	WGPS	TGW
<b>DTB</b>	<b>-0.94</b>	-0.88	-0.72	0.34	0.53	-0.19	0.68	0.52	0.71	0.46
<b>DTH</b>	0.76	<b>0.81</b>	0.62	-0.21	-0.49	0.10	-0.51	-0.36	-0.51	-0.38
<b>DTM</b>	0.22	0.22	<b>0.28</b>	-0.16	-0.14	0.12	-0.14	-0.17	-0.17	-0.07
<b>PH</b>	-0.26	-0.18	-0.39	<b>0.71</b>	0.29	-0.31	0.38	0.48	0.44	0.27
<b>SL</b>	-0.29	-0.31	-0.26	0.21	<b>0.52</b>	0.05	0.37	0.19	0.31	0.36
<b>SPS</b>	0.01	0.01	0.02	-0.02	0.01	<b>0.06</b>	0.00	-0.02	-0.01	0.01
<b>SW</b>	2.09	1.81	1.46	-1.57	-2.06	0.08	<b>-2.90</b>	-1.82	-2.79	-2.02
<b>NGPS</b>	0.89	0.70	0.96	-1.08	-0.59	0.63	-1.01	<b>-1.60</b>	-1.20	-0.09
<b>WGPS</b>	-2.98	-2.46	-2.38	2.45	2.35	-0.70	3.79	2.94	<b>3.93</b>	2.27
<b>TGW</b>	0.39	0.37	0.20	-0.30	-0.56	-0.10	-0.56	-0.05	-0.46	<b>-0.80</b>
<b>Phenotypic correlation with GY</b>	<b>-0.11</b>	<b>0.08</b>	<b>-0.20</b>	<b>0.39</b>	<b>-0.16</b>	<b>-0.28</b>	<b>0.10</b>	<b>0.11</b>	<b>0.25</b>	<b>0.01</b>

### Heat Stress Condition

#### Correlation

The correlation and path coefficient analysis of wheat genotypes at genetic and phenotypic levels under normal condition is presented in Table 8 and Table 9 respectively. There is significant positive correlation of PH, TGW with grain yield at phenotypic level. Mukherjee et al. (2008) had reported similar result for TGW. SW, NGPS and WGPS showed significant positive correlation with grain yield at both levels. Similar results were reported by Ramanuj et al. (2018) for NGPS at genetic level. SPS was observed to be significantly and negatively correlated with grain yield at both levels. AbdulHamid et al. (2017) has recorded significant negative correlation between SPS and GY at both phenotypic and genotypic level. SL is positively correlated with grain yield at genetic level. But contrasting association between SL and grain yield is

observed at phenotypic level. DTB, DTH and DTM showed negative correlation with GY at both levels.

#### Path Coefficient Analysis

##### Path Analysis at Genetic Level

SW exhibited positive correlation and high positive direct effect on GY. It means slight increase in SW will increase the GY significantly. And the positive correlation among SW and grain yield is mainly due to high positive direct effect of SW on grain yield. So, the direct selection of this trait will contribute to increase in Grain yield. High positive direct effect is exhibited by DTH but its correlation with GY is negative. So, a restricted selection model is to be followed.

SW showed high positive indirect effect on grain yield via PH, SL, WGPS, NGPS and TGW and negative indirect effect via DTB, DTH, DTM and SPS. The direct effect of PH, SL, NGPS and WGPS are negative but their correlation with GY is observed to be positive. The negative direct

effect and correlation on grain yield was observed in DTB, DTM and SPS.

#### Path Analysis at Phenotypic Level

WGPS, NGPS and PH exhibited positive correlation and positive direct effect on GY. Similar results of positive direct effect on grain yield were reported by Ramanuj *et al.* (2018) for PH. WGPS and PH exhibited high positive direct effect on grain yield and the positive correlation of WGPS and PH with grain yield is mainly due to their direct effect on grain yield. However, the positive correlation of NGPS

with GY is mainly due to the indirect effect of WGPS via NGPS rather than due to direct effect of NGPS. WGPS showed high positive indirect effect on grain yield via PH, SL, SW, NGPS and TGW and negative indirect effect via DTB, DTH, DTM and SPS. NGPS and PH observed to have low indirect effect via other traits, when compared with WGPS. Positive direct effect is exhibited by DTB and DTM but their correlation with GY is -ve. The direct effect of SW and SPS are negative but their correlation with GY is observed to be positive. The negative direct effect and correlation on grain yield was observed in DTH and SL.

**Table 8:** Correlation and path coefficient analysis of wheat genotypes at genetic level under heat stress condition.

	DTB	DTH	DTM	PH	SL	SPS	SW	NGPS	WGPS	TGW
<b>DTB</b>	<b>-0.39</b>	-0.39	-0.30	0.09	0.12	-0.02	0.20	0.05	0.18	0.11
<b>DTH</b>	4.47	<b>4.52</b>	3.61	-0.60	-1.25	0.09	-1.54	-0.42	-1.40	-1.15
<b>DTM</b>	-3.74	-3.89	<b>-4.86</b>	1.37	1.01	-1.61	1.15	2.27	1.73	-0.11
<b>PH</b>	0.55	0.34	0.71	<b>-2.52</b>	-0.89	1.16	-0.75	0.33	-0.48	-1.24
<b>SL</b>	0.20	0.18	0.13	-0.23	<b>-0.64</b>	-0.04	-0.25	0.01	-0.14	-0.38
<b>SPS</b>	-0.07	-0.02	-0.42	0.58	-0.07	<b>-1.27</b>	0.20	0.63	0.34	-0.20
<b>SW</b>	-2.30	-1.53	-1.07	1.34	1.74	-0.72	<b>4.51</b>	2.03	4.33	3.03
<b>NGPS</b>	0.24	0.19	0.93	0.26	0.04	0.99	-0.90	<b>-1.99</b>	-1.40	0.22
<b>WGPS</b>	1.27	0.85	0.98	-0.52	-0.60	0.73	-2.63	-1.92	<b>-2.74</b>	-1.25
<b>TGW</b>	-0.27	-0.25	0.02	0.47	0.57	0.15	0.65	-0.11	0.44	<b>0.96</b>
<b>Genotypic correlation with</b>										
<b>Grain Yield (GY)</b>	<b>-0.04</b>	<b>-0.02</b>	<b>-0.27</b>	<b>0.25</b>	<b>0.03</b>	<b>-0.55*</b>	<b>0.64**</b>	<b>0.88**</b>	<b>0.87**</b>	<b>-0.02</b>

**Table 9:** correlation and path coefficient analysis of wheat genotypes at phenotypic level under heat stress condition

	DTB	DTH	DTM	PH	SL	SPS	SW	NGPS	WGPS	TGW
<b>DTB</b>	<b>0.74</b>	0.72	0.49	-0.18	-0.22	0.03	-0.30	-0.10	-0.26	-0.21
<b>DTH</b>	-0.84	<b>-0.87</b>	-0.60	0.16	0.23	-0.02	0.27	0.13	0.24	0.22
<b>DTM</b>	0.26	0.27	<b>0.39</b>	-0.12	-0.08	0.12	-0.08	-0.17	-0.10	0.02
<b>PH</b>	-0.13	-0.10	-0.16	<b>0.55</b>	0.24	-0.14	0.24	0.07	0.21	0.27
<b>SL</b>	0.03	0.03	0.02	-0.05	<b>-0.11</b>	-0.01	-0.04	-0.01	-0.03	-0.06
<b>SPS</b>	-0.01	-0.01	-0.07	0.06	-0.02	<b>-0.23</b>	0.02	0.10	0.04	-0.05
<b>SW</b>	0.15	0.12	0.08	-0.17	-0.14	0.02	<b>-0.37</b>	-0.22	-0.36	-0.21
<b>NGPS</b>	-0.06	-0.06	-0.18	0.06	0.03	-0.17	0.24	<b>0.41</b>	0.30	-0.02
<b>WGPS</b>	-0.27	-0.21	-0.20	0.29	0.21	-0.12	0.73	0.56	<b>0.77</b>	0.32
<b>TGW</b>	0.08	0.07	-0.01	-0.13	-0.15	-0.05	-0.15	0.01	-0.11	<b>-0.27</b>
<b>Phenotypic correlation</b>										
<b>with grain yield (GY)</b>	<b>-0.05</b>	<b>-0.03</b>	<b>-0.24</b>	<b>0.46*</b>	<b>-0.03</b>	<b>-0.57**</b>	<b>0.56*</b>	<b>0.79**</b>	<b>0.70**</b>	<b>0.01**</b>



## Conclusion

Genotypic coefficient of variation was lower than phenotypic coefficient of variation under both normal and heat stress conditions, signifying the impact of environment on the expression of these traits. Under normal condition, none of the traits showed high GCV and PCV but moderate GCV and PCV with high heritability and genetic advance as percentage of mean were observed in thousand grain weight. Whereas, in heat stress condition, high GCV and PCV along with high heritability and GAM were recorded in Grain yield. Thus, traits namely thousand grain weight and grain yield can be used effectively in selection process of crop improvement program under normal and heat stress condition respectively. Spike weight and weight of grain per spike showed positive correlation and high positive direct effect on grain yield at genetic and phenotypic level respectively. Hence, selection of these traits might bring improvement in grain yield.

## Authors' Contribution

All authors have contributed equally to the present research work. Final form of the manuscript is approved by all authors.

## Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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