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Relationship between Wheat Yield and Yield Attributing Character at Late Sowing Condition

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Abstract. Correlation coefficient and path analysis were computed between yield and yield attributing trait among twenty genotypes of wheat. The research was conducted during winter season of 2020/2021 in the agronomic field of the Institute of Agriculture and Animal Science (IAAS), Bhairahawa, Nepal to identify the traits which influence the positive and negative relation to grain yield. Twenty genotypes of wheat were sown on 24th December 2020 on alpha lattice design with two replications. It has been found that under heat stress, DTB, DTH, DTM, CLC, PH, NGPS show a non-significant positive correlation with GY. Similarly ET shows a highly significant positive correlation to GY. However, SL, SW, TKW have a non-significant negative correlation with GY. In path analysis, DTM and ET have a positive direct effect on GY and DTH, SL, CLC and NGPS have an indirect effect on GY. Hence, the ET and DTM can be used to select wheat genotype for breeding purpose and studies to improve yield of genotypes under heat stress condition.

Keywords: character, correlation coefficient, grain yield, heat stress, path analysis

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1. Introduction

Wheat (*Triticum aestivum)* is cereal grass under Poaceae family. Wheat is the most important of staple food crop in the world, in terms of production (765.76 million tons) and production area (215.9 million hectare) [1]. In Nepal, in terms of both area (0.7 million hectares) and production (2 million tons) it is 3rd most important cereals crop after rice and maize[2]. Additional 198 million tons is required to meet the future demand of wheat until 2050 [3]. In the tropical and sub-tropical region of the world, wheat experiences various abiotic stresses. In Nepal, productivity of wheat is lower due to drought, heat stress [4], genotype, climate change, global warming [5], lack of inputs, irrigation facility [6], soil fertility degradation and biotic stress [7]. When temperature rises by 1 °C, wheat production reduces by 3-4% [8]. Heat stress is the major abiotic factor for reducing wheat production of world [9]. Wheat is a mesophytic plant i.e. neither grows in dry nor in wet condition. Temperature required during sowing and ripening period ranges from 10-15 °C and 21-26 °C respectively but during maturity also reaches up to 35 °C. Every year there is change

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in rainfall pattern, increase in temperature and CO_2 along with decrease in annual precipitation [10]. Due to climate change, major risks are faced by the agriculture sector because of which crop yield is reduced [11]. Higher temperature during anthesis due to climate change adversely affects winter crops. Grain yield in wheat is a complex quantitative trait because it is directly or indirectly influenced by various yield attributing characters [12], [13]. A correlation coefficient is a statistical tool that helps in selection of higher yield attributing characters and also useful for quantifying the magnitude and direction of that character. Yield and yield attributing characters are highly influenced by genotypes of the plant and environmental conditions. Therefore, only genotypic selection isn't effective[14] and selection should be based on the performance of yield and yield attributing characters[14]. Only correlation between yield and yield contributing characters are not sufficient to specify a relationship between them [15]. We can use path analysis for identifying direct and indirect effect of one variable to another [16]. During production of new variety by breeding, plant breeder should know the relationship between them so that correlation coefficient and path analysis help to select the main trait which influences the grain yield. In this study, relationship between various yield attributing characters like days to booting, days to heading, days to maturity, days to anthesis, plant height, spike length, spike weight, chlorophyll content, number of spikelet per spike, number of grain per spike, thousand kernel weight, number of effective tillers per meter square and grain yield was analysed. We obtain highly significantly positive correlation and highly negative correlation of effective tiller per square meter and spike length on grain yield respectively. In path analysis, days to maturity and effective tiller/m^2 have a positive direct effect on yield and days to heading, spike length, leaf chlorophyll content and number of grains per spike have an indirect effect on yield. This research is aimed to evaluate wheat genotype according to relationship between yield and yield attributing character for their further improvement.

2. Material and Method

2.1. Plant Material

Among 20 wheat genotypes used in this research, 15 Nepal Lines (NL), 3 Bhairahawa lines (BL) and two commercial varieties Gautam and Bhirkuti as check varieties were collected from National Wheat Research Program (NWRP) Bhairahawa, Nepal. All the name, source and origin of genotypes were listed below Table 1.

Table 1. Source and Origin of Wheat Genotypes Used in Research

S.N	Genotypes	Source	Origin
1	Bhrikuti	NWRP, Bhairahawa	CIMMYT, Mexico
2	BL 4407	NWRP, Bhairahawa	Nepal
3	BL 4669	NWRP, Bhairahawa	Nepal
4	BL 4919	NWRP, Bhairahawa	Nepal
5	Gautam	NWRP, Bhairahawa	Nepal
6	NL 1179	NWRP, Bhairahawa	CIMMYT, Mexico
7	NL 1346	NWRP, Bhairahawa	CIMMYT, Mexico
8	NL 1350	NWRP, Bhairahawa	CIMMYT, Mexico
9	NL 1368	NWRP, Bhairahawa	CIMMYT, Mexico
10	NL1369	NWRP, Bhairahawa	CIMMYT, Mexico
11	NL 1376	NWRP, Bhairahawa	CIMMYT, Mexico
12	NL1381	NWRP, Bhairahawa	CIMMYT, Mexico
13	NL 1384	NWRP, Bhairahawa	CIMMYT, Mexico
14	NL 1386	NWRP, Bhairahawa	CIMMYT, Mexico
15	NL 1387	NWRP, Bhairahawa	CIMMYT, Mexico
16	NL 1404	NWRP, Bhairahawa	CIMMYT, Mexico
17	NL 1412	NWRP, Bhairahawa	CIMMYT, Mexico
18	NL 1413	NWRP, Bhairahawa	CIMMYT, Mexico
19	NL 1417	NWRP, Bhairahawa	CIMMYT, Mexico
20	NL 1420	NWRP, Bhairahawa	CIMMYT, Mexico

Source: NWRP, Bhairahawa

2.2. Field Experimentation

The agronomy farm of the Institute of Agriculture and Animal Science (IAAS) Paklihawa, Bahirahawa, Nepal was used for filed experimentation. The coordinates of the research site is 27º30'N and 83º27' E and 79 masl. Research was conducted on sub-humid tropical region of Nepal where winter is cold and summer is hot. Alpha Lattice design was used for research program (Fig1). In this experiment there were 5 blocks with 4 plots in each block and 2 replications for heat stress condition. Each genotype was sown on 4.5m^2 (3m × 1.5m) plot. Within the plot, spacing between rows was 25cm and between plants was 2-3cm. Infield experimental design, gap between two plots and replication was 0.5m and 1m respectively. Similarly, the distance between two blocks was 0.5m within replication.

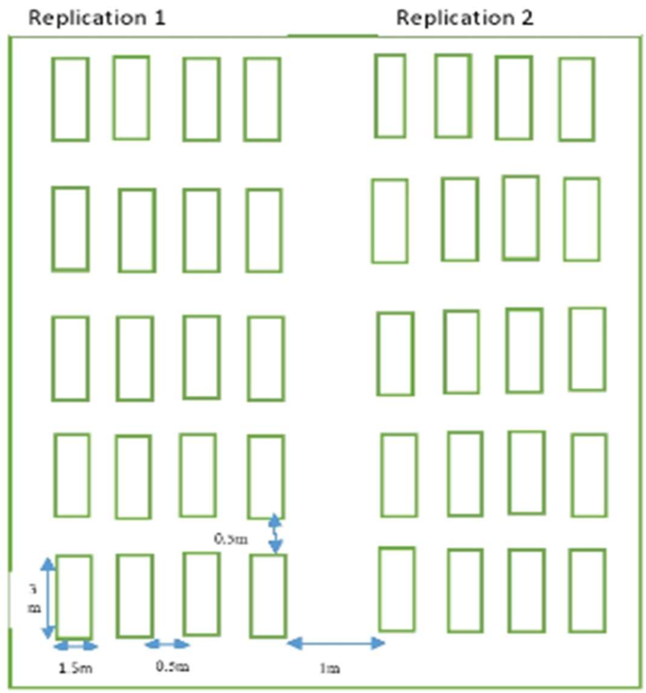

Figure 1. Alpha Lattice Design for Field Experimentation

2.3. Weather Condition

The agro-metrological data required for the research was obtained from National Wheat Research Programme (NWRP), Bhairahawa, Nepal located near to the research site (Fig 2). During research minimum temperature was in January (T_{max}19.2 °C and T_{min} 10.32 °C) at crown root initiation stage and maximum temperature was in March (T_{max} 34.37 °C and T_{min} 15.86 °C) at anthesis and grain filling stage. Maximum rainfall was in March (15mm) at grain filling stage.

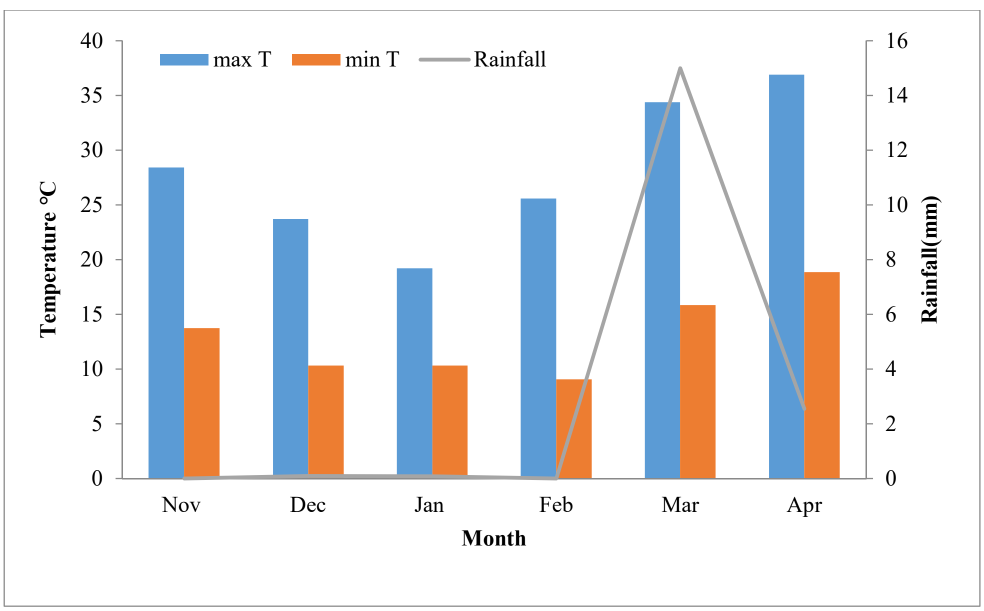

Figure 2. Agro-Meteorological Data of Crop Growing Period

2.4. Agronomic Practice

2.4.1. Field preparation and sowing

During field preparation two deep ploughing was done by using a cultivator and field was manually labelled at last. Seed was sown by line sowing method on 24th December 2020. Late sown wheat face heat stress at the flowering period due to the high temperature present at flowering time.

2.4.2. Nutrient management

Twelve soil samples were taken in W shape at 20-25 cm depth from the field. After thoroughly mixing and air drying and soil sample were sieved to 2mm sieve. The soil samples were analysed in the soil laboratory of IAAS Paklihawa campus, Rupandehi. The soil analysis result showed that soil was clay loam containing 0.39, 160, 130 kg/ha nitrogen, phosphorus and potash respectively. The soil was found slightly acidic (pH 6.7) and organic matter content was 4.5%. Compost manure @ 5 ton/ha and NPK as recommended dose @ 100:50:30 kg/ha was applied on each plot. All recommended dose of phosphorus and potash was broadcasted during field preparation while only half dose of nitrogen fertilizer was applied. The remaining dose of nitrogen was applied in two splits, at 30 days after sowing (DAS) and at 70 DAS.

2.4.3. Irrigation

Irrigation was done as in irrigated farming system. Total five irrigations by flooding method, were done during this research period. 1st irrigation was done at critical root initiation (CRI) stage, 2nd and 3rd in jointing stage, 4th in booting stage and 5th in heading stage. At grain filling stage in March 15 mm rainfall occurred.

Table 2. Irrigation Schedule in Wheat at Heat Stress Condition

No of Irrigation	Date
1	15th January 2021
2	30th January 2021
3	12th February 2021
4	25th February 2021
5	9th march 2021

2.4.4. Harvesting and threshing

Harvesting was done manually with the help of sickles at the harvesting stage of wheat. Harvesting 1 m^2 of each plot was done and tagged while 1 row on both sides was removed before harvesting 1 m^2. Threshing was done manually.

2.4.5. Observation record

Yield attributing character like days to booting (DTB), days to heading (DTH), days to maturity (DTM), days to anthesis (DTA), plant height (PH) in centimetre (cm), chlorophyll leaf content

(CLC), spike length (SL) in cm, spike weight (SW) in gram (gm), number of effective tiller per meter square (ET), number of spikelet per spike (NSPS), number of grain per spike (NGPS), thousand kernel weight (TKW) in gm and their correlation with grain yield (GY) in kg/ha was analysed. Chlorophyll value was observed by using SPAD (soil plant analysis development) after flag leaf emergence with three readings at the top, middle, and bottom of each leaf.

2.4.6. Statistical analysis

Microsoft Office Excel 2010 was used for data entry and processing. For analysis of variance of the parameters and estimation of their means, R3.5.0 a software package for alpha lattice design by ADEL-R (CIMMYT, Mexico) was used. Estimation of correlation coefficient and path analysis was done with the help of SPSS and Excel.

3. Results and Discussion

Under late sown condition, ANOVA table show significant mean difference and genetic variability among various characters of wheat genotype. All yields attributing characters show significant difference except days to anthesis and yield on different treatment at 0.01 level of significance (Table 3). Grain yield was determined by various complex morphological and physiological processes that occur during different stages of a plant.

Table 3. ANOVA Table of Different Quantitative Characters

	Replication (df=1)	Treatment (df=19)	Block (df=4)	Error (df=15)
DTB	30.62**	14.96**	0.44	2.34
DTH	75.62**	11.88**	0.5	2.46
DTA	40	117.44	118.56	117.8
DTM	72.9**	9.37**	3.71*	2.48
CLC	38	44.69**	2.21	8.5
PH	3.05*	23.74**	2.29	5.32
SL	0.0038	0.68**	0.19	0.08
SW	0.9	4.7**	1.5	2.25
NSPS	0.025	1.88**	0.65*	0.39
NGSP	2.5	12.2**	2.18	5.7
ET	60	2467.01**	896.08*	735.27
TKW	9.03*	23.59**	3.4	1.53
GY	80192.03	72345.7^{ns}	164338.4	88977.93

** Significance at 0.01 level of significance, *significant at 0.05 level of significance, ns: non-significance

The correlation coefficient provides the direction and degree of relationship between various yield attributing characters. Correlation among yield and yield attributing character was shown in Table 4.

Table 4. Correlation Coefficient of Thirteen Characters on Yield of Wheat Genotype

Character	DTB	DTH	DTA	DTM	CLC	PH	SL	SW	NSPS	NGPS	ET	GY	TKW
DTB	1												
DTH	0.89**	1											
DTA	0	-0.12	1										
DTM	0.78**	0.87**	-0.23	1									
CLC	0.63**	0.67**	-0.13	0.71**	1								
PH	0.01	0.1	0.1	0.7	0.02	1							
SL	-0.02	0.01	-0.21	0.11	0.24	0.41**	1						
SW	0.24	0.27	-0.32*	0.38*	0.56**	0.24	0.44**	1					
NSPS	0.17	0.19	-0.11	0.22	0.22	-0.01	0.2	0.22	1				
NGSP	-0.07	-0.05	-0.24	0.01	0.09	-0.16	0.01	0.17	0.43**	1			
ET	-0.02	0.01	0.05	-0.02	-0.23	0.29	-0.44**	-0.52**	-0.02	0.1	1		
GY	0.01	0.01	0.03	0.17	0.07	0.001	-0.18	-0.14	0.12	0.05	0.49**	1	
TKW	-0.1	-0.06	-0.06	-0.05	0.07	0.49**	0.62**	0.46**	-0.2	-0.36*	-0.57**	-0.07	1

Direct or indirect effect of various yield attributing characters of wheat genotype was analysed by path analysis (Table 5).

Table 5. Path Analysis of Eleven Characters on Grain Yield of Wheat Genotype

Character	DTB	DTH	DTA	DTM	CLC	PH	SL	SW	NSPS	NGPS	ET
Via DTB	**0.074**	0.07	0	0.058	0.047	0.0007	-0.001	0.018	0.013	-0.005	-0.001
Via DTH	-0.675	**-0.76**	0.091	-0.66	-0.508	-0.068	-0.015	-0.205	-0.144	0.038	-0.008
Via DTA	0	-0.01	**0.064**	-0.015	-0.008	0.006	-0.013	-0.021	-0.007	-0.015	0.003
Via DTM	0.622	0.69	-0.183	**0.797**	0.566	0.056	0.095	0.303	0.175	0.008	-0.016
Via CLC	-0.056	-0.06	0.012	-0.063	**-0.089**	-0.002	-0.021	-0.047	-0.02	-0.008	0.02
Via PH	0.002	0.02	0.02	0.014	0.004	**0.196**	0.081	0.047	-0.002	-0.031	-0.057
Via SL	0.003	0.00	0.027	-0.015	-0.031	-0.055	**-0.133**	-0.058	-0.027	-0.001	0.059
Via SW	0.021	0.02	-0.028	0.033	0.049	0.021	0.039	**0.088**	0.019	0.015	-0.046
Via NSPS	0.026	0.03	-0.016	0.033	0.034	-0.002	0.031	0.034	**0.153**	0.066	-0.003
Via NGPS	0.005	0.00	0.017	-0.0007	-0.006	0.011	-0.0007	-0.012	-0.03	**-0.07**	-0.007
Via ET	-0.011	0.01	0.027	-0.012	-0.125	-0.158	-0.24	-0.283	-0.011	0.055	**0.546**
Correlation	**0.011**	**0.013**	**0.031**	**0.169**	**-0.067**	**0.005**	**-0.177**	**-0.136**	**0.119**	**0.052**	**0.49****

3.1. Correlation Coefficient

Correlation coefficient help to determine the characters for improving yield through mutual relationship. Two plant characters that move in same direction and opposite direction are called positively and negatively correlated variables respectively [17]. A significant positive correlation means a linear relationship between two variables of yield attributing characters and same direction due to correlation coefficient is significantly different from zero at p value <0.05 or 0.01. If the correlation coefficient isn't significantly different from zero (close to zero) this means the correlation coefficient is not significant at $p>0.05$ or 0.01 [18]. Grain yield and yield attributing characters show positive or negative significant correlation due to gene interaction conditioning increase in one character influence another character at other condition remains constant [19].

3.1.1. Days to booting

It has highly significantly ($p<0.01$) positive correlation with DTH followed by DTM and CLC and also has positive correlation with SW, NSPS, PH and GY. It is negatively correlated with SL, NGSP, ET and TKW. It has positive correlation to grain yield which is similar to result recorded by[20]. Early booting indicates long heading period which has positive correlation to growing degree day and rate of grain filling and enhance early maturity to avoid stress conditions [21].

3.1.2. Days to heading

DTH has positive correlation with days to booting which is highly significant followed by DTM and CLC. SW, NSPS, PH, ET and GY have non-significant positive correlation and DTA, NGPS and TKW has non-significant negative correlation with DTH. A positive correlation of DTH with GY was recorded by [22];[19]. Under late sowing condition, early heading avoid terminal heat stress for enhancing grain yield through early maturity of grain [23]. Early heading compensate adverse effect of global warming preventing exposure to extreme heat at anthesis [24].

3.1.3. Days to anthesis

It has positive non-significant correlation with PH, ET and GY. DTA does not have correlation with DTB. It is significantly ($p<0.05$) negatively correlated with SW and non-significantly negatively correlated with DTH, DTM, CLC, SL, NSPS, NGPS and TKW. A positively correlated of DTA with GY was recorded by [22];[25]. Microspore and pollen cell are adversely affected by heat stress condition resulting male sterility [26]. Temperature above 30°C may cause complete sterility during anthesis period [27].

3.1.4. Days to maturity

It has positive correlation with DTH which is highly significant followed by DTB, CLC and SW and also PH, SL, NSPS, NGPS and GY has non-significant positive correlation with DTM. DTM has a non-significant negative correlation with DTA and ET. A positive correlation of DTM with GY and SL was also reported by [28], [29]. Recently, [30] reported that at 32/22°C day/night temperature compared to that at 25/15°C grain filling period is significantly reduced.

3.1.5. Chlorophyll leaf content

Chlorophyll leaf content has a highly significant positive correlation with DTM followed by DTH, DTM and SW. PH, SL, NSPS, NGPS and GY has non-significant positive correlation but DTA and ET has negative non-significant correlation with CLC. A similar result was reported by [28], [29]. Photosystem II ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) and oxygen-evolving complex are affected under high-temperature conditions [31].

3.1.6. Plant height

It has positive correlation with TKW which has highly significant followed by SL. DTB, DTH, DTA, DTM, CLC, GY and SW shows non-significant positive correlation and NSPS, NGPS, and ET non-significant negative correlation with PH. A similar result was reported by [22], [32]. The air temperature increased in late sowing stops vegetative development and shortens the organs [33]. Under stress condition tall plants are preferred because when the plant comes to stress condition it shows reduction in height due to poor vegetative growth so plant height has positive correlation with the yield[34].

3.1.7. Spike length

It is highly significantly positively correlated with TKW, SW and non-significantly positively correlated with NGPS, NSPS. It is highly significantly negatively correlated with yield and ET. A similar result was found by [12]. Under heat stress condition, spike length is reduced which is directly controlled by additive type of gene action [34].

3.1.8. Spike weight

It has a highly significant positive correlation with TKW and a negative correlation with ET. NSPS and NGPS have non-significantly positively correlated but non-significantly negatively correlated to yield with SW. According to [35] in spike, phytohormone ethylene is produced in wheat at heat stress condition which decreases spike weight and grain yield is reduced.

3.1.9. Number of spikelet per spike

NSPS has a highly significantly positively correlated with NGPS. GY shows non-significantly positively correlated but TKW and ET has non-significantly negatively correlated with NSPS. A similar result was recorded by [12]. Semenov reported that temperature above 20°C speeds up the development of spike and anthesis which reduces the number of spikelet and grains per spike[36].

3.1.10. Number of grain per spike

NGPS shows a non-significant positive correlation with GY and ET and significant negative correlation with TKW. NGPS shows positively correlated with grain yield was found by [12], [28], [22]. Above 30°C high temperature stress may cause complete sterility, due to reduced floret development based on wheat genotype which reduces number of grain per spike [27].

3.1.11. Effective tiller/m^2

It is highly significantly positively and negatively correlated with GY and TKW respectively. Similar result was reported by[19], [29]. Drought and heat stress conditions suppress tillering capacity at early growth phase of wheat. [37].

3.1.12. Thousand Kernel Weight

It is highly significantly positively and negatively correlated with SL, SW and ET respectively. It's correlation with CLC and DTB, DTH, DTA, NPSP and GY is non-significant positive and negative respectively. During the reproductive stage or post anthesis stage, high-temperature stress results reduction in kernel weight and also suppresses grain maturation of wheat and reduces grain yield [38]-[40]. Dias et al. reported shrinking of grains due to change in structure of the aleurone layer and cell endosperm at high temperature of 31/20°C during day/night [41].

3.2. Path Analysis

It is simply a partial regression coefficient which splits the correlation coefficient into two direct and indirect effects of the independent variable on a dependent variable [42]. In direct effect, the sensitivity of the dependent variable changes with an independent variable while another factor in the analysis is fixed which means the independent variable has the direct link with the dependent variable [43]. In indirect effect, it's impossible to control the variables during analysis. When independent variable effect on the dependent variable, various intermediates also affect the dependent variable [43], [44].

3.2.1. Direct effect

Among eleven yield attributing characters, DTM followed by ET show the highest positive direct effect on GY. PH, NSPS, SW, DTB and DTA also show positive direct effect on GY. A similar result was reported by [22], [45], [46]. However, indirect effect is shown by DTH, SL, CLC and NGPS on GY. This result was similar to [22];[45].

3.2.2. Indirect effect

DTB and CLC have a positive indirect effect and negative indirect effect on GY via DTM and DTH respectively. DTH have a positive indirect effect on GY via DTM and a negative indirect effect on GY via CLC. DTA have a positive indirect effect on GY via DTH while there is a negative indirect effect on GY via DTM. DTM shows the positive and negative indirect effect on GY via DTB and DTH respectively. In the case of PH, SL and SW a positive and negative indirect effect on grain yield via days to maturity and ET is obtained respectively. In SL, a positive indirect effect on yield via DTH is also reported by [47]. Under high temperature stress, solubility of CO_2 is decreased at higher rate than O_2 which enhance oxygenation activity of Rubisco which increases photorespiration and reduces photosynthesis[48]. Oxidative stress occurs under heat stress condition, which is caused by harmful reactive oxygen species like O_2, O_2^-, H_2O_2 and OH^- reducing yield [49]. The number of spikelet per spike has a positive and negative indirect effect on grain yield via DTM and days to heading respectively. According to [45] NSPS has a negative indirect effect on GY via DTH. NGPS shows the positive indirect effect on GY via NSPS and negative indirect effect on GY via PH. In the case of ET, there is positive and negative indirect effect on GY via SL and PH respectively.

4. Conclusion

The research was aimed to evaluate the wheat genotype, and to identify the characters as tools for wheat selection through correlation between traits and path analysis. The results showed that the effective tiller (ET) and days to maturity (DTM) can be used as selection criteria in breeding studies to improve the high-yielding wheat genotypes under heat stress conditions.

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