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Correlation and path coefficient analysis in wheat (*Triticum aestivum* L.) under heat stress condition

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Background: Twenty distinct wheat genotypes were examined using the path coefficient analysis and correlation of yield-attributing and to determine their direct and indirect effects on grain yield using path coefficient analysis. The experiment was conducted in IAAS Paklihawa Campus, Bhairahawa in 2023 during the winter season in late sowing conditions.

Methods: Two replications in heat stress conditions along with recommended irrigation by the National Wheat Research Program (NWRP). Ten plants were randomly taken from each genotype as a sample plant to measure the six characteristics. Correlation and path coefficient were used for twenty genotypes including three check varieties.

Results: The result revealed highly significant positive and negative relationships among the genotypes for all the traits studied. The highest positive correlation of 0.366 was obtained between Tillers per meter square and yield whereas the lowest positive correlation of 0.060 was expressed between total grain weight and yield.

Conclusion: Breeding efforts should encouraged for those wheat genotypes with tall lengths and higher spike weights in order to boost wheat yields under situations of heat stress.

Keywords: *correlation, path coefficient, breeding, genotypes, wheat*

Introduction

Wheat is considered as staple food in more than 40 countries of the world which provides basic calories and protein for 85% and 82% of the world population respectively. The annual cereal production has to grow by almost one billion to feed the projected population of 9.1 billion by 2050. Annual wheat production is 781.31 million metric tons all over the world. Wheat is cultivated on 78,000 hectares of land in Nepal with a total production of 218, 500 metric tons (Bhandari & Poudel 2024). In the past 10 years, Nepalese agriculture has seen a decrease in the cropping area of wheat and a very low increase in productivity. MoALD (2020) reports a decrease of 4% cropping area from 731131 ha in 2009/10 to 703992 ha in 2018/19. Similarly, in these ten years, the productivity increase has been very slow at the rate of just 0.102 tons/ha (Poudel et al., 2023). The productivity at the start of the decade (2009/10) was 2.13 tons/ha and reached 2.85 tons/ha by the end of the decade (2018/19) (Bishwas et al., 2021a). The area and production of wheat in Nepal have expanded significantly since the introduction of semi-dwarf varieties from Mexico, and it now significantly contributes to the country's food supply, (Pandey et al. 2021). Wheat is composed of Carbohydrates (78%), fat (2%), protein (14%), minerals, B-group vitamins, dietary fiber, riboflavin, thiamine and niacin. Wheat flour is used to prepare bread, biscuits, confectionary products, noodles and vital wheat gluten, also known as seitan (Dhakal et al. 2023). Wheat is known for antinutrients, such as phytic acid, which reduce the absorption of micronutrients, especially Zn from cereal. The most common deficiencies in the human body are Fe and Zn. In addition, micronutrients such as Zn and Fe accumulate mainly in the germ and bran of the wheat grain, i.e., in the parts that are removed during the processing of the grain, suggesting that whole grain products are an important source of daily intake of these minerals in the human diet. Although the environmental conditions can affect the nutritional composition of wheat grains with its essential coating of bran, vitamins and minerals; it is an excellent health-building food (Petrović et al., 2024). Furthermore, the grain along with stalk and chaff serves as an important raw material for Nepalese industries, and stalk and chaff are also used in the form of mulch, construction material, and animal bedding (Poudel et al., 2023). Wheat grows at temperatures between 15°C and 22°C and it usually grows well in cold, dry conditions. Wheat is cultivated in tropical and subtropical regions that face a variety of abiotic challenges throughout the world. Adverse environmental stress significantly may cause detrimental effects to wheat. The major abiotic stresses include heat, drought, salinity cold, chemical and water excess. However, heat stress is the main abiotic stress affecting wheat production worldwide. Moreover, late sowing of wheat is practiced in Nepal which causes terminal heat stress at the reproductive and ripening stage of wheat (Aryal et al., 2021). The mean ambient temperature is predicted to increase by 1–6°C by the end of the 21st century. The grain yield of wheat reduces by 6%–10% by just a 1° rise in temperature whereas, in Nepal, a 1–3°C rise in maximum temperature (during heat stress) causes an 8%–31% decrease in wheat yield (Pokhrel et al., 2019) (Bishwas et al., 2021a). As a consequence of the low productivity, Nepal has been witnessing a gradual annual increase in wheat imports. The present study aims to understand the correlation and path coefficient analysis to ascertain yield components, as it evaluates the direct and indirect contributions of independent factors to the dependent variable (Puri et al., 2020). Correlation analysis measures would help in the selection of high yielding genotypes by the identification of the association between the grain yields of wheat to its attributing parameters. Path analysis helps to know the direct and indirect (positive or negative) effects of yield-attributing parameters on the grain yield of wheat. It is useful to use genotypic and phenotypic correlations to show how different morpho-physiological traits are related to economic production.

The weather of the Terai region in Nepal indicates that the winter is getting delayed and shorter while warm summer days are becoming longer. This change could be unfavorable to wheat cultivation in the whole Indo Gangetic region including Nepal. Long duration wheat varieties are already suffering due to early heat during the grain filling period (Pokhrel et al., 2019). Late planting of wheat especially in the Terai of Nepal is very common due to several factors such as excess soil moisture just after rice harvesting, delay in rice harvesting due to late maturing varieties or shortage of labours and rice harvesters during rice harvesting season. Wheat crop growth is highly dependent on temperature regimes and high temperature reduces the physiological maturity days as well as the grain filling duration, as a result reducing wheat yield (Poudel et al., 2024). Under such situations, wheat varieties with shorter maturity or a faster grain filling rate would be desirable. Therefore, breeding for high-temperature tolerant wheat genotypes having disease resistance and stay green traits that are capable of producing enough endosperm, bold grains within short grain filling duration should be developed for climate resilience (Kumar et al., 2024). The present investigation was conducted to identify terminal heat tolerance in breeding lines of wheat.

Materials and methods

The experiment was carried out on the research field at the Paklihawa Campus, Institute of Agriculture and Animal Science (IAAS), Rupandehi, The experiment site is located at104 meters above sea level and at 27 29'02" N and 8327' 17" E. A set of twenty wheat genotypes (Table 1) was obtained from the National Wheat Research Program (NWRP), Bhairahawa, Nepal including RR, Bhrikuti and Gautam as check varieties

Table1. List of genotype (Source: NWRP, Bhairahawa) used in experiment

S.No.	Genotypes	S.No.	Genotypes
1	BL_5106	11	NL_1447
2	BL_5099	12	NL_1445
3	BL_4984	13	NL_1506
4	Bhrikuti	14	NL_1504
5	NL_1437	15	NL_1503
6	NL_1402	16	NL_1501
7	Gautam	17	RR_21
8	BL_5116	18	NL_1512
9	NL_1492	19	NL_1509
10	NL_1488	20	NL_1508

The experiment was conducted on alpha lattice design (Table 2) with two replications of a plot size $5m^2$ with a dimension of 2.5*2m. The inter replication spacing was maintained at 1 m while interplot spacing was 25cm. Heat stress condition was created by sowing wheat genotypes one month later (26^{th} December) than normal condition (25^{th}

November) so as to coincide heat waves with reproductive stage of the wheat crop. Ten randomly selected plants were tagged independently for each genotype and yield-attributing traits were documented including Plant height (Ph), Spike length (Sl), Spike Weight (SW), Thousand Grain Weight (TGW), Number of Spikes Per Meter Square (NSPMS) and Grain Yield (GY).

Table 2. Layout of Experimental site

Replication 1				Replication 2			
T1	T2	T3	T4	T1	T2	T3	T4
T8	T7	T6	T5	T8	T7	T6	T5
T9	T10	T11	T12	T9	T10	T11	T12
T16	T15	T14	T13	T16	T15	T14	T13
T17	T18	T19	T20	T17	T18	T19	T20

The recommended dose of fertilizer was applied in each individual plot with a dosage of 100:50:25 kgNPK/ha,and compost manure was applied at a rate of 5 tons per hectare. Prior to seeding, all of the phosphorus, potash, and half of the nitrogen dose were administered. Two divided doses of the remaining nitrogen were administered: the first quarter at 30 DAS and the last dosage at 70 DAS. Irrigation was provided as per the recommendation of the National Wheat Research Program (NWRP) MS Excel 2016 was used for data entry and processing. Using SPSS Version 20, the association between the yield and yield-attributing characteristics was determined. The path analysis was done using Microsoft Excel 2016.

Results

The yield-contributing morphological features are essential for high yielding variety breeding to be successful. The quantity of tillers/m^2, the number of grains per spike, the weight of 1000 grains, plant height, and spike length are some of the factors that influence the complicated characteristics of wheat grain production. The correlation analysis (Table 3) shows a significant positive association of grain yield with plant height (160), and spike length (237).

Table 3. Correlation between different quantitative traits

	Ph	SL	SPS	SW	TGW	TPM	YLD
Ph	1	0.134	-0.020	-0.073	-0.020	-0.052	0.160
SL	0.134	1	0.187	0.237	0.023	-0.076	0.199
SPS	-0.020	0.187	1	0.538**	0.042	-0.168	0.073
SW	-0.073	0.237	0.538**	1	0.495**	-0.188	0.150
TGW	-0.020	-0.023	0.042	0.495**	1	-0.215	0.060
TPM	-0.052	-0.076	-0.168	-0.188	-0.215	1	0.336*
YLD	0.160	0.199	0.073	0.150	0.060	0.336*	1

Where, Ph = Plant Height, SL = Spike Length, SPS = Spikelets per Spike, SW = Spike Weight, TGW = Total Grain Weight, TPM = Tillers Per Meter, YLD = Yield

Plant height was significantly positively correlated with yield where Plant height was significantly negatively correlated with spikelet per spike, spike weight, thousand grain weight, and tillers per metre square. Spike length was significantly positively correlated with plant height, spikelet per spike, spike weight, thousand grain weight and yield where spike length was significantly negatively correlated with tillers per metre square. Spikelet per spike was highly positively significantly correlated with spike weight (0.538**) (Table 3) and positively significant with spike length, thousand grain weight and yield where spikelet per spike was negatively significantly correlated with plant height and tillers per metre square but the contrasting association of SPS was observed to be significantly and negatively correlated with grain yield at both levels.

Spike Weight was highly positively significantly correlated with Thousand grain weight (0.495**) and positively significantly correlated with Spike length and Yield where negatively significantly correlated with plant height and tillers per meter square. Thousand grain weight was highly positively significantly correlated with spike weight but negatively correlated with plant height and tillers per meters square. Tillers per meter square is positively significantly correlated with Yield(0.336*) where tiller/ m^2 increases, grain yield per spike increase which is responsible for increase in total grain yield according to Poudel et al. (2023). Negatively significantly correlated with Plant height, Spike length, Spikelet per spike, Spike weight and Tillers per meter square. Path coefficient analysis aims to find out what affects the endogenous variables, that is, how the exogenous variables work together (their covariance) and which paths are important (determined in part by the variances of the exogenous variables).

Table 4. Path analysis of different quantitative trait on grain yield

	Ph	SL	SPS	SW	TGW	TPM
ViaPh	0.185728	0.0248	-0.0037	-0.01347	-0.00367	-0.00974
ViaSL	0.010121	0.075758	0.014187	0.017986	0.001772	-0.00574
ViaSPS	-0.00073	0.0067	0.035774	0.019246	0.001502	-0.00601
ViaSW	-0.01238	0.04053	0.091846	0.170718	0.084505	-0.03204
ViaTGW	-0.00124	0.0014713	0.00264	0.031125	0.062879	-0.01351
ViaTPM	-0.02115	-0.03053	-0.06773	-0.07563	-0.08661	0.403044
ViaYLD	0.160351	0.118742	0.072937	0.14997	0.06037	0.336

Where, Ph = Plant Height, SL = Spike Length, SPS = Spikelets Per Spike, SW = Spike Weight, TGW = Total Grain Weight, TPM = Tillers Per Meter, YLD = Yield. Residual effect=0.3754

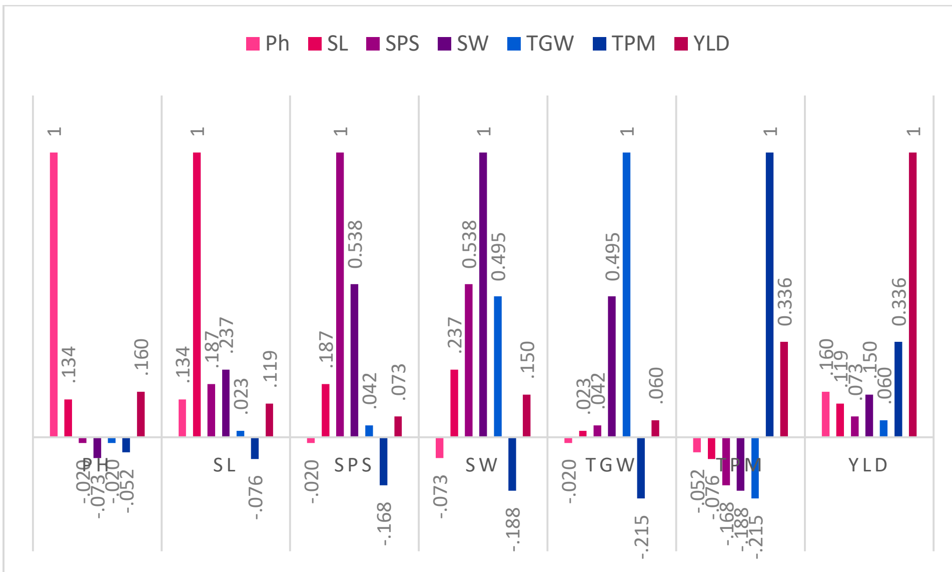

Fig 1. Graphical representation of path coefficient analysis

Plant height had significant direct positive effect on grain yield (0.185728) but plant height showed an indirect negative effect on grain yield via spikelet per spike (-0.00073), spike weight (-0.01238), thousand grain weight (-0.00124) and tillers per meter square (-0.02115) where similar results of positive direct effect on grain yield with Plant height were reported by Poudel et.al. (2023)Spike length had a significant direct positive effect on grain yield (0.075). Spike length showed an indirect negative effect on Tillers per meter square (-0.03053). Spikelet per spike had a significant direct positive effect on grain Yield (0.03577). Spikelet per spike showed an indirect negative effect on plant height and Tillers per meter square. Spike weight had a significant direct positive effect on grain Yield (0.1707) but spike weight showed an indirect negative effect on plant height and Tillers per meter square.

Discussion

Correlation Coefficient measures the strength and direction of a linear relationship between two variables. Correlation refers to the fact that there is a link between various events. One of the tools to infer whether such a link exists is correlation analysis. Practical simplicity is undoubtedly one of its main advantages. Plant height was highly positively significant with grain yield as reported by Mukherjee et al. (2008). The taller the plant, the higher will be the photosynthate area due to the long stem. According to Poudel et al. (2023), SL was positively associated with grain yield which is due to the accumulation of more grains in long spikes. In contrast, a shorter spike accumulates fewer grains and leads to a lower yield of wheat. Path analysis is a statistical technique for examining and testing relationships among a set of observed variables. Relationships—or paths—may be described as representing direct or indirect associations. An indirect relationship occurs when a variable is linked to another variable via a third variable, which in turn is directly associated with the outcome variable. The sum of all direct and indirect relationships, in turn, yields a variable's total association. Because path analysis allows the study of multiple direct and indirect relationships between variables simultaneously, it is regarded as a more complex technique than typical regression analysis. Perhaps the greatest advantage of path analysis over regression analysis is its superior ability to detect associations. With regression, the absence of a direct correlation of one variable with another is usually interpreted as a null association (Wooldredge, 2021). Thousand grain weight had a direct positive effect on grain yield (0.062) but Tillers per meter square showed an indirect negative effect on plant height and Tillers per meter square. According to Chowdry, et al. (1986) and Shamsuddin (1987), the direct effect of 1000 grain weight upon grain yield was high and positive. Tillers per meter square had a significant direct effect on grain yield (0.4030). It may be concluded from the present studies that plant height, peduncle length, tillers per plant, spike length, spike weight and number of grains per spike appeared to contribute to the grain yield. Therefore indirect selection for higher grain yield may be effective for improving these characters, as shown by (Ozukum et al. 2019).

Conclusion

Wheat (*Triticum aestivum*) is one of the most important staple food crops in the lowland Terai area of Nepal. However, the nation's production has failed to meet the growing demand. From a South Asian regional perspective, the average production is low with significant spatial and temporal variability. Heat stress condition provides the adaptability and tolerance of wheat at a heat stress condition. Path coefficient analysis also evaluated that thousand grain weights were highly positively significantly correlated with spike weight but negatively correlated with plant height and tillers per meters square. Tillers per meter square is positively significantly correlated with yield but negatively significantly correlated with Plant height, Spike length, Spikelet per spike, Spike weight and Tillers per meter square. Plants with tall height should be promoted to obtain maximum higher yield.

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Author contributions

All authors have contributed equally to the present research work. The final manuscript was prepared by Pooja Bhushal and MR Poudel.

Conflict of interests

The authors declare no conflict of interest.

Ethics approval

Not applicable.

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