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Agro Morphological Analysis of Wheat Genotype Under Heat Stress Condition

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Abstract: The path coefficient analysis and correlation were studied in twenty different wheat genotypes to understand the contribution and correlation of yield-attributing characteristics to grain yield. The research was conducted on late sowing conditions in alpha lattice design with two replications at the Institute of Agriculture and Animal Science, Paklihawa campus, Bhairahawa, Nepal in 2021. Random ten plants were selected from each genotype provided by National Wheat Research Program (NWRP), Bhairahawa separately to record the measurements on eleven characters. The result revealed highly significant positive and negative relationships among the genotypes for all the traits studied. The grain yield of the wheat has a significant and positive correlation with plant height (0.540), spike length (0.457), spike weight (0.630), and thousand grain weight (0.510). These traits also have a direct positive effect on the grain yield. Wheat genotypes with tall lengths and higher spike weight should be promoted in breeding programs to increase the yield of wheat in heat stress environment conditions.

***Keywords**:* Correlation, Path analysis, Grain Yield, Yield-attributes

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Introduction

Wheat (*Triticum aestivum L.*) is the most important cereal crop under the family Poaceae (Reynolds & Braun, 2022) with an annual production of 781.31 million metric tons all over the world (FAOSTAT, 2023). Wheat is cultivated on 78,000 hectares of land in Nepal with a total production of 218, 500 metric tons (AITC, 2021). Wheat comprises 78% carbohydrate, 14% protein, 2% fat, and 2.5% minerals and vitamins such as thiamine, riboflavin, niacin, etc. (Iqbal *et al.*

2022). Nearly 55% of the population in the world depends upon wheat to fulfill 20% of their calorie requirement (Guarin *et al*. 2022).

Wheat requires an average temperature of 15-22 degree centigrade for its optimum growth (Aryal *et al*. 2021). Wheat is suffering from high temperatures during critical periods especially in reproductive stages due to global warming in the world (Allan *et al*. 2021). The mean temperature of the atmosphere is rising at the rate of 0.18 °C per year causing a significant effect on the yield of wheat (Lindsey & Dahlman, 2020). Furthermore, late sowing of wheat is practiced in Nepal which causes terminal heat stress at the reproductive and ripening stage of wheat (Upadhyaya & Bhandari, 2022).

On a global scale, the population is expected to reach 9 billion by 2050 (Akter and Islam, 2017). The increase in population demands more food resources to eat. Wheat is the largest contributor to the food and nutritional security of the world. The production and productivity of wheat must be increased to cope with existing and future demand for food (Grote *et al*. 2021). The possible way to meet the global food demand in the coming years is by minimizing the yield gap through the specialization of breeding programs for the development of best-suited cultivars that can cope with temperature stress (Yadav *et al*. 2022).

To identify the climate-resilient genotypes it is essential to explore the agro-morphological association of quantitative traits of wheat genotypes (Baye *et al*. 2020). Correlation analysis measures would help in the selection of high yielding genotypes by the identification of association between the grain yield of wheat to its attributing parameters (Tiwari *et al*. 2019). In addition, path analysis helps to know the direct and indirect (positive or negative) effects of yield-attributing parameters on the grain yield of wheat. This study aims at identifying the most appropriate trait for the selection of high yielding elite wheat genotypes under heat stress conditions through correlation and path analysis.

Materials and Methods

The experiment was conducted in the research field at Institute and Agriculture and Animal Science (IAAS), Paklihawa Campus, Rupandehi in 2021. The experiment site lies in the tropical region of Nepal at the geographical location of 27 29′02″ N and 8327′ 17″ E and an altitude of 104 m asl. The agro-meteorological parameters during the experimental year were obtained from the Department of Hydrology and Meteorology (DHM), Bhairahawa, and are presented in Figure 1.

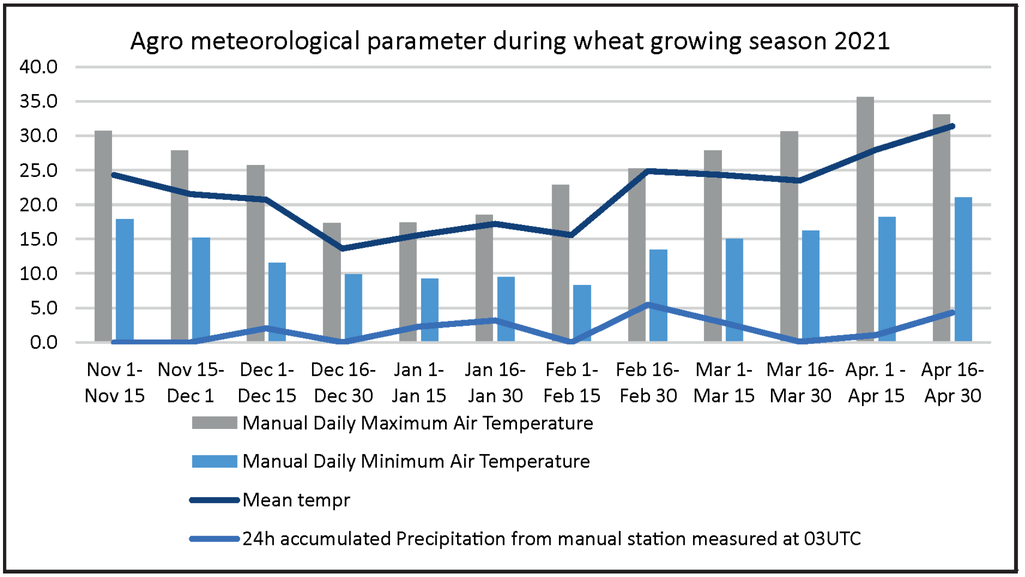

Figure 1: Agrometeorological parameters during the wheat growing season

A set of twenty wheat genotypes used in this experiment were obtained from National Wheat Research Program (NWRP), Bhairahawa, Nepal including Bhrikuti and Gautam as check varieties Table 1.

Table 1: Source and parentage of wheat genotypes used in the experiment

S. No	*Genotypes*	*Source*	*Parentage*	*Released year*
1	Bhrikuti	CIMMYT, Mexico	CMT/COC75/3/PLO//FURY/ANA75	1994
2	BL 4407	Nepal	n.d*	n.d*
3	BL 4669	Nepal	n.d*	n.d*
4	BL 4919	Nepal	n.d*	n.d*
5	Gautam	Nepal	SIDDHARTH/NING8319/NL297	2004
6	NL 1179	CIMMYT, Mexico	n.d*	n.d*
7	NL 1346	CIMMYT, Mexico	n.d*	n.d*
8	NL1350	CIMMYT, Mexico	n.d*	n.d*
9	NL 1368	CIMMYT, Mexico	n.d*	n.d*
10	NL 1369	CIMMYT, Mexico	T. DICCOCON CI 9309/AE. SQUARROSA (409) //MUTUS /3/ 2*MUTUS	2018
11	NL 1376	CIMMYT, Mexico	n.d*	n.d*
12	NL 1381	CIMMYT, Mexico	n.d*	n.d*
13	NL1384	CIMMYT, Mexico	n.d*	n.d*
14	NL 1386	CIMMYT, Mexico	n.d*	n.d*

S. No	Genotypes	Source	Parentage	Released year
15	NL 1387	CIMMYT, Mexico	n.d*	n.d*
16	NL 1404	CIMMYT, Mexico	n.d*	n.d*
17	NL 1412	CIMMYT, Mexico	n.d*	n.d*
18	NL 1413	CIMMYT, Mexico	n.d*	n.d*
19	NL 1417	CIMMYT, Mexico	n.d*	n.d*
20	NL 1420	CIMMYT, Mexico	n.d*	n.d*

*The pedigree information of the genotype is confidential and is maintained by NWRP.

The experiment was laid in alpha lattice design with two replications each having twenty genotypes. The plot size was 10 m^2 with a dimension of 4 m x 2.5 m and a row spacing of 25 cm. The inter replication spacing was maintained at 1 m while interplot spacing was maintained at 50 cm. Random 10 plants were selected and tagged for each genotype separately to record the data. The data on different yield attributing traits such as days to 50% booting (DTB), days to 50% heading (DTH), and days to 50% anthesis (DTA) were recorded. Plant height (Ph), and spike length (SL) were measured using a scale. Spike weight (SW) was measured by weighing balance. Number of spikes per meter square (NSPMS), Number of spikelets per spike (NSPS), number of grains per spike (NGPS), and thousand grain weight (TGW) were counted manually. Grain Yield (GY) of wheat was taken from a 4m^2 area and was converted to tons per hectare. Data entry and processing were performed using MS Excel 2016. The correlation between the yield and yield attributing characteristics was calculated by using SPSS Version 26. MS Excel 2016 was used for path analysis.

3. Results and Discussion

The correlation analysis shows a significant positive association of Grain yield with plant height, spike length, spike weight, and thousand grain weight. It shows the significant negative correlation of grain yield with days to booting, days to heading, and days to anthesis (Table 2).

Days to booting (DTB) were significantly positively correlated with days to heading and days to anthesis ($P<0.01$) whereas significantly negatively correlated with plant height, spike length, spike weight, grain per spike, and grain yield ($P< 0.01$). Late Booting due to late sowing conditions in wheat genotypes receives high temperature stress that triggers tillers mortality (Jaisi *et al*. 2021). Reduction in tillers count decreases net spike per meter square and decrease in NSPMS reduces grain yield. NSPMS is positively correlated with grain yield which was similar to the result observed by (Ayer *et al*. 2017).

Table 2: Correlation between different quantitative traits

	DTB	*DTH*	*DTA*	*PH*	*SL*	*NSPMS*	*SW*	*SPS*	*GPS*	*TGW*	*GY*
DTB	1	0.797**	0.807**	-0.409**	-0.284	0.104	-0.549**	0.026	-0.544**	-0.15	-0.386*
DTH	0.797**	1	0.794**	-0.325*	-0.378*	-0.023	-0.517**	-0.262	-0.472**	-0.141	-0.441**
DTA	0.807**	0.794**	1	-0.355*	-0.400*	-0.043	-0.501**	-0.161	-0.495**	-0.175	-0.515**
PH	-0.409**	-0.325*	-0.355*	1	0.634**	-0.087	0.645**	0.114	0.221	0.448**	0.540**
SL	-0.284	-0.378*	-0.400*	0.634**	1	-0.112	0.679**	0.453**	0.462**	0.370*	0.457**
NSPMS	0.104	-0.023	-0.043	-0.087	-0.112	1	-0.283	0.043	-0.172	-0.254	0.001
SW	-0.549**	-0.517**	-0.501**	0.645**	0.679**	-0.283	1	0.126	0.476**	0.591**	0.630**
SPS	0.026	-0.262	-0.161	0.114	0.453**	0.043	0.126	1	0.315*	-0.019	0.016
GPS	-0.544**	-0.472**	-0.495**	0.221	0.462**	-0.172	0.476**	0.315*	1	-0.05	0.254
TGW	-0.15	-0.141	-0.175	0.448**	0.370*	-0.254	0.591**	-0.019	-0.05	1	0.510**
GY	-0.386*	-0.441**	-0.515**	0.540**	0.457**	0.001	0.630**	0.016	0.254	0.510**	1

Note: Days to booting (DTB), Days to heading (DTH), Days to anthesis (DT**A),** Plant height (PH), Spike length (SL), Net spike per meter square (NSPMS), Spike weight (SW), Spikelet per spike (SPS), Grains per spike (GPS), Total grain weight (TGW), Grain yield (GY)

Days to heading was significantly positively associated with days to anthesis whereas DTH was significantly negatively associated with plant height, spike length, spike weight, grain per spike, and grain yield. Delayed heading under heat stress has a greater impact on grain yield. Heat stress triggers early leaf senescence in wheat and reduces net photosynthetic activity through oxidative damage of chloroplasts (Chen *et al*. 2019). Reduced photosynthesis impairs the photosynthate assimilation between the food source and sink tissues (Ulfat *et al*. 2021). Limitation of food supply makes the grain shrunken and poor grain filling thus reducing grain yield.

Days to anthesis was significantly negatively associated with plant height, spike length, spike weight, grain per spike, and grain yield. High temperature during flowering reduces grain yield. The increasing temperature before anthesis accelerates leaf senescence and degrades chlorophyll content thus reducing photosynthesis. Reduced supply of the photosynthate from green parts of leaves to anther tissues results in pollen shrinkage promoting anther sterility. The inability of the crop to produce functional pollen makes the floret avoid reducing grain number thus reducing the total grain yield (Dwivedi *et al*. 2017).

Plant height was significantly positively associated with spike length, spike weight, thousand grain weight, and grain yield in accordance with the result obtained by (Baye *et al*. 2020). A shorter plant height decreases the net grain yield. Increased temperature in late sowing conditions cease the vegetative growth and limits the photosynthate assimilation towards apical organs thus shortening the size of organs in wheat. Reduced organ size ultimately limits the cell expansion to an appropriate size reducing plant height (Rodríguez-Calcerrada *et al*. 2022).

Spike length was significantly positively associated with spike weight, spikelet per spike, grain per spike, thousand grain weight, and grain yield. Longer spikes play a positive role in increasing the grain yield of wheat. Spike contributes 12-42 % of the dry grain weight (Hossain et al. 2019) and remains green for a longer period than leaves facilitating ear photosynthesis. Heat stress induces senescence in wheat that reduces the potential photosynthate green part of the spike during grain filling (Cheabu *et al*. 2018).

Spike weight was significantly positively associated with grain per spike, thousand grain weight, and grain yield. Lower spike weight decreases the net grain yield. Heat stress damages the leaf's photosynthetic pigments. The reduced photosynthetic activity during the grain filling period inhibits net photosynthesis and the activity of starch synthase reduces net starch accumulation on the grain (Teng *et al*. 2023). Starch contributes about 60-70% to the total grain weight of wheat. Furthermore, heat stress reduces spike length by 10.8- 27.05% and NGPS by 21.95- 47.03% (Mohamed *et al*. 2019) which causes a reduction in spike weight and decreases grain yield.

Thousand grain weight was significantly positively associated with grain yield. Forced endosperm development due to high respiration rate under heat stress reduces grain weight in wheat consequently reducing total grain yield (Poudel and Poudel, 2020).

Table 3: Path analysis of different quantitative traits on grain yield

	DTB	*DTH*	*DTA*	*PH*	*SL*	*NSPMS*	*SW*	*SPS*	*GPS*	*TGW*
DTB	0.543377	0.433072	0.438505	-0.22224	-0.15432	0.056511	-0.29831	0.014128	-0.2956	-0.08151
DTH	-0.19827	-0.24877	-0.19752	0.080851	0.094035	0.005722	0.128615	0.065178	0.11742	0.035077
DTA	-0.37214	-0.36614	-0.46114	0.163704	0.184455	0.019829	0.23103	0.074243	0.228263	0.080699
PH	-0.11335	-0.09007	-0.09838	0.27714	0.175707	-0.02411	0.178755	0.031594	0.061248	0.124159
SL	0.027316	0.036357	0.038473	-0.06098	-0.09618	0.010772	-0.06531	-0.04357	-0.04444	-0.03559
NSPMS	0.011652	-0.00258	-0.00482	-0.00975	-0.01255	0.112036	-0.03171	0.004818	-0.01927	-0.02846
SW	-0.16924	-0.15938	-0.15445	0.198837	0.209318	-0.08724	0.308274	0.038843	0.146739	0.18219
SPS	-0.0054	0.054463	0.033468	-0.0237	-0.09417	-0.00894	-0.02619	-0.20788	-0.06548	0.00395
GPS	-0.07449	-0.06463	-0.06778	0.030262	0.063262	-0.02355	0.065179	0.043133	0.136931	-0.00685
TGW	-0.03545	-0.03332	-0.04136	0.105873	0.08744	-0.06003	0.139667	-0.00449	-0.01182	0.236324
GY	-.386*	-.441**	-.515**	.540**	.457**	0.001	.630**	0.016	0.254	.510**

Days to booting has a significant direct positive effect on grain yield (0.543) but days to booting show an indirect negative effect on grain yield via days to anthesis (-0.372), days to heading (-0.198), plant height (-0.113), spike weight

(-0.169). Days to heading have a significant direct negative effect on grain yield (-0.248). Days to anthesis have a significant direct negative effect on grain yield (-0.461). Plant height has a significant direct positive effect on grain yield (0.277). Spike length has a significant direct negative effect on grain yield (-0.096) but spike length shows an indirect positive effect on grain yield via spike weight, days to anthesis, and plant height. Spike weight has a significant direct positive effect on grain yield (0.308). Thousand grain weight has a significant direct positive effect on grain yield (0.236).

4. Conclusion

Correlation analysis results revealed that there is a positive and highly significant association of grain yield with plant height, spike length, spike weight, and thousand grain weight. It showed a highly significant and negative association between days to heading and days to anthesis. In addition, the path coefficient analysis results also evaluated that days to heading and days to anthesis have a direct negative effect on grain yield. But plant height has a significant and greater positive direct effect on grain yield followed by spike length. So, the taller wheat genotype with a longer spike length that enters the heading and flowering period earlier can be recommended as a selection criterion in bread wheat breeding programs under heat stress conditions.

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Authors Contribution

Mukti Ram Poudel conceptualizes the research. Radhakrishna Bhandari and Shivalal Nyaupane conducted the field experiment. Anjali Dhakal performed the analysis and wrote the manuscript. The final version of the paper was proofread and approved by all the authors.

Conflict of Interest

The authors declared they have no conflict of interest.

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