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Exogenous Applied Zinc, Cytokinin and Gibberellic Acid Affecting Growth and Yield of Timely and Late Sown Wheat (*Triticum aestivum* L.)

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ABSTRACT

Background: Micronutrient deficiency especially of zinc (Zn) impacts wheat growth and yield under both timely sown and late sown conditions. The study investigated the effect of Zn, cytokinin and gibberellic acid (GA) on growth and yield of wheat crop. The design of experiment was split-split plot having three replications.

Methods: The main plots were comprised of two varieties *i.e.,* V1 (PBW 725) and V2 (PBW 752) which were divided into three subplots Zn0 (no Zn), Zn1 (62.5 kg/ha soil application of $ZnSO_4$) and Zn2 (31.25 kg/ha Zn in soil+foliar spray of 0.5% of $ZnSO_4$). The subplots were further divided into four sub-sub plots *i.e.,* H0 (no hormone), H1 (10 ppm GA), H2 (10 ppm cytokinin) and H3 (5 ppm GA+5 ppm of cytokinin).

Result: The results indicated that the combination of Zn2+H1 resulted in maximum height of plant, accumulation of dry matter and straw yield for both varieties. The reported increment for all three parameters was 8.3%, 15.4% and 18.9% for V1 and 10.1%, 14.9% and 17.4% for V2, respectively. However, for both V1 and V2 a combination of Zn2+H2 improved tiller count, leaf area index and ultimately grain yield. The increment for V1 was 24.4%, 15.2% and 17.1%, while for V2 was 30.1%, 17.2% and 19.3%, respectively. The maximum harvest index value was recorded for variety V2 under Zn2+H2. The correlation analysis showed that leaf area index, number of tillers and dry matter accumulation are strongly correlated with grain yield. In general, the study emphasized that soil+foliar application of Zn alongside 10 mg/L cytokinin was most prominent in improving growth and yield of both wheat varieties.

Key words: Cytokinin, Gibberellic acid, Wheat, Zinc application methods and Yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) along with other species like *Triticum durum* L. and *Triticum dicoccum* L. is under cultivation in the Indian subcontinent since the prehistoric era. Historians and researchers showed that the cultivation of wheat started around 3000 BC to 5000 BC (Ghahremaninejad *et al*., 2021). Currently, cultivation of wheat occurs on a large scale in the subcontinent and across the globe. Among major cereals, wheat ranks first in production and consumption in the world (Hasan *et al*., 2016). About 800 million tonnes were produced in the year 2022-23 globally. In India, its production reached 103 million tonnes in the same year (Anonymous, 2023). It is an important cereal and source of nutritional calories, micronutrients and proteins in developing countries, accounting for 50 percent of the daily calorie consumption. Micronutrient deficiency is a more prevalent concern in many regions of the globe than low-calorie intake and poor quality of food (Stewart *et al*., 2010). Zinc (Zn), iron and Vitamin A deficiency is responsible for about 20% mortality in children below age five (Prentice *et al*., 2008). So, it is mandatory to improve the quality of wheat being a cheap source of nourishment.

Wheat is one of the primary sources of Zn having highest grain Zn content among cereals. But nearly 50% of soil under wheat cultivation is Zn deficient which makes the grains Zn deficient. Even if soils under wheat cultivation have adequate concentrations of Zn, the crop plants still show deficiency symptoms. Major soil factor responsible for Zn deficiency are high soil pH, low organic matter, high carbonate content, texture of soil etc. (Rai *et al*., 2017). High concentration of nitrogen (N), phosphorous (p) and potassium (k) in the soil interfere in its root absorption and hinder its translocation and assimilation during grain filling (Cakmak *et al*., 2002; Debnath *et al*., 2015). Wheat yield and quality parameters are affected by Zn deficiency as it has a significant role in auxin production, protein synthesis, pollen development and maintenance of ion transport systems (Ariraman *et al*., 2022). Zinc application on wheat crop increased tiller count, LAI and accumulation of dry matter which increasead grain yield.

Plant hormones are chemical substances that are synthesised by plant in a minute concentration. These

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include auxin, GA, cytokinin, ethylene and abscisic acid. Cytokinin is produced in the plant roots and helps in cell division, regulating primordia number of leaf, size of shoot meristem, impeding leaf senescence, etioplast conversion to chloroplast and assimilate partitioning (Nagar *et al*., 2015; Jakhar *et al*., 2023). Gibberellic acid promotes cell elongation, increase leaf *and* fruit size and seed germination (Alharby *et al*., 2021). These hormones help in proper growth, functioning and regulating stress conditions. This helps to improve the growth of source by improving leaf area duration and delaying leaf senescence (Dinler *et al*., 2021). It also has a crucial and fundamental role in the division of endosperm cells in cereal seeds during the earliest stage of seed development. Hence it has a significant impact on sink size. As a result, use of this hormone can reduce the constraint of source and sink to boost grain production.

The study of plant growth hormones to evaluate their role in micronutrient translocation, germination, enhancing growth parameters and yield components have become an area of interest for the researchers. Keeping in mind the above-mentioned points, the present experiment elucidated the role of Zn and phytohormones (GA and cytokines) on wheat growth and yield.

MATERIALS AND METHODS

The research trial was conducted at the agriculture farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab in the *rabi season* of 2021-22 and 2022-23. The experimental soil had a texture of sandy loam, a pH of 7.4, an electric conductivity (EC) of 0.266 dS/m, 10.5 g readily oxidisable carbon (C) and low status of Zn in soil (0.47 mg/kg).

Two wheat varieties, *i.e.,* PBW 725 (timely sown variety) and PBW 752 (late sown variety) were used and their seeds were obtained from Punjab Agricultural University. Sowing of varieties was done on 25th of November and 15th of December during both the seasons, respectively. The 50% of N *i.e.,* 62.5 kg/ha, P @ 62.5 kg/ha and K @ 30 kg/ha were applied as basal dose at the time of sowing, while the remaining N was applied in two splits at 25 and 55 DAS. Zinc was applied via three different modes, *viz.*, Zn0 (no Zn), Zn1 (soil applied @ 62.5 kg Zn/ha) and Zn2 (soil applied @ 31.25 kg Zn/ha + foliarly spray of 0.5% $ZnSO_4.7H_2O$). Soil application of Zn ($ZnSO_4.7H_2O$) was done before sowing, while foliar application of Zn @ 5 g/L was done at 40, 80 and 120 days after sowing of crop. Plant growth hormones tested in the experiment were gibberellic acid (GA) and cytokinin with various levels *i.e.,* no hormone (H0), 10 mg/L GA (H1), 10 mg/L cytokinin (H3) and 5 mg/L GA+5 mg/L cytokinin (H3). Benzylaminopurine and GA3 were the source of cytokinin and GA, respectively. All hormone levels were foliarly applied immediately after the foliar spray of Zn. The experimental design was split-split plot with three replications of each treatment. There were two (V1 and V2) main plots which were split into three sub plots (Zn0, Zn1 and Zn2). Each sub plot was further split into four sub-sub plots (H0, H1, H2 and H3).

The observation on plant height (cm) of the crop was recorded by using a metre scale at harvest by taking average of five plants. Total numbers of tillers were counted at harvest from one metre row lengths chosen randomly from four distinct plot locations. Leaves were harvested from plants selected from 10 cm row length in each plot and the leaf area index (LAI) was calculated by using the following formula and measuring the leaf area at 90 days after sowing (DAS) with a leaf area meter.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area (cm)}^2}{\text{Ground area (cm)}^2}$$

Crop was harvested at maturity on 18th of April of both 2021-22 and 2022-23 seasons and bundles of plants from each plot were sun-dried in open space for four days after harvesting. Thereafter, the dry weight was recorded and used to compute dry matter accumulation. Later, the bundles were threshed and weight of wheat grains were recorded and expressed in quintals per hectare (q/ha). The grain weight was then subtracted from total weight of the bundle to get the straw yield. The HI (harvest index) was calculated by using following formula and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

The data from all observations was subjected to statistically analysis using ANOVA (analysis of variance) in RStudio. The Duncan's multiple range test was used for doing multiple comparisons at a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Plant height

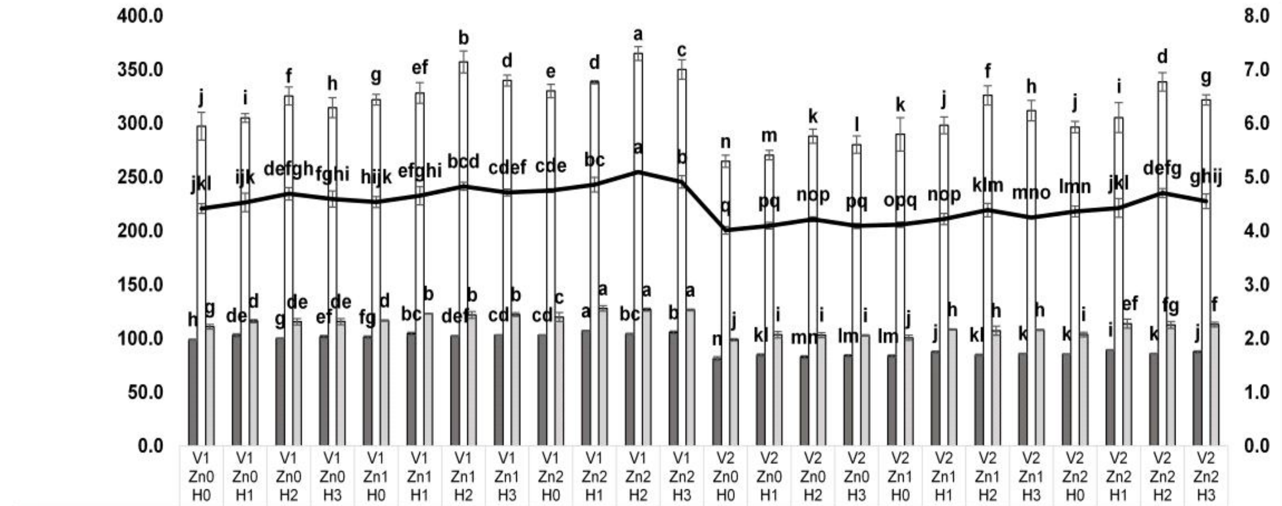
Plant height is a vital parameter of wheat crop that affects its growth and development over a period and increases with the advancement of age. The data concerning plant height at harvest is presented in Fig 1. The effect of different wheat varieties on plant height was found statistically significant and the maximum plant height was recorded under V1 (102.9 cm) and minimum under V2 (85.2 cm). As a regard to the Zn application, all modes had significant effect. Zn2 had the maximum plant height (96.1 cm) followed by Zn1 (94.1 cm) and Zn0 (91.9 cm). Among the phytohormones, all levels enhanced plant height significantly. The level H1 showed maximum plant height (95.9 cm) followed by H3 (94.7 cm), H2 (93.3 cm) and H0 (92.3 cm). The combination Zn2+H1 was seen as the most efficient in enhancing the plant height in V1 which was 8.29% higher than Zn0+H0. Similarly, the combination Zn2+H1 increased height in V2 by 10.09% over Zn0+H0. Singh *et al*. (2023) supported the varietal difference in plant height. Arif *et al*. (2019) observed that height of wheat might be enhanced due to the improved enzymatic activity and auxin biosynthesis because of Zn application along with increased cell elongation and cell division by external application of cytokinin and GA.

Tillers/m^2

The effect of various treatments on number of tillers at harvest is presented in Fig 1. Tillering is a key growth phase in wheat that helps plants to compensate for low plant populations or to benefit from favourable growth circumstances. On comparing the two wheat varieties, a significant effect was found on the number of tillers. The maximum number of tillers was recorded under V1 (351.9) which was greater than V2 (316.0). Among the Zn application methods, all significantly improved the number of tillers. Zn1 and Zn2 improved the tillers/m2 significantly over the Zn0. Zn2 resulted in highest number of tillers (351.6) which was higher than Zn1 (341.3) and Zn0 (309.2). In context to the effect of phytohormones, it was found statistically significant. The concentration H2 showed highest number of tillers (354.5) followed by H3 (339.1), H1 (325.5) and H0 (316.9) at harvest. For V1, combination Zn2+H2 was notable in improving the tillers/m^2, which was 24.38% better than the combination Zn0+H0. However, the same combination enhanced tillers/m^2 by 30.12% for V2. The emergence of tillers is closely synchronised with the formation of leaves on the main stem and the number of tillers produced are determined by variety and growth circumstances (Singh *et al*., 2021). The application of Zn and cytokinin on the leaves may have enhanced the enzyme activity, chlorophyll and metabolite synthesis that allowed the plant to bear a greater number of tillers. The results inclined with the results of Koprna *et al*. (2020).

Leaf area index (LAI)

LAI is a parameter which determines the potential of a plant to use solar energy for photosynthesis. The influence of various treatments on LAI of both the wheat varieties at 90 DAS is shown in Fig 1. A comparison between wheat varieties showed significant impact on LAI. V1 (4.72) had higher LAI than V2 (4.29). In terms of the influence of supply regimes of Zn, all modes had a significant effect on LAI. The maximum LAI recorded under Zn2 (4.71). The effect of various concentrations of phytohormones was found statistically significant. The highest LAI was recorded under H2 (4.66) which was greater than H3 (4.52), H1 (4.47) and H0 (4.37). H1 and H3 were at par with each other at this growth stage. The combination Zn2+H2 for V1 was the most capable in improving the LAI by 15.15% over Zn0+H0 combination. The same combination improved LAI for V2 by 17.21%. Zn application improves stomatal conductance, chlorophyll and other photosynthetic pigment content resulting in improved leaf area (Ilyas *et al*., 2020). Similarly, cytokinin application increased chlorophyll biosynthesis



	V1 Zn0 H0	V1 Zn0 H1	V1 Zn0 H2	V1 Zn0 H3	V1 Zn1 H0	V1 Zn1 H1	V1 Zn1 H2	V1 Zn1 H3	V1 Zn2 H0	V1 Zn2 H1	V1 Zn2 H2	V1 Zn2 H3	V2 Zn0 H0	V2 Zn0 H1	V2 Zn0 H2	V2 Zn0 H3	V2 Zn1 H0	V2 Zn1 H1	V2 Zn1 H2	V2 Zn1 H3	V2 Zn2 H0	V2 Zn2 H1	V2 Zn2 H2	V2 Zn2 H3
Plant height (cm)	98.9	102.9	100.2	101.6	101.2	104.4	102.3	103.4	103.3	107.1	104.3	105.6	81.2	84.6	82.7	83.8	83.6	87.5	84.6	86.0	85.7	89.4	85.9	87.6
Tillers	297.3	305.2	325.5	314.6	322.0	328.2	357.1	339.8	330.1	338.3	365.0	350.1	264.7	270.5	288.0	280.2	289.8	298.2	326.0	311.9	296.5	305.4	338.5	321.8
DMA (q/ha)	111.0	116.1	115.6	115.7	116.7	123.2	122.0	122.2	119.9	128.0	126.8	126.6	99.0	103.5	103.2	102.8	100.6	108.3	107.3	108.0	103.8	113.8	112.6	113.0
LAI	4.4	4.5	4.7	4.6	4.5	4.7	4.8	4.7	4.8	4.9	5.1	4.9	4.0	4.1	4.2	4.1	4.1	4.2	4.4	4.3	4.4	4.4	4.7	4.6

The data is pooled for 2021-22 and 2022-23 seasons. The columns with distinct letters are significantly different from each other at pd"0.05. Detail of treatments; V1: PBW 725; V2: PBW 752; Zn0: No Zinc; Zn1: Zinc soil@62.5 kg/ha; Zn2: Zinc soil@31.25kg/ha+ foliar@0.5%, H0: No hormones; H1: GA@10 ppm; H2: Cytokinin@10 ppm; H3: GA@5 ppm+ Cytokinin@5 ppm.

Fig 1: Effect of different treatments on the growth parameters of wheat.

and stomatal conductance. According to Zaheer *et al*. (2019), cytokinin maintained leaf expansion and delayed leaf senescence contributing to enhanced leaf area.

Dry matter accumulation

The effect of various treatments on accumulation of dry matter in both the wheat varieties at harvest is shown in Fig 1. Dry matter accumulation (DMA) is a vital parameter of growth that expresses the plant's metabolic efficiency. A significant varietal effect was found on dry matter. The maximum dry matter was recorded under V1 (120.3 q/ha) which was greater than V2 (106.32 q/ha). In context to different Zn application modes, all influenced the dry matter accumulation significantly. The average dry matter under Zn2 (118.1 q/ha) was higher than Zn1 (113.5 q/ha) and Zn0 (108.4 q/ha). Among the phytohormones, all hormone concentrations significantly improved dry matter accumulation. Maximum dry matter was recorded under H1 (115.5 q/ha) followed by H3 (114.7 q/ha), H2 (114.6 q/ha) and H0 (108.5 q/ha) at harvest. The level H1, H2 and H3 were at par with each other. The Zn2+H1 combination was most effective in improving the dry matter, which was 15.36% greater than the Zn0+H0 for V1. Similarly, Zn2+H1 increased dry matter for V2 by nearly 14.95%. Dry matter continuously increased over the crop life cycle. Higher leaf area, tillers per m^2 and plant height collectively may be the reason of the improved dry matter, as increased leaf area resulted in improved radiant energy interception and utilisation, resulting in more photosynthesis and eventually more dry matter accumulation. The results of the experiment agreed with the findings of Firdous *et al*. (2018).

Grain yield

Influence of various treatments on grain yield of the two wheat varieties is shown in Table 1. A comparison between the wheat varieties displayed that yield was significantly impacted by the wheat varieties. Maximum grain yield was recorded under V1 (49.2 q/ha) followed by V2 (43.8 q/ha). In context to the impact of Zn application, all methods were significantly different from each other and the maximum average grain yield was recorded in Zn2 (48.4 q/ha) followed by Zn1 (46.6 q/ha) and Zn0 (44.5 q/ha). All phytohormone levels significantly increased the grain yield. The maximum grain yield was recorded under H2 (48.3 q/ha) which was followed by H3 (47.1 q/ha), H2 (46.0 q/ha) and H0 (44.6 q/ha). The combination Zn2+H2 was the most effective with 17.11% increment in yield of V1 and with 19.31% increment in V2 than the least effective combination Zn0+H0. Grain yield is the most commercially valued component of the crops. The metabolic processing of carbohydrates influenced by Zn results in increased photosynthesis, sugar conversions and seed development. So, an increase in Zn content and their ingestion led to bolder grains, which led to an improvement in test weight subsequently increasing grain yield (Kumar *et al*., 2019). The cytokinin application increased the productive tillers and helped in transportation of assimilates to grain, increasing grain size, weight and yield. Zaheer *et al*. (2022) also supported the results of our study.

Straw yield

The effect of different treatments on straw yield of the two wheat varieties is shown in Table 1. A comparison between the wheat varieties showed that both significantly influenced the straw yield. The straw yield under V1 (71.1 q/ha) was higher than V2 (62.5 q/ha). Pertaining to the influence of Zn application methods on straw yield of wheat, all were statistically significant in their effect. The maximum straw yield was observed under Zn2 (69.6 q/ha) followed by Zn1 (66.9 q/ha) and Zn0 (63.9 q/ha). Influence of various phytohormone levels had significant impact on enhancing straw yield. Maximum straw yield was observed under H1 (69.5 q/ha) which was followed by H3 (67.6 q/ha), H2 (66.2 q/ha) and H0 (63.9 q/ha). The Zn2+H1 combination was the most efficient with 18.99% increment in straw yield of V1 than Zn0+H0. Likewise, the same combination produced 17.44% more straw yield in V2 over Zn0+H0 combination. A combined Zn application (soil+foliar) might be more promising than other fertilisation approaches in enhancing plant development and dry matter at maturity, which resulted in higher straw yield (Imran and Rehim, 2017). Application of GA led to increased plant height and dry matter, which contributed to higher straw yield (Mathpal *et al*., 2023).

Harvest index (%)

The HI of a crop determines its physiological efficiency and capacity to convert total dry matter into commercial output. Data regarding the HI is presented in Table 1. The maximum harvest index was resulted under V2 (41.3 %) and minimum under V1 (40.9 %). Among the Zn applications modes, the maximum harvest index was obtained by Zn1 and Zn0 *i.e*., 41.2 % whereas the lowest was recorded in Zn2 (41.1 %). A significant effect of phytohormones was recorded. H2 (42.3 %) was better than H0 (41.2 %), H3 (41.2 %) and H1 (40.0 %). The levels H0 and H3 were at par of each other. The combination of Zn2+H2 was the most effective with 7.35% higher HI in V1 and with 8.11% in V2 than the combination Zn2+H1. The higher HI value indicates more physiological efficiency of dry matter conversion and *vice versa*. Soil+foliar Zn application mode increased wheat yield contributing attributes such as number of effective tillers and grains per spike (Ghasal *et al*., 2017). This further enhanced with foliar spray of PGR which improved grain weight and size, leading to more HI. The findings of Mathpal *et al*. (2023) corroborated these conclusions.

Correlation analysis

The data for correlation among the different growth parameters and yield for the wheat crop is presented in Table 2. The strong and significant correlation coefficient of plant height with other growth and grain yield components indicates the strong association between

Table 1: Effect of different treatments on yield and harvest index of wheat during 2021-22, 2022-23 seasons.

Treatments	Grain yield (q/ha)			Straw yield (q/ha)			Harvest index (%)		
Year	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
V1 Zn0 H0	42.33±1.15^{defghij}	48.93±0.15^{j}	45.63±0.51^{gh}	57.33±4.04^{ghijkl}	73.31±0.31^{i}	65.32±2.15^{ij}	42.52±1.97^{ab}	40.03±0.13^{d}	41.27±0.99^{bcd}
V1 Zn0 H1	43.30±1.13^{cdefgh}	49.97±0.45^{i}	46.63±0.60^{fg}	61.00±4.00^{defgh}	78.00±0.72^{e}	69.50±1.65^{ef}	41.55±1.76^{ab}	39.05±0.07^{ef}	40.30±0.87^{def}
V1 Zn0 H2	44.70±2.25^{bcdefg}	52.10±0.53^{e}	48.40±1.39^{de}	59.00±2.65^{efghij}	75.32±0.43^{h}	67.16±1.49^{gh}	43.10±0.26^{a}	40.89±0.13^{c}	41.99±0.17^{abc}
V1 Zn0 H3	43.97±2.95^{bcdefg}	51.07±0.25^{g}	47.52±1.35^{ef}	60.00±3.61^{defghi}	76.37±0.33^{fg}	68.19±1.80^{fg}	42.29±1.17^{ab}	40.07±0.07^{d}	41.28±0.60^{cd}
V1 Zn1 H0	43.67±3.21^{cdefg}	51.60±0.30^{f}	47.63±1.47^{def}	61.33±1.53^{cdefgh}	76.78±0.70^{f}	69.06±1.00^{f}	41.56±2.41^{ab}	40.19±0.15^{d}	40.88±1.19^{cde}
V1 Zn1 H1	45.67±0.58^{abcde}	52.70±0.20^{d}	49.18±0.21^{cd}	65.00±1.00^{abcd}	82.97±0.57^{b}	73.98±0.24^{b}	41.27±0.48^{ab}	38.85±0.16^{ef}	40.06±0.16^{def}
V1 Zn1 H2	47.00±4.36^{abc}	55.03±0.15^{b}	51.02±2.25^{b}	63.00±2.00^{bcdef}	78.91±0.57^{de}	70.95±0.93^{de}	42.67±1.67^{ab}	41.09±0.15^{c}	41.88±0.83^{abc}
V1 Zn1 H3	46.33±2.31^{abcd}	53.83±0.15^{c}	50.08±1.23^{bc}	63.67±0.58^{bcde}	80.53±0.65^{c}	72.10±0.59^{cd}	42.10±1.11^{ab}	40.07±0.13^{d}	41.08±0.5^{cd}
V1 Zn2 H0	45.00±2.00^{bcdef}	52.97±0.42^{d}	48.98±1.07^{cde}	62.67±8.62^{bcdef}	79.20±0.69^{d}	70.93±4.50^{de}	41.97±4.03^{ab}	40.08±0.03^{d}	41.02±2.01^{cde}
V1 Zn2 H1	46.67±3.51^{abc}	53.77±0.25^{c}	50.22±1.80^{bc}	69.33±1.53^{a}	86.21±0.38^{a}	77.77±0.63^{a}	40.19±1.32^{b}	38.41±0.14^{gh}	39.30±0.72^{f}
V1 Zn2 H2	49.33±1.15^{a}	57.57±0.67^{a}	53.45±0.73^{a}	66.33±0.58^{abc}	80.40±0.69^{c}	73.37±0.64^{bc}	42.65±0.50^{ab}	41.72±0.10^{ab}	42.19±0.22^{abc}
V1 Zn2 H3	48.00±1.00^{ab}	55.20±0.30^{b}	51.60±0.59^{b}	67.33±1.53^{ab}	82.60±0.26^{b}	74.97±0.88^{b}	41.62±0.96ab	40.06±0.09^{d}	40.84±0.51^{cde}
V2 Zn0 H0	37.33±1.53^{k}	43.57±0.21^{p}	40.45±0.67^{l}	51.67±3.06^{m}	65.43±0.50^{n}	58.55±1.65^{n}	41.97±2.38^{ab}	39.97±0.18^{d}	40.97±1.19^{cde}
V2 Zn0 H1	38.67± 3.06^{jk}	44.47±0.25^{o}	41.57±1.60^{kl}	54.33±3.06^{jklm}	69.58±0.42^{k}	61.96±1.37^{lm}	41.55±0.80^{ab}	38.99±0.26^{ef}	40.27±0.53^{def}
V2 Zn0 H2	40.50±2.18^{ghijk}	46.20±0.20^{m}	43.35±1.17^{ij}	52.67±3.51^{lm}	66.95±1.52^{lm}	59.81±1.11^{n}	43.49±0.81^{a}	40.84±0.55^{c}	42.16±0.26^{abc}
V2 Zn0 H3	39.40±2.12^{hijk}	45.30±0.44^{n}	42.35±0.84^{jk}	53.00±1.73^{klm}	67.91±0.87^{l}	60.46±0.94^{mn}	42.63±1.77^{ab}	40.01±0.15^{d}	41.32±0.88^{bcd}
V2 Zn1 H0	39.00±3.46^{ijk}	44.13±0.15^{o}	41.57±1.66^{kl}	51.67±1.53^{m}	66.47±0.35^{m}	59.07±0.71^{n}	42.96±1.56^{ab}	39.90±0.12^{d}	41.43±0.74^{bcd}
V2 Zn1 H1	41.50±2.50^{efghijk}	45.27±0.25^{n}	43.38±1.38^{ij}	58.00±2.65^{fghijk}	71.92±0.28^{j}	64.96±1.25^{ijk}	41.71±2.55^{ab}	38.63±0.07^{fg}	40.17±1.31^{def}
V2 Zn1 H2	43.00±3.00^{cdefghi}	48.13±0.32^{k}	45.57±1.53^{gh}	55.67±5.69^{ijklm}	67.70±0.72^{l}	61.68±3.04^{m}	43.63±1.83^{a}	41.55±0.25^{b}	42.59±0.97^{ab}
V2 Zn1 H3	42.17±1.72^{defghij}	46.97±0.15^{l}	44.57±0.78^{hi}	56.67±0.58^{hijklm}	70.13±0.32^{k}	63.40±0.38^{kl}	42.65±1.23^{ab}	40.11±0.13^{d}	41.38±0.58^{bcd}
V2 Zn2 H0	41.33±3.79^{fghijk}	45.27±0.25^{n}	43.30±1.78^{ij}	53.33±2.31^{klm}	67.60±0.79^{l}	60.47±0.77^{mn}	43.61±2.14^{a}	40.11±0.30^{d}	41.86±1.03^{abc}
V2 Zn2 H1	43.67±5.51^{cdefg}	46.53±0.32^{lm}	45.10±2.88^{gh}	62.00±2.65^{cdefg}	75.40±0.35^{gh}	68.70±1.28^{fg}	41.22±2.19^{ab}	38.16±0.25^{h}	39.69±1.13^{ef}
V2 Zn2 H2	46.00±1.73^{abcd}	50.47±0.45^{h}	48.23±1.06^{de}	59.00±4.36^{efghij}	69.76±0.12^{k}	64.38±2.15^{jk}	43.84±0.88^{a}	41.97±0.22^{a}	42.91±0.36^{a}
V2 Zn2 H3	44.44±0.51^{bcdefg}	48.70±0.26^{j}	46.57±0.29^{fg}	60.00±4.36^{defghi}	72.77±0.67^{ij}	66.38±2.09^{hi}	42.60±1.81^{ab}	40.09±0.28^{d}	41.35±0.83^{bcd}

Mean values with distinct letters are significantly different from each other at $p \leq 0.05$. Detail of treatments; V1: PBW 725; V2: PBW 752; Zn0: No Zinc; Zn1: Zinc soil@62.5 kg/ha; Zn2: Zinc soil@31.25 kg/ha+ foliar@0.5%, H0: No hormones; H1: GA@10 ppm; H2: Cytokinin@10 ppm; H3: GA@5 ppm+ Cytokinin@5 ppm.

Table 2. Correlation coefficient for six different characters with grain yield in wheat crop.

	Tillers/m^2	LAI	DMA	Grain yield (q/ha)	Straw yield (q/ha)	HI (%)
Plant height (cm)	0.78***	0.56***	0.72***	0.79***	0.84***	-0.18
Tillers/m^2		0.68***	0.82***	0.90***	0.78***	0.09
LAI			0.74***	0.79***	0.65***	0.15
DMA				0.92***	0.93***	-0.14
Grain yield (q/ha)					0.84***	0.17
Straw yield (q/ha)						-0.40***

*, **, *** Significant at 5%, 1% and 0.1% levels, respectively.

these parameters. Consequently, selecting plants based on this trait will be highly effective, as these characteristics exhibit both a high correlation and a substantial direct effect (Masood *et al.,* 2014). Gelalcha *et al.* 2013 indicated that an increase in total dry matter of wheat by the increase in straw yield results in lower values of harvest index. All the growth parameters positively affect the yield of wheat crop. However, number of tillers and LAI are important components in enhancing grain yield than plant height which signify the importance of dwarfness and tillering for wheat crop (Sokoto *et al.,* 2012).

CONCLUSION

In conclusion, the study indicated that Zn and phytohormones (GA and cytokinin) had a significant influence on growth and yield of both the wheat varieties. The PBW 725 variety (V1), Zn application via soil+foliar spray (Zn2) and GA application (H1) increased plant height, DMA and straw yield. While V1, Zn2 and H2 (cytokinin application) showed good results for number of tillers, LAI and grain yield. This might be due to combined effect of soil+foliar application of Zn on enzymatic activity of wheat which led to improved auxin biosynthesis, chlorophyll content and better assimilate translocation. Cytokinin and GA also enhanced growth parameters *via* numerous metabolisms. Thus, combined effect of Zn, cytokinin and GA stimulated dry matter and yield. These findings emphasised the significance of proper nutrient management and phytohormone treatments in wheat production for increasing crop yield and agricultural sustainability.

Conflict of interest

All the authors declare that there is no conflict of interest.

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