ORIGINAL RESEARCH

Impact of Nitrogen, Zinc and Humic Acid Application on Wheat Growth, Morphological Traits, Yield and Yield Components

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ABSTRACT

To investigate the response of wheat to different levels of nitrogen (N), zinc (Zn) and humic acid (HA), an experiment was conducted at Agronomy Research Farm, the University of Agriculture, Peshawar, during 2014-15. The experiment was laid out in a randomized complete block design having three replications. Three levels of N (80, 120 and 160 kg ha^{-1}), Zn (6, 12 and18 kg ha^{-1}) and HA (5, 10 and 15 kg ha^{-1}) were used. Results showed that N application at the rate of 160 kg ha^{-1} manifested maximum days to physiological maturity (164 days), productive tillers m^{-2} (248), spikes m^{-2}(258), leaf area $tiller^{-1}$ (113.6 cm^2), spike length (10.4 cm), grains $spike^{-1}$ (52), 1000-grain weight (47.5 g), biological yield (9260 kg ha^{-1}), grain yield (3723 kg ha^{-1}) and harvest index (40%). Zn treated plots at the rate of 12 kg ha^{-1} showed maximum days to physiological maturity (162 days), productive tillers m^{-2} (241), spikes m^{-2} (252), grains $spike^{-1}$ (51), 1000-grain weight (45.2 g), biological yield (8843 kg ha^{-1}), grain yield (3375 kg ha^{-1}) and harvest index (39 %). Similarly, HA treated plots at the rate of 12 kg ha^{-1} revealed maximum days to physiological maturity (162 days), productive tillers m^{-2} (238), spikes m^{-2}(249), spike length (9.7 cm), 1000-grain weight (45.00 g), biological yield (8649 kg ha^{-1}), grain yield (3342 kg ha^{-1}) and harvest index (39%). The combined application of N, Zn, and HA had significantly affected wheat yield and yield components. It was concluded that N at the rate of 160 kg ha^{-1}, Zn 12 kg ha^{-1} and HA 10 kg ha^{-1}significantly increased yield and yield components of wheat.

KEYWORDS: Wheat, nitrogen, zinc, humic acid, Tillers, Physiological maturity

1. INTRODUCTION

Wheat (*Triticumaestivum*L.) is an annual, long-day, self-pollinated plant grown in winter. It belongs to the family Poaceae (Gramineae). It is used as a staple food in Pakistan (Ali et al., 2019a). It dominates other agronomic crops in production (Eeswaran., 2021). Wheat is a rich source of carbohydrates and gluten, increasing its demand for baking products (Cappelli et al., 2020). Wheat straw is also used as fodder for livestock. It is estimated that 5-10% wheat grain is now being consumed as poultry and livestock feed (Tricase et al., 2018). Nitrogen is often the most deficient of all the plant nutrients. Nitrogen is the key element in achieving consistently high yields in cereals (Iqbal et al., 2019; Iqbal et al., 2020, Ali et al., 2020; Wu et al., 2021, Ali et al., 2022).

Zinc is an essential micronutrient for wheat. Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome (Yuvaraj et al., 2020). Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, and regulation of auxin synthesis and pollen formation (Gondalet al., 2021). Zn is a micronutrient that is required for plant growth relatively in a smaller amount. Zn plays a vital role in the physiological process of wheat plants such as cell elongation, cell maturation, sugar translocation, meristematic tissues development and protein synthesis (Mumivand et al., 2021).

Nitrogen and Zn together play a significant role in crop production. The importance of nutrients (micro and macro) for the normal growth of crop plants is universally recognized. Zn is an essential element present in plant enzymatic systems (Yuvaraj et al., 2020). Zn has vast numbers of functions in plant metabolism and consequently, Zn deficiency has many effects on plant growth (Umair et al., 2020). Zn deficiency is a worldwide nutritional constraint for crop production in many types of soil worldwide, particularly in cereals growing on calcareous soil (Rehman et al., 2020; Amanullah, 2020). In Pakistan, Zn deficiency is a general micronutrient disorder on calcareous soil and is considered the third most common deficient nutrient after N and phosphorous (Amanullah, 2020).

Humic acid is complex organic molecules that are formed by the breakdown of organic matter. HA influences soil fertility through its effect on the soil's water-holding capacity (Ali et al., 2019b; Sutton and Sposito, 2005). HA constitutes a stable fraction of carbon that improves soil characteristics such as improved water holding capacity, pH buffering, and thermal insulation (Izhar et al., 2020). It also increases N use efficiency and stimulates shoot and root growth (Leite et al., 2020; Lodhi*et al*., 2013). HAs contributed to soil stability and soil fertility, leading to exceptional plant growth and micronutrient uptake. HA is an organically charged bio-stimulant that significantly affects plant growth and development and increases crop yield. It has been extensively investigated that HA improves soils' physical, chemical, and biological properties (Zaremanesh et al., 2020; Karim et al., 2020; Skowrońska et al., 2020).

Nitrogen, Zinc and HumicAcid are essential nutrient which play a pivotal role in increasing fertility of the soil which in turn increases the yield of the crop. Keeping in view the above facts and figures, the present investigation was therefore conducted to determine the best level of N, Zn and HA for obtaining maximum yield and yield components of wheat.

2. MATERIALS AND METHODS

2.1 Field location and experiment management

The experiment on the response of wheat to different levels of N, Zn and HA on the yield and yield components of wheat was conducted at Agronomy Research Farm, The University of Agriculture, Peshawar, Pakistan, during winter 2014-15. The research comprised of three factors (i) N N kg ha^{-1} (N1 80 kg ha^{-1}, N2 120 kg ha^{-1} and N3 160 kg ha^{-1}) (ii) Zn kg ha^{-1} (Zn_1 6 kg ha^{-1}, Zn_2 12 kg ha^{-1}, Zn_3 18 kg ha^{-1}) and (iii) HA kg ha^{-1} (HA_1 5 kg ha^{-1}, HA_2 10 kg ha^{-1}, HA_3 15 kg ha^{-1})and one control plot for each treatment where no N, Zn and HA applied. All three factors were used in the following combinations. T_1: (Control), T_2: $N_1Zn_1HA_1$, T_3: N_1Zn_1 HA_2, T_4: $N_1Zn_1HA_3$, T_5: $N_1Zn_2HA_1$, T_6: $N1Zn_2HA_2$, T_7: $N_1Zn_2HA_3$, T_8: $N_1Zn_3HA_1$, T_9: $N_1Zn_3HA_2$,T_{10}: $N_1Zn_3HA_3$, T_{11}: $N_2Zn_1HA_1$, T_{12}: $N_2Zn_1HA_2$, T_{13}: $N_2Zn_1HA_3$, T_{14}: $N_2Zn_2HA_1$, T_{15}: $N_2Zn_2HA_2$, T_{16}: $N_2Zn_2HA_3$, T_{17}: $N_2Zn_3HA_1$, T_{18}: $N_2Zn_3HA_2$, T_{19}: $N_2Zn_3HA_3$, T_{20}: $N_3Zn_1HA_1$, T_{21}: $N_3Zn_1HA_2$, T_{22}: $N_3Zn_1HA_3$, T_{23}: $N_3Zn_2HA_1$, T_{24}: $N_3Zn_2HA_2$, T_{25}: $N_3Zn_2HA_3$, T_{26}: $N_3Zn_3HA_1$, T_{27}: $N_3Zn_3HA_2$, T_{28}: $N_3Zn_3HA_3$. The experiment was laid out in a randomized complete block design having three replications. Wheat variety ‘Atta Habib-2010’ was sown on 20th November 2014 at the rate of 120 kg ha^{-1} in a plot size of 3 × 1.8 m having 6 rows 30 cm apart. At the time of sowing full dose of Zn, HA, and half dose of N was used while the rest of 50% N was applied at second irrigation. A basal dose of phosphorous (P_20_5) 100 kg ha^{-1} was applied to each plot. Urea, diammonium phosphate (DAP), Zn sulphate and HA was used as a source for N, P, Zn and HA respectively. Irrigation was done according to the need of crop. Weedicides was used for control of common weeds of wheat. The crop was harvested on May 15, 2015. Excluding the treatments, all the further agronomic practices were done normal and uniform.

2.2 Data collection and analysis

Data concerning days to emergence was recorded by counting the number of days from sowing to 80% of the seedlings emerged in each plot. Emergence m^{-2} data was recorded by measuring the number of plants emerged in one meter row length at three randomly selected rows in each plot and was converted to emergence m^{-2} using the following formula (1);

$$\text{Emergence m}^{-2} = \frac{\text{Total number of seedling emerged}}{\text{Row - row distance} \times \text{row length} \times \text{No. of rows}} \times 1\text{m}^{-2}$$

Data on days to anthesis was recorded when 80% of plants extruded the anthers in each treatment. Days were counted from the date of sowing till the date of anthers extrusion in each plot. Days to physiological maturity were recorded by measuring the days from date of sowing to the date when 80% plants get physiologically mature (Anderson *et al.*, 1985). Leaf area tillers^{-1} was calculated at the anthesis stage from the leaves of ten tillers in four central rows selected randomly at each plot. Leaf area tiller^{-1} was calculated by multiplying the average leaf length (cm), leaf width (cm), number of leaves, and correction factor then dividing by ten tillers.

Leaf area tiller^{-1}= No. leaves × Avg Leaf width (cm) ×Avg leaf length × CF/ No. tiller

Correction factor = 0.75 (Abbas *et al.*, 2014)

For spike length data, the length of ten randomly selected spikes was measured from the basal joint of the spike till the top of the spike and then averaged. Spikes m^{-2} data was recorded by counting the number of spikes in central four rows of each plot and then were converted into spikes m^{-2}. The data on the number of productive tillers m^{-2} was recorded by counting the tillers having a spike in place one meter selected at three time randomly in each plot and were converted into productive tillers m^{-2}. Ten randomly selected spikes for grains spike-1 of wheat were estimated and then averaged. Similarly, a thousand grains were randomly taken from each plot and the weight was calculated with the help of electronic balance. Whereas, the biological yield was recorded by harvesting four central rows in each plot; tied into bundles, sun-dried, weighed and then biological yield was calculated in kg ha^{-1} by using formula ;

$$\text{Biological yield (kg ha}^{-1}\text{)} = \frac{\text{Biological yield in four central rows}}{\text{Row}-\text{row distance x Row length x No. of rows}} \text{x10000}$$

The four central rows was harvested, dried, threshed, cleaned, weighed and then converted into kg ha^{-1}. For Harvest index was calculated by using the following formula; Harvest index (%) = $\frac{\text{Economic yield}}{\text{Biological yield}} \times 100$

2.3 Statistical Analysis

Analysis of variance procedure was followed for the statistical analysis of recorded data according to the design used. Means compared using least significant differences (LSD) test at $P \leq 0.05$ upon significant F-test (Steel, 1997).

3. RESULTS

3.1 Phenology and Growth traits

Analysis of the data on days to emergence and emergence m^{-2} showed that N, Zn, HA, control vs. rest and all the interaction between the nutrients were found non-significant (Figure. 1). Days to anthesis were significantly affected by N and control vs. rest had (Figure. 2). While Zn, HA and all the interaction were non-significant for days to anthesis. The treated plots took more days to anthesis (134) as compared to control (133). N's mean data revealed that minimum days to anthesis (133) were recorded at 80 kg N ha^{-1}. Days to anthesis increased with each increment of N and maximum days to anthesis (134) was observed at 160 kg N ha^{-1}. Similarly data on days to physiological maturity revealed that N, Zn, HA, control vs. rest and N × Zn interaction significantly affected days to physiological maturity, while all other interactions were non-significant (Figure 2B). The treated plots showed more days to physiological maturity (163) as compared to control (156). N's mean data exhibited that minimum days to physiological maturity (161) were noted at 80 kg N ha^{-1}. Days to physiological maturity increased with each increment of N and maximum days to physiological maturity (165) was noted at 160 kg N ha^{-1}. Minimum days to physiological maturity (162) were observed at 6 kg Zn ha^{-1}. Days to physiological maturity increased with each increment of Zn and full days to physiological maturity (163) was observed at 18 kg Zn ha^{-1}. Low level of HA (5 kg ha^{-1}) resulted in minimum days to physiological maturity (162). Days to maturity increased with each increment of HA The maximum days to physiological maturity (163) were revealed at 15 kg HA ha^{-1}. Interaction among N × Zn showed that days to physiological maturity increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar increase in days to physiological maturity was observed with each increment of N with 12 and 18 kg Zn ha^{-1}. Data regardingleaf area $tiller^{-1}$ revealed that N, Zn, HA, control vs. rest, N × Zn and N × Zn × HA interaction had significantly affected leaf area $tiller^{-1}$(Figure 3A), while all other interactions were non-significant for leaf area $tiller^{-1}$. The treated plots showed maximum leaf area $tiller^{-1}$ (111.01) as compared to control (99.00). Mean data for N showed that minimum leaf area $tiller^{-1}$ (108.84) was observed at 80 kg N ha^{-1}. Leaf area $tiller^{-1}$ increased with each increment of N and higher leaf area $tiller^{-1}$(113.66) was observed at 160 kg N ha^{-1}. Minimum leaf area $tiller^{-1}$ (108.88) was noted at 6 kg Zn ha^{-1}. Leaf area $tiller^{-1}$ increased with each increment of Zn and maximum leaf area $tiller^{-1}$ (112.63) was recorded at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) resulted in lowest leaf area $tiller^{-1}$ (107.88). Leaf area $tiller^{-1}$ increased with HA increment and higher leaf area $tiller^{-1}$ (112.44) was recorded at 15 kg HA ha^{-1}. Interaction between N × Zn revealed that leaf area $tiller^{-1}$ increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar increase in leaf area $tiller^{-1}$ was noted with each increment of N with 12 and 18 kg Zn ha^{-1}. In the case of Plant height lower level of HA (5 kg ha^{-1}) produced in smaller plant height (88.3), plant height increased with the increment of HA and taller plant height (92.6) was obtained at 15 kg HA ha^{-1} (Figure 3B). Interaction between N × Zn showed that plant height improved with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Alike increase in plant height was noted with each increment of N with 12 and 18 kg Zn ha^{-1}. Data on spike length of the data pertaining that N, Zn, HA, control vs. rest and N × Zn × HA interaction had significantly affected spike length (Figure 4A). While all other interactions were non-significant spike length. The treated plots resulted in greater spike length (9.7) than control (8.1). Mean data for N showed that smaller spike length (9.2) was recorded at 80 kg N ha^{-1}. Spike length enhanced with each

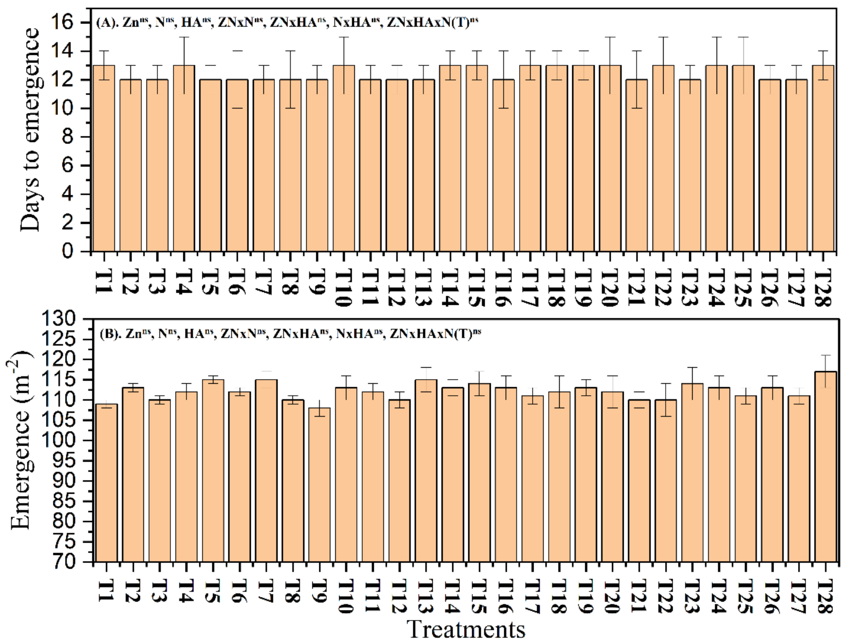

Figure 1. Changes in Days to emergence and emergence (m^{-2}) of wheat to different N, Zn and HA applications. T1 to T28 indicates different treatments, for detail see material and methods.

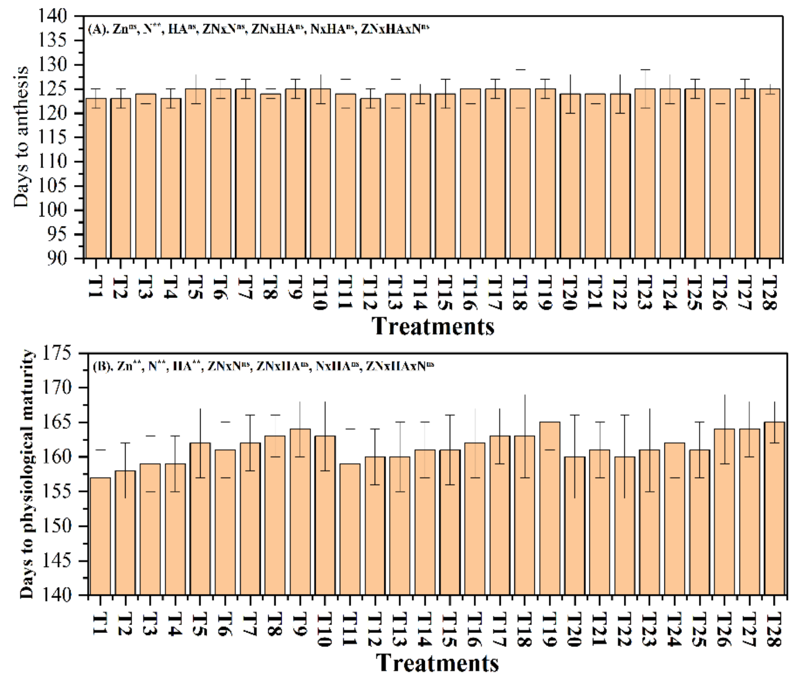

Figure 2. Changes in Days to anthesis and Daysof wheat to different N, Zn and HA applications. T1 to T28 indicates different treatments, for detail see material and methods.

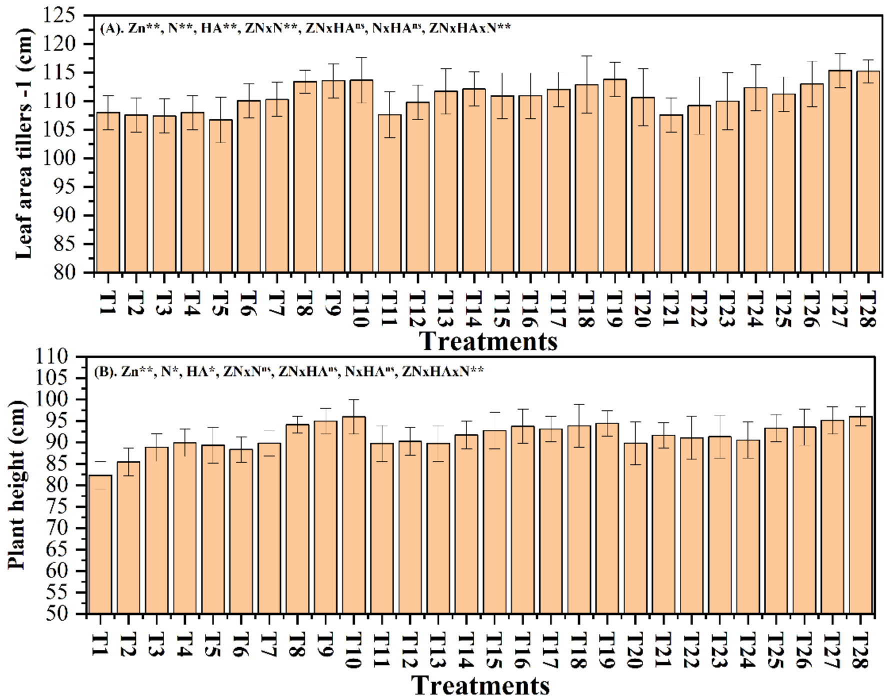

Figure 3. Changes in leaf area tiller^{-1} and plant height of wheat to different N, Zn and HA applications.T1 to T28 indicates different treatments, for detail see material and methods.

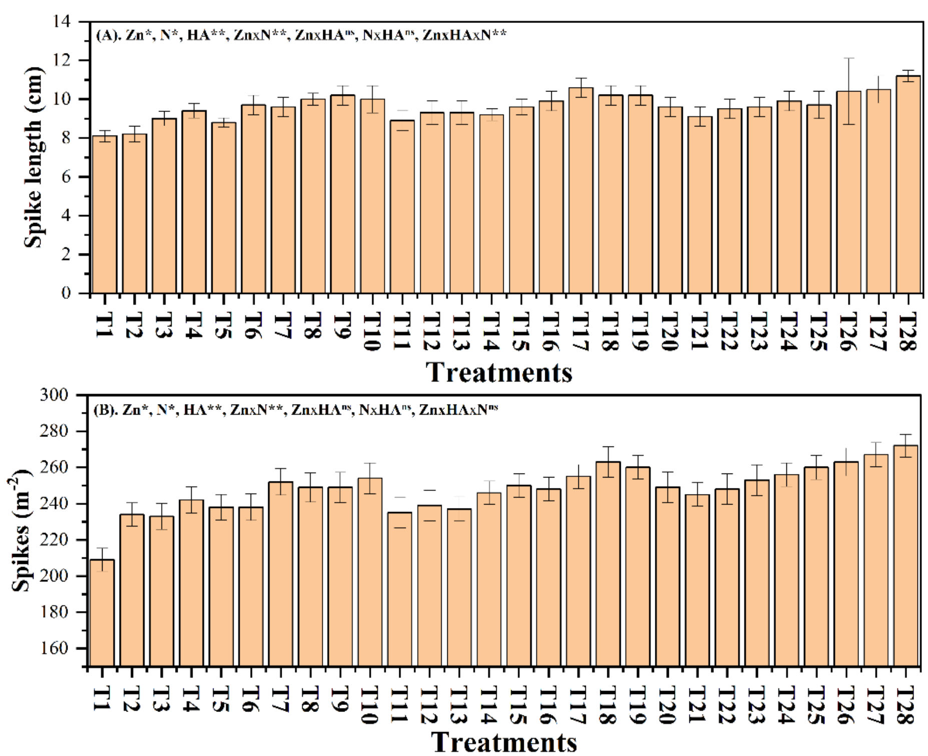

Figure 4. Changes in leaf area tiller-1 and wheat plant height to different N, Zn and HA applications.T1 to T28 indicates different treatments, for detail see material and methods.

increment of N and greater spike length (11) was observed at 160 kg N ha^{-1}. Minimum spike length (9.2) was recorded at 6 kg Zn ha^{-1}. Spike length enhanced with each increment of Zn and maximum spike length (10) was obtained at 18 kg Zn ha^{-1}. The lower level of HA (5 kg ha^{-1}) resulted minimum spike length (9.1). Spike length increased with each increment of HA and maximum spike length (9.9) was recorded at 15 kg HA ha^{-1}.

The application of N, Zn, HA, control vs. rest and Zn × HA interaction significantly affected spikes m^{-2} of wheat (Figure 4B), while all other interactions were non-significant. The treated plots showed maximum spikes m^{-2} (249) as compared to control (209). N's mean data revealed that minimum spikes m-2 (239) were noted at 80 kg N ha^{-1}. Spikes m^{-2} improved with each increment of N and maximum spikes m^{-2} (258) was recorded at 160 kg N ha^{-1}. Minimum spikes m^{-2} (238) was recorded at 6 kg Zn ha^{-1}. Spikes m^{-2} improved with each addition of Zn and maximum spikes m^{-2} (253) was obtained at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) produced minimum spikes m^{-2} (238). Spikes m^{-2} increased with each increment of HA and more spikes m^{-2} (253) was noted at 15 kg HA ha^{-1}. Interaction between Zn × HA showed that spikes m^{-2} enhanced with each increment of Zn up to 18 kg N ha^{-1} with 5 kg HA ha^{-1}. Alike increase in spikes m^{-2} was noted with each increment of Zn with 10 and 15 kg HA ha^{-1}.

3.2 Yield Component and Yield Traits

The addition of N, Zn and HA significantly affected productive tillers m^{-2}(Table 9), whereas the interaction among Zn, N and HA were found non-significant. The treated plots exhibited maximum productive tillers m^{-2} (239) as compared to control (187). Mean data for N exhibited that minimum productive tiller m^{-2} (230) was recorded at 80 kg N ha^{-1}. Productive tillers m^{-2} increased with each increment of N and maximum productive tillers m^{-2} (248) was noted at 160 kg N ha^{-1}. Minimum productive tillers m^{-2} (232) was obtained at 6 kg Zn ha^{-1}. Productive tillers m^{-2} improved with each increment of Zn and higher productive tillers m^{-2} (243) was recorded at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) resulted lower productive tillers m^{-2} (232). Productive tillers m^{-2} increased with each increment of HA and maximum productive tillers m^{-2} (242) was noted at 15 kg HA ha^{-1}. Interaction between Zn × HA revealed that productive tillers m^{-2} increased with each increment of Zn up to 18 kg N ha^{-1} with 5 kg HA ha^{-1}. A similar increase in productive tillers m^{-2} was recorded with each increment of Zn with 10 and 15 kg HA ha^{-1}.

Analysis of the data showed that N, Zn, HA, control vs. rest and N × HA interaction had significantly affected number of grains $spike^{-1}$ (Table 11). At the same time, all other interaction were non-significant. The treated plots revealed more grains $spike^{-1}$ (51) as compared to control (36). Mean data for N manifested that minimum grains $spike^{-1}$ (48) was noted at 80 kg N ha^{-1}. Grains $spike^{-1}$ enhanced with each addition of N and maximum grains $spike^{-1}$ (52) was

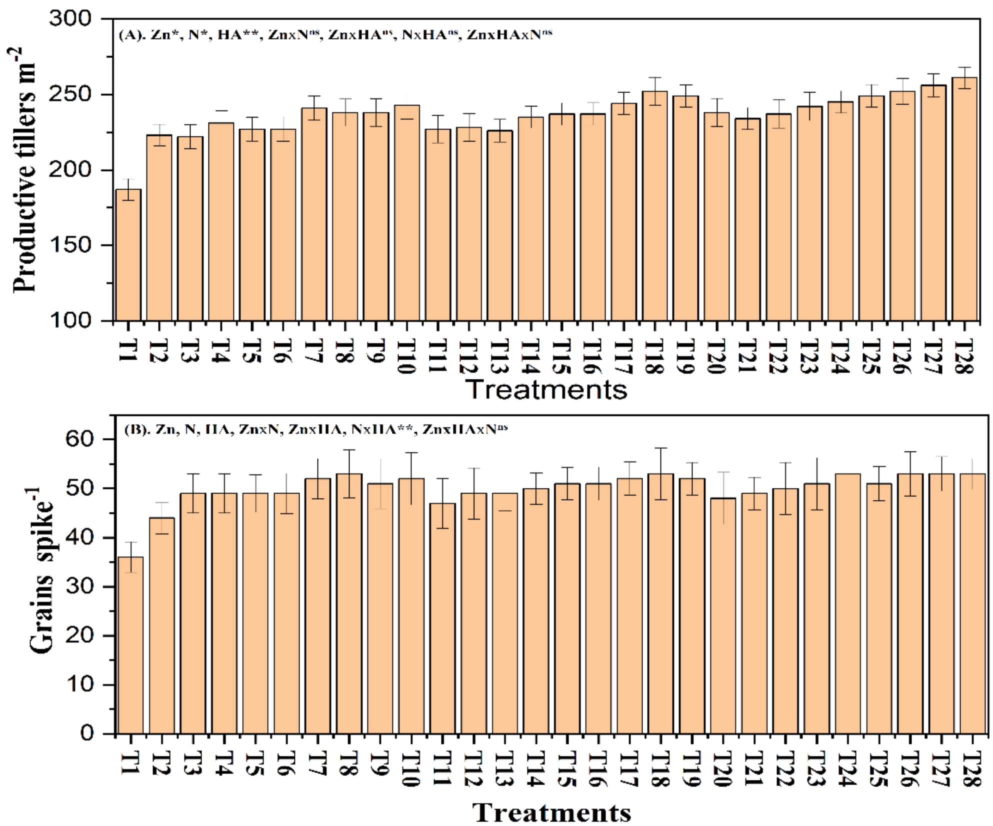

Figure 5. Changes in productive tillers m^{-2}and grains spike^{-1}leaf area tiller-1 and plant height of wheat to different N, Zn and HA applications.T1 to T28 indicates different treatments, for detail see material and methods.

recorded at 160 kg N ha^{-1}. Lesser grains spike^{-1} (47) was observed at 6 kg Zn ha^{-1}.

Grains spike^{-1} improved with each increment of Zn and more grains spike^{-1} (51) was obtained at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) produced in lesser grains spike^{-1} (47). Grains spike^{-1} increased with each increment of HA and more grains spike^{-1} (51) was obtained at 15 kg HA ha^{-1}. Interaction between N × HA showed that grains spike^{-1} improved with each increment of N up to 160 kg N ha^{-1} with 5 kg Zn ha^{-1}. Alike increase in grains spike^{-1} was recorded with each increment of N with 10 and 15 kg Zn ha^{-1}. Data on 1000 grains weight revealed that N, Zn, HA, control vs. rest, N × Zn, Zn × HA and N × Zn × HA interaction had significantly affected 1000-grains weight (Table 1). While other interaction were non-significant. The treated plots showed more 1000-grains weight (45) as compared to control (36). Mean data for N showed that less 1000-grains weight (41.3) was obtained 1000-grains weight improved with each increment of N and higher 1000-grains weight (47.5) was noted at 160 kg N ha^{-1}. Minimum 1000-grains weight (42.4) was recorded at 6 kg Zn ha^{-1}. 1000-grains weight increased with each increment of Zn and maximum 1000-grains weight (45.7) was recorded at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) resulted in minimum 1000-grains weight (43.0). 1000-grains weight increased with the increment of HA and 1000-grains weight maximum 1000-grains weight (45.5) was noted at 15 kg HA ha^{-1}. Interaction between N × Zn manifested that 1000-grains weight increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar improved 1000-grains weightwas noted with each increment of N with 12 and 18 kg Zn ha^{-1}. Interaction among Zn × HA showed that 1000-grains weight increased with each increment of Zn up to 18 kg N ha^{-1} with 5 kg HA ha^{-1}. Alike increase in 1000-grains weight was observed with each increment of Zn with 10 and 15 kg HA ha^{-1}.

Analysis of the data revealed that N, Zn, HA, control vs. rest, N × Zn and N × Zn × HA interaction had significantly affected biological yield (Table 2). While all other interaction were non-significant. The treated plots showed maximum biological yield (8805 kg ha^{-1}) as compared to control (6127 kg ha^{-1}). Mean data for N revealed that lower biological yield (7450 kg ha^{-1}) was noted at 80 kg N ha^{-1}. Biological yield increased with each increment of N and maximum biological yield (9260 kg ha^{-1}) was observed at 160 kg N ha^{-1}. Minimum biological yield (7843 kg ha^{-1}) was noted at 6 kg Zn ha^{-1}. Biological yield increased with each increment of Zn and maximum biological yield (8973 kg ha^{-1}) was noted at 18 kg Zn ha^{-1}. The lower level of HA (5 kg ha^{-1}) resulted in lowest biological yield (7997 kg ha^{-1}). Biological yield increased with increment of HA and higher biological yield (8900 kg ha^{-1}) was observed at 15 kg HA ha^{-1}. Interaction between N × Zn revealed that biological yield increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar increase in biological yield was noted with each increment of N with 12 and 18 kg Zn ha^{-1}.

The data analysis showed that N, Zn, HA, control vs. rest, N × Zn and N × Zn × HA interaction had significantly affected grain yield (Table 3). While all other interaction were non-significant. The treated plots showed maximum grain yield (3420 kg ha^{-1}) as compared to control (2360 kg ha^{-1}). N's mean data revealed that lower grain yield (2862 kg ha^{-1}) was observed at 80 kg N ha^{-1}. Grain yield increased with each increment of N and maximum grain yield (3723 kg ha^{-1}) was observed at 160 kg N ha^{-1}. Minimum grain yield (3080 kg ha^{-1}) was noted at 6 kg Zn ha^{-1}. Grain yield increased with each increment of Zn and maximum grain yield (3544 kg ha^{-1}) was noted at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) resulted in lowest grain yield (3187 kg ha^{-1}). Grain yield increased with the increment of HA and higher grain yield (3493 kg ha^{-1}) was observed at 15 kg HA ha^{-1}. Interaction between N × Zn revealed that grain yield increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar increase in grain yield was noted with each increment of N with 12 and 18 kg Zn ha^{-1}.Analysis of the data showed that N, Zn, HA, control vs. rest, N × Zn and N × Zn × HA interaction had significantly affected

Table 1. 1000-grain weight (g) of wheat as affected by nitrogen (N), Zinc(Zn) andhumic acid(HA).

Zn ($kg\ ha^{-1}$)	HA ($kg\ ha^{-1}$)	N ($kg\ ha^{-1}$)			Mean
		80	**120**	**160**	
		N x Zn x HA			**Zn x HA**
6	5	39.9	40.3	42.3	41.5
	10	41.6	42.8	42.8	41.8
	15	42.2	41.5	42.5	42.1
12	5	44.5	45.9	46.4	45.6
	10	46.3	45.4	45.1	45.6
	15	46.9	44.6	46.9	46.1
18	5	44.3	47.1	48.7	46.7
	10	45.3	47.8	49.1	47.6
	15	47.3	48.6	49.6	48.3
		N x HA			
	5	40.0	43.3	45.6	43.0 b
	10	41.8	45.6	47.6	45.0 a
	15	42.1	46.1	48.3	45.5 a
		N x Zn			
6		39.8	43.0	44.4	42.4 b
12		42.2	45.5	47.9	45.2 a
18		41.9	46.0	49.1	45.7 a
		41.3 c	45.8 b	47.5 a	
Planned Mean Comparison					
	Control	36			
	Rest	45			

Note: Means of same category followed by different letters are significantly different at ($P \leq 0.05$) using LSD test.

Table 2. Biological yield (kg ha^{-1}) of wheat as affected by nitrogen (N), Zinc(Zn) andhumic acid(HA).

Zn (kg ha^{-1})	HA (kg ha^{-1})	N (kg ha^{-1})			Mean
		80	**120**	**160**	
		N x Zn x HA			**Zn x HA**
6	5	7610	7724	7738	7691
	10	7634	7631	8150	7805
	15	7492	7818	8200	7837
12	5	8432	8850	9520	8934
	10	8915	9282	9394	9197
	15	9011	9152	9671	9278
18	5	9099	9604	9739	9481
	10	9259	9730	9866	9618
	15	9562	9864	9786	9737
		N x HA			
	5	7230	7880	8880	7997 b
	10	7636	8660	9650	8649 a
	15	7685	9278	9737	8900 a
		N x Zn			
6		7120	8160	8250	7843 b
12		7620	9178	9733	8843 a
18		7609	9528	9797	8978 a
		7450 c	8955 b	9260 a	
Planned Mean Comparison					
	Control	6127			
	Rest	8805			

Means of same category followed by different letters are significantly different at ($P \leq 0.05$) using LSD test.

harvest index (Table 4). While all other interaction were non-significant. The treated plots showed a maximum harvest index (39 %) compared to control (37 %). Mean data for N revealed that lower harvest index (38 %) was observed at 80 kg N ha^{-1}.

Harvest index increased with each increment of N and maximum harvest index (40 %) was observed at 160 kg N ha^{-1}. Minimum harvest index (38 %) was noted at 6 kg Zn ha^{-1}. Harvest index increased with each increment of Zn and maximum harvest index (39 %) was noted at 18 kg Zn ha^{-1}. Lower level of HA (5 kg ha^{-1}) resulted in lowest harvest index (38 %).Harvest index increased with increment of HA and higher grain yield (39 %) was observed at 15 kg HA ha^{-1}. Interaction between N × Zn revealed that harvest index increased with each increment of N up to 160 kg N ha^{-1} with 6 kg Zn ha^{-1}. Similar increase in harvest index was noted with each increment of N with 12 and 18 kg Zn ha^{-1}.

4. DISCUSSION

Our results showed that days to emergence and emergence m^{-2} of wheat to N, Zn, HA, control vs. rest and all the interactions among the nutrients were non-significantly affected. The possible reason may be that the consumption of its own stored food in the seed as an enough source for seedling to emerge. Our results are similar to (Waraich et al., 2007) who reported that N and HA did not affect emergence. Similar results are also reported by Leghari et al. (2016). It may be because fertilizer response is not so quick and observed immediately after two weeks. Similarly, Leghari et al. (2016) reported that emergence m^{-2} was not affected by N. The reason may be that seed used its own endosperm food for germination and plants did not use nutrients from outside source (Shah et al., 2012). The results also conform to Shah et al. (2009) who stated that fertilizer fertilization had no influence on the emergence m^{-2}.

N, Zn, HA, control vs. rest, and N × Zn, wheat's days to anthesis and maturity were significantly affected, while the early anthesis was recorded inin control plots. The delayed anthesis is due to the nutrients available in an adequate amount, which enlarged the growing time period of cereal crop (Arif et al., 2006). N fertilization increased vegetation, leaf area and light use efficiency (Zeidan et al., 2010). Similarly, N application delayed days to tasseling, silking and maturity in maize (Amanullah et al., 2008&Arif et al., 2006). However, the application of Zn and HA have no impact on days to anthesis (Nawab et al., 2011). Physiological maturity delayed with increased levels of N, Alike results were stated by Sivasankar et al. (1993) who stated that N is very imperative for crop development and growth. Fertilization of N promotes lived green foliage duration (Frederick &Camberato, 1995). Increase in N levels significantly delayed days to maturity Ayoub et al. (1994). The delayed in days to maturity may be due to enough nutrient accessibility, which finally enhanced the growing time period of cereal crops Ullah et al. (2021). Alike results were reported by Zeidan et al. (2010) who reported that N fertilizer improves vegetative growth, increased light use efficiency and grain filling period. Higher levels of Zn and HA increased the time of maturity of wheat crop. Comparable results were reported by Rajput et al. (2004) who stated that Zn and HA application with higher rates late maturity of the crop which due to easily availability of

Table 3. Grain yield (kg ha^{-1}) of wheat as affected by nitrogen (N), Zinc(Zn) and humic acid(HA).

Zn (kg ha^{-1})	HA (kg ha^{-1})	N (kg ha^{-1})			Mean
		N 1	**N 2**	**N 3**	
		N x Zn x HA			**Zn x HA**
6	5	2933	3060	3143	3045
	10	2886	2930	2970	2929
	15	2792	3153	3233	3059
12	5	3167	3503	3624	3431
	10	3415	3485	3498	3466
	15	3511	3355	3775	3547
18	5	3337	3797	3860	3665
	10	3497	3923	3969	3796
	15	3800	4057	4049	3969
		N x HA			
	5	2710	3340	3510	3187 b
	10	2890	3425	3710	3342 a
	15	2956	3547	3975	3493 a
		N x Zn			
6		2732	3214	3295	3080 b
12		2934	3395	3795	3375 a
18		2919	3632	4080	3544 a
		2862 c	3414 b	3723 a	
Planned Mean Comparison					
	Control	2360			
	Rest	3420			

Means of same category followed by different letters are significantly different at ($P \leq 0.05$) using LSD test.

Table 4. Harvest index (%) of wheat as affected by N, Zn and HA.

Zn ($kg\ ha^{-1}$)	HA ($kg\ ha^{-1}$)	N ($kg\ ha^{-1}$)			Mean
		80	**120**	**160**	
		N × Zn × HA			**Zn x HA**
6	5	38	37	39	38
	10	38	38	39	38
	15	37	39	39	38
12	5	38	38	38	38
	10	38	38	37	38
	15	39	37	39	38
18	5	37	40	41	39
	10	38	40	42	40
	15	40	41	42	41
		N × HA			
	5	38	38	39	38 b
	10	38	38	40	39 a
	15	38	38	41	39 a
		N × Zn			
6		38	38	38	38 b
12		39	38	40	39 a
18		38	38	42	39 a
		38 c	38 b	40 a	
Planned Mean Comparison					
	Control	37			
	Rest	39			

Means of same category followed by different letters are significantly different at ($P \leq 0.05$) using LSD test.

essential nutrients thus enhanced vegetative growth of crop which delayed maturity. Leaf area tiller^{-1} and plant height had significantly affected by N, Zn, HA, control vs. rest, N× Zn and N× Zn × HA interactions. Whereas, all further interaction were non-significant. Leaf area tiller^{-1} enhanced with each accumulation of N and maximum leaf area tiller^{-1} was observed at 160 kg N ha^{-1}. While minimum leaf area tiller^{-1} was noted in control plots. Our results conform with Vogeler et al. (2020) who stated that N fertilizer increased leaf area of wheat. This may be because Zn and HA fertilization increased leaf area due to increased vegetative growth. Our results are in contract with Arif et al. (2006) and Iqbal et al. (2020) who stated that significant increase was found in the height of crop with fertilization of N. Increased plant height due to enough amount of N may be credited to additional vegetative growth and improvement as a result in intermodal extension. The soil application of Zn increased plant height linearly. Plant height increased 18.7 % over control by fertilization of Zn (Ali et al., 2013).

Additionally, spikes m^{-2}, tillers m^{-2}, spike length, grains spike^{-1} and 1000-grains weight revealed that N, Zn, HA, control vs. rest and Zn × HA interaction had significantly affected. Whereas all other interactions were non-significant. The nutrients treated plots manifested more spikes m^{-2} as compared to control. Spikes m^{-2} increased with each increment of N and maximum spikes m^{-2} was noted at 160 kg N ha^{-1}. The reason may be that the availability of nitrogen in enough amounts facilitates the plant's tillering ability, which is directly related to spikes m^{-2}. Our results are in line with Jan et al. (2000) who find that spikes population and number of grains spike^{-1} had a significantly increased with increasing levels of N fertilizer. Alike results were published by Shahab et al. (2016). Spikes m^{-2} increased with each addition of Zn and maximum spike m^{-2} was observed at 18 kg Zn ha^{-1}. Our results are in conformity with Keram et al. (2014) who postulated that Zn at the rate of 20 kg ha^{-1} along with a recommended dose of NPK improved yield and yield-related components of wheat. Spikes m^{-2} increased with each incensement of HA and maximum spikes m^{-2} was noted at 15 kg HA ha^{-1}. The reason might be that HA stimulates microbial movement in soil to improve the physical structure and biological environment of soil, which enhances plant growth and development (Zancani et al., 2009). The possible reason increase in spike length might be due to that N fertilization increased the vegetative and reproductive growth of plant (Shahab et al., 2016). Our results are in agreement with Leghari et al. (2016). Zn fertilization also increased spike length linearly with each increment of Zn and maximum spike length was noted at 18 kg ha^{-1} Zn. Alloway et al. (2004) stated that the combine resulting from the effects of N application helps enhance plant growth, change the pH of the root environment, and found significant interactions increasing dose of Zn and N. Zn plays a vital role in protein degradation and protein-protein interactions. This way, it takes part in plant metabolism, growth, and development (Marschner et al., 1995). Spike length increased with each increment of HA and maximum spike length was noted at 15 kg ha^{-1} HA. Grains spike^{-1} might be improved because Zn's application makes readily available nutrients uptake from the soil to plant and enhances their effectiveness greatly in the grains creation time and resulted maximum grains spike^{-1} (Zeidan et al., 2010). HA application promotes plant growth by providing unavailable nutrients and buffering pH of soil (Julie and Bugbee, 2006). Improvement in 1000-grains weight may be due to that plant protein synthesis, production of plant hormones, pollination and fruit setting may be subjected to changes due to Zn (Alloway et al., 2004). Our results conform with Khan et al. (2008) and Alam et al. (2000) who stated that the application of Zn enhances the 1000-grain weight of wheat significantly. The application of HA also increased 1000-grains weight and maximum 1000-grains weight was observed at 15 Kg HA ha^{-1}. The probable reason may be that HA increased the fertility of the soil which contain some elements which have a pivotal role in enhancing the fertility of the soil to a greater extent, thus enhancing the growth of plant and yield components of the crop (Khan et al., 2006). The increase in yield and yield components of wheat due to Zn application might be the fact that Zn played a vital role in the biosynthesis of the IAA and initiation of primodia for reproductive parts and a result of the favorable effect of Zn on the metabolic reactions within the plants Singh et al. (2005).

Biological yield grain yield and harvest index were significantly affected by N, Zn, HA control vs. rest, N × Zn and N × Zn × HA. The treated plots showed maximum biological yield as compared to control. Biological yield, grain yield and harvest index were enhanced with each augmentation of N and maximum biological yield was noted at 160 kg N ha^{-1}. These results are in contract with Khan et al. (2008) who stated that N fertilization improved biomass and yield of the wheat. Zeidan and Amany (2006) gave the same results, who stated that N application enhances vegetative, reproductive growth and grain yield. Similar results are stated by Jan et al. (2000). Zn fertilization improved biological yield linearly with each increment of N and maximum biological yield was noted at 12 kg Zn ha^{-1}. The possible reason may be that Zn plays a vital part in plant growth and metabolism processes and is needed for enzyme activation in plants (Alloway et al., 2004). Our results are in line with Keram et al. (2014) who stated that Zn at the rate of 20 kg ha^{-1} combination with N improved equally grain and biological yield of wheat crop. The combined fertilization of N and Zn increased biological yield significantly. Similar results are reported by Asif et al. (2011) and Amanullah et al. (2009). Biological yield increased with HA increment and maximum biological yield was recorded at10 kg HA ha^{-1}. The possible reason may be that HA provides good soil form and enhances the accessibility of immobile nutrient uptake. These results agree with Ali et al. (2019) who reported that application of HA material has significantly influenced crop production, enhanced the fertility of soil, and minimized the requirement of NPK fertilizer application.

5. CONCLUSION

Based on the results, it is concluded that N fertilization at the rate of 160 kg ha^{-1} produced higher grain yield and yield components of wheat as compared to other levels. Zn fertilization significantly improved yield and yield contributing components. However, application of Zn above 12 kg ha^{-1} up to 18 kg ha^{-1} was found statistically the same. HA significantly increased yield and yield components at 10 kg HA ha^{-1}. Application of N at 160 kg ha^{-1}, Zn at 12 kg ha^{-1} and HA at 10 kg ha^{-1} is recommended for obtaining higher grain yield and yield components of wheat.

Authors Contributions:

A.I and S.K.K conceived the main idea of research, A.I wrote the manuscript. H.R, M.Z and R.K revised the manuscript and provided suggestions. In addition M.A, S.W.K and AK assessed and analyzed the data, and performed data collection. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability statements: The data presented in this study are available on request from the corresponding author.

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