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Effect of Soil Applied Humic Acid and Foliar Applied Zinc on the Growth and Yield of Wheat

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Abstract: *A field study was carried out on the effect of soil-applied Humic acid and Foliar applied zinc on the growth and yield of wheat (variety SKD^{-1}) at the experimental fields of Agriculture Chemistry (Soils) Section, Agriculture Research Institute, Tando Jam during 2013-2014. Observations on Plant height (cm), Tillers plant^{-1}, Spike length (cm), Grains spike^{-1}, Grain weight plant^{-1} (g), Seed index (1000 grains weight, g), Biological yield (kg ha^{-1}) and Grain yield (kg^{-1}) were recorded. The results revealed significant ($P<0.05$) effect of various levels of soil applied humic acid and foliar application of zinc on all the growth and grain yield traits of wheat. The crop supplied with a higher humic acid level of 8.00 kg^{-1} resulted in 97.69 cm plant height, 5.82 tillers plant^{-1}, 11.11 cm spike length, 40.00 grains spike^{-1}, 24.81 g grain weight plant^{-1}, 38.40 g seed index, 9860.30 kg biological yield ha^{-1} and 4838.80 kg grain yield ha^{-1}. The decrease in humic acid upto 6.00 kg ha^{-1}resulted in 95.57 cm plant height, 5.69 tillers plant^{-1}, 10.87 cm spike length, 39.25 grains spike^{-1}, 24.34 g grain weight plant^{-1}, 37.68 g seed index, 9652.70 kg biological yield ha^{-1} and 4747.80 kg grain yield ha^{-1}. The crop under control (no humic acid application) resulted in the lowest values for all the traits studied. The effect of foliar applied zinc indicated that the crop sprayed with Zn at higher concentration of 0.4% resulted in 97.29 cm plant height, 5.79 tillers plant^{-1}, 11.06 cm spike length, 39.81 grains spike^{-1}, 24.69 g grain weight plant^{-1}, 38.22 g seed index, 9820.00 kg biological yield ha^{-1} and 4815.70 kg grain yield ha^{-1}. The crop sprayed with Zn at a lower concentration of 0.2% and control Zn, resulted in lower values for all the growth and yield traits. It was concluded that the differences in the grain weight plant^{-1} and grain yield ha^{-1} between the soil applied humic acid level of 6.00 kg and 8.00 kg ha^{-1} were non-significant, suggesting that 6.00 kg ha^{-1} humic acid would be optimum for wheat variety SKD^{-1}. On the other hand, the values for grain yield and its contributing traits under higher foliar applied Zn concentration (0.3%) were markedly higher than the crop performance under lower Zn concentration and control. Hence, it is suggestible that for achieving economically higher grain yield in wheat variety SKD^{-1}, the crop may be supplied with 6.00 kg ha^{-1} humic acid through the soil, and foliar application of Zn at 0.3% concentration may be ensured in addition to the recommended dose of NPK fertilizers.*

Keywords: Soil; humic acid; foliar applied; zinc, growth, yield, wheat.

1. Introduction

Wheat, *Triticum aestivum* L. is a staple food of billions of people in the world, belongs to the family Gramineae; and other cultivated species of this family are; *Triticum durum*, *Triticum monococcum*, *Triticum dicoccum*, and *Triticum spelta*. *Triticum aestivum* is a hexaploid species that is the most widely cultivated in the world ([21] and [8]. Wheat is used to making flour for leavened, flat, and steamed breads, and most of the baked foods; for fermentation to make beer and alcohol [29]. High adaptation of this plant, as well as its diverse consumption in human nutrition, leads to the present as the most important cereal in the world [8]. In Pakistan, wheat is averagely used for about 60 percent of the daily diet of a common man with average per capita consumption of 125 kg [14]. Pakistan is among top ten wheat producing countries of the world, but the average yield of the wheat is much lower than their potential yield. On the other hand, wheat requirements of the country are increasing due to the rapid increase in population. Wheat yields in the country are 2787 kg ha^{-1} (2012-2013) as against 4762 kg ha^{-1} in China, the world average is 3086 kg ha^{-1}, 3018 kg ha^{-1} in the USA and 2801 kg ha^{-1} in India. The area under wheat cultivation in Pakistan, during 2012-13 was 8693 thousand hectares, showing an increase of 0.5 percent over last year's area of 8650 thousand hectares. The production of 24.231 million tons was achieved during 2012-13 showing 3.20 percent increase over the preceding year; while the yield was 2787 kg ha^{-1} showing 2.7 percent increase over the last years yield ha^{-1}. This positive trend in the area, grain production and yield per hectare was mainly associated with the timely sowing of wheat and favourable climatic factors [10]. Among the various factors responsible for the low yield of the wheat crop in the country, poor fertility status of the soils and improper crop management practices are of primary importance. Production of wheat can be increased either by bringing more area under cultivation or by increasing its yield per unit area. Under the present situation, it is not possible to increase its area under cultivation due to other competing crops and restricted supply of irrigation water. Therefore, the only alternative left for increasing wheat production in the country is to obtain higher yields per unit area [9]. Humic substances are component of humus and widely distributed over earth surface [32]. Humic substances are major components of organic matter, often constituting 60 to 70% of the total organic matter. Humic substances are classified into three categories like humic acid, fulvic acid and humic [27]. The manifold effect of humic substances on the plant, shown both in the external medium, and in the biochemical processes occurring in the plant, has been well demonstrated [11]. There is a growing interest in the use of organic materials as fertilizers or soil amendments [12]. Its direct effect on plant growth has been attributed to the increase in chlorophyll content, the acceleration of the respiration process, hormonal growth responses, increasing penetration in plant membranes or a combination of these processes [11], [6], while [16] reported that humates enhanced nutrient uptake, improve soil structure, and increase crop yields. Humic acid increases the soil ability to hold more nutrients and moisture for the plant to utilize which improves the efficiency of fertilizers. The stimulatory effects of humic substances have been directly correlated with enhanced uptake of macronutrients, such as nitrogen, phosphorus, sulfur and micronutrients, that is, Fe, Zn, Cu and Mn [30]. Seed germination and seedling growth is stimulated by humic substances [2]. [24] revealed that addition of 0.5 kg ha^{-1} humic acid with 60-45-30 kg ha^{-1} NPK produced 26 % significantly ($P < 0.05$) higher yield of 6.0 Mg ha^{-1} than the 0.5 kg ha^{-1} humic acid + 0.0 kg ha^{-1} NPK. Soil N and P concentrations increased significantly ($P < 0.05$) with NPK but non-significantly with humic acid treatments over control. The addition of 0.5 and 1.0 kg ha^{-1} humic acid at 0.0 kg ha^{-1} NPK and 60-45-30 kg ha^{-1} NPK levels of NPK improved N and P accumulations by wheat plants significantly ($P < 0.05$). Zn is classified as a micronutrient and if the deficiency of Zn is severe, the symptoms may last throughout the entire season. The deficiency of Zn is characterized by the development of broad bands of striped tissue on each side of the midrib of the leaf. These stripes begin on the part of the leaf closest to the stalk and appear first on the upper part of the plant [3]. Zn deficient plant also appears to be stunted. Almost 50 percent of the world soils used for cereal production is Zn deficient [29]; as a result, approximately two billion people suffer from Zn deficiency all over the world [4]. Foliar application of zinc, copper, and boron along with straight soil applied NPK maximizes net return to the growers [22]; while[25] applied various concentrations of different organic, inorganic and biofertilizer solutions in foliar method and reported enhanced crop growth and yield. A significant increase was recorded in the number of spikes m^{-2}, grains $spike^{-1}$, a thousand grains weight, biological yield and grain yield of wheat for foliar application of zinc and boron as compared to control treatments[1]. Keeping in view the facts stated above the study was carried out to investigate the effect of soil applied humic acid and foliar applied zinc on the growth and yield of wheat under agro-ecological conditions of Tandojam with the these objectives: To evaluate the effect of soil applied humic acid and foliar applied zinc on the growth and yield of wheat and To identify optimum level of soil applied humic acid and foliar applied zinc for maximum growth and yield of wheat.

2. MATERIALS AND METHODS

The present study was carried out at the Soil Chemistry Section, Agriculture Research Institute, Tandojam during Rabi 2011-12. The experiment was laid out in a three replicated randomized complete block design (Factorial), having net plot size 5.7 x 5.0m (28.5m^2). Humic acid and Zn was applied as per treatments whereas all other agronomic practices were adopted as per recommendation of Agronomy section, Agriculture Research Institute, Tandojam. The treatment details are as follows:

2.1 Treatments = Two factors (A and B)

Factor-A = (Soil applied Humic acid levels) = 03

HA_1 = HA @ 0.0 kg ha^{-1}
HA_2 = HA @ 6.0 kg ha^{-1}
HA_3 = HA @ 8.0 kg ha^{-1}

Factor-B = (Foliar applied Zn levels) = 03

Zn_1 = Zn @ 0.0%
Zn_2 = Zn @ 0.2%
Zn_3 = Zn @ 0.4%

2.2 Land preparation

The land was prepared by two dry plowings followed by precision land leveling. After soaking doze, when soil reaches proper moisture level, two plowings with cultivator plow was done to achieve the fine seedbed.

2.3 Sowing time and method

The seed of wheat variety SKD-I at recommended rate of 125 kg ha^{-1} was sown throughout the experiment using single row hand drill on 30th Nov., 2011, maintaining distance of 22.5cm between rows.

2.4 Fertilizer application

Nitrogen, Phosphorus and Potassium at recommended rate of 168-84-60 Kg ha^{-1} was applied in the form of Urea, DAP and SOP, respectively. All P and K, and 1/3rd of N were applied at sowing time and remaining N in two equal splits at 1st irrigation and 2nd irrigation, respectively.

2.5 Irrigation application

The first irrigation was applied at the crown root initiation stage. The subsequently irrigations were applied as and when needed until the crop reaches physiological maturity. In all 4-5 irrigations were applied.

2.6 Weeding

The weeds was controlled by applying combined mixture of narrow leaf and broad leaf post-emergence herbicides (Puma Super 75 EW @ 0.625 L ha^{-1} + Logran Extra 64 WDG @ 125 g ha^{-1}; one spray at 25 DAS)

2.7 Crop harvesting and threshing

At maturity five plants from each treatment of all replications was selected at random for harvest. These plants were harvested by cutting at soil level with sharp sickle. The ear heads was separated from straw, placed in separate paper bags and oven-dried for 24 hrs at 78°C. Threshing was done by hands.

2.8 Observations recorded

1. Plant height (cm)
2. Tillers plant^{-1}
3. Spike length (cm)
4. Grains spike^{-1}
5. Grain weight plant^{-1} (g)
6. Seed index (1000 grain weight, g)
7. Biological yield (kg ha^{-1})
8. Grain yield (kg ha^{-1})

2. 9 Methodology for recording observations

2.9. 1 *Plant height (cm)*: The plant height (cm) was recorded from five selected plants, taken randomly from each treatment at the time of harvest.

2.9. 2 *Tillers plant^{-1}*: The tillers plant^{-1} was recorded from each treatment from the labeled plants at random in all the replications and average was worked out.

2.9. 3 *Grains spike^{-1}*: The grains spike^{-1} was recorded from five selected plants, taken randomly from each treatment.

2.9. 4 *Grain weight plant^{-1}* (g): The grain weight plant^{-1} (g) was noted from five selected plants, taken randomly from each treatment.

2.9. 5 *Seed index (1000 grains weight, g)*: The seed index (1000 grain weight, g) was recorded by counting and weighing 1000 seeds from each treatment after threshing.

2.9. 6 *Biological yield (kg ha^{-1})*: The biological yield obtained from each treatment was calculated as yield kg ha^{-1} using the following formula:

$$\text{Biological yield (kg ha}^{-1}\text{)} = \frac{\text{Biological yield plot}^{-1}\text{ (kg) x area ha}^{-1}\text{ (m}^2\text{)}}{\text{Area of plot (m}^2\text{)}}$$

2.9. 7 *Grain yield (kg ha^{-1})*: The grain yield obtained from each treatment was calculated as yield kg ha^{-1} using the following formula:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield plot}^{-1}\text{ (kg) x area ha}^{-1}\text{ (m}^2\text{)}}{\text{Area of plot (m}^2\text{)}}$$

2. 10 Statistical analysis

The data on the above characters was collected and subjected to ANOVA technique using MSTAT-C statistical package. The LSD test was applied to determine means superiority, where necessary (Russel and Eisensmith, 1983).

2.11 Layout plan of the experiment

Experimental Design = Randomized Complete Block Design (Factorial)
Replication = 4
Net Plot size= 5.7 × 5m (28.5 m^2)
Treatments= Two factor (A and B)
Factor-A = (Soil applied Humic acid levels) = 03
HA_1 = HA @ 0.0 kg ha^{-1}
HA_2 = HA @ 6.0 kg ha^{-1}
HA_3 = HA @ 8.0 kg ha^{-1}
Factor-B = (Foliar applied Zn levels) = 03
Zn_1 = Zn @ 0.0%
Zn_2 = Zn @ 0.2%
Zn_3 = Zn @ 0.4%
Treatments Combination

$T_1= HA_1 + Zn_1$	$T_1= HA_1 + Zn_2$	$T_1= HA_1 + Zn_3$
$T_1= HA_2 + Zn_1$	$T_1= HA_2 + Zn_2$	$T_1= HA_2 + Zn_3$
$T_1= HA_3 + ZN_1$	$T_1= HA_3 + ZN_2$	$T_1= HA_3 + ZN_3$

3. RESULTS

Generally it is thought that our soils are deficient of major macronutrients, but recent studies have showed that these soils are also inadequate in essentially needed micronutrients. Hence, the present study aimed at examining the effect of soil applied humic acid and foliar applied zinc on the growth and yield of wheat. The wheat variety SKD-1 was supplied with different levels of soil applied humic acid (HA_1=HA @ 0.0 kg ha^{-1}, HA_2=HA @ 6.0 kg ha^{-1} and HA_3=HA @ 8.0 kg ha^{-1}) and Foliar applied Zn (Zn_1=Zn @ 0.0%, Zn_2=Zn @ 0.2% and Zn_3=Zn @ 0.4%). The data were collected on plant height, tillers plant^{-1}, spike length, grains spike^{-1}, grain weight plant^{-1}, seed index, biological yield ha^{-1} and grain yield ha^{-1} (Tables 1-8) and the data were analysed (Appendix I-VIII) to assess the treatment significance, and accordingly the results are described in the following paragraphs:

3.1 Plant height (cm)

The effect of various levels of soil applied humic acid and foliar applied Zn on plant height of wheat was investigated (Table-1) and according to the statistical analysis (Appendix-I), there was significant ($P<0.05$) impact of soil applied humic acid and foliar applied zinc levels as well as their interaction on plant height of wheat. The crop supplied with humic acid through soil @ 8 kg ha^{-1} resulted in maximum plant height of 97.69 cm) and height of the plants reduced to 95.57 cm with decreasing humic acid to 6 kg ha^{-1}, while the minimum plant height of 85.68 cm was observed in wheat crop left untreated of humic acid (control). The effect of foliar applied zinc indicated that the maximum plant height of 97.29 cm was witnessed when wheat crop was sprayed with zn 0.4% Zn; and with reduced Zn level (0.2%), the plant height markedly decreased (92.39 cm); while the minimum plant height of 89.26 cm was witnessed in crop left untreated of foliar zinc. Apparently it looks that with soil applied humic acid, the soil organic matter is improved; while with foliar appleid Zn, the plants receovered from soil zinc deficiency and grew taller than control. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) resulted in maximum plant height of 104.68 cm, and the interaction (no humic acid × no zinc) minimized the plant height (82.81 cm). There was a linear significant ($P<0.05$) effect both of soil applied humic acid and foliar applied zinc levels on plant height, which proved the necessity of improving soil organic matter through different soil amendments such as humic acid application and foliar application of Zn not only ensures the prompt supply of zinc to leaves, but also helps plant to fight water stress.

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Table- 1. Plant height (cm) of wheat variety SKD-1 as affected by different levels of soil applied humic acid & foliar application of zinc

Treatments	Foliar Zn levels			Mean
	0%(Control)	0.2%	0.4%	
Humic Acid 0 kg ha^{-1} (Control)	82.81	85.71	88.52	**85.68 c**
Humic Acid @ 6.0 kg ha^{-1}	92.40	95.63	98.68	**95.57 b**
Humic Acid @ 8.0 kg ha^{-1}	92.58	95.82	104.68	**97.69 a**
Mean	**89.26 c**	**92.39 b**	**97.29 a**	-

Means followed by common letter are significantly different at 5% probability level

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.6444	0.6444	1.1161
LSD 0.05	1.3660	1.3660	2.3660
LSD 0.01	1.8821	1.8821	3.2598

3.2 Tillers $plant^{-1}$

The results in relation to number of tillers $plant^{-1}$ of wheat variety SKD-1 as influenced by soil application of humic acid and foliar application of Zn are presented in Table-2. The analysis of variance (Appendix-II) suggested that there was significant (P<0.05) effect of soil applied humic acid and foliar applied zinc levels as well as their interaction on tillers $plant^{-1}$ of wheat. The application of humic acid through soil @ 8 kg ha^{-1} produced maximum number of tillers $plant^{-1}$ (5.82), and tillering was adversely affected (5.69) with decreasing humic acid (6 kg ha^{-1}); while the lowest tillers $plant^{-1}$ (5.10) was found in control plots. Foliar application of zinc showed that the maximum tillers $plant^{-1}$ (5.79) were noted in crop sprayed with zn 0.4% Zn; and at reduced Zn level (0.2%), the tillers $plant^{-1}$ decreased considerably (5.50); while the lowest tillers $plant^{-1}$ (5.32) were witnessed in control crop. The results lead to assume that the experimental soil was low in organic matter and with application of humic acid, the soil organic matter and other soil properties were improved and hence positive impactonthe tillering capacity. Similarly, foliar application of zinc simply fulfilled the plant zinc needs readily and protected the plants from water stress happend time to time; and hence positive effects on the tillering capacity resulted. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) resulted in maximum tillers $plant^{-1}$ (6.23), and the interaction (no humic acid × no zinc) resulted in lowest tillers $plant^{-1}$ (4.94). The statistical analysis suggested a linear positive effect of each increased level of humic acid and zinc applications, that reflects the need of a regular application of humic acid through soil and foliar application of zinc to ensure the success in achieving the desired tillering capacity in wheat variety SKD-1.

Table -2. Tillers $plant^{-1}$ of wheat variety SKD-1 as affected by different levels of soil applied humic acid & foliar application of zinc

Treatments	Foliar Zn levels			Mean
	%(Control)	0.2%	0.4%	
Humic Acid 0 kg ha^{-1} (Control)	4.94	5.10	5.27	**5.10 c**
Humic Acid @ 6.0 kg ha^{-1}	5.51	5.69	5.87	**5.69 b**
Humic Acid @ 8.0 kg ha^{-1}	5.52	5.71	6.23	**5.82 a**
Mean	**5.32 c**	**5.50 b**	**5.79 a**	-

Means followed by common letter are significantly different at 5% probability lavel

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.0373	0.0373	0.0645
LSD 0.05	0.0790	0.0790	0.1368
LSD 0.01	0.1088	0.1088	0.1885

3.3 Spike length (cm)

The data in regards to spike length of wheat variety SKD-1 as affected by different levels of soil applied humic acid and foliar applied Zn are shown in Table-3. The analysis of variance (Appendix-III) demonstrated significant (P<0.05) impact of humic acid application through soil, foliar zinc application and their interaction on spike length. It is evident from the results that highest level of soil applied humic acid @ 8 kg ha^{-1} produced maximum spike length (11.11 cm), and with reducing the humic acid level upto 6 kg ha^{-1}, the spike length was decreased to 10.87 cm; while the control plots where humic acid was not applied produced the crop with lowest spike length (9.75 cm). The effect of zinc application indicated that foliar applied zinc at higher level (zn 0.4%) produced spikes of maximum mean length (11.06 cm); and at reduced Zn level (0.2%) resulted in a decreased spike length (10.51 cm); while the minimum spike length (10.17 cm) was noted in plots where no zinc was applied (control). The results further indicated with application of humic acid through soil, the spike length was improved makredly; while foliar applicationof zinc also resulted in a positive impact on this plant character. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) produced maximum spike length (11.90 cm), and the interaction (no humic acid × no zinc) resulted in lowest spike length (9.44). This indicates that soil applied humic acid improved the organic matter in the soil and activated the soil organisms to utilize the available nutrients more efficiently. On the other hand, foliar applied zinc secure the plants from drought and other stresses related to water as well as provided the required zinc which may be deficient in the experimental soil.

Table- 3. Spike length (cm) of wheat variety SKD-1 as affected by different levels of soil applied humic acid & foliar application of zinc

Treatments	Foliar Zn levels			Mean
	0% (Control)	0.2%	0.4%	
Humic Acid 0kg ha^{-1} (Control	9.44	9.75	10.06	**9.75 c**
Humic Acid@6.0kg ha^{-1}	10.52	10.87	11.22	**10.87 b**
Humic Acid@8.0kg ha^{-1}	10.54	10.90	11.90	**11.11 a**
Mean	**10.17 c**	**10.51 b**	**11.06 a**	-

Means followed by common letter are significantly different at 5% probability level

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.0872	0.0872	0.1510
LSD 0.05	0.1848	0.1848	0.3201
LSD 0.01	0.4546	0.4546	0.4410

3.4 Grains $spike^{-1}$

The results in relation to number of grains $spike^{-1}$ of wheat as influenced by soil application of humic acid and foliar application of Zn are given in Table-4. The analysis of variance (Appendix-IV) indicated that the number of grains

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spike^{-1} was significantly (P<0.05) affected by various levels of soil applied humic acid, foliar applied zinc as well as by interaction between humic acid and zinc application. The soil applied humic acid at highest level of 8 kg ha^{-1} produced highest number of grains spike^{-1} (40.00), and grains spike^{-1} reduced to 39.25 with decreasing humic acid upto 6 kg ha^{-1}; while the minimum grains spike^{-1} (35.57) were found in control plots. In case of zinc effects on this trait, foliar applied zinc at higher concentration (zn 0.4%) resulted in maximum grains spike^{-1} (39.81); and grains spike^{-1} reduced considerably to 37.94 when Zn was applied at 0.2% concentration; while the minimum grains spike^{-1} (37.07) were noted in control where zinc was not applied. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) produced maximum grains spike^{-1} (42.24), and the interaction (no humic acid × no zinc) resulted in lowest grains spike^{-1} (35.40). The results clearly indicates that there was a linear improvement in grains spike^{-1} with each increase in the humic acid and zinc levels, which suggests that experimental soil needed such amendments to optimize fertility. However, foliar application of zinc impacted the crop in positive direction and hence improved grains spike^{-1}. The results further inidcated that interactive effect of soil applied humic acid and foliar application of zinc was significant (P<0.05) and it is assumed that with humic acid application, the efficiency of foliar zinc application was markedly increased.

Table -4. Grain spike^{-1} of wheat variety SKD^{-1} as affected by different levels of soil applied humic acid and foliar application of zinc Means followed by common letter are significantly different at 5% probability level

Treatments	Foliar Zn levels			Mean
	0% (Control)	0.2%	0.4%	
Humic Acid 0kg ha^{-1}(Control)	35.40	35.09	36.21	**35.57 c**
Humic Acid @ 6.0 kg ha^{-1}	37.88	39.48	40.38	**39.25 b**
Humic Acid @ 8.0 kg ha^{-1}	37.93	39.24	42.24	**40.00 a**
Mean	**37.07 c**	**37.94 b**	**39.81 a**	-

Means followed by common letter are significantly different at 5% probability level

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.3577	0.3577	0.6195
LSD 0.05	0.7582	0.7582	1.3133
LSD 0.01	1.0447	1.0447	1.8094

3.5 Grain weight plant^{-1} (g)

The data in regards to grain weight plant^{-1} of wheat as affected by soil applied humic acid and foliar applied Zn are presented in Table-5. The analysis of variance (Appendix-V) indicated that the grain weight plant^{-1} was significantly (P<0.05) influenced by various levels of soil applied humic acid, foliar applied zinc and by their interaction. The grain weight plant^{-1} was highest (24.81 g) when the wheat crop was given 8 kg ha^{-1} humic acid through soil, and with decrease in humic acid upto 6 kg ha^{-1}, there was a slight (P>0.05) reduction in the grain weight plant^{-1} (24.34 g); while the minimum grain weight plant^{-1} (22.05 g) was recorded in control. In case of foliar zinc application, higher concentration (Zn 0.4%) produced maximum grain weight plant^{-1} (24.69 g); and grain weight plant^{-1} decreased to 23.59 g when Zn was applied at 0.2% concentration; while the lowest grain weight plant^{-1} (22.92 g) was noted in control where zinc was not applied. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) resulted in maximum grain weight plant^{-1} (26.57 g), and the interaction (no humic acid × no zinc) resulted in lowest grain weight plant^{-1} (21.76). It was obsrved that that there was consecutive increase in grain weight plant^{-1} with increase in the humic acid and zinc levels. This guides that soil used in the experiments was not adequate in zinc, low in organic matter; and with soil applied humic acid, the organic matter was improved; while application of foliar Zn resulted in prompt fulfilment of the Zn requirement of the plant. Statistically, the differences in grain weight plant^{-1} was non-significant between humic acid levels of 6.00 kg and 8.00 kg ha^{-1}, which indicates that 6.00 kg ha^{-1} humic acid would be enough to improve the soil fertility.

Table -5. Grain weight plant^{-1} (g) of wheat variety SKD^{-1}as affected by different levels of soil applied humic acid & foliar application of zinc

Treatments	Foliar Zn levels			Mean
	% (Control	0.2%	0.4%	
Humic Acid 0kg ha^{-1} (Control)	21.76	21.95	22.45	**22.05 b**
Humic Acid @ 6.0 kg ha^{-1}	23.49	24.48	25.04	**24.34 a**
Humic Acid @ 8.0 kg ha^{-1}	23.52	24.33	26.57	**24.81 a**
Mean	**22.92 c**	**23.59 b**	**24.69 a**	-

Values followed by same letters do not differ significantly at 0.05 probability level.

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.2596	0.2596	0.4496
LSD 0.05	0.5503	0.5503	0.9531
LSD 0.01	0.7581	0.7581	1.3131

3.6 Seed index (1000, seed weight, g)

The results pertaining to seed index of wheat as affected by different levels of soil applied humic acid and foliar applied Zn are given in Table-6. The analysis of variance (Appendix-VI) indicated that seed index value was significantly (P<0.05) affected by different levels of soil applied humic acid, foliar applied zinc as well as by their interaction. The results (Table-6) showed that maximum seed index (38.40 g) was recorded in plots given soil applied humic acid @ 8 kg ha^{-1}, while decreasing humic acid level upto 6 kg ha^{-1}, resulted in a decreased seed index of 37.68 g. However, the control plots where humic acid was not applied resulted in lowest seed index (34.14 g). The effect of zinc application indicated that foliar applied zinc at higher level (zn 0.4%) resulted highest seed index (38.22 g); and at reduced Zn level (0.2%) the seed index decreased to 36.52 g; while the lowest seed index (35.59 g) was observed in control (no foliar Zn). The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) produced maximum seed index (41.12 g), and the interaction (no humic acid × no zinc) resulted in lowest seed index (33.69 g). The application of soil applied humic acid

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and foliar Zn showed a remarkable interactive effect on seed index, which guided that these elements remained effective to improve the soil fertility and foliar Zn provided external ; while foliar applicationof zinc also resulted in a positive impact on this plant character. This indicates that soil applied humic acid improved the organic matter in the soil and activated the soil organisms to utilize the available nutrients more efficiently. On the other hand, foliar applied zinc secured the plants from drought and other stresses related to water as well as provided the required zinc which was probably inadequate in the experimental soil.

Table -6. Seed index (1000 seed weight, g) of wheat variety SKD-1 as affected by different levels of soil applied humic acid and foliar application of zinc

Treatments	Foliar Zn levels			Mean
	0% (Control)	0.2%	0.4%	
Humic Acid 0kg ha^{-1} (Control)	33.99	33.69	34.76	**34.14 c**
Humic Acid @ 6.0 kg ha^{-1}	36.37	37.90	38.77	**37.68 b**
Humic Acid @ 8.0 kg ha^{-1}	36.42	37.67	41.12	**38.40 a**
Mean	**35.69 c**	**36.42 b**	**38.22 a**	-

Values followed by same letters do not differ significantly at 0.05 probability level.

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	0.2953	0.2953	0.5115
LSD 0.05	0.6261	0.6261	1.0844
LSD 0.01	0.8626	0.8626	1.4941

3.7 Biological yield (kg ha^{-1})

The results pertaining to biological yield ha^{-1} of wheat as influenced by soil applied humic acid and foliar applied Zn are presented in Table-7. The analysis of variance (Appendix-VII) indicated that the biological yield ha^{-1} was significantly (P<0.05) influenced by various levels of soil applied humic acid, foliar applied zinc and their interactive effect was also significant. The biological yield ha^{-1} was highest (9860.30 kg) when the wheat crop was supplied with 8 kg ha^{-1} humic acid through soil, and with decrease in humic acid (6 kg ha^{-1}), the biological yield reduced to 9652.70 kg ha^{-1}; while the lowest biological yield ha^{-1} (8653.80 kg) was observed in control. In case of foliar zinc application, higher concentration (Zn 0.4%) resulted in highest biological yield ha^{-1} (9820 kg); and biological yield ha^{-1} decreased to 9331.10 kg when Zn was applied at 0.2% concentration; while the lowest biological yield ha^{-1} (9015.60 kg) was noted in control where zinc was not applied. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) produced highest biological yield ha^{-1} (10553kg), and the interaction (no humic acid × no zinc) resulted in minimum biological yield ha^{-1} (8364kg). This higher biological yield under higher humic acid and zinc levels was mainly associated with increase in plant height, tillers plant^{-1}, spike length, number of grains spike^{-1} and weight of grains plant^{-1}. There was successive improvement in biological yield with increasing humic acid and zinc levels. It seems that soil under experimental crop was low in organic and Zn deficient; hence after application of these elements, the soil and crop responded positively with increased biological yield.

Table -7. Biological yield (kg ha^{-1}) of wheat variety SKD^{-1} as affected by different levels of soil applied humic acid and foliar application of zinc

Treatments	Foliar Zn levels			Mean
	0% (Control)	0.2%	0.4%	
Humic Acid 0 kg ha^{-1} (Control)	8364.00	8657.00	8941.00	**8653.80 c**
Humic Acid @ 6.0 kg ha^{-1}	9332.00	9659.00	9967.00	**9652.70 b**
Humic Acid @ 8.0 kg ha^{-1}	9351.00	9678.00	10553.00	**9860.30 a**
Mean	**9015.60 c**	**9331.10 b**	**9820.00 a**	-

Values followed by same letters do not differ significantly at 0.05 probability level.

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	77.010	77.010	133.38
LSD 0.05	163.25	163.25	282.76
LSD 0.01	224.93	224.93	389.59

3.8 Grain yield (kg ha^{-1})

The grain yield ha^{-1} in wheat is dependent on a number of its contributing characters. The data in regards to mean grain yield ha^{-1} of wheat variety SKD-1 as affected by soil applied humic acid and foliar applied Zn are shown in Table-8. The analysis of variance (Appendix-VIII) showed that the effect of different levels of soil applied humic acid, foliar applied zinc and their interaction on grain yield ha^{-1} was statistically significant (P<0.05). The grain yield ha^{-1} was maximum (4838.80 kg) when the crop was supplied with highest humic acid level of 8 kg ha^{-1}, and grain yield decreased to 4747.80 kg ha^{-1} with decreasing humic acid level upto 6 kg ha^{-1}, The lowest grain yield ha^{-1} (4302.40 kg) was noted in control. In case of Zn application, its higher level (Zn 0.4%) produced significantly highest grain yield ha^{-1} (4815.70 kg); and grain yield ha^{-1} decreased to 4601.50 kg when Zn was applied at 0.2% concentration; while the lowest grain yield ha^{-1} (4471.83 kg) was observed in control where zinc was not applied. The interaction (humic acid @ 8 kg ha^{-1} × Zn 0.4%) resulted in highest grain yield ha^{-1} (5181.60 kg), and the interaction (no humic acid × no zinc) resulted in lowest grain yield ha^{-1} (4244.60 kg). This higher grain yield under higher humic acid and zinc levels was mainly associated with increased plant height, tillers plant^{-1}, spike length, grains spike^{-1}, grain weight spike^{-1} and seed index value. However, it was observed that the differences in grain yield ha^{-1} between 6.00 kg and 8.00 kg ha^{-1} humic acid were statistically non-significant, suggesting that 6.00 kg ha^{-1} humic acid will be enough to fulfil the crop needs optimally.

Table -8. Grain yield (kg ha^{-1}) of wheat variety SKD^{-1} as affected by different levels of soil applied humic acid & foliar application of zinc

Treatments	Foliar Zn levels			Mean
	0% (Control)	0.2%	0.4%	
Humic Acid 0 kg ha^{-1} (Control)	4282.30	4244.60	4380.40	**4302.40 b**

Humic Acid @ 6.0 kg ha^{-1}	4582.60	4775.80	4885.00	**4747.80 a**
Humic Acid @ 8.0 kg ha^{-1}	4588.30	4746.40	5181.60	**4838.80 a**
Mean	**4484.40 c**	**4588.90 b**	**4815.70 a**	-

Values followed by same letters do not differ significantly at 0.05 probability level.

	Humic acid levels (A)	Zinc levels (B)	A x B
S.E.±	56.422	56.422	97.726
LSD 0.05	119.61	119.61	207.17
LSD 0.01	164.80	164.80	285.44

4. DISCUSSION

Recent studies conducted in Pakistan and in other parts of the world indicate that the soils have become deficient of various micronutrients including zinc, while these soils were already poor in organic matter. However, benefits of micronutrients application and humic acid need for improving soil organic matter is gaining acceptance among the farming communities. In the present study, the effect of soil applied humic acid (HA_1=HA @ 0.0 kg ha^{-1}, HA_2=HA @ 6.0 kg ha^{-1} and HA_3=HA @ 8.0 kg ha^{-1}) and foliar applied zinc (Zn_1=Zn @ 0.0%, Zn_2=Zn @ 0.2% and Zn_3=Zn @ 0.4%) on the growth and yield of wheat was investigated. The present study showed significant ($P<0.05$) effect of various levels of soil applied humic acid and foliar application of zinc on all the growth and grain yield traits of wheat. The crop supplied with higher humic acid level of 8.00 kg ha^{-1} resulted in 97.69 cm plant height, 5.82 tillers $plant^{-1}$, 11.11 cm spike length, 40.00 grains $spike^{-1}$, 24.81 g grain weight $plant^{-1}$, 38.40 g seed index, 9860.30 kg biological yield ha^{-1} and 4838.80 kg grain yield ha^{-1}. The decrease in humic acid upto 6.00 kg ha^{-1} resulted in 95.57 cm plant height, 5.69 tillers $plant^{-1}$, 10.87 cm spike length, 39.25 grains $spike^{-1}$, 24.34 g grain weight $plant^{-1}$, 37.68 g seed index, 9652.70 kg biological yield ha^{-1} and 4747.80 kg grain yield ha^{-1}. The crop under control (no humic acid application) resulted in lowest values for all the traits studied. These results are in accordance with those of [31] found that humic acid promoted the bioaccumulation of different nutrient concentrations and soil behaviour and responses are mainly dependant on the humic acid availability in the soil. In another investigation, [17] found that N uptake by the wheat a seedling was enhanced by 22% in the presence of humic acid. [7] reported that application of humic acid caused increase in the soil organic matter and hence improved the soil microbial and micorrizal activity, promoted nutrient uptake, accelerated seed germination, increase crop yields, aided in reducing frost damage. [18] suggested the application of humic acid that is an active ingredient of bio fertilizers and effectively works as a soil enhancer. [13] reported that addition of higher rates of humic acid resulted in improved soil nutrient uptake, shoot biomass, or grain yield when compared with control treatments. These greenhouse results suggest that low commercial humic acid rates may be insufficient to enhance spring wheat growth; and hence higher humic acid rates would be more beneficial. [19] concluded that humic fertilizers are the only fertilizers which using of them in organic agriculture is allowed and revealed there was a significant difference between examined conditions on seedling length and weight at the 1 percent level and coleoptiles length and number of leaves at the 5 percent level and suggested that application of humic acid based fertilizers resulted in highest values for all the traits in the study. The present study further showed that crop sprayed with Zn at higher concentration of 0.4% resulted in 97.29 cm plant height, 5.79 tillers $plant^{-1}$, 11.06 cm spike length, 39.81 grains $spike^{-1}$, 24.69 g grain weight $plant^{-1}$, 38.22 g seed index, 9820.00 kg biological yield ha^{-1} and 4815.70 kg grain yield ha^{-1}. The crop sprayed with Zn at lower concentration of 0.2% and control Zn, resulted in lower values for all the growth and yield traits. It was concluded that the differences in grain weight $plant^{-1}$ and grain yield ha^{-1} between soil applied humic acid level of 6.00 kg and 8.00 kg ha^{-1} were non-significant, suggesting that 6.00 kg ha^{-1} humic acid would be optimum for wheat variety SKD-1. On the other hand, the values for grain yield and its contributing traits under higher foliar applied Zn concentration (0.3%) were markedly higher than the crop performance under lower Zn concentration and control. Hence, it is suggestible that for achieving economically higher grain yield in wheat variety SKD-1, the crop may be supplied with 6.00 kg ha^{-1} humic acid through soil, and foliar application of Zn at 0.3% concentration may be ensured in addition to recommended dose of NPK fertilizers. These results are fully supported by [5] who suggested Zn at the rates of 11.2 kg ha^{-1} for wheat, while in the present experiment 0.3% has proved to be an optimum level. This difference in Zn requirement might be associated with the experimental soil, variety they used as well as environmental factors of the particular region of the studies. However, [15] obtained higher wheat yields from 2kg Zn ha^{-1} probably these soils would have minor Zn deficiency. [4] recommended application of Zn upto 5 kg along with recommended dose of NPK fertilizers for achieving higher wheat yields in most of the soils in Pakistan. [23] recommended the use of 80 kg ha^{-1} $ZnSO_4$ in soil for higher grain yield with high quality in saline condition. [26] suggested that the soil under experiment was deficient in Zn and after its soil application seed yield per hectare increased remarkably, this necessitates the Zn application in wheat fields to improve the Zn content in soil to harvest an improved grain yield of wheat. [20] determined four levels of Zn (0, 40, & 80 kg ha^{-1}) and found that the highest number of grains resulted from the application of 80 kg $ZnSO_4$ ha^{-1}.

5. CONCLUSIONS

- It was concluded that the differences in grain weight $plant^{-1}$ and grain yield ha^{-1} between soil applied humic acid level of 6.00 kg and 8.00 kg ha^{-1} were non-significant, suggesting that 6.0 kg ha^{-1} humic acid would be optimum for wheat variety SKD-1.

- Humic acid @ 6.0 kg ha^{-1} would be optimum for wheat variety SKD-1 On the other hand, the values for grain yield and its contributing traits under higher foliar applied Zn concentration (0.3%) were markedly higher than the crop performance under lower Zn concentration and control.
- Hence, it is suggestible that for achieving economically higher grain yield in wheat variety SKD-1, the crop may be supplied with 6.00 kg ha^{-1} humic acid through soil, and foliar application of Zn at 0.3% concentration may be ensured in addition to recommended dose of NPK fertilize.

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