

Comparative Efficiency of Soil and Foliar Applied Zinc in Improving Yield and Yield Components of Wheat (Triticum aestivum L.) Variety Kiran-95

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Abstract
A field study was undertaken to evaluate the comparative efficacy of zinc application through soil and foliar spray on growth and yield of wheat variety Kiran-95 at Soil Chemistry Section, Agriculture Research Institute, Tandojam during Rabi 2013-14. The experiment was laid out in three replicated randomized complete block design. The treatments comprised Control (No Zinc), Soil applied Zinc 5.0 kg ha-1 at tillering stage, Soil applied Zinc 10.0 kg ha-1 at tillering stage, Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage, Foliar applied Zinc 0.2% at tillering stage, Foliar applied Zinc 0.4% at tillering and Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage. The statistical analysis of data suggested that soil and foliar applied zinc affected significantly (P<0.05) growth and yield traits of wheat variety Kiran-95. The results illustrated that Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage produced maximum plant height (99.0 cm), tillers (410.7 m-2), spike length (13.1 cm), spikelets per spike (23.0), grains per spike (45.1), seed index (43.4 g), biological yield (9354.4 kg ha-1) and grain yield (5123.4 kg ha-1), closely followed by Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage with 97.6 cm plant height, 408.8 tillers m-2, 13.0 cm spike length, 22.8 spikelets per spike, 45.0 grains per spike, 43.2 g seed index, 9273.4 kg ha-1 biological yield and 5080.7 kg ha-1 grain yield. The performance of wheat variety Kiran-95 ranked 3rd, 4th, 5th and 6th almost in all the growth and yield parameters particularly grain yield (kg ha-1) when fertilized with Soil applied Zinc 10.0 kg ha-1 at tillering stage, Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha-1 at tillering stage and Foliar applied Zinc 0.2% at tillering stage. However, minimum growth and yield traits were registered in Control (No Zinc). Furthermore, the results concluded that although numerically maximum growth and yield values were recorded in Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage but statistically the differences between Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage and Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage were non-significant. Hence, Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage were found the most economical treatment for obtaining optimum yield of wheat variety Kiran-95.
Keywords: Wheat, Comparative Efficiency, Soil, Foliar, Zinc, Improving Yield and Yield Components

1. Introduction 1

Wheat (Triticum aestivum L.) is one of the most important crops in the world. It is the leading food grain of Pakistan and being staple diet of the people. Wheat occupies a central position in formulation of agricultural policies by contributing 10.1 percent to the value added in agriculture and 2.2 percent to GDP. Wheat was cultivated on an area of 8693 thousand hectares during 2012-13 with production of 24231 thousand tonnes (GOP, 2013). Wheat yield in Pakistan is 2787 kg ha-1 as against 4762 kg ha-1 in China, world average 3086 kg ha-1, 3018 kg ha-1 and in the USA. The average yield per unit area of wheat in Pakistan is still far below the potential yields due to a variety of factors.

Micronutrients play a pivotal role in the yield improvement of cereals (Rehm and Sims, 2006). Zn is classified as a micronutrient. Almost 50 percent of the world soils used for cereal production is Zn deficient (Torun et al., 2001); as a result, approximately 2 billion people suffer from Zn deficiency all over the world (Asad and Rafique, 2002). A deficiency of Zn is characterized by the development of broad bands of striped tissue on each side of the midrib of the leaf. A Zn deficient plant also appears to be stunted, commonly known as "little leaf" (Thalooth et al., 2006). Almost 50 percent of the world soils used for cereal production is Zn deficient (Torun et al., 2001); as a result, approximately 2 billion people suffer from Zn deficiency all over the world (Asad and Rafique, 2002). Zinc is essential for the transformation of carbohydrates and regulating consumption of sugars. It is required in a variety of enzymes and plays an essential role in DNA transcription (Don Eckert, 2010). The grain yield can be improved by addition of Zn fertilization (Maqsood et al., 2009).

Zinc deficiency is a worldwide nutritional constraint for crop production, as Zn removed by crops is usually not fully replenished by fertilization in agricultural soils. Its deficiency is particularly widespread in cereals that are grown on calcareous soil (Graham et al., 1992). Deficiency of zinc in wheat has been reported from various parts of the world, Pakistan soils are not exception to this. Almost 50% of the world soils used for cereal production are Zn deficient (Gibbson, 2006). This percentage is even higher in areas with calcareous soils as the proportion of sorbed Zn that could be desorbed back into solution decreased substantially as pH increased to more than 5.5 (Singh et al., 2008), which reduces not only grain yield, but also nutritional quality of grains. As a result, approximately two billion people suffer from Zn deficiency all over the world. Zinc deficiency is the third most serious crop nutrition problem in the Pakistan, ranking after N and P deficiency (Rashid & Rafique, 1996). Zinc deficiency is common in both warm and cold climate. Despite of being graded as less sensitive (Clark, 1990), wheat is severely affected by Zn deficiency in Pakistan.

Foliar fertilization of crops can complement and guarantee the availability of nutrients to crops for obtaining higher yields (Arif et al., 2006). The foliar spray of zinc at tillering and/or booting and milking growth stage (s) increased the grain yield of wheat (Mohammad et al., 2009). Sohu (2008) disclosed that soil application of Zn had significant effect on all the growth and grain yield contributing parameters of wheat. The highest Zn level of 15.0 kg ha-1 produced significantly greater values for plant height (93.26 cm), number of tillers (13.86) plant-1, spike length (12.33 cm), number of grains (62.2) spike-1, seed index (39.27 g) and grain yield (4966.67 kg ha-1). Application of zinc increased wheat dry matter, grain yield, and straw yield significantly over control (Asad and Rafique, 2000). Similarly, in another study Zeidan et al. (2010) concluded that wheat grain yield, straw yield, 1000-grain weight and number of grains spike¬1 and Zn concentration in flag leaves and grains as well as, protein content in grain were significantly increased by the application of zinc.

1.1 Materials and Methods 2

The field study was conducted at Soil Chemistry Section, Agriculture Research Institute, Tandojam to evaluate the comparative efficacy of soil and foliar applied zinc in improving yield and yield components of wheat variety Kiran-95 during Rabi, 2012-13. The experiment was laid out in three replicated randomized complete block design (RCBD), having net plot size 5 m x 4 m (20 m2).

Land preparation

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

Sowing time and method

The sowing was done with the help of single row hand drill on 10th November, 2013, maintaining distance of 22.5 cm between rows.

Irrigation and fertilizer application

The first irrigation was applied at the crown root initiation stage i.e. 21 DAS. Subsequently five irrigations were applied as and when needed until the crop reached physiological maturity. Inorganic fertilizers were used to provide proper nutrition to plants. Nitrogen was applied at 120 kg N ha-1 in the form of Urea and DAP. Urea was applied in three splits, first at the time of sowing, second at the 1st irrigation and the remaining at the 2nd irrigation. Full dose of phosphorus in the form of DAP @ 56 kg ha-1 was applied at the time of sowing.

Crop harvesting

At maturity five plants from each treatment of all replications were selected at random for harvest. These plants were harvested by cutting at ground level with sharp sickle. The spikes were separated from straw, placed in separate paper bags, oven-dried for 24 hours at 78oC. Threshing was done by hands.

Statistical Analysis

The data were subjected to statistical analysis using MSTAT-C (Russel and Eisensmith, 1983). The Duncan's Multiple Range Test (DMRT) was applied to compare treatment means superiority, where necessary.

1.1.1 Results 3

The field study was conducted at Soil Chemistry Section, Agriculture Research Institute, Tandojam to evaluate the comparative efficacy of soil and foliar applied zinc in improving yield and yield components of wheat variety Kiran-95 during Rabi, 2012-13. The experiment was laid out in three replicated randomized complete block design (RCBD). The net plot size was kept as 5 m x 4 m (20 m^2). The treatments included: Control (No Zinc), Soil applied Zinc 5.0 kg ha^{-1} at tillering stage, Soil applied Zinc 10.0 kg ha^{-1} at tillering stage, Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, Foliar applied Zinc 0.2% at tillering stage, Foliar applied Zinc 0.4% at tillering and Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage. The observations were recorded on parameters of economic importance such as Plant height (cm), Tillers (m^{-2}), Spike length (cm), Spikelets per spike, Grains per spike, Seed index (1000-grain weight, g), Biological yield (kg ha^{-1}) and Grain yield (kg ha^{-1}). The results on above parameters are shown in Tables 1-8 and their analyses of variance as Appendices I-VIII. The results are interpreted as under:

Plant height (cm)

The data in relation to plant height (cm) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are shown in Table-1 and their analysis of variance as Appendix-I. The analysis of variance showed that the differences for plant height (cm) between various treatments were statistically significant ($P<0.05$). The results illustrated that maximum plant height (99.0 cm) was recorded in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage which resulted in 97.6 and 94.2 cm plant height, respectively.

The plant height reduced to 93.7, 92.0 and 90.9 cm when crop was fertilized with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum plant height (88.5 cm) was noted in Control (No Zinc). Furthermore, results indicated that although numerically maximum plant height was recorded in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically it differed non-significantly (P>0.05%) with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 1.

Effect of soil and foliar applied zinc on plant height (cm) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	89.9	84.9	90.9	88.5 d
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	92.3	91.4	92.3	92.0 bc
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	94.3	94.4	93.9	94.2 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	99.2	99.0	98.9	99.0 a
Foliar applied Zinc 0.2% at tillering stage	89.9	89.9	92.9	90.9 cd
Foliar applied Zinc 0.4% at tillering	93.9	93.4	93.9	93.7 b
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	97.8	98.0	96.9	97.6 a

S.E ±	1.1198
$DMR_{0.05}$	2.4398
$DMR_{0.01}$	3.4204
CV%	1.46

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Tillers (m^{-2})

The results regarding tillers (m^{-2}) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are presented in Table-2. The analysis of variance indicated that the differences for tillers (m^{-2}) between various treatments were statistically significant (P<0.05). The results suggested that maximum tillers (410.7 m^{-2}) were noted in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage with 408.8 and 395.7 tillers m^{-2}, respectively. The number of tillers m^{-2} reduced to 392.3, 387.3 and 385.3 when crop was supplied with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum tillers (381.5 m^{-2}) were recorded in Control (No Zinc). Moreover, data showed that although numerically maximum tillers (m^{-2}) were observed in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but they demonstrated non-significant (P>0.05%) differences statistically when compared with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 2. Effect of soil and foliar applied zinc on tillers (m^{-2}) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	376.5	386.5	381.5	381.5 d
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	389.6	384.6	387.6	387.3 cd
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	398.0	393.0	396.0	395.7 bc
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	421.0	411.0	400.0	410.7 a
Foliar applied Zinc 0.2% at tillering stage	387.6	382.6	385.6	385.3 cd
Foliar applied Zinc 0.4% at tillering	394.6	389.6	392.6	392.3 cd
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	412.5	405.5	408.5	408.8 ab

S.E ±	3.9009
$DMR_{0.05}$	13.636
$DMR_{0.01}$	17.433
CV%	1.21

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Spike length (cm)

The data pertaining to spike length (cm) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are shown in Table-3. The analysis of variance showed that the differences for spike length (cm) between various treatments were statistically significant (P<0.05). The results exhibited that maximum spike length (13.1 cm) was recorded in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage which resulted in 13.0 and 12.4 cm spike length, respectively. The spike length reduced to 11.4, 11.3 and 9.9 cm when crop was fertilized with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum spike length (9.6 cm) was noted in Control (No Zinc). Furthermore, results indicated that although numerically maximum spike length was recorded in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically it differed non-significantly (P>0.05%) with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 3.
Effect of soil and foliar applied zinc on spike length (cm) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	9.6	9.7	9.6	9.6 d
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	11.3	11.4	11.3	11.3 c
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	12.4	12.2	12.6	12.4 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	13.2	13.1	13.1	13.1 a
Foliar applied Zinc 0.2% at tillering stage	10.5	9.8	9.5	9.9 d
Foliar applied Zinc 0.4% at tillering	11.5	11.3	11.4	11.4 c
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	13.1	13.0	12.9	13.0 a

S.E ±	0.1735
DMR $_{0.05}$	0.6064
DMR $_{0.01}$	0.7753
CV%	1.84

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Spikelets per spike

The results in relation to spikelets per spike of wheat variety Kiran-95 as affected by soil and foliar applied zinc are given in Table-4. The analysis of variance suggested that the differences for spikelets per spike between various treatments were statistically significant (P<0.05). The results illustrated that maximum spikelets per spike (23.0) were found in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage with 22.8 and 22.4 spikelets per spike, respectively. The number of spikelets per spike decreased to 22.1, 21.0 and 19.5 under Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum spikelets per spike (18.9) were registered under Control (No Zinc). In addition, results indicated that although numerically maximum spikelets per spike were recorded in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically non-significant (P>0.05%) differences were observed in comparison with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 4. Effect of soil and foliar applied zinc on spikelets per spike of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	18.9	19.0	18.8	18.9 e
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	21.0	21.0	21.0	21.0 c
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	22.4	22.3	22.5	22.4 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	23.1	23.0	23.1	23.0 b
Foliar applied Zinc 0.2% at tillering stage	19.7	19.3	19.5	19.5 d
Foliar applied Zinc 0.4% at tillering	22.1	22.0	22.2	22.1 b
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	22.7	23.0	22.8	22.8 a

S.E ±	0.0947
DMR $_{0.05}$	0.3311
DMR $_{0.01}$	0.4233
CV%	0.54

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Grains per spike

The results regarding grains per spike of wheat variety Kiran-95 as affected by soil and foliar applied zinc are presented in Table-5 and their analysis of variance as Appendix-V. The analysis of variance indicated that the differences for grains per spike between various treatments were statistically significant (P<0.05). The results suggested that maximum grains per spike (45.1) were noted in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage with 45.0 and 44.0 grains per spike, respectively. The number of grains per spike reduced to 43.0, 42.6 and 37.7 when crop was supplied with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum grains per spike (36.5) were recorded in Control (No Zinc). Moreover, data showed that although numerically maximum grains per spike were observed in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but they demonstrated non-significant (P>0.05%) differences statistically when compared with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 5. Effect of soil and foliar applied zinc on grains per spike of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	36.4	36.7	36.3	36.5 e
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	42.6	42.7	42.5	42.6 c
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	43.6	44.2	44.3	44.0 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	45.3	45.0	45.2	45.1 a
Foliar applied Zinc 0.2% at tillering stage	38.0	37.3	37.6	37.7 d
Foliar applied Zinc 0.4% at tillering	42.7	43.4	43.0	43.0 c
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	45.0	45.2	44.9	45.0 a

S.E ±	0.2136
DMR $_{0.05}$	0.7465
DMR $_{0.01}$	0.9545
CV%	0.62

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Seed index (1000-grain weight, g)

The data pertaining to Seed index (1000-grain weight, g) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are shown in Table-6 and their analysis of variance as Appendix-VI. The analysis of variance showed that the differences for seed index (g) between various treatments were statistically significant (P<0.05). The results demonstrated that maximum seed index (43.4 g) was noticed in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage which resulted in 43.2 and 39.8 g seed index, respectively. The seed index decreased to 37.7, 37.0 and 35.6 g when crop was fertilized with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum seed index (33.7 g) was noted in Control (No Zinc). Furthermore, results indicated that although numerically maximum seed index was recorded in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically it differed non-significantly (P>0.05%) with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 6. Effect of soil and foliar applied zinc on seed index (1000-grain weight, g) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	33.6	33.9	33.5	33.7 d
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	36.4	37.0	37.4	37.0 bcd
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	39.3	39.9	40.3	39.8 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	43.7	42.7	43.7	43.4 a
Foliar applied Zinc 0.2% at tillering stage	38.7	33.3	34.8	35.6 cd
Foliar applied Zinc 0.4% at tillering	37.2	37.8	38.2	37.7 bc
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	43.6	43.2	42.9	43.2 a

S.E ±	0.9581
DMR $_{0.05}$	3.3491
DMR $_{0.01}$	4.2820
CV%	3.04

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Biological yield (kg ha^{-1})

The data in relation to biological yield (kg ha^{-1}) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are shown in Table-7 and their analysis of variance as Appendix-VII. The analysis of variance showed that the differences for biological yield (kg ha^{-1}) between various treatments were statistically significant (P<0.05). The results illustrated that maximum biological yield (9354.4 kg ha^{-1}) was recorded in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage which resulted in 9273.4 and 8440.4 kg ha^{-1} biological yield, respectively. The biological yield reduced to 7650.7, 7415.9 and 7050.2 kg ha^{-1} when crop was fertilized with Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum biological yield (6940.6 kg ha^{-1}) was noted in Control (No Zinc). In addition, results indicated that although numerically maximum biological yield was recorded in Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically it differed non-significantly (P>0.05%) with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 7. Effect of soil and foliar applied zinc on biological yield (kg ha^{-1}) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	6931.0	6989.7	6901.2	6940.6 c
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	7423.5	7529.2	7294.9	7415.9 c
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	8320.1	8173.9	8827.3	8440.4 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	9405.0	9272.0	9386.2	9354.4 a
Foliar applied Zinc 0.2% at tillering stage	7666.2	6532.8	6951.5	7050.2 c
Foliar applied Zinc 0.4% at tillering	7587.9	7739.7	7624.6	7650.7 c
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	9262.7	9314.0	9243.5	9273.4 a

S.E ±	219.71
DMR $_{0.05}$	767.99
DMR $_{0.01}$	981.90
CV%	3.36

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

Grain yield (kg ha^{-1})

The data regarding grain yield (kg ha^{-1}) of wheat variety Kiran-95 as affected by soil and foliar applied zinc are presented in Table-8 whereas, the analysis of variance as Appendix-VIII. The analysis of variance indicated that the differences for grain yield (kg ha^{-1}) between various treatments were statistically significant (P<0.05). The results showed that maximum grain yield (5123.4 kg ha^{-1}) was observed in plots fertilized with Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage, closely followed by Foliar applied Zinc 0.2% tillering stage + 0.2% booting stage and Soil applied Zinc 10.0 kg ha^{-1} at tillering stage with 5080.7 and 4638.0 kg ha^{-1} grain yield, respectively. The grain yield decreased to 4222.4, 4098.8 and 3906.3 kg ha^{-1} under Foliar applied Zinc 0.4% at tillering, Soil applied Zinc 5.0 kg ha^{-1} at tillering stage and Foliar applied Zinc 0.2% at tillering stage, respectively. However, minimum grain yield (3848.7 kg ha^{-1}) was recorded in Control (No Zinc). Furthermore, results suggested that although numerically maximum grain yield was recorded under Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage but statistically non-significant (P>0.05%) differences were found when compared with Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage.

Table 8. Effect of soil and foliar applied zinc on grain yield (kg ha^{-1}) of wheat variety Kiran-95

Treatments	R-I	R-II	R-III	Mean
Control (No Zinc)	3843.6	3874.5	3827.9	3848.7 c
Soil applied Zinc 5.0 kg ha^{-1} at tillering stage	4102.8	4158.4	4035.1	4098.8 c
Soil applied Zinc 10.0 kg ha^{-1} at tillering stage	4574.7	4497.8	4841.6	4638.0 b
Soil applied Zinc 5.0 kg ha^{-1} at tillering + 5.0 kg ha^{-1} at booting stage	5150.0	5080.0	5140.1	5123.4 a
Foliar applied Zinc 0.2% at tillering stage	4230.5	3634.0	3854.4	3906.3 c
Foliar applied Zinc 0.4% at tillering	4189.3	4269.2	4208.6	4222.4 c
Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage	5075.1	5102.1	5065.0	5080.7 a

S.E ±	115.64
DMR $_{0.05}$	404.20
DMR $_{0.01}$	516.79
CV%	3.21

Means not sharing the same letter in a column differ significantly at 0.05 probability level.

1.1.2 Discussion 3

Nutrient deficiency and imbalanced fertilizers use are one of the important factors for low yield of wheat in Pakistan. Zinc (Zn) is an essential micronutrient for plant growth and its deficiency is common in cultivated soils of Pakistan (Zeidan et al., 2010). Zinc plays a very important role for the transformation of carbohydrates and regulating consumption of sugars. It is required in a variety of enzymes and plays an essential role in DNA transcription (Don Eckert, 2010). A typical symptom of zinc deficiency is the stunted growth of leaves, commonly known as "little leaf" (Thalooth et al., 2006).The grain yield can be improved by addition of Zn fertilization (Maqsood et al., 2009). Foliar fertilization of crops can complement and guarantee the availability of nutrients to crops for obtaining higher yields (Arif et al., 2006). The findings of the study suggested that soil and foliar applied zinc affected significantly ($P<0.05$) growth and yield traits of wheat variety Kiran-95. Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage produced maximum plant height (99.0 cm), tillers (410.7 m-2), spike length (13.1 cm), spikelets per spike (23.0), grains per spike (45.1), seed index (43.4 g), biological yield (9354.4 kg ha-1) and grain yield (5123.4 kg ha-1), closely followed by Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage almost in all the growth and yield attributes, particularly grain yield (5080.7 kg ha-1). However, minimum growth and yield traits particularly grain yield (5080.7 kg ha-1). Furthermore, the results concluded that although numerically maximum growth and yield values were recorded in Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage but statistically the differences between Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage and Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage were non-significant. These results showed that foliar application of zinc proved more beneficial and economical as compared to soil applied zinc. Low dose of zinc is required when applied through spray. Application of zinc twice at tillering and booting stage demonstrated more effectiveness as compared to application once at higher or lower dose either through foliar application or soil. These results confirmed that zinc is required at two critical stages i.e. tillering and booting stage. The results are in agreement with those of Arif et al. (2006) who suggested that Foliar fertilization of crops can complement and guarantee the availability of nutrients to crops for obtaining higher yields The results are in line with the findings of Mohammad et al. (2009) who concluded that foliar spray of zinc at tillering and/or booting and milking growth stage (s) increased the grain yield of wheat. Similar results were also reported by Sohu (2008) who found that soil application of Zn had significant positive effect on all the growth and yield contributing parameters of wheat. The results are strongly supported by Asad and Rafique (2000) who indicated that Application of zinc increased wheat dry matter, grain yield, and straw yield significantly over control. Similarly, in another study Zeidan et al. (2010) concluded that wheat grain yield, straw yield, 1000-grain weight and number of grains spike¬1 and Zn concentration in flag leaves and grains as well as, protein content in grain were significantly increased by the application of zinc. Dell et al. (2001) disclosed that Foliar treatments with ZnSO4 and chelated Zn forms resulted in shoot Zn concentrations in 7-week-old plants being about two-fold greater than those in plants supplied with Zn in the root environment or via foliar spray of ZnO. Adding surfactant to foliar sprays containing chelated forms of Zn did not cause negative growth effects, but surfactant added to ZnO or ZnSO4 foliar sprays decreased shoot growth. Adding urea to the ZnO foliar spray had no effect on shoot growth. Foliarly-applied 65 Zn was translocated to leaves above and below the treated leaf as well as to the root tips. These results are in accordance with Hussain and Yasin (2004) who reported 12% increase in wheat yield by the application of 5 kg Zn ha-1, over control. Increasing Zn dose upto 16 kg Zn ha-1 increased spike length, number of spikelets per spike, number of tillers per m2 and 1000 grain weight, significantly over control, while highest straw yield was obtained with the application of 8 kg Zn ha-1. In conclusion, Zn supply along with recommended NPK fertilizers led to satisfactory crop production. The complimentary use of micronutrients is advantageous as it helps increase NPK uptake, maintain micronutrients levels in soil and increases crop productivity. It is possible to obtain higher crop yield with complimentary use of micronutrients along with recommended macronutrient fertilizers.

Conclusion

The results concluded that all the treatments of soil and foliar applied zinc affected significantly ($P<0.05$) growth and yield parameters of wheat variety Kiran-95. Soil applied Zinc 5.0 kg ha-1 at tillering + 5.0 kg ha-1 at booting stage (T4) produced maximum traits, particularly grain yield (5123.4 kg ha-1), closely followed by Foliar applied Zinc 0.2% at tillering stage + 0.2% at booting stage (T7) with 5080.7 kg ha-1 grain yield. However, T7 was found the most economical for obtaining optimum yield of wheat variety Kiran-95 due to non-significant ($P>0.05$) statistical differences with T4.

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