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Impact of Various Soil and Foliar Treatments on Yield and Its Components of Maize (*Zea Mays L.*) In Calcareous Soil of Peshawar, Pakistan

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ABSTRACT

Uptake of micro-nutrients is among one of the prime variables which affects the production of Maize (*Zea mays* L.) in the calcareous soil of Pakistan. Zinc, being one of the most needed plant nutrients for maize is deficient in the soil of Pakistan due to which optimum growth and yield is not obtained. Due to the current scenario, two methods i.e., soil and foliar based zinc application was carried in the present experiment to find out the improved grain quality and production. A Randomized Complete Block Design was designed in which zinc was applied to soil in 5.0 $kgha^{-1}$, 10 kg ha^{-1}, 15 $kgha^{-1}$, 20 $kgha^{-1}$ at sowing and foliar 0.25 %, 0.50 %, 1.0 % and 1.5% during silking. The source of zinc was Zinc sulphate ($ZnSO_4$). Base doses of N, P2O, and K2O were 120, 90, and 60 $kgha^{-1}$. Plant height was considerably altered by foliar and soil treatments. Soil application @10 kg ha-1 Zn and spray @0.5% increased cob weight. Grain production rose considerably to 2821 $kgha^{-1}$ for soil when applied @20 $kgha^{-1}$ Zn and 2513 $kgha^{-1}$ with 1.5% treatment of foliar spray treatment. With 20 $kgha^{-1}$ Zn in soil applications and 1.5% foliar application, biological yield 5849 $kgha^{-1}$ rose dramatically. Number of grains per cob and thousand grains weight rose dramatically @10 and 15 $kgha^{-1}$ Zn in soil and 1.5% foliar spray. Based on these data, zinc soil application yield was observed high compared to foliar spray. This study further suggests to conduct similar studies in other Pakistani locations for different types of soil.

Keywords: Calcareous soil; Foliar application; yield; Maize; Peshawar

1. Introduction:

Maize, scientifically known as *Zea mays L*., belongs to the Poaceae family and holds the position of being Pakistan's third most important cereal crop, following rice and wheat. The primary components of the product consist of minerals (3%), fiber (4%), fat (4%), protein (10%), starch (79%) (Ahmad *et al.*, 2017). It is a nutritious cereal that supplies essential nutrients to both humans and animals. Maize is the third largest cereal crop in Pakistan, following rice and wheat, when measured on a hectare basis. Nevertheless, in terms of maize cultivation, Pakistan's average grain production falls short when compared to other affluent countries (Federal Bureau of Statistics, 2010-11). Maize is commonly referred to as the "brilliant nourishment" due to its abundant grain production, excellent nutritional content, essential role as a source of carbs, and major contribution to daily calorie intake. It is commonly known as the "grain without limits" due to its significant health advantages when incorporated into daily dietary patterns (Enyisi *et al.*, 2014). The impact of nutrient deficiency on maize output is considered the most detrimental among the various factors that influence it. Plant development relies fundamentally on crop nutrition. Micronutrients, such as Zinc (Zn), Manganese (Mn), Iron (Fe), Molybdenum (Mo), Cobalt (Co), Copper (Cu), Boron (B) and Nickel (Ni) are essential for plant growth and development, although being required in smaller quantities compared to macronutrients. Macronutrients provide the main portion of crop nutrition (Davies, 1997). The reason for this is that micronutrients play a dual role in enhancing both the nutritional quality and the production of grains (Johnson *et al.,* 2005). One can assess the effects of properly balanced combinations of micronutrients on attaining optimal production levels. In order to enhance plant growth, the utilisation of certain mineral nutrients has become imperative, particularly in areas with high agricultural activity. These nutrients are commonly found in the form of chemical fertilisers.

Zinc plays a vital role in vascular plants when it comes to the increasing role of agriculture (Genc *et al.,* 2006). Zinc promotes the synthesis of chlorophyll in plants. In soil that lacks zinc, the leaves undergo a colour change to yellow and the growth of plants is limited. Zinc deficiency can lead to chlorosis, a specific form of leaf discoloration where the tissues between the veins turn yellow but the veins themselves remain green. Zinc plays a vital part in almost all agricultural metabolisms, making it the most essential element for the growth and development of plants (George and Schmitt, 2002). Acute zinc deficiency is prevalent in arid and semi-arid regions worldwide, causing a shortage of crops. This issue is a globally recognized issue (Rashid and Ryan, 2004). Compared to previous cultivars, crop cultivars have shown a tendency towards zinc deficiency (Cakmak *et al.,* 2001). Zinc is a crucial element for plant growth and development since it serves as a catalyst in the metabolism of almost all crops (George and Schmitt, 2002) Severe zinc insufficiency is most prevalent in arid and semi-arid regions around the world. The inadequacy of zinc in soil results in a deficit of zinc in crops, which has contributed to a worldwide apprehension (Rashid and Ryan, 2004). A comparison between older crop types and newer ones has revealed a noticeable trend of zinc deficiency (Cakmak *et al.,* 2001). This research was designed keeping in mind the zinc deficiency of calcareous soil reported in various fields of Peshawar. This research aimed to monitor the impact of various soil and foliar treatments on yield and its components of maize (*Zea Mays L.*) in calcareous soil of Peshawar.

2. Methodology:

An experiment was conducted as per Randomized Complete Block Design (RCBD) for the present research at Agricultural Research Farm (ARF), The University of Agriculture, Peshawar in the year 2022. "Azam" cultivar of maize was chosen for the present study. The field was cultivated using the conventional agronomic approach. During the sowing process, a quantity of 20 kilograms per hectare of seeds was utilized, along with a mixture of 60 kilograms each of nitrogen (N), phosphorus pentoxide (P_2O_5), and potassium oxide (K_2O) pre-sowing. There were nine (9) treatments used during the experiment. Each plot had a size of 4×4m; row to row distance was 70 cm, while plant to plant distance kept within a row was 20 cm.

Zinc sulphate ($ZnSO_4$) was used as a zinc source to the soil during the sowing period and in a foliar manner at the silking stage. Treatments applied for the soil and foliar levels were 0 (control), 5 $kgha^{-1}$, 10 $kgha^{-1}$, 15 $kgha^{-1}$, and 20 $kgha^{-1}$ and 0.25%, 0.50%, 1.0%, and 1.5%, respectively, using a spraying machine. The treatments involved mixing the substances with a small quantity of detergent in water. The volume of spray per treatment plot 0.25%, 0.50%, 1.0 % and 1.50 % received were 6.2 g/L, 12.38 g/L, 18.6 g/L and 24.8 g/L respectively.

2.2. Soil Physico-chemical Parameters:

Composite soil samples were taken from the field at a depth of 0 to 15 cm before and after each treatment. These samples were subsequently analysed for different physico-chemical properties listed as:

2.2.1. Soil pH:

1:5 soil Suspension was used to measure the soil pH with the aid of a digital pH meter. First 10g air-dried soil was weight on a digital balance. After weighing the soil, 50mL distilled water was added to the samples with the help of measuring cylinder. The soil-water suspension was kept on a digital stirrer machine for a while. This was later filtered to beakers where the pH was measured with the help of already calibrated digital pH meter (InoLab *pH meter*).

2.2.2. Soil Electrical Conductivity (EC)

EC level was measured for the total soluble salts in a ratio of 1:5. In order to find out the EC of soil samples, first 10 g soil was treated with 50 mL of distilled water. The suspension was later kept on a stirrer machine and then filtered. The filtrate was used for EC analysis using digital EC meter (WTW, Germany)

2.2.3. Soil Texture

Soil texture was determined using the Hydrometer method. 50 grams of soil (air-dried) from each soil sample was placed in dispersion solution followed by 5 minutes shaking via electrical shaker. After dispersion, soil solution was transferred and filled with distilled water to 1 Liter. A hydrometer was inserted after thoroughly shaking in the suspension and the readings were measured after 40 sec for silt +clay and after 2 hours for clay. Temperature was also recorded in order for hydrometer correction. Textural class of USDA triangle was made after calculation of the silt, clay and sand ratio.

Mathematically:

$$\%(silt + clay) = \frac{40\,\text{sec} * Hydrometer\ reading \pm Temperature\ correction}{weight\ of\ soil(g)} \times 100$$

$$\%\ clay = \frac{2\ hrs\ Hydrometer\ reading \pm Temperature\ correction}{weight\ of\ soil(g)} \times 100$$

$$\%\ Sand = 100 - \%(silt + clay)$$

$$\%Silt = 100 - sand - clay$$

2.2.4. Soil Organic Matter Content (SOM)

1 g of air -dried soil was taken to which 20 ml of H_2SO_4 and 10 ml of potassium dichromate ($K_2Cr_2O_7$), was added to make a soil suspension. The suspension was further diluted by 200 mL water followed by filtration. Titration was performed against 0.5 N $Fe_2SO_4.7H_2O$ in the presence of ortho phenolpthale in indicator. The readings were noted after the end point i.e., appearance of dark brown colour.

Furthermore, the formula used for calculation of organic matter is:

$$O.M\ (\%) = \frac{[(mL\ of\ Fe_{2,}\ SO_4.7H_2O\times N)] - (mL\ of\ K_2Cr_2O_{7,}\times N)}{Soil\ weight\ (g)} \times 0.69$$

2.2.5. AB DTPA extractable Soil Phosphorus & Potassium Contents

5g of each soil sample was taken to which 20 ml AB-DTPA solution was later added. The solution was kept it in the mechanical shaker for 15 minutes. The solution, after shaking was filtered through Whatman42-filter paper and P concentration were determined using spectrophotometer. Standards of 0, 2ppm, 4 ppm, 6 ppm, 8 ppm and 10 ppm were used for calibration curve.

2.2.6. Soil Potassium Content:

5g of each soil sample was taken followed by 20 ml AB-DTPA solution. The solution was kept for shaking on a mechanical shaker. After shaking for 15 minutes, the solution was filtered through Whatman42-filter paper and K concentration was determined through flame photometry. Different standards like 2 ppm, 4ppm, 6ppm, 8ppm and 10 ppm were used for the calibration curve.

2.2.7. Total Nitrogen

A digestion mixture comprising of 0.2 g soil was prepared in the digestion flasks. The samples including control were kept on heater at 370 ºC till appearance of light green colour. After when the soil were digested 4 ml of 40% NaOH and 20 ml of extract were added to a distillation flask. Additionally, boric acid was added after which titration was carried out against 0.005 N HCl unless reaching end point light pink colour.

$$\%\ N = \frac{(S\text{-}B) \times 0.005N \times 0.014}{Weight\ of\ sample \times ml\ of\ extract} \times 10000$$

2.2.8. AB-DTPA Extractable Zinc content

In order to find out the extractable zinc content, 20 mL AB DTPA solution was taken to which 10 g soil was added in a conical flask. The solution was subjected to shaking for 20 mins followed by filtration. The filtrate was later subjected to measure the zinc content using atomic absorption spectrophotometer. The following formula is generally used to measure the zinc content.

$$Zinc\ (mg/kg) = \frac{Instrumental\ reading \times volume\ made}{wegiht\ of\ soil\ sample}$$

2.3. Effect of Zinc application (soil and foliar) on various agronomic parameters:

Some of the selected agronomical parameters based on which the effect of zinc application was determined are as:

2.3.1. Plant height:

For plant height, ten plants per plot were randomly selected to measure their heights. A meter rod was utilized to measure the height of each subplot at physiological maturity, from the base to the tip of the tassel. Subsequently, the mean height was calculated.

2.3.2. No. of grains cob^{-1}:

A sample of five cobs was randomly chosen to determine the number of grains on each cob and calculate the average.

2.3.3. Cob weight

Five cobs were randomly chosen to measure their weight. Their weights were recorded using an electronic balance and then averaged.

2.3.4. Thousand Grain Weight:

In order to determine the weight of 1000 grains, a random sample of 1000 grains were taken from the grain yield of each plot and weighed.

2.3.5. Grain yield

The ears of each subplot were husked, shelled, and dried. The resulting grain yield was then quantified and converted to kilograms per hectare using a specific method.

$$Grain\ yield\ (kgha^{-1}) = \frac{Grain\ yield\ of\ harvested\ (3)\ rows}{No\ of\ Rows \times Row\ length \times Row\text{-}row\ distance} \times 10000$$

2.3.6. Biological yield:

Each plot contained two core rows that were gathered and subsequently formed into separate bundles after they reached maturity. In order to determine the biological yield, the bundles were subjected to the process of sun-drying and subsequently weighed using a spring balance. The obtained measurements were then converted into kilograms per hectare.

2.4. Statistics Analysis

The values were statistically examined using the variance analysis approach, employing a randomized complete block design. F-values were statistically significant at a 5% level of significance, the means were compared using the Least Significant Difference (LSD) test.

3. Results and Discussion:

Table.1. depicts all the necessary soil physico-chemical properties of soil before plantation of maize. The study found out that cultivated soil was silty loam which is the ideal soil for growing majority of plants. Furthermore, pH of soil was 8.4, EC (0.21 dSm^{-1}) which was optimum, organic matter (0.67 %) which was below the ideal range, Total Nitrogen (0.09%) while Phosphorus, Potassium and Zinc were in range of 3.20 $mgkg^{-1}$, 103 $mgkg^{-1}$, 0.9 $mgkg^{-1}$

Table.1. Soil Physico-chemical Properties before experiment

pH (1-14)	EC (dSm^{-1})	Texture	Texture (%)			SOM (%)	TN (%)	P ($mgkg^{-1}$)	K ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)
			Sand	Silt	Clay					
8.40	0.21	Silt Loam	12.51	76	11.49	0.67	0.09	3.20	103	0.9

Table.2. Effect of Zn on various agronomical parameters.

Treatments ($Zn\ kgha^{-1}$)		Plant height (cm)	Grains Cob^{-1}	Cob weight (g)	Thousand grains weight	Grain yield	Biological yield
Control		148.0^{d}	288.0^{f}	122.6^{f}	233.2^{g}	1734^{f}	4912^{g}
Soil treatments (kg)	**5**	154.5^{abcd}	302.3^{e}	132.6^{e}	261.7^{de}	2226^{d}	5464^{c}
	10	156.7^{abc}	318.3^{d}	146.3^{b}	294.0^{a}	2614^{bc}	5599^{c}
	15	158.5^{ab}	341.0^{a}	136.8^{de}	283.0^{ab}	2692^{ab}	5746^{b}
	20	160.7^{ab}	339.3^{cd}	133.5^{e}	270.0^{bcd}	2821^{a}	5849^{a}
Foliar treatments (%)	**0.25**	153.2^{bcd}	299.7^{e}	141.1^{cd}	252.7^{ef}	2019^{e}	5149^{f}
	0.50	155.7^{abc}	317.7^{d}	154.5^{a}	266.7^{cde}	2250^{d}	5369^{e}
	1	158.2^{ab}	327.7^{bc}	145.8^{bc}	277.0^{bc}	2448^{c}	5595^{g}
	1.50	159.8^{a}	330.0^{ab}	138.5^{d}	281.7^{ab}	2513^{bc}	5777^{b}
CV%		2.61	2.020	2.13	3.18	4.82	0.53
LSD Value		6.97	10.904	5.05	14.54	190.8	49.24

3.1 Plant Height

Table.2. depicts the plant height of maize after when the zinc was applied to soil as well foliar application was done. It was observed in the study, that both foliar and soil applications of Zn have a significant impact on plant height. The highest plant height in the soil was observed when Zn was supplied @ 20 kg/ha, measuring 160.7 cm. This was followed by a height of 158.5 cm when Zn was provided @ 15 kg/ha. The lowest plant height was 148 cm which was observed in the control group. Compared to soil treatment, highest plant height in the foliar spray treatment was observed @ 1 % resulting in 159.8 cm followed 158.2 cm @ 1%. Both Zn applications led to an increased plant height compared to the control group when Zn was applied to the leaves. Plant height is primarily governed by genetic factors or is a heritable feature, although it can also be influenced by nutrients, environment, and management approaches (Chand *et al.*, 2017). The findings regarding plant height are consistent with the study conducted by Sattar *et al.*, 2011 and differ from the results reported by Saeed *et al.* 2012.

3.2 Grains Cob^{-1}

Table.2. illustrates how the use of Zn applications changed the average number of grains per corn kernel. In soil application, where Zn was applied @ 15 kg/ha resulted in higher grains cob^{-1} (341) followed by (339.3) where Zn was applied @ 20 kg/ha and lower number of grains cob^{-1} was observed in control (288). In foliar application maximum no. of grains cob^{-1} was noted @ 1.50% yields (330.0) followed by (327.7) which were recorded @ 1%. Hence, this experiment showed that foliar and soil-Zn applications resulted in a significantly maximum number of grains cob^{-1}. Grain yields increased as a result of the increased zinc content because the plant was better able to access and absorb the many other elements necessary for healthy metabolic activities. The results of this research was found similar with Umar *et al.,* Lonov and Lonova (1977) found similar results when they tested Zn on rice, finding that it increased grain production.

3.3 Cob Weight

The results presented in table 1 demonstrates that the cob weight of maize is strongly influenced by various zinc treatments. The application of Zn at a rate of 10 kg ha-1 in soil resulted in the highest cob weight of 146.3 g, while the lowest cob weight of 122.6 g was observed in the control group. The highest cob weight due to foliar treatment was observed when Zn was treated at a concentration of 0.50%, resulting in a weight of 154.5 g. This was followed by a weight of 145.8 g, which was recorded when Zn was applied at a concentration of 1%. Compared to the control group, the application of Zn to the soil and leaves led to a considerable increase in the weight of the corn cobs. Furthermore, foliar applications of Zn resulted the highest cob weight than soil applications.

3.4 Thousand Grains Weight

The treatment of zinc on maize crops had a considerable impact on the weight of one thousand grains, as demonstrated in the table.1. The highest grain weight i.e., 294 g was observed when a soil application of 10 $kgha^{-1}$ of zinc was applied. In contrast, the control plot had the lowest grain weight i.e., 232.2 g. The greatest weight of grains (281.7 g) was seen when Zn was applied at a concentration of 1.5% through foliar application. This was followed by a weight of 277 g when Zn was treated at a concentration of 1%. On the other hand, when comparing to control, the treatment of zinc through foliar and soil methods led to a considerably higher thousand grains weight. The soil application of Zn resulted in a greater grain weight compared to the foliar spray. According to Umar *et al.,* (2005), the application of Zn enhances the weight of a thousand grains due to its enhanced participation in many metabolic processes necessary for the normal development of seeds. Hao *et al.,* (2003) found that applying an adequate amount of Zn-fertilizer increased the concentration of zinc in grains, hence increasing the nutritional content of a thousand grains. The findings are consistent with the outcomes reported by Guenis *et al.,* (2003) and Soylu *et al.,* (2005), who noticed a significant increase in thousand grain weight when micronutrients were applied using foliar technique.

3.5 Grain Yield

The use of various Zn-treatments had an impact on the yield of maize grain, as shown in table.1. The highest grain yield (2821 $kgha^{-1}$) was achieved in soil applications of Zn, specifically when Zn was treated at a rate of 20 $kgha^{-1}$ in combination with NPK at rates of 120, 90, and 60 $kgha^{-1}$, respectively. The control group yielded the lowest grain production, with a recorded output of 1734 kg ha^{-1}. The foliar treatment resulted in the maximum grain production of 2513 kg ha^{-1} when 1.5% level of Zn was administered. The second highest yield of 2448 kg ha^{-1} was observed when 1% of Zn was treated. Compared to the control group, the treatment of Zn by foliar and soil methods resulted in a greater yield of grain. When comparing the two, the use of soil application resulted in a higher grain production than the use of foliar sprays. Yilmaz *et al.,* (1997) suggest that fertilizing the soil with zinc is more effective than applying it to the leaves or treating wheat seeds with zinc. Shah *et al.,* (1985) reported similar findings, where the application of Zn at a rate of 5 kgha-1 resulted in increased yields in lentils and maize compared to the control group. Babu *et al.,* (2007) found that adding Zn to cereal crops enhances the production of carbohydrates and facilitates their transportation to grain-producing areas. Zn and B have a substantial influence on the amount of nutrients in crops and the productivity of plants, both of which depend on the quantities of these elements. Studies have found an influence had a predominantly deleterious effect on nutrient levels and a favorable effect on plant productivity.

3.6 Biological Yield

The biological yield results are presented in Table 1. The statistics indicated a notable disparity among all treatments. The application of 20 kgha-1 of zinc in soil, along with 120, 90, and 60 kgha-1 of NPK, resulted in the maximum biological yield of 5849 kgha-1. The control group which did not receive any zinc, had the lowest biological yield of 4912 kgha-1. When comparing the application of Zn to the leaves, the highest biological output of 5777 kg/ha was recorded at a concentration of 1.5%. This was followed by a yield of 5595 kg/ha observed at a concentration of 1%. There was a substantial difference between all treatment strategies. Compared to the control group, the application of zinc to the leaves and soil led to a considerable increase in grain yield. The application of Zn to the soil resulted in a higher biological production compared to the application of Zn to the leaves. Our findings align with the research conducted by Graham and McDonald (2011), which suggests that zinc plays a crucial role in conferring temperature resistance to various plant parts involved in photosynthetic activities. This effect persists throughout the entire lifespan of the plant and leads to improvements in yield-related components, ultimately resulting in an overall enhancement in biological yield. According to the study conducted by Wisal *et al.,* in 1990, the application of soil Zn to rice, maize, and wheat resulted in a considerable increase in their respective biological yields compared to the control group.

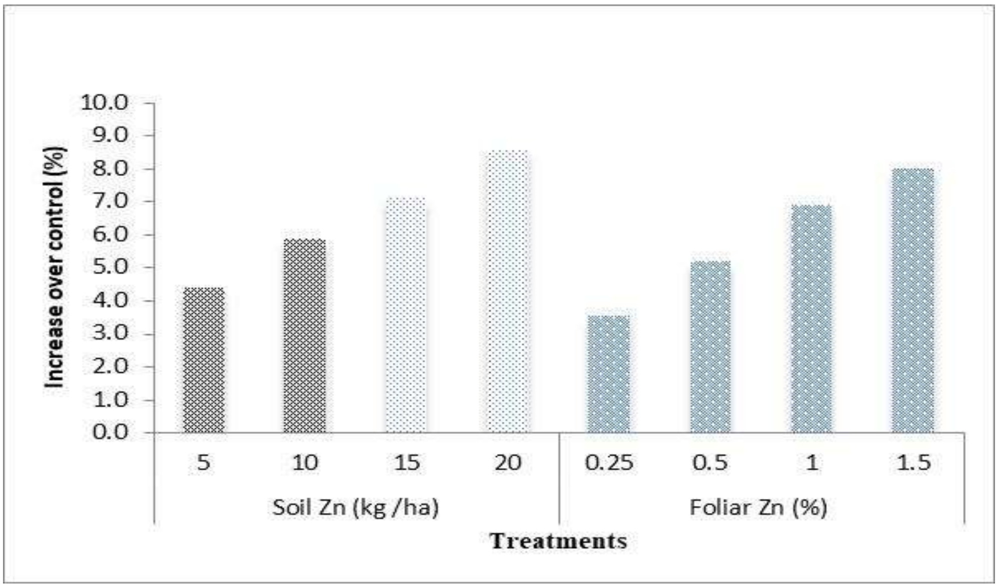

Fig.1. Percent Change in plant height

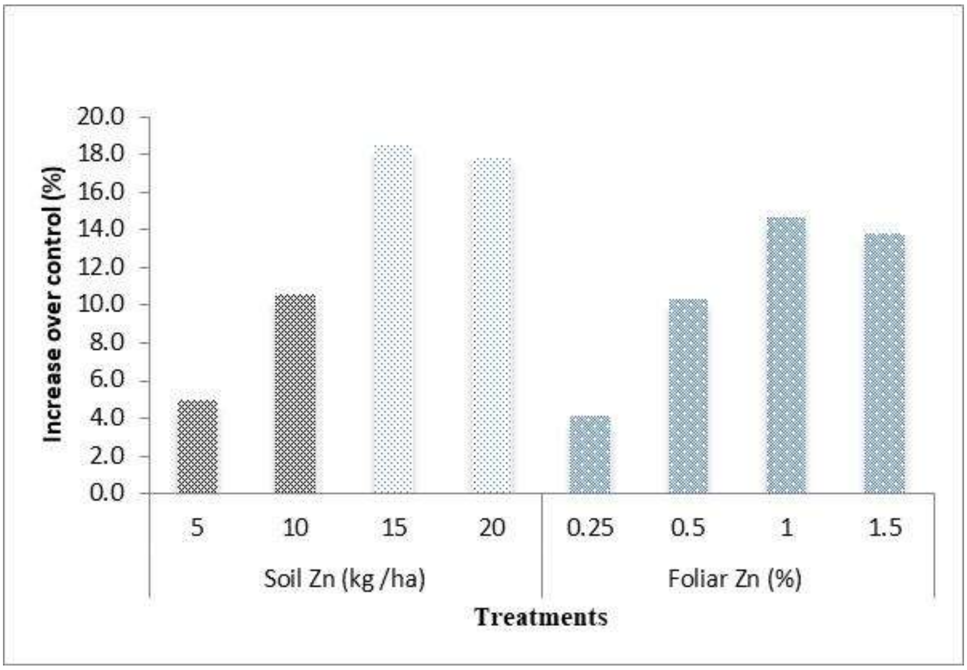

Fig.2. Percent Change in No. of Grains Cob^{-1}

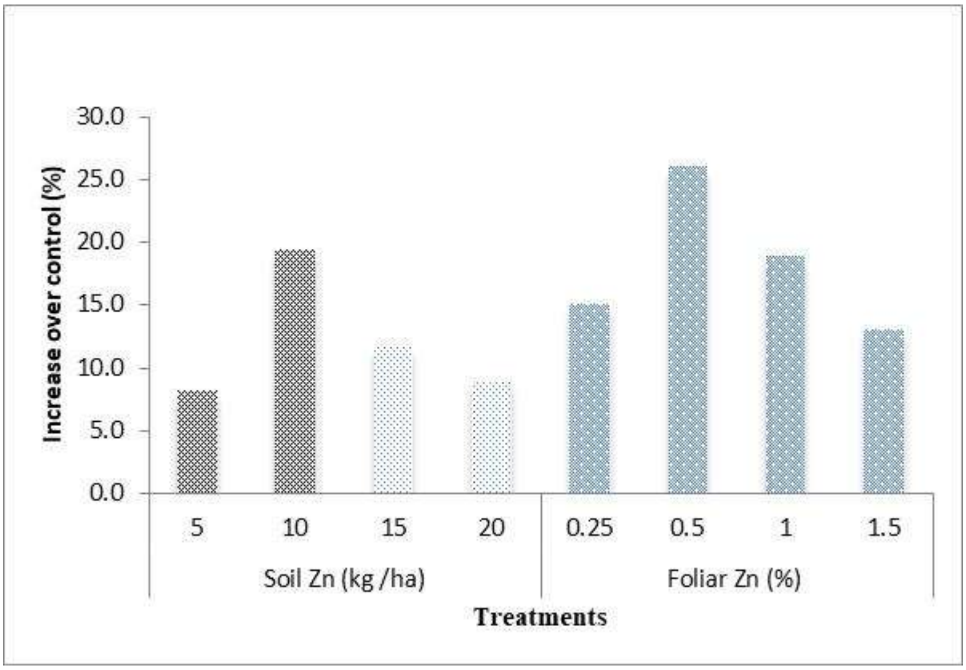

Fig.3. Percent Change in Cob weight

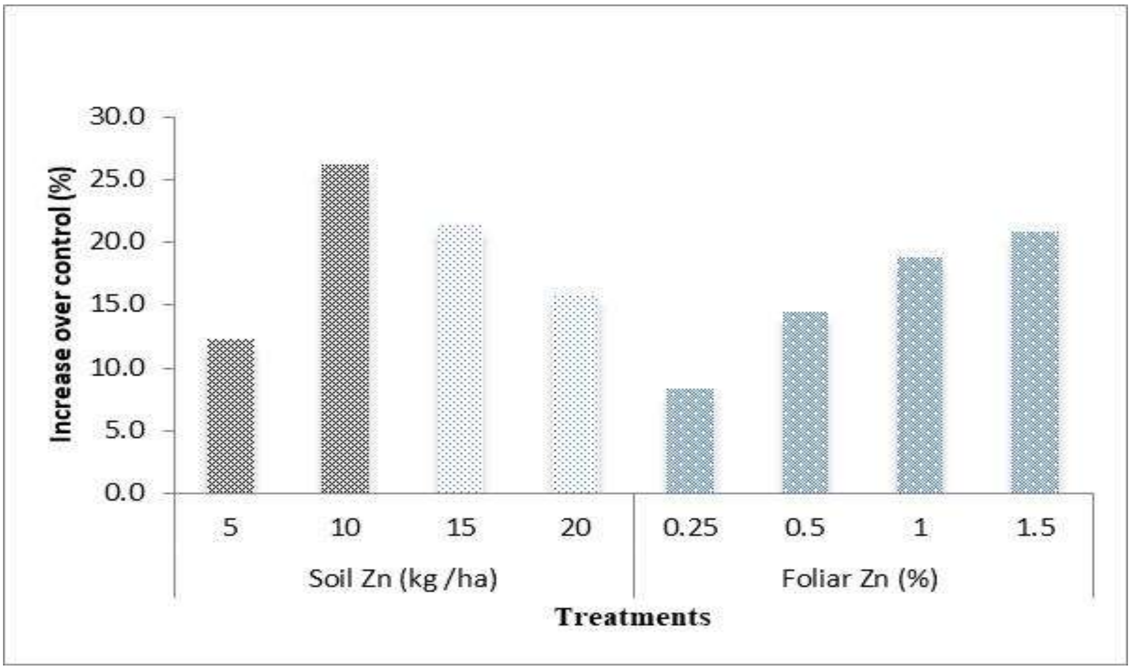

Fig. 4, Percent Change 1000 grain weight

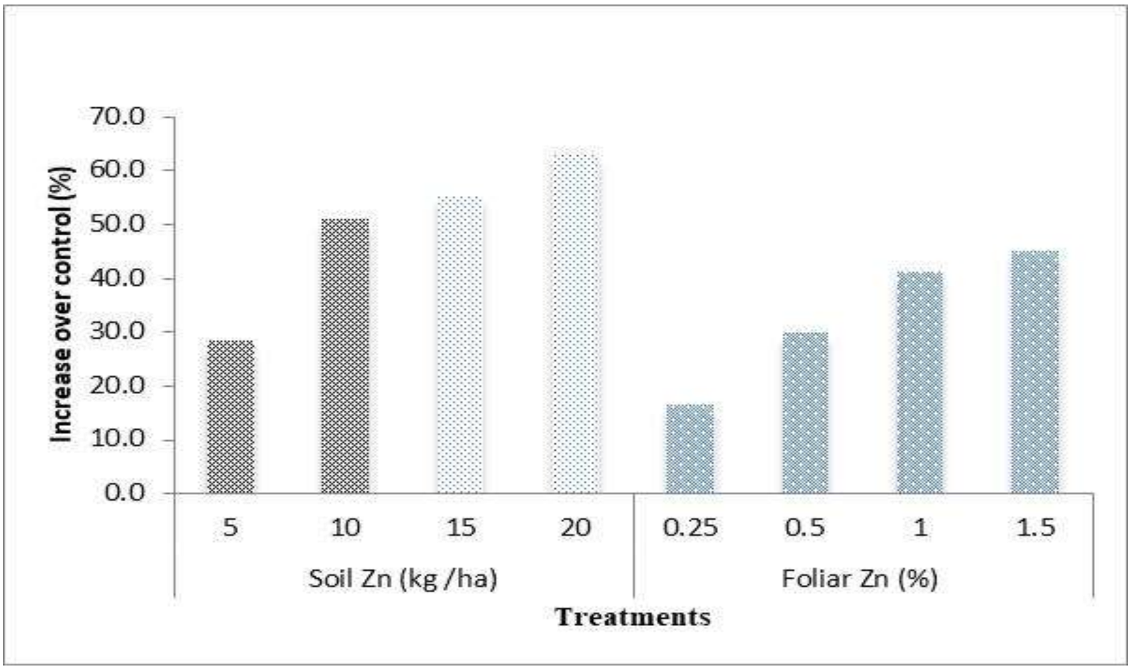

Fig. 5, Percent Change in Grain yield

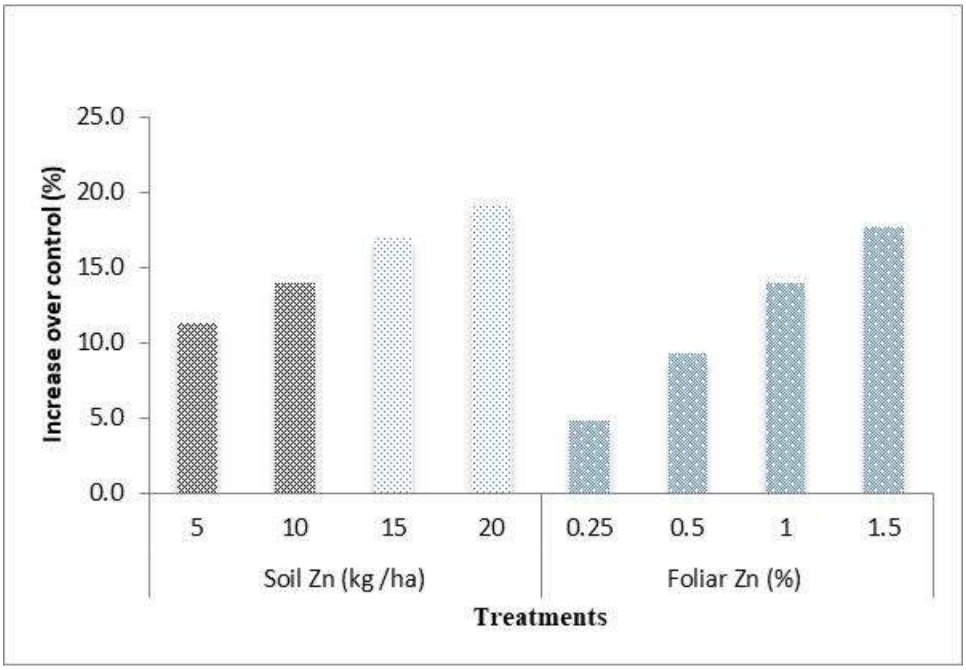

Fig. 6. Percent Change in Biological yield

Conclusion:

It was concluded from the current research that by applying two different zinc application, the agronomical parameters of maize plant were significantly enhanced. It was also concluded that soil application method is better than foliar spray application.

Recommendations:

The current study recommends to apply Zn @20 $kgha^{-1}$ by soil mixing method while 20 kg ha^{-1} as foliar. Furthermore, experiments should be conducted to study the effect of Zn applications in different regions.

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