RESEARCH ARTICLE

Effect of mode of Zinc application on yield and yield components of Maize

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Received: 22 June, 2022, Accepted: 19 July, 2022, Published: 25 July, 2022

Abstract
There are three main methods of adding micronutrients to crops: soil fertilization, foliar spray and seed treatment. Each method has the potential to affect plant micronutrient nutrition. The objective of this research was to evaluate different methods of Zn application in maize. For this purpose, a field experiment was conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar during summer 2006. The experiment was laid out in Randomized Complete Block design with three replications. Three methods of Zn application, soil application, foliar spray and seed treatment were included in the experiment. Three doses of Zinc sulphate (5, 10 and 15 kg ha^{-1}) were supplied to the maize crop as soil application before sowing. Solutions of 0% (water), 0.1%, 0.2% and 0.3% Zinc sulphate were sprayed on the crop at 5-6 leaf stage. For seed priming, the maize seed was soaked in 0% (water), 0.1%, 0.5% and 1% Zinc sulphate solutions for 16 h. The control treatment was dry seeds of maize. Soil application of Zinc sulphate at the rate of 15 kg ha^{-1} resulted in higher grains cob^{-1}, thousand grain weight and grain yield of maize. Planned mean comparison indicated that soil application of Zn was a superior fertilization method as compared to foliar or seed priming. It is concluded that soil application of Zinc sulphate at the rate of 15 kg ha^{-1} enhances yield and yield components of maize.

Keywords: Zinc suphate; maize crop; seed priming

Introduction

Zinc (Zn) deficiency in Pakistan was first recognized by Yoshida and Tanaka (1969) when Hadda disease of rice was diagnosed as Zn deficiency. Later research established the incidence of widespread Zn deficiency in all rice growing tracts of the country (Chaudhry and Sharif, 1975 and Kausar et al., 1976). Now Zn fertilization is widely recommended for rice. Zn deficiency has also been reported in wheat (Khattak and Parveen, 1986), maize (Rashid et al., 1979) and other crops (Tahir, 1981; Rashid and Qayyum, 1991). Based on extensive research on micronutrients in soils and crops, it has been estimated that now about 70% of the cultivated area of the country is considered Zn deficient. Zn deficiency is the third most serious crop nutrition problem in the country after N and P deficiency (Rashid, 1996). There are three main methods of applying micronutrients to crops: soil fertilization, foliar sprays and seed treatment. Foliar applications of micronutrient sprays are effective (Wilhelm *et al*., 1988; Savithri *et al*., 1999), but this method is too costly to be widely practiced by resource-poor farmers in some regions because of the amount of fertilizer, equipment and labour required for repeated spraying.

Likewise, the difficulty in obtaining high quality micronutrient fertilizers and spreading them evenly on the soil can be unaffordable. Treating seeds with micronutrients potentially provides a simple inexpensive method for improving micronutrient plant nutrition. Farmers in south Asia have responded favorably to seed priming, a simple technology of soaking seeds overnight in water prior to sowing (Harris, 1996; Harris *et al*., 1999). Seed priming in water has been shown to decrease time between sowing and emergence and to improve seedling vigour (Harris, 1996; Parera and Cantliffe, 1994). Likewise, priming seeds in solutions of macro or micronutrients has been shown to improve yield of rice (Peeran and Natanasabapathy, 1980), wheat (Khalid and Malik, 1982; Marcar and Graham, 1986; Wilhelm *et al*., 1988) and forage legumes (Sherrell, 1984), but the potential to damage the seed and inhibit germination by priming at high nutrient concentrations has also been reported (Roberts, 1948). There are several advantages of using seed priming to deliver micronutrients to seeds: the effects of uneven application of Zn to the soil are avoided as each seed is exposed to the nutrient; uptake is guaranteed; the amounts required are likely to be orders of magnitude less than for soil application. Conversely, risk of toxicity may be increased by priming.

There are several opinions regarding Zn application methods, for example, Graham and Rengel, (1993) reported that under Zn deficient soil conditions, plants grown from high Zn seeds produced more root and shoot biomass, enabling the plants to take up soil Zn more efficiently in later growth stages. Rush (1972) suggested that the application of low rates of Zn to rice seeds or dippling the roots of transplanted rice in a Zn solution may be effective alternative to broadcast applications of Zn fertilizer. Martens et al. (1973) concluded that band application of Zn fertilizer in contact with the corn seeds at rates ranging from 0.34 to 1.34 kg Zn ha^{-1} produced grains yields equal to those achieved when 26.9 kg Zn ha^{-1} as Zinc sulphate was broadcast on the soil surface and incorporated before planting. Yilmaz et al. (1997) also concluded that soil applied Zn was a superior fertilization method compared with Zn treated seed or foliar Zn applications. Kostas et al. (2005) reported that foliar spray of Zn did not lead to any significant increase in the yield components (spike mass, mass of kernels per spike and 1000 kernel mass) compared with the untreated plots. Other studies have not investigated a complete range of Zn seed treatment compare with standard soil or foliar Zn application methods (Slaton et al., 2001).

As very little work has been conducted on the comparison of different Zn application methods in maize, therefore the present experiment was designed to evaluate different methods of Zn application and to determine the most effective, viable and economical method of Zn application methods in maize for achieving higher yield and yield components of maize.

Materials and Methods

Experimental Site

The field experiment was conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar during summer 2006. Peshawar has a warm to hot, semi-arid, sub-tropical, continental climate with mean annual rainfall of about 360 mm. Summer (May–September) has a mean maximum temperature of 40 ^{o}C and mean minimum temperature of 25 ^{o}C. Winter (December to the end of March) has mean minimum temperature of 4 ^{o}C and a maximum of 18.4 ^{o}C. The average winter rainfall is higher than that of summer. The highest winter rainfall has been recorded in March, while the highest summer rainfall is in August. The soil of experimental site was silty clay loams (fine, silty, mixed calcareous, hyperthermic Udic Haplustalf) deficient in N, P and available Zn, but have adequate K. Canal water is available for irrigation (Harris et al., 2007).

Experimental Procedure

The experiment was laid out in Randomized Complete Block design with three replications. Three methods of Zn application, soil application, foliar spray and seed treatment were included in the experiment. Zinc sulphate ($ZnSO_4.7H_2O$) was used as a source of Zn. Three doses of Zinc sulphate (5, 10 and 15 kg ha^{-1}) were supplied to the maize crop as soil application before sowing. Solutions of 0% (water), 0.1%, 0.2% and 0.3% Zinc sulphate were sprayed on the maize crop at 5-6 leaf stage. For seed priming, the maize seed was soaked in 0% (water), 0.1%, 0.5% and 1% Zinc sulphate solutions for 16 hours. The control treatment was dry seeds of maize. Nitrogen and phosphorus were applied at the rate of 120 and 100 kg ha^{-1}. Urea and single super phosphate were used as sources of N and P, respectively. All phosphorus was applied at the time of sowing while nitrogen was applied in three split doses i.e. 1/3 at the time of sowing, 1/3 with 2nd irrigation and 1/3 at pre-tassling stage. The field was thoroughly ploughed three times at proper moisture condition to make a fine seedbed for maize sowing. Seed of maize variety Azam was sown with the help of a hand hoe on June 20, 2006 in 3m by 3m plot at the rate of 60 kg ha^{-1}. The row to row distance was 70 cm while plant to plant distance of 20 cm was maintained by thinning. All other agronomic practices were carried out uniformly.

The data were recorded on number of emergence m^{-2}, cobs plant^{-1}, grains cob^{-1}, thousand grain weight and grain yield of maize. Emergence m^{-2} data were recorded by counting number of plants emerged in one meter row length at three randomly selected rows in each plot. The data were then converted to emergence m^{-2}. To record number of grains cob^{-1}, grains of five randomly selected plants in each plot were counted and then averaged. For thousand grain weight data, a random sample of thousand grains was taken from the grain yield of each plot and weighed with an electronic balance to record weight for thousand grains. For recording grain yield data, three central rows were harvested in each plot with the help of a sickle. Cobs were removed from the harvested plants, dried, shelled and weighed with the help of an electronic balance and then converted into kg ha^{-1}.

Statistical Analysis

The data were statistically analyzed using analysis of variance appropriate for randomized complete block design. Means were compared using LSD test at 0.05 level of probability, if the F-values were significant (Steel and Torrie, 1984).

Results and Discussion

Emergence m^{-2}

Data regarding emergence m^{-2} of maize are reported in Table 1. Analysis of the data indicated that Zn application methods did not significantly affect emergence m^{-2} of maize. However, seed primed with 1% Zinc sulphate showed higher emergence m^{-2} (10) followed by dry seed, water soaked seed and soil applied Zinc sulphate at the rate of 15 kg ha^{-1} all having same emergence m^{-2} (9). Minimum emergence m^{-2} (6) was recorded for soil applied Zn at the rate of 5 kg ha^{-1}. The foliar spray plots were considered as control because no foliar spray was done at the time of emergence of maize crop. Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses (Heydecker and Coolbaer, 1977; Bradford, 1986). The results agree with the findings of Harris *et al*. (2001) who reported that the direct benefits of seed priming in all crops included faster emergence, better, more and uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield.

Planned mean comparison indicated that the difference between control vs rest, control vs water and seed priming vs soil application were not significant.

Cobs palnt^{-1}

Data regarding cobs plant^{-1} of maize are reported in Table 1. Analysis of the data indicated that Zinc application methods did not significantly affect cobs plant^{-1} of maize.

Planned mean comparison indicated that the difference between control vs water was found significant while the differences among all other planned comparisons were not significant. Water soaked seed resulted in greater number of cob plant^{-1} as compared to control. The resulting improved stand establishment in primed seed plots may be a reason for more cobs plant^{-1} in water soaked seed plots. Similar results were noted by Sharma *et al*. (1993) who attributed higher yield to early floral initiation, more flowers and pods plant^{-1} in salicylic acid primed seed. The increase in cobs plant^{-1} of primed seed plots may be due to the fact that primed seed emerge faster and more uniformly and seedlings grow more vigorously, leading to a wide range of phonological and yield related benefits (Harris *et al*., 2000).

Grains cob^{-1}

Data regarding grains cob^{-1} of maize are reported in Table 1. Analysis of the data indicated that Zinc application methods significantly affected grains cob^{-1} of maize. Soil application of Zn at the rate of 15 kg ha^{-1} produced higher grains cob^{-1} (399) followed by foliar spray of water. Minimum grains cob^{-1} was recorded for foliar spray of 0.1% Zn solution.

Planned mean comparison indicated that the difference between foliar spray versus soil application was found significant while the differences among all other planned comparisons were not significant. Soil application of Zn produced significantly more grains cob^{-1} as compared to foliar spray. Similar results were reported by Gul and Enos (1988) who found that seed number per pod in lentil tended to increase with increase in phosphorus levels in combination with Zn.

Thousand grain weight

Data regarding thousand grain weight of maize are reported in Table 2. Analysis of the data indicated that Zinc application methods significantly affected thousand grain weight of maize. Soil application of Zn at the rate of 15 kg ha^{-1} resulted in higher grain weight followed by soil application of Zn at the rate of 10 kg ha^{-1}. Minimum thousand grain weight was recorded for control plots.

Planned mean comparison indicated that the differences among control versus rest, control versus water, seed priming versus foliar spray, seed priming versus soil application and foliar spray versus soil application of Zn were significant. Zn application and water soaking produced more grain weight as compared to control. Seed priming produced more grain weight than foliar spray and soil application of Zn produced more grain weight as compared to seed priming and foliar spray. Similar results were obtained by Gul and Enos (1988) who reported that Zn application alone produced heaviest grains in lentil. These results agree with Naveed et al. (2005) who reported that Zn application at the rate of 10 mg kg^{-1} resulted in 21% increase in grain weight of mungbean cultivars as compared to control.

Grain yield

Data regarding grain yield of maize are reported in Table 3. Analysis of the data indicated that Zn application methods significantly affected grain yield of maize. Soil application of Zn at the rate of 15 kg ha^{-1} produced higher grain yield followed by seed priming in 0.1% Zn solution. Minimum grain yield was recorded for foliar spray of 0.2% Zn solution.

Table 1. Mean square values for emergence m^{-2}, cobs $plant^{-1}$, grains cob^{-1}, thousand grain weight and grain yield of maize as affected by Zn application methods.

SOV	DF	Emergence m^{-2}	Cobs $plant^{-1}$	Grains cob^{-1}	Thousand grain weight (g)	Grain yield (kg ha^{-1})
Replications	2	9.35 ns	0.0063 ns	449.07 ns	0.527 ns	556132.65 ns
Treatments	11	6.65 ns	0.0040 ns	10272.05 *	721.54 *	716229.75 *
Control vs Rest	1	1.44 ns	0.0050 ns	640.18 ns	2303.09 *	204525.97 *
Control vs Water	1	1.04 ns	0.0150 *	1688.96 ns	216 *	489795.91 ns
SP vs FS	1		0.0070 ns	16226.0 ns	800 *	1551902.50 *
SP vs SA	1	7.73 ns	8.535 ns	3688.45 ns	3120.5 *	113378.68 ns
FS vs SA	1		0.0086 ns	35378 *	760.5 *	2504215.43 *
Error	22	4.8	0.0020	4196.52	9.77	306272.42

SP = seed priming, FS= foliar spray, SA = soil application
ns = Non significant, * = significant at 0.05 level of probability

Table 2. Emergence m^{-2}, cobs $plant^{-1}$, grains cob^{-1}, thousand grain weight and grain yield of maize as affected by Zn application methods.

Treatment	Emergence m^{-2}	Cobs $plant^{-1}$	Grains cob^{-1}	Thousand grain weight (g)	Grain yield (kg ha^{-1})
Dry seed (Control)	9	0.95	290	109	3619
Water soaking	9	1.05	256	121	3048
SP in 0.1% Zn solution	9	0.97	302	123	2857
SP in 0.5% Zn solution	8	1.00	309	126	3619
SP in 1% Zn solution	10	1.01	323	132	4000
FS of water	9	1.02	389	131	3619
FS of 0.1% Zn solution	7	1.00	297	134	3333
FS of 0.2% Zn solution	6	0.93	287	143	2190
FS of 0.3% Zn solution	6	0.94	170	145	2857
5 kg Zn ha^{-1}	6	0.98	320	140	3143
10 kg ha^{-1}	7	1.00	301	155	3714
15 kg ha^{-1}	9	1.02	399	166	4095
LSD	ns	Ns	61.07	2.95	521.77
Planned Mean comparisons					
Control	9 ns	0.95 ns	290 ns	109 *	3619 ns
Rest	8	0.99	305	138	3316
Control	9 ns	0.95 *	290 ns	109 *	3619 ns

Water	9	1.05	256	121	3048
Seed priming	9 *	1.00 ns	311 ns	127 *	3492 *
Foliar spray	6	0.96	251	141	2794
Seed priming	9 ns	1.00 ns	311 ns	127 *	3492 ns
Soil application	7	1.00	340	154	3651
Foliar spray	6 ns	0.96	251 *	141 *	2794 *
Soil application	7	1.00	340	154	3651

SP = seed priming, FS= foliar spray, SA = soil application
ns = Non significant, * = significant at 0.05 level of probability

Planned mean comparison indicated that the differences between seed priming versus foliar spray and foliar spray versus soil application of Zn were significant. Seed priming and soil application resulted in greater grain yield as compared to foliar spray. Similar results were reported by Yilmaz *et al.* (1997) who concluded that soil applied Zn was a superior fertilization method compared with Zn treated wheat seed or foliar Zn applications. Similar results were reported by Shah *et al*. (1985) and Rehman and Barnard (1988) who obtained maximum yields in maize and lentil with the application of 10 and 5.5 kg Zn ha^{-1} as compared to control, respectively. These results agree with Gill et al. (2002) who recorded significantly higher grain yield in maize with application of 15 kg Zn ha^{-1}. Likewise, Naveed et al. (2005) reported that Zn application at the rate of 10 mg kg^{-1} produced significantly higher grain yield in mungbean cultivars as compared to control. These results are also in line with Shukla and Mukhi, 1979; Sharma et al. (1990) who demonstrated increase in cob yield per plant with zinc supplementation by irrigation. However, these results do not agree with Johnson et al. (2005) who reported that soil fertilization with Zn had no effect on yield of chickpea, lentil, rice and wheat but resulted in small increase in concentration of Zn in wheat grain.

Declaration

Acknowledgment: None

Funding: None

Conflict of Interest: N/A

Authors contribution: Sole author

Data availability: From the author

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