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Fortification of Locally Developed Single Super Phosphate With Zinc Sulphate for Enhanced Zinc Nutrition to Maize Crop Under Calcareous Soil Conditions

JAMIL AHMAD*, DOST MUHAMMAD, MUJIBUR RAHMAN and MARIA MUSSARAT

Department of Soil and Environmental Sciences, University of Agriculture Peshawar, Pakistan.

Abstract

A study was carried out in calcareous soil (low in ABDTPA extractable phosphorus and zinc) to evaluate the effect of zinc fortified locally developed single super phosphate fertilizers on maize grown in summer 2016. Zinc fortified fertilizers were prepared in laboratory of soil science department, University of Agriculture Peshawar, Pakistan. Treatments consisted of mixing two levels of zinc 5 and 10 kg ha^{-1} with SSP during its formulation by three methods of fortification coating, blending and reaction along with separate application and no application of zinc or a control treatment. Results showed the two levels of zinc mixed by different methods with SSP significantly influenced various appraised parameters of maize crop variety. With varying zinc level and fortification methods thousand grain weights, biomass yield and zinc concentration in leaves and grain were influenced significantly. Zinc at the rate of 10 kg ha^{-1} fortified with SSP through coating method produced maximum yield and yield components. Zn concentrations were higher in grains than leaves.It was concluded form the study that zinc (at the rate of 10 kg ha^{-1}) mixed with phosphate fertilizer by coating produced highest maize grain yield and this method can be recommended for calcareous soil conditions of Peshawar.

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Introduction

Zinc is one of the essential micronutrients required for better growth and higher grain yields of crops. Crops require 15–20 mg kg^{-1} of Zn on dry weight basis for completion of various physiological and metabolic processes. Zinc is involved in synthesis of protein, metabolism of carbohydrate and nitrogen, auxin production, protein synthesis and quality, stability of genetic material, photosynthesis and chlorophyll synthesis, carbon anhydrase activity; resistance to abiotic and biotic stresses and protection against oxidative damages[5,6]. Zinc is a structural component

CONTACT Jamil Ahmad jamil@aup.edu.pk Department of Soil and Environmental Sciences, University of Agriculture Peshawar, Pakistan.

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of thousand of proteins in organisms, human body contains 1.5–2.5 g Zn and require about 10–14 mg zinc per day[27]. Zinc deficiency causes diarrhea and stunting build in children[18], that causes economic costs to families[24,25]. Almost 0.7 % of world diseases are associated with zinc deficiency, increasing up to 1.5 % in poor countries[28]. With exception of plants, other organisms fulfill the requirements of zinc from animal and plants sources for normal functioning of their bodies. Zinc is important for nutrition of organisms but it is deficient in most soils. Zinc deficiency not only affects plants growth and grain yield but also affect health of human beings. It is prevalent throughout the world; more than 50 % of cereal crops growing soil are zinc deficient[21]. Zinc deficiency has affected >50 % of soils in India, Pakistan and Turkey and >30 % of soils in China, Western Australia and Africa[1]. Soils that have less than 1.5 and 1.0 mg kg^{-1} of (EDTA) and (DTPA) extracts are considered zinc deficient soils[26,11]. The easier strategy to solve this problem on a large scale is application of zinc fertilizers to soil. Zinc fertilizers that can be applied to soil include zinc oxide and zinc sulphate etc. For calcareous soil zinc sulphate is better than zinc oxide. Zinc applied in mixed form with other fertilizer can be a good plane for overcoming zinc deficiency.There are many advantages of fortified fertilizers, for example the zinc fortified fertilizer will act as a compound or complex fertilizer and at one application both zinc as well as the other mixed fertilizer (s) will be available for plant uptake at one application. Zinc sulphate has been tested with macronutrients fertilizers such as Urea and DAP by coating method. But only rare data is available on research about mixing zinc with phosphate fertilizers.

[15]carried out trials on maize crop in spain on zinc lignosalfonate (ZnSL)adhered to NPK (8:15:15) to evaluate efficiency of NPK fertilizer, and compared it to $ZnSO_4$ adhered as well as Zn not adhered in 3 experimental designs in two locations, first location growth chambers and second location agriculture fields. Out of 3 designs, 2 designs were employed in growth chambers and 3rd design in field trials. In growth chambers, using calcareous soil and perlite as substrate, zinc lignosulfonate adhered produced highest dry weight, grain yield and zinc content in shoots. Also in second location, two fields trials, zinc concentration was highest in NPK+ZnLS, but there was no significant difference in grain yield in 2nd location for applied treatments.They recommended NPK+ZnLS butalso suggested further research for evaluation of results.

The present study was carried out with the objective to formulate a fertilizer that is easier for farmers to get the need of zinc fulfilled in one application with the first required fertilizer already needed to be applied. To know if zinc fortified fertilizer can be helpful in improving crop yield.

Materials and Methods

Preparation of Fertilizers

Locally developed SSP fertilizer was prepared in the laboratory of Soil and Environmental Sciences University of Agriculture Peshawar. Two levels of zinc 5 kg ha^{-1} and 10 kg ha^{-1} were mixed with SSP during and after preparation of SSP fertilizer to supply coated, blended and reaction zinc fortified SSP fertilizers. For two rates of zinc, same procedure followed. SSP supplied 100 kg ha^{-1} of P_2O_5. A brief description of local manufacturing is as follow; (1) SSP: To 100 kg RP in ground form, 60 L sulphuric acid (commercial grade acid) was added with 50% dilution i.e. (30 L water + 30 L acid + 100 kg ground RP). (2) Blending: First the mixture for fertilizer (SSP) was prepared by adding water, acid and RP as described in preparation of SSP. After 14 days, zinc sulphate was added to this SSP and thoroughly mixed. (Note): Some water can be added if the SSP paste got dried. Then granules were prepared by passing the paste through metal sieve mesh, dried in sun or under a fan. Old news papers were used to place granules over for drying purpose. (3) Coating: Then zinc sulphate was added to water, stirred well. Once SSP granules were prepared $ZnSO_4$ solution was sprayed on it to get Zn coated SSP fertilizer and later dried for further usage. (Note): It is important to mix zinc sulphate thoroughly and completely and use a sprayer that is efficient and good quality. (4) Reaction: For reaction method, RP and zinc sulphate were mixed uniformly. (then same procedure followed as SSP); acid and water were added to the mixture, cooled at room temperature and granules were prepared.

Crop Experiment

Maize was grown in summer 2016 (one year experiment); layout for experiment was RCBD with three replications (blocks). There were 9 plots in each block including control where zinc was not applied. Size of one experimental unit was 2.5*4.5 m^2. Distance between one block to the next block and between two experimental units was half meter in the form of a water channel. All fertilizers were applied, thoroughly incorporated in root zone (upper 15 cm) soil, using a rotavator, after that maize seeds were sown by drill and then ridges were built to avoid mixing of treatments when irrigated. Half dose of nitrogen (of total at the rate 120 kg ha^{-1}) as urea wasapplied at sowing and second half at silking stage, full dose of potassiumas MOP was applied at the rate of 60 kg ha^{-1}. Phosphorus was applied as single super phosphate at the rate of 100 kg ha^{-1}. While zinc as zinc sulphate was applied in two levels 5 and 10 kg ha^{-1} separately, (not premixed with phosphorus fertilizer served as a control for comparing with mixed fertilizers) and as mixed phosphorus fertilizer (single super phosphate mixed with zinc sulphate) by coating, blending and reaction. Normal activities of weeding, irrigation, insect and disease control were followed during growth season. At maturity stage (standing crop) and after harvesting data was collected for desired parameters and analyzed using excel 2007 and statistix 8. At least ten plants were randomly selected from each experimental unit and then averaged for data recording. Soil composite samples were collected before sowing and after harvesting and analyzed for various physicochemical properties i.e. pH, EC[16], P, Zn, P[23], OC[14], N[4] and $CaCO_3$[3].

Table 1: Physico-chemical properties of soil

S.No	Soil Property	Value	Unit
1	pH (1:5)	7.75	-
2	EC (1:5)	0.19	d S m^{-1}
4	AB-DTPA extractable P	2.31	mg kg^{-1}
5	ABDTPA extractable Zn	0.19	mg kg^{-1}
6	Soil Organic Carbon	0.53	%
7	$CaCO_3$ Content	17.3	%
8	N	12.5	mg kg^{-1}
9	K	97	mg kg^{-1}

Results and Discussions

Physico-Chemical Properties of Experimental Field Soil

The soil on which crop was grown contained low organic matter, had alkaline pH, non saline, low in available nitrogen, phosphorus and zinc, adequate in potassium. High calcareous and silty clay loam textured.

Grain Yield

Zinc mixing methods with single super phosphate and two levels causeda prominent variation in terms of grain yield of maize when the treatments were compared with one another and with control (table 2). Maximum grain yield (4.88 t ha^{-1}); was obtained from treatment of 10 kg ha^{-1} zinc fortified with SSP through coating methodand lower grain yield (3.24 t ha^{-1}) was obtained from check plots where zinc was not applied. Zinc application significantly increased cob length, number of grains cob^{-1} and thousand grains weight that subsequently increased grain yield. When values of grain yield (kg ha^{-1}) were averaged across the zinc fortification methods of coating, blending, reaction with SSP and direct application to soil for the two levels (5 & 10 kg ha^{-1}), the percent increases (%) over control were 24.83, 20.88, 23.4 and 17.58 respectively. Higher grain yield due to Zn application could be due to the full functioning of zinc in activation of enzymes and production of auxin[17], improvement in production of CHO and their transfer to the site of grain production[2]. There are many factors that affect release and absorption of zinc. Acidity/alkalinity or reaction of fertilizer is also a factor that influences absorption of nutrients. Due to low pH of the fertilizer, it affects the pH of soil solution. All the micronutrients are available at acidic pH of soil. A single unit increase in pH causes more than 100 times decrease in availability of Zn to crops. If fertilizer is near to root, then it also affects the rhyzosphere the maize.[12]

correlated pH of the orthophosphate solution with agronomic effectiveness of zinc incorporated into fertilizer; this relation was opposite or inverse with pH of solution, i.e. agronomic effectiveness was lower at higher pH of solution and vice versa. As we know most of the micronutrients are soluble at low pH of soil, phosphate fertilizer (acidic in nature) provides a favorable environment for zinc to become available for roots uptake from soil solution. In our present study, zinc application improved the grain yield many folds which is not unusual, other scientists have already obtained higher yields when applied zinc as seed priming, foliar and soil application, but fortified phosphate fertilizer has not been studied extensively in zinc deficient soils.

Biological Yield

Zinc application significantly influenced biological yield of maize (table 2). With increasing zinc levels (0, 5 and 10 kg ha^{-1}), biological yield increased gradually in both separate application to soil and in fortification form with SSP by coating, blending and reaction methods. Coating at rate of 10 kg ha^{-1} zinc on SSP fertilizer was superior (11.4 ton ha^{-1} B.Y) as compared to blending, reaction and soil application. All other treatments performed better than control treatment where zinc was not applied, showing that zinc application is beneficial in terms of vegetative and reproductive growth of crops, because of its role in activation of enzymes involved in photosynthesis processes and growth hormones. Because of better growth the overall biological yield was improved many fold as compared to control. The averaged percent increases (average of 5 and 10 kg ha^{-1} zinc) over control were 13.66, 20.20, 10.73 and 10.04 percent for blending, coating, reaction and direct separate soil application respectively. Researchers had reported increase in biological yield with zinc application to soil, through seed priming, foliar and fortification methods as well in fertigation methods. In our study the increase in biological yield might be due to high availability of zinc to crops by coating method. Zinc coated on SSP might had easily dissolved to soil solution and hence absorbed by roots resulting increased weight of stem and leaves of maize. Similar results were reported by[19], they found higher dry mass yield and accumulation of micronutrients in shoots from coating of NPK fertilizers with Zn, Cu, Mn and boron compared to physical mixing of major and minor nutrients. The micronutrients he fortified with NPK by coating were Zn, Cu, Mn and boron. [9]Reported good solubility of zinc from blended zinc oxide and copper sulphate with ordinary super phosphate fertilizers. They reported that the acidic solution developed inside fertilizer granules solubilized most of Cu, zinc and readily absorbed by plant roots.

Plant Height (cm)

Plant height is affected by both genetic and environmental factors. The treatments showed non-significant effect when compared to one another however; all zinc treated plots showed longest shoot length when compared to control with no zinc (table 2). Maximum plant length was 161.9 cm from plots treated with coated SSP fertilizers. Zinc deficiency caused comparatively short internodes in control plants.Averaged percent increase in stem length for blending, coating; reaction and direct application to soil (both levels of zinc), over control were 4.13, 5.91, 3.3 and 3.70 percent respectively[20]. Reported that height of rice plants was not affected by various levels of zinc however;[29] concluded significant effect as a result of zinc application on height of crops. Response to zinc for plant height parameter can be related to genetic makeup of plants, different varieties respond differently to fertilizers. Our findings are in positive compliance with[8], who reported non-significant effect of zinc on plant height was observed in different maize cultivars. Genetic makeup of plants might be responsible for no variation in height of plants. Genetically different varieties vary from one another but plants are similar within one variety. [13]Also got non-significant effect of zinc on the height of corn plants at harvesting stage, however during early growth zinc treated plants showed more height than zinc non-treated plants.

Zinc Concentration in Maize Tissues and Grain (mg Kg^{-1})

Zinc concentration of tissue and grain is given in table (2), which shows a significant effect of zinc accumulation in tissue and grain. Maximum zinc content was recorded from coated zinc fertilizers (26 mg kg^{-1}) in tissue and 29 mg kg^{-1} in grains. The averaged percent increase of zinc concentration in leavesas compared to control for (5 & 10 kg ha^{-1} zinc) were 27.78, 32.64, 26.15 and 22.51 percent for blending, coating, reaction and direct application to soil respectively. In the same way the average zinc concentration values (percent increase over control) in maize grains for two levels of zinc (5 and 10 kg ha^{-1}) were 12.05 (blending), 24.08 (coating), 17.05 (reaction) and 17.40% (direct soil application).This could be attributed to the better solubility of zinc from coated SSP granules, as it is readily soluble in soil solution as compared to other mixing methods.[7] Reported that proper Zn application improved zinc absorption in the plant roots and its deposition in the grains. Similar findings were reported by[22], who recorded increased in the grain Zn content of maize with application of Zn as compared to control. Similarly,[10] recorded increase in grain Zn concentration of maize crop by the proper application of $ZnSO_4$ to the roots medium. By comparing effect of two levels of zinc, increasing zinc level increased the concentration of zinc in plant. In most cases the concentration of zinc decreased with increasing level of phosphorus showing an antagonistic relation with one another, but in our case we applied only one level of phosphorus that is 100 kg ha^{-1} of P_2O_5 which is normal level for calcareous soil and not a higher level, that's why effect of P was not significant on decreasing the concentration of zinc in plant of maize.

Table 2: Grain yield, 1000 grain weight, biological yield, plant height, tissue zinc and grain zinc concentration as affected by different mixing methods of zinc with SSP

Fertilizer rate kg ha^{-1}	Fertilizer rate kg ha^{-1}	Type of mixing	Grain Yield	Bio. Yield	Plant height	Tissues zinc	Grain zinc
SSP	**zinc**	**t ha^{-1}**	**t ha^{-1}**	**cm**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**
100	-	Control	3.24 d	7.9 d	149.6 b	16.1 d	19.7 c
100	5	Separate	3.71 cd	8.4 cd	155.7 ab	19.3 bd	23.8 bc
100	5	Blending	3.94 bd	8.0 cd	154 ab	21.9 ac	23.7 bc
100	5	Coating	3.74 cd	8.4 cd	156.1 ab	21.8 ac	22.9 bc
100	5	Reaction	3.91 bd	8.3 cd	153.9 ab	19.0 cd	23.3 bc
100	10	Separate	4.18 bc	9.2 bd	155 ab	22.5 ac	23.9 bc
100	10	Blending	4.25 bc	10.3 ab	158.2 a	22.5 ac	21.1 bc
100	10	Coating	4.88 a	11.4 a	161.9 a	26.0 a	29.0 a
100	10	Reaction	4.55 ab	9.4 bc	155.3 ab	24.6 ab	24.2 b
CV %	5.10	9.4	0.67	14.672	10.34	14.67293	10.34
LSD	21.9	1.4	9.66	6.87	4.91	6.87	4.91

Conclusions

Single super phosphate fertilizer (providing phosphorus in plant available form at the rate of 100 kg ha^{-1}) coated with zinc suphate (providing zinc in plant available form at the rate of 10 kg ha^{-1}) improved the grain yield, biomass yield, thousand grains weight, zinc concentration in maize plant tissue and grainsmore than the blended, reaction or direct separate soil applied fertilizers, under calcareous soil conditions, so coating method at 10 kg ha^{-1} can be recommended for maize crop in calcareous soil series.

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