

Original Research Article

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Effect of Zinc Application on Yield Attributes and Yield of Maize and Wheat in Maize-Wheat Cropping System

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ABSTRACT

An experiment was conducted during 2009-10 and 2010-11 at research farm of division of Agronomy, IARI, New Delhi, to study the effect of various doses and methods of zinc application on maize and wheat. The treatment consisted of control, 12.5 kg ZnSO₄ ha⁻¹, 25 kg ZnSO₄ ha⁻¹ and foliar spray of 0.5 % ZnSO₄ and two wheat Varieties 'DBW 17' and 'PBW 343'. The grain, stover and biological yield of maize were significantly influenced by application of zinc during first year and the maximum yields were recorded with the application of 25 kg ZnSO₄ ha⁻¹ during both the year. During first year application of 25 kg ZnSO₄, 12.5 ZnSO₄ ha⁻¹ and foliar spray of 0.5 % ZnSO₄ increased grain yield by 22.81, 18.63 and 8.36 percent respectively over control, while 4.10, 2.41 and 1.69% increase in grain yield was recorded during second year. In wheat, application of 25 kg ZnSO₄ ha⁻¹ significantly increased 1000 grain weight during both the years while during second year effective tiller m⁻², grain spike⁻¹ and grain diameter; as compared to the remaining treatment. This treatment increased the number of effective tillers by 6, 10 and 11 percent over the application of 12.5 kg ZnSO₄ ha⁻¹, foliar spray and control, respectively, during second year. Direct application of zinc to wheat varieties i.e. 'DBW 17' and 'PBW 343' showed significant variation in grain, straw and biological yield and harvest index during both the years. The yield advantage of 0.35, 0.26 and 0.28 and 0.43, 0.13 and 0.29 t ha⁻¹ was recorded with the application of 25 kg ZnSO₄ ha⁻¹ over control, 12.5 kg ZnSO₄ ha⁻¹ and foliar spray, respectively. Highest straw and total biological yields were obtained with the application of 25 kg ZnSO₄ ha⁻¹.

Keywords

Zinc, Harvest index, Yield, Maize-wheat cropping system

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Introduction

Maize and wheat is the main source of world's food energy and also contains significant amounts of proteins, minerals and vitamins

which are highly essential nutrients for human health. Wheat is a major important crop along with other cereals supplies the bulk of calories and nutrients in the diets of a large proportion of population (Water *et al.*, 2009; Chatzav *et*

al., 2010). Globally, India ranks as second largest wheat producing nation and contributes near about 11.9% to the world wheat production from about 12% area of world (Singh *et al.*, 2010). Study conducted across the country and shows stagnating or declining rice and wheat yields in the Indo-Gangetic Plains, which have likely been related to soil fertility and frequent appearance of micronutrient deficiency especially, zinc (Benbi *et al.*, 2012).

Maize is considered a promising option for diversification of agriculture in upland areas of country and now it is recognised as the third most important food grain crop in the nation. The maize area has slowly increased over the past few years to about 6.2 million ha (3.4% of the gross cropped area) in 1999/2000 (Joshi *et al.*, 2005). It also predicted that area under this crop would grow further to fulfil future food, feed, fodder and other requirements, especially in view of the booming livestock and poultry farming sectors in the country. It not only in our country, but also in our neighbouring country China wheat-maize (*Zea mays* L.) rotation is a predominant cropping system, covering up to 60% of arable land (Liang *et al.*, 2012). Since opportunities are limited for further expansion of maize area, therefore future requirements of maize grain may be achieved through the intensification of current maize production system. It is quite visible now days that micro nutrient getting deficient and the capacity of soils to supply Zn for optimal crop growth vary widely too. Soils deficient in their ability to supply Zn to crops are alarmingly widespread across the world, and it occurs most frequently in arid and semi-arid regions of the including Pakistan, India, Turkey, China, etc. Zn deficiency has been reported in a number of crop species like rice, maize, cotton, etc. (Behera *et al.*, 2011; Ram *et al.*, 2010; Khan and Joergensen, 2010; Cakmak *et al.*, 1999).

Deficiency of zinc affect the yield and quality of crops over large areas of the world's cultivable land (Genc *et al.*, 2009; Coventry *et al.*, 2011; Misra *et al.*, 2005). Micronutrients play an active role in the plant metabolic processes beginning from cell development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation etc.

Micronutrient requirements of the maize and wheat crops are relatively low and ranges between their deficiencies and toxicities in plants and soils are quite narrow. Unlike the malnutrition that is due to lack of food and which has drawn the attention globally, the hidden hunger of micronutrient deficiencies affect severely to even more people and damage is long lasting on human kind and their societies (Teng *et al.*, 2012; Patel *et al.*, 2011; Cakmak 2002; Simic *et al.*, 2012). The main reason behind the wide-spread emergence of Zn deficiency in country; after the Green Revolution high nutrient exhaustive crop rotations followed such as rice-wheat along with imbalanced fertilization and high doses of nitrogen, nutrient uptake by both grain and straw from the field and very less or negligible application of organic manures (Suri *et al.*, 2011). Zinc deficiencies can be corrected in most cases by applying a granular Zn fertilizer or applying it with the starter macronutrient (NPK) fertilizer either as a coating or incorporated into the macronutrient granule and zinc sulfate (ZnSO₄) has been the Zn source of choice.

Materials and Methods

The field experiments were conducted during *kharif* and *rabi* seasons of 2009-10 and 2010-11 at the Research Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi, situated at 28.4⁰N latitude and 77.1⁰E longitude and at an altitude of 228.6 meters above mean sea level. The

climate of site is semi-arid to sub-tropical with extreme cold and hot situations. Average annual rainfall of the site is about 652 mm, 84 % of which is received during south-west monsoon. The mechanical analysis of soil was done using hydrometer method (Bouyoucos, 1962) and the soil was sandy loam in soil texture. The soil of experimental site was normal in reaction, pH 7.8 (1:2.5 soil: water ratio) (Piper, 1950), medium in organic C, 0.38% (Walkey and Black, 1934), low in alkaline permanganate oxidizable nitrogen, 163.2 kg N/ha (Subbiah and Asija, 1956), medium in available P, 12.2 kg ha⁻¹ (Olsen *et al.*, 1954) and 1 N ammonium acetate exchangeable K, 239 kg ha⁻¹ (Jackson, 1973) and DTPA extractable Zn, 0.72 ppm (Lindsay and Norvell, 1978).

The experiment was conducted in split plot design with three replications in a fixed layout. The main-plot treatments consisted of four levels of zinc sulphate (heptahydrate) ZnSO₄ · 7H₂O and two methods of zinc application to maize *viz.* control, 12.5 kg ZnSO₄ ha⁻¹, 25 kg ZnSO₄ ha⁻¹ and foliar spray of 0.5% ZnSO₄ at knee height stage and one week later after previous spray, whereas the sub-plot treatments applied to wheat were four Zn levels *viz.* control, 12.5 kg ZnSO₄ ha⁻¹, 25 kg ZnSO₄ ha⁻¹, and two foliar sprays of 0.5% ZnSO₄ at anthesis and one week after previous spray on two wheat varieties 'DBW 17' and 'PBW 343'. The maize variety 'PEHM 2' was sown with row spacing of 60 cm apart during *kharif* and wheat varieties 'PBW 343' and 'DBW 17' were sown in lines at 22 cm apart during *rabi* season.

Observations

Yield attributes, *viz.* number of grain/cob, number of grain row/cob, 1000-grain weight, girth of cob, and length of cob for maize whereas in wheat number of spikes/m², grains/spike, length of spike, 1000-grain

weight were recorded. The biological yield, grain yield and stover yields were recorded. The harvest index was calculated as the ratio of economic produce (grain yield) and the biological yield (grain + stover or straw).

Statistical analysis

The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a split plot design using MSTAT-C software. Source of variation and corresponding degrees of freedom used in the ANOVA are given in Annexure-I. The results are presented at 5% level of significance (P=0.05).

Results and Discussion

Yields attributes and yield of maize

In present study, yield attributes *viz.* number of grain cob⁻¹, 1000-grain weight, number of grain row cob⁻¹, cob length and cob girth of maize and grain weight spike⁻¹ of wheat were not affected significantly with the application of zinc (Table 1 and 2). However, these parameters were slightly better with the application of 25 kg ZnSO₄ ha⁻¹ to both the crops during the course of study. This might be due to the better role of Zn during reproductive phase of crop growth. The application of 25 kg ZnSO₄ ha⁻¹ increases the yield of wheat as compared to control.

However (Singh *et al.*, 2009) observed that application of 15 kg ZnSO₄ ha⁻¹ found more responsive to 'PBW 343'. Zinc application significantly increases yield of maize (Shukla and Prasad 1974; Sajedi *et al.*, 2010).

The maize grain, stover and biological yields were significantly influenced by zinc application during first year (Table 3) and maximum yields were recorded with the application of 25 kg ZnSO₄ ha⁻¹ during both

the year. During first year grain yield due to application of 25 kg ZnSO₄ ha⁻¹ was higher by 22.81, 18.63 and 8.36 percent and 4.10, 2.41 and 1.69 percent was higher over control, foliar spray of 0.5 % ZnSO₄ and 12.5 kg ZnSO₄ ha⁻¹ during second year, respectively. This might be due to more yield attributing character recorded with the application of 25 kg ZnSO₄ ha⁻¹ and more source translocate towards sink. Sachin *et al.*, (2011) recorded that significantly higher grain yield of maize with increasing dose up to 50 kg ZnSO₄ ha⁻¹. Application of 1 to 2 kg Zn ha⁻¹ to maize increases the grain yield in range of 814-1747 kg ha⁻¹ (Osiname *et al.*, 1973). Comparing different level of zinc application to crop showed that increase in 100 seed weight and seed yield, obtained by zinc spraying (Salehin and Rahman, 2012). The overall performance of yield attributes was better during second year in comparison to first year because the most important weather parameter i.e. rainfall distribution and quantity was more during second year which helped in better crop growth that ultimately reflected in the yield of crop. The dry matter production of maize increased with the increasing zinc levels using three sources of zinc (Goos *et al.*, 2000).

Yields attributes of wheat

The yield attributing character of wheat such as 1000 grain weight during first year and grain weight spike⁻¹ were higher with the application of 25 kg ZnSO₄ ha⁻¹ to preceding maize crop. This might be due to uptake of residual zinc applied to previous maize crop and not fully utilized due to less moisture stress during crop growing season. In wheat varieties the application of 25 kg ZnSO₄ ha⁻¹ gave significantly higher effective tiller m⁻², grain spike⁻¹ and grain diameter during second year; 1000 grain weight during both the year than the control, 12.5 and foliar spray (Table 4). The effective tillers were increased b due to application of 25 kg ZnSO₄ ha⁻¹ by 6, 10

and 11 percent over 12.5 kg ZnSO₄ ha⁻¹, foliar spray of 0.5 % ZnSO₄ and control, respectively during second year. However, 1000 grain weight was 2, 3 and 4 percent higher than 12.5 kg ZnSO₄ ha⁻¹, foliar spray of 0.5 % ZnSO₄ and control, respectively during second year. The effective tiller In variety 'PBW 343' were found higher with the application 25 kg ZnSO₄ ha⁻¹ than control, 12.5 kg ZnSO₄ ha⁻¹ and foliar spray of 0.5 % ZnSO₄ by 15, 2 and 7 percent and 1000 grain by 5, 2 and 4 during first year, respectively.

The increase in these parameters might be due to involvement of zinc in various enzymatic processes which helps in catalyzing reaction for growth finally leading to development of more yield attributing character. The results were in close conformity with Jakhar *et al.*, (2006). Response to zinc of both varieties regarding effective tiller m⁻², 1000 grain weight grains spike⁻¹, and grain diameter was better during second year, because during ear head initiation period light rainfall occurred, which helped in providing favourable growing conditions and better mobilisation of zinc. Hasanzadeh *et al.*, (2012) reported that due to water shortage leads to reduction in concentration of zinc in plant. Another most important factor that zinc play crucial role especially at blooming stage which is required for good grain setting in spike. The variety 'PBW 343' produced bolder grain during both the year than 'DBW 17' this may be due better response of zinc application and inherent character of variety.

Grain, straw and biological yield of wheat

The grain, straw and biological yields recorded marginally higher with the application of 25 kg ZnSO₄ ha⁻¹ to previous maize but it did not show significant variations. All these parameters were recorded more during first year in comparison to second year due to better growing conditions.

Table.1 Effect of zinc application on yield attributing character of maize

Treatment application of ZnSO ₄	Weight of cob plant ¹ (g)		Grains cob ⁻¹		Grain rows cob ⁻¹	
	2009	2010	2009	2010	2009	2010
Control	91.5	99.0	371	385	13	13
12.5 kg ha ⁻¹	96.7	102.0	375	392	14	15
25 kg ha ⁻¹	97.8	103.6	384	394	14	15
Foliar spray of (0.5 %)*	94.3	99.7	377	385	14	14
SEm ±	1.7	4.5	9.5	8.7	0.9	0.4
CD(P=0.05)	NS	NS	NS	NS	NS	NS

* One spray at the four leaf stage and one week after first spray

Table.2 Effect of zinc application on yield attributing character of maize

Treatment application of ZnSO ₄	Length of cob (cm)		Test weight (g)		Cob girth (cm)		Shelling (%)	
	2009	2010	2009	2010	2009	2010	2009	2010
Control	12.5	14.1	223.2	230.1	12.5	13.8	77.5	80.5
12.5 kg ha ⁻¹	13.0	14.5	228.5	237.3	13.7	14.3	80.9	82.0
25 kg ha ⁻¹	13.1	15.1	229.9	243.8	14.6	15.9	82.7	83.9
Foliar spray (0.5 %)*	12.9	14.3	227.2	233.8	13.3	14.3	79.3	80.7
SEm ±	0.61	0.4	1.3	4.2	0.61	0.6	1.8	2.5
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

* One spray at the four leaf stage and one week after first spray

Table.3 Effect of zinc application on yield and harvest index of maize

Treatment application of ZnSO ₄	Grain yield (t ha ⁻¹)		Stover yield (t ha ⁻¹)		Biological yield (t ha ⁻¹)		Harvest index (%)	
	2009	2010	2009	2010	2009	2010	2009	2010
Control	2.03	3.97	4.4	8.32	6.43	12.29	31.7	32.3
12.5 kg ha ⁻¹	2.41	4.07	5.54	8.45	7.95	12.52	30.3	32.5
25 kg ha ⁻¹	2.63	4.14	6.44	8.55	9.07	12.69	29.0	32.5
Foliar spray (0.5 %)*	2.14	4.04	5.38	8.37	7.52	12.41	28.5	32.4
SEm ±	0.11	0.37	0.11	0.87	0.34	0.35	1.5	2.1
CD(P=0.05)	0.38	NS	0.38	NS	1.18	NS	NS	NS

* One spray at the four leaf stage and one week after first spray

Table.4 Effect of zinc application on yield attributing characters of wheat

Treatment Application of <i>ZnSO₄</i>	Effective tillers (m ⁻²)		Grain weight spike ⁻¹ (g)		1000 grain weight (g)		Grain spike ⁻¹		Grain diameter (mm)	
	2009- 10	2010-11	2009- 10	2010- 11	2009- 10	2010 -11	2009 -10	2010 -11	2009- 10	2010- 11
<i>Maize</i>										
Control	299	335	2.03	1.99	35.1	36.5	44	52	2.03	2.80
12.5 kg ha⁻¹	304	356	2.04	2.09	35.5	38.9	45	54	2.04	2.79
25 kg ha⁻¹	306	354	2.19	2.11	37.2	39.3	45	55	2.19	2.86
Foliar spray (0.5%)*	300	351	2.02	2.09	35.2	37.0	44	53	2.02	2.88
SEm±	4.23	5.93	0.08	0.02	0.37	0.9	0.43	0.50	0.08	0.03
CD(P=0.05)	NS	NS	NS	0.08	1.28	NS	NS	1.75	NS	NS
<i>Wheat 'DBW 17'</i>										
Control	302	332	2.01	2.00	35.5	35.7	43	51	2.01	2.76
12.5 kg ha⁻¹	305	350	2.20	2.08	35.3	36.6	45	53	2.20	2.78
25 kg ha⁻¹	307	372	2.22	2.15	36.9	37.2	46	54	2.22	2.79
Foliar spray (0.5%)*	303	336	2.04	2.06	35.5	36.1	45	53	2.04	2.81
<i>'PBW 343'</i>										
Control	295	317	1.89	2.03	34.9	39.3	43	53	1.89	2.88
12.5 kg ha⁻¹	302	366	2.05	2.11	35.9	39.4	45	55	2.05	2.88
25 kg ha⁻¹	306	373	2.11	2.12	36.8	39.7	44	57	2.11	2.87
Foliar spray (0.5%)*	299	346	2.03	1.99	35.2	39.7	43	53	2.03	2.90
SEm±	4.86	10.6	0.08	0.06	0.49	0.6	0.7	0.7	0.08	0.02
CD(P=0.05)	NS	30.1	NS	NS	1.41	1.7	NS	2.2	NS	0.06

*Two foliar spray one at anthesis and another one week later

Table.5 Effect of zinc application on yield and harvest index of wheat

Treatment application of ZnSO ₄	Grain yield (t ha ⁻¹)		Straw yield (t ha ⁻¹)		Biological yield (t ha ⁻¹)		Harvest index	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
<i>Maize)</i>								
Control	4.14	4.48	6.76	6.93	10.89	11.41	38.1	39.5
12.5 kg ha ⁻¹	4.21	4.84	6.81	7.38	11.02	12.22	38.6	39.8
25 kg ha ⁻¹	4.28	4.96	6.98	7.66	11.25	12.62	38.1	39.5
Foliar spray (0.5 %)*	4.18	4.61	6.79	7.19	10.97	11.80	38.1	39.1
SEm±	0.06	0.11	0.09	0.23	0.08	0.24	0.5	0.98
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
<i>Wheat ‘DBW 17’</i>								
Control	4.07	4.39	6.74	6.79	10.81	11.18	37.7	39.6
12.5 kg ha ⁻¹	4.23	4.79	6.92	7.66	11.15	12.45	38.1	38.7
25 kg ha ⁻¹	4.43	4.85	7.13	8.41	11.56	13.26	38.5	36.5
Foliar spray (0.5 %)*	4.17	4.54	6.81	7.20	10.98	11.73	38.0	38.6
<i>‘PBW 343’</i>								
Control	4.05	4.59	6.53	6.32	10.58	10.91	38.3	42.2
12.5 kg ha ⁻¹	4.14	4.89	6.82	7.23	10.96	12.12	37.8	40.4
25 kg ha ⁻¹	4.40	5.02	7.06	7.71	11.46	12.73	38.5	39.4
Foliar spray (0.5 %)*	4.12	4.73	6.66	7.01	10.77	11.73	38.2	40.3
SEm±	0.07	0.13	0.15	0.20	0.17	0.24	0.6	0.9
CD(P=0.05)	0.20	0.38	NS	0.57	0.47	0.67	NS	2.7

*Two foliar spray one at anthesis and another one week later

During second year application of 25 kg ZnSO₄ ha⁻¹ grain yield was higher by eight, 13 and 14 percent than the 12.5 kg ZnSO₄ ha⁻¹, foliar and control treatment of first year, respectively. The grain yield recorded with the application of 25 kg ZnSO₄ ha⁻¹ was higher by 0.36, 0.20 and 0.26 t ha⁻¹ during first year while 0.46, 0.06 and 0.31 t ha⁻¹ during second year than control, 12.5 kg ZnSO₄ ha⁻¹ and foliar spray of 0.5 % ZnSO₄,

respectively (Table 5). The yield advantage with the application of 25 kg ZnSO₄ ha⁻¹ was 0.35, 0.26 and 0.28 during first year and 0.43, 0.13 and 0.29 t ha⁻¹ during second year as compared to control, 12.5 kg ZnSO₄ ha⁻¹ and foliar spray of 0.5 % ZnSO₄, respectively in variety ‘PBW 343’. Highest straw yield 7.13 in first year and 8.41 t ha⁻¹ second year in variety was obtained with the application of 25 kg ZnSO₄ ha⁻¹. While in variety ‘PBW 343’

straw yield was 7.06 in first year and 7.71 t ha⁻¹ during second year. The total biological yield follows the similar trends as it depends upon the output of both grain and straw yield. This increase in yield might be due to better growth and yield attributing character with zinc fertilization. The grain, straw and biological yield were higher in variety 'PBW 343' than 'DBW 17' due to its more responsiveness to zinc application which was reflected in the form of superior yield attributes. The harvest index recorded maximum with 25 kg ZnSO₄ ha⁻¹ during first year and with control during second year in variety 'DBW 17'. This effect might be due to relatively more straw yield during first year with the application of 25 kg ZnSO₄ ha⁻¹ while less grain yield in control during second year. Similar trend was also observed in variety 'PBW 343'. Hossain *et al.*, (2008) reported that the grain yield increases significantly as 7.4, 10.1 and 10.6 t ha⁻¹ with increasing Zn rates from 0, 2 and 4 kg ha⁻¹, respectively. Likewise the straw yield due to 2 and 4 kg Zn ha⁻¹ were found statistically similar particularly for the second and third year, and the yields were significantly different as recorded on the first year trial. Singh 2011 reported that zinc application at the rate of 5-10 kg ha⁻¹ increased the grain yield response by 0.2-2.6 t ha⁻¹ in various prominent cropping systems in India including maize-wheat or rice-pulse cropping systems. Talliee and Abedi (1999) reported that the increase in grain yield of wheat was significantly more (262 kg ha⁻¹) with the application of 10 kg ha⁻¹ Zn than control treatment.

In contrary to the findings, Verma and Minhas (1987) revealed that zinc application did not increase the grain and straw yield of wheat and maize when applied alone but increases significantly when applied in combination with phosphorus. Grant and Bailey (1998) reported that zinc application

did not influence grain yield of durum wheat. Gul *et al.*, (2011) found that foliar spray of 0.5 % zinc has significant effect on number of grain (52) spike⁻¹, 1000 grain weight (46 g), grain yield (295 kg ha⁻¹), straw yield (6074 kg ha⁻¹) and biological yield (8999 kg ha⁻¹).

Application of 12.5 kg ZnSO₄ ha⁻¹ to maize and wheat in system is equally effective as 25 kg ZnSO₄ ha⁻¹ to the yield attributes and yield of both crops. But the maximum yield either in case of maize or in wheat crop obtained with application of highest dose of zinc. Both the crop responded significantly with the application of zinc levels as compared to control.

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