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Effect of zinc on growth, yields, zinc use efficiency and economics in baby corn

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Abstract
The field experiment was conducted at agricultural farm of Palli Siksha Bhavana, Visva-Bharati, Sriniketan, Birbhum district, West Bengal, India during *pre-rabi* season of 2015 to study the effect of zinc on growth and productivity of baby corn. Different treatments viz. absolute control, soil application of Zn @ 6 kg ha^{-1}, soil application of Zn @ 10 kg ha^{-1}, seed treatment @ 0.6% Zn and @ 1.2% Zn, one foliar spray @ 0.05% Zn at 25 DAS, soil application of Zn @ 6 kg ha^{-1} +one foliar spray @ 0.05% Zn, seed treatment @ 0.6% Zn+one foliar spray of 0.05% Zn at 25 DAS. The experiment was carried out in RBD with 8 treatments replicated thrice. At tasseling stage, tallest (136.6 cm) plant produced by seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS and highest (45.26 g plant^{-1}) dry matter accumulation resulted with soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS. In regards to the yield, soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS resulted maximum count (246667) of cobs ha^{-1}, highest (8.06 t ha^{-1}) young cob yield ha^{-1}, highest (1.72 t ha^{-1}) fresh weight of corn ha^{-1} and maximum (20.42 t ha^{-1}) total fodder yield. Moreover, highest net return (₹165442 ha^{-1}), B:C ratio, maximum Zn content in baby corn, green husk as well as total Zn uptake were found with the soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS. Where as one foliar spray @ 0.05% Zn at 25 DAS showed highest zinc use efficiency.

Keywords: baby corn, zinc, methods of application, yield, economics

Introduction
Baby corn, a novel utilization of maize, is used as a vegetable in many Asian countries. It is used as an ingredient in the preparation of many food items. It refers to whole, entirely edible corn of immature cob harvested just before fertilization at the silk emergence stage (Galinat, 1985) [7]. It is dehusked young ear of the female inflorescence of maize plant, harvested at silk emergence before fertilization (Pandey *et al*. 2000; Kapoor, 2002) [15, 21]. Young cobs are handpicked when the silk length was about 2−4 cm. The criteria for marketable yield were 4.5−10 cm length and 0.7−1.7 cm diameter of dehusked cobs having a regular row arrangement (Bar-Zur and Sadi, 1990) [2]. Thavaprakash *et al*. (2005) [18] and Das *et al*. (2008) [4] reported that 100 g of baby corn contained 89.1 g moisture, 0.2 g fat, 1.9 g protein, 8.2 mg carbohydrate, 0.06 g ash, 28.0 mg calcium, 86.0 mg phosphorus, and 11.0 mg of ascorbic acid. Zinc is an essential element for plants, animals and human beings. It is startling to find in the 21st century that an estimated 2 billion people on the planet are zinc deficient. Zinc deficiency is more prevalent in developing countries of the world (Gibbson, 2006) [8]. It is required for a number of metabolic processes. Therefore, Zn deficiency can result in a number of health problems like diarrhoea, low birth weight, and stunted growth in children (Brown, 2003; Rivera *et al*., 2003) [3, 17]. Recommended intake of dietary Zn ranges from 1.1 to 11.2 mg day^{-1} in children and 3.0–19.0 mg day^{-1} in adults (FAO/WHO, 1996; Imtiaz *et al*., 2010) [6, 11]. Recent studies indicated that it is possible to increase Zn concentration in maize grain by either soil Zn application or seed priming with Zn in South Asia (Harris *et al*., 2007; Hossain *et al*., 2008) [9, 10]. Maize seed priming with 1% $ZnSO_4$ not only enhanced plant growth but also increased the final grain yield and seed Zn contents in plants grown on soil with limited Zn availability (Harris *et al*., 2007) [9]. In this context, the information is not available on comparative performance of the zinc levels and method of application of zinc in baby corn for increased crop productivity and zinc use efficiency. Hence, the present field study was undertaken to identify the most suitable level and method of application of zinc in baby corn during *pre-rabi* season.

Materials and Methods
Site description
The experiment was conducted at agricultural farm of Palli Siksha Bhavana, Visva-Bharati at Sriniketan of Birbhum district, West Bengal during *pre-rabi* season of 2015 (From September

2015 to November 2015) in red and lateritic soil on a sandy loam soil. The farm was situated at 23°39' N latitude and 87°42' E longitude with an average altitude of 58.90 m above mean sea level. The soils of the experimental field had 219.29 kg ha^{-1} alkaline permanganate oxidizable nitrogen (N), 16.28 kg ha^{-1} available phosphorus (P), 184.95 kg ha^{-1} 1 N ammonium acetate exchangeable potassium (K) and 0.35% organic carbon (OC). The pH of soil was 4.78 (1:2.5 soil and water ratio) recommended by soil reaction committee and soil EC was 1.22 ds m^{-1} determined by using conductivity meter.

Experimentation

The experiment was conducted in a randomized block design and the treatments were absolute control, soil application of Zn @ 6 kg ha^{-1}, soil application of Zn @ 10 kg ha^{-1}, seed treatment @ 0.6% Zn, seed treatment @ 1.2% Zn, one foliar spray @ 0.05% Zn at 25 DAS, soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS, seed treatment @ 0.6% Zn+one foliar spray of 0.05% Zn at 25 DAS. Source of zinc was zinc sulphate monohydrate (33% Zn). At optimum moisture condition the land was ploughed twice by tractor drawn harrow thoroughly for obtaining good tilth. The experimental plot was applied with fertilizer 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha $^{-1}$ after field preparation as basal application. Seed treatment with Zn@ 0.6% and 1.2% was done and kept overnight before sowing. The maize variety, Navaneet were sown with a seed rate of 40 kg ha^{-1}on September 10, 2015 with uniform row to row spacing of 40 cm and plant to plant spacing of 20 cm for baby corn purpose. Gap filling and thinning were done at 14 DAS and once manual weeding operation and one foliar spray of 0.05% Zn was done at 25 DAS. Gap filling and thinning were done at 14 DAS and once manual weeding operation and one foliar spray of 0.05% Zn was done at 25 DAS. Detasseling is a major operation in baby corn and it was done on a daily basis since start of tassel emergence (first detasseling was done at 50 DAS) till tassels from all the plants are removed. Yield attributes like average number of cobs, fresh weight of cobs and baby corn yield per ha basis were calculated by adding each harvest. Total fodder yield was calculated at final harvest. Plant samples digested by following triacids digestion method and using AAS zinc concentration of baby corn, green husk and whole plant (stover) was calculated. Finally, the uptake of zinc was determined by multiplying dried baby corn yields (baby corn, green husk and stover) and zinc concentration in the respective parts. Total zinc uptake was calculated by summing-up the three values, i.e. baby corn+green husk+stover uptake of zinc for baby corn.

Zinc use efficiency

In general, three terms are used in relation to zinc use-efficiency (ZUE). These are:

Agronomic Efficiency (AE), Recovery Efficiency (RE) and Partial Factor Productivity of

Fertilizers (PFPf). The following expressions were used for determining these as suggested by Singh and Shivay (2003):

$$AE(\text{ kg baby corn increased kg Zn}^{-1}\text{ applied}) = \frac{Yf - Yc}{Zn\ applied}$$

$$RE\ (\text{\% of Zn taken up by a crop}) = \frac{ZnUf - ZnUc}{Zn\ applied} \times 100$$

$$PFPf\ (\text{kg baby corn kg Zn}^{-1}\text{ applied}) = \frac{Yf}{Zn\ applied}$$

In the above expressions, Yf and Yc are the yields (kg ha^{-1}) in fertilized and control (no fertilizer) plots, respectively. ZnUf and ZnUc are the amounts of zinc taken up by a crop in fertilized and control plots, respectively and Zn applied refers to the amount of nutrient applied (kg ha^{-1}).

Statistical analysis

The analysis of variance method (Cochran and Cox, 1977; Panse and Sukhatme, 1978) was followed to statistically analyse the various data. The significance of different source of variations was tested by "Error Mean Square Method" of Fisher Snedecor's 'F' test at probability level of 0.05. In the tables of result and discussion chapter, the standard error of Mean (SEm±) and the value of critical difference (C.D.) to compare the differences between means have been provided.

Results and Discussion

Growth characters

Plant height: At tasseling stage, seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8)recorded highest plant height (136.6 cm) (Table 1) which was significantly higher than all treatments except soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7). Similarly, Soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) also resulted significantly taller plants when compared with rest of the treatments except seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8). This finding was followed the study of Mohsin *et al*. (2014) [14]. He recorded that combined methods of Zn applications gave maximum plant height (251.5 cm) of Pioneer 30-Y-87 variety.

Total dry matter accumulation: At tasseling stage, highest (45.26 g $plant^{-1}$) dry matter accumulation(Table 1) was taken place with soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) that was significantly higher than all treatments. On the other hand, soil application of Zn @ 5 and 10 kg ha^{-1} remained statistically at par. These findings also almost resembled with with Kumar *et al*. (2014) [13] where highest dry matter $plant^{-1}$ (150.6 g) obtained with the soil application of Zn @ 10 kg ha^{-1}. Several researchers had concluded different findings which were closely in accordance of the present findings.

Yield attributes

Number of young cobs ha^{-1}: The results revealed that soil application of Zn @ 6 kg ha^{-1}+ one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (246667) number of cobs ha^{-1}(Table 1) and gave significantly 20.37%, 34.68%, 35.31% and 47.98% higher yield over seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8), soil application of Zn @ 10 kg ha^{-1} (T_3), one foliar spray @ 0.05 % Zn at 25 DAS (T_6) and soil application of Zn @ 6 kg ha^{-1} (T_2), respectively.

Fresh weight of young cob (t ha^{-1}): The findings showed that soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (8.06 t ha^{-1}) young cob yield ha^{-1} (Table 1) which was significantly 15.80%, 36.84%, 44.18% and 44.70% higher over seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8), soil application of Zn @ 10 kg ha^{-1} (T_3), one foliar spray @ 0.05 % Zn at 25 DAS (T_6) and soil application of Zn @ 6 kg ha^{-1} (T_2), respectively. Kumar *et al*. (2014) [13] revealed that highest young cob yield (8.9 t ha^{-1}) was obtained with soil application of Zn @ 10 kg ha^{-1}. However, Ehsanullah *et al*. (2015) [5] while studying the effect of foliar spray of $ZnSO_4$ @ 1% at vegetative stage recorded maximum grain yield (7.6 t ha^{-1}) of Pioneer 32 F 10 variety over the soil application of Zn @ 12 kg $ZnSO_4$.

Fresh weight of baby corn (t ha^{-1})

The result revealed that soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (1.72 t ha^{-1}) fresh weight of corn ha^{-1} which gave significantly more baby corn yield (Table 1) than the other treatments. However, seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) recorded second highest (1.39 t ha^{-1}) baby corn yield ha^{-1} which was though statistically at par, but 19.82% higher yield over soil application of Zn @ 10 kg ha^{-1} (T_3). This soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) produced 23.74%, 48.27%, 50.87% and 66.99% higher yield over seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8), soil application of Zn @ 10 kg ha^{-1} (T_3), one foliar spray @ 0.05 % Zn at 25 DAS (T_6) and soil application of Zn @ 6 kg ha^{-1} (T_2), respectively. Mohsin *et al*. (2014) [14] emphasized integration of methods of application where seed priming and foliar spray @ 2% gave maximum grain yield (7.34 t ha^{-1}) of Pioneer 30-Y-87 variety. Study conducted by Asif (2013) [1] concluded that $ZnSO_4$applied @ 27 kg produced maximum grain yield (6.1 t ha^{-1}) against minimum (5.0 t ha^{-1}) by zero Zn.

Total fodder yield (t ha^{-1})

The result revealed that soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (20.42 t ha^{-1}) total fodder yield (Table 1) which was though statistically at par, but 12.01% and 20.18% higher fodder yield over seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) and soil application of Zn @ 10 kg ha^{-1} (T_3), respectively. This trend was in good agreement with that of dry matter production (Table 1) with soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7). This treatment produced 21.98%, 28.91%, and 29.15% higher total fodder yield over one foliar spray @ 0.05 % Zn at 25 DAS (T_6), soil application of Zn @ 6 kg ha^{-1} (T_2) and seed treatment @ 1.2% Zn (T_5), respectively. These findings were in close supports with Kumar *et al*. (2014) [13] where highest green fodder yield (31.2 t ha^{-1}) was obtained with the soil application of Zn @ 10 kg ha^{-1}. Ehsanullah *et al*. (2015) [5] also recorded that foliar spray of $ZnSO_4$ @ 1% at vegetative stage produced maximum (17.24 t ha^{-1}) biological yield of Pioneer 32 F 10 variety over soil application of Zn @ 12 kg $ZnSO_4$.

Table 1: Effect of treatments on growth and yield attributes of baby corn

Treatment	Plant height at tasseling stage (cm)	Dry matter accumulation at tasseling stage (g)	Average number of cobs ha^{-1}	Fresh wt. of cobs ha^{-1} (t)	Fresh wt. of corn (t ha^{-1})	Total fodder yield (t ha^{-1})
T_1:Absolute control	81.8	29.03	141875	4.01	0.72	12.93
T_2:Soil application of Zn @ 6 kg ha^{-1}	103.7	34.74	166683	5.57	1.03	15.84
T_3:Soil application of Zn @ 10 kg ha^{-1}	97.3	34.50	183150	5.89	1.16	16.99
T_4:Seed treatment @ 0.6% Zn	96.4	31.34	157283	4.53	0.88	14.47
T_5:Seed treatment @ 1.2% Zn	109.2	34.49	158967	4.52	0.93	15.81
T_6:One foliar spray @ 0.05% Zn at 25 DAS	102.6	43.15	182292	5.59	1.14	16.74
T_7:Soil application of Zn @ 6 kg ha^{-1}+One foliar spray @ 0.05% Zn	134.9	45.26	246667	8.06	1.72	20.42
T_8:Seed treatment @ 0.6% Zn+one foliar spray of 0.05 % Zn at 25 DAS	136.6	41.7	204917	6.96	1.39	18.23
SEm±	3.8	0.66	5964.55	0.33	0.08	1.16
CD (p=0.05)	11.6	2.01	18091	1.01	0.24	3.53
CV %	6.1	3.12	5.73	10.22	12.25	12.26

Zinc concentration and total zinc uptake of baby corn

Soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (87.20 ppm) Zn concentration (Table 2) in baby corn and significantly more than all other treatments. Seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) gave second highest (86.4 ppm) zinc concentration value. soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (49.3 ppm) Zn concentration in green husk which was highly significant over other treatments. Seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) was showing second highest (48.4 ppm) zinc concentration value. soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (49.2 ppm) Zn concentration in whole plant which was statistically at par with only seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) and one foliar spray @ 0.05% Zn at 25 DAS (T_6). Seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) was showing second highest (48.50 ppm) zinc concentration value. soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) recorded highest (0.23 kg ha^{-1}) Zn uptake (Table 2) which was significantly higher than all other treatments. Seed treatment @ 0.6% Zn+one foliar spray @ 0.05% Zn at 25 DAS (T_8) was showing second highest (0.2 kg ha^{-1}) Zn uptake value.

Table 2: Effect of treatments on Zn concentration and Zn uptake

Treatment	Zn content in baby corn (ppm)	Zn content in green husk (ppm)	Zn content in whole plant (ppm)	Total Zn uptake (kg ha^{-1})
T_1:Absolute control	67.85	34.30	27.40	0.09
T_2:Soil application of Zn @ 6 kg ha^{-1}	74.30	40.90	40.90	0.15
T_3:Soil application of Zn @ 10 kg ha^{-1}	77.50	42.80	41.95	0.16
T_4:Seed treatment @ 0.6% Zn	69.75	35.60	29.10	0.10
T_5:Seed treatment @ 1.2% Zn	73.20	36.00	40.00	0.14
T_6:One foliar spray @ 0.05% Zn at 25 DAS	80.50	47.50	45.30	0.17
T_7:Soil application of Zn @ 6 kg ha^{-1}+One foliar spray @ 0.05% Zn	87.20	49.3	49.20	0.23
T_8:Seed treatment @ 0.6% Zn+one foliar spray of 0.05 % Zn at 25 DAS	86.40	48.40	48.50	0.20
SEm±	0.36	1.15	1.45	0.01
CD (p=0.05)	1.09	3.48	4.4	0.02

This result followed the findings of Mohsin *et al*. (2014) [14] that maize hybrid DK-919, with combined application of Zn as seed priming (2.0%) and foliar spray (2.0%) produced significantly more zinc grain content. Harris *et al*. (2007) [9] also found that grain zinc concentration was 15.4 mg kg^{-1} in a non-primed crop and was significantly higher with 1% Zn (18.3 mg kg^{-1}). One foliar spray @ 0.05 % Zn at 25 DAS (T_6) resulted significantly higher zinc concentration than soil application of Zn @ 10 kg ha^{-1} (T_3) which was contradiction to the result of Puga *et al*. (2013) [16] that the zinc application in a greater Zn uptake by plants and maize yield, compared to Zn application in the plant by seed or foliar.

Zinc use efficiency

AE(kg baby corn increased kg Zn^{-1} applied) (Table 3) is highest(1669.59) at one foliar spray @ 0.05% Zn at 25 DAS (T_6) and seed treatment @ 0.6% Zn+one foliar spray of 0.05 % Zn at 25 DAS (T_8) showed second in AE (1350.91 kg baby corn increased kg Zn^{-1} applied). Agronomic efficiency is maximum by foliar spray followed by seed treatment and lowest by soil application of zinc. The result revealed that one foliar spray @ 0.05% Zn at 25 DAS (T_6) recorded highest (34.46) RE (% of Zn taken up by a crop). Whereas, seed treatment @ 0.6% Zn+one foliar spray of 0.05 % Zn at 25 DAS (T_8) and seed treatment @ 1.2% Zn (T_5) recorded second (23.07) and third (11.48) highest RE respectively. PFPf (kg baby corn kg Zn^{-1} applied) is highest (4566.79) at one foliar spray @ 0.05% Zn at 25 DAS(T_6) and second highest (3649.88) at seed treatment @ 0.6% Zn (T_4). Zinc use efficiency in terms of PFPf also follows same trend like AE i.e. maximum by foliar spray followed by seed treatment and lowest by soil application of zinc.

Economics

The highest net return (₹165442ha^{-1}) (Table 3) was found from soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) which is₹85057 higher than the net return found from seed treatment @ 0.6% Zn (T_4), which treatment had the lowest cost of cultivation among all. The B:Cratio was highest (4.46) in soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7).

Table 3: Effect of treatments on Zn use efficiency and economics

Treatment	AE (kg baby corn increased kg Zn^{-1} applied)	RE (% of Zn taken up by a crop)	PFPf (kg baby corn kg Zn^{-1} applied)	Net return (≠ ha^{-1})	B:C Ratio
T_1:Absolute control	-	-	-	63909	2.29
T_2:Soil application of Zn @ 6 kg ha^{-1}	51.15	1.01	171.87	94514	2.92
T_3:Soil application of Zn @ 10 kg ha^{-1}	43.84	0.76	116.27	107834	3.18
T_4:Seed treatment @ 0.6% Zn	631.97	6.64	3649.88	80385	2.78
T_5:Seed treatment @ 1.2% Zn	427.38	11.48	1936.33	87700	3.03
T_6:One foliar spray @ 0.05% Zn at 25 DAS	1669.59	34.46	4566.79	108287	3.49
T_7:Soil application of Zn @ 6 kg ha^{-1}+One foliar spray @ 0.05% Zn	159.15	2.37	275.03	165442	4.46
T_8:Seed treatment @ 0.6% Zn+one foliar spray of 0.05 % Zn at 25 DAS	1350.91	23.07	2829.07	132428	3.95

Conclusions

From the investigation, it can be concluded that soil application of Zn @ 6 kg ha^{-1}+one foliar spray @ 0.05% Zn at 25 DAS (T_7) proved best in influencing growth and yield attributes, yield, zinc uptake of baby corn. This treatment however, resulted highest in gross net return (₹165442ha^{-1}) and B:C ratio (4.46) of baby corn.

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