Maize Journal (April 2023) 12(1): 15-19

RESEARCH PAPER

Effect of zinc-based nano fertilizer foliar application with varying fertility levels on yield attributes and yield of single cross maize hybrid (*Zea mays* L.)

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Abstract An experimental field study was carried out during the consecutive *kharif* seasons of 2020 and 2021 at the Instructional Farm of Rajasthan College of Agriculture, Udaipur using single cross maize hybrid. The study encompassed two main factors: the foliar application of nanofertilizer and different fertility levels with three replications. Factor A (Foliar Application of Nanofertilizer) serve the parameters like control receiving water spray, application at the knee-high stage (0.1%), application at the 50 per cent tasseling stage (0.1%), and combined application at both the knee-high and 50 per cent tasseling stages (0.1%) however Factor B represents focusing on fertility levels, included the control, 100 per cent recommended dose of fertilizer (RDF), 90 per cent RDF, and 80 per cent RDF. Significantly highest grain, stover and biological yield (51.90, 82.32 and 134.21 q ha^{-1}) were recorded with the dual foliar application of nanofertilizer at knee high stage and at 50 per cent tasseling stage over single stage foliar application. Among the different fertility levels, the application of 90 per cent RDF significantly increased grain, stover and biological yield. Yield attributing characters viz., grains cob^{-1}, grain weight cob^{-1} (g) and 1000 grain weight (g) were significantly higher with the dual foliar application of nanofertilizer at knee high stage and at 50 per cent tasseling stage and application of 90 per cent RDF in maize. Similarly, the significantly highest protein content of maize (11.13% and 10.97%) was found in dual foliar application of nanofertilizer and 90 per cent RDF, respectively. These findings emphasize the importance of strategic nanofertilizer application and optimal RDF levels in enhancing maize yield and protein content.

Keyword: Maize · Zinc · Nano fertilizer · yield

Introduction

Maize is a versatile crop that integrates effectively into existing cropping systems. In India, it holds significance not only due to its extensive acreage but also because of its adaptability across a wide range of agro-climatic conditions. Currently, maize is cultivated over 9.72 m ha area with 28.64 mt production and an average yield of 29.45 q ha^{-1} In Rajasthan, the crop occupies 0.97 m ha area with an annual production of 2.70 mt and average yield of 27.69 q ha^{-1} (Govt. of India. 2021). Amongst major nutrients, (N) is the most vital nutrient element and performs as a component of many organic compounds viz. proteins, amino acids, nucleic acids and nucleotides, enzymes, vitamins, hormones, alkaloids etc. (P) is the second most essential primary macronutrient, crucial for crop growth and yield. Among micronutrients, (Zn) is the most important micronutrient for crops as per its imperative role in the plant's enzyme system as a co-factor. Presently deficiency of Zn has become so widespread that it ranks next to N and P in Rajasthan as

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Received: 04 January 2023/ Accepted: 25 March 2023

well as many other states under intensive cropping systems (Zhu *et al*., 2012). Thus, a higher yield of a single cross-maize hybrid can be obtained through the judicious use of N, P and Zn. Nanotechnology holds significant potential in modern agriculture, addressing both plant diseases and the limited availability of important plant nutrients (Parisi *et al*., 2015). A variety of nanomaterials, mostly metal and carbon-based nanomaterials has been studied in maize and wheat for plant growth (Yang *et al*., 2015; Choudhary *et al*., 2022a). Recent discoveries reported that various nanomaterials applied to different crops can be serve as nano nutrients. Assessing the potential of nanomaterials to efficiently fulfill plant nutrient requirements, as compared to conventional fertilizers, is a prudent approach (Raliya *et al*., 2018; Choudhary *et al*., 2022b). Chitosan-based nanomaterials like Cu, Zn and salicylic acid (SA) exhibit great potential to be used in crop plants as fertilizers (Choudhary *et al*., 2019).

Materials and methods

The experiment was conducted during *kharif* 2020 and 2021 at the Instructional Farm, Rajasthan College of Agriculture, MPUAT. The climate in the region exhibits sub-tropical characteristics, marked by mild winters and moderate summers. Notably, the monsoon period, spanning from July to September, brings about higher relative humidity. The experiment was laid out in Factorial Randomized Block Design (RBD) with three replications. It comprised sixteen treatment combinations, encompassing two factors. The first factor involved four levels of foliar nanofertilizer application: a *control* treated with water spray, application at the knee-high stage (0.1%), application at the 50 per cent tasseling stage (0.1%), and combined application at both the knee-high and 50 per cent tasseling stages (0.1%). The second factor pertained to fertility levels, encompassing the control, 100 per cent RDF, 90 per cent RDF, and 80 per cent RDF. The recommended fertilizer dosage comprised 120, 60 kg, and 25 kg ha^{-1} N, P_2O_5 and Zn respectively. Treatment application was structured as follows: the entire phosphorus quantity was applied at sowing, while nitrogen was split into three applications: one-third at sowing, one-third at the knee-high stage, and the remaining third at the 50 per cent tasseling stage. The Zn-chitosan NPs were formulated at the Department of Molecular Biology and Biotechnology, Rajasthan College of Agriculture, Udaipur, utilizing ionic gelation between chitosan and sodium tripolyphosphate, as described by Saharan *et al*. (2015) and Kumar *et al*. (2020). The application of Zn-chitosan NPs in a 0.1 per cent solution sprayed at the knee-high stage and the 50 per cent tasseling stage, aligning with the designated treatments. The Zn-chitosan NPs 0.1 per cent solution was sprayed at knee high stage and at 50 per cent tasseling stage as per treatments. For the cultivation of maize, the Pratap Hybrid Maize-3 variety was sown with a seed rate of 20 kg ha^{-1}, coinciding with the commencement of rainfall on July 4th in 2020 and July 5th in 2021. The crop was spaced at dimensions of 60 x 25 cm.

Results and discussion

Yield attributes

Number of grains cob^{-1} (322.8), grain weight cob^{-1} (134.39), 1000 seed weight (236.24), cob length (19.28 cm), girth of cob (16.14 cm) and cob height (96.15 cm) of maize were significantly influenced by the foliar application Zn based nanofertilizer at dual stage *viz*., at knee high stage and at 50 per cent tasseling stage as compared to single stage application (Table 1). This is strongly support that sink strength are advocated by higher sink activity and sink size (Choudhary *et al*., 2019). Based on these outcomes, the study hypothesizes that slow release of Zn outdoes the plant’s antagonistic response by awfully synchronizing the need for zinc at the most ravenous-dynamic development (reproductive and grain filling) stages of maize plant. Furthermore, availability of N and P at the aforementioned crucial stages is also essential for growth and development of maize plants (Razaq *et al*., 2017). Zn based chitosan nanofertilizer used in present study contain 7.40 per cent N as $-NH_2$ group in chitosan backbone and 4.89 per cent P as $-PO_4$ group in TPP cross-linker (Sharma *et al*., 2020). Therefore, study can’t rule out the potential contribution of N and P from zinc chitosan based nanofertilizer to complement source-activity and sink-strength of plants. Outcomes of the study exclusively establish the fact that an conducive cellular environment is imperative for sustained source-activity and sink-strength and the slow release of Zn plays an elite role in enhancing the cellular homeostasis of maize plant for

Table 1. Effect of foliar application of zinc based nanofertilizer and varying fertility levels on yield attributes of maize

Treatment	Cob length (cm)	Girth of cob (cm)	Grains cob^{-1}	Cob height (cm)	Grain weight cob^{-1} (g)	1000 grain weight (g)
Foliar application						
Control	15.6	13.8	263.3	88.8	105.6	198.0
At knee high stage	17.5	15.6	301.3	92.2	121.4	225.2
At 50% tasseling stage	17.2	15.4	297.8	91.2	115.5	219.9
Both stages	19.2	16.1	322.8	96.1	134.3	236.2
SEm±	0.18	0.14	3.44	0.78	1.21	1.11
C.D. (P = 0.05%)	0.52	0.40	9.72	2.20	3.43	3.15
Fertility levels (N, P and Zn kg ha^{-1})						
Control	14.9	13.4	242.2	88.4	96.6	193.9
80% RDF	16.7	15.1	281.9	89.8	114.4	214.0
90% RDF	18.7	16.0	326.5	94.1	131.4	234.2
100% RDF	19.2	16.4	334.7	96.0	134.5	237.2
SEm±	0.18	0.14	3.44	0.78	1.21	1.11
C.D. (P = 0.05%)	0.52	0.40	9.72	2.20	3.43	3.15

higher growth, yield and nutrient content in grain and stover (Choudhary *et al*., 2019). Application of 90 per cent RDF significantly influenced the all-yield attributing characters as compared to 80 per cent RDF and control. The level of Zn in the leaves increased via foliar application of Zn based chitosan nanofertilizer. These improvements suggest greater availability of metabolites and nutrients synchronized to demand for growth and development of each reproductive structure. The better availability of inputs as evident from N, P, and Zn content present in leaves showed reduce competition of these between developing structure. This, in turn, enhances the functional activities of each vegetative structure and results in robust individual plant growth, as evidenced by increased yield attributes.

The positive response of maize under N, P and Zinc fertilization is in close conformity with the findings of different researchers *i.e.*, Sharma *et al*. (2020); Van *et al*. (2020); Kumar *et al*. (2020) and Choudhary *et al*. (2022c).

Yield

The grain, stover and biological yield (51.9, 82.3 and 134.2 kg ha^{-1}) of maize significantly increased to the tune of 15.1, 19.6 and 17.8 per cent with the foliar application of 0.1% zinc based nanofertilizer at knee high stage and 50 per cent tasseling stage over control, respectively (Table 2). Application of 90 per cent RDF had significant influenced on grain, stover and biological yield of maize over 80 per cent RDF and control, although highest yield was recorded with 100 per cent RDF. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, assembly, and translocation of photosynthates depend upon the efficient photosynthetic structure and the extent of translocation into the sink (grains) and plant growth and development during the

Table 2. Effect of foliar application of zinc based nanofertilizer and varying fertility levels on yield of maize

Treatment	Yields (q/ha)		
	Grain	Stover	Biological
Foliar application			
Control	45.1	68.8	113.9
At knee high stage	47.8	75.4	123.2
At 50% tasseling stage	46.6	71.9	118.6
Both stages	51.9	82.3	134.2
SEm±	0.62	0.93	1.04
C.D. (P = 0.05%)	1.74	2.63	2.94
Fertility levels (N, P and Zn kg/ha)			
Control	34.1	53.2	87.3
80% RDF	48.8	75.9	124.8
90% RDF	53.7	84.1	137.8
100% RDF	54.8	85.2	140.0
SEm±	0.62	0.93	1.04
C.D. (P = 0.05%)	1.74	2.63	2.94

early crop growth stages (Bihmidine *et al*., 2013). Zn, among micronutrients, is indispensable for plants as it acts as a structural, catalytic and co-catalytic component in many enzymes (Singh *et al*., 2015; Choudhary *et al.*, 2022a). Overall, it is assumed that application of Zn based chitosan nanofertilizer enhanced cellular homeostasis and positively contribute source-activity and contributes to sink-strength *viz.*, yield attributes and yield (Lemoine *et al*., 2013; Choudhary *et al.*, 2022b). The study thus affirms that application of nanofertilizer both at knee high stage followed by 50 per cent tasseling stage significantly increases the activity of major enzymes of starch biosynthetic pathways and is accountable for higher starch accumulation in grains.

Conclusion

The results of the current study suggest that the most effective approach for enhancing yield attributes and overall maize yield is the foliar application of a 0.1% nanofertilizer containing zinc at both the knee-high stage and the 50 per cent tasseling stage. In the coming years, nanofertilizers hold great promise for revolutionizing modern agriculture through enhanced nutrient delivery and eco-friendly practices.

Acknowledgments

The authors are grateful to the Head, Department of Agronomy, Department of MBBT and Dean Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India, for valuable guidance, support and facilities provided to conduct this research experiment successfully.

Declaration

The authors do not have any conflict of interest.

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