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Response of Foliar Application of Nano Fertilizers on Growth and Yield of Maize (*Zea mays* L.) in South-West Rajasthan

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Abstract

A field experiment was conducted during *kharif* 2020 (June–October) at Instructional Farm of Agronomy, Rajasthan College of Agriculture, Udaipur to study the effect of foliar application nano fertilizers (N, Zn and Cu) on growth and yield of maize crop. The experiment was laid out in randomized block design with three replications and twelve treatments. The foliar application of tricombinations (nano N+nano Zn+nano Cu) of nano fertilizers along with 50% recommended dose of N and Zn plus 100% PK through conventional fertilizers *i.e.,*100% PK+50% N Zn+two sprays of nano N+nano Zn+nano Cu (T_{12}) significantly increased seed yield (4482.2 kg ha^{-1}) and stover yield (7994.81 kg ha^{-1}) by inducing the growth parameters i.e., the plant height (260.44 cm), dry matter accumulation (154.85 g), cob length (23.65 cm), number of grains cob^{-1} (346.7), weight of cob (159.33 g), weight of 100 seeds (24.92 g) of maize over control. However, the application of T_{12} were found statistically at par with 100% PK+50% N Zn+two sprays of nano N+nano Zn (T_{11}) in growth and yield of maize. Based on these results, the application 100% PK+50% N Zn+two sprays of nano N+nano Zn can be recommended for higher maize productivity in Sub-humid Southern Plains and Aravalli Hills of Rajasthan.

Keywords: Conventional fertilizers, foliar application, maize, nano fertilizer, yield

1. Introduction

Maize is important cereal crop grown in more than 165 countries globally. It is third leading staple food crop after rice and wheat (Erenstein et al., 2022). It is known as queen of cereals due to its high yield potential. In India, maize ranks fourth in terms of area and seventh in terms of output, accounting for around 4% of global maize area and 2% of total production. In India, the maize covers an area of 9.2 million hectares with a production of 27.8 million metric tonnes and having average productivity of 2965 kg ha^{-1}, during 2018-19 (FAI, 2021). India's most dominant rice–wheat cropping system has encountered various problems, viz. low input-use efficiency, nutrients imbalances, more groundwater depletion and irrigation water shortages, high emissions of greenhouse gases. Therefore maize can take place of rice in rice–wheat cropping system (Dhanda et al., 2022). Nitrogen fertilizer have great significance to enhance the maize production as nitrogen is a key component in plant metabolism and essential constituent of protein, nucleic acids, ATP, NADH, NADPH, enzymes as well as of cytochrome and chlorophyll (Demari et al., 2016). About 50% or more of applied nitrogen fertilizer is lost through leaching, volatilization, run off, etc and unavailable to crop because of inappropriate rate and time of application of nitrogen fertilizer especially during rainy season. Better understanding of nitrogen management leads to improve maize productivity. Zinc is consider as fourth most yield limiting nutrient after nitrogen, phosphorus and potassium, respectively in world as well as in Indian soils. It is estimated that 36.5 % of Indian soils are deficient in Zn (Shukla et al., 2019). Zn plays a fundamental role in photosynthesis, protein and carbohydrate synthesis and regulate auxin synthesis (Hafeez et al., 2013). Copper is one of the essential micronutrient for plant and humans. The copper content in Indian soils ranges between 1.8 and 285 mg kg^{-1} and 4.2% of Indian soils are deficient in copper (Shukla et al., 2019). It acts as transitional element which actively participates in physiological redox process.

Nanotechnology is an innovative approach for revolutionize the agriculture sector with aiming sustainable intensification which focuses on increasing food production while maintaining the economic and environmental equity (Sekhon et al., 2014). Nanotechnology provides scientific principles and practices to design a materials and structures at nanoscale level generally less than 100 nanometer size which is known as nanomaterials. Nanomaterials differ from conventional materials having specific composition with unique property like small size, high surface area, high reactivity and catalytic activity (Verma and Kapoor, 2020). A smart delivery system of nano fertilizer is seen because of its multidisciplinary character like remotely coordinated, a specific and targeted approach and release nutrient slowly or in controlled way which helps to dodge the biological barriers (Nair et al., 2010). The intensive use of conventional fertilizers leads to degradation of soil and deterioration of soil micro flora and fauna. Continuous use of fertilizers imbalances the soil structure their fertility and mineral system which totally disturb the ecosystem.In this context nano fertilizers are better substitute to conventional fertilizers as they are eco-friendly, cost effective, maintain soil fertility and plant health, enrich the nutritional value of food and reduce environmental hazards (ulAin et al., 2023). We require nano fertilizer to improve crop management in order to meet the rising population's food demand with sustainability.

2. Materials and Methods

2.1. Experimental site and soil

The field experiment was conducted during kharif2020 (June–October) at the Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur (Rajasthan)located at 24° 35′ north latitude, 72° 42′ east longitude, and 579.5 meters above mean sea level. The area is part of Rajasthan's agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills).The soil of experimental area was clay loam (38.82%, silt 26.58% and clay 34.60 %) in texture, saline in reaction (8.40), normal in electrical conductivity(0.81 dSm^{-1}), medium in soil organic carbon (0.55%), low in soil available nitrogen (260.20 kg ha^{-1}), phosphorus 16.09 kg ha^{-1}, high in potassium (350.47 kg ha^{-1}), high in zinc (1.99 mg kg^{-1}) and copper (1.58 mg kg^{-1}).

2.2. Experimental design and treatments

The experiment was laid out in a randomized block design and replicated three times in plot size of 5 x 4.2 m ($21m^2$). The seed of PM 9 (PratapMakka 9) maize variety was used for this experiment. The twelve treatments viz, T_1 (100% PK (Control), T_2 (100% PKZn), T_3 (100% NPK), T_4 (100% PKZn+two sprays of nano N), T_5 (100% PKZn+two sprays of nano N (2X or double dose), T_6 (100% NPK+two sprays of nano Zn), T_7 (100% PK +two sprays of nano N+ nano Zn), T_8 (100% RDF (NPKZn), T_9 (100% PKZn+50% N+two sprays of nano N), T_{10} (100% NPK+50% Zn+two sprays of nano Zn), T_{11} (100% PK+50% NZn+two sprays of nano N+nano Zn) and T_{12} (100% PK+50% N Zn+two sprays of nano N+nano Zn+nano Cu). The recommended dose of nitrogen (90 kg ha^{-1}) was applied in two equal splits, the half as basal and the remaining half was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through diammonium phosphate. The whole quantity of phosphorus (40 kg ha^{-1}), potassium (30 kg K_2O) and zinc (25 kg $ZnSO_4$ ha^{-1}) was basally applied through diammonium phosphate, muriate of potash and zinc sulphate heptadydrate, respectively.The other agronomic practices recommended for Zone IV-A were followed as per Package of Practices, Government of Rajasthan.

2.3. Application of nano fertilizers

Nano fertilizer namely, nano N, nano Zn and nano Cu from Indian Farmers Fertilizer Cooperative (IFFCO), New Delhi were used in this investigation. Nano fertilizers were applied twice through foliar application, one was given at 21 days after sowing and second at 42 days after sowing as per treatments with the help of knapsack sprayer with flat fan nozzle. Foliar spray of nano N was applied @ 4 ml l^{-1}water in all treatments while double dose of nitrogen @ 8 ml l^{-1} water was applied in T_5. Nano Zn @ 2 ml l^{-1} water was given in all zinc treatments except T_{10}, T_{11} and T_{12} in which nano zinc applied @ 1.25 ml l^{-1} water. Nano Cu was given @2 ml l^{-1} water as per the scheduled treatments.

2.4. Studied plant growth and yield parameters

The growth contributing characters like plant height and dry matter accumulation were determined at harvest from each net plot area. The yield and yield attributes *viz*., cob length, number of grains per cob, cob weight, test weight (100 grain weight), grain yield, stover yield and biological yield were recorded at time of harvest from each plot of each replication. The grain yield, stover yield and biological yield were recorded as yield per plot but later converted to kg ha^{-1}.

2.5. Statistical analysis

The obtained data were tabulated and statistically analyzed as per the standard procedure for analysis of variance (ANOVA) as described by Steel and Torrie (1960). The comparison in the treatment mean was tested by critical difference (CD) at 5% level of significance.

3. Results and Discussion

3.1. Growth attributes

The foliar application of nano fertilizers significantly increased the plant height and dry matter accumulation of maize crop over control (Table 1). The highest plant height (260.44 cm) and dry matter accumulation (154.85 g $plant^{-1}$) in maize was recorded with application of 100% PK+50% NZn+two sprays of nanoN+nanoZn+nano Cu (T_{12}) followed by 100% PK+50% NZn+two sprays of nanoN+nano Zn (T_{11}), 100% NPK+50% Zn+two sprays of nano Zn(T_{10}), 100% PKZn+50% N+two sprays of nano N (T_9) and 100% NPK+two sprays of nano Zn (T_6). However, the application of 100% PK+50% NZn+two sprays of nanoN+nanoZn+nano Cu (T_{12}) was found statisticallyat par

Table 1: Effect of foliar application of nano fertilizers on growth attributes of maize

Treatments`		Plant height (cm)	Dry matter accumulation (g plant^{-1})
T_1	100% PK (Control)	187.30	110.68
T_2	100% PKZn	189.47	112.80
T_3	100% NPK	200.67	120.02
T_4	100% PKZn+two sprays of nano N	214.37	129.01
T_5	100% PKZn+two sprays of nano N (2X)	218.07	130.33
T_6	100% NPK+two sprays of nano Zn	232.91	138.07
T_7	100% PK+ two sprays of nano N+nanoZn	220.40	130.41
T_8	100% RDF (NPKZn)	212.13	127.30
T_9	100% PKZn+50% N+two sprays of nano N	236.15	140.01
T_{10}	100% NPK+50% Zn+two sprays of nano Zn	248.10	147.30
T_{11}	100% PK+50% NZn+two sprays of nano N+nanoZn	260.33	154.70
T_{12}	100% PK+50% N Zn+two sprays of nano N+nano Zn+nano Cu	260.44	154.85
SEm±		3.64	2.44
CD (*p*=0.05)		10.69	7.16

with 100% PK+50% NZn+two sprays of nanoN+nano Zn (T_{11}) in terms of plant height and dry matter accumulation of maize.

The better growth of maize is observed under combined application of soil and foliar application of nutrients might be due to supply of nutrients in emergence stage by soil application and later efficient use of nutrients by leaves for better vegetative and reproductive growth of maize by foliar application (Amanullah et al., 2014). The application of nano nitrogen contributes in protein synthesis, which in turn is essential for the functioning of meristematic cells and the process of cell division. When there is an enhanced rate of cell division and nitrogen's impact on cell size, it results in the promotion of plant growth, leading to increased plant height (Tisdal and Nelson, 1975). The observed enhancement in plant growth can be linked to the involvement of zinc in tryptophan production, which serves as a precursor for the indole-3-acetic acid phytohormone. Additionally, ZnO nanoparticles have the capacity to influence the biosynthesis of other phytohormones like cytokinins and gibberellins, thereby promoting the development of a greater number of internodes and stem elongation can result in an increase in plant height of maize (Sturikova et al., 2018).The crop dry matter accumulation per plant was increased due the fact that nitrogen is essential for chlorophyll synthesis and photosynthetic activity which increase the vegetative growth and this increase was mainly dependent on quantity and efficiency of intercepted photosynthetic active radiation by crop (Asibi et al., 2019). Zinc also play role in metabolic processes by improving net carbon assimilation and stomatal conductance in plants thus improved thedry matter accumulation (Rossi et al., 2019).The results obtained in present study collaborates with the results of Khaveh et al. (2015); Tondey et al. (2021) and Abdel-Azizet al. (2018).

3.2. Yield attributes

The application of nano fertilizers significantly increased the cob length, number of grains per cob, cob weight and 100 grain weight of maize over control (Table 2). The highest cob length (23.65 and 23.62 cm), number of grains per cob (346.7 and 346.39), weight of cob (159.33 and 158.67 g) and weight of 100 seeds (24.92 and 24.9 g) of maize was recorded with the combined application of conventional and nano fertilizer as in 100% PK+50% NZn+two sprays of nano N+nano Zn+nano Cu (T_{12}) and 100% PK+50% NZn+two sprays of nano N+nano Zn (T_{11}), without any statistical difference among them, respectively. The application of T_{12} (100% PK+50% NZn+two sprays of nano N+nano Zn+nano Cu) increased the cob length, number of grains per cob, cob weight and test weight (100 grain weight) of maize upto 45.27%, 41.87%, 34.64%, 46.33% over control, respectively.

The foliar application is the most efficient delivery system of nutrients as it allows penetration of nutrients mainly by cuticles and stomata pathway. The nanoparticles having size below 5 nm follow cuticular pathway and nanoparticles having greater size follow stomatal pathway (Eichert and Goldbach, 2008) and finally transport to the conducting system which helps in quick and easy absorption of nutrients by leaves as they 100% soluble (Fernández and Eichert, 2009). The nano fertilizer improved the absorption of nutrients and increased the use efficiency of applied nutrient which tend to enhance vegetative growth and thus improve the biomass of crop (Khardia et al., 2022a). Thus nano fertilizers reduces losses of nutrients by directly assimilating them into crops, thereby reducing the risk of nutrient interaction with soil, water, air, and microorganisms (Panpattee et al., 2016). Another reason for increased yield parameters of maize when using nano fertilizers is the controlled,targeted and continuous supply of nanoscale nutrient throughout the crop growth cycle which stimulate the various metabolic process which in turn produce more shoot and root biomass, high photosynthetic activity and resulting in translocation of assimilate products to sink organs resulting in higher number of grains per cob, cob length, weight of cob and test weight of maize (Elshayb et al., 2021). The current study's findings are comparable to those of Kottegoda et al. (2017) who developed urea-hydroxyapatite nano-hybrids for delayed N release and observed that the

Table 2: Effect of foliar application of nano fertilizers on yield attributes and yield of maize

Treatments`		Cob Length (cm)	No. of Grains Cob^{-1}	Weight of Cob (g)	Weight of 100 Seeds (g)	Grain yield (kg ha^{-1})	Stover Yield (kg ha^{-1})
T_1	100% PK (Control)	16.28	244.37	118.33	17.03	3000.67	5503.07
T_2	100% PKZn	16.69	245.72	119.67	17.11	3018.03	5522.74
T_3	100% NPK	18.17	263.68	125.67	18.58	3250.33	5921.75
T_4	100% PKZn+two sprays of nano N	19.54	283.20	130.11	19.34	3556.04	6490.67
T_5	100% PKZn+two sprays of nano N (2X)	19.55	283.33	130.73	19.36	3572.01	6528.33
T_6	100% NPK+two sprays of nano Zn	20.89	304.71	140.67	21.15	3903.43	6938.44
T_7	100% PK+ two sprays of nano N+nanoZn	19.60	284.33	132.67	19.61	3644.07	6583.70
T_8	100% RDF (NPKZn)	18.69	282.07	127.67	19.07	3494.87	6363.15
T_9	100% PKZn+50% N+two sprays of nano N	21.01	307.04	143.47	21.27	3912.43	6959.81
T_{10}	100% NPK+50% Zn+two sprays of nano Zn	22.34	326.73	150.20	22.92	4187.04	7433.85
T_{11}	100% PK+50% NZn+two sprays of nano N+nanoZn	23.62	346.39	158.67	24.90	4473.36	7983.11
T_{12}	100% PK+50% N Zn+two sprays of nano N+nano Zn+nano Cu	23.65	346.70	159.33	24.92	4482.20	7994.81
SEm±		0.39	6.05	1.75	0.46	78.59	115.66
CD (p=0.05)		1.16	17.76	5.13	1.36	230.49	339.23

nano-hybrids tightly bind to the urea due to the their high surface tension allowing for slower (up to one week) and lower rates of release than conventional urea.Because of improved growth hormone synthesis and metabolic processes, the foliar application of NPK nano fertilizers enhance chickpea yield and yield components (Drostkar et al., 2016). Similary, increased in yield attributes of crop was reported by Adhikari et al. (2015) due to nano zinc application in maize and Mahajan et al. (2013) due to nano ZnCuFe oxide in moong.

3.3. Yield

The grain yield and stover yield of maize was significantly increased with application of different nano fertilizers over control (Table 2). The highest grain yield (4482.20 kg ha^{-1}) and stover yield (7994.81 kg ha^{-1}) was observed with application of 100% PK+50% NZn+two sprays of nano N+nano Zn+nano Cu(T_{12}) followed by 100% PK+50% NZn+two sprays of nano N+nano Zn (T_{11}), 100% NPK+50% Zn+two sprays of nano Zn(T_{10}), 100% PKZn+50% N+two sprays of nano N (T_9) and 100% NPK+two sprays of nano Zn (T_6). However, the seed yield and stover yield of maize was found statistically at par with application of T_{12} and T_{11}. The increased in grain yield and stover yield with application of T_{12} (100% PK+50% NZn+two sprays of nano N+nano Zn+nano Cu was to the extent of 49.37% and 45.27% over control, respectively.

The significant increase in grain yield and stover yield under the influence of nano fertilizers was largely a function of improved growth and yield attributes of maize which eventually contributed in increased seed and straw yield of maize.The increase in yield due to foliar application of nano fertilizers might be the result of overall improvement in soil properties of soil (Khardia et al., 2022b) which provide maximum nutrient availability and congenial environment for their uptake, synthesis of carbohydrate, their efficient portioning into different sinks including reproductive structures which ultimately brought about significant improvement in crop yields. Similar results were also reported by Adhikari et al. (2015); Wang et al. (2019); Meena et al. (2021); Raliya and Tarafdar (2013); Abdel-Aziz et al. (2018);

4. Conclusion

Based on above results, it can be concluded that combined application of nano fertilizers and conventional fertilizers i.e., 100% PK+50% N Zn+two sprays of nanoN+nano Znat 21 DAS and 42 DAS can produce the higher yield attributes and yield of maize crop in southern western region of Rajasthan.

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