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Nanofertilizers for Enhancing Nutrient Use Efficiency and Crop Productivity in Major *Rabi* Season Crops of Gujarat

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ABSTRACT

Background: In era of innovations it times to use nanotechnology, to maintain the ever-increasing market for food crops.

Methods: Indian Farmers Fertiliser Cooperative Ltd. (IFFCO) has introduced its nanotechnology-based products *i.e.*, Nano-N, Nano-Zn and Nano-Cu for initial testing on 7 major crops grown during *Rabi* season in Gujarat.

Result: We tested 5 treatment combinations among which treatment T_5 *i.e.*, 50% farmer fertilizer practices plus 1 spray of Nano-N, 1 spray of Nano-Zn and 1 spray of Nano-Cu give higher return than all there treatments in all crops. It conclude that application of nano-fertilizers significantly increase crop yield over control or without application of nanofertilzer it is mainly because of increasing growth of plant parts and metabolic process such as photosynthesis leads to higher photosynthates accumulation and translocation to the economic parts of the plant. Foliar application of nano particles as fertilizer significantly increases in yield of the crop.

Key words: Economic yield, Nano-Cu, Nanofertilizers, Nano-N, Nano-Zn, NUE Vegetables.

INTRODCTION

Agriculture is the main source of income in developing economies, supplying food and animal feed. In developing countries like India large proportion of people face problem of food shortages due to changing agro climatic conditions. Drought and pest-resistant crops with improved mineral absorption are therefore required to optimize production levels.

Food security is one of the most important issues for any country. In the future, global food and nutrition demands will rise by 70 per cent from current levels in a balanced manner by 2050 (Chen and Yada, 2011). According to this nutrition demands it require more food production in terms of quantity and quality of food and this production needs to meet the nutritional requirements of the crops. One of these requirements is cultivated with micro-nutrients that consuming food products with low nutrient content will introduce more people, especially younger people, small children, to protect from different nutritional deficiencies, improve the nutritional content will reduce these diseases or undernourishment diseases in general (Ali, 2016 and Salman, 2016).

World agricultural cropping systems intensively uses large amount of fertilizers, pesticides, herbicides to achieve more production per unit area but using more doses than optimum of these chemicals and fertilizers leads to several problems like environment pollution (soil, water, air pollution), low input use efficiency, decrease quality of food material, develop resistance in different weeds, diseases, insects, less income from the production, soil degradation, deficiency of micro nutrient in soil, toxicity to different beneficial living organism present above and below the soil surface *etc*. It is time to use new technologies, such as biotechnology and nanotechnology, to maintain the ever-increasing market for food crops. The term "Nanotechnology" was first defined in 1974 by Norio Taniguchi of the Tokyo Science University. Nanotechnology, abbreviated to "Nanotech", is the study of manipulating matter on an atomic and molecular scale. By and large nanotechnology deals with structures in the size range between 1 to 100 nm and involves developing materials or devices within that size.

By the use of Nanotechnology we develop smart materials *i.e.*, Nano fertilizers that can systematically release nutrients to specific targeted sites in plants which could be beneficial in controlling their deficiencies in agriculture, while keeping intact the natural soil structure. Nano fertilizers possess unique features which enhance plants performance in terms of ultrahigh absorption, increase in production, rise in photosynthesis and significant expansion in the leaves surface area. Besides, the controlled release of nutrients contributes in preventing eutrophication and pollution of water resources. Replacement of traditional fertilizer by nano fertilizer is beneficial as upon application, it releases nutrients into the soil steadily and in a controlled way, thus preventing the water pollution (Naderi and Danesh-Shahraki 2013; Moaveni and Kheiri, 2011).

Based on demand of era of innovations the world's largest and wholly owned by cooperatives, Indian Farmers

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Fertiliser Cooperative Ltd. (IFFCO) has introduced its nanotech nology -based products *i.e.*, Nano-N, Nano-Zn and Nano-Cu for initial testing as part of its efforts to cut usage of chemical fertilizers and boost farmers income. In view of paucity of information on performance of nanofertilizers (Nano-N, Nano-Zn and Nano-Cu), this investigation was undertaken to evaluate the effect of foliar sprays of these nanofertilizers on yield and economic returns of 7 major crops grown during *Rabi* season in Gujarat.

MATERIALS AND METHODS

Total 380 on farm yield trials data collected for yield in all the districts of Gujarat for different crops. Crops for trials were chosen based on geographical region during *Rabi* 2019-20. The crops were sown in the months of November and December 2019 with 5 treatments, details in Table 1. Nanofertilizers namely, Nano-N, Nano-Zn and Nano-Cu had nutrient concentrations of 25000, 5000 and 2000 mg L^{-1}, respectively. 4 mL of these liquid fertilizers were added in 1 L of water and for one acre 500 mL of nanofertilizers were added to 125 L of water and sprayed as per treatments detailed in Table 1. The first spray was done three weeks after full germination in each crop and the second spray was made 10-15 days after 1st spray or 5 weeks after full germination. The field was kept weed-free as far as practical according to means and will of the farmers. Plant protection measures were adopted as per need of the crop. The crops were harvested at full maturity and the yield data were recorded from the net plot area harvested.

RESULTS AND DISCUSSION

Data collected from 380 on farm demonstrations with respect to economic yield and per cent increase over FFP are given in Table 2. Crop-wise results are described in following paragraphs.

Castor

Total 21 on farm trials are done and data collected from all the trials are averaged and given in Table 2 for economic yield (q ha^{-1}) and per cent increase over FFP. It shows that highest yield was recorded in Treatment T_5 (26.68 q ha^{-1}) followed by treatment T_2 (26.08 q ha^{-1}), T_4 (25.37 q ha^{-1}), T_3 (25.27 q ha^{-1}) and T_1 (24.8 q ha^{-1}). While treatment T_5 (8.08%) shows highest per cent increase in economic yield over FFP followed by T_2 (5.37%). So it suggest that the positive impact of spraying nano fertilizers on Castor.

Chickpea

17 on farm field trail were done and found that the average economic yield ranges from 17.52 q ha^{-1} (T_1) to 18.25 q ha^{-1}

Table 1: Treatment details.

T_1	Farmer's fertilizer practice (FFP)
T_2	(FFP-50% N) + 2 sprays of Nano-N
T_3	FFP + 2 sprays of Nano-Zn
T_4	FFP + 2 sprays of Nano-Cu
T_5	(FFP-50% N) + 1spray of Nano-N + 1 spray of Nano-Zn + 1 spray of Nano-Cu

Table 2: Effect of IFFCO nanofertilizers on economic yield of crops.

Crop	No. of trials	Average economic yield (Quintal/Ha)					%Increase in economic yield over farmer practice (T_1)			
		Farmer nano practice (T_1)	Nano N (T_2)	Nano Zn (T_3)	Nano Cu (T_4)	(N, due to Zn, Cu) (T_5)	Due to nano N (T_2)	Due to nano Zn (T_3)	Nano cu (T_4)	Due to nano N, Zn, Cu (T_5)
Castor	21	24.8	26.08	25.27	25.37	26.68	5.37	1.96	2.49	8.08
Chickpea	17	17.52	18.11	17.73	17.71	18.25	3.3	1.14	0.97	4.16
Coriander	5	18.74	19.54	19.06	18.86	19.3	4.33	1.65	0.6	2.99
Cumin	21	8.58	8.93	8.77	8.75	8.97	3.81	2.05	1.69	4.51
Maize	19	52.08	55.88	53.73	54.29	57.07	6.96	3.01	3.86	9.27
Mustard	1	20.45	21.45	21.67	21.87	22.4	4.89	5.97	6.94	9.54
Wheat	296	43.57	45.43	44.45	44.05	45.51	4.37	2.12	1.19	4.71

(T_5) across the different treatments. Per cent increase in yield over FPP was 4.16% in T_5 while it was 3.3%, 1.14% and 0.97% in treatment T_2, T_3 and T_4 respectively.

Coriander

The application of nano fertilizers significantly increase the yield over conventional FFP and gives 4.33 per cent higher yield in treatment T_2 followed by treatment T_5 (2.99), T_3 (1.65) and T_4 (0.6). Average yield was recorded highest in T_2 (19.54 q ha^{-1}) followed by treatment T_5 (19.3 q ha^{-1}) and T_3 (19.06 q ha^{-1}).

Cumin

As shown in Table 2 there are 21 farm field trials are done. The highest yield was recorded in treatment T_5 (8.97 q hac^{-1}) and lowest yield recorded in case of T_1 (8.58 q $hac^{-1)}$. There was significant increases in economic yield compare to FFM (T_1) *i.e.,* 3.81 per cent in T_2, 2.05 per cent in T_3, 1.69 per cent in T_4 and 4.51 per cent in T_5.

Maize

Maize is important crop of middle Gujarat region and there was 19 on farm field trials are done to show the effect of nano fertilizer on economic yield. The results of trials shows that average economic yield ranges from 52.08 q ha^{-1} (T_1) to 57.07 q ha^{-1} (T_5) which depict the significant effect of nano fertilizers spray on yield. The per cent increases in yield compare to traditional farmers practices was found highest (9.27%) when we applied treatment T_5 *i.e.,* FFP-50% N + 1 spray of Nano-N + 1 spray of Nano-Zn + 1 spray of Nano-Cu, followed by 6.96% in T_2, 3.86% in T_4 and 3.01 in T_3.

Mustard

In mustard there is only one on farm field trial conducted and found that the yield was highest in treatment T_5 (22.40 q ha^{-1}) followed by treatment T_4 (21.87 q ha^{-1}), treatment T_3 (21.67 q ha^{-1}) and lowest yield observed in treatment FFP (20.45 q ha^{-1}). The per cent increase in economic yield was highest in treatment T_5 (9.54%) and lowest in treatment T_2 (4.89%) compare to treatment T_1 *i.e.*, FFP.

Wheat

Wheat is one of the most important crop of Gujarat and total 296 trials were conducted throughout the state. Highest yield was recorded in treatment T_5 (45.51 q ha^{-1}), followed by treatment T_2 (45.43 q ha^{-1}), T_3 (44.45 q ha^{-1}) and treatment T_4 (44.05 q ha^{-1}). Lowest yield observed in treatment T_1 (43.57 q ha^{-1}). The per cent increases in economic yield was ranged from 4.71% (T_4) to 4.37% (T_2).

The significant increase in economic yield observed through the application of nano fertilizers is because nanofertilizers have higher surface area and very less particles size which provide more site to facilitate different metabolic process in the plant system result production of more photosynthates. Due to higher surface area and very less size they have high reactivity with other compound. They have high solubility in different solvent such as water. Particles size of nanofertilizers is less than 100 nm which facilitates more penetration of nano particles in to the plant from applied surface such as soil or leaves. Nano fertilizer have particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer Samrat *et al.* (2020).

CONCLUSION

The findings of the present study suggested that the IFFCO nanofertilizers in general and Nano urea in particular, will successfully help in reducing the consumption of urea. The trials on application of nanofertilizers significantly increase crop yield over control or without application of nanofertilzer it is mainly because of increasing growth of plant parts and metabolic process such as photosynthesis leads to higher photosynthates accumulation and translocation to the economic parts of the plant. Foliar application of nano particles as fertilizer significantly increases in yield of the crop.

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Conflict of interest

All authors declare that they have no conflict of interest.

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