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Nanofertilizers for Enhancing Nutrient use Efficiency and Crop Productivity in Vegetable Crops of Gujarat

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ABSTRACT

Background: India is a second largest producer of vegetables after China. Fruits and vegetables are essential parts of our diets and vegetables recommended highest by ICMR. Therefore, the vegetables require extra emphasis to improve production and productivity of it to feed the second largest population in the world.

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 11 important vegetable crops grown during winter season in Gujarat with 5 treatment combinations**.**

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 5.34% higher return then all there treatments in all crops. Which conclude that application of nano-fertilizers through foliar spray significantly increase crop yield over control or without application of nano-fertilzer due to its higher Nutrient Use Efficiency (NUE). So it was recommended to use farmers fertilizers practices (FFP) 50% N, 1 spray of Nano-N, 1 spray of Nano-Zn and 1 spray of Nano-Cu to get more economic yield.

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

INTRODCTION

In agriculture, horticulture comprises major share in India. Agriculture contributes about 15% in National GDP and horticulture alone shares about 35% of total agriculture GDP (Chitra Mani and Kumar, P. (2020). Horticulture includes fruits, vegetables, flowers, spices, medicinal and aromatic crops. India is the second largest producer after China. The total area and production of vegetables are 10.2 mha and 184 mt respectively, (Anonymous 2018). Among all states, Uttar Pradesh placed at first rank followed by West Bengal, Bihar, *etc.* in total vegetable production. Potato occupy first place in total production. The major vegetables are being grown in India, Cauliflower, cabbage, okra, brinjal, cucurbits, *etc.* Fruits and vegetables are essential parts of our diets. Among all horticultural crops, vegetables recommended highest by ICMR. Therefore, vegetables occupy essential concern regarding production and productivity. The per capita recommended vegetables per day is 300 g per person per day (ICMR). Therefore, the vegetables require extra emphasis to improve production and productivity of it to feed the second largest population in the world (Kumar, 2019).

It is well known that, each of the nutrient element plays a major role in growth and development of the plants and when present in deficient quantities can reduce growth and yields (Tisdale *et al.,* 1993). Soil is the major natural source of plant nutrients. Soil may support growth and development of wild flora just sufficient for their survival and regeneration. However, intensive crop production that aims at high levels of productivity needs supplemental plant nutrition which may be given through soil application and/or foliar application. Soil application of nutrients is the most common practice, but it has many limitations with respect to availability of nutrients to the plants. The inorganic nutrients get fixed in soil as insoluble forms and also subjected to leaching by rainfall or irrigation water (Alshaal and El-Ramady, 2017). Moreover, anything which restricts root growth reduces the nutrient uptake (Trobisch and Schilling, 1970). Foliar application overcomes these limitations. In addition to that, foliar feeding has proved to be the fastest way of correcting nutrient deficiencies and increasing yield and quality of crop products (Roemheld and El-Fouly, 1999) and it also minimizes environmental pollution and improves nutrient utilization by reducing the amounts of fertilizers added to the soil (Abou-El-nour, 2002).

Even though leaves allow gas exchange, but cuticle present in the leaves restricts the penetration of substances (Schwab *et al.,* 2015; Pérez-de-Luque, 2017). Therefore, there has been a trend to use modern technologies, such as nanotechnology (NT), to increase the productivity of plants. The nano coated substances enhance the penetration via stomata with a size exclusion limit above 10 nm (Eichert *et al.,* 2008; Pérez-de-Luque, 2017). In addition to this, nanocarriers deliver the nutrients in the right place and right time which reduce the extra amount of active

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chemicals deposited into the plant system and increase the nutrient use efficiency. Nano-fertilizers have high surface area, sorption capacity and controlled-release kinetics to targeted sites and have been considered as smart delivery system (Rameshaiah *et al*., 2015; Solanki *et al*., 2015). Indeed, it is necessary to study about the penetration and translocation of nanofertilizer through foliage and its effect on crops with respect of growth and development, yield, quality, tolerance to abiotic stress and alleviation of heavy metal toxicity. In view of this present research was aimed to study the effect of liquid Nano-n, Nano-Zn and Nano-Cu on important vegetables crops grown throughout the Gujarat state.

MATERIALS AND METHODS

Total 167 on farm yield trials data collected for yield in all the districts of Gujarat for 11 different crops. Crops for trails 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 of which are presented in Table 1. Nanofertilizers namely, Nano-N, Nano-Zn and Nano-Cu had nutrient concentrations of 25000, 5000 and 2000 mg L^{-1}, respectively. Four mL of these liquid fertilizers were added in 1L 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.

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) + 1 spray of Nano-N + 1 spray of Nano-Zn + 1 spray of Nano-Cu

RESULTS AND DISCUSSION

Data collected from 167 on fram demonstrations with respect to economic yield and percent increase over FFP are given in Table 2 and Fig 1. Crop-wise results are described in following paragraphs.

Bottle gourd

Data depicted in Table 2 and Fig 1 shows the results of 4 farmers field trials conducted on farmers field which shows that economic yield ranges from 131.71 Qnt ha^{-1} (T_1) to 138.74 Qnt ha^{-1} (T_5). While percent increases in yield over FFP was observed highest in T_5 (5.9%) followed by 4.43% (T_2), 3.17% (T_4) and 2.64% (T_2). The results clearly shows that the spray of nano fertilizers can improved the economic yield and also give high returns.

Brinjal

10 on farmers field trail were done and found that the average economic yield ranges from 311.95 Qnt ha^{-1} (T_1) to 325.93 Qnt ha^{-1} (T_5) across the different treatments in which highest yield observed in treatment T_5 of 325.93 Qnt ha^{-1}. Per cent increase in yield over FPP was 4.34% in T_5 while it was 2.9%, 2.39% and 0.7% in treatment T_2, T_3 and T_4 respectively.

Cabbage

The application of nano fertilizers significantly increase the yield over conventional FFP and gives 5.5 per cent higher yield in treatment T_5 followed by treatment T_2 (4.04), T_3 (4.04)

Table 2: Effect of IFFCO nanofertilizers on economic yield of 11 vegetable crops.

Crop	No. of trials	Average economic yield (Quintal/Ha)					% Increase in economic yield over farmer practice (T_1)			
		Farmer practice (T_1)	Nano N (T_2)	Nano Zn (T_3)	Nano Cu (T_4)	Nano (N, Zn, Cu) (T_5)	Due to Nano N (T_2)	Due to Nano Zn (T_3)	Due to Nano Cu (T_4)	Due to Nano N, Zn, Cu (T_5)
Bottle gourd	4	131.71	136.75	135.18	136.1	138.74	4.43	2.64	3.17	5.9
Brinjal	10	311.95	321.19	319.94	314.58	325.93	2.9	2.39	0.7	4.34
Cabbage	2	228.25	236.5	236.45	230.5	240.1	4.04	4.04	0.99	5.5
Cauliflower	4	278	291.65	280.8	281.08	290	4.47	0.78	0.68	3.98
Chilli	21	149.36	153.6	151.94	151.47	157.12	2.99	1.98	1.48	5.54
Garlic	5	69.05	74.66	71.09	70.77	75.13	6.96	2.82	2.47	7.4
Okra	3	150	155.67	152.53	150.37	160.07	3.76	1.7	0.25	6.69
Onion	12	327.59	340.2	332.37	331.37	339.37	3.71	1.5	1.21	3.54
Potato	101	333.4	344.92	338.48	338.74	346.23	3.45	1.52	1.6	3.86
Ridge gourd	1	70	74.35	74	70.05	75	6.21	5.71	0.07	7.14
Tomato	4	313.53	327.58	317.78	316.66	328.18	4.65	1.56	1.17	4.83
Total	167	214.80	223.37	219.14	217.43	225.08	4.32	2.42	1.25	5.34

and T_4 (0.99). Average yield was recorded highest in T_5 (240.1 Qnt ha^{-1}) followed by treatment T_2 (236.5 Qnt ha^{-1}) and T_3 (236.45 Qnt ha^{-1}).

Cauliflower

As shown in Table 2 and Fig 1 there are 4 farmers field trails are done. The highest yield was recorded in treatment T_2 (291.65 Qnt hac^{-1}) and lowest yield recorded in case of T_1 (278 Qnt hac^{-1}). There was significant increases in economic yield compare to FFM (T_1) *i.e.,* 4.47 per cent in T_2, 3.98 per cent in T_5, 0.78 per cent in T_3 and 0.68 per cent in T_4. As cauliflower required more nitrogen for vegetative part development so nitrogen requirement also high.

Chilli

Chilli is important crop of middle Gujarat region and there was 21 farmers field trails are done to show the effect of nano fertilizer on economic yield. The results of trails shows that average economic yield ranges from 149.36 Qnt ha^{-1} (T_1) to 157.12 Qnt 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 (5.54%) when we applied treatment T_5 *i.e.,* FFP-50% N + 1spray of Nano-N + 1 spray of Nano-Zn + 1 spray of Nano-Cu, followed by 2.99% in T_2, 1.98% in T_3 and 1.48% in T_4.

Garlic

In garlic there was 5 farmers field trial conducted and found that the yield was highest in treatment T_5 (75.13 Qnt ha^{-1}) followed by treatment T_2 (74.66 Qnt ha^{-1}), treatment T_3 (71.09 Qnt ha^{-1}) and lowest yield observed in treatment FFP (69.05 Qnt ha^{-1}). The per cent increase in economic yield was highest in treatment T_5 (7.4%) and lowest in treatment T_4 (2.47%) compare to treatment T_1 *i.e.*, FFP.

Okra

As depicted in Table 1 and Fig 1 highest yield was recorded in treatment T_5 (160.07 Qnt ha^{-1}), followed by treatment T_2 (155.67 Qnt ha^{-1}), T_3 (152.53 Qnt ha^{-1}) and treatment T_4 (150.37 Qnt ha^{-1}). Lowest yield observed in treatment T_1 (150 Qnt ha^{-1}). The per cent increases in economic yield was ranged from 0.25% (T_4) to 6.69% (T_2) over the FFP (T_1).

Onion

On onion there was 12 farmer's field trials are conducted which results are shown in Table 2 and Fig 1. The results shows that economic yield was highest in treatment T_2 (340.2 Qnt ha^{-1}) and lowest in treatment T_1 (327.59 Qnt ha^{-1}) while percent increases over FFP was 3.71% in T_2, 1.5% in T_3, 1.21% in T_4 and 3.54% in T_5. The results depicted that spray on Nano-N with FFP is beneficial for farmers to get more economic returns.

Potato

Potato is one of the major vegetables grown in north Gujarat and also one of the most fertilizer consuming crop so it is desirable to use nano fertilizers in this crop to reduce the chemical fertilizers consumption in view of this total 101 farmers field trails are conducted across the Gujarat state. The results shows that economic yield ranges from 333.4 Qnt ha^{-1} in treatment T_1 to 346.23 Qnt ha^{-1} in treatment T_5. The per cent increases in yield over the FFP are highest in T_5 (3.86%), followed by T_2 (3.45%), T_4 (1.6%) and T_3 (1.52%).

Ridge gourd

In ridge gourd there is only one farmers field trial conducted and found that the yield was highest in treatment T_5 (75.0 Qnt ha^{-1}) followed by treatment T_2 (74.35 Qnt ha^{-1}), treatment T_3 (74 Qnt ha^{-1}) and lowest yield observed in treatment FFP (70 Qnt ha^{-1}). The per cent increase in economic yield was highest in treatment T_5 (7.14%) and lowest in treatment T_4 (0.07%) compare to treatment T_1 *i.e.*, FFP.

Tomato

Total 4 on farm trials are done and data collected for economic yield (Qnt ha^{-1}) and per cent increase over FFP.

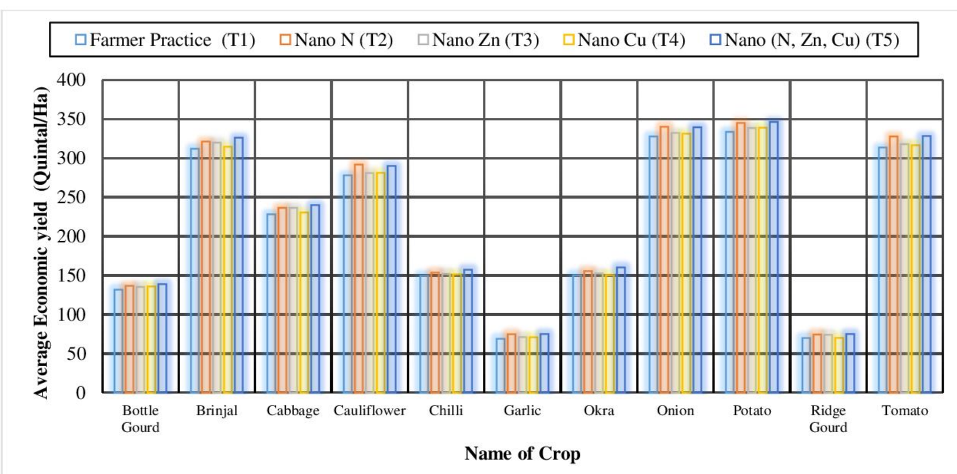

Fig 1: Effect of IFFCO nanofertilizers on economic yield of 11 vegetable crops.

It shows that highest yield was recorded in Treatment T_5 (328.18 Qnt ha^{-1}) followed by treatment T_2 (327.58 Qnt ha^{-1}), T_3 (317.78 Qnt ha^{-1}), T_4 (316.66 Qnt ha^{-1}) and T_1 (313.53 Qnt ha^{-1}). While treatment T_5 (4.83%) shows highest percent increase in economic yield over FFP followed by T_2 (4.65%). So it suggest that the positive impact of spraying nano fertilizers on tomato.

There are total 167 trails are performed over the Gujarat state which shows the effectiveness of IFFCO nano fertilizers in increasing economic yield over the farmers fertilizers practices. There was 6.69% increasing in yield recorded in 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 3.76% in T_2 which shows that foliar applications of nanofertilizer had reflected in improvement in yield parameters of vegetables crops. Tahmasbi *et al.* (2011) suggested that the tuber yield of potato increased with the foliar application of nanofertilizers possibly by reason of its effect which might have helped seed tubers to stay healthier for longer time in the soil and subsequently produced more vigorous plants. 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 (NUE) of the nano-fertilizer.

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 trails on application of nanofertilizers through foliar spary significantly increase crop yield over control or without application of nanofertilzer due to its higher Nutrient Use Efficiency (NUE). So it was recommended to use fermers fertilizers practices (FFP) 50% N, 1 spray of Nano-N, 1 spray of Nano-Zn and 1 spray of Nano-Cu to get more economic yield.

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