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Effect of IFFCO Nanofertilizer on Growth, Grain Yield and Managing *Turcicum* Leaf Blight Disease in Maize

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Authors' contributions

This work was carried out in collaboration among all authors. Author KA, YK, CN and MRK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ASS and MYA managed the analyses of the study. Author RR and SNB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Nanoscience coupled with nanotechnology emerged as possible cost-cutting approach to prodigal farming and environmental clean-up operations. Hence there is a need for a more innovative fertilizer approach that can increase the productivity of agricultural systems and more environmental friendly than synthetic fertilizers. The trial was laid out in randomized complete block design with 11 treatments in three replications. The field experiment was carried out at Main

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Agricultural Research Station, University of Agricultural Sciences, Raichur during *Kharif* seasons of 2019 and 2020. In this research, we studied the recent development and potential benefits derived from the use of nanofertilizers (NFs) in modern agriculture. Nanofertilizers facilitate slow and steady release of nutrients, thereby reduce the loss of nutrients and enhance the nutrient use efficiency. In the present study, the nanofertilizers such as IFFCO nanonitrogen (nano N), IFFCO nanocopper (nano Cu), IFFCO nanozinc (nano Zn) and IFFCO sagarika were sprayed to the maize crop in different combinations with recommended dose of fertilizers. Among the different combinations of nanofertilizers with recommended dose of fertilizers the treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] showed significant effect on the growth and yield parameters with maximum yield of 58.90 q/ha and highest B:C of 2.99. Whereas, treatment T_{10} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with nano Zn (2 ml/l) and IFFCO nano Cu (2ml/l)] was found superior with regard to management of *Turcicum* leaf blight disease with minimum of 18.20 per cent severity.

Keywords: IFFCO nanofertilizers; growth and yield parameters; maize; turcicum leaf blight.

1. INTRODUCTION

Maize is botanically known as *Zea mays*, belong to graminae family. It ranks 3rd among the cereals in India after wheat and rice. The term corn refers as “to sustain life” that provides nutrients for human and animals worldwide [1]. It is cultivated throughout the year in all the seasons and grown around the globe. The nutritional value of maize is high as it contains 72% starch, 10% protein, 8.5% fibre, 4.8% oil, 3.0% sugar and 1.7% ash [2]. Comparatively maize gives more yield than the other cereals such as rice, wheat *etc*., hence it is known as the “Queen of Cereals”. It is an important staple food and also used as a fodder crop in India. Starch, cooking oil and gluten are also extracted from maize. The starch in maize can be hydrolysed and enzymatically treated to produce syrups, particularly high fructose corn syrup, a sweetener and also as fermented and distilled to produce grain alcohol. Grain alcohol from maize is traditionally the source of Bourbon whiskey [3].

Maize is an exhaustible crop that demands high nutrition for their growth and development. The productivity of the crop depends on nutrient management system. Inorganic fertilizers are most widely used all over the world as it gives higher yield and the end result is also much appreciable. Efficient use of nitrogen is important for maize production as it increases the yield and maximize economic return and minimize NO_3 leaching to ground [3]. An organic fertilizer such as poultry manure, FYM and vermicompost are free from synthetic compounds and chemicals. The best source of nutrients can be received from the organic manure. It is not harmful to the environment. Biofertilizers are also a good source of nutrients as it binds the atmospheric nitrogen which is inaccessible to plants and ammonium ion and is released into the soil. It also enhanced the fertility of the soil.

Sustainable agriculture with a high productivity is crucial to alleviate the perils of hunger and increase food security. Food production and distribution are under an increased and continuous stress at a global scale due to climate change, an increased human population, decreased fertile lands and freshwater resources. This challenge could be addressed with technological advancements coupled with significant modifications to existing global food production systems [4]. Currently, modern agriculture is heavily supported by the use of high rates of agrochemicals. Synthetic chemical fertilizers are used for the optimal growth and productivity of crops, but they are not successful to enhance plant nutrient use efficiency (NUE) and crop productivity [5]. The NUE values of the three most basic macronutrients *i.e*., nitrogen, phosphorus and potassium are low at 30–35%, 18–20% and 35–40%, respectively [6], which shows that more than half of the broadcasted fertilizers in the fields are lost and do not reach their targeted sites due to different factors such as photolysis, hydrolysis, leaching and microbial immobilization and degradation.

Nanoscience and Nanotechnology represent a new frontier for the research community. Nanofertilizer is working with the smallest possible particles which elevate hopes for improving agricultural productivity through encountering problems unsolved conventionally. Nanotechnology has its goal in realization of novel materials and devices with features on the nanoscale, drawing from fields such as colloidal science, device physics and supramolecular chemistry. In the management aspects, efforts are made to increase the efficiency of applied fertilizer with the help of nano clays and zeolites and restoration of soil fertility by releasing fixed nutrients. It has found potential applications in controlling nutrient release and availability, characterization of soil minerals, weathering of soil minerals and development, nature of soil rhizosphere and nutrient ion transport in soil plant system.

Direct application of fertilizers to the soil will results in loss of nutrients in different ways such as photolysis, hydrolysis, leaching and degradation. Hence the applied fertilizer may not able to reach the targeted sites in the plant system and unable to enhance the optimal growth and productivity of crops. Hence an attempt was made to increase the efficiency of applied fertilizer in the form of nanofertilizer through foliar spray to the crop.

Therefore in the present investigation, the role of different nanofertilizers such as IFFCO nano N, IFFCO nano Cu, IFFCO nano Zn and IFFCO sagarika on the yield and yield components as well as in managing the *Turcicum* leaf blight of maize were studied.

2. MATERIALS AND METHODS

The field experiment was carried out in the experimental block of Main Agricultural Research Station, University of Agricultural Sciences, Raichur during *Kharif* seasons of 2019 and 2020. The trial was laid out in randomized complete block design with 11 treatments replicated thrice by using the popular hybrid N-6240 and individual treatments were laid out with the plot size of 4 m X 5 m. The main field was prepared by opening ridges and furrows with 60 cm spacing and seeds were dibbled in the ridges with 20 cm between the plants. The details of the treatment and the dosage of the chemicals were followed as per the protocol. First foliar spray of recommended nano-particles were given as per the respective treatments at 30 days after sowing and the second spray was given after initiation of the tassel.

The observations on different growth parameters such as height of the crop, leaf area and stem girth were taken seven days after second spray, whereas yield parameters such as weight of the cob, 100 kernel weight and kernel yield were recorded after the harvest and the data was analyzed statistically by using randamized block design (RBD design). The severity of *Turcicum* leaf blight in maize was recorded in all the treatments seven days after the second spray and the per cent disease severity was recorded as per disease index by following 1 – 5 disease scale [7] on the leaves as mentioned below (Table 1).

The data were computed to per cent disease index (PDI) using the following formula [8]

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum grade}}$$

3. RESULTS AND DISCUSSION

The experiment was laid out during *Kharif*, 2019 and *Kharif*, 2020 at Main Agricultural Research Station, UAS, Raichur in order to assess the role of IFFCO nanofertilizers on the growth, yield and yield attributes of maize as well as influence on the management of *Turcicum* leaf blight disease. The two seasons result has shown the similar inclination by all the treatments of IFFCO nanofertilizers and its different combinations with recommended dose of fertilizers. The pooled result of the two seasons of field experiment has been presented in Table 2 and Fig. 2.

Table 1. Scale used to assess the severity of Turcicum leaf blight of maize

Disease scale	Symptom descriptions	Disease reaction
1	Very slight to slight infection, one or two to few scattered lesions on lower leaves	Highly Resistance (HR)
2	Light infection, moderate number of lesions on lower leaves only	Resistance (R)
3	Moderate infection, abundant lesions on lower leaves, few on middle leaves	Moderately Resistance (MR)
4	Heavy infection, lesions are abundant on lower and middle leaves, extending to upper leaves	Susceptible (S)
5	Very heavy infection, lesions abundant on almost all leaves, plants prematurely dry or killed by the disease	Highly Susceptible (HS)

Table 2. Effect of nanoparticles on growth, yield parameters and *Turcicum* leaf blight disease of maize (Pooled data of 2019and 2020)

Tr. No.	Treatments detail	Crop height (cm)	Leaf area (cm^2)	Girth of stem (cm)	Weight of 100 kernel (g)	Weight of cob (g)	Yield/plot (kg)	Yield (q/ha)	Severity of *Turcicum* leaf blight (%)	BC Ratio
T_1	Control (No nitrogen and zinc, 100% P & K fertilizers)	180.67	484.75	4.83	28.12	142.42	6.92	34.58	25.07 (30.04)	1.97
T_2	T_1 + 2 sprays of nanonitrogen (4ml/l)	211.00	634.25	5.83	31.38	144.96	7.65	38.27	41.50 (40.11)	2.04
T_3	T_1 + 2 sprays of IFFCO nano N 2X (8ml/l)	213.00	666.62	5.90	32.84	147.40	7.63	38.15	43.57 (41.30)	1.91
T_4	T_1 + 2 sprays of IFFCO nano Zn (2ml/l)	186.33	490.04	4.97	29.50	143.83	7.35	36.75	24.17 (29.45)	1.96
T_5	T_1 + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO nano Zn (2 ml/l)	210.67	629.77	6.03	32.97	146.43	7.74	38.68	41.17 (39.91)	2.00
T_6	RDF (100% NPK) + 100% zinc	207.00	616.57	5.97	34.91	164.52	9.48	47.40	35.10 (36.33)	2.55
T_7	50% N, 100% PK + 2 sprays of IFFCO nano N (4ml/l)	215.00	662.32	6.10	36.43	169.98	9.87	49.37	39.83 (39.13)	2.59
T_8	RDF (100% NPK) + 2 sprays of IFFCO nano Zn (2ml/l)	207.67	623.24	5.93	35.21	164.24	9.77	48.85	32.80 (34.94)	2.60
T_9	50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO nano Zn(2 ml/l)	214.33	665.88	6.23	36.82	168.74	10.25	51.25	37.83 (37.96)	2.60
T_{10}	50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO nano Zn (2 ml/l) and IFFCO nano Cu (2ml/l)	217.33	742.20	6.40	39.18	176.06	10.58	52.90	18.20 (25.25)	2.61
T_{11}	50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)	226.00	801.16	6.97	40.71	182.68	11.78	58.90	38.60 (38.41)	2.99
	S. Em. ±	**5.44**	**46.95**	**0.4**	**0.89**	**4.84**	**0.58**	**2.91**	**0.77**	
	C. D. at 5%	**16.05**	**138.49**	**1.19**	**2.65**	**14.27**	**1.72**	**8.58**	**2.28**	

**Figures in the parenthesis are Arcsine transformed values.*

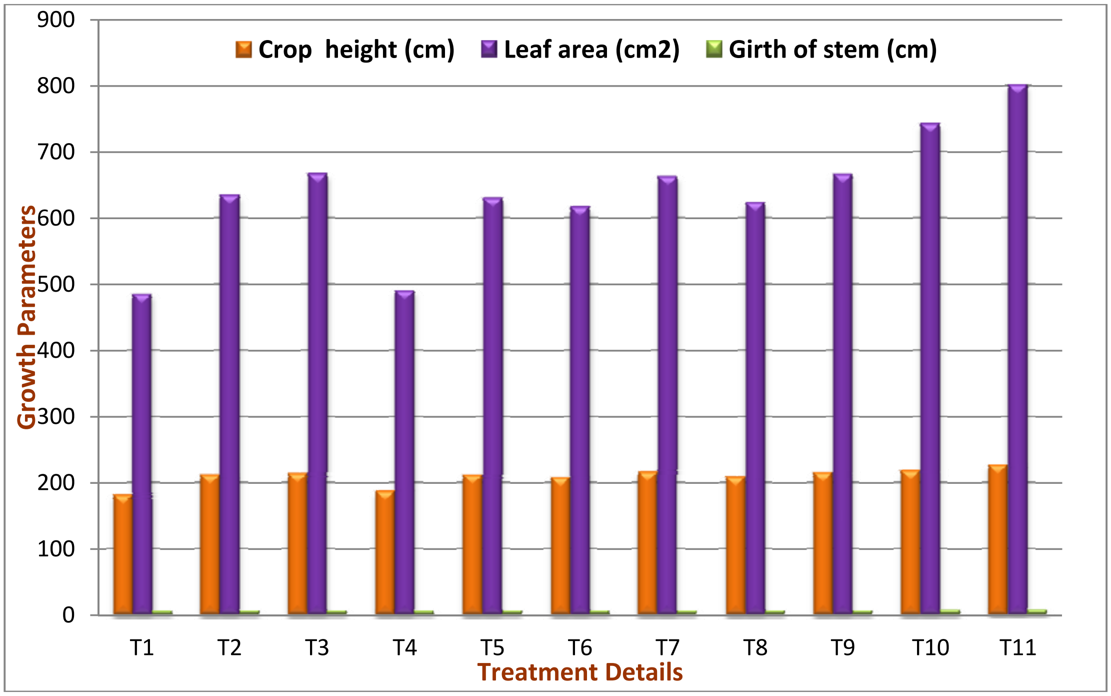

Fig. 1. Effect of IFFCO nanofertilizers and straight fertilizers on the growth parameters of maize

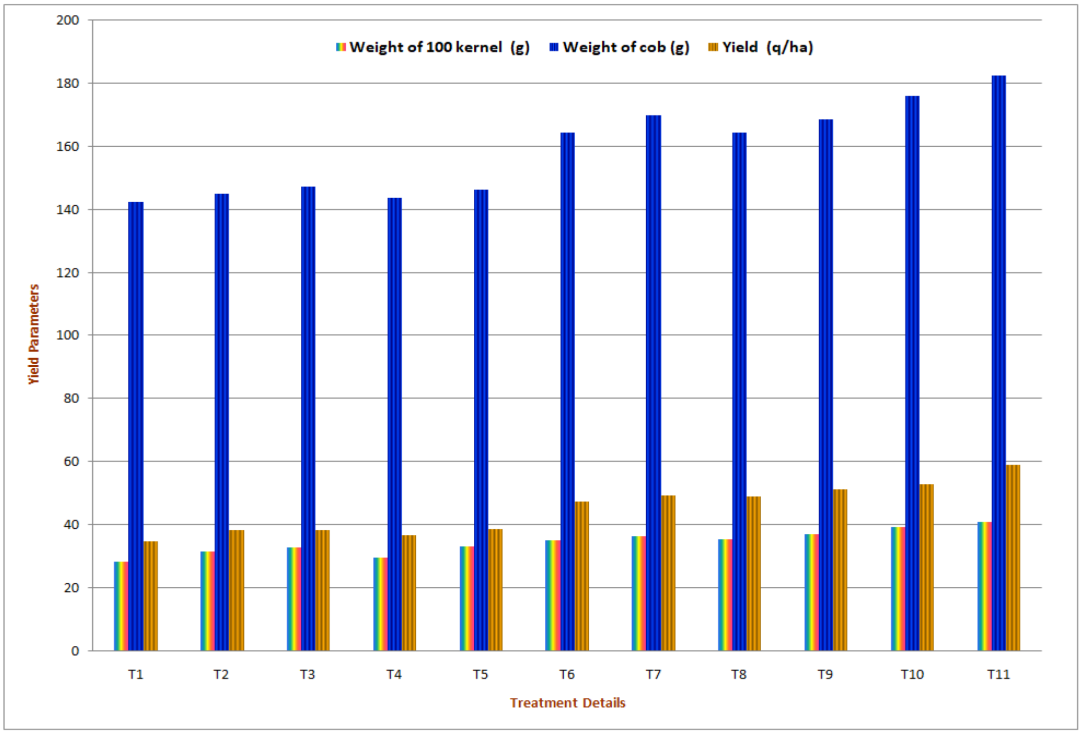

Fig. 2. Effect of IFFCO nanofertilizers and straight fertilizers on the yield and yield attributes of maize

3.1 Growth Parameters

The results showed that among all the treatments the maximum height of the maize was recorded under treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] was 226 cm which was on par with T_{10}, T_7, T_9, $T_{3,}$ T_2 and T_5 and T_{11} treatment was significantly superior over rest treatments (T_8 and T_4) and the control (T_1 – 180.67 cm).

The maximum leaf area was recorded under T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] was 801.16 cm^2. The T_{11} was on par with $T_{10,}$ T_3 and T_9 and significantly superior over the remaining treatments ($T_{2,}$ $T_{4,}$ $T_{5,}$ $T_{6,}$ T_7 and T_8) and the control (T_1 – 484.75 cm^2).

The results of the experiment demonstrated that, the maximum girth of the stem was recorded by treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] with 6.97 cm and all the treatments ($T_{10,}$ T_9, T_7, $T_{5,}$ $T_{6,}$ $T_{8,}T_3$ and T_2) were on par with each other and T_{11} was significantly superior over the T_{10} and the control (T_1 – 4.83 cm).

3.2 Yield Parameters

The outcome of the experiment demonstrated that, among all the treatments the maximum weight of the 100 kernel was recorded under treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] was 40.71 g which was at par with T_{10} whereas significantly superior over rest of the treatments (T_9, T_7, T_8, T_6, $T_{5,}$ $T_{3,}$ and T_4) and the control (T_1 –28.12 cm).

The maximum weight of the cob was recorded under treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] was 182.68 g and the treatments T_{10}, T_3 and T_9 were at par with T_{11} and significantly superior over remaining treatments (T_6, $T_{8,}$ $T_{3,}$ $T_{5,}$ $T_{2,}$ and T_4) and the control (T_1 – 142.42 g).

The maximum yield was recorded for T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] with 58.90 q/ha and the treatments T_{10} and T_9 (52.90 and 51.25 q/ha) were at par with treatment T_{11} where as T_{11} was found superior over the remaining treatments ($T_{7,}$ $T_{8,}$ $T_{6,}$ $T_{5,}$ $T_{2,}$ T_3 and T_4) and the control (T_1 – 34.58 q/ha).

3.3 B:C Ratio

Among the 11 treatments, the maximum B:C ratio was recorded in treatment T_{11} [50% N, 100% PK, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO Sagarika (2 ml/l)] treatment with 2.99 which was followed by T_{10} (2.61) and $T_{9,}$ T_{10} (2.60). The least BC ratio was recorded by T_3 [(No nitrogen and zinc, 100% P & K fertilizers) $_+$ 2 sprays of IFFCO nano N - 2X (8ml/l)] with 1.91 whereas T1 [control- (No nitrogen and zinc, 100% P & K fertilizers)] has recorded BC ratio of 1.97 (Fig. 3).

3.4 *Turcicum* leaf blight disease of maize

The effect of IFFCO nanoparticles was also assessed on the severity of *Turcicum* leaf blight disease of maize (Table 2, Fig. 3, Plate 2). Among all the treatments, the least mean percent disease severity was noticed in T_{10} [50% N, 100% P and K, 0% Zinc + 2 sprays of IFFCO nano N (4ml/l) mixed with IFFCO nano Zn (2 ml/l) and IFFCO nano Cu (2ml/l)] was 18.20 and was significantly lower than other treatments. The next best treatment was T_4 [No nitrogen and zinc, 100% P and K fertilizers $_+$ 2 sprays of IFFCO nano Zn (2ml/l)] with 24.17% *Turcicum* leaf blight. However the treatment, T_{11} which was recorded maximum growth and yield parameters with maximum BC ratio has recorded 38.60% *Turcicum* leaf blight.

3.5 Chemical Properties of Soil

The chemical properties of the soil before start of the experiment and after the harvest of the crop are presented in Table 3. The results revealed that there was slight increase in the soil chemical properties after the harvest of the crop. The soil pH was slightly decreased from 8.12 to 8.05 and slight increase in EC, per cent organic Carbon, available N, P, K, Zn and Fe were slightly increased (0.83 from 0.32, 0.37 from 0.31, 122.4 kg from 118.5 kg N, 22.1 kg from 12.4 kg P, 774.3 kg from 683.1 kg K, 0.88 ppm from 0.81 ppm Zn and 1.31 ppm to 1.24 ppm Fe, respectively).

There was clear evidence that nitrogen nutrition was a major component to maize production. Application of nitrogen fertilization produced the highest yield irrespective of the rate. The results of the present investigation are supported by

Adeboye et al. [9] who reported 90 kg N ha^{-1} to be optimum for maize in Minna and an increased grain yield of maize with nitrogen application [10]. The applied N has been found as a key input for achieving the highest yield of maize in the Savanna agroecological zones [11].

The positive effect of IFFCO nano Cu found in enhancing plant biomass in maize and also reduces the severity of *Turcicum* leaf blight. These results were supported by previous studies that copper plays an important role in plant growth, development and plant productivity as well as very effective in reducing the *Turcicum* leaf blight disease [12,13,14]. The higher plant biomass found in nanocopper applied plants indicated the reduction of drought effect on maize, which was associated with the higher water status of leaf in nano-Cuo group [15]. The higher leaf water status of nano-Cuo priming plants could result in maintaining of photosynthesis under drought [16,17], therefore might affect the plant recover and productivity.

The application of zinc fertilizer judiciously has been reported to increase crop production as well as enrich the zinc content in plant organs including grains [18]. The soil application of zinc resulted in an increase in the grain weight of maize [19,20] and the increased maize yield was attributed to the foliar application of zinc [21]. An increase in the maize grain yield due to the application of 5 kg zinc ha^{-1} to the soil was also observed [22].

The different fungicides including copper based fungicides were tried under *in vitro* and *in vivo* [23]. Among the different fungicides copper oxy chloride was found effective in inhibiting the mycelial growth of *Helminthosporium maydis* under *in vitro* as well as effective in managing the leaf blight disease of maize under field condition.

Table 3. Estimation of chemico-nutritional properties of soil

Characters	pH	E.C. (dS/m)	Organic Carbon (%)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Av. Zn (ppm)	Av. Fe (ppm)
Before Sowing	8.12	0.32	0.31	118.5	12.4	683.1	0.81	1.24
After Harvesting	8.05	0.83	0.37	122.4	22.1	774.3	0.88	1.31

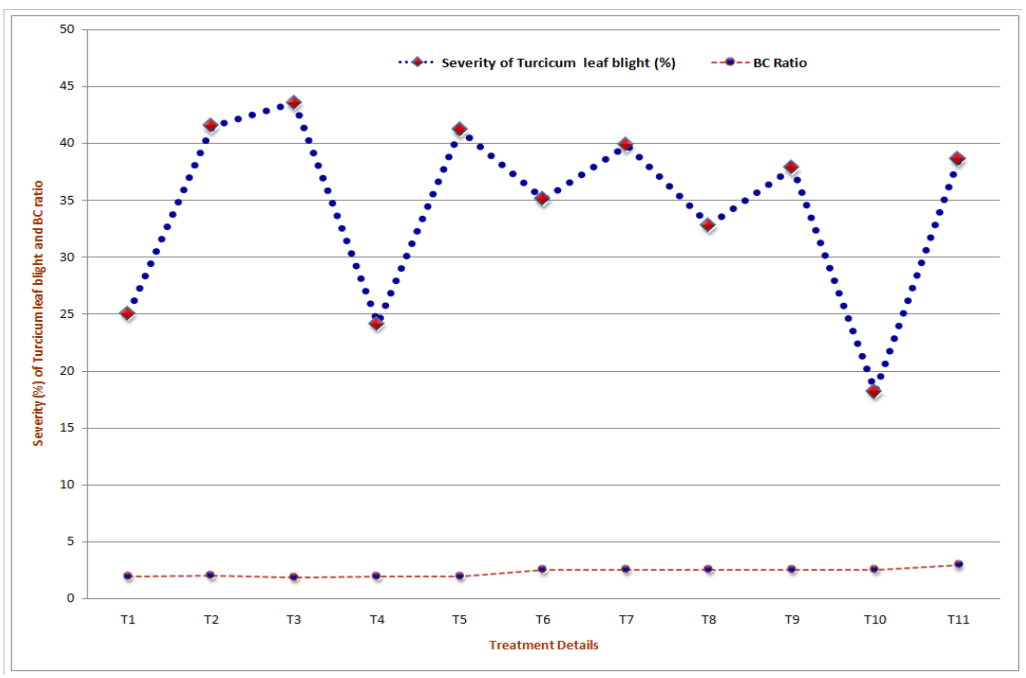

Fig. 3. Effect of IFFCO nanofertilizers and straight fertilizers on the severity of *Turcicum* leaf blight and economics of maize

A: T_1-(No nitrogen and zinc, 100% P & K fertilizers) **B:T_5-RDF (100% NPK & 100% Zn)** **C: T_6- (50 % N, 100 % PK), 2 sprays of nano-nitrogen**

Plate 1. The different sizes of the cobs noticed in different treatments

A. T_4: T_1, 2 sprays of nano-co **B: T_6- (50 % N, 100 % PK),** **2 sprays of nano-nitrogen**

Plate 2. The effect of IFFCO nano-particles on *Turcicum* leaf blight disease of maize in different treatments:

4. CONCLUSION

Application of IFFCO nanofertilizers (IFFCO nano N, IFFCO nano Cu, IFFCO nano Zn) and IFFCO sagarika through foliar spray as an alternative to soil application of fertilizers in combination with synthetic fertilizers through soil application for maize was very effective in enhancing the yield and yield attributing parameters as well as recorded maximum BC ratio. The soil chemical properties were also slightly increased in the soil. This study clearly suggests that, soil application of fertilizer can be replaced by nanofertilizer through foliar application which enhanced the growth and yield attributes of the crop. In addition the foliar application of nanofertilizer will also diminish the soil pollution and enhances soil fertility by improving the physical and chemical properties of the soil. One litre IFFCO Nano N will replaces 100 kg of urea, hence the use of nanofertilizer will reduces the economic burden on the government investment for the production of direct fertilizers, enhances the socio-economic status of the farming community by reducing the cost of production.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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