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Nano-Formulation of Gluconate and Study on Field Response of Gluconate Based Nano Fertilizers

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ABSTRACT

The proliferation of fertilizers can be attributed to the heightened worldwide need for sustenance. Although chemical fertilizers are frequently employed to enhance plant growth and yield, they can have detrimental impacts on the soil, the ecosystem, and human well-being. As a result, nano fertilizers are regarded as one of the most auspicious remedies or alternatives to traditional fertilizers. The present study has demonstrated that the desired zinc concentration for wheat and tomato crops was successfully attained through the application of Zn gluconate-CS Nano fertilizers at a dose of 42 mg L−1 Zn. This dosage is ten times lower than that of EDTA Based Zn (1.4%) with a concentration of 420 mg L−1 Zn for foliar applied fertilizer. In present study, the maximum wheat grain yield (53.25 q/ha) was found in treatment of Zn gluconate-CS Nano fertilizers was significant as compare of Zinc Sulfate (44.30 q/ha) and Zinc EDTA (48.78 q/ha). In case of tomato crop, Zn gluconate-CS Nano formulation) was recorded maximum number of fruits per cluster (7.00) and maximum number of fruits per plant (40.60) as maximum yield per acre (8.33 ton/acre) followed by Zn EDTA treatment (7.48 ton/acre), Zinc Sulfate (6.66 ton/acre) and minimum were recorded with treatment Control (5.10 ton/acre). The present study mainly concerns the development of slow-release Nano materials, which are comprised of nanoparticles that contain Zn gluconate-CS (Chitosan) Nano based micronutrients. These materials are designed to be delivered to the rhizosphere of plants in a controlled and regulated manner. This nano formulation of gluconate possesses superior nutritional management capabilities, as they can enhance nutrient uptake efficiency.

Keywords: Nano Fertilizers, Plant Nutrition, Sustainable Agriculture, Zinc gluconate-chitosan nano formulation

INTRODUCTION

Nanotechnology is a promising field of interdisciplinary research. It opens a wide array of opportunities in various fields like medicine, pharmaceuticals, electronics and agriculture. The potential uses and benefits of nanotechnology are enormous. Agriculture is the backbone of developing countries, with more than 60% of the population depending on it for their livelihood [1]. Nanotechnology has the potential to revolutionize the agricultural and food industry with novel tools for the molecular management of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients, among others.

Fertilizers are chemical compounds applied to promote plant and fruit growth. Fertilizers are usually applied either through the soil (for uptake by plant roots) or by foliar feeding (for uptake through leaves). Fertilizers can also be applied to aquatic environments, notably ocean fertilization. Artificial fertilizers are inorganic fertilizers formulated in appropriate concentrations and the combinations supply three main nutrients: nitrogen, phosphorus, and potassium (N, P and K) for various crops and growing conditions. N (nitrogen) promotes leaf growth and forms proteins and chlorophyll. P (phosphorus) contributes to root, flower, and fruit development. K (potassium) contributes to stem and root growth and the synthesis of proteins. However, about 40–70% of nitrogen, 80–90% of phosphorus, and 50–70% of potassium of the applied normal fertilizers is lost to the environment and cannot be absorbed by plants, causing not only substantial economic and resource losses but also very serious environmental pollution [2]. Recently, the use of slow release fertilizers has become a new trend to save fertilizer consumption and to minimize environmental pollution [3].The usage of natural polysaccharides in the preparation of nanoparticles has attracted attention because of their biodegradability and hydrophilic characters which are favorable characters in multiplication application.

Plant micronutrients include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and molybdenum (Mo) among others. Compared with the macronutrients (N, P, and K), only trace levels of micronutrients are required for healthy growth of crops and other plants as is shown in the composition of Hoagland solution. However, plant-availability of the applied micronutrients may become low and micronutrient deficiency may occur in some soils of alkaline pH, coarse texture, or that containing low soil organic matter. Presumably, micronutrient nano fertilizers may enhance bioavailability of these nutrients to plants even under these worst-case scenarios[4]. Since development and application of nano fertilizers are still at initial stages, there are few if any specific research or systemic studies on the effects and advantages of applying micronutrient nano fertilizers under field conditions [5]. Several laboratory observations have indicated that some NPs (silica, Fe oxides, C-coated Fe, and polymers) can enter plant tissues/cells and transport DNA and chemicals inside the tissues/cells [6]. Such studies have promoted a hypothesis that these NPs can deliver nutrients to the plants as a new fertilizing or nurturing technique. For example, since crops can naturally absorb soluble nutrients (e.g., N, P, and K) from soil solutions through root systems, is it necessary to inject the nutrient-loaded NPs into plant tissues to enhance their growth [7]. More vigorous and specific rationales are required to support the research and application of this type of new nutrient-delivery approach to crops through those inert NPs[8].

The Soil micro flora produces a wide variety of enzymes. One of these is glucose oxidase, a common enzymethat can produce gluconic acid in the root zone. Gluconic acid can very readily solubilize phosphate in the soil and render it available as a plant nutrient. Gluconic acid can react with various mineral sources, carbohydrate, oxalates etc. To produce mineral gluconate that can be readily absorbed by plants [9].

Commercial Fertilizers producers use gluconate in a mineral extraction process to produce highly soluble liquid fertilizers.

The mineral gluconate (ca, Fe, K, Zn, Mg, Mn) because of their solubility and lack of tissue irritability are gaining acceptance in hydroscopic and foliar fertilizers applications. The chelated gluconate is suitable for soil or foliar applications and use for drip irrigation. It is also stable and will not precipitate at low temperatures. It also shows compatibility with herbicides and insecticides. The use of gluconate improves the uptake of nutrients by the plant root system. In addition to chelated gluconates, chitosan nano material with gluconate salts provides absolute plant nutrition and helps to improve immune system of plant and protected from soil nematodes and fungal infections [9].

Thus, the major objective of this research work is to collate, analyze, and synthesize the most current knowledge regarding these NPs and chitosan nano materials along with gluconate-based micronutrients which can improve plants' growth and yields and/or reduce the environmental risks (such as those caused by conventional fertilizers applications).

Wheat (*Triticum aestivum L.)* is an annual plant belonging to family *Poaceae*(*Gramineae*) is the most important cereal crop and is the third major cereal produced after maize and rice worldwide. Wheat crop is the second important cereal food in India. As a Rabi season (winter season, sowing is done in autumn and harvesting in summer). It plays a vital role in stabilizing food grain production in our country. Wheat contains more protein [8-15% (grain), 8-13% (flour)] than other cereals. Wheat protein has special significance in nutrition; these are principally connected with providing the characteristic ‘gluten’ material, which is very essential for bakery business. Wheat straw is a good source of feed for livestock in our country. Wheat can be grown successfully in those regions where annual rainfall varies from 25 to 150 cm. A well distributed winter rainfall of 15-20 cm is required for rainfed cropping. Wheat plants require medium (50-60%) humidity for their growth, but at the time of maturity, crops require less humidity. The normal time required for sowing of high-yielding cultivars in irrigated areas starts in November-December month. Usually, a seed rate of 100-120 kg/ha is sufficient under favorable conditions of normal sowing. By adopting improved technology, the crop may yield 4-5 t grain and 6-7 t straw/ha from dwarf wheat varieties under proper irrigated conditions.

Tomato (*Solanum lycopersicum L.*) is an important vegetable crop in the world. It belongs to the family Solanaceae. It occupies an area of about 4.73 million hectares with a production of 163.96 million tons in the world. It is the world’s 3rd largest vegetable crop after potato and onion. Tomato is the most widely cultivated crop in India. In india, occupies an area of 8,65,000 ha with an annual production of 1,65,26,000 metric tons/ha and productivity of 19.1metric tones/ha. Tomato grows very well on a wide range of soils, but it grows well on deep, well-drained soils with good drainage ability. Sandy loam to medium black soils is best suitable for Tomato cultivation. Seedlings are raised during May-June, September October, and December-January months for kharif, rabi and summer crops, respectively. Tomato is a very important vegetable crop regarding both income and nutrition. Tomatoes are predominantly summer crops, but they can be cultivated throughout the year. It is a self-pollinated crop. Tomato is one of the most popular vegetables in India having good medicinal value and it is used in various forms of salad, chutney, pickles, powder, soup, ketchup, juice, sauce, paste, whole canned fruits. In its fruit contain vitamins like ‘A’ and ‘C’ and antioxidant in abundance quantity. Due to the unique properties contained in its fruit, tomato demand remains almost the same throughout the year. It is believed that consumption of one tomato per day enhances the health status of individuals and is important in diet as it is quite high in nutritive value. It contains higher quantity of total sugar (2.5 -4.5%), starch (0.6-1.2%) and minerals like potassium, calcium, sodium, magnesium, phosphorus, boron, manganese, zinc, copper, iron, etc., Apart from these, it also contains organic acids such as citric, malic and acetic acids which are known as health acids in fresh tomato fruit. The flavor of tomato fruits is controlled by various volatile compounds like ethanol and acetaldehyde. Tomato juice promotes gastric secretion, acts as a blood purifier and works as intestinal antiseptic. Micronutrients have an important role in plant activities and foliar application can improve the vegetative growth, fruit set and yield of tomatoby increasing photosynthesis of green plants [10],[11]. Among micronutrients, Zn and B are important for plant nutrition. Tomato requires both major and micronutrients for its proper plant growth [12]. Zn plays important role on growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plants [13], [14]. while B deficiency reduced yield and quality in tomatoes [15]. Balanced fertilization of macro and micronutrients can increase production [16]but foliar application of micronutrients is not only efficient but also secured way [17]. The most easily observed symptom of iron deficiency in plants is extensive chlorosis in the leaves [18]. The role of boron in the formation of chlorophyll in plants was well established. The zinc deficiency in tomato causes decrease in rate of protein synthesis, reduction in shoot growth and finally yields. Thus, micronutrients as their requirement is low but they are essential as the larger amount of primary and secondary nutrients for plant growth and development.

Fertilization program with balanced macro and micronutrients in plant nutrition is very crucial in the production of high yield with high quality of crop yield [19]. The amount of Zn micronutrients required by wheat crop is very small, but it is essential for a healthy growth and life cycle completion. Micronutrients are involved in numerous physiological processes that are essential for plants. They play an important function in the growth and development of plants. Their necessary function in plant nutrition and rising soil productivity makes their significance ever greater. Zn, one of the essential micronutrients and an important constituent of several enzymes and proteins, is only needed by plants in small quantities. Zn activates enzymes that are responsible for the synthesis of certain proteins. It is used in the formation of chlorophyll and some carbohydrates, conversion of starches to sugars and its presence in plant tissue helps the plant to withstand cold temperatures. Zn is essential in the formation of auxins, which help with growth regulation and stem elongation.

One of the main roles of Zn micronutrients in plants is derived from their presence in the active centers of many enzyme molecules [20]. Utilization efficiency in terms of dry matter production per unit of zinc present in the dry matter may be directly linked to differences in the ability of a genotype to maintain an optimal activity of the important zinc-regulated enzymes, viz. super oxide dismutase (SOD) and carbonic anhydrase (CA). There are also many enzymes in which zinc is an integral component of the enzyme structure (zinc enzymes). Activity of these enzymes has been correlated with zinc availability to the plants. Differences in internal utilization or mobility of Zn have been shown to be involved in expression of Zn efficiency [21]. Carbonic anhydrase can occur as a dimer, tetrameter, hexamer, or octamer, with a zinc atom in every subunit and a molecular mass ranging from 42 to 250 kDa [22]. CA is present in leaves of higher plants in abundant quantities (1–2% of total soluble leaf protein) and thus represents a significant storage pool of Zn in leaf cells. Generally, CA is present in excess of what may be required for photosynthesis, particularly in C3 plants. CA activity is much lower in wheat compared to several other species [23]. Activity of CA decreases in several plant species as a consequence of Zn deficiency. CA activity is closely related to zinc content in C3 plants. Under extreme zinc deficiency, CA activity is almost absent. High CA activity is required in the mesophyll chloroplast of C4 plants and removal of zinc from the CA molecule in vitro results in an irreversible loss of catalytic activity [24]. There is a quantitative difference between total and physiologically active Zn in leaves. Activity of CA was suggested to be a suitable indicator for the levels of physiologically active Zn in the leaf tissue [25]. Deficiency of Zn is known to decrease CA activity drastically in several plant species [26].

Under zinc deficiency, there was twofold higher CA activity in zinc-efficient than Zn inefficient genotypes of wheat, indicating a higher level of physiologically active Zn pool in leaves of Zn-efficient genotypes. Upon resupply of zinc to zinc-deficient plants, zinc-inefficient wheat genotype lost the ability to increase CA activity, while zinc-efficient genotype Warigal showed a saturating, curvilinear increase in the CA activity, indicating a positive relationship between CA activity and Zn efficiency of the model wheat genotypes [27](Rengel, Z et al., 1995). Ability of Zn efficient wheat genotype to maintain greater CA activity under Zn-deficient conditions may be beneficial in maintaining the photosynthetic rate and dry matter production at a higher level; a characteristic that may be especially important for wheat as a species with inherently lower CA activity compared to other species [27]. Zn appears to have a regulatory influence on stomatal opening, possibly as a constituent of CA [28]. Recently, Kochian’s grouphas shown that zinc efficiency (ZE) in wheat is correlated with enhanced expression and activity of zinc-requiring enzymes and thus, biochemical Zn utilization is an important component of ZE in wheat. They found no correlation between ZE and Zn translocation to the shoot [21]. Further, total, and water-soluble concentrations of leaf Zn were not associated with ZE, and no differences in sub-cellular Zn compartmentation were found between Zn-efficient and Zn-inefficient genotypes.

Zn deficiency symptoms vary depending on the crop. Zn deficiencies are expressed as some varying pattern of chlorosis of the new leaves (often interveinal) and necrotic spots may form on the margins or leaf tips. These new leaves are smaller in size and often cupped upward or distorted. The internodes shorten, giving the plant a rosette appearance and bud development is poor resulting in reduced flowering and branching. In the case of wheat crop, Zn deficiency is severe the leaves may turn white and die. The most characteristic effect of wheat plants to zinc deficiency is reductions in plant height and leaf size. Wheat plants show dusty brown spots on upper leaves of stunted plants, shoot growth is more inhibited than root growth, tillering decreases, spikelet sterility increases, midrib becomes chlorotic particularly near the leaf base of younger leaves, leaves lose turgor and turn brown as brown blotches and streaks appear on lower leaves. A white line sometimes appears along the leaf midrib and the size of the leaf blade is reduced [29]. Symptoms may be more pronounced during early growth stages due to Zn immobilization. For a genotype to be zinc-efficient, it should not only be able to absorb more zinc from deficient soils but should also produce more dry matter and grain yield. It, however, may not necessarily have the highest zinc concentration in tissue or grain10. It is evident from the available literature that the crop response to zinc deficiency in terms of dry mass production is diverse and there is no unanimity in using root and shoot dry mass production or shoot:root ratio as an indicator for zinc efficiency of cereals under low Zn condition. Although root and shoot growth is distinctly reduced under zinc deficiency [23,30]. shoot dry weight is depressed to a greater extent than root dry weight [31], [32], [33].

Field experiments on wheat in India showed that application of Zn-enriched urea (up to 3% Zn) significantly enhanced both grain Zn concentration and grain yield in wheat. Zn application could improve wheat growth under drought stress [34]. Therefore, proper Zn application in crops would be necessary to alleviate climate change impacts on crop yield and nutritional quality.

Chitosan possesses all the properties sought by sustainable systems such as renewability, nontoxicity, and biodegradability. It is the second most profuse polysaccharide in nature after cellulose with sound biocompatibility [35]. The benefits of coupling nanotechnology with any material are well known, corresponding to their very small size and high surface area, which motivates efficacy and reduces wastage. Hence the utilization of nano-chemicals pre-pared using chitosan is foreseen as an alternative to maintain the sustainability of the agroecosystems and environment. Since chitosan NPs possess antimicrobial properties, these can be used as inhibitors of micro-pests like bacteria and fungi in addition to being used as plant growth promoters. For instance, when chitosan Nano Particles (chitosan NPs) were applied on soil and as foliage treatment in paddy, a significant augmentation in the growth of seedlings was noticed. The same report has also concluded the nontoxicity of chitosan NPs [36]. Other examples pointing towards the sustainable management of crop pests such as bacteria, fungi, viruses, and plant growth-promoting agents include the use of different nanocomponents based on chitosan such as nanocapsules, nanogels, nanospheres, and nanocomposites [37], [38]. In another instance, the zinc amalgamated with chitosan NPs was tested on two durum wheat cultivars MACS 3125 and UC1114 via the foliar application, and it was noticed that the zinc content in grains has increased by 27% and 42%, respectively, as compared to the zinc-deficient control plants [39]. In addition, Chitosan also acts as an elicitor for the induction and synthesis of several secondary metabolites in the plant systems. Therefore, the spray with chitosan is often utilized to improve the yields of secondary metabolites in in-vitro cultures. The elicitation of *Lippia alba* with chitosan promoted the synthesis of new compounds namely 5-methylene-2-norbornene, ethyl pent-4-enoate, p-cymene, and limonene in the plant essential oil [40].

Keeping in view all the above facts, this research work is to Study on field response of slow-release Zn gluconate base Nano fertilizers formulation on wheat and tomato crops. These NMs are promising candidates for a new type of fertilizers (nano fertilizers) to meet the incoming challenges of food availability and environmental protection.

MATERIALS AND METHODS

Preparation of zinc gluconate-CS-PMAA Nano formulation:

The CS-PMAA (Chitosan and Potassium persulfate (K2S2O8) and methacrylic acid (MAA) nanoparticles were obtained by polymerization of MAA in CS solution in a two-step process [41](de Moura M. R. et al 2008). In the first step, chitosan was dissolved in a 0.5% (v/v) methacrylic acid aqueous solution for 12 h under magnetic stirring. The CS concentration used in synthesis was 0.2% (w/v). In the second step, 0.2 mmol of K2S2O8 was added to the solution with continued stirring, until the solution became clear. The polymerization was then carried out at 70°C under magnetic stirring for 1 h leading to the formation of CS-PMAA nanoparticles, which was then cooled in an ice bath. The morphology and size of the CS-PMAA nanoparticles were investigated using a transmission electron microscope.

Role of Zinc gluconate Nano Fertilizers on improving crop production of Wheat:
The experiment on evaluating Zinc gluconate-CS Nano formulation on wheat was conducted during Rabi season for year in field month of December 2017 at Tal- Sonai Dist. Ahmednagar.

The first spray has been done at vegetative stage in month of January and second spray in February and March at leaf stage accordingly. The treatment consisted of combination micronutrients and their salts T1: Control, T2: Zn EDTA (14%) (Dose: 3 gm/liters of water), T3: Zn gluconate-CS Nano formulation (1.4%) (Dose: 3 ml/liters of water), T4: Zinc Sulphate (Dose: 5 gm/liter of water). The trial was laid out with wheat crop seed rate 45-50 Kg per acre of Western Seed Variety 496. All regular fertigation practices are carried out uniformly to raise the crop. The wheat crop was harvested at month end of March 2018. After harvesting wheat crop data were recorded for Grain yield (q/ha), Straw Yield (q/ha), Thousand numbers of grains weight (gms) mentioned in result section.

Role of Zinc gluconate Nano Fertilizers on improving crop production of Tomato:
The experiment was carried at place at post Shrigonda, Maharashtra. During rabbi season, the experiment was evaluated in randomized block design with four treatments and replicated thrice. The trail was laid out with tomato seed rate 20 gm per acre of Namdhari Seed 2535 variety.

Accordingly, the treatment consisted of combination micronutrients and their salts T1: Control, T2: Zinc Sulphate (Dose:5 gm/liter of water)., T3: Zn EDTA (14%) (Dose: 3 gm/liters of water), T4: Zn gluconate-CS Nano formulation (1.4%) (Dose: 3 ml/liters of water). During the spray schedule, for experiments purpose first spray has been done on 10th days and second spray on 25th days after seed sowing process. All agronomical practices to raise uniform growth of crop. The data observation made on basis of three parameters as Growth parameters, flowering parameters, and yield parameters.

RESULTS AND DISCUSSIONS

Preparation of zinc gluconate-CS-PMAA Nano formulation:
In this study, the gluconate salt of Zn, used to incorporate fertilizers in chitosan nanoparticles was obtained by dissolving 5 gm of salts into 50 ml of nanoparticle solution under magnetic stirring for 6 h at 25°C. The resulting solutions had a pH between 4.2 and 4.7.

The zeta potential and particle size distribution measurements of CS-PMAA suspension nanoparticles with entrapment of gluconate fertilizers in different concentrations. FT-IR spectra were taken in the range of 4000 to 400 cm–1 to evaluate the chemical interaction between gluconate fertilizers and CS nanoparticles (Figure 1).

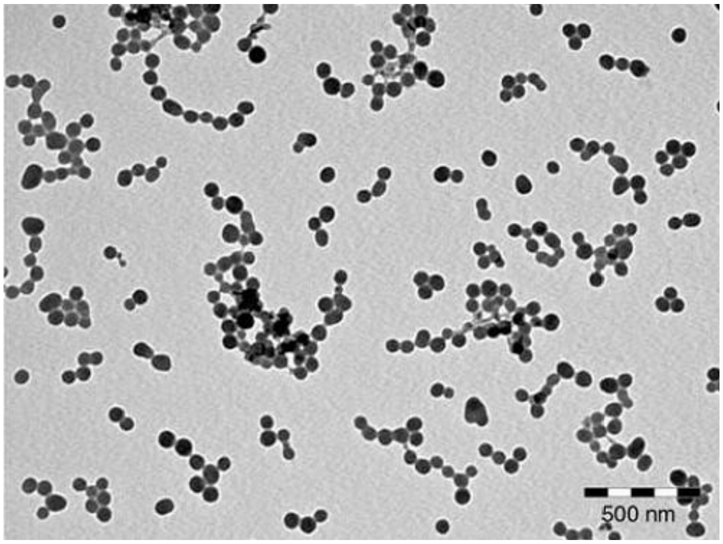

Figure 1: TEM microphotograph obtained for chitosan nanoparticles (CS-PMAA)

Role of Zinc gluconate Nano Fertilizers on improving crop production of Wheat:
Zinc based micronutrients play an important role in plant growth & final crop yield as zinc is required to trigger certain microbial enzymes. The Zn has been shown to be a specific inducer for pyruvic carboxylase in Rhizopus nigricans and of

alcohol dehydrogenase. Zn activates enzymes carbonic anhydrase and dehydrogenase. Zn plays a role in photosynthesis, protein synthesis and nitrogen metabolism. Zn was involved in auxin production in plants. So, micronutrients like Zn is important for plant growth and effective crop production in different ways. The results given in table no indicate some important parameters of Grain yield (q/ha), Straw Yield (q/ha), Thousand numbers of grains weight (gms) on wheat crop.

Table 1: Effect of different treatments on Grain yield (q/ha), Straw Yield (q/ha), Thousand numbers of grains weight (gms) of Wheat Crop

Treatments No	Treatment	Grain Yield (q/ha)	Straw Yield (q/ha)	Thousand numbers of grains weight(gms)
T1	Control	42.48	43.50	38
T2	Zinc Sulphate	44.30	59.80	42.75
T3	Zn EDTA	48.78	61.50	44.30
T4	Zn gluconate-CS Nano formulation	53.25	65.30	48.80

The grain yield, straw yield, thousand grain weight of wheat crop was significantly higher with spray of chelated micronutrients and their salts over that of control. The maximum grain yield (53.25 q/ha) was found in treatment of T4 was significant as compare of T2 and T3 (Table 1). Similarly, the maximum straw yield (65.30 q/ha) was observed significant in T4, but it is par with treatments of T2 and T3. The maximum grain weight (48.80 gms) was found in treatment of T4 was significant, but it is par with T2. Hence, grain yield, straw yield & thousands of grain weight of wheat crop increased significantly with application of Zn gluconate-CS Nano formulation-based micronutrients.

It was concluded from field trail of micronutrient application of Zn salts in experiment treatment of T4 Zn gluconate-CS Nano formulation was found to be best in increasing grain yield 53.25 q/ha, Straw yield 65.30 q/ha and Thousand numbers of grain yield 48.80 gms of wheat crop. The treatments T4 was significantly higher as compared to other traditional micronutrient combinations.

Role of Zinc gluconate Nano Fertilizers on improving crop production of Tomato:

Growth parameters: The data clearly indicated that different Zn based micronutrients affected growth parameters showing significant differences in plant height. The treatment T4 (Zn gluconate-CS Nano formulation) recorded the maximum plant height (137.50 cm) followed by T3 (Zn EDTA) with 128.16 cm plant height which differed significantly from each other as well as other treatments (Table 2). Due to greater availability of zinc nutrients in form of T4 treatment, plants observed Zn adequately to give maximum vegetative growth. On other treatments, minimum growth of plant due to traditional form of Zn nutrients. Similar observations were reported by *Patil et al* 2004 in tomato crop [42] and Sugeet *et al* 2011 in brinjal crop [43].

Table 2: Effect of foliar applications of zinc nutrients on growth parameters of tomato crop

Treatments No	Treatment Name	Plant height (cm)			
		@30 days	@60 days	@90 days	@120 days
T1	Control	51.33	85.66	98.33	107.00
T2	Zinc Sulphate	56.00	90.33	102.00	119.00
T3	Zn EDTA	61.66	93.66	110.00	128.16
T4	Zn gluconate-CS Nano formulation	68.00	101.33	124.33	137.50

Flowering parameters: The data recorded different forms of Zn micronutrients in various flowering parameters of tomato crop. The treatment T4 (Zn gluconate-CS Nano formulation) showed the minimum days required for first flowering after transplanting (25.00 days) in comparison to treatment T1 (control) showed 42.00 days. In addition, T4 treatment showed maximum number of flowers cluster per plant (9.66) and maximum number of flowers per cluster (8.00). The earlier to flowering treatment T4 might be due to favorable conditions for better retention of flowering (Table 3) similar finding were reported by Naidu *et al* 2002 [44] and Prativa *et al* 2011 in tomato crop [45].

Table 3: Effect of foliar applications of zinc nutrients on flowering parameters of tomato crop

Treatments No	**Treatment Name**	**Number of Flower Clusters**		**Number of Flowers per Cluster**		**Days to Flowers**
		@45 days	**@75days**	**@45 days**	**@75 days**	
T1	Control	3.66	4.66	3.00	4.00	42.00
T2	Zinc Sulphate	5.00	6.16	4.66	5.66	36.00
T3	Zn EDTA	6.00	7.50	6.33	7.10	32.00
T4	Zn gluconate-CS Nano formulation	8.00	9.66	6.66	8.00	25.00

Yield parameters: The data recorded different sources of Zn micronutrients were also affected the final yield of tomato crop. In present study among various treatment, T4 (Zn gluconate-CS Nano formulation) was recorded maximum number of fruits per cluster (7.00) and maximum number of fruits per plant (40.60) as maximum yield per acre (8.33 ton/acre) followed by T3 treatment (7.48 ton/acre) and minimum were recorded with treatment T1 (5.10 ton/acre). Due to Zn gluconate-CS Nano formulation maximized photosynthesis activity and accumulation of number of fruits (Table 4). T4 treatment also increases in dry matter production of fruit may attributed of photosynthesis by vegetative parts and its subsequent translocation to the sink. These observed results were also similar by Rafi *et al* 2001 [46] and Rodge *et al* 2009 [47].

Table 4: Effect of foliar applications of zinc nutrients on yield parameters of tomato crop

Treatments No	**Treatment Name**	**Number of Fruits Per Cluster**		**Number of Fruits Per Plant**	**Fruits Yield Per Acre**
		@60 days	**@90days**		
T1	Control	3.16	4.33	27.06	5.10
T2	Zinc Sulphate	3.88	5.00	33.66	6.66
T3	Zn EDTA	5.10	5.88	36.93	7.48
T4	Zn gluconate-CS Nano formulation	5.38	7.00	40.60	8.33

CONCLUSION

To the best of our knowledge, this is the first proper field-scale study of formulation and its responses of indigenously developed Zn gluconate-CS Nano fertilizers on wheat and tomato crops. The foliar delivery of Zn gluconate-CS Nano fertilizers using nano material represents a novel agriculture fertigation technology in cereals and vegetable crops. The present study establishes benchmark in enhanced 'use efficiency' of zinc upon active uptake, translocation, and accumulation of zinc in the wheat and tomato crop.

The results obtained in the present study prove that the target zinc concentration applied on wheat and tomato crop was achieved using a Zn gluconate-CS Nano fertilizers fertilizer dose (42 mg L^{-1} Zn) which is 10-fold lower than that of EDTA Based Zn (1.4%) with dose 420 mg L^{-1} Zn concentration in case of foliar applied fertilizer. As observed results, with foliar application of traditional Zinc Sulfate (33% Zn) with applied dose 1650 mg L^{-1}. In a previous study, foliar application of ZnO nanoparticles with dose (100 mg L^{-1} ZnO) also observed much higher crop yield in comparison of other traditional spray [48]. The wheat and tomato crop yield achieved in the present study indicates the role of Zn gluconate-CS Nano fertilizers in making the foliar-applied nutrient in the 'plant-available' form and clearly indicating the potential application of nano-fertilizers in agriculture.

In addition, a Zn gluconate-CS Nano fertilizer triggers the natural defense response of plants against pathogenesis due to presence of Chitin as immunomodulator, that ultimately helps in yield enhancement of wheat and tomato crop. In our opinion, such studies can improve our understanding of the process underlying nano carrier delivery of agrochemicals. Furthermore, a balance fertigation program with nano based micro and macronutrient in plant nutrition holds the main key for improving growth and yield production of crops. And several other studies be needed to develop nano fertilizer formulation to achieve greater crop production.

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