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Review Article

NANOTECHNOLOGY: INNOVATIVE APPROACH IN CROP NUTRITION MANAGEMENT

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Abstract- Nanotechnology is revolutionary change in science and has generate extensive opportunity in the field of biotechnology, medicine, pharmaceuticals, electronics and agriculture. Present situation in nanoscience is one in which there is great potential for transforming agriculture and food production through efficient management of soil nutrients, pesticide, herbicide and water management. The development of nano materials could open up the novel thing in the discipline like agronomy in relation to maximization of crop production along with quality of the produce. Nano fertilizers in plant nutrition can play crucial role in resolving the problem of low nutrient use efficiency, soil residues and water pollution. Use of nano material is one of the innovative idea for enhancing nutrient use efficiency and helps for reduction in the environmental degradation. The use of nano fertilizers helps in encouraging plant growth, crop production and reduces the soil toxicity of the soil. Nano fertilizers also helpful to moderates the negative effects, caused by the excessive use of fertilizers and reduces the frequency of application of fertilizer. In many part of the country, soil is deficient in major nutrients and at the sometime there is widespread multi-nutrient deficiency due to dominant cropping pattern. Negative nutrient balance and low fertilizer use efficiency is often associated with many part of the country. From single plant nutrient deficiency, at present country is experiencing multi-nutrient deficiency. The nano technology is miracle in plant nutrition system as it becoming important aspect in crop management practice. The advancement in modern techniques in fertilizer application system like nano technology will saves substantial amount of budgetary provisions. The fertilizer use efficiency can be improved drastically by avoiding and minimizing the precious nutrient via different ways and means due to nanotechnology in nutrient supplementation.

Keywords- Nano-fertilizer, Nano-technology, Nutrient use efficiency, Nutrient management

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Introduction

Nanotechnology is the emerging science which consists integration of some basic science secrets and facts at nanoscale level. Nanotechnology is the science in which the individual atoms manipulated otherwise self-assemble of, different ultrafine particle into definite assemblies to generate elements and substances with innovative or immeasurably unlike properties. In fact, several products enabled by nanotechnology are already in the market, such as antibacterial dressings, transparent sunscreen lotions, stain resistant fabrics, scratch free paints for cars, and self-cleaning windows. India is endowed with rich and vast diversity of natural resources, particularly soil, water, weather, trees and shrubs. In order to realize the potential of production systems on a sustained basis, efficient management of resources is very crucial. Soil productivity is decreasing globally due to enhanced soil degradation in the form of erosion, nutrient depletion, water scarcity, acidity, salinization, depletion of organic matter and poor drainage. However, with ever-increasing population the utilization of all resources should be very precise and concise manner. Indiscriminate use of agricultural inputs viz. fertilizer and water led to degradation of resources. There is urgent need to utilize advance knowledge about different tools and techniques for improving the resource use efficiency. Nutritional deficiency is the third most important in limiting factor for plant growth and productivity next to drought and salinity. Use of nanotechnology can aid to some extent to tackle this issue. Nano particles are having high surface area, high reactivity, better catalytic activity and rapidly dispersible. These properties support in better uptake of nutrients by plants. nutrients occupy the top position and nutrient management is crucial to the success of any farming system. The usual practice is to apply nutrients at one rate throughout the farming area. Nanomaterials are at the leading edge of rapidly developing field of nanotechnology. In nanotechnology, foliar fertilization is an important tool for the sustainable and productive management of crops. Present understanding of the factors that influence the ultimate efficacy of foliar applications may be resolved because of state-of-the-art technology like nanotechnology [1-5].

Fundamental concept of nanotechnology

They are the simplest form of structures with sizes between 1 and 100 nanometres. It's hard to imagine how small nanotechnology is one nanometre is a billionth of a meter, or 10^{-9} of a meter, Nanometre is a distance unit representing one-billionth of a meter, or one-millionth of a millimetre Nanoscience and nanotechnology encompass the capacity to perceive and to control individual atoms and molecules [6,7]. Nano material possess greater surface area and improved reactivity in nanostructured materials which helps to create better catalysts. A nanoparticle is the most essential component in the creation of a nanostructure. Nanoparticles are very usual in landscape, for example, proteins exist in nearly all living structures. It comprises, big molecules, like proteins and even hydrogen bonded assemblies of water molecules which exist in water at ambient temperatures. They are unquestionably the most widely used nanomaterials. Now a day ever-increasing curiosity and attention towards the evolving bio-based products and state-of-the-art process knowledge that will be helpful to reduce the reliance on fossil fuel and motivation towards the sustainable things basis Renewable resource-based biodegradable polymers including cellulosic plastic (plastic made from wood), corn-derived material and poly hydroxy alkanoates (plastics made from bacterial sources) are some of the potential biopolymers which, in combination with nanoclay reinforcement, can produce nanocomposites for a variety of applications.

Problems associated with agronomic management

Effective and systematic manipulation and use of agro-input is prerequisite for sustenance in global market. In India, fertilizers along with quality seed and irrigation, are mainly responsible for enhanced food grain production coinciding with the spectacular increase in fertilizer consumptions. It has been conclusively demonstrated that fertilizer contributes to the tune of 35-40 percent of the productivity of any crop. Production and productivity are the closely associated issues of an individual and as whole, however both are regulated by short term and long-term management practices of the famers. India is experienced green revolution as there is fourfold increase in agricultural production. As green revolution technologies change our scenario by changing the image of India from food importing country to food exporting or self-sufficient nation. Now changing agricultural practices more cautious about the sustainability in crop production which threaten very seriously by indiscriminate use of resources utilization. Nutrient management is crop need to be manipulate and practises very systematically for achieving higher yield and sustaining soil health is ultimate and unbiassed goal of any farmer and agronomist. However, to achieve this there are different methods of application of nutrient via various sources, forms and manners. There are some conventional methods already in vogue, some of those because of there is no alternative. However, as nutrient supplementation differs with methodology there is miracle change with adoption of the advance method. Precision agriculture referred as most systematic management of inputs as per the crop need. The need based nutrient application is possible by different ways particularly foliar application of nutrient. As soil application of fertilizer often associated with delay in correcting nutrient availability and deficiency. Nano technology as a novel method expected to be more effective under such circumstances as ever-increasing pollution hazards. Zinc deficiency in human diet was reported as early as 1961 and expressed its syndrome as hypogonadism, dwarfism, hepatosplenomegaly, anaemia and geophagia [8-11].

Discussion

Nano fertilizer in crop nutrition and fertilizer use efficiency

Encapsulation of nutrient within the nanoparticle is one of the new and dynamic capacity performed in different ways particularly, i) The nutrient can be encapsulated inside nonporous materials ii) Coated with thin polymer film iii) Delivered as particle or emulsion of nanoscale dimension [12]. In similar fashion the nano fertilizer combine nano device for the synchronization for release of fertilizer nitrogen and phosphorous with their uptake by crops. In these ways nutrient losses in soil, water and air get decreased or reduced due to direct insertion by crop plants and also eliminate the interaction of nutrient with soil, micro-organism, water and air [13]. Nano clays and zeolites naturally occurring minerals with a honeycomb-like covered crystal structure are other strategies for increasing fertilizer use efficiency [14]. Zeolites have been used as fertilizer delivery mechanism [15]. It intermingled with primary nutrients particularly nitrogen, potassium, phosphorous and also calcium as a broad set of major and trace nutrients. Nanofertilizer attempts to supply nutrient as per the necessity for specified time, site and rate. Nitrogenous fertilizer is more vulnerable with groundwater contamination and hazard. dynamics of Nitrogen releasing is in absorbed form (in zeolites) is much slower than for the ionic form. Slow/controlled release nanofertilizers coating and binding of nano and subnano-composites are able to regulate the release of nutrients from the fertilizer capsule [16]. The final goal is production of nanofertilizers that will release their shipment in a controlled manner (slowly or quickly) in reaction to different signals such heat, moisture and etc. Nano fertilizers poses great opening to greatly influences economy, energy and the ecology by minimizing nitrogen loss due to leaching, emissions, and continuing amalgamation by soil microorganisms. Nano fertilizers that exploit natural constituents for coating and cementing granules of soluble fertilizer have the advantage of being cost effective to produce than those fertilizer that rely upon manufactured coating materials. Slow and controlled – released fertilizers may also improve soil by decreasing toxic effects associated with over application of fertilizer. Enhancement of nutrient use efficiency and to mitigate the serious problems of eutrophication, nano fertilizer are might be a best alternative. Nonfertilizer are synthesised in order to regulate the release of nutrients depending as per the requirement of crops, and it evident that nano fertilizers are more effective than ordinary fertilizer [17]. Slow and controlled release in case of nano fertilizer helpful for the improving status of soil by decreasing toxic effects associated with traditional methods of fertilizer. Widespread micronutrient deficiency also threatens due to overexploitation of soils, eventhough their requirement in nutrition is less but their deficiency causes hidden hunger. Deficiencies need to be rectify by supplementation of associated nutrient with more intensive techniques like nano scale particle of Zinc which being ideal to enhance the uptake pattern by the plants. Particle size may affect agronomic efficiency of Zinc fertilizers. Decreased particle size results in increased number of particles per unit weight of applied Zn and also increases the specific surface area of a fertilizer, Granular Zinc sulphate ($ZnSO_4$) (1.4 to 2 mm) was somewhat less effective than fine $ZnSO_4$ (0.8 to 1.2 mm), whereas granular ZnO was completely ineffective [18]. the granules of 2.0 or 2.5 mm, smaller granules were used for the same weight, resulting in a better distribution of Zn and the higher surface area of contact of Zn fertilizer resulted in better Zn uptake [19]. Therefore, major work has been done and emphasis was made on the particle size to increase the efficiency of the fertilizers for better uptake and higher yields. Effectiveness of Zinc oxide was studied on seed germination, seedling vigour, plant growth, flowering, chlorophyll content, pod yield and root growth of peanut. Peanut seeds which are treated with different concentrations of nano Zinc oxide along with chelated Zinc Sulphate ($ZnSO_4$). Treatment of nano scale ZnO (25 nm mean particle size) at 1000 ppm concentration promoted both seed germination and seedling vigour and in turn seedlings showed early establishment in soil. Higher leaf chlorophyll content and manifested by early flowering These particles proved effective in increasing stem and root growth. Pod yield per plant was 34 percent higher compared to chelated bulk $ZnSO_4$ [20]. The effect of nano Zinc oxide particles on the growth of plant seedlings of mung (Vigna radiate) and gram (*Cicer arietinum*) was studied by conducting experiment in agar media. The main experimental approach using correlative light and scanning electron microscopy provided evidence of adsorption of nanoparticles on the root surface. Absorption of nanoparticles by seedlings root was also detected by inductive coupled plasma/atomic emission spectroscopy (ICP-AES). It was found that at certain optimum concentration, the seedlings displayed good growth over control and beyond that retardation in growth was observed due to toxicity [21]. Nano-formulations enhanced production levels of crops through foliar application of nano particles as fertilizer. The experiment conducted at arid environment at jodhpur revealed that the, the use of nanomaterial substantial reduces the fertilizer quantity, nanophosphors @ 640 mg ha^{-1} foliar spry at the concentration of 40 ppm give 80 kg ha^{-1} phosphorous equivalent yield in cluster bean and pearl millet [22,23]. The results demonstrated a significantly higher plant growth in field owing to application of Zinc nonfertilizer. Significant improvement was noticed in shoot length, root length and root area due to foliar application of Zinc nonfertilizer over the control photosynthetic pigment chlorophyll and total soluble leaf protein were increased by 24.4 and 38.7 percent, respectively, due to application of Zinc nonfertilizer at 10 mg L-1 concentration at critical growth stage (6 weeks) of crop with respect to control. It was found that Zinc nanoparticles enhanced plant dry biomass (12.5 %), grain yield (37.7 %), and plant Zinc concentration (10.4 %) over the control [24]. Anusha, *et. al*. conducted field and laboratory experiments were conducted at Farmer's field near ZARS V.C. farm, Mandya and Department of Seed Science and Technology, University of Agricultural Sciences, Bengaluru, respectively during *Kharif* 2015. Influence of foliar application of nano nutrients on plant growth, seed yield and quality of paddy (*Oryza sativa* L.) genotypes were studied. The parameters like plant height, number of tillers, leaf area-1, number of panicles plant-1, panicle length, seed yield-1, seed yield ha-1 and also the dry matter production plant-1 was found highest in genotype BR-2655 as compare the rest of the genotype under study. Ramesha Raddy, (2014) conducted physiological studies with imposed water stress for experimental crops at 40 days after sowing for six days along with the different Zinc sources treatment [25] and similar findings observed during investigation, crop plants like Rice, Ragi, Sunflower and cowpea shoed positive trend. Initially concentrations of nano Zinc fertilizer (Zinc oxide nano particle), Zinc gluconate and Zinc sulphate for seed priming were standardized invitro. The standardized concentrations were further

used to conduct pot experiments along with the foliar application. Different combinations of treatment for investigation include seed priming, foliar application and combinations of seed priming and foliar application with different source of Zinc. The obtained results based on the physiological and yield parameters showed that the usage of nano Zinc fertilizers either through any of the method of application has significant positive effect compared to Zinc gluconate and Zinc sulphate. Zinc was known to act as a cofactor for so many important enzymes in plant system including carbonic anhydrase, Zn/Cu Super oxide dismutase (SOD), alcohol dehydrogenase, ascorbate peroxidase *etc*., which requires Zinc for their activity. Among them Zn/Cu SOD is one of the important enzymes which is known to directly scavenge the toxic ROS produced in the plants under stress condition. The activity of the enzyme can be enhanced by external Zinc application. Pramod *et al*., conducted study dealing with effect of nano Zinc oxide suspension, as a micro-nutrient on the growth of mung and gram seedlings at different concentrations. Investigation reveals that, the maximum effect was found at 20 ppm for mung (*Vigna radiata*) and 1ppm for gram (*Cicer arietinum*) seedlings. Beyond this concentration, the growth was inhibited. The nano-Zinc oxide application shoed that when applied at certain optimum concentration found effective growth, however growth is retarded at increasing concentrations attributed to accumulation of uptake of nano-Zinc oxide particle by the roots. It was found that the accumulation and uptake of nanoparticles was dependent on the exposure concentrations. Tarafdar, *et.al*., conducted field experiment under rainfed condition during *Kharif* 2011 at arid zone agricultural field of CAZRI to determine the effect of biologically synthesized Zinc nanoparticles as Zinc nanofertilizer reveals that biosynthesis of Zinc nanoparticles which were used as nanofertilizer to enhance crop production in pearl millet (*Pennisetum americanum* L.) *cv*. HHB 67 [26]. After synthesis of nano-particle it is characterized to know their size, shape, surface structure, crystalline nature validation and to study their basic proportion. Results indicate that synthesized nanoparticle size ranged between 15 and 25 nm. A significant improvement in shoot length (15.1 %), root length (4.2 %), root area (24.2 %), chlorophyll content (24.4 %), total soluble leaf protein (38.7 %), plant dry biomass (12.5 %), and enzyme activities of acid phosphatase (76.9 %), alkaline phosphatase (61.7 %), phytase (322.2 %), and dehydrogenase (21 %) were observed over control in 6 weeks old plants. Severe increase in the grain yield which is increased to tune about 37.7 % due to application of nano-Zinc fertilizer. Anjuman, *et al*., realised same trend in respect of growth of Kalmi, its uptake and concentration of phosphorus (P) and potassium (K) were better in nano fertilizer treatments than in the conventional fertilizer treatments indicating the fact that there is a bright possibility of nano-fertilizer in agriculture [27].

Conclusion

The emerging new science and enabling technology, working with the smallest particle, the nanotechnology raises hope for new innovations in the field of biology, especially in agriculture. Emerging problems associated with nutrient and fertilizer management in the field of agriculture and nano technology particularly, nano fertilizer play crucial role in modern agro-techniques. It saves energy, production cost and eliminates ecological hazards observed due to ineffective method. Because of dynamic nature and properties, nanoparticles are having high surface area, high activity, better catalytic surface, rapid chemical reaction, rapidly dispersible and adsorb abundant water. It has shown that nanoparticles get into plant cells through either stomatal or vascular system. It is evident that the stomatal pathway is highly capacitive because of its large size exclusion limit and its high transport velocity.

Application of review

These scientific reports support the present hypothesis of nanoparticle penetration in the plant cell through stomatal opening and natural nanopore which may enhance plant cell metabolic activities that lead to higher crop production. The better response of Zinc nanofertilizer might be due to its essentiality as trace nutrient element, resulting in to increase the efficiency of nutrient uptake, enhance yield and nutrient content in the edible parts and also minimize its accumulation in the soil.

Review Category: Nanotechnology

Abbreviations:
SOD: Super oxide dismutase
ICP-AES: inductive coupled plasma/atomic emission spectroscopy
ZnSO4: Zinc sulphate

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