Article Id
AL04159

RECENT DEVELOPMENT OF NANOFERTILIZERS AND SUSTAINABLE AGRICULTURE

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Agriculture is a major economic sector related to the production and provision of a wide range of crops for food, feed, and ornamental purposes, and services to majority of the population of the world. The growing human population, with limited land and water resources put an immense pressure in agriculture sector for greater agriculture production. Chemical, natural or synthetic fertilizers have been an important input in agriculture for better plant growth and development boosting their yield and productivity. Since a very long time ago, farmers have been using agrochemicals continuously to provide macro- as well as micro-nutrients to crop plants. In soil these nutrients are present in an inadequate amount, so the existing production practices cannot fulfil the ever growing demand of food without relying on the extensive use of commercial fertilizers.

Nutrient use efficiency of conventional fertilizers by plants is very low. Not all applied fertilizers are used up by plants efficiently. Crop usage is generally less than half of the applied amount of fertilizer, some are lost in leaching, some by runoff and they will get accumulated in water bodies causing water pollution affecting the water and ultimately to land ecosystem; it also causes soil quality degradation, and hence causing imbalance in the environment. Higher cost input due to intensive use of fertilizers leads to increase in production cost and hence the market price of agricultural products. Numerous human diseases have also been reported due to consumption of excess N-compounds in the food we eat. Hence a number of environmentalists, consumers and scientists have developed great interest in the science and technology of fertilizers for their efficient utilisation with minimum negative effects. In order to maximize production of agriculture products with minimal fertilizer input while balancing the ecosystem and the environment, nano fertilizers come into light. A correct application of nano fertilizers can give nutrients to plants gradually in a controlled manner. Nano fertilizers are nutrients encapsulated/coated with nanomaterial

for the control and slow delivery of one or more nutrients in order to fulfil the essential nutrient requirements of plants. These, in several cases, are being considered to be the preferred form of fertilizers over the conventional ones at present. Nanomaterials, being highly reactive,interact with fertilizers resulting in an increased and effective absorption of nutrients by plants.

How are the Nanofertilizers Developed?

Nano fertilizers are prepared by methods such as adsorption, attachment on nanoparticles, entrapment of polymeric nanoparticles and encapsulation in nanoparticulate matters.The use of nano sized materials (1-100nm) for coating the fertilizer particles has various advantages like having large surface area, higher adsorption capacity, extra infiltration capacity, and its appropriate and controlled kinetics to deliver nutrients at targeted sites causing minimum loss of nutrients. To obtain the desirable effects from nano fertilizers, its formulations and delivery methods should be proper so as to facilitate the proper uptake of nutrients (Boehm *et al*. 2003). The nanoparticles such as carbon-based, metal oxides, and other nanoporous materials are used as the composition of nano fetilizers depending upon the combinational and compositional properties.

Nanofertilizers can be prepared by methods like biological, chemical(bottom-up), or physical(top-down) approaches. Non-hazardous, environmentally friendly procedure, such as green nanotechnology or bio-fabrication, can also be employed for preparation of nanofertilizers. The bottom-up method employs at the atomic or molecular scale to build up nanoparticles using chemical reactions. This method controls the particle size better and reduces impurities as it is a chemically controlled synthetic process. The top-down method is basically the reduction of size to nanoscale well organised assemblies from bulk materials. There are some natural sources for the biological synthesis approach, viz., plants, fungi and bacteria. The biological approach has greater control of the toxicity. The most effective approach used nowadays for nanofertilizer production is the chemical method. The use of different nanofertilizers including N, P, K, Fe, Cu, Zn, Mn, Moand carbon nano tubules have shown agreat controlled release for a targeted delivery. The nanoparticles used for encapsulating the chemical fertilizers are made from organic and inorganic nanomaterials. The inorganic nanomaterials include ZnO, TiO_2, MgO and AgO, and organic nanomaterials including lipids, polymers, and carbon nano tubules are used according to the chemical or physical methods to be employed. The nanofertilizers are classified based on the type of

nutrient present; micronutrient nanofertilizers and macronutrient nanofertilizers. The different types of nanofertilizers having different compositions of nutrients help improving the nutrient solubility, dispersal of insoluble nutrients, phyto-availability to the targeted plants minimizing the nutrient losses and high nutrient uptake efficiency.

Application in Agriculture

The nanofertilizers can be utilised in various ways in agriculture according to their properties including their efficiency, timely-controlled release, solubility, targeted delivery, stability, and less toxicity. The effectiveness of nanofertilizer is very much influenced by the mode of application. Nanofertilizers can be absorbed by crops through the roots or leaves. Two commonly used are, *in-vitro* and *in-vivo* methods. In *in-vitro* methods, the nanofertilizer application is done in aeroponics and hydroponics which are both soil less methods. In aeroponic solution containing nanofertilizers are sprayed in the form of mist to make it available near the floating root in air. The roots absorb the mist containing nanfoertilizers. In hydroponics, nutrient solutions are used for culture, and nanofertilizers are mixed in the nutrient solution to make it available to the plants through roots. *In-vivo* methods are of two types, foliar application and soil application. In foliar application, the nanofetilizers containing micronutrients are sprayed directly to the leaves, nutrients are uptake by the plants immediately after application. In soil application, the uptake of nanofertilizers at root level are influenced by various constraints such as nanoparticle size, acquaintance situations, plant structure, rhizospheric activities, and crop phenology. Soil applied nanofertilizers enter the roots through their surface and pass through a series of barriers before reaching the plant's vascular system. The size of nanofertilizers should be small enough to penetrate into the plant cells so that plants can get the nutrients sufficiently. Generallythe pore size of plant cell wall ranges from 3-8nm, the nanoparticles should be smaller than 8nm.

Among the essential plant nutrients, N, P, Mg, and K are the most crucial components required by the plant. They cannot be absorbed directly from the atmosphere, but they can be absorbed by plants through their roots. As a result, nanofertilizers has emerged as a solution to this problem.

Other applications of nanotechnology in the agriculture sectors include uses of nano-based herbicides, insecticides, pesticides, and fungicides also play a role in sustainable agriculture.

Risks associated with Nanofertilizers

As being a recently developed technology, the ethical and safety issues surrounding the use of nanoparticles in plant productivity are limitless and must be very carefully evaluated before adapting the use of the nanofertilizers in agricultural fields.Huge concerns were reported by researchers regarding the ill effects associated with the inappropriate use of nanofertilizers.

The extensive release of nanomaterials into the environment and food chain may pose a risk to human health. Although nanofertilizers use in agriculture is offering great opportunities to improve plant nutrition and stress tolerance to achieve higher yields with regards to climate change, not all nanomaterials will be equally safe for all applications. For sustainable crop production, nanofertilizers having potential of releasing nutrients as per plant requirements in temporal and spatial dimensions must be formulated. The risks of nanofertilizers should be carefully examined before use, and further biotechnological advances are required for a correct and safe application of nanomaterials in agriculture.

Conclusion

Inappropriate use of agrochemicals in agriculture causes soil fertility degradation, which in turn affects the plants and ultimately causing imbalance in ecosystem, *flora* and *fauna*. There have been environmental issues pertaining to rapid accumulation of agrochemicals in rivers, lakes and other fresh water bodies. A strategy to utilize fertilizers in an environment friendly way to improve agricultural production is to make use of nanotechnological tools and techniques. As we all know, nanofertilizers play an important role in crop protection as well as increasing their productivity in a sustainable way, use of organic manures and other organic farming methods with integrated use of nanofertilizers is still recommended. Numerous advantages of using nanofertilizers in crop production have been reported like the stability of crop growth, lesser fertilizer application hence lesser input cost, reduced nutrient loss through leaching or runoff, etc. Different nanomaterials have different impacts on plants viz., increase in germination rate, plant height, root development, antioxidants and chlorophyll content in leaves. Nanofertilizers have the advantage of controlled and timely release of nutrients to plants throughout their growth period over other forms of fertilizers. Nanomaterials are highly reactive as well as dispersive that they are easily absorbed through the cuticles in the leaves. But certain toxic impacts of nanotechnology in food industries and the environment need to be looked upon by future

researchers. Researchers also need to look for improving further technological advances in synchronizing the uptake of nutrients with their release according to plants requirement. Safety and ethical issues of using nanofertilizers, alongside their importance and advantages in agriculture need to be addressed during awareness programmes held at farmers' level.

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