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Role of Nano-Fertilizers in Sustaining Soil Productivity

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INTRODUCTION

Since green revolution, chemical fertilizers are deemed as an indispensable input of modern crop production systems, but their use is associated with some environmental and ecological consequences. In India, loss of nutrients from agricultural fields through leaching, immobilization, volatilization, denitrification and gaseous emissions has been a leading cause of environmental pollution and climate changes due imbalance of use fertilizers (optimal ratio is 4:2:1 & it being used as 6.7:3.1:1). Nutrient use efficiency is low and the figures for nitrogen, phosphorus, potassium, sulphur and micronutrients are 30-35%, 15-20%, 35-40%, 8-10% & 2-5% respectively. Presently, the agricultural sector is facing various global challenges; climate change, urbanization, sustainable use of resources, and environmental issues such as run-off and accumulation of pesticides and fertilizers. These situations are further exacerbated by stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies and some of the fertilizers effect the plant growth directly. Developing efficient crop fertilization practices has become more and more important due to the ever-increasing global demand for food production. Nitrogen being the most important crop nutrient, its use as fertilizer is associated with negative environmental footprint that dampen farmers' confidence in the efficacy and profitability of fertilizers. Among the nitrogenous fertilizers, urea is the most commonly used fertilizer in India which accounts 83% of total N fertilizer consumption in the country. Efficient use of nitrogen is absolutely essential for sustaining agriculture productivity as well as acting as a driving force for climate mitigation. Therefore, improving N use efficiency of the fertilizers will be a major challenge. Thus, there is a triplet of agronomic, environmental, and human health motivations to improve N fertilizer use efficiency.

To deal with the situation, it is pertinent to develop smart materials that can release nutrients to targeted areas and contribute to clean environment.

Nanotechnology, which utilizes nanoparticles of sizes between 1-100 nm, may offer an unprecedented opportunity to develop concentrated sources of plant nutrients having higher-absorption rate, utilization efficacy, and minimal losses. Nanofertilizers (NFs) are being prepared by encapsulating plant nutrients into nanoparticles, having core properties like small size, high surface area, slow and steady release of nutrients, higher nutrient use efficiency, and solubility. Encapsulation of nutrients with nanoparticles can be performed in three distinct ways; Nutrient particles may be coated with a thin layer of NFs such as polymer film, plant nutrients can be encapsulated within the Nanoparticles of varying nature and chemical composition and nutrients may also be delivered in the form of emulsions and particles having dimension in the range of nanoparticles. A critical review of NFs revealed a median efficacy gain of 18–29% with NFs as compared to the conventional fertilizers. NFs sustain the soil productivity by different means like increasing nutrient availability, increasing nutrient use efficiency, improving soil fertility, reducing nutrient losses, increasing crop yield, lowering environmental pollution, increasing soil water availability, improving soil quality, crating suitable environment for microorganisms and flora & fauna.

NFs also increased the plant growth, root & shoot growth, SPAD value, photosynthesis, biomass, yield and TSS in fruits etc. Nano-based target delivery approach (gene transfer) is used for crop improvement. Nanopesticides can be used for efficient crop protection. Uses of nanosensors and computerized controls greatly contribute to precision farming (site-specific crop management). Nanomaterials can also be used to promote plant stress tolerance and soil enhancement. NFs applied alone and in conjunction with organic materials have the potential to reduce environmental pollution owing to significant less losses and higher absorption rate in comparison to conventional fertilizers. Finally NFs improve the physical, chemical and biological properties of soil and sustain the soil productivity. The use of NFs is likely to increase the crop productivity and may prove to be economical for the farmers.

Role of nanotechnology in enhancing crop productivity

Unchecked use of chemical fertilizers has resulted in substantial loss of soil fertility, intensified episodes of environmental contamination, pest resistance, and dangers to biodiversity and economy as a whole. As a result, a major focus of current agricultural research is to find a friendly alternative to the use of chemical fertilizers, allowing for a more environmentally friendly approach to agriculture. The variety of robustly prepared nano-materials has huge promise for generating better, safer, and easily biodegradable fertilizers, as well as enhancing nutrient distribution in soil and plants, when compared to chemical fertilizers. In a word, nano-fertilizers have the ability to significantly increase agricultural output at the desired rate when utilised at optimal concentrations, overcome the limits of traditional fertilisers. NFs have shown real potential in terms of crop productivity. However, much more appears to be un-established in order to reinforce scientific knowledge in order to produce another green revolution in the coming years for the benefit of global food and nutritional security in the context of climate change, adverse environmental variables and growing population in developing countries.

Future prospects

Most studies focused on the assessment of nutrients' release pattern between traditional fertilizers and NFs but knowledge on mechanism and kinetics of nutrient releases are lacking. There is a need to conduct lot of research regarding the influence

of NFs on plant bio chemical and physiological phenomenon's. An in-depth evaluation of the effect of NFs on soil physico-chemical and biological properties is necessary to recommend specific NFs for a specific crop and soil type. Economic feasibility, soil, and environmental compatibility of the NFs must be adequately addressed. Assessment of the positive and negative impact of NFs on crop-ecosystem services-human health is highly essential. There is a need to frame uniform guidelines for use of NFs formulation and usage of sophisticated research and extension infrastructure to be developed for R&D and adaption. Last but most important thing is appropriate budget allocation for R&D, scaling up, commercialization and extension for adaption to be required. There is a need to establish an agency to coordinate research and development of NFS among different stakeholders at national and international level. Need to study socioeconomic impact of NFs on farming community and grassroot efforts in awakening the farming community and farmers about the positives of NFs use.

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