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Agrochemical Delivery using Nanocomposites

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Abstract

Excessive fertiliser use has a negative impact on soil health, lowers plant nutrient consumption efficiency, and pollutes the environment. The use of controlled-release fertiliser is gaining traction as a solution to the dilemma. Engineered nanocomposites (ENCs) have showed great potential for delivering agrochemicals (macro- and micronutrients, insecticides, and other agrochemicals) to where they are needed. This review covers the synthesis of nanocomposites, as well as their physical and chemical characterisation and approaches for achieving continuous release and targeted distribution to crops, with a focus on their beneficial role in plant production and protection. Aspects such as the application's practicality, commercialization of nanoformulations, and biosafety concerns are also discussed. This will aid in the development of a critical understanding of the current state of the art in nanocomposites for the controlled release of agrochemicals. Future research should pay more attention to critical issues including scaling up manufacturing, economic analyses, field-based trials, and environmental safety concerns.

Introduction

Agrochemicals, tailored nanocomposites, controlled release, targeted delivery By 2050, the world's population is forecast to reach 9.6 billion, and it is estimated that worldwide grain output will need to expand by 70% to meet food demands for the fast growing population. On the other side, due to reduced agricultural productivity, restricted land availability, and other factors, food supply is projected to fall. Although fertiliser application has been instrumental in increasing agricultural output in recent decades, recent studies on the long-term consequences of such agrochemicals reveal a reduction in soil health. Farmers, on the other hand, frequently employ excessive amounts of fertilisers, pesticides, and herbicides in order to boost crop yield. Because of their carcinogenic and mutagenic effects, such agrochemicals should not be used indiscriminately. Furthermore, conventional agrochemicals have significant drawbacks: application of these fertilisers in the soil causes an initial rise in concentration levels, but this quickly drops to below effective levels over time due to degradation, leaching, or volatilization of the compound. This tendency leads to the use of conventional fertilisers on a regular basis, resulting in deterioration of soil quality and eutrophication of surrounding water bodies. A large number of fertilisers, in the form of ammonium salts, urea, nitrate, or phosphate compounds, are put in the fields for soil nutrient augmentation, resulting in exceptionally high local concentrations that severely damage the crops. The majority of the applied urea is also lost by volatilization, leaching, and other means, and the accumulation of NH^{4+} raises soil pH. The loss of nitrogen from surface soil due to volatilization can be as high as 40% to 70%.Phosphate fertilisers are likewise inaccessible to plants because they tend to produce insoluble inorganic compounds primarily Fe- and Al-based oxides, lower soil phosphate levels by 0.01 ppm to 1.00 ppm, and 80 to 90% of applied phosphate fertilisers are lost to the environment. Furthermore, high ammonia and salt might block potassium absorption, resulting in very low (18) potassium levels. Potassium fertilisers have a 20% usage efficiency. Micronutrient insufficiency has an impact on agricultural yield as well. Due to the low solubility of the oxidised ferric form in an aerobic environment, major micronutrients such as iron are mostly unavailable to plants in calcareous soil. In neutral and alkaline (pH) soil, as well as calcium-rich soil, zinc and manganese shortage is frequent. Controlled release is defined as the permeation-controlled transfer of active ingredients from a modified reservoir to a specific target location

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while maintaining the active ingredient's concentration at a predetermined level for an extended period of time. Several nanocomposites have been developed for the gradual delivery of agrochemicals, and their great resilience and extended shelf life make them ideal for use in agricultural field situations. The bulk of nanocomposites reports focus on their synthesis, characterisation, and release kinetics in soil and water. There are only a few research that have reported on the use of nanocomposites on plants. Agrochemicals have lately been delivered using nanoencapsulated goods, which not only provide gradual release but also give protection to the delivery payload at its core. The delivery payload is coated with a hydrophilic coating that actively absorbs water, causing swelling and then disintegration and release of the cargo through diffusion . Several polymer-based nanocomposites are also being employed to create pesticide delivery nanocomposites. The sol gel technique is a well-known bottom-up nanoparticle creation process. Hydrolysis and polycondensation, gelation, ageing, drying densification, and crystallisation are some of the processes involved. Solgel is the most common method for making silica-based hybrid nanomaterials and zeolites.

Different approaches can be used to create polymer silicate nanocomposites: template synthesis, exfoliation adsorption, in situ intercalative polymerization, melt intercalation. The melt intercalation synthesis process is the simplest, most cost-effective, and environmentally benign of all the approaches. As a result, it is widely recognised as a synthesis procedure for creating polymer silicate nanocomposite. Using an extruder, the polymer is melted and mixed with desired amounts of intercalated clay in this procedure. Molten or intercalated nanocomposite can be made based on the compatibility of the silica layers and the polymer. Organic solvent is not required because the entire process is carried out in an inert atmosphere. Nanocomposites can be far more useful than bulk chemical fertilisers and pesticides because of their unique qualities, such as gradual release and tailored delivery of agrochemicals. Nitrogen, phosphorus, and potassium are essential macronutrients for plant growth and maintenance. Nitrogen and phosphorus are essential for plant structure growth, as well as the synthesis of nucleic acids, proteins, and other biomolecules, and potassium is essential for maintaining osmotic potential and ion balance. Several nanocomposites have been developed to ensure that these macronutrients are delivered effectively in agricultural fields.