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Application of Chitosan in Plant Growth

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Abstract

Chitosan has a wide range of sources, is safe and non-toxic, and increasingly used in agriculture, and is a natural polysaccharide that is commonly produced by chitin deacetylation, which is the structural component in see crustaceans, which is helpful for the growth of the plant. In the present review, it was briefly described that chitosan was used in different agriculture sectors, and it's an extensive application to promote plant growth. The chitosan was applied as a fertilizer (controlled-release fertilizer, liquid fertilizer, fertilizer, and micronutrient delivery). It had a significant response supportive role for the plant growth. Besides, chitosan was used as a pesticide (Insecticide, against viruses, antimicrobial, herbicide delivery) and also observed the role of chitosan in plant defense. It was observed that chitosan had played a significant responsibility to control different pests. However, it was utilized as plant resistant material (induction of plant resistance by chitosan, the role of chitosan improving in the plant, defense-related enzymes, and plant disease resistant, electrophysiological modification induced by chitosan) and it was observed that chitosan was had a great response to improving the plant's growth by resistance against pests. Our whole review showed that chitosan had positive impacts on the plant's growth, and it had a great response to the reduction of pests and reduce the effects of diseases and give the resistance to plants against these and chitosan is an environment-friendly.

Keywords: Plant Growth, chitosan, Deacetylation, Biochemical

Introduction

In the year of (1894) the scientist Hoppe-Seyler was the first researcher who suggested the term chitosan and it has a wide range of sources, are safe and non-toxic, and are increasingly used in agriculture. It is a natural polysaccharide that is commonly produced by chitin deacetylation, which is the structural component in sea crustaceans. Chitosan, a derivative of chitin, can promote plant growth, has coating properties, broad-spectrum antibacterial properties. It has been utilized to evaluate disease or decrease its transmission, chelate nutrients, and minerals, prohibit pathogens from transferring them, or promote fundamental defenses of plants for promoting the plant growth. It has proved and used as antiviral, antibacterial, and antifungal, when it was used to increase plant defenses, the chitosan triggers the host defense system in both monocotyledons and dicotyledons.

In recent years, more and more attention has been paid to the development and utilization of this resource in many countries. Chitin research has become a new interdisciplinary subject, and has been widely used in many important fields such as agricultural environment, analysis, and detection. By summarizing their research and application in agriculture and collating their main application mechanisms, they can be more intuitive and faster. Understanding the application of chitosan in agriculture can provide a theoretical basis for future research. Since 1988, China has started to develop an upsurge of studying chitin and chitosan, and its derivatives. Many scientific research institutions have conducted a large amount of research and achieved many results. Chitosan was formulated by deacetylation of chitin. It not only has the common characteristics of common polysaccharides, but also has many unique functions, in agricultural sector fertilizers are being used to release the nutrients necessary to grow the plants. However, a large amount of the fertilizer used has been lost to the environment, often through leaching, volatilization, micro - organisms and chemical processes such as hydrolysis [1].

Application of Chitosan as fertilizers

The agrochemicals such as organic fertilizers are the most important products of the agricultural industry. While supportive nutrients to crops, they build up their growth and at the same time play a key role in regulating both the pH and the fertility of the soil.

Chitosan as fertilizer

As a new type of fertilizer, chitosan liquid fertilizer has been widely used in agricultural production. It is a significantly deacetylated derivative of chitin, one of the most valuable natural and biodegradable polymers. However, this soluble fertilizer covered by polymers of carbohydrates, such as chitosan, would be an ideal slow-release fertilizer formulation. Superabsorbent are poorly cross-linked hydrophilic polymers that can absorb and maintain aqueous fluids nearly equivalent to numerous times their weight, the absorbed water almost not be detachable or changeable even under some pressure. Researchers have been investigating the probability of using chitosan in the agrochemical sector for numerous years now. A review of the literature on this field investigates to signify that the main area of research is focused on how to use chitosan as a nutrient inorganic or mineral fertilizers, which can increase soil fertility, plant growth, and promote crop yield. demonstrated that chitosan may use for plant growth, and the results of chitosan had great and valuable which is good to suggest to the farmers in the future. The usage of a Nano-engineered mixture formed of N, P, K micronutrients, mannose, and amino acids promotes the absorption and uptake of nutrients by grain crops. Nanomaterials can improve crop seed germination and promote plant growth. The utilization of carbon nanoparticles facilitated the development of tobacco plants at a resettling stage of growth, rapid growth stage, and maturity level relative to traditional fertilizers. A review of the analysis indicated that the life cycle of the control and normal NPK fertilized wheat plants cultivated on sandy soil followed 170 days from seed germination. On the opposite side, wheat plants cultivated on sandy soil and fertilized with chitosan-NPK nano-fertilizers, after 130 days reached the harvesting position from seed germination. Therefore, throughout this linkage and of particular importance, it is important to note that the treatment with nano-fertilizers resulted in a reduction in the full life cycle of wheat crops by 23.5 percent from the natural life of the respective crops [2].

The article showed that different techniques of application and levels of chitosan had a massive impact on the number of leaves, number of flower clusters, and duration of flowering, length of fruit, yield, significant biochemical, and mineral nutrients of tomato (L. esculentum). The maximum fruit yield and lycopene content of tomato were reported in the treatments T6 (i.e. soil appliance of chitosan @80 ppm + foliar usage of chitosan @60 ppm) and T10 (i.e. soil application of chitosan @120 ppm + foliar treatment of chitosan @80 ppm), respectively. On the other hand, treatment T4 (i.e. foliar method of chitosan @ 80 ppm) was more valuable for maximum growth and biochemical parameters of the tomato (L. esculentum). Therefore, it can be outlined from the results of this study that foliar formulation of chitosan alone or in mixture with soil application has a positive effect on growth, yield, and biochemical morphology of tomato fruits (L. esculentum), but some variations may be attributed to fruit maturity level, size, and environmental conditions. Thus, these methods and application doses of chitosan, further this study is desirable in different years and agro-ecological zones.

The possibilities of using chitosan in CRF

The researcher showed that chitosan is one of the possible material to use as Controlled-Release Fertilizer (CRF), it's a natural polysaccharide which is commonly found in the chitin of crustaceans, and chitosan comfortably undergoes biodegradation and is particularly biocompatible in the natural world. It has special polycationic properties. For several decades the scientists are doing experiments and establishing new researches that exactly how to use chitosan for Control Release of Fertilizer (CRF), for the improvement of the soil fertility, plant growth, and the yield. In the recent decade, there were some research articles and patients found from some countries (China, South Korea, and Japan). The advantage of applying chitosan as a fertilizer's compound, which had played a responsible for nutrients' controlled release many articles are published and additionally, still there is no information in the literature available on the topic on the functionality, level, and effectiveness of the release of nutrients, stressful activities or their effects on the environment of this kind of fertilizer [3]

Fertilizer and Micronutrient Delivery

It is well-identified that the production capacity of sufficient fertilizer and water, as well as micronutrients, such as Mn, Cu, B, Mo, Fe, Cl, and Zn, facilitate superlative favorable growth. Therefore, any enhancement in plant yield demands a proper application of the nutrients and growth factors and water resources. In this decade many scientists proved that some agrochemicals, for example, NPK they are not just economically loss to the farmers and also they have a significant role in the environmental pollution. Farmers need to turn towards more suitable and safe techniques to respond to the increase in fertilizer costs and the demand for environmentally sustainable agriculture. In this context, CHT-based polymers may be the solution. Nanoparticles composed by an internal coating of CHT, an external coating of cross-linked poly (acrylic acid)/diatomite—covering urea and a core of water-soluble granulated nitrogen (N), phosphorus (P), and potassium (K) and (NPK) fertilizer demonstrated controlled released fertilizer of the nutrients without any negative influence on the soil.

Chitosan use as liquid fertilizer

There are several articles which showed that chitosan also used as liquid fertilizer which is usually known as a foliar application, it had an abundant response to the plant growth and yield. Demonstrated that the application of chitosan liquid fertilizer on lettuce showed that it could accelerate the growth of lettuce and increase the yield rate is 19.7%. The results show that chitosan as a slow-release carrier of fertilizer can effectively achieve the purpose of slow-release. The previous studies have shown that when chitosan is used as a fertilizer with other substances, it is not that simply mixed, but under the action of additives, the molecules in the solution are fully swelling and dissolving, and the polymers are fully extended and mixed, forming a new physical connection between the macromolecules. The results showed that the secondary valence force within and between molecules changes greatly, resulting in the change of molecular structure and the arrangement and recombination of molecules, forming a new stable structure membrane.

There are many reports on the application of chitosan in crop growth. It was found that foliar application of chitosan can improve the single fruit quality and yield of tomato (Lycopersicum esculentum Mill), increase the fruit yield, plant height and number of leaves of okra, promote growth and the biomass accumulation of tissue culture seedlings of observed that adding chitosan to the soil the results showed that it can improve pepper the plant height, crown width, and leaf area were measured.

revealed that by spraying chitosan at different growth stages of wheat could affect the yield of large-scale field experiments by increasing yield traits such as ear number and grain number per spike, and shown that, chitosan can effectively enhance microspore embryogenesis and plant regeneration of the researcher proved that it can also increase the somatic embryogenesis of under tissue culture conditions. Observed the effect of foliar application of chitosan and some organic fertilizers French bean plant. It has been revealed that with reduced concentrations of Nano-fertilizers, all growth requirements were observed in CS-10%, CS-NPK 10%, and CNT-20 μg/L as compared with the control and decrease at higher Nano-fertilizer concentrations. Nano-fertilizers have harmonized fertilizer-N and -P delivery with their crop absorption to effectively stop necessary nutrient losses to the soil, water, and air through direct crop intake and to help avoid nutrient bonding with soil, micro-organisms, water, and air. For effective foliar concentration, in addition to element size, other several factors require also be considered such as controlling environment (light, water, and gas), plant species, and Nano-particle uses techniques.

Some scientists claimed that chitosan can also promote the growth of flowers. For example, chitosan treatment can increase the seed germination rate of (Dendrob ium formosum Roxb) and chitosan treatment of (Gladiolus communis L.) bulb can promote bulb germination, increase the number of bulblets, and prolong the vase life. Similarly, the application of chitosan in the corm culture of (Freesia eckl. Exklatt) can improve the plant height and promote the growth of leaves, buds, flowers, and corms. This research paper reveals that the utilization of 80 ppm polymeric chitosan via seed absorption before sowing, accompanied through four-fold soil application during the crop season, appeared to stimulate growth and massively increase rice yield. On the other side, seed soaking followed by the foliar application before growing noticed to produce an opportunity to suppress the disease [4].

Chitosan applied as pesticides

Chitosan is a natural, secure, and inexpensive biopolymer produced from chitin, the important component of arthropods exoskeleton and fungi cell walls and the second renewable carbon source after lignocellulosic biomass. In the last few years, and several studies have explained the formulation and application of chitosan nanoparticles, as a pesticide delivery system.

Insecticidal Activity

Were studied and surveyed that the chitosan has the ability to control different insect pests such as Helicoverpa armigera, Plutella xylostella, Hyalopterus prun, Penicillum italicum etc. they usually serious pests and cause a high damage the crops and stop the growth of plants and they are the thread of economy for the farmers. Cotton Leaf worm S. Littoralis is a dangerous disease in subtropical and tropical cultivation, which has the ability to be a significant pest for agricultural crops. The larval stages (caterpillars) consume on a massive range of plants, particularly ornamental and edible crops. Many species are highly immune to pesticides, which may be particularly difficult to control and then they become well established. In the present study, the five new heterocyclic chitosan byproducts were tested for their effectiveness as growth inhibitors and antifeedants against the larvae of S. littoralis. Reviews observed N-[(5-methylfuran-2-yl) methyl) chitosan has been the most effective against P. grisea whereas N-(benzo[d] dioxol5-ylmethyl) chitosan and N-(methyl-4H-chromen-4-one) chitosan were the highest active compounds against P. debaryanum and F. oxysporum. It was also found that N-(methyl-4H-chromen-4-one) chitosan revealed an important growth inhibition and antifeedants activity between the combined compounds against the larvae of the cotton leafworm Spodoptera littoralis. These scientists demonstrated that derivatives of chitosan (i.e., N-alkyl-, N-benzyl chitosan's) are made untaken through chemical synthesis, their insecticidal actions are being described using oral larvae feeding bioassay. Twenty-four new derivatives have shown massive insecticidal activity when prescribed in an experimental diet at a rate of 5 g kg, N-(2-chloro-6-fluorobenzyl) chitosan, the most active derivative, affected 100 percent larvae death rate and its LC50 was reported at 0.32 g kg. All combined derivatives potently inhibited larvae development by 7% relative to chitosan and the most powerful derivative was O-(decanoyl) chitosan, with growth inhibition of 64% after 5 days of feeding on the behave towards artificial diet.

Against viruses

From the recent papers, it was examined that results showed that chitosan could also be used as a plant sterilization agent. Spraying 0.4% chitosan solution on tomato could eliminate the harm of the tobacco mottle virus. Shell polymerization the solution of sugar dissolving in weak acid can improve the resistance of plant seeds or seedlings to pathogenic factors and environment. This effect can be applied to forestry, horticulture, and other cereal and fruit production. The film made of chitosan-coated on the outer layer of some pesticides can slow down the release rate of pesticides so that pesticides can play a long-term effect in the soil.

showed that integrated usage of PGPR with chitosan massively decreased symptoms caused by PRSV-W and TCSV in squash and tomato, when contrasted to PGPR treatment alone. The highest reduction in disease sternness of PRSV-W and TCSV was attained when a mixture of two (IN937a + SE34) or three (IN937a + SE34 + SE56) PGPR strains were combined with chitosan at 250 or 500 ppm. More experiments are needed to research the negative impact of higher chitosan concentration on plants and to establish a bio-preparation of PGPR and chitosan solution to control such plant viruses. It revealed that planta, histo-cytochemical analysis demonstrates that TNV resistance was connected to the system of callose compounds, segments, and sub-oxidant releases and micro lesions. Even this reported all the functionalities of micro-hypersensitive responses (Micro-HRs). The responsibility of callose in controlling viral infection is well identified. Extracellular callose deposition about plasmodesmata (callose collar) limits the cell-to-cell transport of viral particles, and callose isolated in palisade mesophyll primarily implies an improved performance of callose formation in tobacco leaves treated with CHT. Diaminobenzidine (DAB) particles make a contribution to the generation of ROS in leaf mesophyll tissues. The Reactive Oxygen Species (ROS) formed through (phospholipase-) lipoxygenase procedure has long been known to contribute to the establishment of Hypersensitive Response (HR) instigated by a viral infection. Epidermal cells of chitosan applied on leaves did not appear any helpful histo-cytochemical response, such as tissues from solvent-treated plants. Showed that the treatments of tobacco with chitosan extensively decreased the size of damages affected by tobacco necrosis necrovirus (TNV). This resistance was detected by specific pigments, complex of callose particles, micro-oxidative releases, and micro-hypersensitive reactions. Chitosan also prevented localized lesion necroses caused by Tobacco Mosaic Virus (TMV). This action was enhanced by lowering the degree of polymerization process and was based on lower acetylation.

Reported that the spraying of bean leaves with 0.1% chitosan solvent resulted in almost 100°/o decreased of the local damages caused by A1MV. In addition, the same level of decrease in the number of infections was reported whenever chitosan was added 3 hours or 5 days before AIMV addition. The AIMV infectivity was also suppressed through the treatment of chitosan on the leaves 1- 4 h after inoculation. The last words of the scientist that it must be noticed that chitosan utilized at a concentration higher than 0.25%, occasionally it seemed to be toxic for bean plants however when used at concentrations lower than 0.1%, it was less effective in the decrease of regional damages.

Compared with the studies of antibacterial and antifungal activity of chitosan, comparatively few scientific reports have been published on its antiviral activity. Chitosan antiviral efficacy has been reviewed in micro-organisms, and plants. It promoted tolerance to viral diseases in plants and suppressed the widespread transmission of viruses and viroid's so that most or all of the treated plants with chitosan did not acquire systemic viral infectivity. Lower molecular weight of chitosan prevents the development of tobacco mosaic virus provoked local necroses by 50% to 90%. In fact, the direct protective action of chitosan on viruses had been expressed primarily during the inactivation of viruses, it was active in preventing coliphage infectivity and the replication of 1–97 A phage in Bacillus thuringiensis culture. When chitosan applied to a mutation suspension, its titer reduced with chitosan. Electron microscopic analyses revealed that chitosan induced massive reforms in mutation particles and destabilized their stability.

Antimicrobial Activity

The antimicrobial action of chitosan and its derivative of oligosaccharides has been identified and has been regarded among the most important characteristics, immediately relating to their applicable biological applications.

The recent research publications were observed stated that chitosan and its impacts had wide-spectrum antimicrobial effects. Subsequently, the antibacterial effect of chitosan was further studied. The isolated chitosan had been used against the pathogens of root rot and treated the root with chitosan. In the previous studies, it was found that chitosan with different molecular weight had a certain inhibitory effect on the pathogen of Isatis indigotica root rot. The effects of acid-soluble chitosan and two kinds of water-soluble chitosan on 15 kinds of plant pathogenic fungi, such as Fusarium oxysporum, Rhizoctonia cerealis and Fusarium graminearum, were determined on potato glucose agar. The results showed that three kinds of chitosan could inhibit 15 kinds of plant pathogenic fungi to a certain extent, and the inhibition intensity was different due to the physicochemical properties of chitosan and different pathogenic fungi and expanse the resistance to plants promotes the host's immune response to infection. Stated that chitosan fungicidal response has been described against multiple species of fungi and oomycetes The lower limit growth-inhibiting concentration levels varies from 10 to 5 000 ppm. The supreme level of antifungal action of chitosan is repeatedly experiential about its pKa (pH 6.0). These two scientists reported on the fungicidal behavior of 24 new mixtures of chitosan (i.e., N-alkyl, N-benzylchitosans) and demonstrated that, using a rotational hyphal evolution bioassay of P. grisea and B. cinerea, that all complexes have a significant fungicidal activity than the native chitosan. N-dodecylchitosan, N-(p-isopropylbenzyl) chitosan and N-(2, 6-dichlorobenzyl) chitosan were the most vigorous against B. cinerea, with EC50 values of 0.57, 0.57 and 0.52 g.L-1. Against P. grisea, N-(m-nitrobenzyl) chitosan was the record effective, with 77% breakdown at 5 g.L-1. O-(decanoyl) chitosan at mol ratio of 1:2 (chitosan to decanoic acid) was the best vigorous complex against B. cinerea (EC50 =1.02 g.L-1) and O-(hexanoyl) chitosan showed the greatest response against P. grisea (EC50 = 1.11 g.L-1). Some of the derivatives also suppressed spore formation at relatively high applications (1.0, 2.0 and 5.0 g.L-1). Revealed that chitosan should base on the important the Neurospora crassa plasma membrane and damage the cells in an energy-dependent method. In fact, chitosan, applied at such a level of 1 mg / mL, may minimize the in vitro growth of a wide range of fungi and oomycetes with the exception of Zygomycetes, which contain chitosan as a component of their cell walls. An additional class of fungi that appears to be strong to the antifungal influence of chitosan, the nemato-/entomo-pathogenic fungi that hold extracellular chitosan lytic activity. Detailed that after the detection of chitosan's wide-spectrum antimicrobial effect, considerable concern throughout this polymer, as well as its derivatives, had increased in recent decades as a consequence of its novel properties. Certainly, additional investigation reports demonstrated their prospective use in agriculture, medicinal industry, food production, and so on. Whenever we all noticed, antimicrobial control system investigation is a truly required stage of the microbicide development. Therefore, the actual mechanism of the antimicrobial properties of chitosan and its variants are still uncertain, which control their additional application to some extent. Proved that structural variations would explain for their differing prevention actions that also indicate that the influence of amino groups is the source of antimicrobial chitosan behavior. Some other scientists demonstrated that because of the established crystalline form, chitosan is generally unsolvable in water, but solvable in diluted aqueous acidic solutions under its pKa (∼6.3), in which amine (−NH2) groupings in glucosamine units are transformed into the solvable protonated form (−NH3+).

The Role of Chitosan in Plant Defense

Observed that a maximum number of Pathogen-Related proteins (PR) have been reported to be enabled after applications have been applied to plants. In some other experimental study it was found that, most remarkably this contains chitinase, but also includes glucanases, polyphenol oxidases, and MAP-kinases. Stated that protease blockers are also probably obtained to reduce the function of the pathogen's enzymes implicated in attacks. In addition to contributing to the initial stages of pest and pathogen identification, plant chitinases have also been shown to help combat fungal growth, and are therefore assumed to be a controlled defensive strategy in their own right and are identified as Pathogen-Related (PR) proteins in this role. Whereas, competitive against the fungal pathogen, it seems insect pests are not regulated by plant chitinases. The author described in his book that, for example, if a rice chitinase was differentially expressed in rice, the converted plants had no immunity to attack by the fell armyworm moth caterpillars (Spodoptera frugiperda).

Herbicide Delivery

In advanced agriculture, the adoption of herbicides greatly enhanced to mitigate the loss of the productivity in plant species and this superfluous application caused dangerous impacts in environmental and human health long term issues, herbicides presence the phytochemicals most broadly polluting hydrological systems. To control these issues, the exploitation of natural polysaccharides such as chitosan was probed. For example, several scientists formulated and evaluated modified chitosan nanoparticles to convey paraquat, the most extensively utilized herbicide. Revealed that alginate/CHT nanoparticles replace the release of the herbicide and its linkage with the soil. Besides, CHT/tripolyphosphate nanoparticles lessened paraquat harmful effects and enhanced herbicide response was observed for Eichhornia crassipes when paraquat was articulated in silver/CHT nanoparticles. In addition, a method related on CHT nanoparticles could be used to regulate and isolate excess herbicide or heavy metals from soil and water. The herbicide clopyralide available in water and soil was adsorbed and extracted with a nanocomposite substance of CHT and montmorillonite expressed that CHT helps to improve the bioactivity of chiral herbicide dichlorprop to the green algae Chlorella pyrenoidosa, and a plant esterase-CHT/gold nanoparticles-graphene nanosheet composite-based substance was positively established for ultrasensitive exposure of organophosphate pesticides in various samples. Chitosan micro particles from allergens of Acer negundo, Cupressus sempervirens, and Populus nigra were treated to isolate trace elements. Comparably, spores of the phytopathogenic microfungi, Ustilago maydis and U. digitariae were incapacitated in cross-linked chitosan solution and performed to remove trace elements from water.

Plants resistant material

Induction of plant resistance by chitosan

The scientists explained that all plants, whether resistant or susceptible to pathogen infection, can respond to pathogen infection by inducing a coordinated signal transduction system, resulting in the accumulation of different gene products. Plant response to pathogen infection can play a role at different levels: first, plant recognition of pathogens leads to the rapid death of local cells in plants, also known as the Hypersensitive Response (HR), leading to necrosis of the infected site (local response). Then, even in other uninfected parts of plants, a broad-spectrum and persistent expression of systemic resistance to pathogen infection will be induced, which leads to the production of Reactive Oxygen Species (ROS), at the same time, it is accompanied by the triggering of defense connected genes and the up-regulation of gene expression related to phytoalexin, terpenes, course-related protein (PR protein) and multiple enzymes involved in defense reaction (pal, PPO, pod, and APX).

The signal molecules that can activate the defense response mechanism of plants are called elicitors. In another review it was observed that in the infected parts of plants, elicitors can be produced by infected plant cells (endogenous elicitors, which are released by plants when contacting with pathogens) or by pathogens themselves (exogenous pathogen elicitors). These elicitors mainly include oligosaccharides, lipids, peptides and proteins, which can be used as signal molecules to induce plant defense response at low concentrations. Once the elicitor is recognized by the plant cell transmembrane receptor, it can induce local response (at the infected site) and systemic immune response through signal transduction molecules in the distal tissue of the plant.

A review of a researcher revealed that with the increasing research on the mechanism of plant response to pathogen infection, researchers found that exogenous substances with elicitor function can be used to artificially induce plant resistance, obtain broad-spectrum disease resistance and enhance plant resistance to pathogenic pathogens. At present, there are many reports about elicitors treating plants to initiate induced resistance to pathogen infection. Another scientist showed that, the use of elicitors to improve plant resistance in agricultural production is an environmentally friendly method for plant disease control, which can be used as a substitute for chemical pesticides to control plant diseases to reduce the negative impact of chemical pesticides on the environment [5].

Chitosan improve crop resistance

Many studies have shown that low molecular weight chitosan is an effective biological elicitor, which can induce plant defense response and activate different signal transduction pathways that can improve crop resistance to disease. At present, most researches on the response of plants to chitosan treatment are the formation of chemical and mechanical barriers such as lignin and callose, and the synthesis of substances and enzymes involved in defense reaction. In this review. it was stated that, in some cases, the allergic reaction (mainly the infected site) caused by chitosan leads to programmed cell death. At the same time, these allergic reactions are accompanied by systemic reactions of plant defense mechanisms, which mainly include the synthesis and accumulation of secondary metabolites that play an active role in the defense response, such as lignin, callose, phytoalexin, disease-related proteins; involved in the regulation of key enzyme activities of defense reaction metabolic pathway, such as phenylalanine ammonia-lyase, peroxidase, and chitinase.

Plant disease resistance

In recent years some authors published papers and showed that, the mechanism of plant disease resistance induced by chitosan and the reaction induced by chitosan in plant-pathogen interaction have not been fully explored. Plants recognize elicitors through transmembrane receptors, but the specific receptors for recognition of chitosan have not been determined, and the protein kinase cascade that transmits signals to transcription factors (TFs) has not been determined. At present, different models have been proposed to elucidate the role of chitosan in the activation of plant defense genes. In these models, the up-regulation of plant defense genes induced by chitosan involves the direct interaction between chitosan and DNA, these models suggest that chitosan induces the activation of defense genes by changing the structure of DNA (chromatin structural recombination), accompanied by the decrease of HMGA or the interaction with DNA polymerase complex. The defense response induced by chitosan treatment may depend on the difference in the plant-pathogen system. Even for the crops, different defense responses will be induced due to the difference in treatment time and method.

Defense-related enzymes

Observed that as a physiologic elicitor, chitosan can induce resistance in the target by boosting the function of too many enzymes linked to the protection system, including such phenylalanine ammonia-lyase, peroxidase, polyphenol oxidase, catalase, and superoxide dismutase. It appeared that seed treatment with chitosan would accelerate their germination pace and boost their resistance to stress factors. Related increases in chitosan-induced catalase activity in fish have suggested that chitosan has antioxidant potential. Observed that, as augmentation of catalase is helpful to eliminate free radicals. This article showed that, chitosan was hypothesized to delay plant growth and senescence through control of antioxidant enzyme.

Electrophysiological modifications induced by chitosan

Indicated that, the application of chitosan to the soaking medium of M. pudica pulvini induced a spontaneous depolarization of the motor cell membrane in a concentration-dependent manner at concentration > 10 lg ml and up to 100 lg ml. Demonstrative time sequences of the bioelectrical activities documented throughout this range of doses: the depolarization took place after a time gap (in the order of several mins), reducing as the formulated concentrations higher, reached its peak at; 10-15 min, and returned to its original resting capability after; 30-40 min even in the appearance of chitosan.

The observation of this research article. It was stated that O-chitosan nano-particles were positively arranged using the O/W emulsification technique. The nano-particles preparation had a virtually sphere-shaped and the average diameters were 296.962 nm. O-chitosan nano-particles also displayed nice dispersal in the PDA medium. But for G. zeae and F. culmorum, the mycelium evolution of N. sphaerica, B. dothidea, N. oryzae and A. tenuissima was relegated by the adding of chitosan. Fatty acid examines shown that the plasma membranes of chitosan-sensitive fungi were presented to have minor levels of unsaturated fatty acid than chitosan-resistant fungi. The phylogenetic ITS gene categorizations analysis designated that two chitosan-resistant fungi had a close phylogenetic connection, proposing that some collective factors of the structure can lead to their resistance to chitosan. Founded on these outcomes, O-chitosan nano-particles might be utilized as an antifungal dispersal system to regulator pathogenic fungi. Whereas, further reviews are required to describe why some pathogenic fungi are sensitive to chitosan but others are resistant? The particular methods of the antimicrobial actions of chitosan and its derivatives are still unidentified, while, the investigation never stop the search of fact. So, the upcoming work will be aimed at the diversity of cell membrane composition between chitosan-sensitive and chitosan-resistant fungi.

Conclusion

Our review showed that chitosan has existed as a valuable polymer with a wide range of functionalities due to the multipurpose biological actions, tremendous biocompatibility, and comprehensive biodegradability, in combination with low toxicity. Chitosan had been utilized as fertilizers, pesticides, and plant resistant material. Remarkable theoretical and practical outcomes were collected in recent years, whereas more are required to examine the appliances prevailing the mode of action of these mixtures. Besides, the effectiveness of nitrogen adaptation by plants is relatively low and this is an important problem in the viewpoint of environmental protection. The perfection of fertilizer immersion can be carried out among the increasing, producing, and applying the controlled release fertilizers. Biodegradable chitosan has been suggested as an alternate substantial material in the expression of controlled-release fertilizers. These methods were helpful to promote plant growth. In some experiments in the present review were noticed that chitosan was also used as pesticides. It was one the best option to prevent pests and many scientists used different pests and various techniques. Applied chitosan against insect pests, viruses, microbial, and herbs. It was very helpful to prevent all pests (insect's pests and herbs) and diseases and improved the stability (immune system) properties of the plants. Chitosan was also applied as plant resistant material. Induction of chitosan into plants was helpful to plants and found that chitosan had the ability to resist against diseases by improving the defense related-enzymes, physiological modification of chitosan, and help to the progress of the plants' growth. Whereas, the application of chitosan in plants has been few different, particularly under abiotic anxieties. As far as a deficiency is concerned, chitosan induces various favorable reactions in plants such as antitranspirant, triggering of ROS scavenging system, boosted stomatal conductance, better-quality root growth, and complete plant growth.

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