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A review on chitosan: A new solution for combating abiotic stresses in agriculture

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Abstract

Chitosan is a second most abundant naturally occurring polysaccharide after cellulose derived from chitin which commercially produced from seafood shells, fungi (*Aspergillus* and *mucos*) and also from algae by alkaline deacetylation of chitin. It is bio adhesive, biocompatible, biodegradable, organic molecule. Chitosan has wide spread application in agriculture. Chitosan acts as bio-stimulant which upon application to plants stimulates photosynthetic rate, enhances antioxidant production, increases tolerance to biotic and abiotic stresses. Chitosan causes hydrolysis of peptidoglycan of microbes resulting to death of microbes. Recent studies have shown that chitosan induces mechanisms in plants against various biotic and abiotic stresses and helps in formation of barriers that enhances plant's productivity. This paper takes a closer look at the genesis, structural alteration and physiological responses of chitosan foliar applications on plants. AS, Abiotic stresses is an important multidimensional environment stresses that damage plant physiology, biochemical properties and Molecular traits. Chitosan help to combat abiotic and biotic stresses.

Keywords: Chitosan, Biotic, Abiotic, Agriculture

Introduction

Chitosan is a natural biopolymer molecule which is second most abundant extracted by deacetylation of chitin. Source of chitosan is Shell of seafoods, Algae, and Various microbes also produce chitin in cell walls, membranes and spores, including fungi (Castro *et al.* 2012)^[4] and the spines of diatoms (Bartnicki-Garcia *et al.* 1982)^[5]. It produced from crustacean shells due to removal of Protein, mineral, colour followed by removal of acetyl group (deacetylation) as shown in figure 1 (Chemical and Biological preparation). Activity of Chitosan are predominantly dependent on its degree of deacetylation, molecular weight and pH of solution (Xu *et al.*, 2007)^[1]. Difference of chitin and chitosan by degree of acetylation and deacetylation as, chitin-Degree of acetylation- 0.90 and Chitosan- degree of deacetylation- > 0.65 (Daniel Elieh-Ali-Komi *et al.* 2016)^[6]. Chitosan Registered (licensed for sale) as active ingredient in 1986 (Chitosan; Poly-D-glucosamine (128930) Fact Sheet"). Chitosan is a weak base and is insoluble in water, but soluble in dilute aqueous acidic solutions below its pI (~6.3), in which it covers -NH₂ (glucosamine) into the soluble protonated Form -NH₃⁺ (Jagadish *et al.* 2017)^[3]. Commercially, Chitosan is available with >85% deacetylation units and molecular weight between 100 & 1000kDa. Structure of chitosan was identified by X-ray diffraction, infrared spectra, and enzymatic analysis. Chitosan composed of D-glucosamine and N-acetyl-D-glucosamine linked with 1,4-glycoside bond in which glucosamine backbone of chitosan contains high degree of amine group. The glucosamine backbone of Chitosan Contain Amine group which offers the opportunity to form complex of Chitosan with negative charge DNA molecule (Zhao *et al.* 2011)^[8] which help in transcriptional regulation. It is also used as Nanoparticle (Zhou *et al.* 2014)^[9]. There are several derivate of Chitosan like Oligochitosan. Oligo-chitosan (82.20 kDa) was prepared from chitosan (337.73kDa) by application of 100 kGy γ -irradiation (Muley *et al.* 2019)^[2]. Before this during 2003 chitosan, cellulose, alginate and starch have been successfully degraded by application of gamma irradiation as glycosidic bond between C1 and C4 positions of the monomeric sugar residues is broken down and respective oligomers are generated (Cho, Kim, & Rhim, 2003)^[11]. Chitosan form gel tha absorb water due to its high molecular weight (MW) and porous structure (Tamura *et al.* 2006)^[10]. Advanced development of chitosan hydrogels has led to new drug delivery systems that can release their active ingredients in response to environmental stimuli.

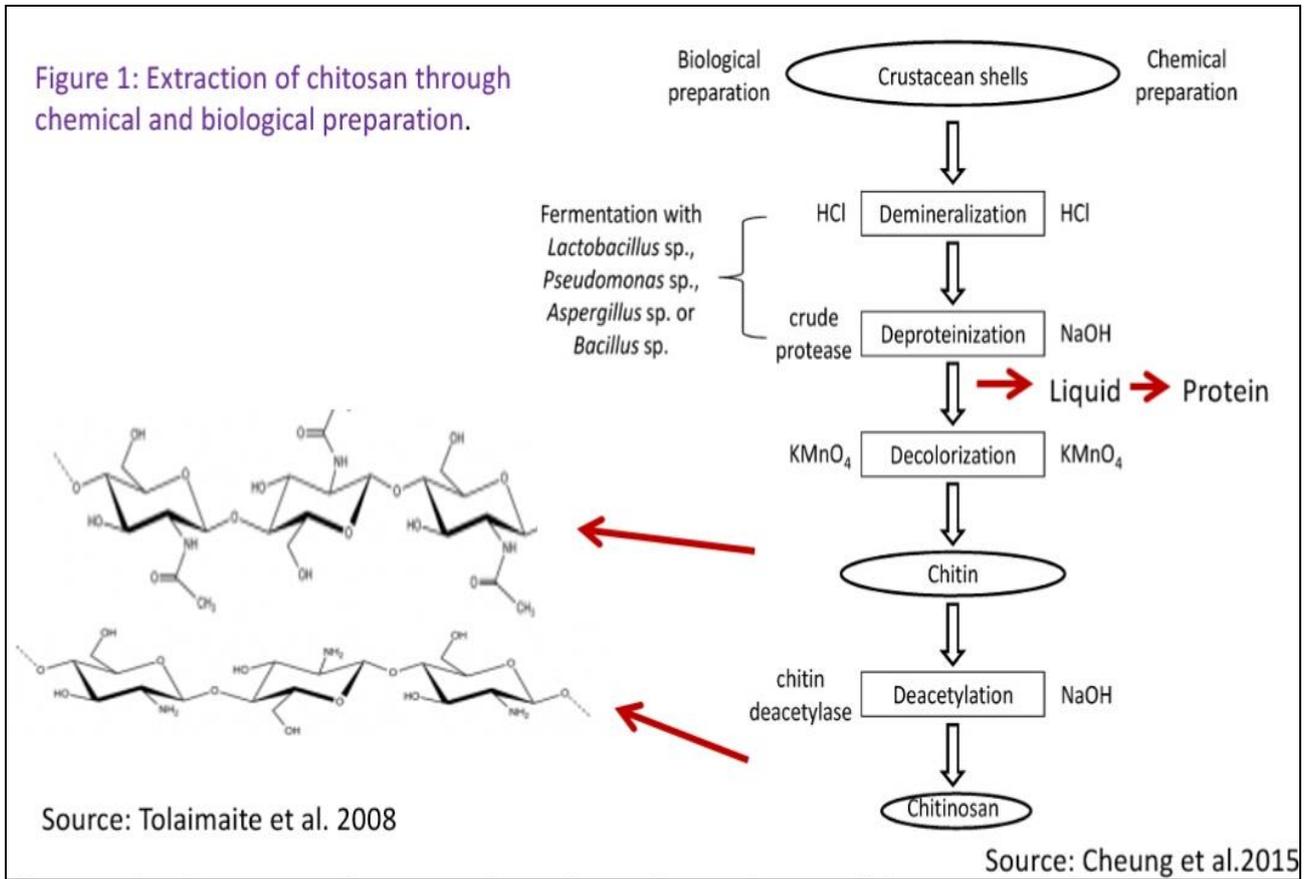


Fig 1: Extraction of chitosan through chemical and biological preparation.

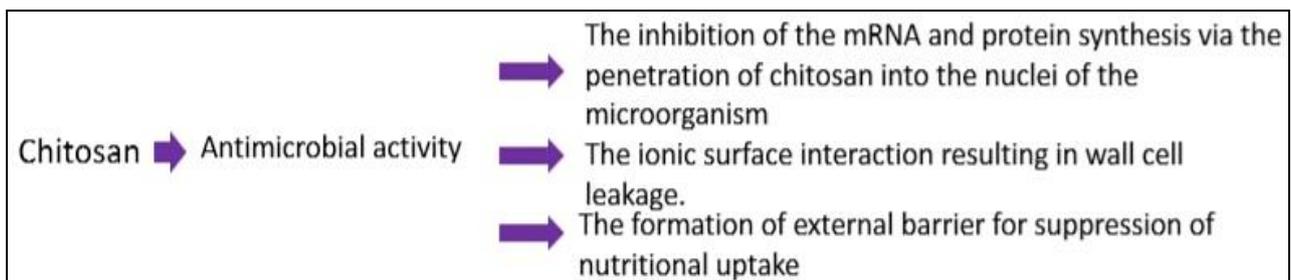


Fig 2: Details about Chitosan properties

Chitosan has a good physiochemical properties bio adhesive, biocompatible, biodegradable and it helpful in Antimicrobial activity, Bio-stimulant (Stimulate Expression of gene), Growth promoter, Antioxidant Activity, Insecticidal Activity, Osmoprotectant, act as Biofertilizer, Antimicrobial activity, modification of post-harvest crop as in cotton. In short it is multi-purpose bio-polymer help to combat abiotic and biotic stresses. Goy *et al.* (2009) [15] suggested three antimicrobial mechanism of chitosan first for cell wall leakage, second for inhibiting protein and mRNA synthesis, third for film forming which result into limiting nutrition availability for microorganism as shown in figure 2.

Importance

1. Antioxidant Activity: Chitosan show Antioxidant Activity solution which was estimated by using 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) assay. The free radical activity of Chitosan by presence of Nitrogen containing group (-NH₂).

- 2. Antimicrobial Activity:** Goy *et al.* 2009 [15] Suggested three mechanism of Chitosan which are - The inhibition of the mRNA and protein synthesis via the penetration of Chitosan into the nuclei of the microorganism, The ionic surface interaction resulting in cell wall leakage, The formation of external barrier for suppression of nutritional uptake. Also, a supportive figure for Antimicrobial activity in figure 3 (sharif *et al.* 2018) [16]. (Liang *et al.* 2017) [17], it help to destruction of bacterial cell wall.
- 3. Gene Expression:** Hadwiger *et al.* 1986 Reported Chitosan Activates genes and inhibite RNA Synthesis in fungi and also help in increasing pathogen protection. In dendrobium, Chitosan induced expression of Ycf2 gene in young leaves, conferring enlarged Chloroplast (Limpanavech *et al.* 2008) [19].
- 4. Surface modification:** Cotton is most important crop in all over world as well as in India due to flexibility, versatility but due to intrinsic problems such as shrinkage, wrinkle formation and microbial degradation

which may be overcome by surface modification with chitosan (Bhaskar *et al.* 2012) [20].

5. **Chitosan-DNA Complex:** Chitosan has also used and studied for its Activity to protect DNA against nuclease degradation and transfect DNA to several kinds of cells (Bravo-anaya *et al.* 2016) [21]. It is possible because Chitosan composed of D-glucosamine and N-acetyl-D-glucosamine linked with 1,4-glycoside bond in which glucosamine backbone of chitosan contains high degree of amine group. Amine group can get inter linked with DNA molecules therefore form Chitosan-DNA complex.
6. **Biofertilizer:** As, day by day chemical uses increases and due to which lot of side effect on environment and on human directly or indirectly. Chitosan act as Biofertilizer which help to reduce the use of chemicals. Chitosan with lysozyme produce a beneficial role which can reduced the rate of lesions in tomato stems. Application of Chitosan in soil help to reduce the late blight disease and also increase nutritional uptake (O' Herlihy *et al.* 2003) [22]
7. **Effect on Abiotic stresses:** As, Abiotic stresses is an important multidimensional environment stresses that damage plant's physiology, biochemical properties and

Molecular traits. Yang *et al.* 2009 [23], In Apples young seedlings were foliar sprayed with chitosan, which showed enhanced antioxidant activity, reduced electrolyte leakage, and restored moisture content under continuous drought stress for 35 days. Muley *et al.* 2019 [2], Gamma radiation degradation of chitosan (Oligochitosan) for application in growth promotion and induction of Stress tolerance in potato. As, it act as osmoprotectant, and also help in antioxidant production. Rahat sharif *et al.* 2018 [16] explain Positive effect against Abiotic stresses (Drought tolerance in plants like Apples, rice, grapevine, moth orchid and Heat tolerance). Heat stress it, is complicated abiotic issue in Agriculture and need to compact which is overcome by Chitosan. In May papers HS related genes induced by Chitosan (Zhang *et al.* 2008, Choi *et al.* 2013) [24, 25].

8. **Insecticidal Activity:** Chitosan and its derivatives show good insecticidal activities. Chitin derivative also show insecticidal property against the oleander aphid (*Aphis NERII*) and larvae of leaf-worm (*Spodoptera littoral is*) of cotton crops (Rabea *et al.* 2005) [26]. Also, a Nano-chitosan has potential insecticidal against soyabean insect (Sahab *et al.* 2015) [27].

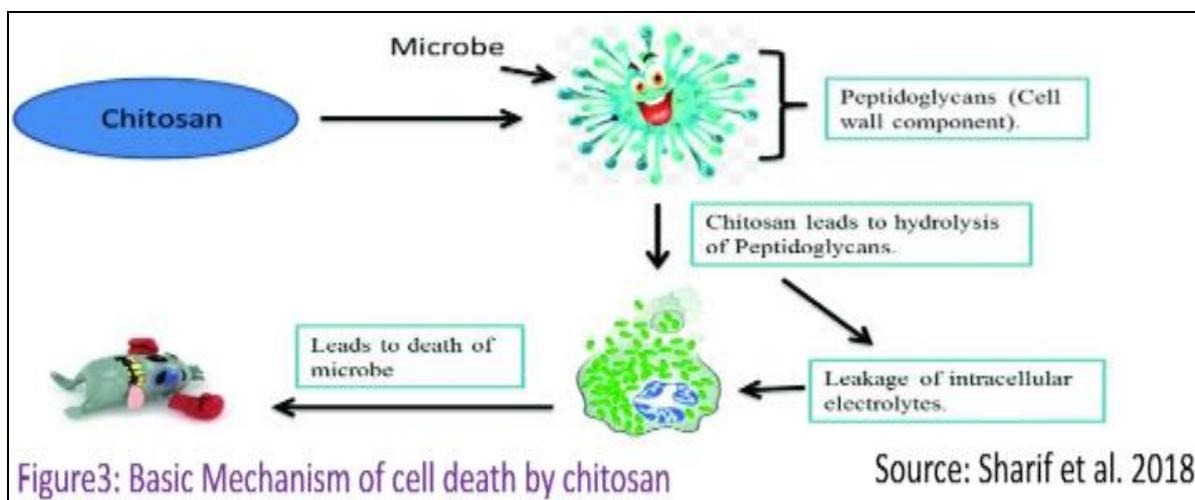


Fig 3: Basic Mechanism of cell death by chitosan

9. **Growth promotion:** Application of Chitosan help to promote growth. Muley *et al.* 2019 [2] described that derivative of Chitosan like Oligochitosan which is derived by Gamma radiation promote growth of potato plant and determined by growth associated parameters. Chitosan help act as extra reservoir of nitrogen (Shibuya *et al.* 2001) [28]. Oligo-chitosan at 1% concentration was found to promotion of growth of Malabar spinach (Rahman *et al.*, 2013) [29].

Future Thrust

The plethora of available and ongoing research on chitosan utilization continues to present its efficacy. Chitosan has shown great importance in improving the physiological mechanisms and post-harvest shelf life of fruits and vegetable against biotic and abiotic stress. In addition, chitosan derivatives possess good insecticidal activity. Chitosan plays a role in regulating gene expression and inducing molecular defense systems in plants.

Moreover, bio-fertilizer and fertilizer coated in chitosan triggers the plant growth more, compared to synthetic fertilizers.

Furthermore, chitosan and its derivatives provide good antifungal activity.

Therefore, more research is required to utilize chitosan against abiotic stresses for utilization in Agriculture.

Conclusion

Chitosan Research increases day by day. Chitosan proved it's effeciencially in several aspect in terms of biotic and abiotic. Additionally, Derivative of Chitosan like COS or Oligochitosan has effectively effect in growth promotion, Microbial, insecticidal and abiotic Activity. Chitosan has also role in gene expression, modification of post-harvest crops. Chitosan also, effective in Biofertilizers and Nanoparticles in drug delivery. It has Antigua and nematode activities (Mishra *et al.* 2014, Zhang *et al.* 2018) [30, 31]. More work will be required in abiotic stresses which reduce overuse of synthetic fertilizers.

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