



## A Review on Chitosan: A New Solution for Combating Abiotic Stresses in Agriculture

### Abstract:

Chitosan is a second most abundant naturally occurring polysaccharide after cellulose derived from chitin which commercially produced from seafood shells, fungi (*Aspergillus* and *mucus*) 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 helps to combat abiotic and biotic stresses.

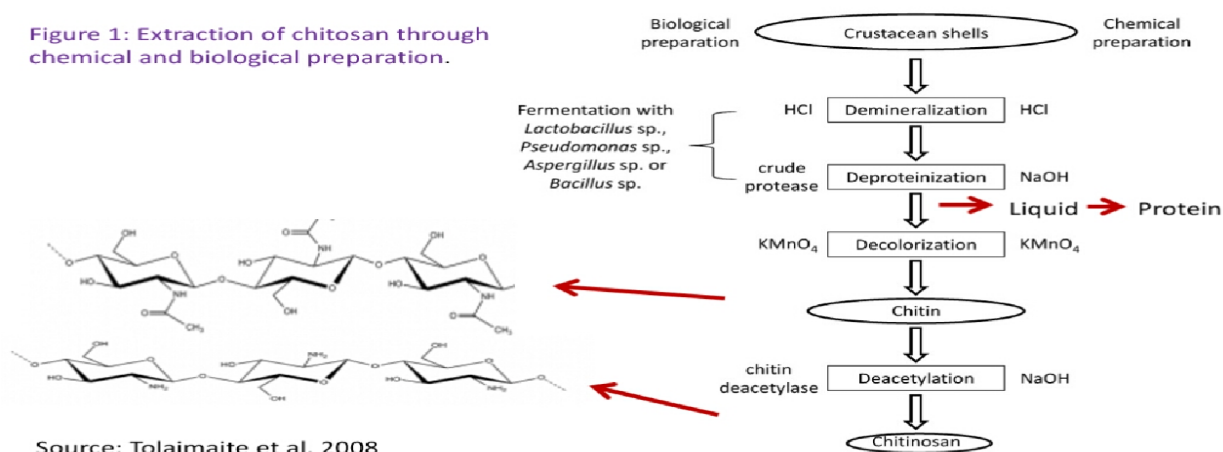
**Keywords:** Chitosan, Biotic, Abiotic, Agriculture.

### 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) and the spines of diatoms

(Bartnicki-Garcia et al. 1982). It is produced from crustacean shells with 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).

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



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). 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 -NH<sub>2</sub> (glucosamine) into the soluble protonated Form -NH<sub>3</sub><sup>+</sup> (Jagadish et al.2017). 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 β - 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) which help in transcriptional regulation. It is also used as nanoparticle (Zhou et al. 2014). There are several derivatives 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). Before these researches during the years of 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). Chitosan forms gel that absorb water due to its high molecular weight (MW) and porous structure (Tamura et al. 2006). Advanced development of chitosan hydrogels has led to the new drug delivery systems that can release their active ingredients in response to environmental stimuli (Hamedi et al. 2016).

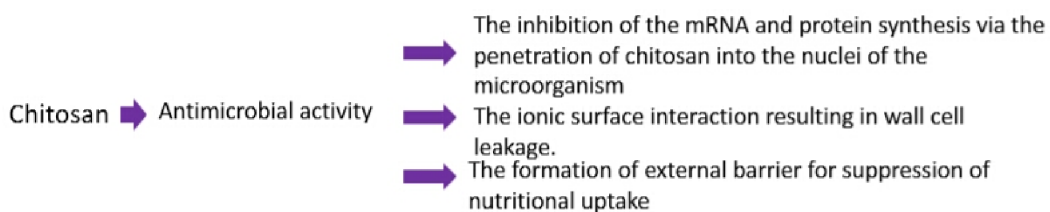
Figure 2: Chitosan and its antimicrobial properties

Chitosan has a good physiochemical properties like bio-adhesive, biocompatible, biodegradable and is helpful in antimicrobial activity (Rahat sharif et al.2018), Bio-stimulant (Stimulate Expression of gene), growth promoter, antioxidant activity, insecticidal activity, osmo-protectant, 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) suggested three antimicrobial mechanisms of chitosan. First for cell wall leakage, second for inhibiting protein and m-RNA 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 (Muley et al., 2018). The free



radical activity of Chitosan by presence of Nitrogen containing group (-NH<sub>2</sub>).

**2. Antimicrobial Activity:**

Goy et al. 2009 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). (Liang et al. 2017), it helps to destruction of bacterial cell wall.

### **3. Gene Expression:**

Hadwiger et al. 1986 Reported Chitosan Activates genes and inhibitor 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).

### **4. Surface modification:**

Cotton is the 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).

### **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). 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:**

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)

### **7. Effect on Abiotic stresses:**

Abiotic stresses is an important multidimensional environment stresses that damage plants physiology, biochemical properties and Molecular traits. Yang et al. 2009, 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, gamma radiation degradation of chitosan (Oligochitosan) for application in growth

promotion and induction of Stress tolerance in potato. As, it acts as osmo-protectant, and also help in antioxidant production. Rahat sharif et al. 2018 explain Positive effect against Abiotic stresses (Drought tolerance in plants like Apples, rice, grapevine, moth orchid and Heat tolerance).

Heat stress is a complicated abiotic issue in agriculture and need to combat which is overcome by Chitosan. Researches reveal that HS related genes are induced by chitosan (Zhang et al. 2008, Choi et al. 2013).

### **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 littoralis*) of cotton crops (Rabea et al. 2005). Also, a Nano-chitosan has potential insecticidal against soyabean insect (Sahab et al. 2015).

### **9. Growth promotion:**

Application of Chitosan help to promote growth. Muley et al. 2019 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). oligo-chitosan at 1% concentration was found to promotion of growth of Malabar spinach (Rahman et al., 2013).

**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 its efficiency in several aspect in terms of biotic and abiotic. Additionally, derivative of Chitosan like COS or Oligochitosan has effectively affect 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 antitumor and nematocidal activities (Mishra et al. 2014, Zhang et al. 2018). More work will be required in abiotic stresses which reduce overuse of synthetic fertilizers.

**Acknowledgments:**

Our thanks are due for Vice-chancellor and Dean (Agri.) Dr. PDKV, Akola for extending all

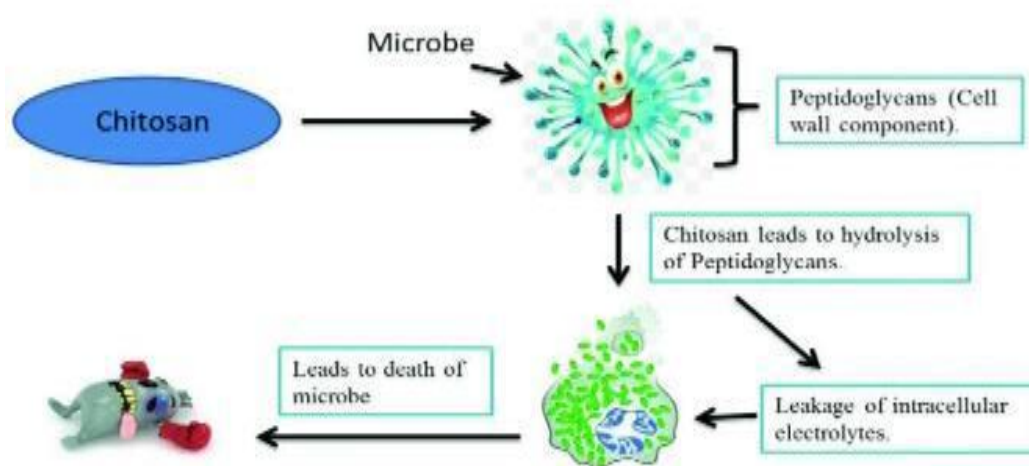


Figure3: Basic Mechanism of cell death by chitosan

Source: Sharif et al. 2018

the facilities to carry out the work.

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