



# Osa-miR1861e Modulates Sodium Toxicity Responses in Rice Immature Grains via *OsGST* and *OsPILS7b*

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## Abstract

The microRNAs (miRNAs) have received considerable attention for their potential exploration in development of high-yielding, stress-resilient (including salt-tolerant) rice varieties owing to their key regulatory roles during plant stress interactions. Under sodium chloride (NaCl)-induced salinity stress, rice has been reported for its higher sensitivity to sodium ( $\text{Na}^+$ ) than its other counter-ion chloride ( $\text{Cl}^-$ ), especially during the reproductive phases. However, the miRNAs specifically responsive to the  $\text{Na}^+$  are yet to be explored in rice. The present investigation is associated with decoding the regulatory role of miR1861e, an important miRNA known for its role in rice grain development, under  $\text{Na}^+$  stress. We generated transgenic rice lines overexpressing the *Osa-miR1861e*. The expression levels of *Osa-miR1861e* displayed elevated patterns in transgenic rice when treated with NaCl or  $\text{Na}^+$  gluconate ( $\text{Na}^+$  specific treatment). The study also validated *OsGST* (involved in defense against oxidative stress) and *OsPILS7b* (involved in auxin transport) as the targets of *Osa-miR1861e* as confirmed through the RNA ligase-mediated rapid amplification of cDNA ends (RLM-RACE). The overexpression of *Osa-miR1861e* also caused a reduction in expression levels of *OsGST* and *OsPILS7b* in transgenic plants under the applied stress condition which can be attributed to the *Osa-miR1861e*-directed cleavage. Further, the ion content analysis revealed high  $\text{Na}^+$  in developing grains under excess  $\text{Na}^+$  stress levels. Also, the immature grains from transgenic plants displayed a high rate of reactive oxygen species (ROS) production as well as upregulated enzymatic antioxidants. Overall, the  $\text{Na}^+$  stress impacts were intensified in the transgenic plants, which can be accredited to the lessened ROS scavenging due to the lowered *OsGST* activities as well as hindered auxin transport. Taken together, the findings confirm the modulatory roles of *Osa-miR1861e* during the excess  $\text{Na}^+$ -driven interactions in developing grains of rice and have the potential for exploration for engineering salinity/sodium stress-tolerant rice.

**Keywords** *Osa-miR1861e* · *OsGST* · *OsPILS7b* · Rice · RLM RACE · Transgenics

## Introduction

To meet the ever-increasing global food requirements significant increment in global crop production that too in a sustainable manner is a must. However, climatic changes and challenging environments are major hurdles in this context. To serve this purpose, molecular crop breeding, which incorporates advances in physiology, genetics, genomics and biotechnology-based approaches, can be effectively used (Tang and Chu 2017). The introduction of new genetic materials or manipulation of existing genetic materials is one of the choices for crop improvement (Anwar and Kim 2020; Steinwand and Ronald 2020). In this regard, numerous genes controlling various important agronomic traits and stress resilience have been identified and characterized in recent decades (Descalsota-Empleo et al. 2019; Li et al.

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# Non-target influence of imidacloprid residues on grape global metabolome and berry quality with the identification of metabolite biomarkers

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## Abstract

This paper illustrates the non-target impact of imidacloprid (IM) residues on the grape global metabolome and biomarker identification with high-resolution mass spectrometry. IM was applied at the recommended dose (SD), and ten times SD (10 RD). The global metabolome analysis revealed that 21 metabolites were up- and down-regulated with IM SD treatment. In 10 RD, 9 metabolites were upregulated, and 28 were downregulated. Pathway enrichment analysis revealed the primary and secondary pathway disruption in grapes. Berry quality was affected with decrease in flavonoids by 32.97% in 10 RD; phenols were reduced by 53.93 in SD, 50.8% in 10 RD. The non-target and target study revealed the degradation of IM in grapes to desnitro-IM and IM-urea which were identified as a potential biomarker for IM residues in grapes, which would benefit the authentication of organic product. Overall, imidacloprid showed a significant impact on the grape metabolome and quality.

**Keywords** Pesticide residues · Neo-nicotinoids · Grape · Global metabolome · Biomarker · Degradation kinetics

## Abbreviations

IM	Imidacloprid
SD	Recommended dose
DD	Double of recommended dose
10 RD	10 Times recommended dose
BLQ	Below limit of quantitation
MRL	Maximum residue level
HRMS	High-resolution mass spectrometry
PCA	Principal component analysis
OPLS-DA	Orthogonal projections to latent structure discriminant analysis

## Introduction

The climatic fluctuations lead to infestation of various pests and diseases in commercial viticulture. Application of different classes of chemical pesticides became inevitable to control the pests and diseases in commercial viticulture. Amongst them, imidacloprid [1-(6-chloro-3-pyridylmethyl)-N-nitroimidazolidin-2-ylideneamine], a broad-spectrum neonicotinoid insecticide, is widely recommended in different crops to control diverse insects. Amongst the group of neonicotinoids, imidacloprid is the second most extensively used pesticide in the world (Al-Hawadi et al. 2023). Global imidacloprid market size is expected to reach nearly USD 22 billion by 2030, with an annualized growth rate of 5% through the projected period (<https://straitresearch.com/report/insecticides-market>). In India, imidacloprid is a major insecticide used by grape growers for the control of various insect pests, such as thrips and hoppers, at various stages of grape cultivation ([https://apeda.gov.in/apedahindi/Grapenet/Annexure5\\_RMP\\_Grapes\\_2022\\_23\\_24082022.pdf](https://apeda.gov.in/apedahindi/Grapenet/Annexure5_RMP_Grapes_2022_23_24082022.pdf)) and has an official label claim for use in grapes by CIB and RC (2022). ([https://ppqs.gov.in/sites/default/files/minutes\\_62nd\\_cib.pdf](https://ppqs.gov.in/sites/default/files/minutes_62nd_cib.pdf)). The direct application of imidacloprid led to its residues at the time of harvest and became a concern in trade and safety. Since limited insecticides have label claims for use in grapes for various insect management purposes


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# Non-target impact of imidacloprid residues on wine aroma characteristics assessed by GCxGC-TOF/MS analysis and its residual transformation in vinification by UHPLC-Orbitrap-MS analysis

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## ARTICLE INFO

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## ABSTRACT

Grapes are a commercially important fruit crop worldwide. The use of pesticides for the control of insects and diseases is prevalent in commercial viti-viticulture. However, pesticide residues are known to impact wine quality significantly. The impact of imidacloprid residues on wine flavor was assessed by GCxGC-TOF/MS. Imidacloprid was applied at the recommended dose (SD) and ten times SD (10RD). Substantial degradation of imidacloprid residues was recorded from grape to wine, with 5.79% to 8.95% transfer rates and processing factors ranging between 0.08 and 0.13. The degradation pathway of imidacloprid was established by UHPLC-Orbitrap-LC/MS in wine with its identified metabolites as 6-chloronicotinic acid, desnitro imidacloprid, and imidacloprid-urea. Imidacloprid residue impacted wine flavor compounds, acids, esters, and alcohols. Glycolysis, pyruvate, glyoxylate, and dicarboxylate were the most significantly affected pathways. Volatiles, viz., phenol 3-(trifluoromethyl), acetic acid hydroxy, and ethyl acetate, were identified as biomarkers for imidacloprid residues in wine.

## 1. Introduction

Grapes (*Vitis vinifera* L.) are sensitive to several pests and diseases, necessitating the application of pesticides to manage pests and diseases. However, indiscriminate use and overuse of pesticides can result in pesticide residues at the time of harvest. Also, pesticide accumulation will adversely affect non-target organisms and the quality of the produce besides food and environmental safety concerns [1]. Pesticide residues are monitored in grapes for their regulatory compliance in trade and risk assessment as they cause potential health risks to consumers [2,3]. Further, the residues present in/on harvested grapes may transfer to its processed products, such as wine or raisin, leading to deterioration of quality and safety [4,5]. The decline of wine quality can be attributed to various factors, including the impact of pesticide residues on the quality of fresh grapes, residual toxicity on the fructospheric microbiome, and any residual effects during different stages of fermentation. Therefore, it is essential to study the transformation process of pesticide residues

during winemaking and their impact on wine quality.

Grape berry surfaces contain complex microflora with different physiological characteristics, including bacteria, fungi, and yeasts [6]. The grape microflora at harvest strongly determines wine quality [7]. During vinification, the microflora, particularly yeast, is responsible for wine aromas by biotransforming juice into aroma components, whereas primary and secondary metabolites contribute to wine flavor [8]. The pesticide residue at harvest can undergo alteration during vinification and can affect the microflora at different stages of fermentation. A correlation between the physicochemical properties of pesticides and their content alterations during the transformation from grapes to wine has been observed [9,5]. Application of pesticides reduces the fermentation activity of yeast [10], and transfer of pesticide residue from grape to wine during fermentation influences the wine quality [11,12]. A wide variation in anthocyanin constituents of wine was observed after the application of iprovalicarb, mepanipyrin, and tetraconazole [13]. Similarly, an increase in phenolic content was observed in the wine after

**Abbreviations:** IM, imidacloprid; SD, recommended dose; 10RD, 10 times recommended dose; SPME, solid phase microextraction; LC-HRMS, liquid chromatography high-resolution mass spectrometry; PCA, Principal Component Analysis.

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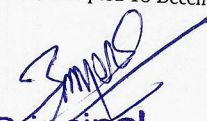
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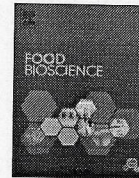
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# Establishing the processing factor and degradation kinetics of hexaconazole residues in vinification and its residual impact on wine quality and aroma characteristics by GCxGC-ToF/MS analysis

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## ARTICLE INFO

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## ABSTRACT

Hexaconazole (HX), a triazole fungicide, is widely used for controlling mildews in commercial viticulture, and residues at harvest are a challenge. The pesticide residues in the harvested grapes may impact the grape and wine quality. In this study, we have investigated the fate of HX residues in the vinification with wine aroma and quality. HX was applied at the recommended dose (RD) and 10 times RD (10 RD). The HX residue dissipation exhibited first-order kinetics with a half-life of 3.5 and 2.5 days for RD and 10 RD, respectively. The processing factor from grape to wine ranged from 0.04 to 0.09, the transfer rate ranged from 2.46% to 6.47%. The HS-SPME-GCxGC-ToF/MS analysis revealed a significant impact on volatile organic compounds (VOCs). The concentration of key VOCs varied in control as esters (147.62  $\mu\text{g L}^{-1}$ ), alcohols (144.81  $\mu\text{g L}^{-1}$ ), acids (82.92  $\mu\text{g L}^{-1}$ ) and in HX RD treated wines showed reduction in alcohols (111.32  $\mu\text{g L}^{-1}$ ), esters (91.57  $\mu\text{g L}^{-1}$ ) and acids (67.10  $\mu\text{g L}^{-1}$ ). In 10 RD, alcohols, esters, acids were declined as 131.42  $\mu\text{g L}^{-1}$ , 118.65  $\mu\text{g L}^{-1}$ , and 75.73  $\mu\text{g L}^{-1}$  respectively. In HX RD, 28 were up and 58 VOCs were down-regulated. 40 VOCs were up and 46 were down-regulated in HX 10 RD wine. The pathway enrichment analysis revealed impact of HX residues on glycolysis and pyruvate metabolism. Quality analysis showed variation in total flavonoids, phenols, and anthocyanin content. The results revealed that HX residues have a negative impact on wine aroma and metabolism during vinification.

## 1. Introduction

Managing disease incidences in commercial viticulture under tropical conditions became inevitable without the advent of synthetic fungicides. Applications of fungicides show residues in harvested produce that become an alarming situation for the environment, affect product quality, and raise food safety issues. The behaviour of pesticide residues in the environment is affected by their persistence, bioaccumulation, and sorption. Hexaconazole (HX) (2-(2,4-dichlorophenyl)-1-(1H-1,2,4-triazol-1-yl)hexan-2-ol), a broad-spectrum systemic triazole fungicide inhibiting the biosynthesis of sterols, is widely recommended in grapes for the control of mildews (Trosken et al., 2005; CIB & RC, 2023). The dissipation of HX in grapes with a half-life of 5–25 days is reported, indicating its moderate persistence in/on berries and residues at harvest

(Heshmati et al., 2020). The European Union has fixed a regulatory limit of 0.01 mg kg<sup>-1</sup> in table grapes for HX. In India, the Central Insecticide Board and Registration Committee (CIB & RC, 2023), Ministry of Agriculture and Farmers Welfare, Government of India, has approved an official label claim for use in grapes against powdery mildew and recommended a waiting period of 60 days in table grapes for export to the European Union (APEDA 2022–23). However, no official recommendation is available for the use of HX in wine grapes to control powdery mildew. Moreover, the residues present in harvested produce may further transfer to the processed product at higher or lower levels, resulting in food safety concerns for processed products (Cabras & Angioni, 2000; Sabale et al., 2015; Shabeer et al., 2015a, 2020, 2023).

Processing wine is considered a tool for pesticide residue removal; however, in rare cases, the residue may concentrate on the processed

**Abbreviations:** HX, Hexaconazole; RD, recommended dose; 10 RD, 10 times recommended dose; HS-SPME, headspace solid-phase microextraction; VOCs, Volatile organic compounds; GCxGC, ToF/MS-gas chromatography time of flight mass spectrometry.

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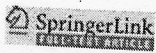
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3 Biotech. 2024 Mar;14(3):82. doi: 10.1007/s13205-024-03919-6. Epub 2024 Feb 18.

# Optimization of fungal chitosan production from *Cunninghamella echinulata* using statistical designs

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## Abstract

Fungal chitosan (FCH) is superior to crustacean chitosan (CH) sources and is of immense interest to the scientific community while having a high demand at the global market. Industrial scale fermentation technologies of FCH production are associated with considerable challenges that frequently restrict their economic production and feasibility. The production of high quality FCH using an underexplored fungal strain *Cunninghamella echinulata* NCIM 691 that is hoped to mitigate potential future large-scale production was investigated. The one-factor-at-a-time (OFAT) method was implemented to examine the effect of the medium components (i.e. carbon and nitrogen) on the FCH yield. Among these variables, the optimal condition for increased FCH yield was carbon (glucose) and nitrogen (yeast extract) source. A total of 11 factors affected FCH yield among which, the best factors were screened by Plackett-Burman design (PBD). The optimization process was carried out using the response surface methodology (RSM) via Box-Behnken design (BBD). The three-level Box- Behnken factorial design facilitated optimum values for 3 parameters-glucose (2% w/v), yeast extract (1.5% w/v) and magnesium sulphate (0.1% w/v) at 30°C and pH of 4.5. The optimization resulted in a 2.2-fold higher FCH yield. The produced FCH was confirmed using XRD, <sup>1</sup>H NMR, TGA and DSC techniques. The degree of deacetylation (DDA) of the extracted FCH was 88.3%. This optimization process provided a significant improvement of FCH yields and product quality for future potential scale-up processes. This research represents the first report on achieving high FCH yield using a reasonably unfamiliar fungus *C. echinulata* NCIM 691 through optimised submerged fermentation conditions.

**Supplementary information:** The online version contains supplementary material available at 10.1007/s13205-024-03919-6.

**Keywords:** Chitosan; *Cunninghamella*; Media optimization; Response surface methodology; Statistical designs; Zygomycetes fungi.

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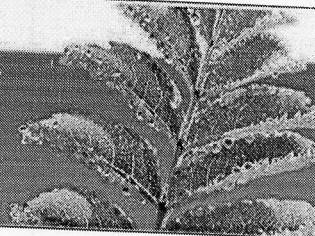
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## Chitosan fortified briquette implications in water stressed okra (*Abelmoschus esculentus*)

**Vishwajeet Kale, Dr. Prashant Bodake, Dr. Vaibhav Rajemahadik, Dr. Sagar More, Dr. Prakash Sanap, Dr. Sunil Dalvi, Prarthana Mhatre, Sefali Thite and Bhakti Patil**

### Abstract

A field experiment was conducted during summer season, 2022 at Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra (India) to study Chitosan fortified briquette implications in water stressed Okra (*Abelmoschus esculentus* L.) in hot and humid climate of coastal region of Maharashtra where red lateritic soils are prominent. The field was laid out in strip plot design where 3 irrigation stress levels (vertical strip), 8 fertilizer treatments (horizontal strip) which formed 24 treatment combinations and replicated three times to get unbiased and correct data. Variety Konkan Bhendi was used for experimentation. In irrigation stress levels, I<sub>2</sub> (80% ETC irrigation) treatment was most superior for most of the growth and yield attributes. In fertilizer treatment levels, T<sub>7</sub> (100% RDF through 2% chitosan fortified briquettes) and T<sub>5</sub> (100% RDF through 1% chitosan fortified briquettes) were both treatments at par for most of the growth and yield attributes. In treatment interaction, I<sub>3</sub>T<sub>7</sub> (60% ETC irrigation with 100% RDF through 2% chitosan fortified briquettes) was most superior for growth and yield attributes with 224.27 q/ha fresh okra fruit yield. Nearly 108.7% yield increase in I<sub>3</sub>T<sub>7</sub> treatment interaction over, i.e. I<sub>1</sub>T<sub>2</sub> (conventional practice, 100% ETC irrigation with 100% RDF through straight fertilizer) was noted.

**Keywords:** Chitosan, lateritic soils, briquettes, stress

### 1. Introduction

In conventional agriculture, leaching of fertilizers is a major concern creating low fertilizer use efficiency (FUE) of crop, increased cost of cultivation, contaminating groundwater with chemical nutrients, etc. Climate change has propped up as a burning issue. Rise in abiotic and biotic stresses for crop is noticed. Water constraint in agriculture is present concern in agriculture and hence, water budgeting is required. To deal with these rising problems, some new products are in research and development that will lead to sustainable and precision agriculture.

To improve fertilizer use efficiency, briquette technology in fertilizers play a pivotal role. As a novel and innovative attempt, Chitosan fortified fertilizer briquettes are developed. Chitosan is a derivative of chitin and is considered the second most common polymer in the world after cellulose. The application of Chitosan in controlled release fertilizer is still in primary stage. However, it can be excellent fertilizer based on its biodegradable, environment friendly and other peculiar characteristics like biocompatibility and bioactivity. Chitosan also acts as plant growth enhancer, antitranspirant, etc and affects positively on plant growth even under various stress factors. Chitosan functions for hardiness of crop, improve water use efficiency, redefines opportunities for dryland agriculture, catalysis to per drop more crop initiative, etc. Briquettes can be used as spot application in vegetable crops like Okra with an object to improve production of crop, reduce leaching losses of fertilizers and as a slow nutrient release technologies for precision agriculture.

Okra (*Abelmoschus esculentus* L.) of family Malvaceae is grown as summer vegetable in India. It grows best at temperature range of 24-27 °C. It grows best in loose, friable well drained sandy loam soils rich in organic matter having optimum soil pH range between 6.0-6.8. In World, the total area and production under okra is reported to be 2.5 million ha and 10.5 million tons respectively (Food and Agriculture Organization of the United Nations, 2020). India is the largest producer of okra contributing 73.25% share in world production (Indian Horticulture Database-2011).

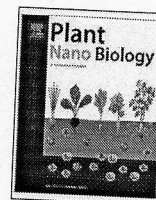
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# Chitosan-based nanoconjugates: A promising solution for enhancing crops drought-stress resilience and sustainable yield in the face of climate change

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Sustainable agriculture

## ABSTRACT

Climate change poses significant challenges to agriculture, impacting crop production through various means such as rising drought, temperatures, altered rainfall patterns, extreme weather events, and changing pest dynamics. These changes pose a threat to global food security and livelihoods due to reduced yields, lower crop quality, and increased vulnerability to pests and diseases. To safeguard crops and build resilience, addressing climate change and adopting sustainable agricultural practices is crucial for sustainable productivity. The review highlights the chitosan based nanoconjugates potential as a tool to revolutionize agricultural practices and help address the challenges posed by climate change on crop production and food security. Environmental stresses trigger a range of responses in plants, including changes to growth rate, productivity, cellular metabolism, and gene expression alterations. One of the paramount impacts of climate change on plants is water deficit stress, which disrupts water relations, causes metabolic disturbances, generates reactive oxygen species, and leads to crop damage. To counteract these adverse effects, chitosan, a naturally occurring polymer emerged as a promising biostimulator and elicitor in agriculture. Its non-toxic, biodegradable, and biocompatible properties make it well-suited for various applications. Chitosan enhances physiological responses in plants and helps to mitigate the negative impacts of abiotic stresses by activating stress transduction pathways. Chitosan nanoconjugates, formed by integrating chitosan with metallic nanoparticles, exhibit modified structural and functional properties, making them more effective in mitigating stress-related effects in plants. Their intelligent and slow delivery mechanisms contribute to their success in enhancing plant growth and development sustainably. Additionally, the encapsulation of metals or elements in chitosan reduces toxicity, enables slow-release properties, and ensures long-lasting effects. Nanoconjugates have been successfully utilized for priming agricultural and horticultural crops to enhance their tolerance to abiotic stress and promote sustainable yield improvement. Given their promising results, the use of nanoconjugates for priming agricultural crops and promoting sustainable yield improvement warrants continued exploration and development in the field of agricultural nanotechnology.

## Introduction

Chitosan, a natural cationic polysaccharide derived from deacetylation of chitin, a polymer comprising two sub-units, namely D-glucosamine and N-acetyl-D-glucosamine, connected by glycosidic bond, ranks as one of the most abundant polysaccharides in nature, second only to cellulose. It possesses a multitude of favourable attributes, including non-toxicity, non-allergenicity, biodegradability, and biocompatibility, making it highly versatile for diverse applications in plant stress tolerance enhancement (Malerba and Cerana, 2016; Mirajkar et al., 2019).

Chitin typically consists of up to 70% acetylated units, whereas chitosan exhibits less than 30% acetylation (Pandey et al., 2018; Zhou et al., 2021). With three reactive groups - a primary hydroxyl at carbon 6, a secondary hydroxyl at carbon 3, and an amino group at carbon 2 - chitosan can undergo chemical modifications that alter its physical, mechanical, and biological properties. The amino group, abundant in chitosan with a high degree of deacetylation, is a commonly chosen site for modifications (Issahaku et al., 2023). It is important to recognize that chitosan preparations exhibit heterogeneity in terms of deacetylation degree, molecular mass, polymerization degree, viscosity, and acid

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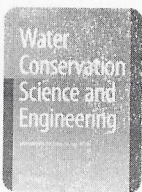
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# Unlocking the Potential of Adsorption in Distillery Wastewater Treatment: a Comprehensive Review

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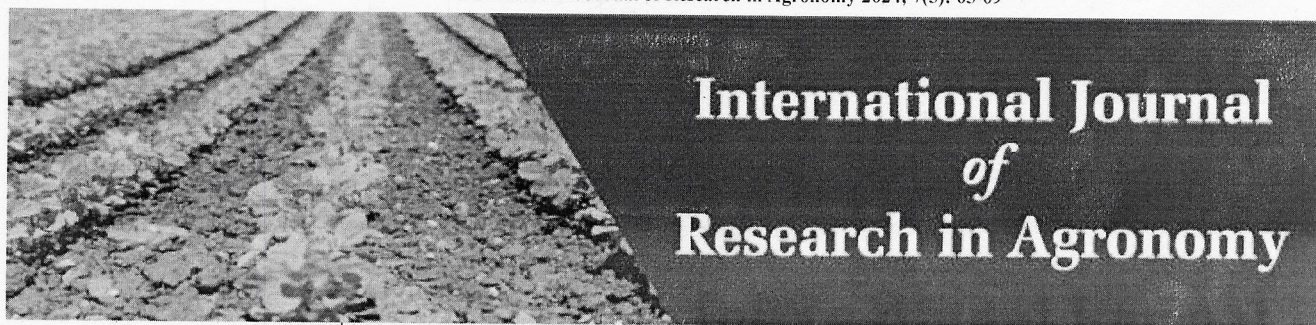
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## Abstract

The world's top two producers of sugarcane are India and Brazil. After China, India is the second-largest manufacturer of alcoholic beverages. The distillery industry in India produces a huge amount of wastewater that is often released untreated into water bodies. Different distilleries have common pollutants that are being discharged into water bodies including wastewater, chemicals and solvents, cooling water, and agricultural runoff. Water pollution due to distilleries is causing a significant impact on the water's quality, making it





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## Responses of foliar application of low molecular weight derivatives gamma radiated chitosan (Bio stimulator) in sugarcane under irrigated condition in Subtropical India

**AP Dwivedi, Sunil G Dalvi, Kamini Kumari, KK Singh and MK Tripathi**

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### Abstract

Chitosan, being one of the most promising biological macromolecules, has an immense scope in agriculture to boost crop growth and defense mechanism responses resulting enhanced crop yield. In this study, chitosan was exposed to gamma rays in order to obtain a low molecular weight derivative. Viscometric characterization showed a sharp decrease in molecular weight and FTIR based analysis confirmed retention of structural integrity of the polymer upon gamma irradiation. Assessments of various physiological and biochemical attributes were carried out on sugarcane crop to study, that were subjected to progressive for better growth and development of sugarcane crops. The irradiated chitosan was found to be better response for growth and development of sugarcane due to chitosan through positive modulation of various gas exchange parameters alongside significant improvement in relative tissue water content, SOD activity, soluble sugars and adenine energetics. Furthermore, application of irradiated chitosan significantly reduced cell membrane damage, lipid peroxidation, H<sub>2</sub>O<sub>2</sub> and free-proline accumulations. This is also reported on the use of gamma irradiated chitosan to boost in bio-physiological functions in sugarcane. Overall comparative assessments showed that differential plant responses were triggered upon foliar application of normal and gamma irradiated chitosan in sugarcane crop grown under irrigated conditions.

**Keywords:** Chitosan, sugarcane, irrigation, antioxidant enzymes adenine energetics biostimulant

### 1. Introduction

There is a need to develop appropriate agronomic, breeding, and genomic strategies to enhance growth and development in sugarcane through effective physio-biochemical process with higher productivity and input use efficiency. While conventional production techniques & breeding and transgenic methods are responsible for low productivity and time consuming, use of bioregulators for enhancing crop productivity has attracted much attention. Various chemical and hormonal based bio regulators are exogenously applied to boost the plant signaling to enhance growth and crop yield is most vulnerable able to input efficiency. Input efficiency is one of the limiting factors to sugarcane yield and sugar productivity. Developmental growth stages, the tillering and grand growth phases are considered the most critical contributing to N80% of sugarcane yield and it is at these stages. Input efficiency is one of the limiting factors to sugarcane yield and sugar productivity. Chitosan, derived from chitin which is one of the most abundant biopolymers, next to cellulose, has non-toxic, non-allergenic, biodegradable and biocompatible properties and imparts multiple stress tolerance in plants. Therefore, it has been immensely exploited as a versatile bioactive substance with superior material and functional properties. Much of the chitosan is derived from different waste materials, chiefly wastes of fishery and sea food industries which have abundant renewable resource and alternative for waste management. Being a potential bioactive substance, chitosan and its derivatives have found immense applications in diverse fields that include cosmetics, pharmaceuticals to agriculture. Biological effects of chitosan include antimicrobial (against bacteria, fungi and viruses) and antioxidant (to encounter oxidative damages caused due to adverse conditions) activities beside its growth promoting properties.

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