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REVIEW

Chitosan and its derivatives: Promising biomaterial in averting fungal diseases of sugarcane and other crops

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Abstract

Sugarcane (*Saccharum officinarum*)—a prominent cash crop accounts for around 80%

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ORIGINAL ARTICLE

Radiation induced mutagenesis, physio-biochemical profiling and field evaluation of mutants in sugarcane cv. CoM 0265

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ABSTRACT

Purpose: Sugarcane is an important cash crop and is affected by soil salinity. CoM 0265, a moderately salt-tolerant variety grown in the Maharashtra region (India), has low sugar content. The present study was aimed to employ gamma ray induced in vitro mutagenesis with repeated and step-wise selection in sugarcane for the isolation and physio-biochemical profiling of the selected salt-tolerant mutants for improved agronomic performance and sugar content.

Materials and methods: Embryogenic callus culture of CoM 0265 variety was subjected to different doses of gamma radiation (10, 20, 30, 40, 50, and 60 Gy) followed by selection on NaCl containing media (50, 100, 150, 200, and 250 mM NaCl). The regenerated plantlets were hardened and selected based on ground nursery field trial on normal soil and saline field trial, in augmented block design for the selected mutant clones. Different physio-biochemical changes and activity of antioxidant enzymes were analyzed in the salt selected in vitro cultures and field-grown mutant clones.

Results: Dose optimization showed 40 Gy as the LD_{50} for gamma radiation and 150 mM NaCl as the dose for in vitro selection experiments. The selected mutant clones showed higher tissue water content (TWC), chlorophyll, and lower sodium content indicative of tolerance to salt stress. Catalase and peroxidase enzyme activities in the top visible dewlap (TVD) of the putative mutant clones were significantly higher than the control. The average yield and sucrose percent of the selected mutant clones were significantly higher than control checks in the saline field trial. Mutant clones MB457 and M8721 exhibited improved yield and commercial cane sugar over the parent control check varieties under saline field conditions. Catalase activity was strongly associated with TWC ($r = 0.34$) and chlorophyll content ($r = 0.41$) while it was negatively correlated with sodium ion content ($r = -0.38$). Peroxidase activity in TVD also showed a significant positive correlation with chlorophyll content ($r = 0.42$) and a negative correlation with sodium ion content ($r = -0.39$). The improvement in yield and CCS (t/ha) was strongly associated with the lower sodium ion content of the mutant clones ($r = -0.54$ and -0.53, respectively).

Conclusions: Gamma ray induced mutants were isolated for improved sucrose and high yield in sugarcane var. CoM 0265. The results suggest that gamma radiation induced mutations result in physiological and metabolomic alterations for better growth and adaptation under in vitro and field stress conditions in sugarcane. The improved mutants can be further useful for commercial cultivation in saline areas.

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Introduction

Sugarcane (*Saccharum* spp.) contributes nearly 70% of raw table sugar worldwide. Besides, it is considered as the first generation biofuel crop with several important industrial products like bagasse, molasses, and filler cakes. Sugarcane crop improvement programs are undertaken through conventional breeding methods for higher yield, sucrose content, and abiotic and biotic stress tolerance but limitations such as a complex genome, poor fertility and long duration required for breeding and selection cycles make further improvement a difficult task (Yasmin et al. 2011; Mirajkar et al. 2019). It is hence desirable to reduce selection cycles to generate breeding material for use in crop improvement. Among the different traits for sugarcane improvement, salt tolerance assumes importance since it has become a global problem affecting more than 20% of irrigated land worldwide. Under salinity, every single unit increase in soil EC causes a 14% decrease in estimated sugarcane yield (Nelson and Ham 2000; Rietz and Haynes 2002). In India, out of 192 million hectares of net cropped area (Land Use Statistics 2017–2018), 6.727 mha are salt-affected soil areas (Mandal

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Electron Beam Irradiated Chitosan elicits enhanced antioxidant properties combating resistance to Purple Blotch Disease (*Alternaria porri*) in Onion (*Allium cepa*)

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Abstract

Purpose: This study was carried out to assess the effect of irradiated chitosan as an elicitor on the biochemical traits associated with resistance to purple blotch disease in onion.

Materials and methods: Chitosan was electron beam irradiated at 100 kGy dose to obtain low molecular weight chitosan. Irradiated chitosan at 20 and 0.04% concentration and different time intervals was used as a biological elicitor cum antimicrobial agent against purple blotch disease in onion. Field grown onion (Variety Basanvant 780) plants were foliar sprayed with irradiated chitosan and the biochemical responses were monitored using parameters namely chlorophylls, carotenoids, antioxidant enzymes, phenols, and antifungal enzyme β-1,3 Glucanase using standard methods.

Results: Compared to control treatment, a positive correlation with irradiated chitosan treatment was observed for an increase in β-1,3-glucanase, peroxidase activity, and contents of total phenolics, chlorophylls, and carotenoids, which cumulatively contributed to resistance response against the purple blotch disease. Irradiated chitosan (0.04%) treated onion plants at 30, 45, and 60 DAT showed a higher total phenolics, β-1,3-glucanase activity, and peroxidase activity besides enhanced antioxidant properties.

Conclusion: The results suggest that irradiated chitosan has elicited resistance responses against purple blotch disease in onion. The increased production of antioxidant metabolites may provide value addition to onion as a food commodity.

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Life cycle and economic assessment of sugarcane bagasse valorization to lactic acid

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ABSTRACT

In this work, detailed life cycle assessment (LCA) and techno-economic analysis (TEA) of a novel lactic acid (LA) production process from sugarcane bagasse is performed, with the objective of identifying process improvement opportunities. Moreover, this is first such study in the Indian context. Experimental data generated at the Vasantdada Sugar Institute (VSI) for upstream processes is combined with ASPEN Plus simulation of the downstream steps for a commercial plant producing 104 tonnes per day of LA. Equipment sizing is performed and costing is done using standard approaches. OpenLCA is used to develop the LCA model and Ecoinvent database is used to quantify life cycle impacts for 1 kg of LA. Different scenarios for the LA plant are studied. Results showed that the pretreatment stage was crucial from both economic and environmental perspectives. The total life cycle climate change impact for production of 1 kg of lactic acid was 4.62 kg CO_2 eq. The product cost of LA was USD 2.9/kg, and a payback time of 6 years was achieved at a selling price of USD 3.21/kg. Scenario analysis has revealed that lactic acid plant annexed to a sugar mill led to significant environmental and economic benefits. Sensitivity analysis has identified opportunities to reduce the life cycle climate change impact to 2.29 kg CO_2 eq. and product cost to USD 1.42/kg through reduced alkali consumption, higher solid loading, and reduced enzyme loading.

1. Introduction

Sugarcane bagasse, the fibrous lignocellulosic residue obtained after extraction of juice from sugarcane, accounts for 25–30% of the sugarcane on a wet basis. Consequently, it is a prominent source of waste generated in sugarcane cultivating countries like India and Brazil. India generates about 75–90 million tonnes of bagasse waste annually on a wet basis (Quereshi et al., 2020) and is mainly used for cogeneration in medium and large sugar mills (Meghana and Shastri, 2020). However, a significant amount of bagasse still remains unutilized, and valorizing it to produce high-value biochemicals is an attractive option. It can improve the economic viability of sugar mills and make them resilient against demand and price shocks (Özüdoğru et al., 2019; Meghana and Shastri, 2020). Such a strategy also preserves its inherent complexity of the residue, thereby adhering to the principles of green chemistry (Anastas and Zimmerman, 2003), and will also contribute towards the implementation of circular bioeconomy. With the chemical industry roughly contributing 20% of the greenhouse gases (GHG) emitted by the industry sector (Biddy et al., 2016), utilization of biomass as feedstock to produce bio-based chemicals will also mitigate GHG emissions (Kätelhön et al., 2019).

In this work, we are focusing on lactic acid (LA), identified as a potential platform chemical by the US department of energy (DOE) (Bozell and Petersen, 2010) with versatile applications in pharmaceutical, food, cosmetic, leather tanning, textile, and polymer industry (Dusselier et al., 2013; De Oliveira et al., 2018). Production of LA from agricultural residues has been reported in literature (De Oliveira et al., 2020; Isikgor and Becer, 2015; Taherzadeh and Karimi, 2008. Various lignocellulosic (second generation or 2G) feedstock such as sugarcane bagasse (Daful et al., 2016; Van Der Pol et al., 2016; Wischral et al., 2019; Nalawade et al., 2020a), corn stover (Ögmundarson et al., 2020b), vine shoots (Pachón et al., 2020), orange peel (Ricci et al., 2019), wheat straw (Aulitto et al., 2019), and food waste (Kwan et al., 2018) have been examined. Among these, sugarcane bagasse has a lot of potential, especially in developing countries like Brazil, India, and China (Ullah et al., 2015; Zhao et al., 2015).

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RESEARCH ARTICLE

Isolation and HPLC assisted quantification of two iridoid glycoside compounds and molecular DNA fingerprinting in critically endangered medicinal *Picrorhiza kurroa* Royle ex Benth: implications for conservation

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Abstract *Picrorhiza kurroa* is a medicinally important, high altitude perennial herb, endemic to the Himalayas. It possesses strong hepato-protective bioactivity that is contributed by two iridoid picroside compounds viz Picroside-I (P-I) and Picroside-II (P-II). Commercially, many *P. kurroa* based hepato-stimulatory Ayurvedic drug brands that use different proportions of P-I and P-II are available in the market. To identify genetically heterozygous and high yielding genotypes for multiplication, sustained use and conservation, it is essential to assess genetic and phytochemical diversity and understand the population structure of *P. kurroa*. In the present study, isolation and HPLC based quantification of picrosides P-I and P-II and molecular DNA fingerprinting using RAPD, AFLP and ISSR markers have been undertaken in 124 and 91 genotypes, respectively. The analyzed samples were collected from 10 natural *P. kurroa* Himalayan populations spread across four states (Jammu & Kashmir, Sikkim, Uttarakhand and Himachal Pradesh) of India. Genotypes used in this study covered around 1000 km geographical area of the total Indian Himalayan habitat range of *P. kurroa*. Significant quantitative variation ranging from 0.01 per cent to 4.15% for P-I, and from 0.01% to 3.18% in P-II picroside was observed in the analyzed samples. Three molecular DNA markers, RAPD (22 primers), ISSR (15 primers) and AFLP (07 primer combinations) also revealed a high level of genetic variation. The percentage polymorphism and effective number of alleles for RAPD, ISSR and AFLP analysis varied from 83.5%, 80.6% and 72.1%; 1.5722, 1.5787 and 1.5665, respectively. Further, the rate of gene flow (Nm) between populations was moderate for RAPD (0.8434), and AFLP (0.9882) and comparatively higher for ISSR (1.6093). Fst values were observed to be 0.56, 0.33, and 0.51 for RAPD, ISSR and AFLP markers, respectively. These values suggest that most of the observed genetic variation resided within populations. Neighbour joining (NJ), principal coordinate analysis (PCoA) and Bayesian based STRUCTURE grouped all the analyzed accessions into largely region-wise clusters and showed some intermixing between the populations, indicating the existence of distinct gene pools with limited gene flow/exchange. The present study has revealed a high level of genetic diversity in the analyzed populations. The analysis has resulted in identification of genetically diverse and high picrosides containing *P. kurroa* genotypes from Sainj, Dayara,

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Article

γ-Irradiated Chitosan Mediates Enhanced Synthesis and Antimicrobial Properties of Chitosan–Silver (Ag) Nanocomposites

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ABSTRACT: Chitosan (CSN) and its derivatives are being exploited for their potential role in agriculture in mitigating environmental stress factors. The present study was aimed to enhance the synthesis of chitosan (CSN)-based silver nanoparticles (Ag NPs) using γ-irradiated chitosan (IR-CSN) and to study the antimicrobial activity of IR-CSN−Ag NPs. The chitosan−silver nanocomposites (CSN−Ag NPs) were prepared by employing the green synthesis method using normal chitosan (high molecular weight (MW), NL-CSN) and oligochitosans (low MW, IR-CSN). The latter was derived by irradiation with γ rays (^{60}Co) at 100 kGy dose to obtain a lower MW (approximately 25 kDa). NL-CSN and IR-CSN (0.0−2.5% w/v) were amalgamated with different concentrations of silver nitrate (0.0−2.5% w/v) and vice versa. The UV−visible spectra displayed a single peak in the range of 419−423 nm, which is the characteristic surface plasmon resonance (SPR) for Ag NPs. The physicochemical properties were assessed using different methods such as transmission electron microscopy (TEM), Fourier transform infrared (FTIR), zetasizer, elemental (CHNS) analysis, etc. The degree of Ag NP synthesis was more in IR-CSN than NL-CSN. The *in vitro* disc diffusion assay with IR-CSN−Ag NPs exhibited a significantly higher antimicrobial activity against *Escherichia coli*. Further evaluation of the antifungal activity of IR-CSN and Ag NPs showed a synergistic effect against chickpea wilt (*Fusarium oxysporum* f. sp. *ciceris*). The study has provided a novel approach for the improved synthesis of CSN−Ag nanoparticle composites using γ-irradiated chitosan. This study also opens up new options for the development and deployment of γ-