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The Role of Chitosan and Silixol in Regulating Canopy Temperature and Leaf Area in Sugarcane under Drought Stress

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ABSTRACT: Climate change has augmented abiotic stresses on crops, particularly through increased instances of water stress, which pose significant threats to the cultivation of commercial crops such as sugarcane. The sensitivity of sugarcane to drought stress emphasizes to formulate effective and scalable strategies such as, application of biostimulants to ensure the resilience and sustainability of sugarcane cultivation under stress conditions. In this study, we evaluated the efficacy of bio stimulants in mitigating the adverse effects of drought on sugarcane, focusing on two key parameters: canopy temperature and leaf area. The experimental treatments include control, stress, stress with irradiated chitosan (0.1%), non-irradiated chitosan (0.5%), and silixol (0.03%), measuring the responses at 30, 60, 90, and 120 days after planting in sugarcane seedlings. Our findings revealed that drought stress elevated canopy temperature and reduced leaf area in sugarcane seedlings. However, the application of biostimulants, particularly silixol, effectively counteracted these effects. Irradiated chitosan (0.1%) and non-irradiated chitosan (0.5%) also significantly mitigated these adverse impacts. This study demonstrates the significant potential of biostimulants, such as silixol and chitosan, in reducing canopy temperature and minimizing leaf area reduction in sugarcane under drought conditions. This study provides valuable insights into the efficacy of biostimulants, particularly silixol and chitosan, in mitigating drought-induced stress on sugarcane. These findings emphasize the promising role of biostimulants in promoting sustainable agricultural practices in the face of changing global climate patterns.

Keywords: Biostimulants, sugarcane, water stress, canopy temperature.

INTRODUCTION

Climate change poses a significant threat to agricultural production worldwide by intensifying abiotic stresses like drought, salinity, and extreme temperatures (Caney, 2015). These stresses are expected to become more frequent and severe, threatening food security and livelihoods. Among these stresses, water scarcity, or drought stress, is particularly concerning (Yadav *et al.*, 2020). It affects plant growth and development, leading to significant reductions in crop yield and quality (Calanca, 2017).

Sugarcane (*Saccharum* spp.) plays a vital role in the global sweetener market and the biofuel industry. As a C4 plant, sugarcane thrives in photosynthesis, demonstrating exceptional efficiency even in the elevated temperatures (Altpeter and Oraby 2010). However, the frequent occurrence of drought conditions worldwide poses a major threat to its cultivation and productivity (Vital *et al.*, 2017). Drought stress can cause physiological changes in plants, such as increased canopy temperature and decreased leaf area, which can negatively impact photosynthetic efficiency and biomass accumulation (Ribeiro *et al.*, 2013).

In this context, biostimulants have emerged as a promising tool to mitigate the effects of abiotic stresses. These substances can enhance plant growth, improve nutrient uptake efficiency, and increase plant tolerance to various stresses, including drought (Van Oosten *et al.,* 2017). Biostimulants like chitosan and silixol have been reported to modulate physiological traits such as canopy temperature and leaf area in plants under water stress (Jain *et al.*, 2018; Silveira *et al*., 2019). Considering the crucial role of sugarcane in the global agricultural economy and the need for climate-resilient crops, this study aims to evaluate the effectiveness of different biostimulants in regulating canopy temperature and leaf area in sugarcane under drought condition.

MATERIAL AND METHODS

The experiment was conducted at National Institute of Abiotic Stress Management (NIASM), Baramati (MS), India (latitude 18.16 N, longitude 74.50 E, altitude 570 mamsl). The pot experiment was conducted in controlled environmental conditions with Co 86032, Co M 0265 and VSI 08005 cultivars. Single bud seedling was planted in each plastic pot filled with 13 kg clay loam soil. Two moisture treatments were imposed, control (maintained at 60% FC) and stress (withholding irrigation) with four replications, with the pots arranged in a completely randomized design. Stress treatment was imposed at 30 days after planting. After 5 days of stress imposition irradiated chitosan (0.1%), non-irradiated chitosan (0.5%) and silixol (0.3%) foliar application was given to stress plants. Canopy temperature and leaf area observations were recorded at 30, 60, 90 and 120 days after planting.

Leaf area was recorded at regular intervals, fully-expanded green leaves (defined as those leaves with a clearly-visible ligule and having more than 50% green area) width at the widest part of the leaf and the length from ligule to tip were recorded. Temperature was recorded by thermal gun (Helect Non-Contact Digital Laser Infrared Thermometer Temperature Gun). The thermal gun was 5 m from the plants. Data obtained in the experimentation were subjected to analysis of variance (ANOVA) in completely randomized design.

RESULTS

A. Impact on Canopy Temperature

The analysis of canopy temperature data indicated that drought stress significantly elevated canopy temperature across all treatments when compared to the control plants. However, the application of biostimulants altered this impact to different extents. It is important to note that the observed canopy temperature on specific days was influenced by atmospheric temperature. The control plants maintained a relatively consistent canopy temperature from 30 to 120 days after planting. In absolute stress plants, there was a noticeable increase in canopy temperature, reaching its peak at 35.9°C on 120 days after planting, indicating the stress impact over time and significant difference among the treatments.

In contrast, sugarcane treated with irradiated chitosan (0.1%) demonstrated a lower temperature under stress than the absolute stress plants, with a notable decrease in canopy temperature, at the 60 and 120-days after planting, suggesting a potential mitigating effect of the biostimulants. Similarly, treatments with non-irradiated chitosan (0.5%) and silixol (0.03%) under stress conditions also resulted in a decrease in canopy temperature when compared to the plants under absolute stress, although the reduction was not as prominent as observed with irradiated chitosan.

Table 1: Effect of biostimulant treatments on canopy temperature in sugarcane under water stress.

Treatments	Days after Planting			
	30	60	90	120
Control	26.05	26.00	25.10	25.52
Stress	26.47	30.90	31.32	35.90
Stress + Irradiated Chitosan (0.1%)	26.20	29.62	29.30	30.05
Stress + Non-Irradiated Chitosan (0.5%)	26.27	31.02	30.57	26.10
Stress + Silixol (0.03%)	26.65	31.10	28.65	29.27
S.E (m)±	0.27	1.18	0.30	0.17
C.D at 5%	N. S	3.64	0.93	0.54

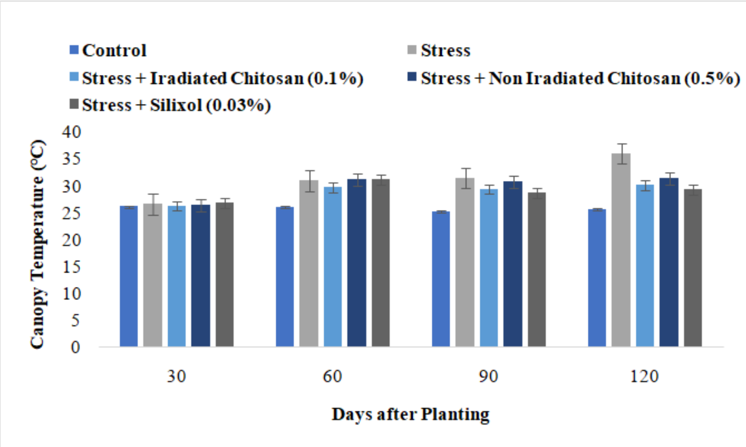

Fig. 1. Impact of biostimulant applications on sugarcane canopy temperature under water stress.

Table 2: Effect of biostimulant treatments on leaf area in sugarcane under water stress.

Treatments	Days after Planting			
	30	60	90	120
Control	421.65	682.12	753.36	965.84
Stress	423.68	484.31	530.20	588.95
Stress + Irradiated Chitosan (0.1%)	420.69	577.40	647.82	760.18
Stress + Non-Irradiated Chitosan (0.5%)	423.70	549.02	621.69	748.95
Stress + Silixol (0.03%)	425.37	581.13	650.16	775.45
S.E (m)±	2.8	7.19	2.11	3.01
C.D at 5%	N. S	22.16	6.49	9.28

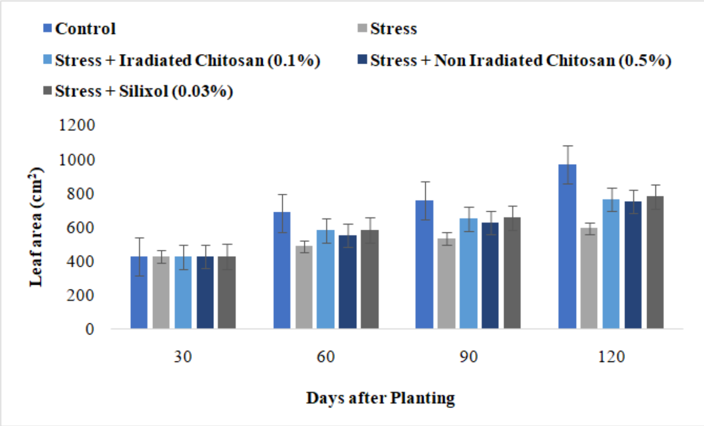

Fig. 2. Impact of biostimulants applications on sugarcane leaf area under water stress.

B. Impact on Leaf Area

The leaf area of sugarcane exhibited a significant response to both drought stress and biostimulant treatments. The control plants showed steady growth in leaf area, beginning at 421.65 cm² at 30 days, and increasing to 965.84 cm² at 120days after planting. In contrast, plants under stress showed substantial decrease in leaf area growth, with the stress plants leaf area of 588.95 cm² at 120 days, indicating 39.1% decrease relative to the control plants.

Treatment with irradiated chitosan (0.1%) in stress plants resulted in higher leaf area, 760.18 cm² at 120 days, which is 29.0% increase over the stress plants. Similarly, non-irradiated chitosan (0.5%) had a positive effect, with leaf area reaching 748.95 cm² at 120 days, indicates 27.1% increase when compared to the stress plants. The highly significant difference in leaf area was observed in plants treated with Silixol (0.03%) under stress, leaf area of 775.45 cm² at the 120-day, which was 31.7% increase compared to stress plants.

The results suggest that biostimulants, particularly irradiated chitosan and silixol, can effectively modulate physiological responses to drought stress in sugarcane, as evidenced by the reduced canopy temperature and increased leaf area compared to the stress plants. These findings point towards the potential of biostimulants as an agronomic tool for enhancing sugarcane resilience to drought conditions, which is crucial in the context of climate change and water scarcity.

DISCUSSION

The observed decrease in canopy temperature for sugarcane treated with biostimulants, notably irradiated chitosan and silixol, under drought conditions suggests an improvement in water use efficiency and a potential reduction in plant stress (Neeru *et al.,* 2019). This aligns with studies indicating that chitosan can enhance stomatal conductance, allowing for better cooling of the plant through transpiration (Bittelli *et al.,* 2001). The moderated canopy temperatures in the biostimulant-treated groups may also reflect improved physiological status, possibly due to enhanced osmotic adjustment (Jain *et al.,* 2018). Such responses could help to maintain cellular integrity and function during drought stress. Additionally, silixol, being rich in silicon, may strengthen the cuticular barrier, reducing water loss and thereby lowering canopy temperature (Jain *et al.,* 2018; Jawahar *et al*., 2019).

The leaf area is a direct indicator of the plant's ability to capture light and perform photosynthesis; thus, the maintenance of leaf area is crucial for sustaining growth under stress conditions (Mondal *et al*., 2013). The leaf area data substantiate the idea that biostimulants provide a protective effect against the inhibition of foliar growth caused by drought stress (Chaski and Petropoulos 2022). Application of orthosilicic acid formulation (silixol) showed an increase in specific leaf weight. Similar results were reported earlier in maize (Rohanipoor *et al.*, 2013) and sugarcane (Jain *et al.*, 2017) following Si application.

These findings highlight the necessity of integrating biostimulant treatments into standard cultivation practices, especially in regions prone to water scarcity. These results reinforce the potential of biostimulants as an adaptive measure to enhance crop resilience in an era of increasing climatic change.

CONCLUSIONS

This study investigated the role of biostimulants in modulating canopy temperature and leaf area in sugarcane under drought stress. The findings provide compelling evidence that biostimulants can significantly mitigate the effects of water stress. Specifically, the application of irradiated chitosan (0.1%) led to a marked reduction in canopy temperature, with a notable difference of approximately 5°C from the peak stress condition at 120 days after planting. Furthermore, the same treatment improved leaf area measurements, with an increase of 122.23 cm² compared to the stress plants at 120 days after planting. The application of biostimulants, especially irradiated chitosan and silixol, exhibited promising results in enhancing the drought resilience of sugarcane. These treatments maintained lower canopy temperatures and higher leaf areas compared to plants under stress. These results suggest that biostimulants enhance the plant's physiological resilience to drought, potentially through mechanisms that improve water use efficiency, maintain cellular function, and support growth under stress conditions. These findings suggest that biostimulants could play a crucial role in the adaptive strategies for sugarcane cultivation underdrought stress.

FUTURE SCOPE

The promising results obtained in this study underscore the future potential of utilizing biostimulants, specifically silixol and chitosan, as an effective tools for mitigating the adverse impacts of drought on sugarcane cultivation.

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Conflict of Interest. None.

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