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**LUCAS MORAES JACOMASSI**

# SEAWEED EXTRACT- BASED BIOSTIMULANT AS DROUGHT MITIGATION IN SUGARCANE

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# SEAWEED EXTRACT-BASED BIOSTIMULANT AS DROUGHT MITIGATION IN SUGARCANE

Dissertação apresentada à Faculdade de Ciências Agronômicas da Unesp Câmpus de Botucatu, para obtenção do título de Mestre em Agronomia (Energia na Agricultura).

Orientador: Prof. Dr. Carlos Alexandre Costa Crusciol

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## CERTIFICADO DE APROVAÇÃO

TÍTULO DA DISSERTAÇÃO: SEAWEED EXTRACT- BASED BIOSTIMULANT AS DROUGHT MITIGATION IN SUGARCANE

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## Abstract

Drought is one of abiotic factors most inherent to the decrease in field yields, inducing the plant to morphological and physiological responses, severely affecting plant metabolism due to cellular oxidative stress, even in C4 crops species as sugarcane. Algae extracts based as biostimulants are agricultural practices used to mitigate negative plant responses caused by drought conditions. However, it remain unexplored its effects as foliar aplication in sugarcane field exposed to water stress that can promote increases in plant metabolism, stalk and sugar yields, as well as an extracted juice with greater technological quality. Thus, study aimed to evaluate the effectiveness of using an algae extract based foliar fertilizer at application timings under the influence of the driest period of the year in late harvest sugarcane. The commercial sugarcane fields consisted of three experiments carried out in harvest seasons of 2018 (site 1), 2019 (site 2) and 2020 (site 3) in Brazil, using RB85-5536 and SP80-3280 varieties in different ratoons ($5^{th}$ and $3^{rd}$). The treatments consisted of application and no application timings of foliar biostimulant in June (sites 2 and 3) and July (site 1). The dose used was 500 ml a.i $ha^{-1}$ in a 100 L $ha^{-1}$ water volume. The use of seaweed extract (SWE) mitigated the negative effects of drought, increasing the stalk yield per hectare by up to 3.08 Mg $ha^{-1}$, in addition to enabling greater accumulation of sucrose in the stalks by up to 2.8%, generating gains of 3.4 kg Mg $^{-1}$ of sugar per hectare, which raises the quality of the industrializable raw material. The Trolox-equivalent antioxidant capacity of treated plants was improved by up to 22%, increasing the activity of antioxidant enzymes in relation to the decrease of the metabolite 3-carbon dialdehyde MDA. Leaf analysis shows an efficient metabolic activity for SWE aplication, decreasing carbohydrate reserve levels in leaves while increasing total sugars by up to 34%. By positively stabilizing the cellular redox balance of plants, the action of SWE increases biomass production, resulting in greater energy generation up to 10.5%. Thus, the SWE strategy is a tool in alleviating drought stress while enhancing sugarcane development, stalk yield and sugar production, and improving plant physiological and enzymatic processes.

**Keywords**: drought; *Saccharum spp*; bio-stimulant; antioxidant metabolism; protection; yield.

## RESUMO

A seca é um dos fatores abióticos mais inerentes à diminuição da produtividade das culturas no campo, induzindo a planta a respostas morfológicas e fisiológicas, afetando severamente o metabolismo vegetal devido ao estresse oxidativo celular, mesmo em espécies de cultivo C4 como a cana-de-açúcar. O uso de extratos de algas com ação bioestimulante é uma prática agrícolas quem vem sendo usada para mitigar as respostas negativas das plantas causadas pelas condições ambientais de seca. No entanto, ainda é pouco explorado seus efeitos na aplicação foliar em canaviais comerciais expostos ao estresse hídrico. Esses extratos podem promover aumentos no metabolismo da planta, produtividade de colmos e açúcar, bem como um caldo extraído com maior qualidade tecnológica. Assim, esse estudo teve como objetivo avaliar a eficácia da utilização de um fertilizante foliar à base de extrato de algas em épocas de aplicação sob a influência do período mais seco do ano na cana-de-açúcar de colheita tardia. O trabalho consistia em três experimentos realizados nas safras de 2018 (site 1), 2019 (site 2) e 2020 (site 3), utilizando as variedades RB85-5536 e SP80-3280 em diferentes soqueiras (5ª e 3ª soqueiras). Os tratamentos foram a aplicação ou não aplicação do bioestimulante foliar em junho (site 2 e 3) e julho (site 1). A dose utilizada foi de 500 ml a.i $ha^{-1}$ em um volume de água de 100 L $ha^{-1}$. O uso do extrato de algas marinhas (SWE – Seaweed extract) mitigou os efeitos negativos da seca, aumentando a produtividade de colmos por hectare em até 3,08 Mg $ha^{-1}$, além de possibilitar maior acúmulo de sacarose nos colmos em até 2,8%, gerando ganhos de 3,4 kg $Mg^{-1}$ de açúcar por hectare, o que eleva a qualidade da matéria-prima industrializável. A capacidade antioxidante equivalente a Trolox das plantas tratadas foi melhorada em até 22%, aumentando a atividade das enzimas antioxidantes em relação à diminuição do metabólito dialdeído 3-carbono MDA. A análise das folhas mostra uma atividade metabólica eficiente para aplicação do bioestimulante, diminuindo os níveis de reserva de carboidratos nas folhas enquanto aumenta os açúcares totais em até 34%. Ao estabilizar positivamente o balanço redox celular das plantas, a ação do SWE aumenta a produção de biomassa, resultando em maior geração de energia em até 10,5%. Assim, a estratégia de SWE é uma ferramenta para aliviar o estresse hídrico e, ao mesmo tempo, melhorar o desenvolvimento da cana-de-açúcar, o rendimento do colmo e a produção de açúcar, além de melhorar os processos fisiológicos e enzimáticos da planta.



**Palavras-chave**: seca; *Saccharum spp*; bioestimulante; metabolismo antioxidante; proteção; produtividade.

SUMÁRIO

## 1 INTRODUCTION

Globally, the crop migration to non-traditional areas of cultivation and climate change have increasingly put pressure on modern agriculture. As crop cultivation is more exposed to the inconsistencies of abiotic stress conditions, it is responsible for losses of up to 50% in the yield of the most crops (QIN; SHINOZAKI; YAMAGUCHI-SHINOZAKI, 2011; VIANNA; SENTELHAS, 2014; VINOCUR; ALTMAN, 2005; VOSS-FELS; SNOWDON, 2016). Thus, examples of some of these stresses; drought, luminous intensity, high and low temperatures, among others, are limiting conditions to agricultural productivity (ASHRAF; FOOLAD, 2007).

For sugarcane, despite being a C4 species, the water availability in the soil is the abiotic factor that most interferes in its field yield, altering and/or inhibiting metabolic processes, and having negative effects on the plant's evapotranspiration rates, tillering, as well as on leaf area, inducing senescence. These negative effects affect growth rate of stalks and crop development (INMAN-BAMBER, 2004; INMAN-BAMBER; SMITH, 2005).

Among plant responses to stress conditions at cellular level, there are the changes in the content of chlorophyll pigments (BANERJEE; ROYCHOUDHURY, 2019; CHA-UM et al., 2012); cellular osmotic adjustment (MELO-ABREU; RIBEIRO, 2010; PATADE; BHARGAVA; SUPRASANNA, 2011); early stomata closure (DE ALMEIDA SILVA et al., 2013; VAN HEERDEN et al., 2004; ZHAO; GLAZ; COMSTOCK, 2013); decreased quantum efficiency of photosystem II (BANERJEE; ROYCHOUDHURY, 2019; TAKAHASHI; BADGER, 2011); production of reactive oxygen species (ROS's), weakening cellular redox homeostasis in favor of oxidizing molecules, which results in oxidative stress (PINCIROLI et al., 2019).

Within oxidative stress, the main molecules characterized as oxidants are the superoxide anion ($O_2^-$), singlet oxygen ($^1O_2$), hydrogen peroxide ($H_2O_2$) and the hydroxyl radical (OH-), which are produced in different cell compartments, mainly in mitochondria, chloroplasts and peroxisomes, caused by the dependence on O2 by the metabolic processes of aerobic respiration, photosynthesis and photorespiration (BARBOSA et al., 2014). These molecules are highly harmful to plant cells, causing damage to proteins, nucleic acids, photosynthetic pigments, in addition to activating programmed cell death and causing lipid peroxidation of membranes (CHOUDHURY et al., 2017).

As an alternative to climate pressure patterns, products with bio-stimulant characteristics help to reduce the use of agrochemicals (SHUKLA et al., 2019; VAN OOSTEN et al., 2017; YAKHIN et al., 2017). According to the European Biostimulant Industry Consortium (EBIC), bio-stimulants are classified as substances that stimulate plant nutrition, improving the availability and absorption of nutrients from the soil, in addition to enabling greater tolerance to abiotic stresses (DU JARDIN, 2015). Therefore, they are molecules that work and improve plant physiology and metabolism (MARIANI; FERRANTE, 2017), used in several crops, with applications made via foliar or soil, including for organic agriculture (MÓGOR et al., 2008).

Within the category of bio-stimulants, algae extracts have great representation and are the fastest growing sector in this market (GOÑI; QUILLE; O'CONNELL, 2018). The bio-stimulant effects of products based on algae extracts over agricultural crops includes drought tolerance (CRAIGIE, 2011; SANGHA et al., 2014). Most of the algae species used for its extracts are those classified as brown algae, with greater representation for the specie *Ascophyllum nodosum* (CRAIGIE, 2011), however, it can also be used as a source of raw material algae of green or red species (GOÑI; QUILLE; O'CONNELL, 2018).

These algae extracts are important sources of polysaccharides, polyunsaturated fatty acids, enzymes, bioactive peptides, Lea proteins (Abundant Late embryogenesis), amino acids, plant hormones, macro- and micro-nutrients (DE ABREU; TALAMINI; STADNIK, 2008; OKOLIE; MASON; CRITCHLEY, 2018; SHUKLA et al., 2016). These extracts act in a specific or generalized way in the plant metabolism (CARMODY et al., 2020; ŁANGOWSKI et al., 2021). However, in general, these products stimulate the synthesis of pigments such as chlorophyll, optimizing photosynthesis, stimulating root growth and improve the water and nutrients uptake, with direct effect on crop's yields (BULGARI et al., 2015; YAKHIN et al., 2017).

On the other hand, brown algae extract (*Ascophyllum nodosum*) acts by stimulating the activity of antioxidant enzymes and in the cellular accumulation of defense metabolites. Usually, products with these characteristics show protection and response in the crop to water stress, mitigating yield losses under such circumstances (GOÑI; QUILLE; O'CONNELL, 2018; JITHESH et al., 2019).

Emphasizing the great importance of sugarcane, its scope in varied edaphoclimatic environments and the use of foliar fertilization as a management tool in situations of abiotic stress, the hypothesis of this study as follow: algae extract as foliar fertilizer and biostimulant improves the activity of the antioxidant system of plants and promoters positive impacts on raw material quality and on biometric aspects in sugarcane under water stress.

This study aimed to evaluate the effectiveness of using a protective product based of algae extract based to sugarcane under water stress on physiological changes and its implications for quality and stalk yields.

## 6 CONCLUSION

Here we showed that a protective product based on algae extract applied in sugarcane is effective to quality and stalk yields under drought stress. The management of drought stress mitigation by SWE application improves sugarcane stalk yield and sugar production. Yet, SWE action represents an alternative to enhance the physiological and enzymatic sugarcane response of metabolic processes and stimulate the carbon assimilation and carbohydrates metabolization. The SWE positively acts on the plant antioxidant system and carbohydrates synthesis, which, in turn, reduce the concentration of reducing sugars and fiber, and increase purity of the juice. In addition, algae extract is a new option for managing sugarcane under stress by enhancing biometric parameters such as taller and thicker stalks, and, consequently, higher yields of stalk and sugar and a metabolically stronger plant. Relevant questions about how is the SWE effectiveness across a complete sugarcane cycle and in the long-term grown deserve further investigations.

# REFERENCES

ALI, N. et al. The effect of Ascophyllum nodosum extract on the growth, yield and fruit quality of tomato grown under tropical conditions. J**ournal of Applied Phycology**, v.28, p. 1353-1362, 2016.

ALI, N. et al. Ascophyllum extract application causes reduction of disease levels in field tomatoes grown in a tropical environment. **Crop Protection**, v. 83, p. 67–75, 1 maio 2016.

ALI, O.; RAMSUBHAG, A.; JAYARAMAN, J. Biostimulatory activities of Ascophyllum nodosum extract in tomato and sweet pepper crops in a tropical environment. **PLOS ONE**, v. 14, n. 5, p. e0216710, 1 maio 2019.

ALLAIN, C. C. et al. Enzymatic Determination of Total Serum Cholesterol. **Clinical Chemistry**, v. 20, n. 4, p. 470–475, 1 abr. 1974.

ALLEN, V. G. et al. Tasco: Influence of a brown seaweed on antioxidants in forages and livestock—A review. **Journal of Animal Science**, v. 79, n. suppl_E, p. E21–E31, 1 jan. 2001.

ALMESELMANI, M. et al. Protective role of antioxidant enzymes under high temperature stress. **Plant Science**, v. 171, n. 3, p. 382–388, 1 set. 2006.

ARIOLI, T.; MATTNER, S. W.; WINBERG, P. C. Applications of seaweed extracts in Australian agriculture: past, present and future. **Journal of Applied Phycology 2015 27:5**, v. 27, n. 5, p. 2007–2015, 14 abr. 2015.

ASADA, K. Production and scavenging of reactive oxygen species in chloroplasts and their functions. **Plant Physiology**, v. 141, n. 2, p. 391–396, 1 jun. 2006.

AZEVEDO, R. A. et al. Sugarcane Under Pressure: An Overview of Biochemical and Physiological Studies of Abiotic Stress. **Tropical Plant Biology**, v. 4, n. 1, p. 42–51, 28 mar. 2011.

BALLESTEROS, M. L.; WUNDERLIN, D. A.; BISTONI, M. A. Oxidative stress responses in different organs of Jenynsia multidentata exposed to endosulfan. **Ecotoxicology and Environmental Safety**, v. 72, n. 1, p. 199–205, 1 jan. 2009.

BALTAZAR, M. et al. Recent Advances in the Molecular Effects of Biostimulants in Plants: An Overview. **Biomolecules 2021, Vol. 11, Page 1096**, v. 11, n. 8, p. 1096, 25 jul. 2021.

BANERJEE, A.; ROYCHOUDHURY, A. Cold stress and photosynthesis. **Photosynthesis, Productivity, and Environmental Stress**, n. October, p. 27–37, 2019.

BARBOSA, M. R. et al. Geração e desintoxicação enzimática de espécies reativas de oxigênio em plantas. **Ciencia Rural**, v. 44, n. 3, p. 453–460, mar. 2014.

BARREIROS, A. L. B. S.; DAVID, J. M.; DAVID, J. P. Estresse oxidativo: relação entre geração de espécies reativas e defesa do organismo. **Química Nova**, v. 29, n. 1, p. 113–123, 2006.

BATTIE LACLAU, P.; LACLAU, J. P. Growth of the whole root system for a plant crop of sugarcane under rainfed and irrigated environments in Brazil. **Field Crops Research**, v. 114, n. 3, p. 351–360, 12 dez. 2009.

BHATTACHARJEE, S. Reactive oxygen species and oxidative burst: Roles in stress, senescence and signal transducation in plants. **Current Science**, v. 89, n. 7, p. 1113–1121, 2005.

BHATTACHARJEE, S. Sites of Generation and Physicochemical Basis of Formation of Reactive Oxygen Species in Plant Cell. In: **Reactive Oxygen Species and Antioxidants in Higher Plants**. 1. ed. [s.l.] Science Publishers, 2010. p. 1–30.

BLOKHINA, O.; VIROLAINEN, E.; FAGERSTEDT, K. V. Antioxidants, oxidative damage and oxygen deprivation stress: A review. **Annals of Botany**, v. 91, n. 2, p. 179–194, 1 jan. 2003.

BOECKX, T. et al. Polyphenol oxidase-mediated protection against oxidative stress is not associated with enhanced photosynthetic efficiency. **Annals of Botany**, v. 116, n. 4, p. 529–540, 1 set. 2015.

BOUKHARI, M. E. M. EL et al. Trends in Seaweed Extract Based Biostimulants: Manufacturing Process and Beneficial Effect on Soil-Plant Systems. **Plants 2020, Vol. 9, Page 359**, v. 9, n. 3, p. 359, 12 mar. 2020.

BRADFORD, M. M. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. **Analytical Biochemistry**, v. 72, n. 1–2, p. 248–254, 7 maio 1976.

BRASIL, A. et al. Acta Scientiarum. Agronomy. **Acta Scientiarum. Agronomy**, v. 28, n. 2, p. 179–185, 2006.

BUCHELI, C. S.; ROBINSON, S. P. Food Chew. **Journal. Agriculture. Food Chem**, v. 42, p. 257–261, 1994.

CARMO-SILVA, A. E. et al. Rubisco activities, properties, and regulation in three different C4 grasses under drought. **Journal of Experimental Botany**, v. 61, n. 9, p. 2355–2366, 1 maio 2010.

CARR, M. K. V; KNOX, J. W. THE WATER RELATIONS AND IRRIGATION REQUIREMENTS OF SUGAR CANE (SACCHARUM OFFICINARUM): A REVIEW. **Experimental Agriculture**, v. 47, n. 1, p. 1–25, 2021.

CARVALHO, M. E. A. et al. Is seaweed extract an elicitor compound? Changing proline content in drought-stressed bean plants. **Comunicata Scientiae, ISSN-e 2177-5133, Vol. 9, Nº. 2, 2018, págs. 292-297**, v. 9, n. 2, p. 292–297, 2018.

CATHERINE J. HOWARTH. Genetic Improvements of Tolerance to High Temperature. In: M. ASHRAF P. I. C. HARRIS (Ed.). . **Abiotic Stresses**. 1. ed. [s.l.] CRC Press, 2005. p. 299–322.

CAVERZAN, A.; CASASSOLA, A.; PATUSSI BRAMMER, S. Reactive Oxygen Species and Antioxidant Enzymes Involved in Plant Tolerance to Stress. In: **Abiotic and Biotic Stress in Plants - Recent Advances and Future Perspectives**. [s.l.] InTech, 2016. p. 463–480.

CHA-UM, S. et al. Evaluating sugarcane (Saccharum sp.) cultivars for water deficit tolerance using some key physiological markers. **Plant Biotechnology**, v. 29, n. 5, p. 431–439, 2012.

CHEN, D. et al. Effects of Seaweed Extracts on the Growth, Physiological Activity, Cane Yield and Sucrose Content of Sugarcane in China. **Frontiers in Plant Science**, v. 0, p. 865, 26 maio 2021.

CHUIAN-FU KEN, ‡ et al. Characterization of Fe/Mn−Superoxide Dismutase from Diatom Thallassiosira weissflogii: Cloning, Expression, and Property. **Journal of Agricultural and Food Chemistry**, v. 53, n. 5, p. 1470–1474, 9 mar. 2005.

CRAIGIE, J. S. Seaweed extract stimuli in plant science and agriculture. **Journal of Applied Phycology**, v. 23, n. 3, p. 371–393, 29 jun. 2011.

DAVAR, R.; DARVISHZADEH, R.; MAJD, A. Changes in antioxidant systems in sunflower partial resistant and susceptible lines as affected by Sclerotinia sclerotiorum. **Biologia (Poland)**, v. 68, n. 5, p. 821–829, 31 out. 2013.

DE ABREU, G. F.; TALAMINI, V.; STADNIK, M. J. Bioprospecção de macroalgas marinhas e plantas aquáticas para o controle da antracnose do feijoeiro. **Summa Phytopathologica**, v. 34, n. 1, p. 78–82, jan. 2008.

DE ALMEIDA SILVA, M. et al. BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY Photosynthetic Capacity and Water Use Efficiency in Sugarcane Genotypes Subject to Water Deficit During Early Growth Phase. **Arch. Biol. Technol. v**, v. 56, n. 5, p. 735–748, 2013.

DE AZEVEDO, A. C. B. et al. Enzymatic polyphenoloxidase inactivation with temperature and ozone in sugarcane variety RB 92579 to produce lower color sugar. **Brazilian Journal of Food Technology**, v. 22, 25 fev. 2019.

DESHMUKH, P. S.; PHONDE, D. B. Effect of seaweed extract on growth, yield and quality of sugarcane. **International Journal of Agricultural Sciences**, v. 9, p. 750–753, jun. 2013.

DEUBER, R. **Maturação da cana-de-açúcar na região sudeste do Brasil. In: Seminário de tecnologia agronômica.** Piracicaba - SPCopersucar, 1988.

DI STASIO, E. et al. Ascophyllum nodosum-based algal extracts act as enhancers of growth, fruit quality, and adaptation to stress in salinized tomato plants. **Journal of Applied Phycology 2018 30:4**, v. 30, n. 4, p. 2675–2686, 28 mar. 2018.

DIETZ, K. J.; PFANNSCHMIDT, T. Novel regulators in photosynthetic redox control of plant metabolism and gene expression. **Plant Physiology**, v. 155, n. 4, p. 1477–1485, 1 abr. 2011.

DINAKAR, C.; DJILIANOV, D.; BARTELS, D. Photosynthesis in desiccation tolerant plants: Energy metabolism and antioxidative stress defense. **Plant Science**, v. 182, n. 1, p. 29–41, 1 jan. 2012.

DIWEN, C. et al. Alleviation Effect of Foliar Application with Seaweed Extract on Sugarcane under Drought Stress. **Chinese Journal of Tropical Crops**, v. 42, n. 5, p. 1348, 26 maio 2021.

DO ROSÁRIO ROSA, V. et al. Increased soybean tolerance to water deficiency through biostimulant based on fulvic acids and Ascophyllum nodosum (L.) seaweed extract. **Plant Physiology and Biochemistry**, v. 158, p. 228–243, 1 jan. 2021.

DONG, S.; BECKLES, D. M. Dynamic changes in the starch-sugar interconversion within plant source and sink tissues promote a better abiotic stress response. **Journal of Plant Physiology**, v. 234–235, p. 80–93, 1 mar. 2019.

DOS SANTOS, C. M. et al. Physiological Changes Associated with Antioxidant Enzymes in Response to Sugarcane Tolerance to Water Deficit and Rehydration. **Sugar Tech**, v. 17, n. 3, p. 291–304, 13 set. 2015.

DU JARDIN, P. Plant biostimulants: Definition, concept, main categories and regulation. **Scientia Horticulturae**, v. 196, p. 3–14, 30 nov. 2015a.

DU JARDIN, P. Plant biostimulants: Definition, concept, main categories and regulation. **Scientia Horticulturae**, v. 196, p. 3–14, 30 nov. 2015b.

DUBEY, D.; PANDEY, A. Effect of Nickel (Ni) on chlorophyll, lipid peroxidation and antioxidant enzymes activities in black gram (Vigna mungo) leaves. **International Journal of Science and Nature**, v. 2, n. 2, p. 395–401, 2011.

ELANSARY, H. O.; SKALICKA-WOŹNIAK, K.; KING, I. W. Enhancing stress growth traits as well as phytochemical and antioxidant contents of Spiraea and Pittosporum under seaweed extract treatments. **Plant Physiology and Biochemistry**, v. 105, p. 310–320, 1 ago. 2016.

ENDRES, L. Photosynthesis and Water Relations in Brazilian Sugarcane. **The Open Agriculture Journal**, v. 4, n. 1, p. 31–37, 29 dez. 2010.

FAN, D. et al. Commercial extract of the brown seaweed Ascophyllum nodosum enhances phenolic antioxidant content of spinach (Spinacia oleracea L.) which protects Caenorhabditis elegans against oxidative and thermal stress. **Food Chemistry**, v. 124, n. 1, p. 195–202, 1 jan. 2011.

FERNANDES, A. C. **Cálculos na agroindústria de cana-de-açúcar**. Piracicaba: STAB, 2011. 240 p.

GADJEV, I.; STONE, J. M.; GECHEV, T. S. Chapter 3: Programmed Cell Death in Plants. New Insights into Redox Regulation and the Role of Hydrogen Peroxide. **International Review of Cell and Molecular Biology**, v. 270, n. C, p. 87–144, 1 jan. 2008.

GIANNOPOLITIS, C. N.; RIES, S. K. Superoxide DismutasesII. Purification and Quantitative Relationship with Water-soluble Protein in Seedlings. **Plant Physiology**, v. 59, n. 2, p. 315–318, 1 fev. 1977.

GILL, S. S.; TUTEJA, N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. **Plant Physiology and Biochemistry**, v. 48, n. 12, p. 909–930, 1 dez. 2010.

GONG, X. et al. Arabidopsis AtSUC2 and AtSUC4, encoding sucrose transporters, are required for abiotic stress tolerance in an ABA-dependent pathway. **Physiologia Plantarum**, v. 153, n. 1, p. 119–136, 1 jan. 2015.

GOÑI, O. et al. Comparative Transcriptome Analysis of Two Ascophyllum nodosum Extract Biostimulants: Same Seaweed but Different. **Journal of Agricultural and Food Chemistry**, v. 64, n. 14, p. 2980–2989, 27 abr. 2016.

GOÑI, O.; QUILLE, P.; O'CONNELL, S. Ascophyllum nodosum extract biostimulants and their role in enhancing tolerance to drought stress in tomato plants. **Plant Physiology and Biochemistry**, v. 126, n. March, p. 63–73, 2018a.

GOÑI, O.; QUILLE, P.; O'CONNELL, S. Ascophyllum nodosum extract biostimulants and their role in enhancing tolerance to drought stress in tomato plants. **Plant Physiology and Biochemistry**, v. 126, p. 63–73, 1 maio 2018b.

GUPTA, A.; RICO-MEDINA, A.; CAÑO-DELGADO, A. I. The physiology of plant responses to drought. **Science**, v. 368, n. 6488, p. 266–269, 17 abr. 2020.

HASSUANI, S. **Biomass power generation : sugar cane bagasse and trash**. Piracicaba : CTC ed. Piracicaba ;Brasília: CTC ;;PNUD, 2005. v. 1

HATCH, M. D. C4 photosynthesis: a unique elend of modified biochemistry, anatomy and ultrastructure. **BBA Reviews On Bioenergetics**, v. 895, n. 2, p. 81–106, 1 jan. 1987.

HAUVERMALE, A. L.; SANAD, M. N. M. E. Phenological Plasticity of Wild and Cultivated Plants. **Plant Communities and Their Environment**, 8 maio 2019.

HAVIR, E. A.; MCHALE, N. A. Biochemical and Developmental Characterization of Multiple Forms of Catalase in Tobacco Leaves. **Plant Physiology**, v. 84, n. 2, p. 450–455, 1 jun. 1987.

HAYAT, S.; AHMAD, A. **Salicylic acid: A plant hormone**. Springer Science & Business Media, 2007.

HEATH, R. L.; PACKER, L. Photoperoxidation in isolated chloroplasts: I. Kinetics and stoichiometry of fatty acid peroxidation. **Archives of Biochemistry and Biophysics**, v. 125, n. 1, p. 189–198, 1 abr. 1968.

HELDT, H.-W. **Plant Biochemistry**. 3. ed. Oxford: Elsevier Inc., 2005.

JALEEL, C. A. et al. Alterations in osmoregulation, antioxidant enzymes and indole alkaloid levels in Catharanthus roseus exposed to water deficit. **Colloids and Surfaces B: Biointerfaces**, v. 59, n. 2, p. 150–157, 1 out. 2007.

JOSEMARA, R.; QUEIROZ, B. **RESPOSTA FISIOLÓGICA E MOLECULAR DE DOIS GENÓTIPOS DE MILHO À LIMITAÇÃO HÍDRICA**. [s.l.] Universidade Estadual Paulista (UNESP), 1 out. 2010.

KAR, M.; MISHRA, D. Catalase, Peroxidase, and Polyphenoloxidase Activities during Rice Leaf Senescence. **Plant Physiology**, v. 57, n. 2, p. 315–319, 1 fev. 1976.

KARTHIKEYAN, K.; SHANMUGAM, M. The effect of potassium-rich biostimulant from seaweed Kappaphycus alvarezii on yield and quality of cane and cane juice of sugarcane var. Co 86032 under plantation and ratoon crops. **Journal of Applied Phycology 2017 29:6**, v. 29, n. 6, p. 3245–3252, 15 jul. 2017.

KARUPPANAPANDIAN, T. et al. Reactive oxygen species in plants: Their generation, signal transduction, and scavenging mechanisms. **Australian Journal of Crop Science**, v. 5, n. 6, p. 709–725, 2011.

KHAN, W. et al. Seaweed Extracts as Biostimulants of Plant Growth and Development. **Journal of Plant Growth Regulation 2009 28:4**, v. 28, n. 4, p. 386–399, 8 maio 2009a.

KHAN, W. et al. Seaweed Extracts as Biostimulants of Plant Growth and Development. **Journal of Plant Growth Regulation 2009 28:4**, v. 28, n. 4, p. 386–399, 8 maio 2009b.

KHOMPATARA, K. et al. Enhanced Resistance to Leaf Fall Disease Caused by Phytophthora palmivora in Rubber Tree Seedling by Sargassum polycystum Extract. **Plants 2019, Vol. 8, Page 168**, v. 8, n. 6, p. 168, 11 jun. 2019.

KRIEGER-LISZKAY, A.; FUFEZAN, C.; TREBST, A. Singlet oxygen production in photosystem II and related protection mechanism. **Photosynthesis Research**, v. 98, n. 1–3, p. 551–564, 9 set. 2008.

KROUK, G. et al. Nitrate-Regulated Auxin Transport by NRT1.1 Defines a Mechanism for Nutrient Sensing in Plants. **Developmental Cell**, v. 18, n. 6, p. 927–937, 15 jun. 2010.

LEMOINE, R. et al. Source-to-sink transport of sugar and regulation by environmental factors. **Frontiers in Plant Science**, v. 0, n. JUL, p. 272, 24 jul. 2013.

LOCATO, V. Reactive oxygen species and ascorbate glutathione interplay in signaling and stress responses. In: GUPTA, S. **Reactive Oxygen Species and Antioxidants in Higher Plants** . 1. ed. p. 45–64.

LOLA-LUZ, T.; HENNEQUART, F.; GAFFNEY, M. Effect on health promoting phytochemicals following seaweed application, in potato and onion crops grown under a low input agricultural system. **Scientia Horticulturae**, v. 170, p. 224–227, 7 maio 2014.

MACHADO, R. S. et al. Biometric and physiological responses to water deficit in sugarcane at different phenological stages. **Pesquisa Agropecuaria Brasileira**, v. 44, n. 12, p. 1575–1582, 2009.

MANO, J. Reactive carbonyl species: Their production from lipid peroxides, action in environmental stress, and the detoxification mechanism. **Plant Physiology and Biochemistry**, v. 59, p. 90–97, 1 out. 2012.

MARIANI, L.; FERRANTE, A. Agronomic Management for Enhancing Plant Tolerance to Abiotic Stresses—Drought, Salinity, Hypoxia, and Lodging. **Horticulturae 2017, Vol. 3, Page 52**, v. 3, n. 4, p. 52, 1 dez. 2017.

MEDEIROS, D. B. et al. Physiological limitations in two sugarcane varieties under water suppression and after recovering. **Theoretical and Experimental Plant Physiology**, v. 25, n. 3, p. 213–222, 2013.

MEYER, A. J.; HELL, R. Glutathione homeostasis and redox-regulation by sulfhydryl groups. **Photosynthesis Research**, v. 86, n. 3, p. 435–457, 11 dez. 2005.

MHAMDI, A.; NOCTOR, G.; BAKER, A. Plant catalases: Peroxisomal redox guardians. **Archives of Biochemistry and Biophysics**, v. 525, n. 2, p. 181–194, 15 set. 2012.

MICHALAK, I.; CHOJNACKA, K. Algal extracts: Technology and advances. **Engineering in Life Sciences**, v. 14, n. 6, p. 581–591, 1 nov. 2014.

MITTLER, R. Oxidative stress, antioxidants and stress tolerance. **Trends in Plant Science**, v. 7, n. 9, p. 405–410, 1 set. 2002.

MOREIRA, R. et al. Aqueous extracts of Ascophyllum nodosum obtained by ultrasound-assisted extraction: effects of drying temperature of seaweed on the properties of extracts. **Journal of Applied Phycology 2017 29:6**, v. 29, n. 6, p. 3191–3200, 21 maio 2017.

MUSTAFA OZGEN, † et al. Modified 2,2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic Acid (ABTS) Method to Measure Antioxidant Capacity of Selected Small Fruits and Comparison to Ferric Reducing Antioxidant Power (FRAP) and 2,2‘-Diphenyl-1-picrylhydrazyl (DPPH) Methods. **Journal of Agricultural and Food Chemistry**, v. 54, n. 4, p. 1151–1157, 22 fev. 2006.

NAIKOO, M. I. et al. Role and Regulation of Plants Phenolics in Abiotic Stress Tolerance: An Overview. **Plant Signaling Molecules: Role and Regulation under Stressful Environments**, p. 157–168, 1 jan. 2019.

NASCIMENTO, J. B.; BARRIGOSSI, J. A. F. O papel de enzimas. **Agrarian Academy**, v. 1, n. 01, p. 234–250, 2014.

NELSON, N. A PHOTOMETRIC ADAPTATION OF THE SOMOGYI METHOD FOR THE DETERMINATION OF GLUCOSE. **Journal of Biological Chemistry**, v. 153, n. 2, p. 375–380, 1 maio 1944.

NEVES, M. F. Mais econômico e renovável, etanol conquista os consumidores brasileiros. In: **Caminhos da Cana**. [s.l: s.n.]. p. 27–28.

NGOROYEMOTO, N. et al. Effect of organic biostimulants on the growth and biochemical composition of Amaranthus hybridus L. **South African Journal of Botany**, v. 124, p. 87–93, 1 ago. 2019.

OKOLIE, C. L.; MASON, B.; CRITCHLEY, A. T. **Seaweeds as a Source of Proteins for Use in Pharmaceuticals and High-Value Applications**. Novel Proteins for Food, Pharmaceuticals, and Agriculture: Sources, Applications, and Advances, v. 217, 2018.

OLIVEIRA, C. E. G. Acompanhamento de safra brasileira cana-de-açúcar - safra 2019/2020. **Companhia Nacional de Abastecimento**, v. 6, n. 4, p. 57, 2019.

OMIDBAKHSHFARD, M. A. et al. A biostimulant obtained from the seaweed ascophyllum nodosum protects arabidopsis thaliana from severe oxidative stress. **International Journal of Molecular Sciences**, v. 21, n. 2, p. 1–26, 2020.

PATADE, V. Y.; BHARGAVA, S.; SUPRASANNA, P. Salt and drought tolerance of sugarcane under iso-osmotic salt and water stress: Growth, osmolytes accumulation, and antioxidant defense. **Journal of Plant Interactions**, v. 6, n. 4, p. 275–282, dez. 2011.

PAUL, M. J.; FOYER, C. H. Sink regulation of photosynthesis. **Journal of Experimental Botany**, v. 52, n. 360, p. 1383–1400, 1 jul. 2001.

PEREIRA, L. B. et al. Prospecting Plant Growth-Promoting Bacteria Isolated from the Rhizosphere of Sugarcane Under Drought Stress. **Current Microbiology 2019 76:11**, v. 76, n. 11, p. 1345–1354, 2 ago. 2019.

PHOTINI V. MYLONA; ALEXIOS N. POLIDOROS. ROS Regulation of Antioxidant Genes. In: S. DUTTA GUPTA. **Reactive Oxygen Species and Antioxidants in Higher Plants**. 1. ed. p. 102–117. 2010.

PRASCH, C. M. et al. ß-amylase1 mutant Arabidopsis plants show improved drought tolerance due to reduced starch breakdown in guard cells. **Journal of Experimental Botany**, v. 66, n. 19, p. 6059–6067, 1 set. 2015.

PUTEH, A. B. et al. Chlorophyll fluorescence parameters of cultivated (Oryza sativa L. ssp. indica) and weedy rice (Oryza sativa L. var. nivara) genotypes under water stress. **Australian Journal of Crop Science**, v. 7, n. 9, p. 1277–1283, 2013.

QUAN, L. J. et al. Hydrogen peroxide in plants: A versatile molecule of the reactive oxygen species network. **Journal of Integrative Plant Biology**, v. 50, n. 1, p. 2–18, 1 jan. 2008.

RASUL, F. et al. Priming with a Seaweed Extract Strongly Improves Drought Tolerance in Arabidopsis. **International Journal of Molecular Sciences 2021, Vol. 22, Page 1469**, v. 22, n. 3, p. 1469, 2 fev. 2021.

RATHORE, S. S. et al. Effect of seaweed extract on the growth, yield and nutrient uptake of soybean (Glycine max) under rainfed conditions. **South African Journal of Botany**, v. 75, n. 2, p. 351–355, 1 abr. 2009.

REIS, S. P. DOS; LIMA, A. M.; SOUZA, C. R. B. DE. Recent Molecular Advances on Downstream Plant Responses to Abiotic Stress. **International Journal of Molecular Sciences 2012, Vol. 13, Pages 8628-8647**, v. 13, n. 7, p. 8628–8647, 11 jul. 2012.

RIBEIRO, R. V. et al. Revealing drought-resistance and productive patterns in sugarcane genotypes by evaluating both physiological responses and stalk yield. **Experimental Agriculture**, v. 49, n. 2, p. 212–224, abr. 2013.

RODRIGUES GABRIEL SALES, C. et al. Trocas gasosas e balanço de carboidratos em plantas de cana-de-açúcar sob condições de estresses radiculares Cristina. ***I***, v. 22, n. 3, p. 13084–200, 2012.

RONSEIN, G. E. et al. Oxidação de proteínas por oxigênio singlete: Mecanismos de dano, estratégias para detecção e implicações biológicas. **Quimica Nova**, v. 29, n.

3, p. 563–568, 2006.

ROSA, M. et al. Soluble sugars. **https://doi.org/10.4161/psb.4.5.8294**, v. 4, n. 5, p. 388–393, maio 2009.

SALAH, I. BEN et al. Seaweed polysaccharides as bio-elicitors of natural defenses in olive trees against verticillium wilt of olive. **http://mc.manuscriptcentral.com/tjpi**, v. 13, n. 1, p. 248–255, 1 jan. 2018.

SHARMA, I.; AHMAD, P. Catalase: A Versatile Antioxidant in Plants. In: **Oxidative Damage to Plants: Antioxidant Networks and Signaling**. Elsevier Inc., 2014. p. 131–148.

SHARMA, P. et al. Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions. **Journal of Botany**, v. 2012, 2012.

SHI, P. et al. Effects of Ascophyllum nodosum extract on growth and antioxidant defense systems of two freshwater microalgae. **Journal of Applied Phycology**, v. 30, n. 2, p. 851–859, 2018.

SHUKLA, P. S. et al. Seaweed extract improve drought tolerance of soybean by regulating stress-response genes. **AoB PLANTS**, v. 10, n. 1, 1 fev. 2018.

SHUKLA, P. S. et al. Ascophyllum nodosum-based biostimulants: Sustainable applications in agriculture for the stimulation of plant growth, stress tolerance, and disease management. **Frontiers in Plant Science**, v. 10, n. May, p. 1–22, 2019.

SILVA, M. A. DA et al. Biostimulant alleviates abiotic stress of mango grown in semiarid environment. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 24, n. 7, p. 457–464, 13 jul. 2020.

SILVA, M. DE A. et al. Pigmentos fotossintéticos e índice SPAD como Descritores de intensidade do estresse por deficiência hídrica em cana-de-açúcar. **Bioscience Journal**, v. 30, n. 1, p. 173–181, 2014.

SILVA, T. T. DE A. et al. Qualidade fisiológica de sementes de milho na presença de bioestimulantes. **Ciência e Agrotecnologia**, v. 32, n. 3, p. 840–844, 2008.

SINGH, I. et al. Can we not mitigate climate change using seaweed based biostimulant: A case study with sugarcane cultivation in India. **Journal of Cleaner Production**, v. 204, p. 992–1003, 10 dez. 2018.

SOMOGYI, M. A NEW REAGENT FOR THE DETERMINATION OF SUGARS. **Journal of Biological Chemistry**, v. 160, n. 1, p. 61–68, 1 set. 1945.

SPANN, T. M.; LITTLE, H. A. Applications of a Commercial Extract of the Brown Seaweed Ascophyllum nodosum Increases Drought Tolerance in Container-grown 'Hamlin' Sweet Orange Nursery Trees. **HortScience**, v. 46, n. 4, p. 577–582, 1 abr. 2011.

STURM, A. Invertases. Primary Structures, Functions, and Roles in Plant Development and Sucrose Partitioning. **Plant Physiology**, v. 121, n. 1, p. 1–8, 1 set. 1999.

TAIZ, L.; ZEIGER, E. **Fisiologia Vegetal**. 6. ed. Porto Alegre: Artmed, 2017.

TAKAHASHI, S.; BADGER, M. R. Photoprotection in plants: A new light on photosystem II damage. **Trends in Plant Science**, v. 16, n. 1, p. 53–60, 1 jan. 2011.

TAN, C.-Y. et al. Regulation of algal and cyanobacterial auxin production, physiology, and application in agriculture: an overview. **Journal of Applied Phycology 2021 33:5**, v. 33, n. 5, p. 2995–3023, 19 maio 2021.

TEZARA, W. et al. Effects of water deficit and its interaction with CO2 supply on the biochemistry and physiology of photosynthesis in sunflower. **Journal of Experimental Botany**, v. 53, n. 375, p. 1781–1791, 1 ago. 2002.

THALMANN, M.; SANTELIA, D. Starch as a determinant of plant fitness under abiotic stress. **New Phytologist**, v. 214, n. 3, p. 943–951, 1 maio 2017.

THIPYAPONG, P. et al. Suppression of polyphenol oxidases increases stress tolerance in tomato. **Plant Science**, v. 167, n. 4, p. 693–703, 1 out. 2004.

TOMÁS-BARBERÁN, F. A.; ESPÍN, J. C. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. **Journal of the Science of Food and Agriculture**, v. 81, n. 9, p. 853–876, 1 jul. 2001.

TRIANTAPHYLIDÈS, C.; HAVAUX, M. Singlet oxygen in plants: production, detoxification and signaling. **Trends in Plant Science**, v. 14, n. 4, p. 219–228, 1 abr. 2009.

TRIPATHY, B. C.; OELMÜLLER, R. Reactive oxygen species generation and signaling in plants. **Plant Signaling and Behavior**, v. 7, n. 12, p. 167–173, 2012.

VALERIO, C. et al. Thioredoxin-regulated β-amylase (BAM1) triggers diurnal starch degradation in guard cells, and in mesophyll cells under osmotic stress. **Journal of Experimental Botany**, v. 62, n. 2, p. 545–555, 1 jan. 2011.

VAN HEERDEN, P. D. R. et al. Limitation of photosynthetic carbon metabolism by dark chilling in temperate and tropical soybean genotypes. **Plant Physiology and Biochemistry**, v. 42, n. 2, p. 117–124, 2004.

VAN OOSTEN, M. J. et al. The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. **Chemical and Biological Technologies in Agriculture 2017 4:1**, v. 4, n. 1, p. 1–12, 3 abr. 2017.

VAUGHN, K. C.; DUKE, S. O. Function of polyphenol oxidase in higher plants. **Physiologia Plantarum**, v. 60, n. 1, p. 106–112, 1 jan. 1984.

VICKERS, J. E. et al. Overexpression of Polyphenol Oxidase in Transgenic Sugarcane Results in Darker Juice and Raw Sugar. **Crop Science**, v. 45, n. 1, p. 354–362, 1 jan. 2005.

VRANOVA, E. Signal transduction during oxidative stress. **Journal of Experimental Botany**, v. 53, n. 372, p. 1227–1236, 15 maio 2002.

WAGNER, D. et al. The genetic basis of singlet oxygen-induced stress response of Arabidopsis thaliana. **Science**, v. 306, n. 5699, p. 1183–1185, 12 nov. 2004.

WATANABE, K. et al. Effects of Superabsorbent Polymer on Soil Water Content and Sugarcane Germination and Early Growth in Sandy Soil Conditions. **Sugar Tech 2018 21:3**, v. 21, n. 3, p. 444–450, 28 set. 2018.

WINTER, H.; HUBER, S. C. **Regulation of sucrose metabolism in higher plants: Localization and regulation of activity of key enzymesCritical Reviews in Plant Sciences**Taylor & Francis Group, , 2000. Disponível em: <https://www.tandfonline.com/doi/abs/10.1080/07352680091139178>. Acesso em: 10 set. 2021

WOZNIAK, E. et al. Biostimulant Mode of Action. **The Chemical Biology of Plant Biostimulants**, p. 205–227, 2 mar. 2020.

XU, C.; LESKOVAR, D. I. Effects of A. nodosum seaweed extracts on spinach growth, physiology and nutrition value under drought stress. **Scientia Horticulturae**, v. 183, p. 39–47, 12 fev. 2015.

YAKHIN, O. I. et al. Biostimulants in plant science: A global perspective. **Frontiers in Plant Science**, v. 7, p. 2049, 26 jan. 2017.

YAMADA, K. et al. Functional Analysis of an Arabidopsis thaliana Abiotic Stress-inducible Facilitated Diffusion Transporter for Monosaccharides *. **Journal of Biological Chemistry**, v. 285, n. 2, p. 1138–1146, 8 jan. 2010.

YILDIZTEKIN, M.; TUNA, A. L.; KAYA, C. Physiological Effects of the Brown Seaweed (Ascophyllum nodosum) and Humic Substances on Plant Growth, Enzyme Activities of Certain Pepper Plants Grown under Salt Stress. **Acta Biologica Hungarica 2018 69:3**, v. 69, n. 3, p. 325–335, 30 dez. 2018.

YUN-HEE KIM; SANG-SOO KWAK. The Role of Antioxidant Enzymes during Leaf Development. In: **Reactive Oxygen Species and Antioxidants in Higher Plants**. 1. ed. Boca Raton: CRC Press, 2010. p. 145–166.

ZEEMAN, S. C.; KOSSMANN, J.; SMITH, A. M. Starch: Its Metabolism, Evolution, and Biotechnological Modification in Plants. **http://dx.doi.org/10.1146/annurev-arplant-042809-112301**, v. 61, p. 209–234, 4 maio 2010.

ZHAO, D.; GLAZ, B.; COMSTOCK, J. C. Sugarcane leaf photosynthesis and growth characters during development of water-deficit stress. **Crop Science**, v. 53, n. 3, p. 1066–1075, 1 maio 2013.