RESILIENT ECOSYSTEMS GRASSLAND STRESS PHYSIOLOGY

Valentina STOIAN, Ștefania GÂDEA, Sorin VÂTCĂ*

** Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Plant Physiology, Cluj-Napoca, Calea Manastur 3-5, Cluj-Napoca, 400372, Romania*
***sorin.vatca@usamvcluj.ro*

Abstract

Stress in grasslands arises from both abiotic factors, such as drought, extreme temperatures, nutrient deficiencies, soil salinity, and biotic factors. These stressors can disrupt the physiological processes of grassland plant communities, leading to reduced growth, impaired reproductive success, increased mortality and disturb dominance of sensible species. Plants have evolved a variety of mechanisms to cope with stress, ranging from morphological adaptations and changes in root architecture to biochemical and molecular responses that enhance tolerance degree and resilience. Understanding the stress physiology of grasslands is crucial to managing and preserving these ecosystems, particularly in the face of increasing environmental stressors such as climate change, drought, and human activity improper interventions. In this context, the study of stress physiology in grasslands is not only important for ecological research but also for practical applications in agriculture, conservation, and land management.

Keywords: grassland dynamics, physiological responses, resistance, stress responses, resilience.

INTRODUCTION

More and more extreme events because of climate warming will be encountered and in the current context of changes produced by regional climate it is important to have sufficient tools to predict the vegetation shifts and overall the ecosystems severe stress (Van Peer et al., 2004). As extreme weather is predicted along climate changes patterns, heat waves along intensive drought periods will represent the major thread for grasslands and agriculture with increased concern in central Europe (Signarbieux and Feller, 2012).

One of the third terrestrial surface, grasslands, represent 70% from the agricultural area (Reynolds and Frame, 2005). The particular importance of grasslands is due to its higher resilience toward heat stress compared to forests and represents a carbon sink that can store more than 50% more carbon in comparison with forests ecosystems (Conant, 2010; Reinermann et al., 2020). The grasslands high biodiversity represents an essential ecosystem service along with purifying water, preventing erosion, landscape sightseeing, stable carbon pool (Păcurar et al., 2014; Reinermann et al., 2020; Stoian et al., 2022). and provided agriculture and livestock resources (Van Peer et al., 2004). Plants will be exposed to warmer and drier conditions, therefore will suffer severe or even lethal stress levels (Signarbieux and Feller, 2012). Also, plant communities' composition and distribution will change because of the climatic changes especially in grasslands. Diversity loss affect plant communities' resistant to extremes and accelerate the overall diversity decline (Van Peer et al., 2004).

Grassland contain woody shrubs, grasses (Letts et al., 2010) and also annual plants (Signarbieux and Feller, 2012). Woody shrubs and grasses usually manifest competition by co-occurrence in grasslands ecosystems (Clarke and Knox, 2009). Annual plants possess stress mechanisms to avoid water-loss together with the ability to reduced metabolism activity sometimes become dormant due to intensive stress generically called physiological adjustments (Zavalla, 2004). Understanding how stress physiology and plant community structure interact to assure resistance and resilience is essential to overcome stress (Ungar, 2018; Yang et al., 2023). Increased species richness could sustain the probability that a single or a group of plants drought tolerant with specific adaptation sustain the grassland functioning and persistence of the species (Nijs and Impens, 2000). An alternative mechanism linking diversity to resistance might arise from the dominance of highly productive species in species-rich mixtures (Van Peer et al., 2004).

The interspecific differences between plants could be influenced by morpho-eco-physiological interactions and determine changes in phenology, physiological characteristics and rooting depth (Vico et al., 2015).

The methodology proposed for highlighting the research interest in the subject selected implied a search in WOS –Web of Science database sustained by Clarivate (accessed on 30.05.2024). The topic field was selected and "grassland stress physiology" was then filtered from the scientific database. A number of 109 articles were found of which 98 were articles, 9 were reviews, 2 were proceeding papers and one was early access. The time interval with this subject interest in research and publication was between 2011-2024 with 83% from the total number of online articles (17% were published between 1994-2010). The aim of the study was set to highlights the most important aspects interdisciplinary connected with the plants physiology under stress in grasslands.

STRESS CATEGORIES IN GRASSLANDS

Grasslands face a range of abiotic and biotic stressors (Surówka et al., 2020) that can impact growth, development and reproduction of grassland plants. Abiotic stressors encompass drought, extreme temperatures, nutrient deficiencies, and soil salinity, while biotic stressors include herbivory, pests, and diseases. Plants adapt to abiotic challenges and stress by metabolic transformation in response to all threats (Fig. 1).

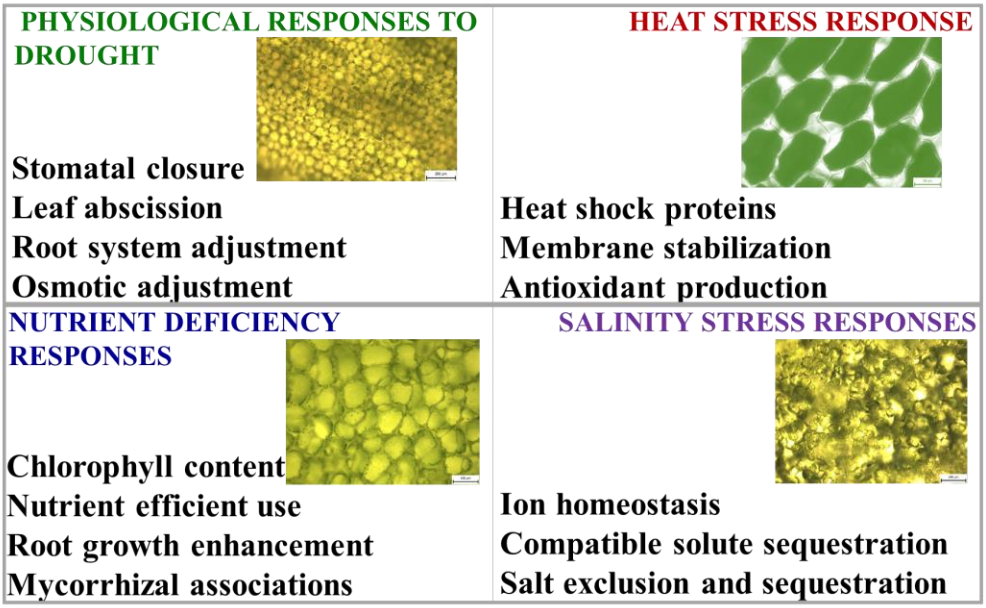

Fig. 1 Categories of abiotic stress for grasslands plant species

PHYSIOLOGICAL RESPONSE TO DROUGHT

Drought represents one of the most significant stressors for grasslands. Plants respond to water deficit through a range of physiological mechanisms (Kang et al., 2021):

Stomatal closure: To minimize water loss, grassland plants often close their stomata, the pores on their leaves, which also reduces gas exchange, transpiration and in the end photosynthetic activity.

Leaf abscission: Shedding leaves can reduce water loss and preserve essential nutrients under drought stress periods.

Root system adjustment: Plants may develop deeper or more extensive root systems to access water from deeper soil layers.

Osmoregulation: solutes accumulation like proline and sugars helps maintain cell turgor and enzyme function under drought conditions.

The search performed to highlight connections between grassland stress physiology for ensuring ecosystem resilience provide us useful insights for further interdisciplinary research.

In the last 24 years, drought was the most studied abiotic stress (Loka et al., 2019) with a share of 22% from the total 10 keywords selected from the published articled from the WOS (Fig. 2).

Close connected with this first research subject, high percentages of interest of climate changes effect and eco-physiological conditions influence of grassland resilience around 18%.

Abiotic stress was also in an increased share of 11%, for this class were counted articles with water stress, temperature stress, extreme events or multiple stress which determine plant physiological changes (Fig. 2). Community composition, dynamics along with competition (8%) for providing resilience (7%) from increasing the plants tolerance, were studied in the presence of different nutrients (5%).

Physiological assessment was concentrated on osmoregulation (5%), stomatal conductance (4%) and the lowest percentage was found for chlorophyll content only 2%. Future research perspectives must be related with this physiological parameter respectively chlorophyll content (Tong and He, 2017), the pigment which is sensitive to reflectance index in the red to near red-edge wavelength between 660-720 nm (Sims and Gamon, 2002).

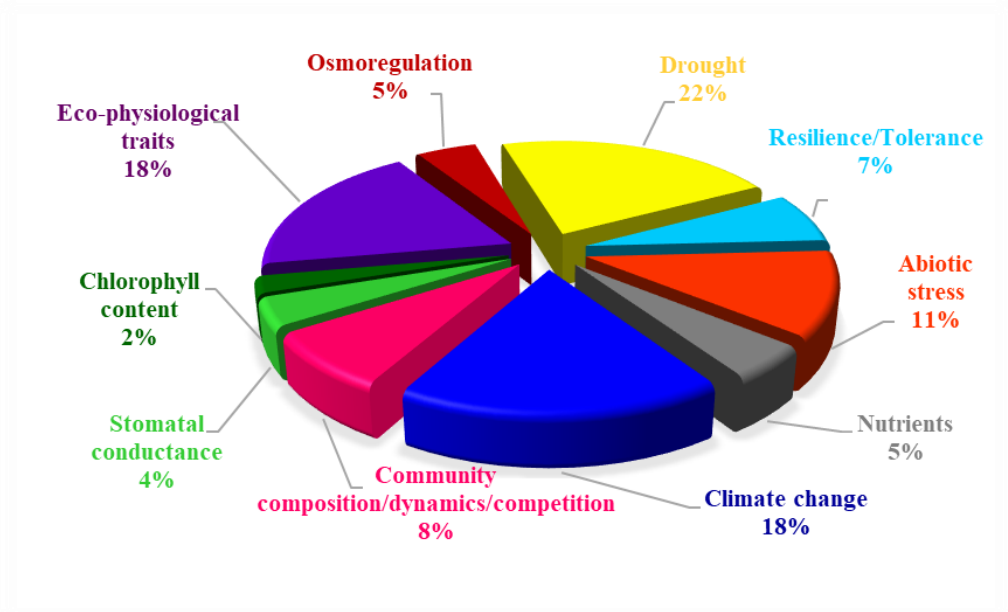

Fig. 2. Results obtained after applying filters to the WOS database after a search based of combined keywords “grassland stress physiology”

HEAT STRESS RESPONSE

Heat stress can damage cellular structures and disrupt metabolic processes. Grassland plants employ several strategies to cope with high temperatures (Hemantaranjan et al., 2018):

<u>Heat shock proteins (HSPs)</u>: These proteins help in stabilizing and refolding denatured proteins, ensuring cellular function.

<u>Membrane stabilization</u>: Adjusting the composition of membrane lipids helps maintain membrane fluidity and integrity under heat stress.

<u>Antioxidant production</u>: To combat oxidative stress caused by high temperatures, plants increase the production of antioxidants like superoxide dismutase and catalase.

NUTRIENT DEFICIENCY RESPONSES

Nutrient deficiencies, particularly of nitrogen and phosphorus, can limit growth and productivity in grasslands (Hill et al., 2006). Plants adapt through:

<u>Chlorophyll content</u>: The plant chlorophyll content represents an indicator of growth, development, photosynthetic activity and biochemical properties of grassland plant providing an overview about plants physiological status (Shiflett et al., 2014; Zang et al.,2020). Higher leaf nitrogen provides increased growth rates and photosynthesis, also provide resistance and persistence of plants under stress (Shiflett et al., 2014).

<u>Efficient nutrient use</u>: Improving the efficiency of nutrient use by optimizing metabolic pathways to make the most of available resources.

<u>Enhanced root growth</u>: Increasing root biomass and root hair development to explore a larger soil volume for nutrients (Corcoz et al., 2022).

<u>Mycorrhizal associations</u>: Forming symbiotic relationships with mycorrhizal fungi, which enhance nutrient uptake (Stoian et al., 2019; Corcoz et al., 2021).

SALINITY STRESS RESPONSES

Soil salinity represents another critical stressor, especially in arid and semi-arid grasslands (Trușcă et al., 2022; Trușcă et al., 2023). Plants adapt to salinity through:

<u>Ion homeostasis</u>: Maintaining ions balance within cells to prevent toxicity.

<u>Compatible solute accumulation</u>: Synthesizing compounds like glycine betaine and proline to protect cellular structures.

<u>Salt exclusion and sequestration</u>: Excluding salt from uptake or sequestering it in vacuoles to prevent damage to vital cellular processes.

BIOTIC STRESS RESPONSES

Grasslands face biotic stresses from herbivores, pests, and pathogens (Sánchez-Sánchez and Morquecho-Contreras, 2017). Plants have evolved various defense mechanisms:

Physical defenses: Developing structures like thorns and trichomes to discourage herbivores approach.

Chemical defenses: Producing secondary metabolites such as alkaloids, terpenoids, and phenolics that are toxic or unpleasant to herbivores and pathogens.

Induced resistance: Activating systemic acquired resistance (SAR) and induced systemic resistance (ISR) pathways to enhance defense against a broad range of pathogens and pests.

GRASSLAND MANAGEMENT IMPLICATIONS

Understanding grassland stress physiology is essential for developing strategies to manage and conserve these ecosystems (Trușcă et al., 2022; Milazzo, et al., 2023). This includes:

Selecting drought-resistant species: Utilizing plant species or cultivars that are more resistant to drought and other stresses.

Sustainable grazing practices: Implementing grazing regimes that minimize stress on plants and allow for recovery and regeneration.

Soil management: Enhancing soil health through practices that improve water retention, nutrient availability, and microbial activity

Plant physiology in grasslands assessment could provide vital information about net primary production (Ling et al., 2019), nutrients status (Moran, 2000) and stress level (Netto et al., 2005. The health and physiological function is provided by the vegetation chlorophyll, today many nondestructive methods could be used for evaluation this physiological indicator. The estimation and prediction of chlorophyll content can be also quantified using remote sensing (Tong and He, 2017).

CONCLUSIONS

The stress physiology of grasslands encompasses a complex interplay of mechanisms that plants use to survive and thrive under adverse conditions.

For ensuring practical applications in agriculture, conservation, and land management, the studies of stress physiology in grasslands should provide information connected with stress resistant species, species specific responses and ecosystem resilience.

Dominant species under different eco-physiological conditions should be proposed for reshaping grasslands community composition in the regions or areas with altered climatic parameters like low precipitation level and increased heat events.

One of the most important physiological parameter is chlorophyll content hereby further studies should be concentrated for assessing this pigment change for different plant species in differend grasslands type along with management implications.

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