A Systematic Review: Thermal Stress Impacts on Growth and Physiology of the Poaceae Family

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Abstract: Thermal stress is a major abiotic factor affecting species within the Poaceae family, yet its geographic impacts remain insufficiently explored. As global temperatures continue to rise, understanding how grasses respond to temperature extremes is increasingly important for agricultural productivity and ecosystem stability. This systematic review examined the effects of thermal stress on Poaceae species, with emphasis on growth and physiological responses. Following PRISMA guidelines, peer-reviewed English articles from multiple databases were screened, resulting in ten high-quality studies. Evidence certainty was evaluated using the GRADE framework to synthesize findings. Results indicate that temperature significantly affects growth, physiology, germination, and reproductive development in Poaceae species. Most grasses grow optimally within 20–30°C. High temperatures cause physiological stress, including reduced photosynthesis, increased leaf senescence, oxidative damage, and decreased grain yield in crops such as wheat and rice. Low temperatures slow metabolic processes but may also trigger protective responses, such as increased antioxidant production. Thermal tolerance varies among species, with some grasses showing greater adaptability to fluctuations. Heat stress can lead to sterility and yield loss, while cold stress delays flowering and disrupts pollination. Overall, thermal stress alters key physiological and developmental processes, emphasizing the need to maintain optimal temperature conditions.

Keywords: *Temperature, Climate Change, Thermal Stress, Poaceae, Abiotic Stress, Heat Stress, Cold Stress, Plant Physiology, Growth Response, Germination, Photosynthesis, Oxidative Stress, Antioxidants, Crop Yield, Reproductive Development, Stress Tolerance, Phenology, Agricultural Resilience, Climate Adaptation, Cereal Crops.*

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I. INTRODUCTION

The Poaceae family, also known as the grass family, is a globally important plant family in terms of both economic and ecological importance. It consists of significant quantity of essential foods and resources, such as, rice (Oryza sativa), wheat (*Triticum aestivum*), maize (*Zea mays*), barley (*Hordeum vulgare*), pearl millet (*Pennisetum glaucum*) and bamboo (*Bambusa vulgaris*), which are generally sufficient to support a large proportion of the global population. In addition to their importance as food sources, these species are essential for crop cultivation, serve as bioenergy, and have essential components that support various wildlife and promote soil sustainability in the ecosystems.

The growth and physiological diversity within the Poaceae family is characterized by features such as different photosynthetic pathways, rapid growth rates, extensive root systems, and tolerance to a wide array of environmental stresses. However, despite these adaptive features, some parts of this family are increasingly vulnerable to the adverse effects of climate change, particularly the rising global temperatures and the occurrence of extreme heat events. Increasing temperatures disrupt fundamental biological processes, including seed germination, photosynthesis, transpiration, growth and reproductive development, eventually leading to reduced yields and compromised crop quality. These impacts cause a serious threat to global food security, especially in regions where agriculture already faces challenges related to water shortage, poor soil conditions, and socio-economic limitation.

Recent studies have highlighted the complex molecular and physiological mechanisms controlling plant responses to abiotic stresses such as heat and drought (Chirivì & Betti, 2023; Sharma et al., 2025). For instance, studies on C4 grasses like *Setaria viridis* have provided valuable insights into adaptive responses at the systems level, revealing how these plants modify their metabolism and gene expression to cope with heat stress (Zhang et al., 2025). Understanding these responses is critical for developing strategies to enhance resilience, whether through traditional breeding, genetic

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modification, or agronomic practices. Despite the expanding literature work on this topic, there remains a need for a comprehensive synthesis that consolidates current knowledge, identifies gaps, and highlights promising methods for future research.

This systematic review aims to analyze existing studies on the effects of temperatures on the growth, development, and physiological responses of Poaceae species (Dajac et al., 2025). By combining findings from different experimental approaches and environmental contexts, this review seeks to provide a clearer understanding of the mechanisms underlying heat tolerance and vulnerability in these vital plants. Finally, this review underscores the urgency of advancing scientific efforts to develop climate-resilient Poaceae crops capable of thriving amid the ongoing and future challenges caused by global warming. (Zhang et al., 2025).

II. METHODOLOGY

To gather studies investigating the impacts of thermal stress on Poaceae species. Relevant articles were identified through targeted database searches, screened for alignment with the review objectives, and assessed against predefined eligibility criteria. Eligible studies were then subjected to systematic data extraction and quality appraisal to ensure accurate and reliable synthesis of findings on growth and physiological responses of the Poaceae family under thermal stress.

➢ *Eligibility Criteria*

To ensure alignment with the review's objectives and mitigate selection bias, the study adheres to a systematic algorithm (see Fig 1) that emphasizes methodological rigor, consistency, and the inclusion of highly relevant sources.

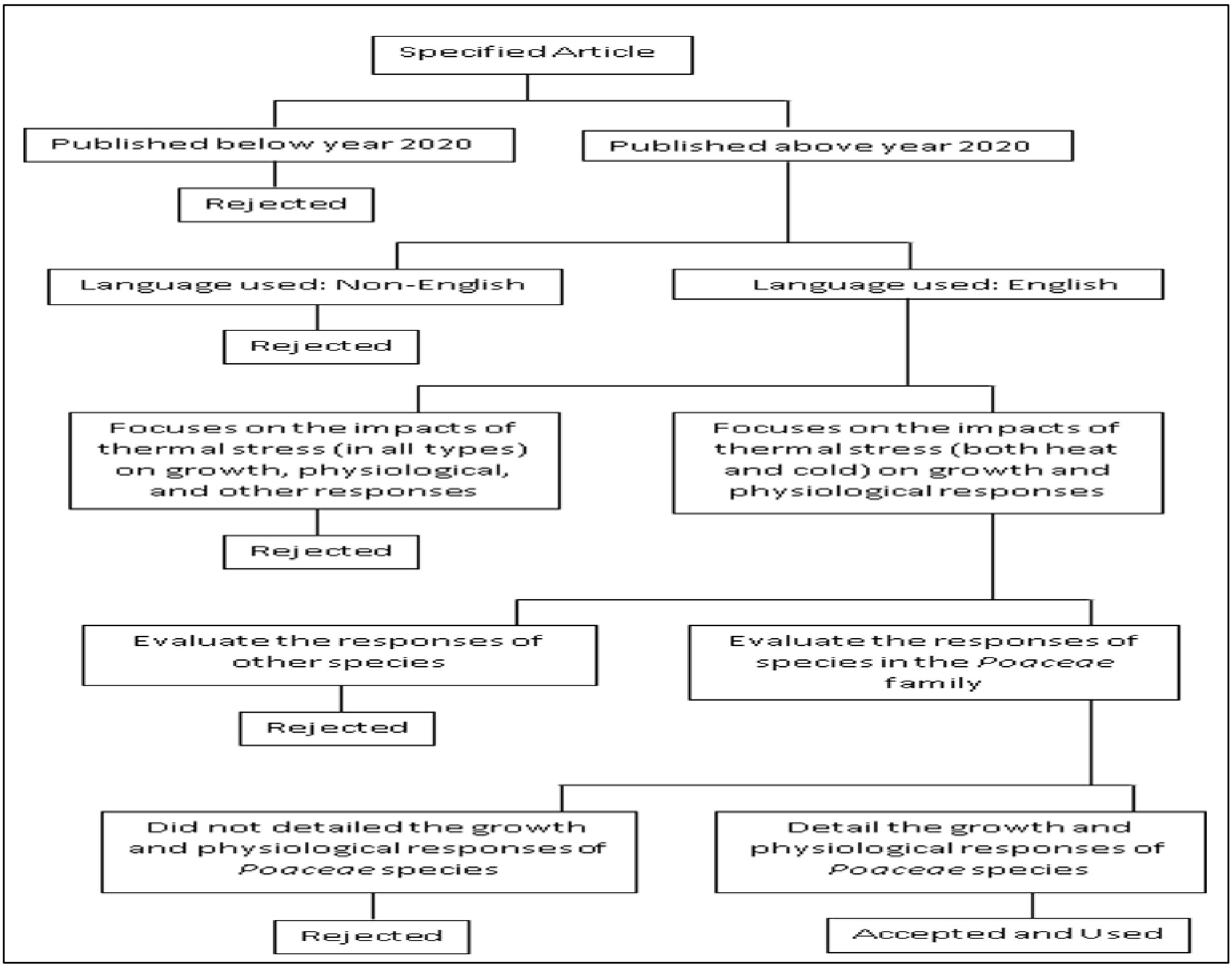

Fig 1 Systematic Algorithm of Eligibility Criteria for "A Systematic Review: Thermal Stress Impacts on Growth and Physiology of the Poaceae Family."

To comply with the review's objectives and limit selection bias, the first 20 relevant articles (n = 20) were randomly chosen. Articles were evaluated as follows, (1) the articles focus on the effects of thermal stress (both heat and cold) on growth and physiological responses; (2) articles evaluate the responses of species in the Poaceae family; (3) articles are written in English; (4) articles detail the growth and physiological responses of Poaceae species; (5) articles are published in the years 2020 – 2026 in a peer-reviewed journal.

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Articles were excluded if; (1) they studied non-Poaceae species; (2) they studied other stress types; (3) they provided little or no evidence on the growth or physiological responses; (4) they studied unrelated subjects like biotechnology; (5) they were published before 2020 or were not peer-reviewed. Included studies were organized by type of stress and species of Poaceae for easier comparison.

➢ *Information Sources and Search Strategy*

A thorough search of the literature was carried out using the following resources: Taylor & Francis Group, ScienceDirect, ResearchGate, Alchetron, Brazilian Academy of Sciences, PLOS, American Society of Plant Biologists, Google Scholar, and National Library of Medicine. Combinations of keywords and Boolean operators were used in the search strategy, such as "thermal stress," "heat stress," or "cold stress," "Poaceae," or "grasses," "growth", and "Physiology." The search was restricted to research and experimental studies where appropriate, and only peer-reviewed English-language publications were included.

➢ *Selection and Data Collection Process*

An initial database search identified 9 records. After removing 4 duplicates, 20 articles proceeded to title and abstract screening for relevance to thermal stress (heat and cold) effects on Poaceae growth and physiology. Two studies were excluded, leaving 18 full-text articles sought for retrieval; 3 were inaccessible. The remaining 15 studies were assessed using the inclusion and exclusion criteria, and 5 were excluded due to insufficient data or lack of focus on Poaceae under thermal stress. The remaining studies underwent independent quality appraisal and bias assessment by two reviewers. Data were systematically extracted on species, temperature treatments, stress type, and physiological responses. Ultimately, 10 studies met all criteria and were included in the final synthesis, contributing 24 reports of evidence (Fig 2).

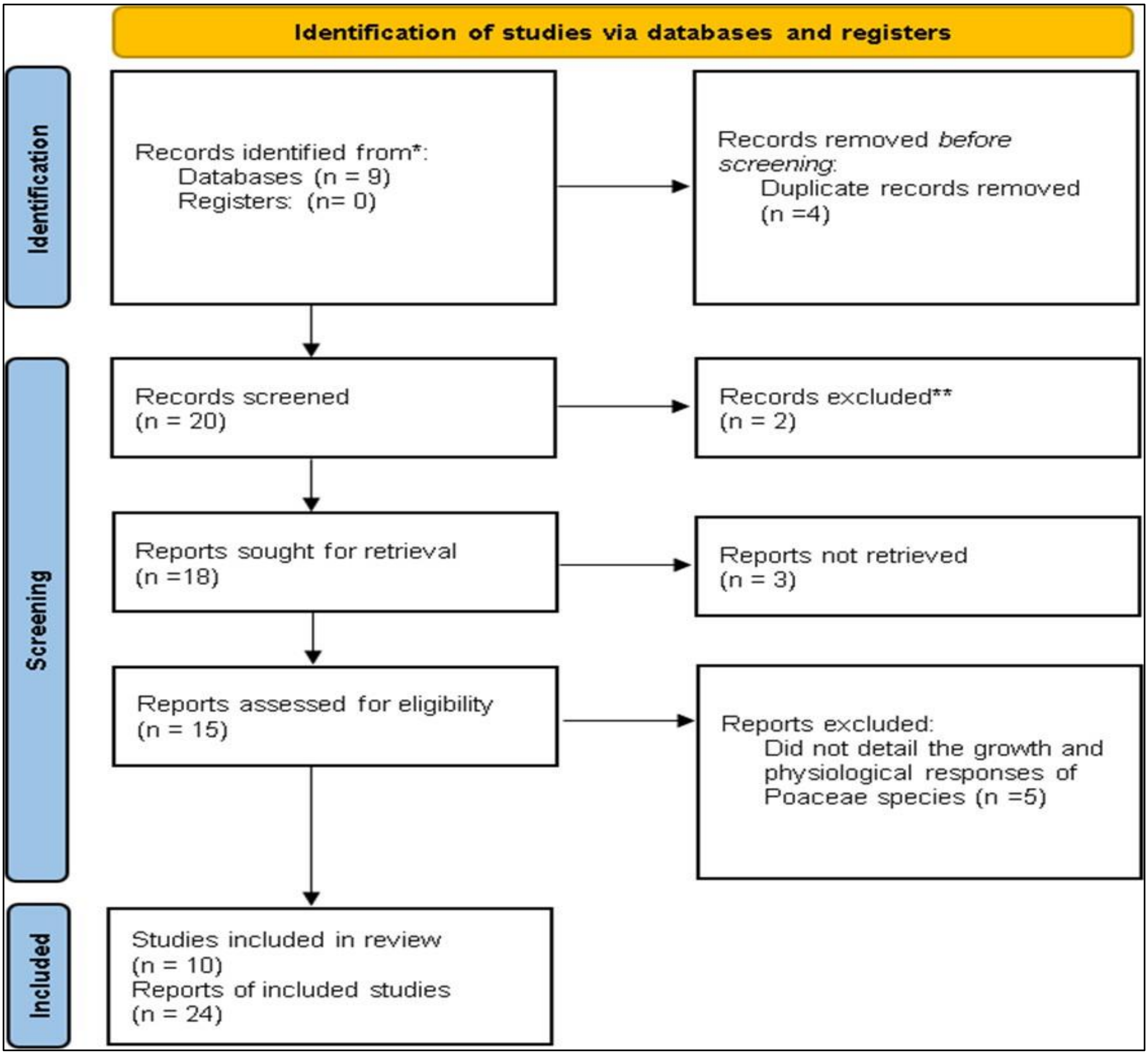

Fig 2 PRISMA Flow Diagram of the Study Selection Process.

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➢ *Study Risk of Bias Assessment*

The first 20 pertinent articles were selected at random from the pool of studies found by the literature search in order to minimize selection bias and conform to the review objectives. First, titles and abstracts were checked for relevancy. The studies that were evaluated in full were chosen at random, and each study was assessed independently by two reviewers. To maintain uniformity and objectivity, disagreements were settled by discussion or consultation with a third reviewer.

➢ *Effect Measures*

Effect measures were defined in accordance with the review objectives and eligibility criteria, focusing on studies that examined the effects of thermal stress (heat and cold) on the growth and physiological responses of Poaceae species. Outcomes were considered based on comparative assessments between control and stress conditions, emphasizing measurable changes in growth performance and physiological activity. Given the variability in experimental conditions, species characteristics, and outcome measurements, results were synthesized descriptively and organized by type of thermal stress and Poaceae species rather than combined quantitatively.

➢ *Reporting Bias Assessment*

To assess risk of bias due to missing results, each study was carefully evaluated for selective outcome reporting. Reported results were compared with outcomes described in the methods to identify omissions, incomplete data, or discrepancies in reported time points and measures. Studies were examined for evidence of publication bias, including absence of negative or non-significant results, and whether only significant findings were highlighted. Any missing or unclear data were documented, and the potential impact on the overall synthesis was considered. Studies with substantial unreported outcomes or unclear reporting were classified as having a higher risk of reporting bias.

➢ *Certainty Assessment*

The certainty of the body of evidence for each outcome was assessed using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) approach. Each outcome was evaluated across five domains: risk of bias, by considering study design and methodological limitations; inconsistency, by examining variability in results across studies; indirectness, by assessing the applicability of the evidence to the review question; imprecision, by evaluating confidence intervals and sample sizes; and publication bias, by considering the likelihood of unreported or selectively reported outcomes as shown in Table 1.

Table 1 GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) for Certainty Assessment.

Item	Definition
Level of evidence	
A. High-quality evidence	Further research is unlikely to change our confidence in the estimate of effect. Consistent evidence derived from a comprehensive and systematic selection of eligible peer-reviewed studies with minimal methodological limitations.
B. Moderate-quality evidence	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. Evidence derived from peer-reviewed experimental studies meeting predefined eligibility criteria but with some methodological limitations in study selection or scope.
C. Low-quality evidence	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. Evidence derived from a limited number of selected studies (n = 20) based on predefined eligibility criteria, with potential
Strength of recommendation	
1 – Strong recommendation	Recommendation can be applied broadly when evidence is comprehensive, consistent, and methodologically rigorous across included studies.
2 – Weak recommendation	The best interpretation may differ depending on study scope, species variability within Poaceae, and experimental conditions. Alternative conclusions may be reasonable due to limited number of included studies and selection constraints.

Based on these criteria, each outcome was assigned a certainty rating of high, moderate, low, or very low, reflecting the overall level of confidence in the available evidence. The evaluation considered key factors including methodological quality, consistency of findings across studies, directness of evidence, and potential risk of bias. Evidence was further interpreted according to its overall quality, ranging from high-quality evidence, characterized by consistent findings from comprehensive and methodologically rigorous studies, to low-quality evidence, which was derived from a limited number of studies with potential methodological constraints. The strength of recommendation was also categorized as strong or weak, depending on the consistency, scope, and robustness of the evidence base. All outcomes were assessed independently by two reviewers to maintain objectivity, and any discrepancies in judgment were resolved through discussion and consensus, ensuring transparency, methodological rigor, and reliability in the certainty grading process.

III. RESULTS AND DISCUSSION

The synthesis of findings in Table 2 demonstrates that temperature is a primary determinant of physiological performance, growth dynamics, and reproductive development across species within the Poaceae family and related model organisms. Across the reviewed studies, both high and low temperature extremes are consistently associated with disruptions in metabolic processes, although the magnitude and nature of these effects vary among species

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and functional groups.

Heat stress is widely reported to impair physiological function, particularly in major crop species such as *Oryza sativa* and *Triticum aestivum*. Evidence from multiple studies (e.g., Davies et al., 2018; Sharma et al., 2025) indicates that elevated temperatures reduce photosynthetic efficiency, destabilize cellular membranes, and disrupt carbohydrate metabolism and hormonal balance. These physiological impairments are frequently linked to reproductive failure, including reduced pollen viability, spikelet sterility, and decreased grain filling, ultimately resulting in yield loss. Similar trends are observed in *Setaria viridis*, where heat stress alters abscisic acid regulation and ribosomal function, leading to reduced protein synthesis and stunted growth (Acharya et al., 2017; Anderson et al., 2021).

Comparative evidence further highlights differences between *C3 (Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei)* and *C4 (Eragrostis elongata, Imperata cylindrica, and Themeda triandra)* species in response to thermal stress. Studies such as Davies et al. (2018) show that C4 species generally maintain higher biomass and exhibit greater tolerance to combined heat and drought stress, partly due to more efficient carbon fixation and increased production of heat shock proteins. In contrast, C3 species are more prone to leaf senescence, water loss, and reductions in biomass under similar conditions. This distinction underscores the adaptive significance of photosynthetic pathways in determining thermal resilience.

Cold stress responses, while also associated with reduced growth, appear to involve protective biochemical adaptations. In species such as *Hordeum vulgare* and wheat, low-temperature exposure induces increased antioxidant activity, including elevated levels of phenolic compounds, flavonoids, and enzymatic antioxidants (Kumar et al., 2024; Sharma et al., 2025). These responses mitigate oxidative damage but are often accompanied by reduced metabolic rates and limited biomass accumulation. In contrast, cold-adapted species within the genus Poa, including *Poa sphondyllodes*, demonstrate high germination rates at low temperatures, suggesting inherent physiological mechanisms that confer cold tolerance (Dajac et al., 2025).

Temperature also plays a central role in regulating flowering time and reproductive transitions through complex genetic pathways. Across species such as *Zea mays* and *Sorghum bicolor*, temperature interacts with photoperiod-sensitive genes to influence flowering initiation and developmental timing (Brambilla et al., 2023). Heat stress is frequently associated with delayed or disrupted flowering, although in some cases it may accelerate phenological development at the cost of reproductive success. Conversely, vernalization responses observed in species such as *Triticum monococcum* illustrate how prolonged cold exposure is required to trigger flowering, reflecting an adaptive mechanism for seasonal synchronization.

Collectively, the reviewed literature indicates that plant responses to temperature are governed by interconnected physiological, biochemical, and genetic processes. Importantly, temperature effects rarely occur in isolation; rather, they interact with other abiotic stressors such as drought and water availability, amplifying their impact on plant performance. The variability in responses among species highlights the importance of species-specific thresholds and adaptive strategies in determining resilience under changing environmental conditions. Temperature stress has a substantial impact on plant physiology and development among various species, according to the findings. In general, heat stress impairs metabolic processes, lowers photosynthetic efficiency, and harms cellular functions, whereas cold stress induces defensive mechanisms but may still restrict growth.

Table 2 Summary of Findings for the Impacts of Thermal Stress on the Growth and Physiology of the Poaceae Family

Species	Temperature	Impacts on Physiology	Impacts on Growth	Author and Date
Setaria viridis	28 °C day / 20 °C night (control); 42 °C day / 32 °C night heat stress; 37 °C prolonged heat	Heat stress increases ABA, alters carbohydrate metabolism, and impairs ribosome biogenesis, reducing ribosomal proteins.	Control plants grow normally; heat stress causes stunted/dwarf growth due to reduced protein synthesis.	Blackshaw et al. (1981); Acharya et al. (2017); Anderson et al. (2021); Burbulis et al. (2013); Luo et al. (2011); Ferreira et al. (2020); Boyd et al. (2015);Chatte rjee et al. (2021); Martins et al. (2016); Travassos-Li ns et al. (2021)
Lolium perenne	Heat stress, °C not specified	Kangaroo Valley has higher photosynthesis and low stress compared to Norlea, indicating greater tolerance to heat stress. The offspring had traits that were a mix of the two parents.	The variation among offspring means that some plants can continue to grow well under heat stress, indicating potential for breeding heat-tolerant varieties.	Soliman et al. (2021)

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Oryza sativa	40/35 ° C (Day/Night)	High temperatures damage cell membranes, reduce photosynthesis, disrupt sugar transport, and imbalance hormones, causing poor pollen development and spikelet sterility.	Heat stress lowers seed germination, seedling vigor, tiller and panicle number, and grain weight, reducing overall rice yield.	Davies et al (2018)
Saccharum	20–30 °C	Exhibits physiological plasticity	Demonstrates high ecological	Damor et al.
spontaneum		and stress-response mechanisms associated with tolerance to heat and drought.	adaptability and resilience under temperature fluctuations.	(2025)
Triticum aestivum	20/15 °C (day/night)	Higher chlorophyll content and increased photosynthetic efficiency.	Optimal growth performance and biomass accumulation.	Kumar et al. (2024)
	30/25 °C (day/night)	Reduced photosynthetic efficiency indicating heat stress.	Decreased biomass accumulation and reduced grain filling.	
	10/5 °C (day/night)	Increased antioxidant activity including phenols, flavonoids, vitamin C, catalase, peroxidase, and glutathione reductase.	Reduced growth under cold stress conditions.	
	≥32 °C	Induces oxidative stress characterized by lipid peroxidation and disruption of nitrogen metabolism.	Reduced productivity and yield potential.	Sharma et al. (2025)
Poa pagophila, Poa megalothyrsa, Poa malaca, Poa sphondyllodes	5–15 °C	High cold tolerance enables germination at low temperatures.	High germination rates under cold conditions.	Dajac et al. (2025)
Triticum aestivum and Hordeum vulgare	10/5 °C	Increased metabolic responses including elevated phenols, flavonoids, and vitamin C under cold stress.	Reduced root and shoot growth under low temperature conditions.	
Poa sphondyllodes, Poa poophagorum	20–30 °C	Physiological responses support adaptability under moderate temperature conditions.	Highest germination and growth performance; suitable for artificial grassland establishment.	
Oryza sativa	13-35 °C ; ~ 37 °C heat stress	High temperature increases Hd3a florigen expression; extreme heat damages reproductive tissues.	Heading accelerates under SD but fertility decreases under extreme heat.	Brambilla et al. (2023)
Triticum aestivum	17–23 °C optimal; ≥32 °C heat stress	Heat stress damages pollen and reproductive tissues.	Grain filling decreases and yield loss occurs.	
Hordeum vulgare	25 °C	High temperature regulates Ppd-1 and HvODDSOC2 flowering pathways.	Flowering promoted in LD but delayed in SD.	
Zea mays	6–42 °C growth range; ~37 °C anthesis limit	Stress responses regulated by ZmCCT and circadian genes.	Stress conditions may delay flowering.	

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Sorghum bicolor	25 °C	Reduced oxygen affects mitochondrial metabolism.	Flowering was delayed and yield reduced.	
Brachypodium distachyon	27 °C (high temperature stress)	Temperature stress disrupts flowering regulation.	Heading is delayed.	
Arabidopsis thaliana	27 °C	ELF3, CO, PIF4 activate FT gene.	Early flowering occurs.	
Oryza officinalis	~37 °C heat	qEMF locus shifts flower opening	Early flowering reduces heat	
	during flowering	earlier.	damage.	
Triticum monococcum	4 °C	VRN1 activates COR genes in cold response.	Flowering occurs after winter.	
C3 (Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei) and C4 (Eragrostis elongata, Imperata cylindrica, and Themeda triandra)	25/18 °C (Day/Night)	Under Heat and drought, *Austrostipa ramosissima, Microlaena stipoides,* and *Poa labillardierei* reduced the most leaf water and photosynthesis, while *Eragrostis elongata, Imperata cylindrica,* and *Themeda triandra* grasses stayed in between.	Leaf death was highest under heat and drought, in between under heat or drought, and lowest under control, showing that stress intensity directly affected plant survival and growth.	Davies et al. (2018)
Setaria glauca	~35 °C (high temperature stress)	Germination processes are sensitive to abiotic stress.	Lower germination rate under stress conditions.	Amini et al. (2015); Feldman et al. (2018)
Setaria verticillata	~35 °C (environmental heat stress)	Stress affects early developmental responses.	Reduced germination and early seedling development.	
Setaria italica	~34 °C (drought-related heat stress)	Drought responses vary due to water-source sensitivity.	Differences in drought tolerance among *Setaria species.*	

➢ *Temperature as a Regulator of Physiological Processes* Across

The reviewed studies, temperature is consistently identified as a key regulator of plant physiological activity, including photosynthesis, membrane stability, and enzymatic function. Elevated temperatures are commonly associated with reduced photosynthetic efficiency and increased oxidative stress, while low temperatures tend to suppress metabolic activity but may induce protective biochemical responses.

➢ *Effects on Growth and Productivity*

Temperature extremes—both high and low—are generally associated with reduced growth performance and productivity. Heat stress frequently leads to decreased biomass accumulation, impaired grain filling, and reduced yield, whereas cold stress limits growth through reduced metabolic rates and delayed development. Optimal temperature ranges, in contrast, support stable growth and efficient resource utilization.

➢ *Differential Thermal Responses of C3 and C4 Species*

Comparative evidence indicates that C4 *(Eragrostis elongata, Imperata cylindrica, and Themeda triandra)* species exhibit greater tolerance to heat and drought stress than C3 species *(Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei)*. This enhanced tolerance is attributed to differences in photosynthetic pathways, including improved water-use efficiency and higher production of protective proteins. C3 species, by comparison, show greater susceptibility to thermal stress, particularly in terms of water loss and biomass reduction.

➢ *Temperature-Dependent Regulation of Reproduction and Flowering*

Temperature significantly influences reproductive development and flowering time through interactions with genetic regulatory pathways. Heat stress is commonly linked to reduced fertility and reproductive damage, while cold exposure may delay development or trigger vernalization-dependent flowering. These responses directly affect reproductive success and crop yield.

➢ *Biochemical and Molecular Adaptations to Thermal Stress*

Plants respond to temperature stress through a range of adaptive mechanisms, including increased antioxidant production, hormonal regulation, and stress-related protein synthesis. These responses help mitigate cellular damage but may not fully prevent reductions in growth or productivity under prolonged stress conditions.

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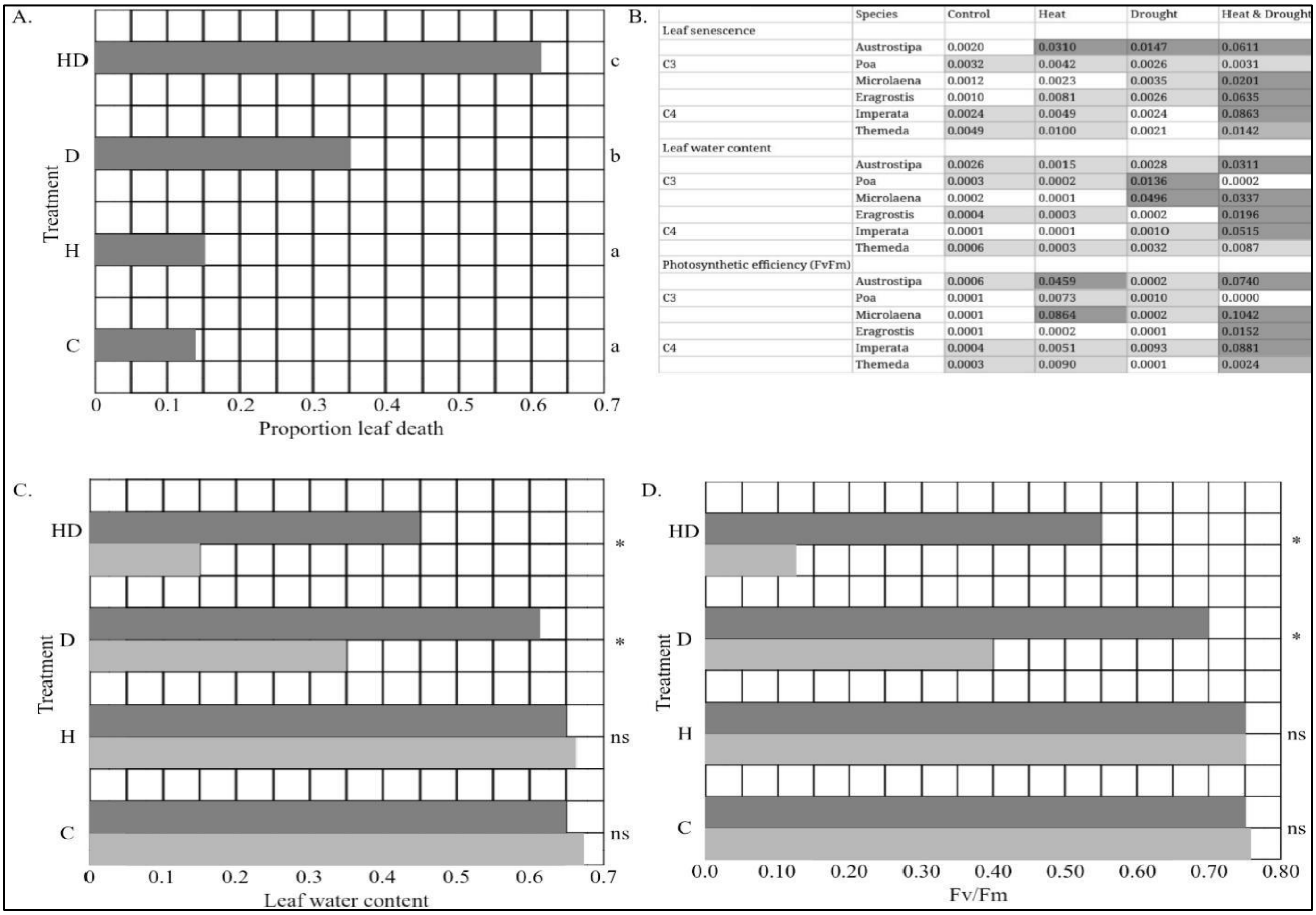
➢ *Species-Specific Thermal Tolerance and Adaptation*

Thermal tolerance varies substantially among species within the Poaceae family. Cold-adapted species, such as Poa, exhibit strong germination and survival under low temperatures, while major crops like rice and wheat show greater sensitivity to extreme conditions. This variability reflects diverse evolutionary adaptations and ecological niches.

➢ *Implications for Crop Resilience and Climate Adaptation*

The collective evidence underscores the importance of understanding temperature-driven responses in plants, particularly in the context of climate change. Insights into species-specific tolerance mechanisms and stress responses can inform breeding strategies aimed at improving thermal resilience, enhancing productivity, and ensuring agricultural sustainability under increasingly variable environmental conditions.



	Species	Control	Heat	Drought	Heat & Drought
Leaf senescence					
	Austrostipa	0.0020	0.0310	0.0147	0.0611
C3	Poa	0.0032	0.0042	0.0026	0.0031
	Microlaena	0.0012	0.0023	0.0035	0.0201
	Eragrostis	0.0010	0.0081	0.0026	0.0635
C4	Imperata	0.0024	0.0049	0.0024	0.0863
	Themeda	0.0049	0.0100	0.0021	0.0142
Leaf water content					
	Austrostipa	0.0026	0.0015	0.0028	0.0311
C3	Poa	0.0003	0.0002	0.0136	0.0002
	Microlaena	0.0002	0.0001	0.0496	0.0337
	Eragrostis	0.0004	0.0003	0.0002	0.0196
C4	Imperata	0.0001	0.0001	0.0010	0.0515
	Themeda	0.0006	0.0003	0.0032	0.0087
Photosynthetic efficiency (FvFm)					
	Austrostipa	0.0006	0.0459	0.0002	0.0740
C3	Poa	0.0001	0.0073	0.0010	0.0000
	Microlaena	0.0001	0.0864	0.0002	0.1042
	Eragrostis	0.0001	0.0002	0.0001	0.0152
C4	Imperata	0.0004	0.0051	0.0093	0.0881
	Themeda	0.0003	0.0090	0.0001	0.0024

Fig 3 A Collection of Data from a Study About Six Types of Native Grasses C3 (Austrostipa Ramosissima, Microlaena Stipoides, and Poa Labillardierei) and C4 Species (Eragrostis Elongata, Imperata Cylindrica, and Themeda Triandra) Under four Conditions: C (Control), H (Heat), D (Drought) and HD (Heat and Drought).

The study compared physiological and growth responses of six native Eastern Australian grasses. The grasses were grouped according to their photosynthetic pathways: C3 (cool-season) species: *Austrostipa ramosissima*, *Microlaena stipoides*, and *Poa labillardierei* and C4 (warm-season) species: *Eragrostis elongata, Imperata cylindrica, and Themeda triandra*. To understand how native grasses respond to heat waves and limited water conditions, experiments were conducted under four conditions: (C) control, (H) heat, (D) drought, and (HD) heat and drought. The numbers on the X - axis are the proportion or measured value of the plant response under four conditions. A value of 0 means all the parts of the plants stayed alive, while a higher value (0.7 or 0.70) means 70% died. Key metrics measured included leaf death, leaf water content, and photosynthetic efficiency (Fv/Fm).

➢ *Leaf Senescence Responses of Six Native Grasses Under Four Conditions*

Show that plants exposed to both heat and drought had the most leaf death, meaning they were the most stressed. Plants with only heat or drought had also more leaf death than the control. The control had the least leaf death, proving that the changes were caused by the treatments.

➢ *Variation in Leaf Senescence, Leaf Water Content, and Fv/Fm About Six Species Under Four Conditions*

Variances are grouped by shading: no shading shows the lowest 25%, light shows the middle 50%, and dark shows the highest 25%. Leaf death was higher and most varied under heat and drought, meaning some plants lost a lot of leaves while others were less affected. The amount of water in the leaves was also the most varied when the grasses faced heat and drought. Even though drought caused little change, it

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shows that some grasses can hold water better than others in tough conditions. The ability of plants to perform photosynthesis was also affected differently by the conditions.

➢ *Leaf Water Content of Australian Native Grasses Under Four Conditions*

The light gray represents C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) grasses while the dark gray represents C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses. Under heat and drought, C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) grasses had the lowest leaf water content, while C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses still had their water. In drought, C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) grasses lost more water from their leaf than C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses. Under control and heat, both C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) and C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses had similar leaf water levels.

➢ *Maximum Photosynthetic Efficiency (Fv/Fm) of Australian Native Grasses Under Four Conditions*

In normal and heat conditions, both C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) and C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses performed the same and had good photosynthesis. Under drought, C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) grasses performed worse in photosynthesis, while C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses did not change at all. Under heat and drought, C3 (*Austrostipa ramosissima, Microlaena stipoides, and Poa labillardierei*) grasses performed the worst, meaning their photosynthesis was badly affected. C4 (*Eragrostis elongata, Imperata cylindrica, and Themeda triandra*) grasses still remained unchanged.

IV. CONCLUSION

This systematic review emphasizes the significant influence of thermal energy on the growth and physiological response within the Poaceae family. The findings show that the ideal temperature range for growth, physiology and high yields is between 20°C - 25°C. A temperature outside of this range triggers a stress reaction that may interfere with the species' typical physiology, growth, production, development, and flowering.

These findings show the primary strategies used to reduce the detrimental effects of temperature on the Poaceae family by utilizing their natural genetic and physiological adaptations. These methods include choosing species with enhanced vernalization and controlling environmental factors, such as modifying the planting time slightly, providing protection during extreme temperatures, and checking to see if there are any changes or other factors influencing it.

Despite existing gaps in the current understanding of the thermal energy responses influencing growth and physiological processes within the Poaceae family, as well as their long-term adaptive capacity, future research should prioritize interpreting the genetic and physiological mechanisms underlying thermal resilience. The integration of advanced analytical technologies, climate modeling frameworks, and comprehensive field investigations will be instrumental in developing sustainable and evidence-based solutions. By synthesizing multidisciplinary scientific insights and methodological approaches, researchers will be better positioned to anticipate, mitigate, and manage the impacts of thermal stress on Poaceae species, thereby contributing to the preservation of global food security in the context of ongoing climate change.

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