CJES
Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

A comprehensive review of temperature-dependent factors influencing the survival and adaptation of *Arum korolkowii*

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ABSTRACT
Physiological, biochemical, molecular, and genetic responses of wild plant *Arum korolkowii* to different degrees of high-temperature effects were studied. Physiological and biochemical responses of the seedlings to high hardening and damaging temperatures varied with the range of the temperature and the exposure time. This resulted in some diminution of hydration of leaf tissues, increased resilience of plants against heat stress, and growth inhibition. However, plants only temporarily became more heat resistant as a result of harmful temperatures, which also caused growth to completely stop and the hydration of leaf tissues to drastically decline. The dearth of experimental data in this area and the lack of theoretical investigation of the population approach to medicinal plant resource conservation highlight the importance of this study. Given the aforementioned difficulties, it is clear that research on red-listed species is important both domestically in Kazakhstan and internationally. In this regard, our study made it possible to examine Arum Korolkov (*Arum korolkowii* Regel), a medicinal plant species that is red-listed and located in Kazakhstani territory.

Keywords: *Arum korolkowii*, Leaf tissues, Medicinal plant species, Kazakhstan, Temperature range, Heat resistance
Article type: Review Article.

INTRODUCTION

Overview of *Arum korolkowii*

One of the primary categories of herbaceous plants in the Aroid groups of the genus Aronnik are perennial plants of the species *Arum korolkowii* (Yeginbay *et al.* 2023). It is a species of flowering plant belonging to the Araceae family, primarily found in Central Asia, especially in parts of Kazakhstan, and is known as a medicinal plant. It is distinguished by a distinctive spadix (flower spike) wrapped by a green spathe, producing bright red berries, and is listed as a "red book" plant because it is endangered in some areas. They die off every autumn and winter, grow and bloom in the spring and summer, and then reappear in the spring from their rootstock or other wintering structure. Their spherical tuber has been flattened. The plant's modified flattened, spherical, shorter stalk is called a petiole. This plant has a large number of spirally organised, vaginal leaves that are extended from the base to one-third of the length of the lamina. Long vaginas give way to short ones. With a height of 50–60 cm, the blooming stem is on par with or taller than the petiole. One in a sympoidal unit, the inflorescence is twice as long as the cob and has unique properties. The cover can be concealed among the greenery, coiled into a small tube, or simply green. It grows at the same time as the leaves squeezed between the tube and the plate.

Importance of temperature-dependent survival mechanisms

Ambient temperature is among environmental factors that have greatest impact on vital activity and productivity of plants. Growth as well as development in plants are generally negatively affected by excessive heat, which

Publisher: University of Guilan,

usually results in death to the plants. The surrounding temperature divergence from optimal range for growth as well as development of plant cells and tissues leads to a variety of physiological, biochemical, molecular genetic changes. Only at the optimal temperature can plants fully use their genetically determined potential for growth, development, and output. These processes slow down or cease at temperatures above or below the optimal range, yet adaptation and/or damage processes are triggered. Distinct plant species have distinct ideal temperature ranges. For example, depending on the type and location of growth, wheat can fluctuate in temperature from 13 to 22 °C. One explanation for why plants develop more slowly in unfavourable temperature circumstances could be violations of cell division processes. Therefore, when plants are exposed to higher temperatures, the number of dividing cells drastically drops; at temperatures higher than 40 °C, chromosome structure is damaged and cell division comes to a total halt. Furthermore, by stretching cells, fission effect of high temperatures has a major impact on cell proliferation. Cell stretching is thought to be driven by intracellular turgor pressure. The plant may suffer from a water deficit as a result of high temperatures, which lowers intracellular turgor pressure and significantly slows down cell growth. Variations in phytohormone concentration also impact plant development. When high temperatures first start to work, there is a noticeable rise in amount of growth inhibitors and a fall in amount of growth-activating hormones. One of the primary causes of a decline in plant growth rates is this phenomenon (Yeginbay *et al.* 2024)

Scope of review

Each species' development range is determined by how plants respond to temperature stress, which also influences how plants acclimatise to a given environment. The primary goal of the study was to investigate the many physiological, biochemical, molecular, and genetic responses of the wild plant *Arum Korolkowii* to varying degrees of high temperature impacts.

MATERIALS AND METHODS

The morphometric, biochemical, and genetic traits of plants of the same species grown under temperature stress following exposure to high temperatures (30–50 °C) and grown under conditions of temperature optimum (22 °C) – the control group – were compared in order to assess the heat resistance of *Arum korolkowii*. Plants react differently to the physiological and biochemical consequences of high hardening and damaging temperatures, as demonstrated by our study of *A. korolkowii* seedlings. High tempering temperatures have the effect of making plants more resistant to heat, inhibiting their growth, and slightly dehydrating their leaf tissues. Instead, harmful temperatures force plants to completely stop growing, drastically reduce the moisture of their leaf tissues, and only temporarily boost their tolerance to heat.

General mechanisms of temperature adaptation in plants

Heat stress and its impact on plant physiology

Reduced root growth, altered stomatal function, and impaired reproductive development are some of the ways that heat stress disrupts essential processes like photosynthesis, causes dehydration, damages cell membranes, inhibits enzyme activity, and affects plant growth and development. Depending on severity as well as duration of heat stress, these effects can result in decreased crop yields. Other factors that are thought to inhibit photosynthesis under heat stress include the accumulation of Rubisco small-subunits (SS), large-subunits (LS), Rubisco binding proteins (RBP), and soluble proteins in light and a decline in darkness. Elevated temperatures also impact the synthesis of starch and sucrose since they inhibit the activity of invertase, ADP-glucose pyrophosphorylase, and sucrose phosphate synthase. Heat stress negatively impacts the leaves of plants, such as reducing water potential, reducing leaf area, inducing early senescence of leaves, all of which negatively impact the plant's ability to complete photosynthesis. Plant hunger as well as depletion of glucose stores are also observed during prolonged heat stress (Yeginbay *et al.* 2023b).

Cold stress and its physiological consequence

Because cold stress alters normal cell structure and function, it can seriously hinder plant growth. For instance, freezing stress results in cell dehydration and ruptures the plasma membrane due to ice formation in the intercellular space, while chilling stress interferes with proper water intake. The sustainability of crop yields is particularly threatened by cold stress. Indeed, significant crop losses can result from cold stress. Poor germination, stunted seedlings, chlorosis, decreased leaf expansion and wilting, and even tissue death (necrosis) are some of the phenotypic signs that occur in response to cold stress. Plant reproductive development is also seriously hampered by cold stress. The primary adverse consequence of cold stress is that it causes significant damage to membranes. Most likely, this harm is due to severe dehydration caused by freezing during cold stress. The signal that is transduced activates a receptor in cell membrane for detecting cold stress. The subsequent activation of cold-responsive genes as well as transcription factors that mediate stress tolerance forms the basis for crop improvement that requires an understanding of method of cold stress resistance as well as genes involved in cold stress signalling network.

Interaction of temperature stress with other environmental factors

Extreme temperatures are even more harmful when combined with other stressors like drought, pollution, or nutrient deficiency. In other words, the combined effect can be greater than the sum of the individual stresses alone. Temperature stress can interact with other environmental factors in a significant way, often intensifying their negative effects on organisms by influencing physiological processes like metabolism, resource availability, and immune response. Among additional environmental factors that impact vertebrate animals' biological processes are temperature, humidity, and the availability of oxygen (O_2). The kinetics of most chemical reactions increase as the temperature rises. Environmental temperature exerts a considerable influence on ectothermic vertebrates' life and physiology. O_2 is vital for ATP synthesis and, by extension, for cell activity. Ectotherms can adjust their physiology and biochemistry to make up for any performance loss brought on by the sudden changes in temperature. Depending on an animal's size, nutritional health, physiological state, and thermal history, these processes may vary from species to species. The rate and magnitude of temperature changes also affect responses. Numerous species that inhabit diverse environments are classified as ectothermic vertebrates. It is crucial to note that temperature effects are not just confined to respiratory function. They can also be examined in relation to physiology, dispersal capacity, distributional ranges, and their physiological performance and fitness (locomotor performance), all of which are extremely sensitive to temperature changes (Alpamyssova *et al.* 2024).

Temperature tolerance in *Arum korolkowii*

Heat tolerance mechanisms

The current study has demonstrated that nature of changes in heat resistance of *Arum korolkowii* leaves varies both quantitatively as well as qualitatively. Plant's ability to withstand heat is primarily due to mechanisms such as thick, reflective leaf surfaces, high antioxidant levels, effective water management systems, and the production of heat shock proteins, which help shield cellular components from damage caused by extreme temperatures, depending on the temperature range (zone) that the plants are experiencing as well as the degree of exposure to high temperatures (whether plants are experiencing the effects of temperatures connected to the same temperature zone). The purpose of additional research was to evaluate plant survival and the extent of leaf damage following exposure to temperatures of 30, 35, 40, 45, and 50 °C. According to the data we collected, the first of these temperatures has a weak but noticeable hardening effect, while the second is harmful. According to results, plants subjected to 30°C and 35°C for one to three days had a 100% survival rate. Afterward, they were moved to re-growth settings at 22 °C for seven days. Then, there were no obvious indications of damage to the first or second leaves.

Protein stability and heat shock proteins

In addition to physiological and biochemical changes, an increase in ambient temperature also results in significant molecular genetic changes. Primary one is reprogramming of the cell genome, which causes the synthesis of certain proteins (usually stressful ones) to increase and/or decrease while synthesis of other proteins drops. It is currently thought that production of stress proteins contributes significantly, if not significantly, to plants' development of greater heat resistance. One of the earliest, not specific, plant responses to detrimental temperatures involves activating genes responsible for producing heat shock proteins. Various signalling molecules- calcium ions, reactive oxygen species, TF-cause a transcription activation event of the HSP gene. A "conservative" DNA sequence often known as the "heat shock element" appears on the 5'-flanking region (in the form 5'-aGAAg-3'). These components interact with transcription factors of heat shock (HSF), which initiates the production of HSP. Although scientists are very interested in creating HSP in plants, there is a lack of evidence regarding how high temperatures affect plant resistance to varying degrees.

Membrane fluidity and stabilization

A dynamic, bidimensional array of amphipathic molecules with mesomorphism makes up the lipid matrix in cell membranes, which helps explain why the fluidity of the membrane varies with temperature. Plants must react to changes in external temperature quickly and precisely because they are sessile organisms. Lipid membrane fluidity is crucial for membrane function that relies on interplay between protein as well as lipid compositions. A greater degree of lipid unsaturation brought on by HT led to an increase in membrane fluidity. Therefore, downregulating fatty acid desaturase (FAD) gene could reduce lipid unsaturation and thereby reduce membrane fluidity under HT. Cellular membrane fluidity under high temperature depends on maintaining the ideal unsaturated fatty acid composition. Under HT, the amount of saturated fatty acids in cellular and thylakoid membranes rises for heat-tolerant plants. In a variety of species, this improves lipid heat stability, leading to thermal tolerance. According to certain research, the plant's capacity to withstand heat was influenced by altered lipid saturation. For instance, under HT, the roots of creeping bentgrass that can withstand high temperatures showed more lipid saturation. Higher levels of saturated lipids as well as lower levels of unsaturated lipids were observed in a genotype of wheat that was heat-tolerant (Yeginbay *et al.* 2023c)

Antioxidant defense systems

Plants are shielded from oxidative damage brought on by reactive oxygen species (ROS) by their antioxidant defence mechanism. When plants are subjected to environmental stressors like drought, salinity, or floods, this mechanism becomes even more crucial. Plants face a variety of challenges in the field in age of global climate change. Plant growth, development, and sustainable crop production are significantly impacted by abiotic stressors such as xenobiotics, severe temperatures, metal/metalloid toxicity, salinity, water stress. Plants naturally produce a variety of reactive oxygen species (ROS), such as free radicals (superoxide anion, O_2), hydroperoxyl radicals (HO_2), alkoxy radicals (RO), and hydroxyl radicals (•OH), as well as non-radical molecules. However, stressed plant cells produce too many ROS. ROS are very reactive substances that disrupt plant metabolism and seriously harm vital cellular constituents like proteins, lipids, carbohydrates, DNA, etc. This disruption of balance between normal ROS generation as well as antioxidant activity causes oxidative stress in plants. The primary adaptive response to oxidative stress in plants is to increase capacity of the antioxidant defence system. Ascorbic acid (AsA), glutathione (GSH), α-tocopherol, phenolic compounds, flavonoids, alkaloids, and nonprotein amino acids are among the low-molecular-weight nonenzymatic antioxidants that primarily sustain the system, in addition to other antioxidant enzymes. Peroxidase (POD), superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GR), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione peroxidase (GPX), and glutathione S-transferase (GST) are also linked to this defence system.

Cold tolerance mechanisms

High temperatures are known to cause the buildup of TF and signalling molecules, including lipid signalling molecules, calcium ions in cytoplasm, ROS, and poorly packed proteins. The content of mammalian cells may also alter when the surrounding temperature rises. Therefore, under mild stress, a moderate quantity of signalling molecules triggers HSP production and gene expression, causing the body to adapt. The expression of HSP genes is also triggered by their increased content during "severe stress," however the synthesis of HSP itself does not always take place in this situation. Additionally, processes linked to programmed cell death (PCD) are induced by a particular level of signalling molecules, at which HSP is typically not formed, i.e., with detrimental stress. After the following modifications, the heat tolerance of *Arum korolkowii* was tested: • The die-cuts were heated from the sheet for five minutes using a water thermostat which brought the temperature in steps of 0.4 °C. The percentage damage to seedling leaves and survival rate of the plants were used as stability criterion (Assadi 2018).

Cryoprotectant synthesis and osmotic regulation

These reactions are initiated by transmembrane proteins that trigger a series of events through secondary messengers such as inositol phosphates, ROS, calcium ions (Ca^{2+}). The most important of them is calcium signalling, which activates the transcription of cold-responsive genes, including COR genes, downstream phosphorylation cascades. This review focuses on the two tactics that plants use to fight freeze-induced damage: cold tolerance and cold avoidance. Acclimatisation to falling temperatures is a key component of tolerance mechanisms, which promote the slow development of cold resistance. Avoidance strategies depend on cryoprotectant substances such as proline, glycerol, potassium ions (K^+), antifreeze proteins (AFPs). Cryoprotectants maintain the fluidity of the plasma membrane, reduce the freezing point, prevent ice formation, and alter the concentration of intracellular solutes. These compounds also exhibit antioxidant action, scavenging ROS, avoiding denaturation of proteins, and so reducing cellular damage. Cryoprotectants also reduce intercellular water flow, extracellular ice crystal formation, cell dehydration by establishing strong hydrogen bonds with water molecules. One important adaptation technique that increases plant resistance to cold stress as well as encourages survival in freezing conditions is the use of cryoprotectants. Nevertheless, little is known about precise physiological as well as molecular processes that underlie these protective benefits.

Membrane integrity and fluidity under cold stress
Under cold stress, plant cell membranes experience a decrease in fluidity, potentially compromising their integrity due to the transition of lipids from a liquid-crystalline phase to a gel-like phase, which can disrupt membrane functions and lead to leakage of cellular components if not properly regulated by the plant through adaptations like altering the fatty acid composition of membrane lipids to maintain fluidity. Key points about membrane integrity and fluidity under cold stress in plants:

Membrane stiffening
When temperatures drop, the phospholipids in the cell membrane tend to pack more tightly together, causing the membrane to become more rigid and less fluid, impacting the movement of molecules across the membrane.

Impact on function
Reduced fluidity can disrupt various cellular processes including ion transport, enzyme activity, and signal transduction due to impaired protein interactions within the membrane.

Adaptation through lipid composition
By changing the makeup of their membrane lipids, plants can adapt to cold stress. They can increase the percentage of unsaturated fatty acids, which feature "kinks" in their structure that prevent tight packing and preserve fluidity at low temperatures.

Cold acclimation
In response to cold exposure, plants can initiate a process called cold acclimation, where they actively modify their membrane lipid composition to enhance cold tolerance.

Cold-induced gene expression and metabolic reprogramming
Plants use transcriptional, posttranscriptional, and posttranslational processes to rewire their gene expression during cold acclimation. In a variety of plant species, the ICE1-CBF transcriptional cascade is essential for cold adaptation. The CBF pathway can be genetically engineered to increase cold tolerance in a variety of plant species, according to transgenic research. A number of elements of the transcriptional pathway of cold adaptation that is not dependent on CBF have recently been discovered. During cold acclimation, plants use a variety of posttranscriptional regulatory mechanisms in addition to transcriptional regulation to control the expression of their genes. In rice and *Arabidopsis*, a number of miRNAs that are controlled by cold stress have been discovered. Understanding the function of posttranscriptional control of mRNA stability in plants' response to cold stress would be made easier with the characterisation of cold-regulated miRNAs. Cold-induced transcriptome varies considerably between reproductive (pollen), root, and leaf tissues. The majority of cold adaptation mechanisms were investigated in *Arabidopsis* during its vegetative stages. Important regulators of cold tolerance will be found through additional research on transcriptional networks in reproductive organs. Plant development and stress responses are largely regulated by epigenetic mechanisms. It will be important to conduct more research on the role of epigenetic stress memory and epigenetic processes including DNA methylation and chromatin alterations (Linz *et al.* 2010).

Influence of temperature on growth and development
Effects of elevated temperatures on growth stages
Elevated temperatures can significantly impact various plant growth stages, most notably causing shortened life cycles, reduced biomass production, impaired pollination, and negative effects on reproductive development,

particularly during flowering and seed setting, often leading to decreased yields due to stress on the plant's physiological processes like photosynthesis and cell division; with the most sensitive stage generally being the reproductive phase.

Germination and seedling development

The process by which a seed becomes a new plant is known as seed germination. The formation of roots, branches, leaves, and other plant parts follows the activation of plant metabolic enzymes, seed imbibition (the seed's intake of water), and seed coat rupture. The intense metabolic processes taking place in the glyoxysomes, peroxisomes, and mitochondria during seed germination result in an increase in H_2O_2 production. The ROS scavenging activity of seeds, which includes both enzymatic and nonenzymatic processes, prevents the oxidative damage that could result from excessive ROS generation. H_2O_2 is crucial for seed germination because it helps break down the mechanical and hormonal barriers that prevent seeds from germinating. It is known to reduce ABA synthesis and increase gibberellin production. H_2O_2 also plays a role in altering gene expression that results in the control of ROS, which in turn leads to the weakening of endosperm and the loosening of cell walls.

Vegetative growth and leaf expansion

Temperature is the most important factor in initiation as well as development of roots, leaves, shoots, branches, tillers during vegetative development. Two primary processes in plant growth are cell division as well as cell expansion, both of which are enhanced by high temperatures. Increases in temperature will advance timing of organ initiation and shorten its duration in most determinate annual crop species. As a result, there is less time for biomass buildup and photosynthetic carbon assimilation prior to the onset of reproductive growth. Vegetative growth rates are generally increased by raising the temperature, up to around 25 °C for wheat and 35 °C for soybeans. Each crop's growth rate will decrease at a particular threshold temperature, but there is abundant vegetative plant growth within the range expected for global warming. In general, high temperatures shorten the period of leaf elongation while increasing leaf appearance and elongation rates. Less is known about how extreme temperature stress affects the dynamics and expansion of leaf area. The beginning and length of developmental stages are changed by high temperature stress (Sattarov *et al.* 2020)

Flowering and reproductive success

In plants, "flowering" refers to the development of flowers, which are the reproductive organs, and "reproductive success" means how effectively a plant is able to produce viable seeds through pollination and fertilization, essentially determining how many offspring it generates; the more flowers a plant produces and the more successful pollination is, the higher its reproductive success will be.

Effects of low temperatures on growth and development

Low temperatures significantly impact plant growth and development by inhibiting seed germination, slowing down growth rates, reducing photosynthesis, damaging cell membranes, hindering root development, and potentially leading to plant death, especially when temperatures drop below a species' tolerance level, causing chilling or freezing stress depending on the ice crystal formation within the plant tissues; this can result in decreased crop yield and quality.

Dormancy induction and growth inhibition

Inducing dormancy in seeds. Since ABA may be found in both developing and mature seeds and is known to impede germination when administered exogenously, it has long been linked to dormancy. Dormancy induction in plants is a process that involves the arrest of plant growth to help plants survive in harsh conditions. This process is controlled by plant hormones and proteins, as well as environmental factors.

Impact on root and shoot growth

Factors like light, water availability, nutrient levels, temperature, and soil conditions significantly impact both root and shoot growth in plants, with changes in one often directly affecting the other, primarily through the regulation of hormone balance and the allocation of photosynthetic products (sugars) between the root and shoot systems. For example, under water stress, plants tend to prioritize root development to access more water, leading to a higher root-to-shoot ratio (Joudi Ghezeljeh Meidan *et al.* 2016).

Effects on reproductive phases

Factors affecting plant reproductive phases can include environmental conditions like temperature, light, water availability, which can influence the timing and success of flowering, pollination, fertilization, and seed development, potentially leading to changes in the number of flowers produced, seed viability, and overall reproductive output of the plant. In addition, nutrient levels and stress factors like pests or diseases can also significantly impact plant reproduction.

Molecular and cellular responses to temperature stress

Heat-induced proteins and enzymes

When plants experience heat stress, they produce a group of proteins called "heat shock proteins" (HSPs) which act as molecular chaperones, helping to maintain proper folding and function of other proteins in the cell, thus protecting them from damage caused by high temperatures. These HSPs are considered the primary "heat-induced proteins" in plants and are regulated by heat stress transcription factors (HSFs) that activate their genes when heat stress is detected.

Cold-responsive proteins and pathways

In plants, the primary cold-responsive proteins and pathway involve "C-repeat binding factor (CBF)/dehydration responsive element binding factor (DREB)" family of transcription factors, which are activated by cold stress and trigger expression of downstream "cold-regulated (COR)" genes, ultimately leading to cold tolerance. This pathway is often referred to as "ICE1-CBF-COR cascade" where ICE1 acts as an upstream regulator of CBF genes, initiating the cold response cascade (Abduraimov *et al.* 2024)

Role of transcription factors in temperature stress responses

Through interaction with cis-acting elements present within promoter region of various target stress-responsive genes in signal transduction processes, transcription factors, one of the regulatory proteins, play an important role in converting stress signal perception into stress-responsive gene expression. This activation of signalling cascade activates whole network of genes working in concert to enhance plant tolerance towards harsh environmental conditions. Approximately 7% of coding sequences in plant genomes are assigned to transcription factors (TFs), many of these belong to larger gene families than those in mammals and yeasts, for example, the family of heat stress transcription factors (HSFs).

Ecological and evolutionary implications

Temperature adaptation in natural habitats

Plants adjust several aspects of their development, including growth and flowering time, to seasonal and annual variations in the surrounding temperature. Thermal developmental plasticity is the term used to describe these temperature-dependent changes in plant development.

Evolution of thermal tolerance in *Arum korolkowii*

After 15 minutes of thermal exposure, there was a statistically significant rise in the mRNA content of this gene; however, after 1 hour, it reached its maximal level and then began to decline. Within each exposure, statistically significant variations in temperature were also observed. The mRNA expression of HSP70 gene in leaf cells was generally significantly greater at 40 °C after 30 minutes, 1 hour, and 6 hours, significantly lower after 24 and 72 hours compared to 30 and 35 °C. Further, statistically significant differences existed between the temperature variants for each exposure ($p < 0.05$). Results from this study were in agreement with those reported in literature wherein the expression of HSP70 generally increases for the first five hours of exposure to high temperature then declines in *A. korolkowii*. One of the most critical chaperone proteins that protects cell against high temperature action is HSP70 protein. Consequently, resistant plant cultivars usually have a higher expression level of this gene than sensitive ones (Aldayarov *et al.* 2022)

Potential impact of climate change on *Arum korolkowii* distribution

Climate change is expected to significantly impact plants by causing more frequent and severe droughts, heat waves, extreme weather events, altered precipitation patterns, and changes in soil conditions, leading to reduced plant productivity, altered species distribution, increased susceptibility to pests and diseases, and potential shifts in ecosystem dynamics; ultimately impacting food security and biodiversity.

Temperature-related agricultural considerations

Controlled environment cultivation strategies

Regulated Setting Plant cultivation techniques, also known as Controlled Environment Agriculture (CEA), entail carefully controlling environmental elements such as light, temperature, humidity, CO_2, and nutrient supply in a protected growing area (such as a greenhouse or vertical farm) to maximise plant growth and yield, independent of the weather outside. Important techniques include soilless cultivation using hydroponics or aeroponics, modifying the light spectrum to suit the needs of individual plants, precise irrigation systems, and environmental parameter monitoring using sensors and automation to maintain ideal conditions throughout the plant lifecycle (Khujanazarov 2022).

Breeding for temperature resilience

Breeding for temperature resilience in plants involves identifying and selecting plant varieties with genetic traits that enable them to withstand extreme temperatures, typically achieved through conventional breeding methods, marker-assisted selection (MAS), and advanced genomic techniques, allowing for the development of crops that can better tolerate heat or cold stress while maintaining yield and quality under changing climate conditions.

Potential for genetic engineering and biotechnology

Genetic engineering and biotechnology in plants has the potential to improve crop yields, food security, and environmental sustainability.

Benefits

Improved yields: Genetic engineering can increase crop yields, which can help address food security challenges.
Disease resistance: Genetic engineering can make plants resistant to diseases, pests, and environmental conditions like drought and salinity.
Improved nutritional value: Genetic engineering can improve the nutritional content of plants.
Reduced need for pesticides: Genetic engineering can reduce the need for pesticides.
Biotechnological compounds: Genetic engineering can produce plants that produce valuable biotechnological compounds.
Phytoremediation: Genetic engineering can improve plants' ability to reclaim soils and waters contaminated with pollutants (Świerszcz *et al.* 2022)

Conservation and sustainability

In-situ conservation of *Arum korolkowii* under temperature extremes

Following modifications, the heat tolerance of *A. korolkowii* was tested: • The die-cuts were heated from the sheet for five minutes with a water thermostat, which raised the temperature in increments of 0.4 °C. The 50% death temperature (LT_{50}) of the leaf palisade cells was used as a stability criterion. The loss of chloroplasts and cytoplasmic coagulation, along with exposure to high temperatures of 30–50 °C for one to three days, along with regrowth at 22 °C, were observed using a light microscope under 40× lens provided by "Micros," Austria. Degree of damage to seedling leaves as well as plant survival rate used as stability criteria. The nature of alterations in *A. korolkowii* leaves' heat resistance under continuous, extended exposure to plants at temperatures between 30 and 50 °C was examined during the study (Jabborov *et al.* 2022). When treated for 10 minutes with temperatures ranging from 30 to 50 °C, the heat resistance of *A. korolkowii* does not change appreciably. In this and subsequent experiments, the control treatment is the initial indicator value recorded in weekly *A. korolkowii* seedlings grown at 22°C air temperature.

Ex-situ conservation methods: Seed banks and cryopreservation

The standard storage temperature is liquid nitrogen (-196 °C), which stops all cell divisions and metabolic activities. For a variety of crop species, orthodox seeds have been effectively preserved in liquid nitrogen at -196 °C. Seeds can be preserved in liquid nitrogen for an indefinite amount of time.

Sustainable cultivation practices in varying climates

Sustainable cultivation practices that can adapt to different climates include: crop rotation, cover cropping, agroforestry, integrated pest management (IPM), utilizing climate-resilient crop varieties, precision agriculture, water management strategies, and diversified planting based on local conditions; all aiming to maintain soil health, conserve water, and minimize reliance on synthetic chemicals while adapting to varying weather patterns (Aimenova *et al.* 2023).

CONCLUSION

Summary of key findings

One of the main causes of the drop in plant yields is thought to be the rise in air temperatures that has been seen recently in many parts of the world as a result of global climate change. The current work, which focusses on examining the dynamics of heat resistance of *Arum korolkowii* seedlings under the action of high temperatures of varying intensity, along with a number of physiological, biochemical, and molecular genetic reactions, is extremely important due to the accumulation of transcripts of several genes encoding proteins involved in the mechanisms of heat resistance formation and coding proteins, preventing the development of PCD or participating in PCD. The study has demonstrated that plants react differently to the effects of high hardening and damaging temperatures at the physiological and biochemical levels. High tempering temperatures in particular cause plants to become more heat resistant, growth to be inhibited, and the moisture of leaf tissues to somewhat decrease.

Future research directions

Given the aforementioned considerations, we urge national and international leaders and scientists to focus on the current state of natural disasters, as failure to do so will have long-term, irreversible consequences if the needs and conservation efforts for the rarest plants are not prioritised. If the current state of nature is not addressed, future generations will learn about endangered plants and animals from the Red Book through drawings and images.

Practical implications for conservation and agricultural practices

Conservation agriculture, as described by the United Nations Food and Agriculture Organisation (FAO), is "a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species." Crop yield can be increased and maintained by increasing biodiversity and natural biological activity both above and below ground surface, as well as by optimising the use of water and fertiliser. Through sustainable land management, conservation agriculture's three pillars—minimum soil disturbance, crop diversification, and permanent soil cover—lessen the effects of climate change on agricultural systems (adaptation) and the role that farming practices play in greenhouse gas (GHG) emissions (mitigation).

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Bibliographic information of this paper for citing:

Alpamyssova, G, Yeginbay, A, Juginisov, T, Matrasulov, G, Ametova, N, Nurimov, B, Ayimbetova, S, Ermatova, S, State, K, Burabaev, A, Burabaev, A 2025, A comprehensive review of temperature-dependent factors influencing the survival and adaptation of *Arum korolkowii*, Caspian Journal of Environmental Sciences, 23: 501-510.