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Abiotic Constraints in Field Pea (*Pisum sativum* L.): Impact and Approaches for Improvement

V Mouleeshwaran [a] and Gritta Elizabeth Jolly [a*]

[a] *Lovely Professional University, Punjab, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Pulses are a major source of dietary protein and play an important role in food and nutritional security, particularly in developing countries. However, climate change combined with the growing incidence of abiotic and biotic stresses represent major limitations to pulse production. Field pea (*Pisum sativum* L.) being one of the most important pulse crop has a range of adaptive responses under drought and heat stress such as changes in roots architecture and increased activity of antioxidant enzymes. Moreover, salt and the heavy metals exposure also cause complex metabolic adaptations. highlighting the need to deepen our understanding of these physiological processes to maintain productivity and crop quality. This paper describes the wide range of stress responses present in field peas and emphasizes the need for integrating classical breeding with novel scientific advances. With increasing demand for food and a changing climate, the paper also identifies research needs for identifying and improving physiological traits related to stress tolerance. Enhancing breeding efforts aimed at developing stress-tolerant field pea genotypes is emphasized as one of the key strategies for sustainable agroecosystems and global food security.

**Corresponding author: E-mail: elizabethgritta41@gmail.com;*

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1. INTRODUCTION

Pisum sativum L., which is commonly referred to green or field pea has gained significant recognition and economic importance as a legume. The presence of nutrients and bioactive compounds has sparked interest in the potential health benefits of consuming peas. As a result, there is an increasing fascination with their use as food (Wu et al., 2023). Peas have their origins in Central Asia, Abyssinia (modern day Ethiopia) and the Mediterranean basin. Additionally, the Near East is recognized as a centre of origin for peas (Vavilov et al., 1926). India holds the second position of being the worlds producer of green peas after China leading. In terms of production 14.5 million tons of green peas and 22 million tons of dry peas are cultivated globally on an annual basis (Senapati et al., 2019). which rank fifth in production after soybeans, peanuts, dry beans, and chickpeas are highly esteemed for their protein profile. They serve as a source of protein with a variety of nutrients distinguishing them from other natural sources of protein (Arif et al., 2020). Field peas can be affected by different stresses such as high salt levels, excessive boron caused by alkaline soil, damage from frost, during reproductive stages, heat stress and moisture stress (Dita et al., 2006). This all-encompassing review systematically investigates and dissects the complex spectrum of mechanisms that enable the pea plant to withstand abiotic stress. It provides a thorough exploration of the varied strategies utilized by the plant to endure and acclimate to adverse environmental conditions.

2. NUTRIENT VALUE OF FIELD PEA

Field peas possess a stability when it comes to viscosity and temperature setting them apart from starch found in tubers or cereals (Guillon and Champ, 2002). Pea starch comes in three forms. One is rapidly digesting starch (RDS), which causes a rapid rise in blood sugar levels. Slowly digestible starch (SDS) is slowly digested in the small intestine and resistant starch (RS) is fermented in the colon and contributes to a lower glycemic index (Guillon and Champ, 2002). The ratio of amylose to amylopectin in pea starch has an influence on how it is digested and its effect on blood glucose levels, after a meal. Moreover, peas have an amylase content of 38% which reduces their digestibility leads to a release of glucose and ultimately contributes to a low glycemic index (Chung et al., 2010). Field peas are a source of protein, with protein content ranging from 14.5%, to 28.5% (Reichert and MacKenzie et al., 1982). There are four categories of pea protein: globulin, albumin, prolamin and glutelin. Globulin and albumin serve as storage proteins with globulin making up 55% to 65% and albumin accounting, for 18% to 25% (Lu et al*.,* 2019). Pea proteins have a balanced composition of amino acids with various amount of essential amino acids. Among these methionine and cysteine are identified as the limiting amino acids (LACs) in pea seeds (Wu et al., 2023). Peas contain lectins also referred to as phytohemagglutinins, that possess the capability to coagulate red blood cells (Owusu-Ansah., 1991). Potassium content in peas is around 1.04% of their weight when they are dry and without hulls. Additionally, phosphorus, magnesium and calcium account for 0.39%, 0.10% and 0.08% of their composition respectively (Dhal et al., 2012). Pea seeds contain minerals such as potassium (ranging from 97 to 99 mg per 100 grams) calcium (between 9 and 11 mg per 100 grams), magnesium (5 to 7 mg per 100 grams) and sodium (3 to 4 mg per 100 grams).

Table 1. Nutrient composition of field pea

S.no	Nutrient	Composition	References
1.	Starch	RDS, SDS, RS	Guillon and Champ, 2002; Singh et al., 2017
2.	Amylase Content	~38%, reduces digestibility, lowers glycemic index	Chung et al., 2010
3.	Protein Content	14.5% to 28.5%, globulin, albumin, prolamin, glutelin	Reichert and MacKenzie et al., 1982; He et al., 2019
4.	Amino Acids	Balanced, methionine and cysteine as limiting	Wu et al., 2023
5.	Minerals	Potassium (1.04%), phosphorus (0.39%), magnesium (0.10%), calcium (0.08%), traces of copper, nickel, selenium, folate, boron	Dhal et al., 2012
6.	Vitamins	Rich in Vitamin B and E (β and γ tocopherols)	Boschin and Arnoldi, 2011
7.	Fiber Composition	Pectin, cellulose, hemicellulose, lignin	Dhingra et al., 2012

They also contain traces of copper, nickel, selenium, folate, and boron (Reichert and MacKenzie et al., 1982). Peas are also rich, in vitamin B. and vitamin E (β and γ tocopherols) (Boschin and Arnoldi, 2011). Peas contain fiber including pectin, cellulose, hemicellulose, and lignin. To extract fiber from pea pods methods, like gravimetric hydrolysis are usually employed. Furthermore, pea pods exhibit antioxidant properties and has the capability to remove free radicals (Dhingra et al., 2012).

3. IMPACT OF DROUGHT STRESS ON FIELD PEA

Plants experience drought stress when soil moisture decreases and water loss through transpiration or evaporation impact them. Drought stress is marked by reduced water content, leaf water potential and pressure potential as the closing of stomata and a decline, in cell enlargement and growth (Anjum et al., 2011). Cell growth is greatly affected by drought because it reduces the pressure, inside cells. When there is lack of water, it can hinder the elongation of cells by interrupting flow of water to those cells that're in the process of elongation (Nonami et al., 1998). Drought stress leads to changes in the morphological, physiological and biochemical reactions. It reduces the transmission rate of nutrients from the soil to the roots and decreases their uptake efficiency (Etienne et al., 2018); It can significantly decrease crop yield and its components viz., grains per pod, 100-seed weight, pods per plant, grain yield per plant, biological yield per plant, and harvest index (Anjum et al., 2011). During periods of drought the roots of field peas tend to grow into the soil as compared to the irrigated one. In fact, 34% of the pea roots can extend beyond a depth of 0.23 meters, in dry soil conditions (Benjamin and Nielsen, 2006). Drought evokes the closure of stomata, which leads to diminished cell growth and photosynthesis (Yudina et al., 2022); Finally, due to drought, there is a decrease in nodulation and the plants' ability to symbiotically fix nitrogen, resulting in less growth of crop yields. Decrease in the rate of water availability, results in a strong reduction in the rate of N uptake in pea plants (Prudent et al., 2016). The levels of chlorophyll showed an increase whereas the amounts of anthocyanins remained unaffected under stress condition. Additionally, there was a rise in the concentration of phenols, in the leaves. (Alexieva et al., 2001). Nitrogen accumulation and dry weight in all parts of the pea plant tend to reduce under moisture stress (Mahieu et al., 2009). Impact and extent of the damage depend on factors such as the duration and severity of water scarcity, stage of crop growth and the specific genotype of the pea plant (Seleiman et al., 2021). In pea plants, the drought stress initiates generation of reactive oxygen species (ROS) in the targeted cell organelles such as chloroplast, peroxisomes and mitochondria subsequently leading to lipid peroxidation, cellular membrane injuries, protein oxidation and DNA damage (Pandey et al., 2023). Deprivation of water at the beginning of flowering stage reduces yield of the pea plants as compared to the water deficiency at the pod-filling stage (Mahieu et al., 2009). The study of Guilioni et al., 2003 indicated that water stress leads to smaller number of reproductive nodes in pea.

In the face of drought stress the levels of antioxidant enzymes such as catalase, ascorbate, superoxide dismutase (SOD) and peroxidase showed an increase in activity. Additionally, oxidative stress triggered the production of glutathione (Mittler et al., 2002). The presence of ABA accumulation, in response to stress is a result of the activation of synthesis and the inhibition of degradation processes. In pea plants it is observed that ABA aldehyde oxidase, Peroxisomal acyl-coenzyme A oxidase 3 plays a role in the generation of ABA, under stress conditions (Zdunek-Zastocka et al., 2004). In pea nodules the presence of an amount of ascorbate (ASC) and glutathione (GSH) under normal condition suggests that these substances have more important roles, than just being used as substrates for enzymes like Ascorbate peroxidase (ASC) peroxidase and docosahexaenoic acid (DHA) reductase. Their abundance is crucial for two purposes creating and maintaining reducing conditions that are necessary for efficient nitrogen fixation and protecting the nodules by counteracting activated oxygen through their antioxidant properties. In essence ASC and GSH play roles in providing the environment for nitrogen fixation while also acting as protective agents against oxidative stress, in the nodules (Dalton., 1995). Antioxidants have a role in keeping the balance of redox and safeguarding plants from harm when they face drought stress. They assist plants in managing the generation of reactive oxygen species (ROS) and ensuring cellular

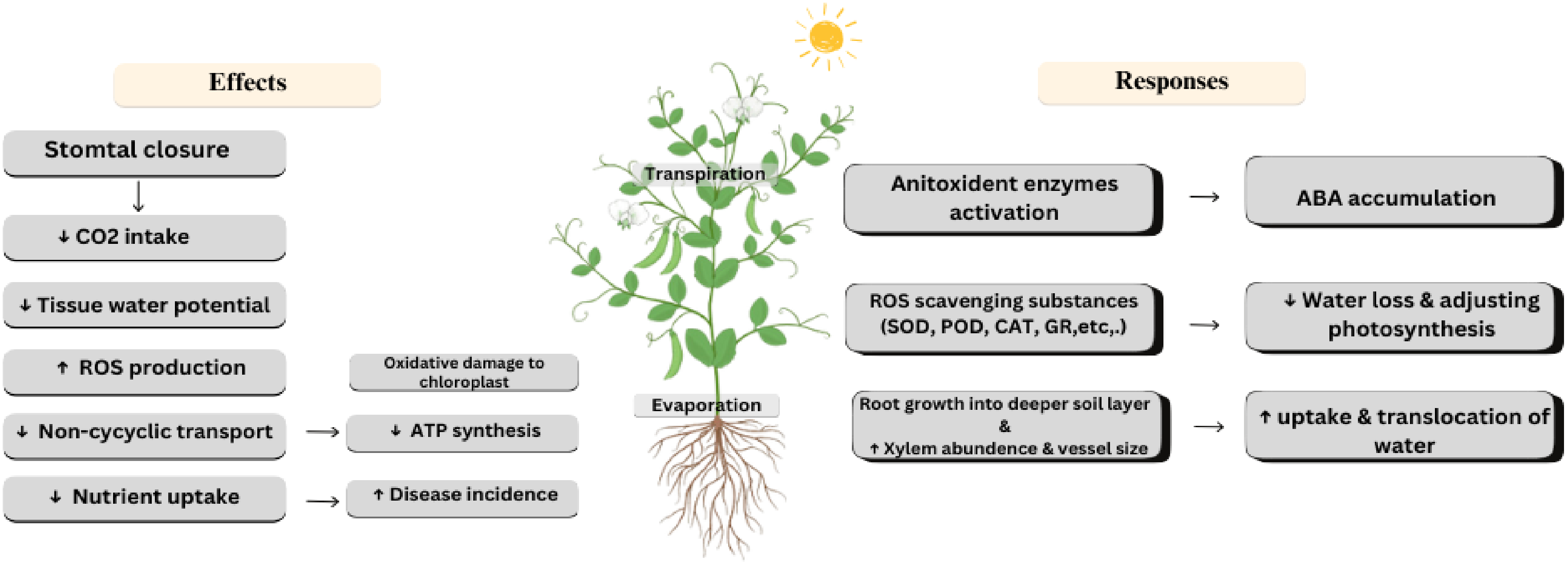

Fig. 1. Effects and responses of drought stress in Field pea

stability ultimately enhancing the plants resistance to unfavourable environmental circumstances (Moran et al., 1994).

4. IMPACT OF HEAT STRESS ON THE FIELD PEA

Heat stress can have effects on pea plants leading to a decrease in growth related factors reduced ability for conductance of lower leaf moisture content and noticeable signs such as leaf curling, wilting, and yellowing. The severity of these impacts varies based on the intensity, duration, and timing of the heat exposure (Sita et al., 2017). The yield of peas decreases when the temperature is exceeded above 25^0C in Australia and 30^0C in Saskatchewan (Sadras et al., 2012). Field pea cultivars grown in the Indian subcontinent under normal growing conditions Flowering stage is the most sensitive phase for field pea cultivars under longer growing conditions especially in regions where flowering occurs during higher atmospheric as well as soil temperature in the months of March and April. The temperature is one of the main challenges faced by pea crop plant at the early vegetative or reproductive growth stage and this may reduce the various yield components of pea. Heat stress resulted in decreased pod and seed number per plant and reduced 100 seed weight of pea cultivars. High temperature induces hot and dry weather during the critical growth stages can check the growth of their host plant by reducing photosynthesis and chlorophyll formation resulting low assimilates utilized for formation of reproductive organs and also reduce pollen germination number of pollen tube per pod and pollen vitality of flowers hence resulting in lesser pod formation and seed setting that ultimately lead to decrease pea crop yield and its quality (Tafesse et al., 2020). The increase in temperature leads to reduction in germination of different pea cultivars on an average of 4-8% which have maximum impact on long maturing cultivars with the germination loss of 16% as compared to early genotypes (Lamichaney et al., 2021). High temperature of 30°C will hinder the formation of root nodules as a result in decrease of root length and leaves size, that promotes early leaf senescence which has a detrimental effect, on their physiological functions (Huang et al., 2016). The maximum threshold temperature for the pollen germination and pollen length for the pea is 36^0C (Jiang et al., 2015). Under late sown condition, for the late maturing genotypes the reduction in the reproductive period (RP) is 6-13% and 18-32% for days to maturity (DTM) (Lamichaney et al., 2021) And also a reduction in plant height (60.2%), total biomass yield (61.7%), seed yield (68.9%) and harvest index (19.3%) has also been observed (vijaylaxmi et al., 2013). Under heat stress, the biomass of field pea tends to decline due to a decrease in leaf area and a reduction in chlorophyll content. These factors adversely affect the efficiency of the crop (McDonald and Paulsen et al., 1997).

Moreover, when plants experience stress, they tend to produce an amount of reactive oxygen species (ROS) which in turn assimilate their ability to effectively convert carbon dioxide during photosynthesis. As a result, the overall efficiency of photosynthesis is negatively affected (Hussain et al. 2021). Field pea plants that are semi leafless and grow upright have shown to have tolerance to heat stress because they can maintain temperatures in their canopy. When choosing plant varieties that can withstand temperatures it is important to focus on traits that are closely linked to yield. It is crucial to plant characteristics based on different indices for effective screening under heat stress conditions as this provides valuable knowledge for the development of resilient field pea varieties (Mahmud et al., 2021).

5. IMPACT OF SALT STRESS IN FIELD PEA

High concentrations of salt in soil can limit the growth and productivity of crops like field peas. This is because most crop plants are sensitive to salt which restricts their ability to reach their potential in terms of growth and yield (Ahmad et al., 2012). Seed germination is negatively affected by salt stress which can hinder water absorption due to stress or the build-up of sodium and chloride, this disrupts nutrient uptake and lead to toxicity. The early stages of seed germination seedling emergence and initial survival are particularly susceptible to the effects of salt (Katembe et al., 1998). Treatment with sodium chloride resulted in a decrease of 77% in Acetylene Reduction Activity (ARA) and a 50% reduction in nitrogenase activity within the nodules of pea plants (Delgado et al., 1994). Salt stress triggered the oxidative stress within their chloroplast and mitochondria resulting in elevated formation of oxide O_2^- and Hydrogen peroxide H_2O_2 (Hernandez et al., 1999). The response of pea plants to different levels of salt varied in terms of reduced shoot weight, nodulation, and recovery after experiencing stress (Hernandez et al., 2002).

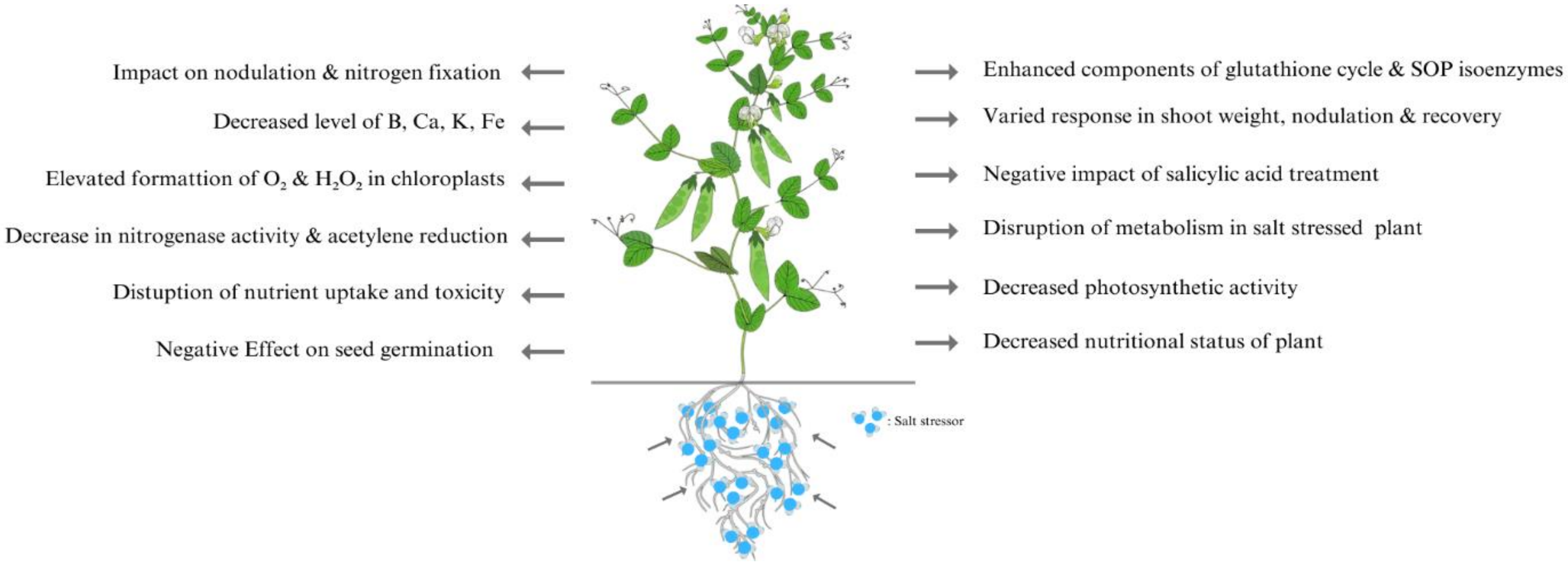

Fig. 2. Effects and responses of salt stress in Field pea

The presence of salt stress resulted in a decrease in the levels of Boron (B), Calcium (Ca), Potassium (K) and Iron (Fe) in pea shoots. This in turn had an impact on the process of nodulation and nitrogen fixation (El-Hamdaoui et al., 2003). Different types of pea plants that can tolerate salt have shown improvements in their ability to defend against damage caused by oxygen species. These improvements were observed in the mitochondria, chloroplasts and cytosolic enzymes where there was an increase in the components of the glutathione ascorbate-glutathione (ASC-GSH) cycle and superoxide dismutase (SOD) isozymes (Hernandez et al., 2002).

6. IMPACT OF HEAVY METAL STRESS ON FIELD PEA

Human activities lead to the buildup of metals including iron (Fe), manganese (Mn), copper (Cu), nickel (Ni), cobalt (Co), cadmium (Cd), zinc (Zn), mercury (Hg) and arsenic in soil. Such activities involve the release of waste the use of fertilizers smelting procedures and sewage disposal (Aydinalp and Marinova et al., 2009). Plants undergo metabolic changes when they are exposed to high levels of toxic heavy metals (Dubey et al., 2011). Cd can also disrupt the absorption and transportation of nitrates which, in turn impacts nitrogen fixation and the process of assimilation (Balestrasse et al., 2003). The xylem vessel, adaxial sclerenchyma, epidermis, stomata and mesophyll cells of Cd-treated plants under CLSM (Confocal laser scanning microscopy) showed strong red fluorescence, indicating O_2^- raises. When dihydroethidium (DHE) was incubated with 2,2,6,6-tetramethylpiperidinooxy (TMP) for 15 min, it was found that the DHE fluorescence was completely eliminated (Rodríguez-Serrano et al., 2009) Excessive exposure to copper results in the generation of stress leading to damage to molecules and causing leaf discoloration. When copper and cadmium are combined it has an impact on the germination process and growth of seedlings (Neelima and Reddy, 2002). Accumulation of Hg2+ in plants can cause damage to disturb the functioning of mitochondria and result in oxidative stress, which can ultimately lead to disruption of biomembrane lipids (Zhou et al., 2007). Cr impact the process of photosynthesis, indues metabolic modification and increases antioxidant mechanisms (Shanker et al., 2003). hexavalent chromium (Cr) affects the pea root plasma membrane (PM). With increasing Cr concentration, the pea root PM structure and function are impaired, resulting in inhibited photosynthesis and suppressed pea growth (Pandey et al., 2009[a]). Addition of chromium to pea plants resulted in an increase in reactive oxygen species (ROS) produced in chloroplasts, and the highest effect was observed for hydroxyl radicals. The increase in ROS levels was found to be concurrent with the decrease in the activity of photosynthetic electron transport under chromium stress especially at 100 µM chromium, suggesting a possible link between chromium-induced generation of ROS and photosynthetic impairment in plants (Pandey et al., 2009[b]). Chromium treatment affected both the ascorbate (ASC) and glutathione (GSH) pool in pea chloroplasts in a similar way, but the effect was more pronounced on the GSH pool with longer exposure to chromium. The ASC level was significantly decreased on chromium application with higher concentrations producing a greater decrease, but the reduced ASC/oxidized dehydroascorbate (DHA) ratio decreased only at higher chromium concentrations. GSH level was significantly changed with higher chromium concentrations and longer duration of treatment, and the oxidized glutathione (GSSG) level was increased (Pandey et al., 2009[b]). Excessive levels of lead can result in characteristics and hinder the functioning of enzymes leading to imbalances, in water content and oxidative stress (Reddy et al., 2005). The exposure to cadmium results in an increased oxidative damage that is reflected by malondialdehyde (MDA) and hydrogen peroxide (H2O2) levels. As an adaptive response to the reported increased oxidative stress, plants can further increase the activity of antioxidant enzymes like catalase (CAT) and peroxidase (POD). The increased activity of these enzymes may represent a key mechanism employed by plants to avoid oxidative stress in response to cadmium-metal exposure. Henceforth, plants' defensive strategies against cadmium-metal induced oxidative stress potentially enhances the resistance of the plant to its harmful effects (El-Okkiah et al., 2022). According to the research conducted by glala et al (2021), the Bioaccumulation Factor (BAF) values suggest that there is an hyperaccumulation of lead and zinc. The reduction in the shoot growth seen in this study unambiguously illustrates that the photosynthetic pigments and Rubisco activity declines with high probability. It means that Cu, in the case of heavy metal toxicity, could disturb some essential biochemical reaction (especially decrease the photosynthesis) that is crucial for growth of plants. However, it is perceived that reduction in photosynthetic pigments, like chlorophyll, is attributed to diminish the efficiency of photonic absorption that provides light energy. While a reduced Rubisco activity impairs the initial carbon fixation phase of Calvin cycle in photosynthesis. The harmful effects, consequently, of biochemical reactions of plant stresses on Chlorophylls and Rubisco eventually decrease the plant growth. (Galal et al., 2021). The translocation factor (TF) values indicate that roots tend to accumulate metals than the aerial parts. Specifically, both lead and cadmium demonstrate a level of translocation (Wysokinski et al., 2023)**.** The pea plants were found to be most sensitive to Cd and Co and slightly tolerant to Pb. All growth attributes decreased significantly in a dose-dependent manner. Peas exhibited 100% sensitivity to both Cd and Co with concentrations ≥750 ppm. The toxicity of heavy metals to pea plants was found in the following order Co > Cd > Pb (Majeed et al., 2019).

7. BREEDING APPROACHES

Enhancing the ability of crops to withstand stress, through breeding methods is restricted by the complex multi gene characteristic of the trait. Nevertheless, stress resistant crops have primarily been developed by incorporating characteristics, from relatives adapted to conditions (Bartels and Sunkar, et al., 2005). Common practices include utilization of intermediary germplasm, hybridization between local varieties and elite lines, and the discovery of drought-adapting traits by exploring the specific growth stages responding to drought stress. High-throughput phenotyping and genotyping, marker-assisted selection (MAS), QTL mapping and GS contributed to accelerating breeding activities. High-throughput technologies, such as next-generation sequencing (NGS) and whole-genome re-sequencing, of various accessions have expanded knowledge on genetic diversity and candidate genes, promoting development of superior, pest and disease free SIFSs (Srivastava et al., 2022). Assessing genotypes for stress response in conditions and comparing yields across environments is a common practice in the field. Drought resistant pea cultivars showed inhibition in their growth rate compared to sensitive varieties with noticeable differences in above ground and root dry matter as well as shoot and root length (Grzesiak et al., 1997). Genome editing approaches, in particular CRISPR/Cas9, have become a powerful tool in contemporary breeding designs for stress resistance in crops. Such methods provide for precise and targeted manipulation of genes and pathways related to stress tolerance, and are more efficient than traditional methods (Sharma et al., 2023; Li et al., 2021). The advancement of marker-assisted selection (MAS), which enables breeders to pick superior genotypes based on genetic information rather than just on observable qualities, depends on the identification of quantitative trait loci (QTLs) associated with drought tolerance (Huang, 2023). These QTLs provide crucial targets for creating markers and enhancing MAS efficiency by identifying particular genomic areas that regulate drought-related characteristics. The development of climate-resilient varieties, such as stress-tolerant peas can further be fast-tracked as breeders can directly manipulate genomic regions associated with desirable traits to increase crop adaptability to altered environmental conditions (Sharma et al., 2023). Different types of peas showed trends in the flavonoid content (TFC) and the activities of antioxidant enzymes. Climax displayed TFC levels and better responses from antioxidant enzymes in situations indicating its ability to thrive as a strong variety. Examination of correlations unveiled connections, between TFC and antioxidant enzymes offering understanding into how these pea varieties respond to stress (Farooq et al., 2021).

8. BIOTECHNOLOGICAL APPROACHES

Traditional breeding methods may not be sufficient to maximize crop yield performance. Therefore, it is essential to enhance breeding efforts by leveraging all resources including advancements (Tábori et al. 2011). The application of tools necessitates an understanding of the target species and the mechanisms underlying stress tolerance (Dita et al.,2006). The management of stress tolerance at a level includes activating and controlling particular stress related genes along with triggering a series of interconnected molecular pathways. Biotechnological techniques are increasingly significant as scientists clone genes linked to stress resilience and uncover how they function (Smirnoff et al.,1998). Novel breeding techniques involve enhancing stress resistance in plants by creating varieties with stress tolerance and studying the cellular basis of stress resilience (Toldi et al. 2010). Stomata regulate water evaporation and research indicates that the lip1 gene plays a role in controlling opening

(Ghasemi et al., 2010). The genetic makeup of field peas comprises around 4.8 billion base pairs distributed across 14 chromosomes with a chromosome count of 2n=2x=14 (McPhee et al. 2007). Recent advancements have identified genes for characteristics and introduced biotechnological approaches to combat both biological and environmental stresses in leguminous plants (Dita et al., 2006). While there have been limited trait locus (QTL) analyses in field peas primarily focused on stress factors with the identification of 72 QTLs for 11 traits none have been associated with environmental stress factors (Dita et al., 2006; McPhee et al., 2007). The use of markers to indirectly select breeding lines accelerates the selection process compared to screening in controlled environments. Various factors such as polymorphism levels between parent lines, marker expression ambiguity, positives discrepancies between marker presence and target genes and the presence of genes across different linkage groups need careful consideration (Dita et al., 2006).

9. TRANSGENIC APPROACHES

In the past the main goal of modification, in peas has been to show that transformation is feasible and to set up a system for genetic alteration. In these experiments genes conferring resistance to antibiotics and herbicides (like nptII, hpt, bar among others) were introduced into pea plants. Although challenges may arise in relation to regeneration during organogenesis there have been gene modifications with agricultural significance reported such as the introduction of genes encoding virus coat proteins and alpha amylase inhibitor (McPhee et al., 2008). Given the risk posed by genetically modified peas characterized by minimal outcrossing rates (less than 1%) gene transformation could prove to be a valuable tool in breeding programs aimed at improving drought tolerance in peas (McPhee et al., 2008). Furthermore, genetic engineering becomes essential when genes associated with drought tolerance originate from species where sexual hybridization's unfeasible (such as relatives or non-plant sources) (Bhatnagar-Mathur et al., 2008). Limited experiments have been conducted on gene modifications to enhance drought tolerance in field peas due to the nature of plant mechanisms for drought resistance at various levels. Whole plant, cellular, metabolic, and genetic (Jewell et al., 2010).

10. CONCLUSION

Field pea is a cool season crop therefore the cultivation is limited to an area. To extend its cultivation to the non-traditional areas, the identification of cultivars that are resilient to the changing environment is important. Climate change leads to variations in precipitation, temperature, and soil characteristics, including increased levels of salt and heavy metals. Therefore, this impact affects crop productivity due to the sensitivity of the crop to climate change. This review examines how the plant responds to stresses such as drought, heat, salt and heavy metal exposure. Field peas exhibit adaptive mechanisms, such as adjusting root growth and activating antioxidant enzymes, to cope with drought conditions. The complex interaction of factors like salt and exposure to metals on field peas requires a detailed understanding of how they respond metabolically. Salt stress can lead to metabolic shifts highlighting the need to uncover the details involved in the plants adaptive processes. As agriculture faces challenges from climate change and the increasing demand, for food sources the insights provided by this thorough review are crucial. Blending centuries wisdom, with cutting edge biotechnological progress presents a harmonious route to cultivating field peas with enhanced resistance to stress. This does not enhance food security but also aligns with the crucial goal of promoting sustainable farming methods. "Future research is likely to explore where ongoing research, into the physiological factors controlling stress responses in field peas could lead to advancements. The search for robust plant varieties of flourishing in environmental settings becomes crucial for sustaining the productivity and nutritional value of this important legume. In this blend of age knowledge and modern scientific advancements field peas emerge as a symbol of optimism providing answers for sustainable farming amidst changing environmental conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahmad, P., Azooz, M. M., & Prasad, M. N. V. (Eds.). (2012). *Ecophysiology and responses of plants under salt stress*. Springer Science and Business Media.

Al Mahmud, A., Alam, M. J., Kundu, B. C., Skalicky, M., Rahman, M. M., Rahaman, E. S., … & Sabagh, A. E. (2021). Selection of suitable potato genotypes for late-sown heat stress conditions based on field performance and stress tolerance indices. *Sustainability, 13*(5), 2770.

Alexieva, V., Sergiev, I., Mapelli, S., & Karanov, E. (2001). The effect of drought and ultraviolet radiation on growth and stress markers in *pea* and *wheat*. *Plant, Cell and Environment, 24*(12), 1337-1344.

Anjum, S. A., Xie, X., Wang, L., Saleem, M. F., Man, C., & Lei, W. (2011). Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research, 6*(9), 2026-2032.

Arif, U., Ahmed, M. J., Rabbani, M. A., & Arif, A. A. (2020). Assessment of genetic diversity in *pea* (*Pisum sativum* L.) landraces based on physico-chemical and nutritive quality using cluster and principal component analysis. *Pak. J. Bot., 52*(2), 575-580.

Aydinalp, C., & Marinova, S. (2009). The effects of heavy metals on seed germination and plant growth on alfalfa plant (*Medicago sativa*). *Bulgarian Journal of Agricultural Science, 15*(4), 347-350.

Balestrasse, K. B., Benavides, M. P., Gallego, S. M., & Tomaro, M. L. (2003). Effect of cadmium stress on nitrogen metabolism in nodules and roots of soybean plants. *Functional Plant Biology, 30*, 57–64.

Barba-Espín, G., Clemente-Moreno, M. J., Alvarez, S., García-Legaz, M. F., Hernández, J. A., & Díaz-Vivancos, P. (2011). Salicylic acid negatively affects the response to salt stress in *pea* plants. *Plant Biology, 13*(6), 909-917.

Bartels, D., & Sunkar, R. (2005). Drought and salt tolerance in plants. *Critical Reviews in Plant Sciences, 24*(1), 23-58.

Benjamin, J. G., & Nielsen, D. C. (2006). Water deficit effects on root distribution of soybean, field *pea* and chickpea. *Field Crops Research, 97*(2-3), 248-253.

Bhatnagar-Mathur, P., Vadez, V., & Sharma, K. K. (2008). Transgenic approaches for abiotic stress tolerance in plants: Retrospect and prospects. *Plant Cell Reports, 27*, 411-424.

Boschin, G., & Arnoldi, A. (2011). Legumes are valuable sources of tocopherols. *Food Chemistry, 127*(3), 1199-1203.

Chung, H. J., Liu, Q., & Hoover, R. (2010). Effect of single and dual hydrothermal treatments on the crystalline structure, thermal properties, and nutritional fractions of *pea*, lentil, and navy bean starches. *Food Research International, 43*(2), 501-508.

Dahl, W. J., Foster, L. M., & Tyler, R. T. (2012). Review of the health benefits of *peas* (*Pisum sativum* L.). *British Journal of Nutrition, 108*(S1), S3-S10.

Dahuan, C., & Kamrun, N. (2023). First report of *Fusarium commune* causing root rot of field *peas* in Canada. *Plant Disease*. Available from https://doi.org/10.1094/PDIS-11-22-2657-PDN

Dalton, D. A. (1995). Antioxidant defenses of plants and fungi. In *Oxidative stress and antioxidant defenses in biology* (pp. 298-355).

Delgado, M. J., Ligero, F., & Lluch, C. L. (1994). Effects of salt stress on growth and nitrogen fixation by *pea*, faba-bean, common bean and soybean plants. *Soil Biology and Biochemistry, 26*(3), 371-376.

Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: A review. *Journal of Food Science and Technology, 49*, 255-266.

DITA, M. A., Rispail, N., Prats, E., Rubiales, D., & Singh, K. B. (2006). Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. *Euphytica, 147*, 1-24.

Donna, L., Lindsay, A., Jha, A. B., Arganosa, G., Glahn, R. P., & Warkentin, T. D. (2021). Agronomic performance in low phytic acid field *peas*. Available from https://doi.org/10.3390/PLANTS10081589

Dubey, R. S. (2011). Metal toxicity, oxidative stress and antioxidative defense system in plants. In S. D. Gupta (Ed.), *Reactive Oxygen Species and Antioxidants in Higher Plants* (pp. 177–203). CRC Press.

El-Hamdaoui, A., Redondo-Nieto, M., Torralba, B., Rivilla, R., Bonilla, I., & Bolaños, L. (2003). Influence of boron and calcium on the tolerance to salt of nitrogen-fixing *pea* plants. *Plant and Soil, 251*, 93-103.

El-Okkiah, S. A., El-Tahan, A. M., Ibrahim, O. M., Taha, M. A., Korany, S. M., Alsherif, E. A., … & Sharaf-Eldin, M. A. (2022). Under cadmium stress, silicon has a defensive effect on the morphology, physiology, and anatomy of *pea* (*Pisum sativum* L.) plants. *Frontiers in Plant Science, 13*, 997475.

Etienne, P., Diquelou, S., Prudent, M., Salon, C., Maillard, A., & Ourry, A. (2018). Macro and micronutrient storage in plants and their remobilization when facing scarcity: The case of drought. *Agriculture, 8*.

Farooq, M., Ahmad, R., Shahzad, M., Sajjad, Y., Hassan, A., Shah, M. M., … & Khan, S. A. (2021). Differential variations in total flavonoid content and antioxidant enzymes activities in *pea* under different salt and drought stresses. *Scientia Horticulturae, 287*, 110258.

Galal, T. M., Hassan, L. M., Ahmed, D. A., Alamri, S. A., Alrumman, S. A., & Eid, E. M. (2021). Heavy metals uptake by the global economic crop (*Pisum sativum* L.) grown in contaminated soils and its associated health risks. *PLoS One, 16*(6), e0252229.

Ghasemi, S., Moazam Jazi, M., & Seyedi, S. M. (2010). A role for *Pisum sativum* lip1 protein in the regulation of stomatal opening. *Abstract Book of the International Food Legumes Research Conference and 7th European Conference on Grain Legumes*, Antalya, April 26–30, 2010.

Grzesiak, S., Iijima, M., Kono, Y., & Yamauchi, A. (1997). Differences in drought tolerance between cultivars of field bean and field *pea*. Morphological characteristics, germination and seedling growth. *Acta Physiologiae Plantarum, 19*, 339-348.

Guilioni, L., Wéry, J., & Lecoeur, J. (2003). High temperature and water deficit may reduce seed number in field *pea* purely by decreasing plant growth rate. *Functional Plant Biology, 30*(11), 1151-1164.

Guillon, F., & Champ, M. J. (2002). Carbohydrate fractions of legumes: Uses in human nutrition and potential for health. *British Journal of Nutrition, 88*(S3), 293-306.

Hernandez, J. A., & Almansa, M. S. (2002). Short-term effects of salt stress on antioxidant systems and leaf water relations of *pea* leaves. *Physiologia Plantarum, 115*(2), 251-257.

Hernandez, J. A., Campillo, A., & Lluch, C. (2000). Effects of salt stress on nitrogen fixation by *pea* (Pisum sativum L.). *Agronomie, 20*(3), 217-225.

Huang, R., Wang, J. Y., Yao, M. Z., Ma, C. L., & Chen, L. (2022). Quantitative trait loci mapping for free amino acid content using an albino population and SNP markers provides insight into the genetic improvement of tea plants. *Horticulture Research, 9*, uhab029.

Huang, S. (2016). *Characterization of a pea recombinant inbred population for resistance to heat at flowering* (Doctoral dissertation, University of Saskatchewan).

Hussain, A., Ali, S., Rizwan, M., Zia-ur-Rehman, M., Yasmeen, T., Hayat, M. T., … et al. (2019). Morphological and physiological responses of plants to cadmium toxicity. In *Cadmium Toxicity Tolerance Plants* (pp. 47–72). Elsevier. https://doi.org/10.1016/B978-0-12-814864-8.00003-6

Hussain, S., Ulhassan, Z., Brestic, M., Zivcak, M., Zhou, W., Allakhverdiev, S. I., … & Liu, W. (2021). Photosynthesis research under climate change. *Photosynthesis Research, 150*, 5-19.

Jewell, M. C., Campbell, B. C., & Godwin, I. D. (2010). Transgenic plants for abiotic stress resistance. In *Transgenic Crop Plants* (pp. 67-132).

Jiang, Y., Lahlali, R., Karunakaran, C., Kumar, S., Davis, A. R., & Bueckert, R. A. (2015). Seed set, pollen morphology and pollen surface composition response to heat stress in field pea. *Plant, Cell and Environment, 38*(11), 2387-2397.

Katembe, W. J., Ungar, I. A., & Mitchell, J. P. (1998). Effect of salt on germination and seedling growth of two *Atriplex* species (Chenopodiaceae). *Annals of Botany, 82*(2), 167-175.

Kole, C. (Ed.). (2007). *Pulses, sugar and tuber crops* (Vol. 3). Springer Science and Business Media.

Lamichaney, A., Parihar, A. K., Hazra, K. K., Dixit, G. P., Katiyar, P. K., & Singh, D. (2021). Untangling the influence of heat stress on crop phenology, seed set, seed weight, and germination in field pea (*Pisum sativum* L.). *Frontiers in Plant Science, 12*, 635868.

Li, J., Røise, J. J., He, M., Das, R., & Murthy, N. (2021). Non-viral strategies for delivering genome editing enzymes. *Advanced Drug Delivery Reviews, 168*, 99-117.

Lu, Z. X., He, J. F., Zhang, Y. C., & Bing, D. J. (2019). Composition, physicochemical properties of pea protein and its application in functional foods. *Critical Reviews in Food Science and Nutrition*. https://doi.org/10.1080/10408398.2019.1651248

Magyar-Tábori, K., Mendler-Drienyovszki, N., & Dobránszki, J. (2011). Models and tools for studying drought stress responses in peas. *OMICS: A Journal of Integrative Biology, 15*(12), 829-838.

Mahieu, S., Germon, F., Aveline, A., Hauggaard-Nielsen, H., Ambus, P., & Jensen, E. S. (2009). The influence of water stress on biomass and N accumulation, N partitioning between above and below ground parts and on N rhizodeposition during reproductive growth of pea (*Pisum sativum* L.). *Soil Biology and Biochemistry, 41*(2), 380–387.

Majeed, A., Muhammad, Z., & Siyar, S. (2019). Assessment of heavy metal induced stress responses in pea (*Pisum sativum* L.). *Acta Ecologica Sinica, 39*(4), 284-288.

Malik, N. J., Chamon, A. S., Mondal, M. D., Elahi, S. F., & Faiz, S. M. A. (2011). Effect of different levels of zinc on growth and yield of red amaranthus and rice. *Journal of Bangladesh Young Researchers, 1*(1), 79-91.

McDonald, G. K., & Paulsen, G. M. (1997). High temperature effects on photosynthesis and water relations of grain legumes. *Plant and Soil, 196*, 47-58.

McPhee, K. E. (2007). Pea. In C. Kole (Ed.), *Genome Mapping and Molecular Breeding in Plants: Pulses, Sugar and Tuber Crops* (pp. 32–47). Springer.

McPhee, K. E. (2008). Pea. In C. Kole & T. C. Hall (Eds.), *Compendium of Transgenic Plants: Transgenic Legume Grains and Forages* (pp. 57–70). Blackwell Publishing.

Mejri, F., Khoud, H. B., Njim, L., Baati, T., Selmi, S., Martins, A., … & Hosni, K. (2019). In vitro and in vivo biological properties of pea pods (*Pisum sativum* L.). *Food Bioscience, 32*, 100482.

Mittler, R. (2002). Oxidative stress, antioxidants and stress tolerance. *Trends in Plant Science, 7*(9), 405-410.

Moran, J. F., Becana, M., Iturbe-Ormaetxe, I., Frechilla, S., Klucas, R. V., & Aparicio-Tejo, P. (1994). Drought induces oxidative stress in pea plants. *Planta, 194*, 346-352.

Neelima, P., & Reddy, K. J. (2002). Interaction of copper and cadmium with seedlings growth and biochemical responses in *Solanum melongena*. *Environmental Pollution Technology, 1*, 285-290.

Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials. *Journal of Plant Research, 111*, 373-382.

Owusu-Ansah, Y. J., & McCurdy, S. M. (1991). Pea proteins: A review of chemistry, technology of production, and utilization. *Food Reviews International, 7*(1), 103-134.

Pandey, J., Devadasu, E., Saini, D., Dhokne, K., Marriboina, S., Raghavendra, A. S., & Subramanyam, R. (2023). Reversible changes in structure and function of photosynthetic apparatus of pea (*Pisum sativum*) leaves under drought stress. *The Plant Journal, 11*.

Pandey, V., Dixit, V., & Shyam, R. (2009a). Chromium (VI) induced changes in growth and root plasma membrane redox activities in pea plants. *Protoplasma, 235*, 49-55.

Pandey, V., Dixit, V., & Shyam, R. (2009b). Chromium effect on ROS generation and detoxification in pea (*Pisum sativum*) leaf chloroplasts. *Protoplasma, 236*, 85-95.

Prudent, M., Vernoud, V., Girodet, S., & Salon, C. (2016). How nitrogen fixation is modulated in response to different water availability levels and during recovery: A structural and functional study at the whole plant level. *Plant and Soil, 399*(1), 1–12.

Reddy, A. M., Kumar, S. G., Jyotsnakumari, G., Thimmanayak, S., & Sudhakar, C. (2005). Lead induced changes in antioxidant metabolism of horsegram (*Macrotyloma uniflorum*) and bengal-gram (*Cicer arietinum* L.). *Chemosphere, 60*, 97–104.

Reichert, R. D., & MacKenzie, S. L. (1982). Composition of peas (*Pisum sativum*) varying widely in protein content. *Journal of Agricultural and Food Chemistry, 30*(2), 312–317. https://doi.org/10.1021/jf00110a024

Rodríguez-Serrano, M., Romero-Puertas, M. C., Pazmino, D. M., Testillano, P. S., Risueño, M. C., Del Río, L. A., & Sandalio, L. M. (2009). Cellular response of pea plants to cadmium toxicity: Cross talk between reactive oxygen species, nitric oxide, and calcium. *Plant Physiology, 150*(1), 229-243.

Sadras, V. O., Lake, L., Chenu, K., McMurray, L. S., & Leonforte, A. (2012). Water and thermal regimes for field pea in Australia and their implications for breeding. *Crop and Pasture Science, 63*(1), 33-44.

Seleiman, M. F., al-Suhaibani, N., Ali, N., Akmal, M., Alotaibi, M., Refay, Y., Dindaroglu, T., Abdul-Wajid, H. H., & Battaglia, M. L. (2021). Drought stress impacts on plants and different approaches to alleviate its adverse effects. *Plants, 10*(2), 259. https://doi.org/10.3390/plants10020259

Senapati, A. K., Varshney, A. K., & Sharma, K. V. (2019). Dehydration of green peas: A review. *International Journal of Chemical Studies, 7*(2), 1088–1091.

Shanker, A. K., Sudhagar, R., & Pathmanabhan, G. (2003). Growth, phytochelatin SH, and antioxidative response of sunflower as affected by chromium speciation. In *2nd International Congress of Plant Physiology on Sustainable Plant Productivity under Changing Environment* (pp. 23–25). New Delhi, India.

Sharma, A., Boelens, J. J., Cancio, M., Hankins, J. S., Bhad, P., Azizy, M., ... & LaBelle, J. L. (2023). CRISPR-Cas9 editing of the HBG1 and HBG2 promoters to treat sickle cell disease. *New England Journal of Medicine, 389*(9), 820-832.

Sita, K., Sehgal, A., HanumanthaRao, B., Nair, R. M., Vara Prasad, P. V., Kumar, S., ... & Nayyar, H. (2017). Food legumes and rising temperatures: Effects, adaptive functional mechanisms specific to reproductive growth stage, and strategies to improve heat tolerance. *Frontiers in Plant Science, 8*, 298433.

Smirnoff, N. (1998). Plant resistance to environmental stress. *Current Opinion in Biotechnology, 9*(2), 214-219.

Srivastava, R. K., Yadav, O. P., Kaliamoorthy, S., Gupta, S. K., Serba, D. D., Choudhary, S., ... & Varshney, R. K. (2022). Breeding drought-tolerant pearl millet using conventional and genomic approaches: Achievements and prospects. *Frontiers in Plant Science, 13*, 781524.

Tafesse, E. G., Gali, K. K., Lachagari, V. B. R., Bueckert, R., & Warkentin, T. D. (2020). Genome-wide association mapping for heat stress responsive traits in field pea. *International Journal of Molecular Sciences, 21*(6), 2043. https://doi.org/10.3390/ijms21062043

Tamindžić, G., Ignjatov, M., Miljaković, D., Červenski, J., Milošević, D., Nikolić, Z., & Vasiljević, S. (2023). Seed priming treatments to improve heat stress tolerance of garden pea (*Pisum sativum* L.). *Agriculture, 13*(2), 439.

Tkalec, M., Styefanić, P. P., Cvjetko, P., Sikic, S., Paulica, M., & Balew, B. (2014). The effect of cadmium-zinc interactions on biochemical responses in tobacco seedlings and adult plants. *PLOS ONE, 9*(1), e87582. https://doi.org/10.1371/journal.pone.0087582

Toldi, O. T. T. O., Tuba, Z., & Scott, P. (2010). Can lessons learned from resurrection plants be extended to crop plant species? *Romanian Biotechnological Letters, 15*(2), 3–11.

Vavilov, N. L. (1926). Centers of origin of cultivated plants. *Institute of Applied Botany and Plant Breeding, 16*(2).

Vijaylaxmi, (2013). Effect of high temperature on growth, biomass, and yield of field pea. *Legume Research, 36*, 250–254.

Vinocur, B., & Altman, A. (2005). Recent advances in engineering plant tolerance to abiotic stress: Achievements and limitations. *Current Opinion in Biotechnology, 16*(2), 123-132.

Wu, D. T., Li, W. X., Wan, J. J., Hu, Y. C., Gan, R. Y., & Zou, L. (2023). A comprehensive review of pea (*Pisum sativum* L.): Chemical composition, processing, health benefits, and food applications. *Foods, 12*(13), 2527. https://doi.org/10.3390/foods12132527

Wysokinski, A., Kuziemska, B., & Lozak, I. (2023). Heavy metal allocation to pea plant organs (*Pisum sativum* L.) from soil during different development stages and years. *Agronomy, 13*(3), 673. https://doi.org/10.3390/agronomy13030673

Yudina, L., Gromova, E., Grinberg, M., Popova, A., Sukhova, E., & Sukhov, V. (2022). Influence of burning-induced electrical signals on photosynthesis in pea can be modified by soil water shortage. *Plants, 11*(4), 534. https://doi.org/10.3390/plants11040534

Zdunek-Zastocka, E., Omarov, R. T., Koshiba, T., & Lips, H. S. (2004).

Activity and protein level of AO isoforms in pea plants (*Pisum sativum* L.) during vegetative development and in response to stress conditions. *Journal of Experimental Botany, 55*(401), 1361-1369.

Zhou, Z. S., Huang, S. Q., Guo, K., Mehta, S. K., Zhang, P. C., & Yang, Z. M. (2007). Metabolic adaptations to mercury-induced oxidative stress in roots of *Medicago sativa* L. *Journal of Inorganic Biochemistry, 101*, 1–9.

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