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# Drought Stress on Barley Crop: A Review

Anand George[1], R. Murali[1], Gritta Elizabeth Jolly[1], M. Jincy[1]

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## ABSTRACT

In worldwide water is one of the main limiting factor for crop production. Drought stress is one of the complex phenomenon affects the crop growth in physiological, morphological and molecular level. Barley (*Hordeum vulgare*) is a cereal crop of commercial importance, which is subjected to severe drought stress. Drought stress is the main constraint in crop production of barley, it will cause more yield loss than other abiotic stress. Due to climate change the severity and frequency of drought stress is also increasing worldwide. Drought stress affects and influence almost all the stages of plat growth development by decreasing the photosynthetic rate, flowering, quality of grain and ultimately end up with reduction in yield. Meanwhile it is a serious challenge for global food security due to increase in world population. Therefore the most effective way to overcome the food crisis due to climate change for the increasing population is identification and development of high drought tolerance barley cultivars with good yield.

**Key words:** Antioxidant, Barley, Drought, Oxidant, Salicylic acid, Selenium.

[1]School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India.

**Corresponding Author:** M. Jincy, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India. Email: mjincyk@gmail.com

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Barley is a cereal crop which is scientifically known as *Hordeum vulgare*, is of the family of grasses (Poaceae) and it is a popular edible grain. Barley has been an invaluable crop since the fertile crescent period. It was the major cereal crop for man before the massive cultivation of major food grains namely paddy, wheat and maize (FAO-2022 Report). Globally, after wheat, rice and maize, barley has the 4$^{th}$ great position of grain crop. Today, 55-60% of the total world production is used as animal feed and 30-40% is used to produce malt (Shahbandeh, 2022). It also acts as a food source for regions like Africa, the Arabian Peninsula and South America. The food crisis prevailing in these regions can also be considered as an outcome of the declined barley production. As per the well-known fact, carbon dioxide levels had a drastic magnification since 1760 namely, industrial revolution. This has been resulted in the rising global temperatures which could also cause drought conditions all over the globe and specifically affected acres of agricultural land and production. Overall, the unpredictably changing climates are becoming a usual thing is not an easy one to overcome through climate forecasting and all. So obviously we should rely on tolerant cultivar breeding like technologies to bring this situation under control. Barley can be grown in a variety of environments like arctic latitudes and alpine latitudes to saline desert oases. So, barley is also known as a tough cereal due to its stress tolerance which can't be found in other cereals. Samarah *et al.* (2009) reported that in barley drought stress could highly affects the grain yield by 49-87%.

The barley does its finest in growing seasons of 90 days at least, but barley can also able to be grown and produce yields in a small time period when comparing with any cereal crop. Cultivating barley is convenient even in brief length of growing period (LGP) which is usually said as of the Himalayan slopes, in spite of that the yield is low than in better areas. This crop, has better resistance to drought stress in contrast to other edible grains and thrives in the dessert like areas of North Africa, where it is mainly grown in the autumn (Guo *et al.,* 2009). Barley crop in spring season is giving a good yield in the cold and moist regions of North America and western Europe. Even though barley has the drought tolerance characteristics than other cereals, it also undergoes several severe symptoms and even crop failure. Inducing drought tolerance in somewhat tolerant crop is a neither easy nor a tough situation, but needs thorough research and numerous trials which could also benefit other crops of the same situation (Elakhdar *et al.,* 2022). In this review, the treatments with salicylic acid and Selenium are identified as means of drought stress mitigation in barley.

## Drought stress-Impact and response of plants

Drought stress is a factor which can't be avoided for every plant's life cycle as it directly affects the plant biomass production and quality. It is a stress condition which can be occurred by various causes like rise in temperature (Cohen *et al.,* 2021), light intensity and rain scarcity. These causes can be also defined as the result of various environmental phenomena like global warming (Warner and Afifi, 2014), rainfall anomalies (Konapala *et al.,* 2020) and monsoon pattern change. At the same time, the plant shows significant and identifiable symptoms of drought stress

which can be named as leaf rolling, permanent wilting, stunning plants, leaf scorching, yellowing leaves, *etc*. Also, it has huge impact which has cumulative and multi-dimensional character as it results in crucial damage on plant morphological, physiological, bio-chemical and molecular attributes (Ortiz *et al.,* 2015). Adverse impact on photosynthetic capacity is an inevitable fact. The optimum availability of water in the root area has a significant role even in the uptake of nutrients (Elemike *et al.,* 2019). As the greatest fact, water availability and plant growth have strong relationship due to its correlation with cell enlargement than with cell division. In such circumstances, the decline in plant growth is observed as a result of hindrance of cell turgor and extensibility of cell wall (Seleiman *et al.,* 2021). Extreme conditions of water scarcity can cause diminishing rate of respiration and could be the source of oxidative damage in chloroplast by inducing reactive oxygen species production.

Each plant species has its own unique tolerance mechanisms and adaptation systems while they face unavailability of required water which can be either physiological or biochemical responses or both. The primary responses of plant towards drought stress are initiated with cuticle thickness, stomatal closing, enhancement of phytohormones and increase of root length and density. But there is a sequence of response mechanism namely stress avoidance, escape and tolerance which implies that stress response varies from molecule level to plant level (Galindo *et al.,* 2018). Other strategies followed by plants under drought stress such as osmotic and hormonal regulation, altering stomatal conductance (Forner *et al.,* 2018) and distribution, enhancement in transpiration efficiency, delayed senescence and it will go on.

Even though, the yield loss and crop failure due to drought stress can't be avoided and a lot of scientific approaches are on hand. Breeding strategies (Ullah *et al.,* 2018) and altered omics technologies like proteomics, genomics, glyomics are some technologies which successfully enhance tolerance towards stress in plants. Drought stress can also be mitigated by worth induction treatments like seed priming, growth hormones, osmo-protectants, potassium and silicon application. In addition to that, plants can be adapted to the drought condition through application of microbes, hydrogel, nanoparticles which manipulates antioxidant enzyme activity and enhancing stress tolerance through maintaining perfect cell homeostasis also regarded as ideal strategies (Baghaie and Jabari, 2019).

## Impact of drought stress in Barley

The so-called stress is considered as a usual disaster in the agriculture sector. Whereas in barley plant, drought stress is severely affected in roots by inhibiting growth and reduced caryopsis development. The ability of barley roots to take in salts without organic content and water and to transfer all over the plant has already proven with early learnings (Xiong *et al.,* 2006). So, it is obviously a key feature in the resistance to drought of barley (Chloupek *et al.,* 2010). There had been lots of research on the drought impact and had been found that number of tillers, grains per ear and plant height are reduced and consequently a remarkable decline in yield of the ear and thousand kernel weight (Samarah, 2005). Protein and starch accumulation in the plant was also impacted by the shortage in the water availability (Maryada and Thind, 2016). Previous researches showed an incline in protein content, significant change according to starch size and content, while structure of starch doesn't have notable modifications under drought stress (Yu *et al.,* 2017). Researchers on breeding has come to a conclusion that tolerance indices shown by barley plant during drought stress can be employed as criteria for assessing the tolerance level of sensitive and susceptible barley genotypes (Sharafi *et al.,* 2014). In the breeding and improvement of barley, acknowledgement of genes which are resistant to drought and their quantitative characteristic loci has a salient role (Nevo and Chen, 2010).

Every plant needs change in their metabolic processes according to the adverse conditions for the successful survival and it clearly reflects on broad transcriptional level modifications on the happening of stress (Janiak *et al.,* 2018). The easiest way to find the underlying causes of drought stress tolerance is to do transcriptome analysis by providing data on regulation of gene expressions at transcriptional level. Also, the previous years' studies on transcriptome analysis have a drastic incline due to the availability of draft genome (http://plants.ensembl.org/Hordeum vulgare/Info/Index) of barley. During previous researches, the morphology of root hairs and transcriptional features of 2 wild type barley genotypes which are being at variance with and drought resistant variety are found and then the complete-length cDNA of a new beta expansin-gene (HvEXPB7) was replicated, the gene related to distinctive root hair development. In addition to that, it had been compared the response towards the transcriptome of the pale, awn, lemma and seed to stress from drought and reached at a conclusion of rise in transcript which is followed by the spike's water condition. Whilst, a thorough transcriptome examination on the transgenic plants especially on leaves which undergone irrigating after drought. The experiment outcomes brought light on the elevated gene expression which coding for potential enzymes associated with manufacturing of jasmonates and other easily volatile compounds is a cause for the fast propensity of come back to first phytochemical actions in contrast to wild-type.

The repercussions of drought levels on growth stages and development of barley plant are visible on the root and shoot parts as well as underground and above ground parts. Root morphologies and yield traits were the focus of earlier researches (Barnabás *et al.,* 2008; Haddadin, 2015). However, few studies are showing that root

morphology features and caryopses formation in barley plant during drought and their connections are lacking clarity. The latest studies on Suluomai1 (SLM1) variety under drought stress is observed during flowering period to maturing stage of caryopses and observation of microstructural and morphological modifications of roots and caryopses is stated. The underlying mechanism of caryopses development factors which responding to drought can be found by further transcriptome analysis and it can also be value of lots of yield losses in the future (Fig 1).

## Impact of drought stress on vegetative growth

The consequences and period of stress due to drought on various stages have been observed by subjecting the barley plant under stress on each stage such as tillering, stem elongation and grain yield (Damptey *et al.,* 1978). The assessment and analysis of stress includes repeated short cycles of stress, single short stress and single long stress. Recent research has proved that stress due to drought could increase root: shoot ratio and subsequently prompted the ear weight decrease up to 20.16% and 1000-grain weight reduction by 7.75% which finally exerts influence on the biomass accumulation of roots and caryopses.

The thorough research works done on this has collected data on support with the finding that the plant part which was growing under stress is the one most impacted by the stress. In support with this argument, we could spot seriously affected grains per ear during drought stress prior to anthesis. The process of spikelet initiation is also affected followed by impact on the development of gametes. Reduction of grain dimensions is always noted during drought stress, but it is significant when stress occurred at the formation of anthers and shortly after that. Increase of length of internodes is another remarkable change due to the stress and it is more visible during stress at earing or just before earing. The elongation is not seriously affected when the drought stress was a bit earlier or later than earing.

## Impact of drought stress on reproductive stage

In Mediterranean and semi-arid region barley is usually grown. In this region conditions of terminal drought that usually have an impact on the yield (Kandic *et al.,* 2018; Ceccarelli *et al.,* 2007). Passioura (1996) identified that increasing flower initiation during stress is inevitable for achieving drought resistance and stable yields. Delayed flowering phenotypes have been observed in barley within low temperature environments. Early flowering has been recognized as an adjustment to short length growing periods to avoid drought stress. Many crops display susceptibility to drought stress during flower initiation and the pre-meiotic differentiation of flower parts (Winkel *et al.,* 1997). Guo *et al.* (2009) used the microarray technique to observe alterations in expression of gene at the transcriptional level in leaves of barley throughout the stage of reproduction. The drought-resistant genotype such as Martin and the sensitive genotype like Moroc9-75 were utilized in their study. Under both water lacking and controlled conditions, they noticed 17 genes exhibited constitutive expression in the drought-resistant Martin compared to the susceptible genotype Moroc9-75. Additionally, they found that seven annotated genes were associated with signalling (calcium-dependent protein kinase, CDPK and membrane steroid binding protein, MSBP), anti-senescence and pathways of detoxification.

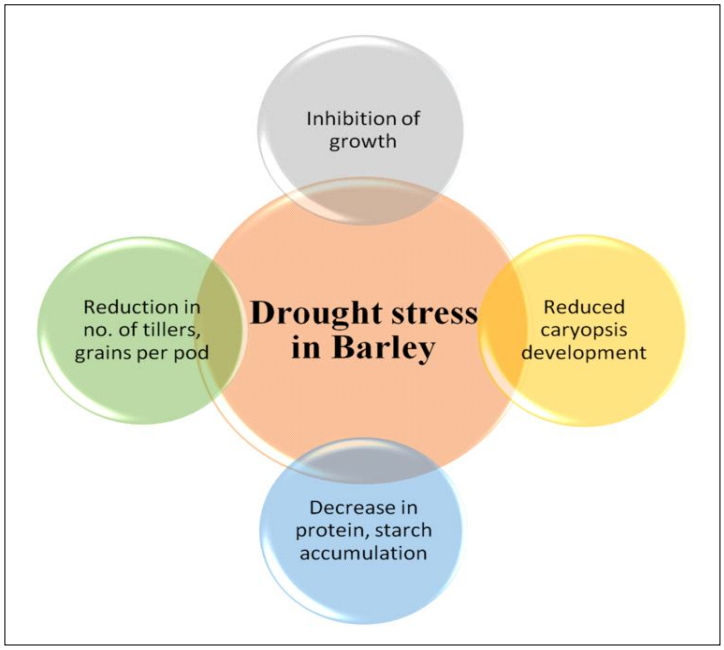



**Fig 1:** Impact of drought stress in barley.

Winkel *et al.* (1997) noted that drought can either postpone the induction of flowering or lead to its complete inhibition. Nearly all cereals exhibit high sensitivity to drought and elevated temperatures during the meiotic stage of plants, as highlighted by Boyer and Westgate (2004). As a consequence, wheat (Saini and Lalonde (1997) and rice (Panja *et al.,* 2024) experience a reduction in the ultimate productivity or yield or output by up to 75%. Prolonged water deficit leads to sterility of pollen, such as wheat (Koonjul *et al.,* 2005), attributed to anomalies in microsporogenesis. The pollen's sterility is a result of diminished carbohydrate supply to the anthers and decreased action of cell wall and vacuolar invertases (Koonjul *et al.,* 2005; Oliver *et al.,* 2005). Hence, the indication for pollen sterility in grains seems to be associated with decreased carbohydrate levels and a decline in invertase action (Mäkelä *et al.,* 2005).

In addition to inducing sterility in pollen grains, drought also retards the development of female organs in maize and other grains (Damptey *et al.,* 1978; Blum *et al.,* 2000). The ovary has been observed to assemble abscisic acid (ABA) under extended stress (Boyer and Westgate (2004), but this accumulation diminishes once the plants commence flowering. The abscisic acid (ABA) has an important part in the female flower abortion. (Yang *et al.,* 2001) additionally emphasize that the build-up of abscisic acid (ABA) in reproductive structures during stress may hinder cell division, lead to the abortion of female floral parts and consequently impact grain formation. As drought stress induces significant photosynthate loss, there is a reduction of nutrients involving carbohydrates, to the components of female reproductive system. Ultimately, this reduction in nutrient influx would lead to decreased ultimate output in grains. The findings from researches of (Zinselmeier *et al.,* 1995) unveiled that the provision of sucrose in ovaries is crucial and sucrose has the potential to protect the ovaries from being aborted under water stress situations. In the time of stress due to drought, the sucrose which may function as a substrate necessary for the survival of plants also functions as a signalling component, as noted by Thomas and Beena (2024).

A lot of studies have indicated that the sucrose transporters, hexose transporters and sucrose partitioning genes, were reduced in intensity of the parts of female reproduction system, which is connected to the ovarian abortion. This occurrence increases the genes for the ribosome-inactivating protein (RIP2) and phospholipase D (PLD1) (McLaughlin and Boyer, 2005; Mäkelä *et al.,* 2005), initiating the ovarian abortion and senescence. Hence, these genes serve as an aim for avoiding ovary abortion in grains (Boyer and McLaughlin, 2007) (Fig 2).

## Effect of drought stress in translocation of carbon source between source sink

Grain yield of cereals is influenced by the organized interactions between source and sink tissues. During optimum conditions, grain development, or seed yield, is typically affected negatively by the capacity of the sink tissues (Jenner *et al.,* 1991). Sink strength, which refers to the characteristic ability of developing seeds to attract and utilize assimilates, has a crucial part in the grain development process of food grains. Lack of water during terminal drought diminishes the photosynthesis and induce senescence, leading to a reduced grain development period

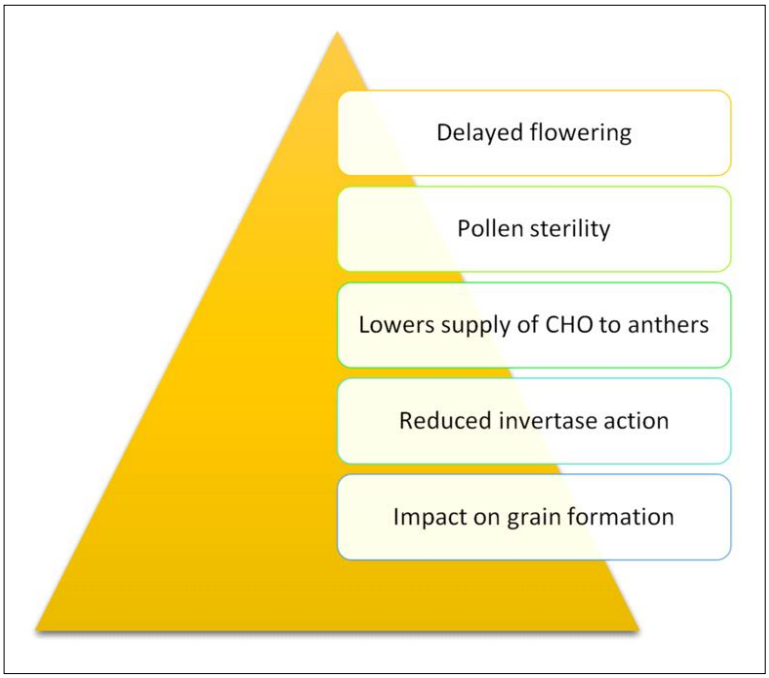



**Fig 2:** Impact of drought stress in barley during reproductive stage.

(Guzenko *et al.,* 2024). Genotypes with efficient mobilization capabilities can transfer stem stores to the grain development site, aiding in the filling process (Yang and Zhang, 2006).

In cereals, the accumulation of stem reserves before flowering influences flower and grain development (Blum, 2000). These crops have a reserve of excess carbohydrates, in different forms such as soluble sugars or sugar polymers, mostly within vegetative tissues (Davis *et al.,* 2011). Non-structural carbohydrates, like sucrose, fructans, or starch, are stored in parenchyma cells surrounding vascular bundles in internodes. This whole-plant carbon partitioning concept is essential to buffer source-sink interactions, providing an another assimilate origin when ability for photosynthesis is reduced under drought stress. Additionally, the accumulation of sugars in stems may facilitate water uptake from the soil through roots into the leaves (vegetative parts) by adjusting turgor. Pre-anthesis assembling of non-structural carbohydrates in the bark improves the sink strength of developing seeds, as observed in cereals like rice (Reynolds *et al.,* 2011).

Optimizing carbon partitioning among vegetative organs, particularly the stem, is crucial for increasing kernel weight (Reynolds *et al.,* 2011). This adaptation is influenced by elements such as photosynthetic efficiency, assimilate competition between organs and environmental conditions like water and nutrient availability, photoperiod and temperature. Genetic factors controlling the partitioning of assimilates determine whether stems accumulate water-soluble carbohydrates or support sink tissues, ultimately influencing seed filling. Understanding the intricate mechanisms of carbohydrate partitioning at the whole-plant level is essential for implementing strategies to enhance crop performance.

Usage of nitrogen (N) during the differentiation stage of spikelet enhances pre-anthesis water-soluble carbohydrate (WSC) reserves and sink strength. Although, during terminal drought, yield losses in grains which is an outcome from both source and sink restrictions (Barati *et al.,* 2024) Instead of providing adequate assimilates through artificial feeding to developing grains, yield reduction in barley and other crops underscores the significant part of sink action in identifying yield under terminal drought (Westgate, 1994). Apart from this limiting factor of a lower number of endosperm cells, the rate of storage product accumulation and the period of seed development are identified as crucial characteristics for increasing weight of the grains during stress conditions.

## Effect of salicylic acid in mitigating drought stress in barley

Barley genotypes subjected to drought stress displayed acute phenotypic abnormalities such as leaf rolling, chlorosis and necrosis of older leaves, along with a remarkable decrease in assimilated organic matter of the plant (Mohammadi *et al.,* 2022). Indistinguishable phenotypic deformations produced by drought stress and decline in the biomass has analysed in other cereal crops such as rice, maize, wheat, *etc* (Panda *et al.,* 2021). Conversely, the foliar application of salicylic acid (SA), specifically SA1, mitigated the adverse outcomes of drought conditions, as evidenced by reduction in rolling, chlorosis, drying of leaves and improved production of biomass compared to plants under drought stress which are not treated with SA1 (Majeed *et al.,* 2016). The optimistic bit part of SA in enhancing appearance in the phenotypic manner and production of plant biomass has also seen and marked important in other cereals also (Nawaz *et al.,* 2020).

Plants accumulate various low-molecular-weight osmotic compounds, including Proline (Pro), which is also an amino acid to maintain the osmotic balance during water stress conditions (Zulfiqar *et al.,* 2020). The barley genotypes under drought stress have collected high levels of Pro while storing remarkably low relative water content (RWC) in their photosynthetic surfaces in contrast to control plants (Mohammadi *et al.,* 2022). This suggests that Proline deposition in barley plants which are exposed to drought was not enough to store water during acute water scarcity, with early learnings (Dien *et al.,* 2019). However, SA application to plants under drought stress has increased their Pro levels and also increased relative water content (RWC) of leaves under water-deficit situations. Positive correlations between enhanced drought tolerance, increased Pro levels and higher leaf RWC have also seen in other crops like wheat and mung bean (Altaf *et al.,* 2021; Bangar *et al.,* 2019). The PCA biplot which demonstrated an optimistic connection with barley plants which are treated with SA and also facing the drought conditions, have a huge rise in the levels of Pro and relative water content of the leaf.

Numerous studies have reported a connection between drought-induced biomass reduction and oxidative stress injury due to drastic release of reactive oxygen species (ROS), $O_2$.-, $H_2O_2$ and afterwards, malondialdehyde (MDA) content in the photosynthetic surfaces of the above-mentioned barley genotypes (Mohammadi *et al.,* 2022), suggesting a crucial role of SA in reducing oxidative stress induced by ROS and safeguard the integrity of cell membrane from damage due to drought stress. PCA results further supported these findings, showing that SA-treated barley plants under stress showed a diminished and hopeful correlation with these reactive oxygen species outcomes and MDA levels in contrast to barley plants exposed to drought without SA treatment.

Plants evolved a strong protection system against antioxidants to counteract oxidative stress due to the production of ROS during water stress. Barley plants subjected to drought stress and supplemented with SA showed enhanced ventures of enzymatic antioxidants, such as Superoxide Dismutase (SOD), Catalase (CAT), Ascorbate Peroxidase (APX), Peroxidase (POD) and Glutathione Peroxidase (GPX), in contrary to drought-

stressed barley plants without SA treatment. Increase in the activity of SOD in SA-treated barley plants which exposed to stress correlated with reduced $O_2$.- levels, as SOD catalyses the dismutation of $O_2$.- to $H_2O_2$ (Mostofa *et al.,* 2021). Foliar application of Sa improves the expression of SOD in plants under drought stress. CAT, APX and POD play roles in detoxifying $H_2O_2$ (Dumanović *et al.,* 2021) and the reduced levels of $H_2O_2$ in SA-treated drought-exposed barley plants coincided with elevated activities of CAT, APX and POD. Additionally, increased GPX activity in SA-treated drought-exposed barley plants under drought conditions suggested the involvement of SA in enhancing the GSH-dependent peroxide-detoxification system. A lot of studies have detailed the probable role of SA in activating ROS-detoxification mechanisms in plants under water lacking conditions (Shemi *et al.,* 2021). The PCA results demonstrated an important optimistic of SA-treated drought-stressed barley plants with the activities of enzymatic antioxidants.

SA supplementation improves drought resistance in some genotypes by enhancing plant biomasses, Pro levels and RWC while reducing $O_2$.-, $H_2O_2$ and MDA levels by activating key antioxidant enzymes (Mohammedi *et al.,* 2022). Within the barley genotypes which all are studied, BB-5 is the best genotype and has the better resisting in drought-induced conditions with adverse effects in the presence of SA. Overall, the ability of SA in mitigating damage caused by drought to an important crop, barley. To further validate the positive influence of SA in managing drought-related issues, extensive field research involving various crop species under different low water stress conditions and SA application methods should be conducted. Additionally, investigating the impact of SA supplementation on the organic components and nutrient status of barley seeds could provide insights into addressing malnutrition in developing nations (Fig 3).

## Effect of selenium in mitigating drought stress in barley

Effectively addressing drought stress in plants, Selenium enhances antioxidant defences, reduces water-scare conditions and results in healthier, more resilient crops by minimizing oxidative damage and improving water retention (Wahab *et al.,* 2022). By boosting plants' capacity to rebound from water scarcity, Proline, a crucial osmo-protectant in plants, will improves drought tolerance and preserves cellular integrity (Shabbir *et al.,* 2022). Additionally, plants under stress exhibited increased Proline accumulation, potentially attributed to Proline's essential function in regulating osmotic balance amid low water stress (Abdelaal *et al.,* 2021). Selenium elevates plant Proline levels during stress due to drought through the regulation of stress-responsive signalling pathways. It also promotes enhanced Proline biosynthesis while ensuring the maintenance of osmotic balance and cellular integrity, ultimately contributing to improved health of plant (Zaib *et al.,* 2023). Furthermore, additional studies conducted by other researchers have recommended that Selenium have an important and inevitable part in enhancing Proline levels during low water stress (Ahmad *et al.,* 2016). The membrane thermostability index evaluates the quality of complete cell membranes and their sensitivity to temperature stress injury, providing an estimation of a plants' stress resistance, especially in the context of drought stress (Ul *et al.,* 2021). Djanaguiraman *et al.* (2018) observed that Selenium decreases the

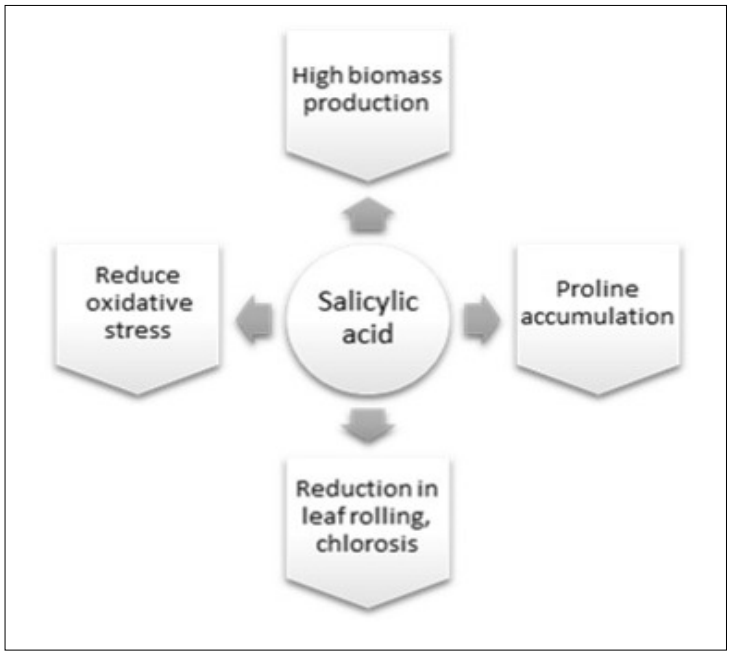



**Fig 3:** Effect of salicylic acid in barley during drought stress.

membrane thermostability index through the mitigation of oxidative stress and the enhancement of membrane fluidity, as supported by (Singhal *et al.,* 2023). Such actions promote heat resistance and quality, fortifying antioxidant systems and diminishing peroxidation of lipids, finally amplifying tolerance of plant to temperature stress (Hayat *et al.,* 2023). Selenium also decreases the membrane thermostability index (Karumannil *et al.,* 2023). The impact of drought stress induces increased transpiration, resulting in withering plant and disturbance in crucial physiological processes such as respiration, nutrient uptake and photosynthesis. This compromises overall crop height, as outlines by (Rao *et al.,* 2016). Similarly, Selenium aids plants in mitigating excessive leaf water loss through advancement of stomatal control. This, in turn, leads to the regulation of rate of transpiration loss, also promotes improved water use efficiency (Ahmad *et al.,* 2016). The ability of Selenium to achieve this, is credited to its impact on hormone signalling and antioxidant defence systems at a basic physiological extent (Mostofa *et al.,* 2021).

The application of Selenium during low water stress situations decreases excess transpiration through leaves, contributing to the enhancement of tolerance to lack of water (Rady *et al.,* 2020). Under water scarcity or the so-called unavailability of water, SPAD chlorophyll readings can either increase because of stress adaptation or decrease, based on the specific response of the crop and the intensity of the stress. Certain de*via*tions were identified wherein Selenium boosts the quantity of chlorophyll by encouraging the production of chlorophyll and protecting chlorophyll from oxidative stress injury. This is achieved by the regulation of enzymes required for chlorophyll metabolism (Zaib *et al.,* 2023). Hence, with the assistance of Selenium, there is an elevation in SPAD values chlorophyll concentration (Naseem *et al.,* 2021). The leaf area index (LAI) serves as an inevitable criterion for plants under drought, providing insights into the amount of foliage and canopy development (Panigrahi and Das, 2021). The leaf area index directly influences a plant's capacity to endure unavailability of water, ensuring the perfect photosynthesis and enabling adaptation to water stress (Seleiman *et al.,* 2021). Selenium plays a significant role in enhancing the leaf area index plants by fostering sound growth and development. This, in turn, optimizes photosynthetic process and alle*via*tes oxidative stress (Rady *et al.,* 2021). Similarly, this profound physiological influence contributes to the augmentation of leaf area, thereby increasing the total leaf area (Pandey *et al.,* 2017). Selenium has been shown to elevate the leaf area index in plants. Morphology of barley may change and have alterations during drought stress, such as diminished tillering, reduced plant height, shorter leaves and smaller grain size. These changes represent adaptive responses aimed at conserving water and enhancing survival, underscoring the significance of water conservation in plant life (Farooq *et al.,* 2012). According to Siddiqui *et al.* (2021), the application of Selenium improves the morphology of barley plants. In conditions of drought stress, water scarcity causes a decline in seed yield components, encompassing seeds quantity per plant and seed size. Consequently, this leads to diminished crop productivity (Ahanger *et al.,* 2016; Batool *et al.,* 2023). The reduction in seed yield components in barley plants under drought stress is primarily attributed to water scarcity. Selenium plays a significant role in enhancing seed yield by improving flowering, optimizing pollination and reducing oxidative stress. Both seed quantity and size, showcasing the profound physiological impact of Selenium on barley plant physiology (Saini *et al.,* 2020; Sami *et al.,* 2023; Seleiman *et al.,* 2021). Hence, we discovered that the application of Selenium under drought stress leads to an increase in seed yield (Ferdous *et al.,* 2017; Nawaz *et al.,* 2015).

## CONCLUSION

Barley is a resilient cereal crop that exhibits drought tolerance, but it still experiences negative effects on growth, yield and development under drought stress. Understanding the mechanisms of drought tolerance and developing breeding strategies are crucial for improving barley's resilience to drought conditions. Also, we can alter the drought tolerance of barley in different growth periods by application of some amendments like Salicylic acid and Selenium to some extent, which will influence the yield parameters in a better way.

### Conflict of interest

The authors declare that they have no conflict of interest.

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