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Physiological Stress in Agricultural Crops: An Overview

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ABSTRACT: Plants face a lot of stress during their growth period, which affects their physiology and disrupts their homeostasis. Stress in crop plants can be defined as any change in the external environment that has a very negative impact on crop growth and development. Plant stress can be divided into two main categories, such as abiotic stress and biotic stress. These two stresses limit the sustainability of agricultural production because they adversely affect all plant metabolic activities. Abiotic stresses such as drought, salinity, heavy metal stress, flooding, low and high-temperature stress, etc. reduce crop quality and productivity. Biotic stress, on the other hand, includes diseases caused by fungi, bacteria, viruses and nematodes. The plant's response to these stresses is a very complex process. Some plants have the potential to withstand physiological stress due to their morphological, physiological and biochemical activities. However, most plants do not tolerate these stresses because they reduce photosynthetic rates, reduce water availability, which restricts soil nutrient uptake and disrupts cell homeostasis. Some defensive mechanisms are also activated to cope with this stress plant. This review shows, therefore, the different types of physiological stress, their effect on plants and the different approaches and methods developed for inducing crop resistance. The world's population is increasing at a higher rate, creating a high demand for food grains worldwide. Simultaneously, climate change also poses various problems, increasing environmental stress, pathogens and insect pests. There is therefore a great need to develop plant varieties that have resistance to these biotic and abiotic stresses.

Keywords: Abiotic, Biotic, Climate, Drought, Environment, Flooding, Homeostasis, Resistance, Salinity, Temperature

INTRODUCTION

The world population is increasing at a very alarming rate year after year which expected to reach more than 9 billion in 2050 (United Nation's World Population Prospects Report) and simultaneously raise the demand for food and create pressure on the nations to feed their citizens. As per the report of the Food and Agriculture Organization (FAO) nearly more than one billion people around the world suffer from malnutrition. The world population is increasing and on the other hand, global food production and productivity are decreasing due to climate change and the bad impact of the different biotic and abiotic stresses on the crops. Between the period of 1981 and 2002, there is a huge reduction in the yield of the crops like wheat, maize and barley by 40 m metric tons because of global warming (http://environmentalresearchweb.org/cws/article/news/27343).

All of the above information shows that there is a greater need to improve crop production by understanding the different types of physiological stresses faced by crop plants and how to reduce the impact of those stresses is a matter of concern.

There is the presence of different biotic and abiotic stresses which adversely affect the growth and development of the crops and reducing the yield to a higher extent through changing in the gene expression and metabolism in the cells. All these physiological changes disturb the homeostasis of the crops and create stress in the plant body which produce the condition to force a system to leave its optimal stage (Cramer *et al.*, 2011). Adverse climatic conditions develop stress on the plants which inhibit the life cycle of the crops. Some plants can survive under various physiological stresses through some modifications. For example: under salinity stress some plants going through modification like the formation of salt glands on their leaves which then store those salts in the gland. Under the negative climatic conditions, plants adopt some defensive mechanism to acclimatize in that area. In some metabolic mechanism, there is re-programming inside the cells which helps to sustain the physio-chemical reaction in the plant body even under harsh environmental conditions. Many times, plants get facilitated in reducing the burden of environmental stresses with the support of the microbiome they inhabit. Some susceptible plants can't even tolerate lower stress which leads to the death of the crop by reducing flowering, seed formation and cause senescence that is the last stage of growth and development. There are two types of stresses viz, biotic and abiotic stress. Plants going through different biotic and abiotic stresses during their life cycle. Some of which are tolerant and others are susceptible which leads to death (Foyer *et al.,* 2016).

Stress is caused by living organisms such as fungi, bacteria, viruses, insects and nematodes known as biotic stress. These organisms are responsible for a huge reduction in the yield of the crops by causing various diseases or make them more susceptible to plants for any environmental stress. According to Wang *et al.,* (2013), biotic stress causes a 28.2% yield loss of wheat, 37.4% loss of rice, 31.2% loss of maize, 26.3% loss of soybeans, 40.3% loss of potatoes and 28.8% loss of cotton. Different diseases like rust, wilt, spots on leaves and stem, root rot, blight, damping off and others are caused by these organisms. These diseases affect almost all of the crops which results in the death of the plants. Chewing type of insects decreases the leaf area which affects the photosynthesis rate and translocation of the photosynthates from source to sink. Plants adapt some physiological strategies to overcome these biotic stresses and show some defence mechanism against these diseases for survival. This resistance is provided by the specific genes which are available in the genome encoded in the plants.

Other than the biotic stresses there is the presence of environmental stresses which also have the great potential to affect the growth and development of the crops and even damage the whole crop. Farmers have to face a large amount of loss in crop yield due to these stresses. These stresses we can call abiotic stresses. Abiotic stresses named drought or water stress, salinity stress, water logging stress, heavy metal stress and temperature stress (low and high-temperature stress). These adversely affect the quality of the crops (Atkinson & Urwin, 2012). There is an increasing problem of climate change around the world due to anthropogenic activities which enhance the intensity of these abiotic stresses for the past decades. This is a very serious problem faced by the world today and have a big challenge ahead to feed the peoples and upcoming generation. According to the existing situation, there is a greater need to develop such crop varieties which shows resistance against these abiotic stresses to ensure food security (Ali *et al.,* 2021). The roots of the plants are healthy then there is a higher chance to survive under these stresses. But due to the use of a higher amount of fertilizers and agrochemicals in crop production reduces the health of soil because these fertilizers are inorganic in nature which impose a bad impact on the soil microbes. These microbes are very useful for maintaining the health and long-term fertility of the soil. For maintaining sustainability in agriculture, it is very important to maintain soil fertility and productivity. Under the high salinity stress, disruption of the sodium-potassium ratio takes place in the cytoplasm of plant cells (Jouyban, 2012).

Under the different abiotic stresses such as drought, salinity and low-temperature stress one plant hormone i.e. abscisic acid (ABA) plays a very significant role in plant survival to a greater extent and also some plants can overcome the adverse abiotic situations through their intrinsic metabolic capabilities. Abiotic stresses disturb the homeostasis and metabolism of the plant cells which inhibits their proper functioning and ultimately reduces the average yield of the crops. Disturbance in the cell homeostasis due to the alteration in the gene sequences and expression which then leads to the reduction in the crop yield and quality. Variations in the outside environment could put the plant metabolism out of homeostasis and create the necessity for the plant to harbour some advanced genetic and metabolic mechanisms within its cellular system. It has been estimated that the yield reduction due to environmental stresses is around 54-82%. According to Wang *et al.,* (2013), Yield losses from abiotic stress were estimated at 65.8% for maize, 82.1% for wheat, and 69.3% for soybeans and 54.1% for potatoes. Identification of these genes is very important to get an understanding of the responses shows by the plants under a stressed condition.

Varying environmental conditions are the main cause of decreasing agricultural productivity. According to the report of the Food and Agricultural Organization FAO, (2007), only 3.5% of the total land area remains unaffected by environmental stress (http://www.fao.org/docrep/010/a1075e/a1075e00.htm). Dominant abiotic stresses comprise drought, low/high temperature, salinity and acidic conditions, light intensity, submergence, anaerobiosis and nutrient starvation. Out of the total affected land area, 64% of the land under drought stress, 13% under the flooding situation, 6% under salinity stress, 9% under mineral deficiency, 15% under the acidic soils and 57% under cold situation. Out of the world's 5.2 billion ha of dryland agriculture, 3.6 billion ha is affected by the problems of erosion, soil degradation and salinity. Although any accurate estimation of agricultural loss (reduction of crop production and soil health) in terms of agro-ecological disturbances due to abiotic stresses could not be made, it is evident that such stresses affect large land areas and significantly impact qualitative and quantitative loss in crop production (Cramer *et al.,* 2011).

A. Drought stress

According to United Nations Convention to combat desertification (UNCCD), drought means a naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect the land resource production system. Deficiency of water cause this stress which largely affects the productivity of the crops by disturbing the osmotic equilibrium and cell membrane structure. Environmental pollution increases the concentration of greenhouse gasses in the atmosphere which leads to a rise in the temperature of the atmosphere and results in global warming (Tuteja *et al.,* 2011). Drought stress becomes more severe due to the effect of global warming. Due to the changes in the climatic conditions, there is a need to develop such strategies of crop production which can improve the crop yield and sustain it for the future generation. Under any environmental stress condition, the phospholipids present in the cell membrane is highly affected which disturbs the cell homeostasis. In response to this, there is various alteration taking place in the composition of phospholipids which may help to stabilize the cell membrane (Dresselhaus & Hückelhoven, 2018). Various researches have been shown that the total content of lipids in the leaf reduced under the water-stressed condition.

The drought stress inside the phospholipid bilayer leads to the protein displacement in the cell membrane. Water stress within the plant also disturbed the cellular compartmentalization, membrane integrity and inhibit the enzymatic activity. Deficiency of water cause dehydration of the protoplasm which highly affects cellular metabolism (Sharma *et al.,* 2019). Under this condition, to reduce the water loss or transpiration plant adopt various physiological strategies for survival such as plant close their stomata through which water is a loss, reduce their cell growth, shed its older leaves so that transpiration area is reduced and expand the root system to extract the water from the deeper layers to meet the water and nutrient requirement of the crops (Alscher & Cumming, 1990). Under the water stress condition, the plant tries to balance the osmotic and ionic equilibrium so that all the metabolically activities take place as such and sustain the homeostasis of the cell. To repair the damaged parts detoxification signalling and coordinate cell division taking place to meet the nutritional requirements of the crop under drought stress.

To survive under the drought stress there is various alteration within the cell

- Changing in the gene expression and molecular chaperones are under action which prevents the proteins from degradation. The proteins which are damaged due to the stress removed from the cell with the help of the proteinase enzyme.
- Under this stress, some enzymes are activated and removed from the reactive oxygen species (ROS).
- Some reports have been showing that to prevent the plant from the stress overexpression of genes also takes place such as barley group 3 LEA gene HVA1 in the leaves and roots of the rice which helps to recover the stressed crop plants and also to protect the cell from the dehydration there can be seen the accumulation of the dehydrins.
- One more example which helps the crops to tolerate the drought stress is overexpression of vacuolar sodium/hydrogen antiporter and H+-pyrophosphatase pump.
- In the case of transgenic Arabidopsis, stomata are closed due to the overexpression of AtMYB44 under the drought condition which then reduces the transpiration rate and helps to maintain the water level in the plant system.
- Ca^{2+} binding protein calreticulin (CRT) helps to tolerate the drought stress in the wheat crop (Jia *et al.,* 2008).
- Under the water stress condition, some compounds are formed in the root system, which helps the plant to acclimatize to that condition and transportation of those compounds to above-ground parts through xylem sap.

Performance of plants under the drought stress. Under this stress, first of all, plants closed their stomata to prevent the water loss from the system and then evaporation takes place from the guard cell known as hydro passive closure in which there is no metabolical involvement. On the other hand, there is metabolical involvement, which required various ions and metabolites for the closing of stomata known as hydro active closure. Hormones play a major role in the opening and closing of stomata such as abscisic acid (ABA) which enhances the K+ ions efflux from the guard cell leads to the loss of turgor pressure, which results in the closing of stomata. Abscisic acid acts as communicating signals from the roots to shoot parts for stomatal closure (Blackman & Davies, 1985). The closing of stomata not always depends only on the signals produces under the water stress conditions in the plant system but also respond under soil desiccation conditions directly before there is any reduction in the leaf turgor pressure. Due to the closing of stomata, the photosynthetic rate is severely affected because of reducing the rubisco activity and carbon dioxide deficiency (Bota *et al.,* 2004). CO_2 deficiency within the cells leads to a reduction of components in the electron transport chain (ETC) and electrons are transferred to oxygen at photosystem I (PSI) which then produce reactive oxygen species (ROS) might lead to the photo-oxidation. To control the concentration of ROS within the cell plants adopt many strategies like ascorbate and glutathione pools, which detoxify ROS. It has been seen that photosystem II (PS II) is also affected by the water stress condition. Under the prolonged water stress condition shrinkage of plant, cells take place which acts as constraints on the membrane of cell which then vitiate the proper working of ions, transporters and various enzymes.

Drought stress and oxidative stress. Under any environmental stress condition like drought, stress leads to the generation of reactive oxygen species (ROS) in a very higher amount, which is very dangerous for lipids, proteins, carbohydrates and DNA, which produces oxidative stress. This stress can be the major cause of affecting the growth and development of crop and reduced the yield drastically. This overproduction of the ROS can be reduced by some antioxidants such as SOD, CAT, GR and APX etc. For example, in rice and beans, there can be seen the increased activity of SOD. The negative impact of the ROS can effectively reduce by the expression of two or more antioxidant enzymes, especially in transgenic crops. Chang-Quan & Rui-Chang (2008) studied the effect of polyethene glycol (PEG)-induced water stress on the activities of total leaf SOD and chloroplast SOD (including thylakoid-bound SOD and stroma SOD) in white clover (*Trifolium repens* L.). With the enhanced concentration of PEG-induced drought stresses, the SOD activity in both leaves and chloroplast increased which plays a very important role in scavenging the ROS (O_2^-). Under the deficiency of water in transgenic rice, the activity of CAT is enhanced which provide tolerance under drought stress. Increased activity of APX can be seen in the *Nicotiana tabacum*.

Drought stress tolerance through osmotic adjustment. Abiotic stresses are a very limiting factor in agricultural production and productivity. Water plays a very important role in plant metabolism including translocation of all nutrients from root to shoot part. However, drought stress largely inhibits the growth and development of crops. To tolerate this condition plant going through osmotic adjustment in which plants reduce the cellular osmotic potential through the formation of different solutes like mannitol, sorbitol, proline, glutamate, glycine-betaine, fructans, sucrose, carnitine, polyphenols, oligosaccharides and inorganic ions like K^+. All these accumulated solutes help the plant cells to be hydrated under the prolonged deficiency of water and provide some resistance against water stress (Ramanjulu & Bartels, 2002). To stabilize the hydrophilic interaction with the phospholipids membrane and proteins under drought stress OH group of water is replaced by the hydroxyl group of sugar alcohols. This replacement helps to maintain the structure of the cell membrane.

It has been noted that the synthesis of glucose and fructose enhances the activity of invertase in the plant leaves that suffer from drought stress (Trouverie *et al.*, 2003). Some research also shows that role of abscisic acid has been increased under drought stress which involved in increasing the vacuolar invertase activity (Trouverie *et al.,* 2003). Glucose implicated in the activity and synthesis of ABA especially in Arabidopsis seedlings because genes that take part in ABA synthesis increased by glucose (Cheng *et al.,* 2002). There is cross-talk between glucose and phytohormones like ABA. Under the drought stress for maintaining the proper functioning of the plant ABA and glucose works in coordination. A low concentration of ABA and glucose is useful for maintaining growth and development but their high concentration can inhibit plant growth. In response to drought, stress the osmolytes in low accumulation function in protecting macromolecules either by stabilizing the tertiary structure of a protein or by scavenging ROS. In the transgenic plant's osmolytes in higher amount can diminish the growth even without any stress. This is because under severe water stress plants adopt such strategies, which conserve the water level in the plant body. Therefore, for the production of the transgenic crop, controlled synthesis of osmolytes is the main concern that has to be taken under consideration.

B. Salinity stress

The occurrence of salt-affected soils can be found everywhere almost in all climatic conditions. Nearly 147 million ha of land is subjected to soil degradation, including 94 million ha from water erosion, 23 million ha from salinity/alkalinity/acidification, 14 million ha from water-logging/flooding, 9 million ha from wind erosion and 7 million ha from a combination of factors due to different forces (Fig. 1) (Kumar & Sharma, 2020). We can find the saline soils at various altitude from below sea level to the 5000 m above the mean sea level. Salts are found everywhere from soil to water. It has no harm to the plants when present in the optimum quantity but can be very toxic to the plants if its level goes beyond the optimum amount. The quality of water, which is used for irrigation purpose highly, depends upon the concentration of salts in it. Salts are present in all types of soils and some of which acts as an essential nutrient for crop growth such as nitrates and potassium salts. Salts have been taken to the field from the canals during irrigation.

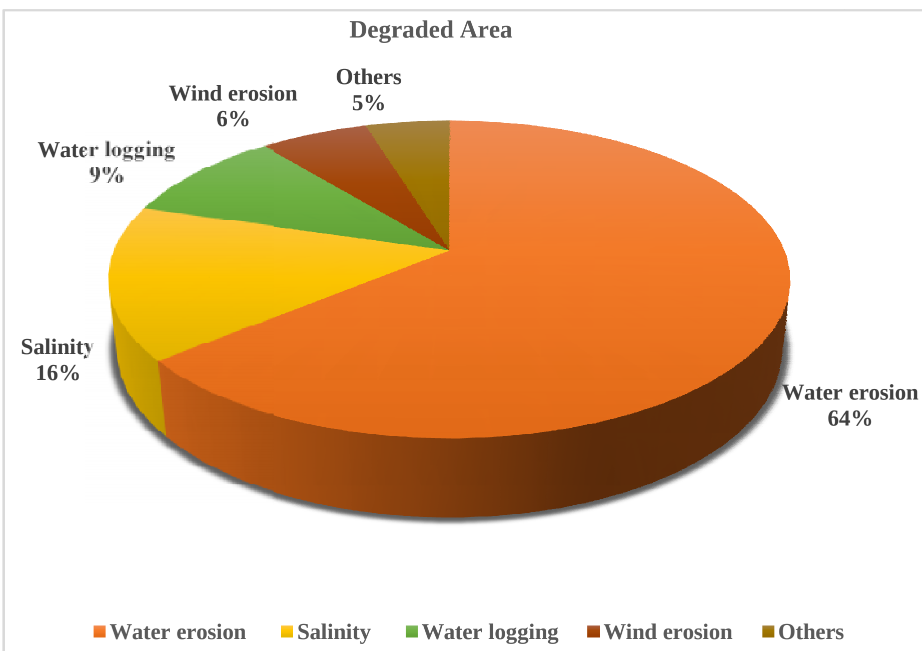

Fig. 1. Total degraded land of India through abiotic stress.

The overall effect of irrigation in the context of salinity is that its "imports" large quantities of new salts to the soil that was not there before. Excessive use of inorganic fertilizers in the field and use of poor quality irrigation water increased the salt concentration in the soil, which causes salinity stress and disturbs the osmotic balance of the crops. It has been noted that the salts affect more than 45 million hectares of the irrigated area (Pitman & Lauchli, 2002; Munns & Tester, 2008). At present Mediterranean region is highly under the salt stress condition. Irrigation water constitutes the salts of calcium, magnesium and sodium. When this water is used in the field then after some time water is evaporated into the atmosphere and salts remain in the soil dominantly, the sodium salts (Na^+) which act as a deflocculating agent in soil. As the concentration of sodium is going increase in the soil, which reduces the availability of the essential nutrients, which plays a very important role in proper functioning and completing the life cycle of plants. An increase in the number of salts especially NaCl in soil decreases the influx of water into the plant root system due to the production of external osmotic potential. This salinity stress reduces the water availability to plants, which can create drought stress, which then collectively severely affected the plant growth even leads to death.

Consequences of salinity stress on plants. Soil salinity is one of the major environmental stress, which cause a huge reduction in the yield of the crops, and it is a main concern under the increasing population. If there is a limited amount of salts in the field then it could not create a big issue in terms of yield but when its concentration is increased then the total output of the crop can be a move towards zero. Most of the crop plants especially glycophytes have not the ability to tolerate the salinity stress and growth is severely inhibited or killed by 100-200 mM NaCl (Munns & Termaat, 1986). On the other hand, halophytes include those plants, which can tolerate a higher concentration of salts or even tolerate the salinity up to 300-400 mM NaCl. These plants develop such resistance against the salts due to the phylogenic adaptation. Depending on their salt-tolerating capacity, these plants can be either obligate and characterized by low morphological and taxonomical diversity with relative growth rates increasing up to 50% seawater or facultative and found in less saline habitats along the border between saline and non-saline upland and characterized by broader physiological diversity which enables them to cope with saline and non-saline conditions (Parida & Das, 2005). Through the significance of some papers, it has been noted that glycophytes tend to debar the salts while halophytes try to gather up the salts under the salinity stress condition (Zhu, 2007). The high content of salts in the rhizosphere inhibits the roots to absorb water and uptake essential nutrients. All the metabolical and physio-chemical activities inside the plant body is severely affected due to salinity stress (Hasegawa *et al.,* 2000; Munns & Tester, 2008). These effects drastically reduce the growth of the crops. Plants tolerate the salinity stress depends upon the rate at which salts reaches from the root to shoot parts. In some plants, the period is in days, weeks, or months. Susceptible plants are highly affected by salinity stress in a very short period. Initially in both the tolerant and susceptible plants growth is affected due to the osmotic effect of the salt solution outside the root system. After some time leaves in the susceptible plants turn yellow which reduce the photosynthetic rate leads to the death of the whole plants (Carillo *et al.,* 2011).

Abscisic acid plays a very crucial role under the salinity stress to provide some tolerance to the plants. ABA helps in expressing those genes which help the plants to withstand under the high concentration of salts in the soil such as late embryogenesis-abundant (LEA)-type genes and dehydration-responsive element (DRE)/C-repeat (CRT) class of stress-responsive genes (Xiong *et al.,* 2001). LEA-types genes activate the pathways, which repair the damaged parts of the plant (Xiong *et al.,* 2002). The LEA gene expression is arbitrated by ABA-dependent as well as independent signalling pathways. Both the pathways in the salt stress use Ca^{2+} signalling. It has been noted that ABA-dependent and independent transcription factors cross synergistically talk with each other to amplify the response and improve stress tolerance (Shinozaki & Yamaguchi-Shinozaki, 2000).

Salinity tolerance to plants. Genetic traits of the plant decide the extent of tolerance under salinity stress. All types of plants even the halophytes are affected initially by the sudden shock of salts (Albert, 1975). After the exposure, tolerant plants adopt the defensive mechanism for acclimatizing in that condition while sensitive plants are not able to tolerate this sudden exposure of salinity stress. Resistance to salinity stress varies according to species to species and the concentration of salts in the soil. Plants adapt the strategies for survival, which are as follows:

Osmotic tolerance. The osmotic effect of salinity stress highly affects the growth and development of the crop, which is the main reason for reducing the crop yield under this stress. Therefore, to tolerate the osmotic effect, the plant can withstand salt stress, which helps in expanding the leaf area and stomatal conductance. As salt concentration is increasing, the older leaves are dying and younger leaves do not support the transport of photosynthates, which then leads to death and new growth of the leaves taking place.

Na^+ exclusion. Sodium exclusion is one of the major strategies adopted by the plants to reduce their concentration within the plant. During the initial phase of salinity can be called the first phase there is the exclusion of Na^+ from the cell membrane in the salt-resistant plants. The membrane of the cell is selectively permeable for the transport of ions when there is a development of a gradient. When plants face the salinity stress then a signal is received by the plant system for the accumulation of osmolytes for maintaining the high concentration outside the cell cytoplasm and exclude the Na^+ from the cell membrane. For the Na^+ exclusion from a cell, ATPase plays a very crucial role, which then lower down the salts concentration in the cytosol of the cell, and thus reduces the salinity stress.

Tissue tolerance against stress. When a higher concentration of salts is accumulated in the leaves then this mechanism of tissue tolerance comes into action. In tissue tolerance compartmentalization of Na^+ and Cl^- at the cellular and intracellular level particularly in vacuole which involves the ion transporters, proton pumps and generation of compatible solutes which can reduce the toxic concentration of salts in the cytoplasm. Increasing the concentration of Na+/H+ antiporters i.e. NHX in the vacuole and vacuolar H+ pyrophosphatases lead to the formation of compatible solutes like proline & glycine betaine, which then detoxify the ROS and provide tolerance to the salinity stress. The synthesis of compatible solutes provide protection to enzymes from denaturation, maintain the membrane integrity in the cell and plays adaptive roles in mediating osmotic adjustment.

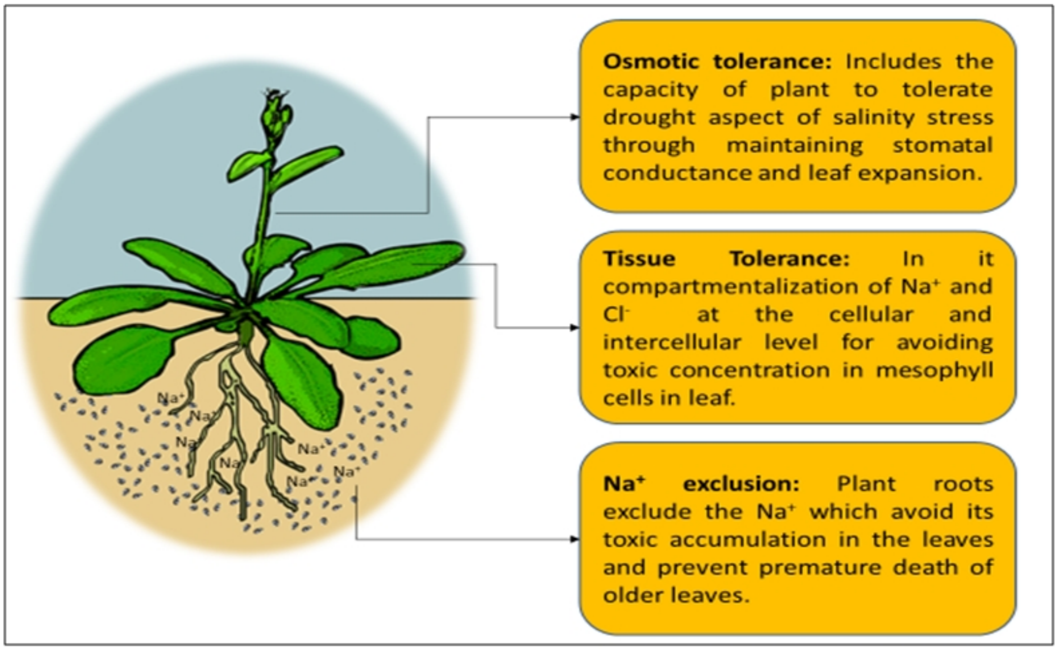

Fig. 2. Salinity tolerance through osmotic tolerance, tissue tolerance and Na^+ exclusion.

Engineering methods to provide tolerance to plants. To maintain sustainability in agricultural production it is very important to adopt strategies that can increase the tolerance in the economically important crops by using some traditional breeding methods and biotechnological approaches. Some crop varieties are being developed through breeding methods for tolerance against salinity stress but their continued success is affected by polygenic inheritance. Screening of previous varieties against salt stress and marker assisted breeding for salinity tolerance has proved to be beneficial for modern breeding techniques (Ali *et al.,* 2021). Susceptibility, as well as tolerance in the plant species to stress, depends upon the expression of multiple genes, which do cross-talk with each other for activation of some defensive mechanism. However, the results we get through the traditional methods are not consistency because of difficulty in finding the genomic regions, which control the tolerance in the plant species under salinity condition. Hence, biotechnological or genetic engineering methods have the potential to give long-term benefit to resistance against salinity stress.

C. Heavy metal stress

Heavy metals are metallic element having a high atomic weight and density as compare to water. These include lead (Pb), nickel (Ni), cobalt (Co), copper (Cu) cadmium (Cd), iron (Fe), zinc (Zn), chromium (Cr), arsenic (As), silver (Ag) etc. Out of them, some are metalloids, which are very toxic to plants even at very low concentration. Some heavy metals like copper and zinc are very important for plant growth and development, which acts as co-factor and activates many enzymatic reactions. These elements also involved in nucleic acid metabolism. Increased industrialization, urbanization, mining activities, excessive use of inorganic fertilizers in the fields and many more anthropogenic activities enhance the concentration of these metals in the environment. This increased concentration creates many problems, which are very harmful to human and animal health. Due to heavy metal toxicity in the soil, plant suffers a lot and reduce the crop yield in very higher amount because it inhibits the plants to absorb essential nutrients from the soil and affect all the metabolical activities of the plant. Disposal of industrial effluents to the water bodies also have a very bad impact on the aquatic animals, which also disturb the food chain. The toxicity of heavy metals depends upon the various factors like the source of heavy metals and their type, concentration in soil, plant species and their genetic makeup, soil composition and pH (Ali *et al.,* 2019). All these factors collectively decide the extent to which the plant is affected by heavy metals (Fig. 3).

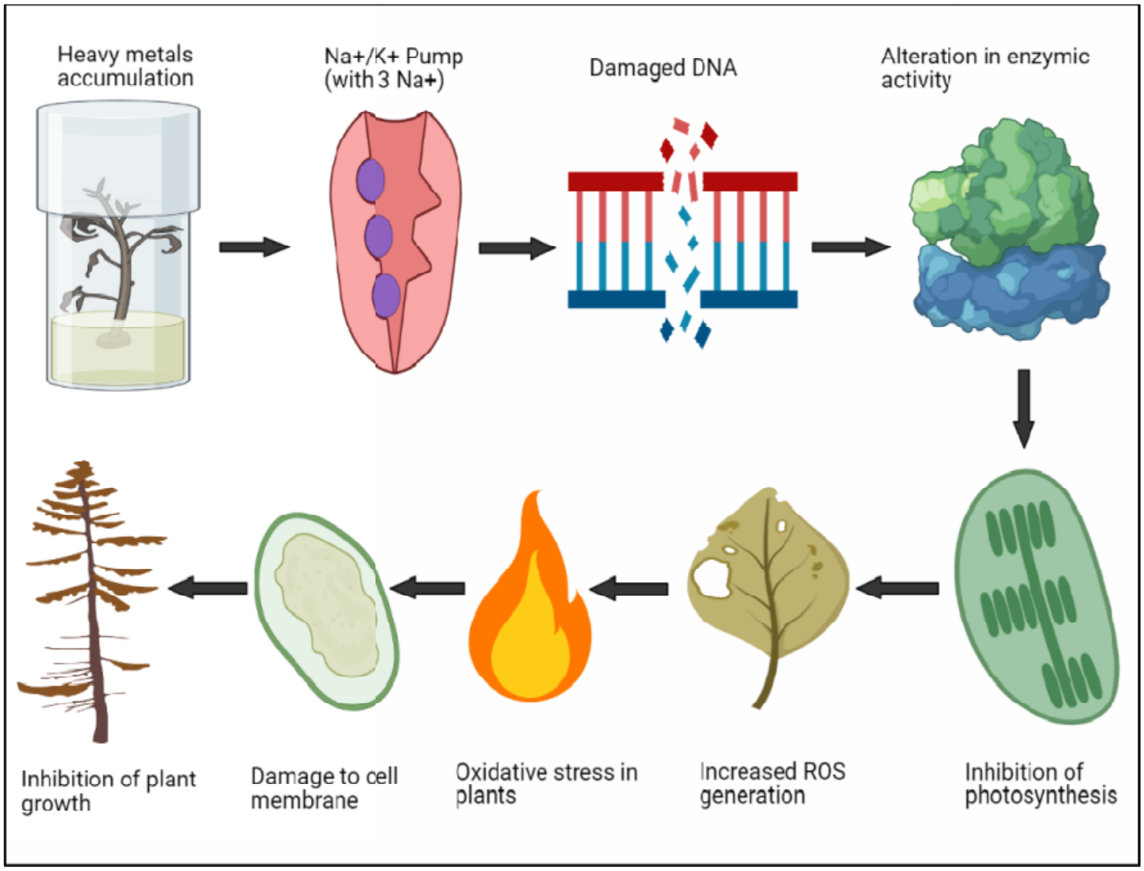

Fig. 3. Mechanism of heavy metal mediated ROS induction and damage to the development of higher plants.

Consequences of heavy metal toxicity in plants. Plants require some heavy metals for their proper growth and development only when they are present in optimum amount. If their concentration is increased by threshold level then they become toxic for the plant growth. Heavy metals have a direct or indirect effect on plant growth. Their direct effect is that they inhibit the functioning of cytoplasmic enzymes, deteriorate the cell structure and having a wide range of physiological & metabolical alteration (Dubey, 2010; Villiers *et al.*, 2011). The indirect effect is that they reduce the availability of essential nutrients because heavy metals replace them from the cationic exchange site. A higher concentration of heavy metals in soil reduces the activity of soil microorganisms, which simultaneously decreases the soil organic matter leads to lowering down the soil fertility. Soil with a low fertility level cannot maintain good crop growth. The most widespread visual evidence of heavy metal toxicity is a reduction in plant growth including leaf chlorosis, necrosis, turgor loss, a decrease in the rate of seed germination, and a crippled photosynthetic apparatus, often correlated with progressing senescence processes or with plant death (Sharma & Dubey, 2007). The extent to which crop growth is hampered depends upon the particular type of heavy metal stress. Heavy metals like cadmium (Cd), mercury (Hg), arsenic (As) and lead (Pb) does not play any beneficial role in crops, even their minute concentration can cause a greater effect on crop productivity (Gill, 2014). It has found that soil contaminated with 1 mg Hg/kg of soil affect the height of rice plants and reduces the tiller and panicle formation (Kibra, 2008). Such toxic elements adversely affect crop growth due to their wide occurrence and chronic toxic effect on the plants grown on these soils.

Mode of action of toxic heavy metals in plant cells. When the heavy metals are accumulated in the cell at a very high amount then their toxicity symptoms are expressed in many ways. There are two types of heavy metals, one is redox-active heavy metals like Fe, Cu, Co and Cr and another one is redox inactive like Cd, Al, Ni and Zn. The redox-active heavy metals are directly involved in the redox reaction in cells and result in the formation of $O_2^{\bullet-}$ and subsequently in H_2O_2 and •OH production via the Haber-Weiss and Fenton reactions. Redox inactive heavy metals lead to oxidative stress, which interacts with the antioxidant defence system and disarrays the electron transport chain. An increase in the heavy metal concentration enhances the lipoxygenase (LOX) activity. These metals also bind with the oxygen, nitrogen and sulfuratoms, which inhibit the metabolism of plants, show toxicity symptoms. Enzymic activity is reduced by the heavy metals because they bind with the cysteine residues (Fig. 4).

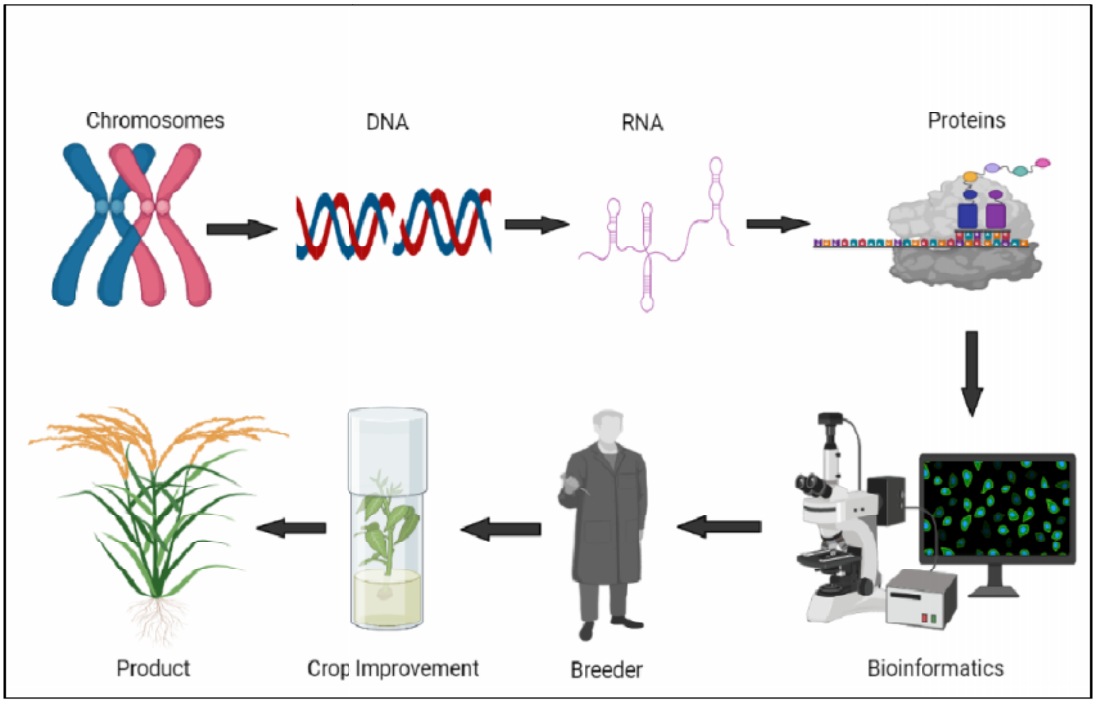

Fig. 4. Tools for enhancing breeding efficacy against the biotic stress.

D. Waterlogging stress

Waterlogging stress is one of the major cause, which limits crop growth and affects sustainability in agriculture. Due to the prolonged period of the rainy season, there is stagnation of water in the agricultural fields, which develop this type of stress to the plants. Waterlogging deteriorates the many soil physical, chemical and biological properties (Ashraf, 2012). Soil structure and texture is disturbed. Microbial activities of the soil are also inhibited. In the waterlogged condition deficiency, (hypoxia) or absence of oxygen (anoxia) is taking place, which adversely hampered the crop growth and development due to restriction in the respiration of plant roots (Gambrell, 1978). The expression of most of the genes under waterlogging condition takes part in the synthesis of such enzymes, which plays a very crucial role in the establishment of an anaerobic fermentative pathway. Under the flooding condition, various alteration takes place in the plant system, which converts the aerobic respiration to anaerobic fermentation for attaining the continuous supply of Adenosine triphosphate (ATP) (Davies, 1980; Vartapetian, 1991).

Plants exhibit various responses under the flooding stress including reduced stomatal conductance, root hydraulic conductivity and net carbon dioxide-assimilation rate (Folzer *et al.,* 2006; Ashraf *et al.,* 2011). Generation of reactive oxygen species (ROS) also under this stress, which causes oxidative stress. ROS damage the integration of cell membrane and thus reduces the efficiency of photosystem II (Kumar *et al.,* 2020). All these physiological changes decrease the process of photosynthesis and translocation of photosynthates. Some plants can withstand the water logging condition through their efficient carbohydrate utilization. Crop growth is severely affected by this condition because it reduces the availability of essential nutrients like nitrogen, magnesium, potassium etc. It had been seen that some morphological changes also take place under this stress, which includes the formation of adventitious roots and the establishment of aerenchyma.

Waterlogging effect on nutrient composition. The waterlogging condition creates a severe deficiency of essential nutrients such as nitrogen, phosphorus, potassium, magnesium and calcium. It reduces the number of nutrients in the plant body. Deficiency of N, P and K can be seen in canola when there is stagnation of water for a longer period. Under waterlogged conditions, there is a deficiency of P, K and Mg in wheat shoots. Moreover, the hampered efficiency of PS II is attributed to the deficiencies of N, P, K, Mg and Ca (Smethurst *et al.,* 2005). It is evident from the literature that adverse effects of waterlogging are not due to the toxic levels of Na and Fe but reduced concentrations of N, P, K, Ca and Mg are the major contributors (Sharma and Swarup, 1989; Smethurst *et al.,* 2005).

Genetic variation for resistance against waterlogged stress. Under the flooding stress crops show marked up and down regulation of several genes. Expression of these genes can be seen under the waterlogging condition, which provides tolerance to plants to some extent. Isolation of these genes are possible from these plants and then introduced in the transgenic plants to get knowledge about its mechanism of tolerance. Early studies performed by isotopic labelling of maize roots with 35S-methionine indicated the synthesis of anaerobic polypeptides when plants were subjected to a low oxygen environment (Sachs *et al.,* 1980). The plant for the synthesis of anaerobic polypeptides utilizes pyruvate decarboxylate, alcohol dehydrogenase and lactate dehydrogenase. Furthermore, in the waterlogging stress condition, the tolerant plants undergo great variation in genetic resources. For example, the wheat crop shows a variation in the genetic resources for tolerance. Setter *et al.* (1999) showed that there is a presence of impressive genetic diversity among 14 wheat varieties when exposed to flooding stress under glasshouse conditions.

Shotgun approaches to induce waterlogging tolerance. Researchers from all around the world try to develop resistance in the crops against the waterlogging stress through the application of nutrient and plant hormones. The application of potassium in the cotton crop grown under waterlogging stress reduce its adverse effect and maintain the growth and development of the cotton crop (Ashraf *et al.,* 2011). In the case of the maize crop, the application of nitrate fertilizers in the soil increases its tolerance against flooding stress (Ashraf & Rehman, 1999). Yiu *et al.,* (2009) showed that the application of spermidine and spermine stimulate various biochemical and physiological adaptations in onion crop when exposed to flooding stress. To provide tolerance to wheat and oilseed rape plants the exogenous application of uniconazole gives a positive response (Webb & Fletcher, 1996; Zhou *et al.,* 1997). Hence, the application of these nutrients and plant hormones plays a very useful role in inducing tolerance in plants under waterlogging condition.

E. Temperature stress

Temperature stress can be divided into two parts which as follows:

1. Low-temperature stress
2. High-temperature stress

Low-temperature stress. Temperature plays the most important role inthe proper growth and development of crops and acts as a major deciding factor for the yield of the crops. But temperature below the optimum level can have a very negative impact on crop productivity which we called as low-temperature stress. Tolerance against low-temperature stress is a very complex process in which crops hardened themselves when there is exposure to low temperature. This phenomenon of tolerance process gives the result, which is irreversible in nature, include damaging the proteins of cell and disturb the cell membrane integrity. Plants, which prefer the tropical conditions for growth, are very sensitive to low-temperature stress because oxidative damage is enhanced by the low temperature. In response to this stress, there is an increasing antioxidant defence mechanism in the plants.

Chilling Injury. When the atmospheric temperature drops to below 14-15 °C but above the freezing point i.e. 0°C because of chilling injury to the crops. Among the crops, maize, rice, tomato, beans, cucumber, sweet potato and cotton are very sensitive to chilling injury (Lynch, 1990; Hopkins, 1999). The exposed plants show the symptom of purple or reddish leaves which leads to wilting of the plant. There is also the development of water-soaked lesions on the affected leaves, which then turn into sunken pits because of cell damage (Kumar *et al.,* 2018). The most common site implicated for chilling injury is the cell membrane, which then results in leakage. The changes in physical characteristics of the cell membrane are implicated as having a role in chilling injury by the finding that chilling stress evokes an elaborate membrane retailoring response that leads to enhanced fluidity at reduced temperature (Tuteja *et al.,* 2011). There is a loss of turgor pressure in the leaves due to this leakage and wilting of the whole plant, which then leads to death. Sometimes plants develop physiological disorders under the low-stress condition. The first time the German plant physiologist Molisch uses the term "chilling injury" in 1897 to describe this phenomenon.

For deciding on the control methods for chilling injury it is very important to understand the potential biochemical mechanisms which start the chilling injury. The direct effect of the chilling injury on the activities of enzymes and have an indirect effect of membrane perturbations on intrinsic enzymes (Parkin *et al.,* 1989). During the low-temperature stress, there are irreversible injuries on the plants, which are mediated by lipid peroxidation. The effect of chilling injury varies according to the plant species. Plants present in tropical climates are very sensitive to chilling injury and adversely affected while temperate plants can withstand the chilling injury stress (Sanghera *et al.,* 2011) (Table 1).

Table 1: Effect and symptoms of chilling injury.

S. No.	**Effect of chilling injury**		**Symptoms of chilling injury**	
	Direct effect	**Indirect effect**	**Visible symptoms**	**Physiological symptoms**
1.	Necrosis of the leaves	Delaying in harvest	Yellowish appearance due to loss of chlorophyll	Abnormal patterns of ethylene production in fruits
2.	Discoloration	Reduce grain setting	Necrosis	Inhibition of starch conversion in fruits
3.	Reduce growth and development	Inhibit the process of photosynthesis	Loss of turgor pressure which leads to wilting	The decrease in photosynthetic activity
4.	Reduce the seed germination	Affects the absorption of water	Increased insect-pest and pathogen attack	Cessationof protoplasmic streaming
5.	Breakdown of tissue and browning		Discoloration on the fruit surface	Inhibition of development of flavorcomponents in fruit

Freezing injury. Freezing injury in plants occurred from two sources:

1. **Freezing of soil water**
Water, which is present in between the soil pores, gets freezes at about -2°C temperature, which is then not available to plants roots, and the plant is deprived of water availability.
2. **Freezing of water within a plant**
Water freezing within the plants can cause damage to the structure and functioning of the cells and tissue. Initially, the formation of ice takes place in cell walls and intercellular spaces. When the ice crystals grow then this cause damage and puncture into the cytoplasm.

Two types of freezing occur in plant cells and tissue

1. **Vitrification:** It is the rapid freezing of cellular components into an amorphous state without the formation of ice crystals. The decrease in temperature at a very fast rate i.e. 30°C/min.
2. **Crystallization:** When there is a formation of ice crystal either extracellularly or intracellularly due to a decrease in temperature.

Phenomenology of Frost damage. Damage caused by the freezing injury under the field condition in various forms and is not easy to identify the damage. Damage caused by the freezing injury can be connected with the occurrence of prolonged frost event. At the end of winter causes of damage on the crop plants might be very complex. The phenomenology of frost damage on the crop plants is better explained in handbooks of plant pathology, horticulture, agriculture and forest sciences. In the field of applied science there observed having considerable value to the ecologist.

Symptoms of freezing injury. Under the freezing stress, plants going through destructive events and mechanical damage caused by the formation of ice crystal, which ruptures the cell membrane, leads to leakage of cell constituents. Here are some symptoms, which occurred immediately after freezing and thawing:

i. **Discolouration:** It is the most common symptom of freezing injury, which can be seen on leaves and fruits. It is because of the decay of bio membranes. Cell contents that meet each other are initially present in their compartments under this stress. This results in coloured reaction products, which then hold on to the cell proteins and cell walls.
ii. **Bleaching:** Under freezing stress, plants are not able to synthesize the chlorophyll. As a result, plants produce leaves that are yellowish in colour i.e. chlorotic.
iii. **Dieback and shrinkage of plant tissue:** Freezing stress cause shrinkage of leaves, stems, roots and flower stalks of crop plants and then the formation of holes in leaves.
iv. **Rupturing of cell membrane:** Due to the formation of intracellularly and extracellularly ice crystal, which then grow and rupture the cell membrane, which disturbs the cell homeostasis.
v. **Malformations:** Freezing stress leads to the formation of organs that are distorted, stunted or fragmented. Hence, this freezing temperature cause malformation, flower sterility and buds fail to open properly.
vi. **Heterochronism:** It refers to the process in which various development stages of the crop are delayed because they undergo the dormant phase. For example: inhibit sprouting and flowering.

High-temperature stress. For the proper functioning of all the metabolically activities of plants, temperature plays a very important role. Particularly temperature and photoperiod are the main deciding factor for good crop growth. Cultivation of a specific type of plant species in an area depends upon the temperature because some plants prefer low temperature and others prefer high temperature for completing their life cycle. The temperature has a very significant role in the distribution, abundance, phenology and physiology of varied types of crop species. Several kinds of research have been shown that any changing in climatic conditions affects the survival of various types of crop species. Species capable of migrating at high rates and higher fitness are more likely to survive and dominate, and in some cases may gain geographic range (Thomas *et al.,* 2004; Menendez *et al.,* 2006). Climate change has a very negative effect on crop survival. According to some reports, climate change reduces the arable area of about 80-90% of plant species and the size of some crops like groundnut, potato and cowpea at a very high rate. Almost 16-22 % of the plant species assumed to be extinct. Fischer *et al.* (2002) predicted the loss of suitable area for crop production in sub-Saharan Africa, which already has harsh environments; however, some regions will experience a considerable expansion of suitable arable land (higher altitudes) and have the potential to increase crop production area. India and Northern Australia also face the problem of reduction in the size of the arable area but some parts of the world show the increase in areas like Canada, Northern USA and most of Europe.

Effect of high-temperature stress

Physiological processes

- High-temperature stress reduces the chlorophyll content of leaves due to a change in the chlorophyll a:b ratio which is the result of premature leaf senescence.
- Under the high temperature than optimum level increases the generation of reactive oxygen species (ROS) which also affects the chlorophyll content of leaves.
- Thylakoid membrane is also deteriorated by the high-temperature stress.
- Due to the effect on the thylakoid membrane, the activity of photosystem II is highly reduced because PS II is highly temperature-sensitive.

Development and growth processes

- High temperature adversely affects plant growth and development leads to a reduction in crop yields at a very higher rate.

- An unnecessary increase in the photosynthetic rate significantly enhanced the leaf number by reducing the reproductive development of plants.
- There is an increase in the leaf elongation rates but a reduction in leaf elongation duration.
- Cell division and cell elongation rates enhanced under high-temperature stress.

Reduction in reproductive processes and yield

- Plant reproduction is highly affected under high-temperature stress because microsporogenesis, megasporogenesis, pollination, pollen tube growth, anthesis, fertilization, and embryo development all these processes are highly sensitive to high-temperature stress.
- Inhibition of all the reproductive processes leads to a reduction in the number of grains and thus reduces crop yield.
- Several crop plants (germination percentage), dry matter production (growth, tillers, reproductive sites), numbers of seed, seed size (sed filling duration) collectively all these factors decide the crop yield.
- High-temperature stress adversely affects pollen and ovule functioning. High-temperature stress directly influences seed fill duration by decreasing the grain fill duration, leading to smaller seed size and lower yields (Prasad *et al.,* 2002, 2003, 2006a,b, 2008a,b).

Approaches for development of high-temperature stress-tolerant genotypes

Backcross approach. In the backcross breeding method, the hybrid and the progenies in subsequent generations are repeatedly backcrossed to one of the parents. As a result, the genotype of progeny from backcross is very same as that of the recurrent parent. The major objective of this method is to correct some limitations of the crops. Backcross breeding is very useful method of transferring the desired traits from one plant to another through naturally or engineered methods. For developing the heat tolerant crops, the backcross breeding method plays very important role (Wang *et al.,* 2019). Through the crossing of high temperature tolerant rice line N22 and high temperature sensitive line Xieqingzao B lead to the development of high temperature stress tolerance rice varieties at the milky stage (791 backcross introgression lines) 703T (high temperature tolerant) and 704S (high temperature sensitive) are the two backcross introgression rice lines are selected through evaluation of phenotypic characteristics and comparison of genomic polymorphism, with identical genetic material but having different high temperature tolerance at the milky stage and renamed as XN0437T (high temperature tolerant) and XN0437S (high temperature sensitive) (Liao *et al.,* 2011). Rodriguez-Garay and Barrow (1988) developed high-temperature-tolerant cotton lines by the backcross method. They developed these tolerant lines of cotton by using a high-temperature resistant line of *Gossypium barbadense* L. and Paymaster 404 was used as high-temperature susceptible lines. The crossing of these two lines was made to develop F1, F2 and second backcross populations which provide tolerance against the high-temperature stress.

Quantitative trait loci approach

There is not only one thermotolerant gene in crops that provide tolerance against high-temperature stress. There is an expression of different sets of genes at various stages of crop growth. Quantitative trait loci (QTL) analysis is used for the identification of those genes, which can be utilized for tolerance. Wild types of crop species and ecotypes play a very crucial role in the identification of novel QTLs and alleles, which can be used for providing tolerance to high-temperature stress. Constitutive QTL can be found in every type of climate while adaptive QTLs are only detected in the specific type of environmental conditions. Genetic resources found in rice subspecies like indica and japonica are tolerant to high temperature stress. On the several rice populations specifically at booting (Zhao *et al.,* 2006) and flowering stages (Xiao *et al.,* 2011), QTL mapping studies for high temperature tolerance have been conducted. With the help of recombinant inbred lines which is a result of cross between 996 (high temperature stress tolerant rice cultivar) and 4628 (high temperature stress sensitive rice cultivar, two QTLs which are tolerant to high temperature has been found. The lines which are subjected to high temperature stress at the flowering stage uses pollen fertility as an indicator of high temperature tolerance. In the rice variety (N22) the QTLs for high temperature stress tolerance were found by Ye *et al.,* 2012, who identified four chromosomal locations associated with spikelet fertility under high temperature stress by genotyping a BC_1F_1 population and four putative QTLs by composite interval mapping of an F_2 population.

Transgenic approaches

Heat shock proteins (HSP). When the plants are exposed to high-temperature stress then there is the formation of heat shock proteins, which provide tolerance to plants. These proteins are synthesized by the cells to prevent the damage caused by high temperature. Mainly they serve as chaperone function for the stabilization of new proteins and repair the damaged proteins due to stress. Molecular chaperone helps in the restoration of the cell structure and denatured proteins. The formation of HSPs is a universal phenomenon due to its occurrence in all types of plant and animal species. These are also referred to as “stress proteins” because they are produced under almost every kind of stress like heavy metal stress, free radicals and stress produce by viruses etc. The induction of genes encoding heat shock proteins is one of the most prominent responses observed at the molecular level of organisms exposed to high temperature (Vierling, 1991). In maize crop, high amount of HSP101 is found especially in tassel, embryo and endosperm than in roots and leaves, which plays a very important role against high-temperature stress. The unwanted increase in temperature affects the plant metabolism and initiation of programmed cell death or apoptosis because the cell fails to produce proteins. Then heat shock factor (HSF) is activated and increases transcription of heat shock genes. Synthesis of heat shock proteins suppress the process of apoptosis and provide stability to the cell.

F. Biotic stress

Biotic stresses also have the great potential to cause a huge reduction in crop yield and productivity. Biotic agents like fungi, bacteria, viruses and nematodes develop diseases in the plants, which reduces the ability of plants to produce the required yield. Throughout history, various plant diseases cause great loss of crops such as potato blight in Ireland, leaf blight of maize in the USA, coffee rust in Brazil and the great Bengal Famine (Hussain, 2015). All these events cause a very high reduction in food production and affect human life to a very high extent, which also led to death. Due to climate change, there is an occurrence of several new pathogens and insect-pests, which pose a great threat to the plants (Sanghera *et al.,* 2011). Genetic polymorphism is present in the plant pathogen and insect-pests, alteration in this polymorphism due to changed climatic conditions increase their aggressiveness for the development of diseases (Anderson *et al.,* 2004). Now, these agents also present in those areas of the world where they are not prevalent before. Hence, to sustain world food security there is a demand to develop resistant varieties by using the resistance alleles, which can be isolated from the wild genotypes. Pathogens constitute about 15% loss in the crop yield, which create the great need to develop pathogen-resistant crop varieties (Onaga & Wydra, 2016). Hence, examine the tolerance mechanism controlled by these resistance genes is insist upon to enable their use for improving the crop species and sustain the crop yield. Stresses caused by biotic agents can be reduced by studying their genetic mechanism. Genetically modified plants have the potential to tolerate a particular type of biotic stress.

There is the involvement of several morphological, genetic, biochemical and molecular processes which decides the resistance of plants against the pathogens and insect-pest attack. All these processes take place continuously in the plants but can be more involved after the biotic attack on crops. The success of plants in expanding these tolerance mechanisms is an evolved capability to endure in unfavourable climatic conditions. According to a recent study, it has been shown that plant resistance mechanism against pathogens and insect-pests are related to mechanistic animal immunity. The identification of plant pattern recognition receptors (PRRs) that sense pathogens or insect pests conserved molecules termed pathogen-associated molecular patterns or herbivore associated molecular patterns (PAMPs/MAMPs/HAMPs)—and the subsequent PAMP-triggered immunity (PTI) is a paradigm for plant-pathogen interaction studies.

G. Defence mechanisms of plants in response to pathogens

Phytopathogens causes diseases on the crop plants and reduce the ability of the crop to produce the required yield. These pathogens attack almost all types of plant species under favourable environmental conditions. Plants show response to several pathogens by the intricate and dynamic defence system. The defence mechanism adopted by plants against pathogens has been categorized as innate and systemic plant response. Specific and non-specific general resistance is involved in the innate defence mechanism of the plant. The molecular basis of non-host resistance is not well studied but presumably relies on both constitutive barriers and inducible responses that involve a large array of proteins and other organic molecules produced before infection or during pathogen attack (Király *et al.*, 2007). Morphological and structural barriers (cell walls, trichomes, thorns), chemical compounds such as phenolics, metabolites, nitrogen compounds, saponins, steroids and glucosinolates and enzymes included under the constitutive defences. All these compounds provide tolerance to plants under biotic stress conditions by imparting strength and rigidity to plants. Generation of toxic chemicals and enzymes, which degrade the pathogens like glucanases & chitinases, included under the inducible defences. All these compounds present in plants as active or inactive forms. When the pathogens attack on the plants than in the response of this inactive form of compounds are converted into active forms. Although, innate immunity is a highly efficient and most common type of defence mechanism which provide resistance to pathogens.

H. Modern approaches for improving biotic stress tolerance in plants

Conventional breeding methods have great potential to develop new crop varieties. However, by considering biotechnological approaches the chances of success can be increased. For enhancing the efficacy of conventional breeding one biotechnological approach i.e. molecular marker-assisted breeding (MAB) plays a very crucial role. The accurate indirect selections, which depend upon genomic tools, have been utilized continuously to increase the functioning of the biotic stress tolerance traits. The advantage is that, to date, the genome sequences for more than 55 plant species have been produced and many more are being sequenced (Guo *et al.,* 2015). Knowledge about genome sequencing is very important for finding genome-wide markers. These markers then utilized for the development of special population like near-isogenic lines, chromosome segment substitution lines, recombinant inbred lines and introgression lines. According to the latest research, heterogenous inbred family (HIF) and multiparent advanced generation intercross (MAGIC) populations can be utilized for the development of tolerant varieties. Genome-wide association (GWA) analysis has successfully applied to the rice, maize, wheat, sesame and barley. GWA also adapted to the "breeding by design" approach often stated as genome selection, which prognosticate the results of different crosses on the ground of molecular markers information.

"Green Super Rice" is the new rice cultivar developed by using the different approaches and this rice cultivar have resistance against many diseases, insect-pest and drought stress (Onaga & Wydra, 2016). Its nutrient use efficiency is also very high. Similarly, the combination of different approaches with breeding by genome selection help to develop a novel type of plants with selected major loci. Plant breeders have a great interest in the field of expression studies. Out of them, next-generation sequencing (NGS) technology helps in studying the different complex traits, genome sequencing and compare with reference sequences becomes more practicable. To get the information about the whole genome sequence variation in Arabidopsis, resequencing has been used and to identify the single nucleotide polymorphisms (SNPs) (Guo *et al.,* 2016).

II. CONCLUSION

Due to an increase in the world population, there is a greater need to produce a high amount of food grains to sustain food security. During the plant growth period, it faces several stresses, which reduces its growth and development. There are two types of stresses such as biotic stress and abiotic stress. Both have the potential to cause a huge reduction in crop yield and crop quality. All the physiological and biochemical activities of the plants severely affected. Abiotic stress like drought stress, flooding, heavy metal stress and temperature stress (low and high temperature). A prolonged period without rain leads to drought or water stress. Due to the water deficiency, plant also fails to uptake the nutrients because there is a disturbance in the transpiration process. The drought stress inside the phospholipid bilayer leads to the protein displacement in the cell membrane. Soil salinity causes two main effects on plants such as osmotic stress and ionic toxicity. Osmotic pressure is increased under the salinity condition, which reduces the plants to uptake the essential nutrients, and water from the soil while uptake of Na^+ and Cl^- is increased which damage the cell homeostasis and create toxicity in plants. Salt stress increases the ROS generation, which decreases the immune power of plants, their growth and development. Waterlogging stress is also one of the major problems for sustainable agriculture because it disturbs the soil fertility level. Flooding stress reduces the oxygen level in the soil solution, which inhibits the respiration process. The waterlogging condition also affects various physio-chemical processes because inducing the deficiency of nitrogen, potassium, magnesium and calcium. The formation of ice crystal intracellularly and extracellularly rupture the cell membrane, which leads to oozing out of cell constituent. Chilling and freezing injury both disturb the photosynthesis process, respiration and metabolism. On the other hand, high temperature causes heat stress, which increases the flip-flop movement of phospholipids and damages the cell proteins and cell membrane structure. Industrialization, urbanization, mining activities, excessive use of the inorganic fertilizers and other human activities increased the heavy metal stress which has a direct effect on cytoplasmic enzymes, deteriorate the cell structure and having a wide range of physiological & metabolically alteration. Biotic stress includes disease caused by fungi, bacteria, virus, insect-pest and nematodes, which adversely affects crop yield and productivity. Biotic stress agents made their host deprived of the nutrients, which decrease the plant vigour and death of plants under severe cases. Biotic stress makes crop plants more susceptible to environmental or abiotic stress. To tolerate these stresses, plants undergo various defensive mechanism through the activation of some genes and enzymes, which activate several defensive pathways. Nevertheless, some susceptible plants have not such ability to withstand these conditions, which then leads to death. Hence, to maintain sustainability in agriculture there is a greater need to develop such plant varieties which provide tolerance against biotic and abiotic stresses. By using conventional breeding methods, genetic engineering and biotechnological approaches etc. or by the combination of these approaches, biotic and abiotic stress tolerance varieties can be developed which can maintain agricultural food production and maintain sustainability in agriculture. Thus, by utilizing the biotic and abiotic stress tolerant crop varieties promises their future perspective for maintaining better crop production and stabilizes the income of farmers even under adverse environmental conditions.

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Conflict of interest

The authors state that they have no interest in conflicts.

List of Abbreviation

ABA = Abscisic acid, APX = Ascorbate Peroxidase, ATPase = Adenosine Triphosphatase, As = Arsenic, Ag = Silver, CRT = Calreticulin, CO_2 = Carbon dioxide, CAT = Catalase, Ca = Calcium, Co = Cobalt, Cu = Copper, Cd = Cadmium, Cr = Chromium, DNA = Deoxyribonucleic acid, DRE = Dehydration Responsive Element, ETC = electron transport chain, Fe = Iron, FAO = Food and Agriculture Organization, GR = Glutathione reductase, GWA = Genome-wide association, HSP = Heat shock protein, HSF = Heat shock factor, HIF = Heterogenous inbred family, K = Potassium, LOX = Lipoxygenase, LEA = Late Embryogenesis Abundant, MAB = Marker-assisted breeding, MAGIC = Multiparent advanced generation intercross, mM = Millimolar, Ni = Nickel, Na = Sodium, NGS = Next-generation sequencing, NaCl = Sodium Chloride, PRRs = Plant pattern recognition receptors, PAMP = Pathogen associated molecular pattern molecules, PS = Photosystem, Pb = Lead, QTL = Quantitative trait loci, ROS = Reactive Oxygen Species, SNP = Single nucleotide polymorphisms, SOD = Superoxide dismutase, UNCCD = United Nations Convention to combat desertification, Zn = Zinc

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