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RESEARCH ARTICLE

THE IMPACT OF ABIOTIC STRESSES ON PLANT GROWTH AND DEVELOPMENT

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Abstract

Drought, cold, excessive salt, and heat are key abiotic factors limiting global food crop yields. Due to the multigenic nature of tolerance to stress, traditional cultivating plant techniques for improving agricultural tolerance to abiotic stress have had little effectiveness.Plants are regularly exposed to unfavorable environments such as abiotic stresses, which significantly influence yield determination and the distribution of distinct plant species in various situations. Plants respond to adversity by activating enzymes, creating intricate gene linkages, and engaging with molecular processes.In contrast, plant tolerance to heat stress is mediated by several processes and genes that can be directly introgressed into high-yielding modern crop cultivars. The important issue here is identifying the metabolic and cellular pathways damaged because of heat stress find methods to decrease the detrimental impacts on crop productivity.

Introduction:-

Abiotic stressors, for example, regularly expose plants to adverse environments, which have a significant influence on determining yields(1) and the distribution of distinct plant species in a variety of situations(2). Abiotic stresses which limit plant development and growth include a lack of available water, extreme temperatures, a lack of soil supplements as well as a surplus of hazardous impurities, and an abundance of mild soil dryness (3). The variety and power of the photosynthetic process, together with the different kinds of metabolic processes related to development and growth, influence the adaptability of the plant in several circumstances (4).In reaction to abiotic stressors, plants activate a large number of enzymes, and develop intricate gene connections, in addition to interacting with molecular mechanisms (5).Abiotic stressors (heat, cold, aridity, and salt) have an impact on crop survival, productivity, and biomass output by as much as 70%, jeopardizing global food security. Desiccation is a key consideration in plant growth, evolution, and output because it is mostly induced by salt, dryness, and heat stress(6).Whenever vegetation is subjected to environmental stressors it may encounter a few issues (Figure 1).

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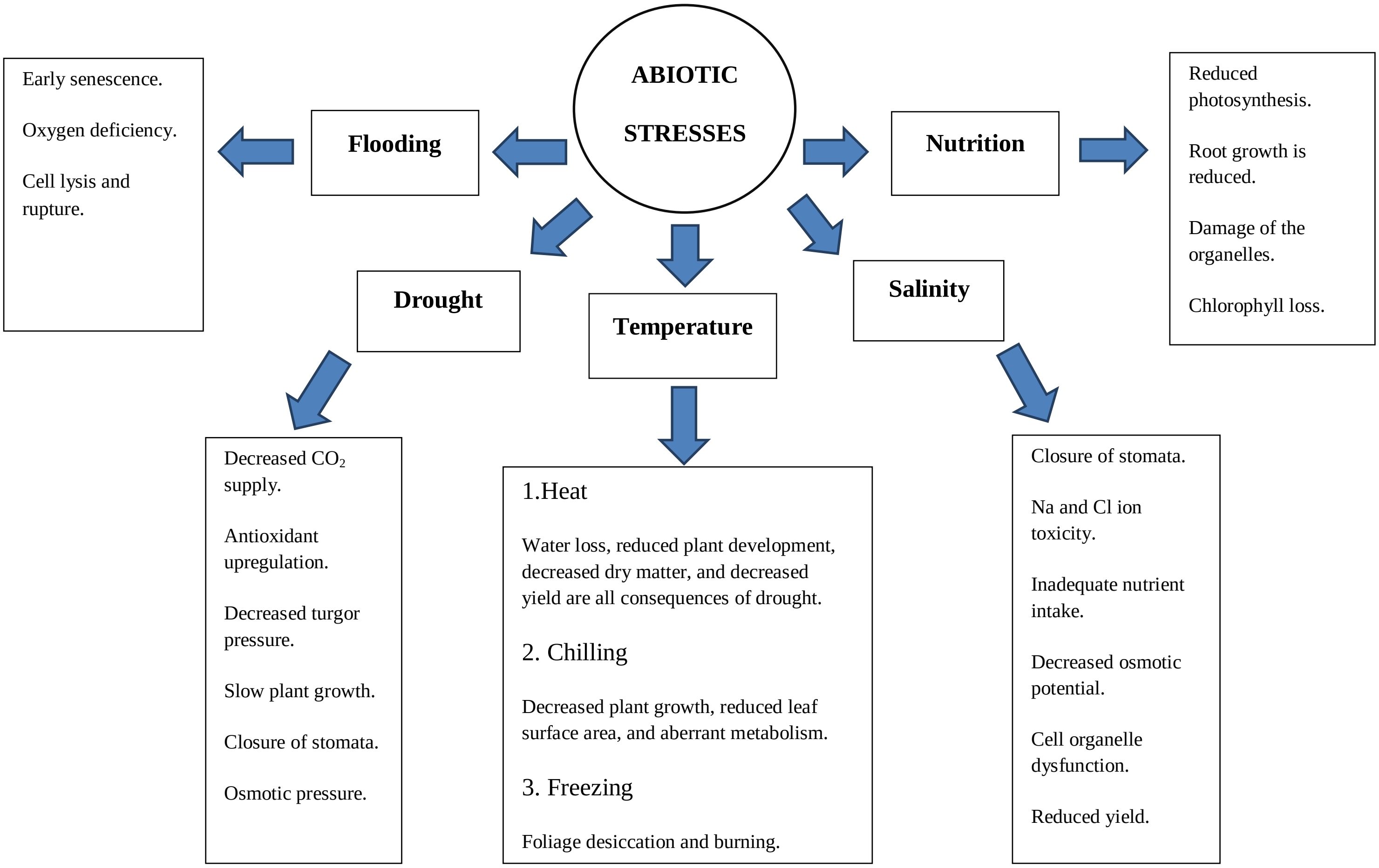

Fig.1:- Plant response to several abiotic stressors (salinity, nutrition, temperature, floods, and drought).

Plant breeders have enormous challenges in an attempt to manage genetics in vegetation to fix the problem since plant resilience and tolerance to this issue exist in crucial natural environments [7].

The Impact Of Abiotic Stress On Plant Development:

Temperature:

Chilling:

The susceptibility of plant components to cold temperatures determines chilling harm. Cell membrane stability is a critical component that is directly related to connecting plants, which are susceptible to cold stress [8].When plants are subjected to low-temperature light, their cell membrane lipids shift largely from liquid to solid state affected by the amount they are rich in unsaturated fatty acids. [9].Plants with a higher concentration of fatty acids in their cell membranes may be particularly vulnerable to freezing or frost damage, implying that changes in these conjugated fatty acid groups are required for them to withstand frost or chilling stress.In extremely low temperatures, the contents and activity of many enzymes rise or decrease (Figure 2).

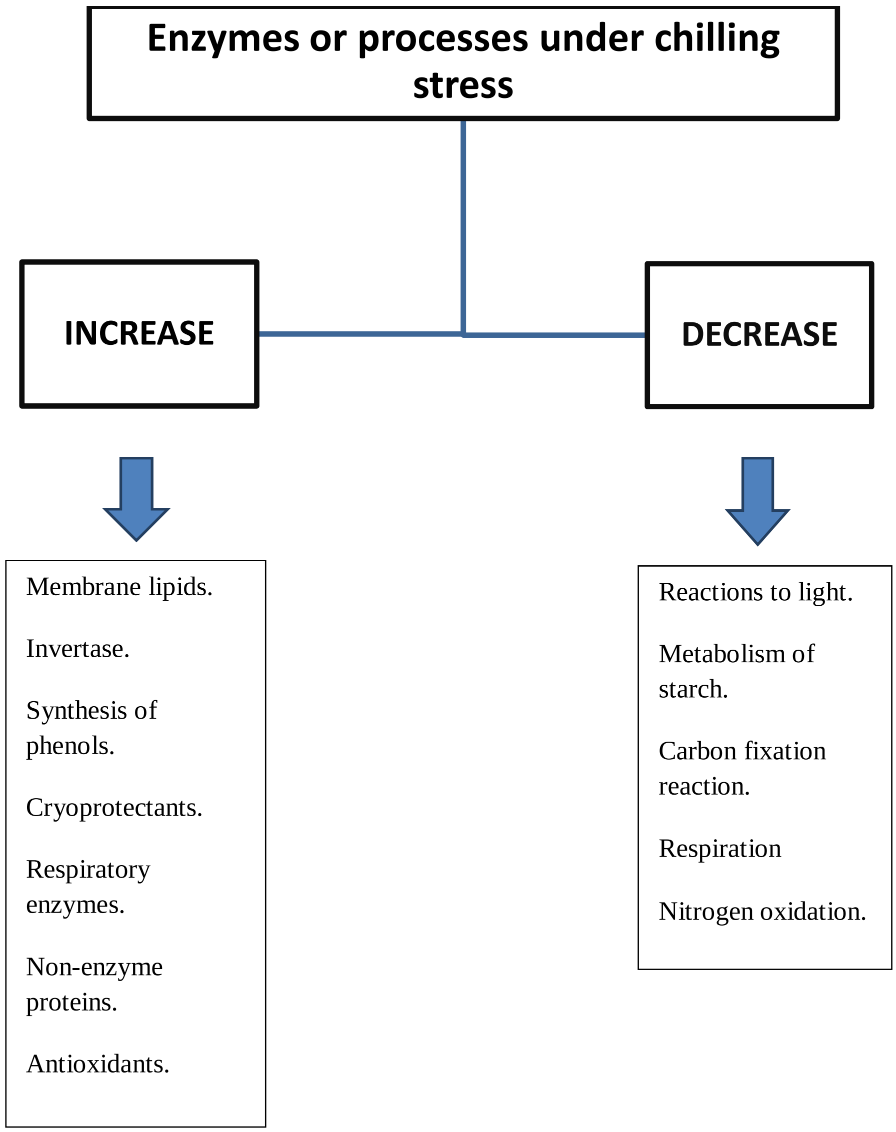

Fig.2:- Enzymes and processes that increase or decrease in response to cold stress.

Freezing:
The capacity of plants to endure freezing temperatures varies widely. Agriculture crops growing in tropical and subtropical environments(for example, corn, cotton, soybeans, rice, mango and tomato, and so on) are more prevalent and vulnerable to frigid temperatures. Plants that thrive in moderate climates can withstand cold temperatures, however,the level of resistance varies according to species. Nevertheless, these plants' extraordinary freezing resistance isn't innate, plants become active at low temperatures in distinct biochemical and physiological systems to deal with freezing, a procedure called "cold acclimation."In one study, rye plants exposed to -5C without prior cold acclimatization died, but after 7-14 days of cold acclimatization at 20C, they were capable of withstanding temperatures down to -30C[(10)].

A previous study on plant cold acclimation was intended to understand what happens at low temperatures in order to develop resilience under these conditions.According to a previous study, Plants activate their antioxidant defenses, both enzymatic and non-enzymatic defense systems when exposed to freezing temperatures [(11)].Plants produce a variety of osmolytes and osmolyte inhibitors, including proline, glycine betaine, lipids, and carbohydrates, to assist them in freezing injury (damage to the cellular membrane) in low-temperature environments. Several genes, in addition to solutes and polypeptides, have been found to be implicated in cold acclimation activation mechanisms, thereby increasing the ability to withstand frigid temperatures.To cope with cold, for example, all chromosomes are engaged, in hexaploid wheat

Acclimatization to cold temperatures is caused by a synthesis of physiological, biochemical, and genetic factors.Plants undergo changes when exposed to subzero temperatures, yet unclear which changes occur during the cold adaptation process while others occur during other resistance processes mechanisms. On the other hand, freeze-tolerance mechanisms have not been linked to any particular gene-encoding responseto freezing injury.There have been several efforts to isolate and characterize the genes involved activated at very temperatures that are too low. The most recent research confirms that ICE2 has a role in Arabidopsis acclimatization, eventually boosting plant resistance to low-temperature stress. The CBF cold-response pathway, which was newly identified, explains the role of clod acclimation in tolerance to low temperatures.

Heat:

Plants exposed to extreme temperatures endure various unique alterations and modifications. Adaptation to extreme temperatures occurs over different duration and layers of plant structure.Plants can suffer major injury and even death if exposed to excessively high temperatures for a long amount of time. Different plant components are influenced differently at certain temperatures. The type of harm relies on the plant's development stage, sensitivity, and cellular activities at the moment. Heat, on the other hand, not only has an impact on the plant at not just at the cellular level, but also has an influence on a variety of complicated structures and processes, ultimately leading to the death of a plant.When plants are subjected to extreme temperatures, they undergo a variety of biological changes, including the formation of ROS (reactive oxygen species), which affects the metabolism of cell membranes.Proteins are effective at a particular temperature, but when that temperature is exceeded, they deactivate, as a result of alterations and an increase in enzyme activity and in the generation of active oxygen species (AOS) and ROS.To combat ROS, numerous enzyme-based (e.g., SOD, POD, CAT) and not enzymatic (e.g., proline, GB) antioxidants are produced.; nevertheless, antioxidants have relatively little impact on the activity of AOS, which is predominant at temperatures that are exceptionally high.The consequences of AOS, which include decreased photosynthesis, enhanced oxidative stress, and alterations in assimilate transport, severely injure and finally kill the plant(12).Plant resistance to heat stress, on the other hand, is mediated by a number of processes and genes. Heat is commonly combined with additional stressors in the field,heat, and drought stress, or heat and radiation stress.Other stresses, when combined with heat stress, can produce comparable effects.Plants produce proteins as a result of heat stress in order to deal with the biological effects of high temperatures.They are referred to as heat-shock proteins(13).Heat tolerance is achieved by a variety of methods, with HSPs serving as the only component. Many signaling genes become involved in resistance strategies since a plant is subjected to very high temperatures through signaling and activation of a variety of metabolic processes. More study is needed to discover and characterize the genes involved in plant tolerance to extremely high temperatures. As the routes that are involved in plant heat stress resistance and tolerance are better understood it will be simpler. to identify interactions between extreme temperature stress and other stressors, this will assist in the development of methods to make plants more resistant(14).The main issue here is determining which cellular and metabolic processes are damaged by thermal stress in order to devise methods to alleviate the detrimental impact on crop productivity.

Salinity:

Stress from salt is a severe issue in arid and semiarid areas, lowering crop productivity and global agricultural yields. Salinity affects around 20% of harvested land and 50% of irrigated land, reducing agricultural output and productivity(15).The basic research goal at the moment is to increase plant growth and yield in salinized soils. Tolerance for salt in agricultural plants can be enhanced using both traditional and molecular breeding strategies(16).Crop yield stability is also crucial in salt-stress settings. There is limited knowledge of how salt-stress circumstances influence the many cellular metabolisms of cell division and differentiation. This, in turn, reduces plant growth and yield(17).Plant adaptation to salinity is thought to entail phenological responses that are required in a salty environment for plant wellness management but may reduce productivity (18).Yet, by employing suitable crop management strategies, excellent crop yields may be obtained under salty circumstances in some situations(19).

Several tomato types, most of which are wild or primitive varieties, have salt tolerance genes.Instances in which significant genetic variation salt resistance appears in cultivars or is accessible and often utilized when it comes to breeding efforts are dangerous(20).The salt-resistance varieties have a constrained gene pool with unfavorable connections between genes required for robust growth and salt endurance. Current research on differentiating salt-resistance drivers and separating the incorporation of plant expansion and growth, and tolerance to salt provide certain plant cultivation and biotechnology concerns techniques to increase yield. Based on a molecular marker breeding strategies will differentiate salt-resistant loci and stimulate the separation of physically related loci that have a negative impact on yield [(21)]. To boost yield, Salt resistance factors may be measured directly introgressed into recent high-yielding crop cultivars. The essential stage in a seedling establishment that impacts crop production performance is seed germination[(22)]. Crop growth is dependent on the interplay of seed quality and seedbed conditions[(23)].Susceptibility to water deficiency and salt resistance are two factors that have a negative impact on seed germination. Early development stages are more prone to salt as opposed to mature phases, and lower humidity has a negative influence on plant development and cultivation.Poor and unsynchronized seedlings are generated as a result of limited precipitation at sowing time if moisture levels in seedbeds are low during the planting season [(24)] altering the uniformity of the plant population and having a detrimental influence on agricultural output.

Furthermore, salt stress inhibits seed germination and slows germination, leading to reduced plant growth, improper development, and poor crop yield. The seeds have minimal resistance to stress, Specifically, the stress experienced during planting and growing seeds, although plant salt tolerance often develops with regard to plant development. Soil salinity may impact seed germination by raising osmotic potential outside the seeds, avoiding water intake, And by observing the adverse impacts of Na^+ and Cl^- ions upon growing seeds [(25)].

Water Stress:

Drought:

Living beings are classified among two categories: biological structure and basic requirement of water. Without being affected by the living origins of life might be debated, particularly considering evolutionary scientific advances. The necessity for water is paramount. Life forms may use any biological specialty, no matter how great free water is accessible.Water is necessary for plants because it conducts various critical activities.Herbaceous vegetation contains 90% water by dry weight.Water supports plant cell turgor, facilitating respiration. Water also has various biophysical characteristics that make it a useful solvent (for example, high-temperature vaporization and enhanced surface energy). These properties enable water to stay liquid even at severe temperatures and to operate as a solvent for a wide spectrum of elements, molecules, minerals, and ions. Moreover, water is essential in many biological processes, such as photosynthesis, where it serves as the principal electron donor[(26)].Water scarcity is a key concern in plant production, reducing plant health, productivity, and plant species dispersion. Almost 35% of the area on Earth is dry or semi-arid. Rainfall is the only source of water in this area. Regions with enough rainfall but unequal distribution throughout the year confront water-deficit conditions, which reduce crop production. Drought accounts for over half of worldwide crop loss. Virtually all farmed regions throughout the world are experiencing water scarcity. Drought stress or water scarcity is largely unpredictable; however, 'dry seasons' are foreseen in some locations.One of the key study themes in agriculture in the twenty-first century is producing plants that can resist drought stress or tolerate water-deficit circumstances for an extended period of time while maintaining their health and output. Further research is needed to understand the cell physiology of plants under drought stress. Such research will aid us in increasing plant growth and production in water-stressed situations

Flooding:

Over-irrigation, inadequate drainage, and severe rainfall are the primary causes of land flooding [(27)].Waterlogging is presently a major problem, not just in rainy areas but also in locations where irrigation water is utilized. Flooding affects around 0.7 million acres in certain nations, and 60 thousand acres are always flooded owing to inadequate drainage and water channel leaks. Sodium can also promote waterlogging in some soils, while sodicity can cause infiltration in various soil types. When the quantity of Na ion in the soil increases, it constricts the soil pores, restricting the circulation of air and water and resulting in waterlogging. Several investigations of citrus rootstocks under flood circumstances discovered that flood resistance ability varies across fruit plants. Citrus jambhiri plants, for example, can survive waterlogging for two months, but Citrus aurantium plants can only tolerate one month. Plants are harmed in a variety of ways when they are subjected to flood stress (i.e., decreased photosynthesis, decrement in stomatal conductance, reduced chlorophyll, and rubisco or RuBisCO)[(28)].

Plants behave differently in waterlogging situations based on their stage. Waterlogging circumstances drastically reduce a plant's yield and production when it is in the growth stage. While a plant is dormant, the effect is very tiny and only lasts a brief period [(29)]. Waterlogging stress affects plants in a variety of ways, including decreased seed germination, decreased vegetative and reproductive development, structural changes, and premature senescence. Plant responses to waterlogging vary with plant age, genotype, length of stress, and water characteristics [(30)].

Flooding's unfavorable effects typically result in changes in forest distribution and character [31]. Trees and plants that can be cultivated in flooded soil for short or extended periods of time are included here in Figure 3

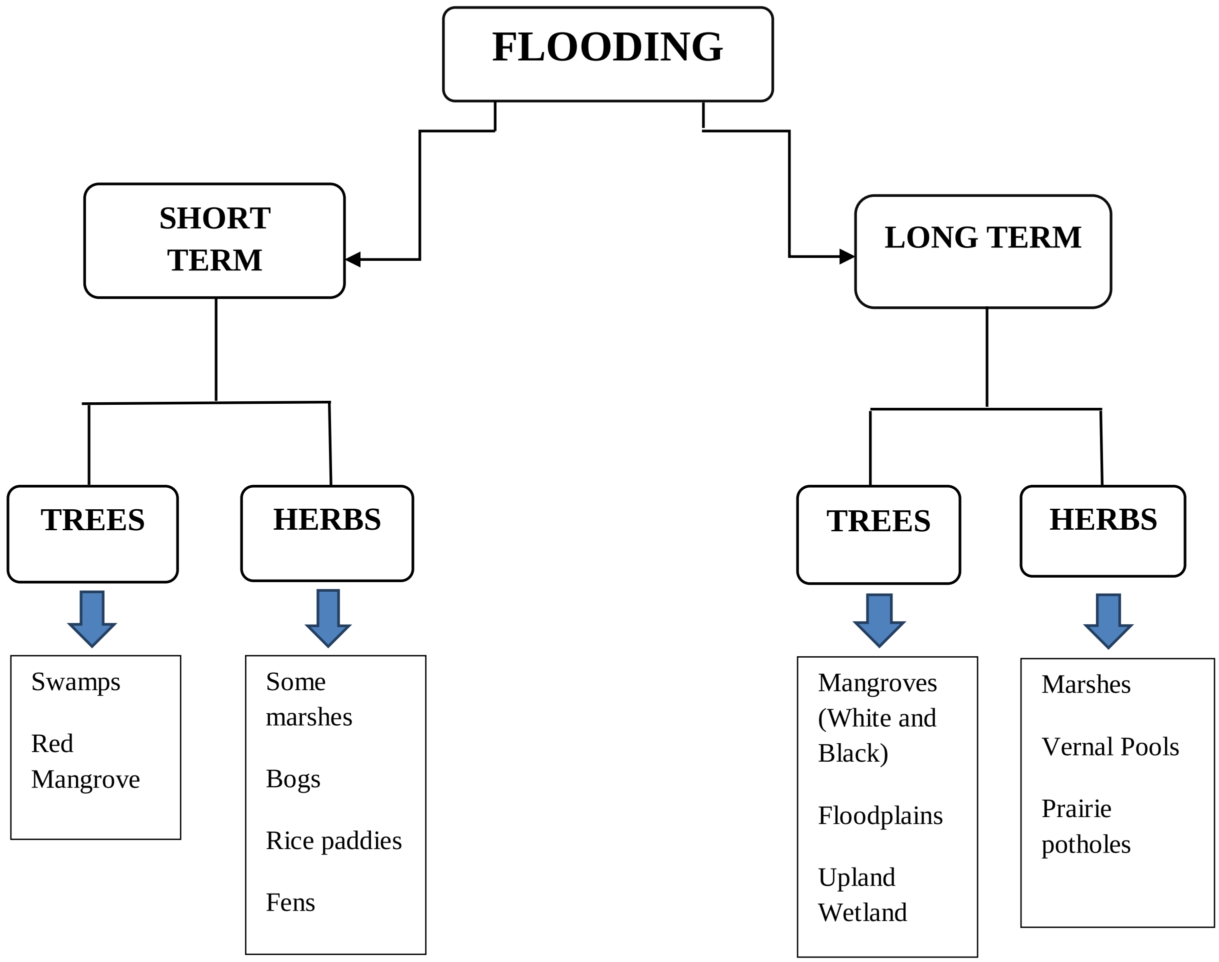

Fig.3:- Trees and plants flourish in both short- and long-term flooded regions.

Nutrition:
Metals are more easily carried into the roots of plants in caustic soils. At higher concentrations, metals that are toxic to plants (iron, manganese, copper, and zinc) can hinder plant development by reducing ion concentrations,affecting root growth, decreasing photosynthesis, and inhibiting certain enzymes, which can cause cell deterioration. Several plant species, however, have evolved genetic and physiological tolerances that allow them to survive in common mineral-rich soils or soils with higher concentrations of heavy metal contamination [32].Excluders and gatherers are two types of plants or crops that can survive heavy metals. Heavy metal transport in plants is regulated by an isolation mechanism, leading to a generally constant low metallic content within sprouts even during prolonged periods of peripheral concentrations.Metals, on the contrary, are collected by gatherers and stored in non-food portions of animals or utilize a chemical alteration to minimize the toxicity of metal salts. Metals can be kept beyond the root by chelating chemical exudation or by stimulating membrane transporters, which force metal ions back to the soil via excluder processes.

Plant Development And Morphology In The Presence Of Abiotic Factors:
Seedling And Germination:
Plant development is a complex system influenced by abiotic as well as biotic variables. Amongst these, moisture in the soil is an important element in seedling germination and development. This trait is particularly essential in riparian species. The availability of oxygen may have an essential function in the start of physiological reactions involved in seed germination. The moisture in the soil can limit the growing embryo's ability to use oxygen,

resulting in seed germination being accelerated or delayed[33].Certain species that develop normally under the pressure created by oxygen compared to that of the air have faster germination and respiration rates. A decrease in the portion of pressure of oxygen may lead to seeds failing to grow and develop slowing dramatically[34].

Vegetative Growth:

Leaves:

Plant reactions to diverse stressors are multilateral in nature; nonetheless, it is considered that leaves respond first.Even though the fact that roots are extremely vulnerable to environmental stresses, they are added to blame for poor foliage, shoot, and other plant component development. Abiotic stress inhibits shoot development in many woody plants by lowering leaf elongation, internode length, and leaf initiation, which leads to early senescence of leaves and dieback[35].

Shoots:

Salinity hinders shoot growth by delaying foliage production and tendril development and accelerating the decay of leaves[36].Decreased development might be related to chloride buildup, which could result in the falling of leaves in all types of vegetation, comprising gymnosperms and angiosperms [37].

Roots:

Soil humidity reduces the physiological growth of different wood crops by numerous methods, which may include preventing Root growth and spreading and inhibiting the expansion ofmaturetendrils.Moreover, such occurrences may increase the plant's vulnerability to numerous pathogenic illnesses[38].Shallow, extending root structures are typical of excessive water table locations[39].When root development diminishes faster in comparison to stem development,the root/shoot ratio decreases. It is important to note that after floods recede, the overflowing plants become more vulnerable to abiotic pressures due to their diminished root network.

Increase in Fertility:

The impacts of persistent high temperatures are numerous, but heat stress is more likely to influence grain growth, yield, and fertilization. Inevitably, diminished fertility and the filling of grains were not adequately investigated, and many areas need to be assessed due to continuous changes over time. Such challenges include male meiotic division, pollen formation, pollen tube growth and development, and megagametophyte surrenders.Furthermore, factors influencing blossom development, grain set,endosperm division, source photosynthesis, absorption transit, and splitting can all contribute to abnormally high seed output and weight.Heat-sensitive variations of many different plant species are continually being described[40].Wheat starch concentration may change dramatically. The heat treatment significantly reduced the transcript level of three variants of starch synthesis, but this had little effect on the pace of starch accumulation. The overall time to grain fill was reduced greatly, and the starch particle size was changed. Heat stress influences on the enzymes that are involved in starch synthesis. They concluded that high temperatures might reduce enzyme activity considerably, leading to poor grain filling and yield. Soil moisture typically decreases flowering bud initiation, anthesis, natural product set, and natural product extension in flood-intolerant plants.It also hastens the abscission of blossoms and natural commodities. The rate of modification to regenerative growth varies depending on the plant genotype and the intensity of the flood. Saltiness has a detrimental influence on several aspects of regeneration development, including blooming, fertilization, natural product development, quality and yield, and the generation of seeds. Citrus rejuvenation growth is very susceptible to saltwater flooding[41].As previously said, when plants are subjected to environmental stress, they confront a slew of issues. When Citrus sinensis is stressed by salt, it inhibits flowering, which diminishes fruit set and fruit quantity. Fruit trees subjected to salt stress have delayed fruiting and yield[42].

Conclusion:-

A lot of environmental factors adversely affect physiological and chemical changes in plants, which involve abiotic ones. Abiotic stresses include extreme temperatures, inadequate nutrition, salinity, and a dearth of water and excess.These external stresses affect physiological (decreased cycle of photosynthesis stomatal activity, and transpiration) and biochemical changes in plants (protein denaturation, ROS production, and antioxidant activation). The impacts of many abiotic stressors overlap.Stress from drought happens when plants are exposed to extreme-temperature. Nutritional imbalance can also occur as an outcome of drought or salinity stress.Tolerant genotypes have been developed to deal with these abiotic challenges, but further work is needed to genetically modify plant genomes, which can aid us sustain plant development and, eventually, raisingproduction to fulfill the world's rising population's food demands.

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