Abiotic Disorders of Cultivated Crops

Amar Bahadur
Asstt. Professor (Plant Pathology)
Department of Pant Pathology, College of Agriculture, Tripura, Lembucherra, Agartala-799210 (Tripura), India
*e-mail:*amarpatel44@rediffmail.com, Ph no. 9436323299 (M)

Abstract

Abiotic disorders are associated with non-living causal factors Abiotic disorders are associated with non-living causal factors as a result of one or more factors *viz*., space for root growth, presence of air, water pollutants, temperature, drought, salinity, mineral toxicity, presence of moisture, heat, light, soil pH, and nutrients are limiting plant growth and productivity worldwide and can't spread from plant to plant. Crops are continuously threatened by abiotic stresses to world agriculture productivity. Abiotic disorders can reduce plant health, even kill plants, and affect farmers' livelihoods, national economies and food security. Abiotic diseases don't show the presence of disease signs, it difficult to diagnose as its necessary step in managing the diseases. The damage caused by abiotic factor very similar to caused by biotic agents. Abiotic stresses change the interactions and enhance host plant susceptibility to pathogenic organisms. Plants defense against abiotic stress in their roots, reactive oxygen species and stress hormones interacting with signaling pathways. The abscisic acid hormone is involved in many abiotic stresses. The crop yield reducing gradually due to various factors and necessary to diagnose the factors in crops cause disorders for management and enhance their productivity.

Keywords: abiotic factors, disorders, diagnosis**,** management

Introduction

The stresses are affecting the growth of plants leads to significant scarcity in the production of agriculture worldwide (Shinwari et al. 1998). Plant stress depends upon the stress factors being living or nonliving and thus the stress divides into biotic (living) stress and abiotic (nonliving) stress in plants (Bechtold and Field 2018). A number of abiotic and biotic stresses severely affect their growth and yield (Suzuki et al. 2014; Ramegowda and Senthil 2015). Plant growth and crop yield are affected by cold, drought, salt, and heavy metals. The three stages of plant viz., vegetative development, pre-anthesis and terminal phase that affected by the drought (Shavrukov et al. 2017). Multiple abiotic stresses viz., salinity and drought affect the crop in semi-arid tropical regions (Cairns et al. 2012). Abiotic stresses such as drought and heat have been shown to be more destructive to crops (Mittler 2006). Abiotic stress drought, high and low temperature and salinity are known to influence the occurrence and spread of pathogens, insects, and weeds (Coakley et al. 1999). Plants sustain themselves against various environmental factors (Andjelkovic 2018). Abiotic stresses are nonliving factors influencing plants' metabolism, growth, and development (Dresselhaus and Hückelhoven 2018; Hasanuzzaman et al. 2020). Abiotic stresses are excessive hot temperature, extreme cold temperature, salinity; drought, mineral availability and toxicity are the major abiotic stress factors for a plant (Sharma et al. 2019; Gull et al. 2019). Temperature directly affects physiological processes such as photosynthesis, respiration, membrane permeability, water and nutrient absorption, transpiration, enzyme activity and denaturation of proteins. Low temperatures may kill the young roots and tree bark to split allowing cankering development. Low-temperature formation of ice crystals inside plant cells, and chilling injury occurs in a wide range of crops. High-temperature influence seed germination, plant growth and development, which triggers drought stress and lead to the death of plants (Takahashi et al. 2013). High-temperature stress can cause serious protein damage, interrupt the synthesis of protein, inactivate critical enzymes, and damage membranes that have significant effects on the cell division process (Smertenko et al. 1997). Plants show a variety of responses to high temperatures, seedlings may show symptoms of 'stem girdling' due to radiating heat from the soil scorching young stem tissue, the stem above the injured zone swells, and a 'heat canker' formed. Cold stress causes injury to plants by changes in the membrane structure and decrease protoplasmic streaming, electrolyte leakage and plasmolysis which cause cellular damage and altered metabolism, reduced plant growth, abnormal ripening of fruits, internal discolouration (vascular browning), increased susceptibility to cause the death of the plant (Devasirvatham and Tan 2018). An increase in salt content in soil is referred to as soil salinity (Bockheim and Gennadiyev 2000). In drought, farmers turn to irrigation, which adds more salts to the soil causing salinity (Enebe and Babalola, 2018). Adverse weather conditions such as drought, flood, high winds, frost, hail, snow and lightning may damage or kill plants and access places for pathogens infection. Abiotic stresses are of greater importance that cannot be prevented, such as drought, salinity, cold, heat, metal, etc. Plant reactions to abiotic stress are dynamic and complicated (Cramer et al. 2011). Abiotic stresses such as water scarcity, high salinity, extreme temperatures, droughts, stagnation, mineral deficiencies and metal toxicities reduce the crop's productivity. Climate change has greatly threatened food security as additional external pressures which directly impact the agricultural output. Abiotic stress changes in the growth of plants as well as stress-related phytohormones affect the normal functioning of plants and production. Toxins are also considered to be the stress released by the plant tissues in response to several abiotic stress factors (Nadarajah 2020). Abiotic stress impacts plants at molecular levels from morphological levels that are visible in all phases of plant development (Fahad et al. 2017). The abiotic stress factors have negatively impacted crop yields, need of breed resistant plant varieties that sustain against abiotic stress factors (Dresselhaus and Hückelhoven 2018). These stresses on the plants influence their growth and development, various types of plant metabolism get triggered by stresses, such as the altered expression of the inherited genes, metabolism of the cells, and changing patterns of growth and crop yields (Bechtold and Field 2018). Abiotic stress creates adverse effects on crop morphology, biochemistry and physiology that are directly relatedto the growth and yield of plants. The abiotic factors that influence plant growth in an agricultural ecosystem include temperature, water, salts, essential nutrients, and pH. The high pH (alkaline) in soils reduces the availability of essential macro and micronutrients viz., phosphorus, manganese, zinc, copper, and iron causing nutrient deficiency and osmotic imbalance (Chen et al. 2011). Water is a crucial element of plant survival and is essentially needed for the transportation of nutrients. Plants undergo various physiological, molecular, and biochemical changes under these environmental stresses that impact overall plant development and growth. Water deficit stress, salt stress, imbalances in nutrients (toxicity and deficiencies) and temperature are significant limitations on the productivity of crops (Fahad et al. 2017). The deficiency of water leads to drought stress, which reduces plant vitality (Ashkavand et al. 2018). Cell elongation decreases under drought conditions due to a decrease in turgor pressure (Shaheen et al. 2016). Abiotic diseases are the result of genetic changes that occur in the meristematic cells that cannot be transmitted fromaffected plants to healthy plants. Climate change reduced cultivated lands, exhausting soil nutrition, less responsiveness to agrochemicals, and environmental degradation (Shinwari et al. 1998a). Therefore it is essential to find safe and ecologically viable solutions for sustainable agricultural (Kumar and Verma 2018). Plant physiological reactions to stress include wilting of the leaf, abscission of the leaf, decreased leaf region and decreased water loss through transpiration (Fghire et al. 2015). The abiotic stress influences the plant-pathogen interaction both positively and negatively, thereby enhancing and decreasing the severity of the disease. Fusarium pathogens exist in the soil more severely under drought conditions.

Diagnosis

Diagnosis is the identification of the cause of agent. Leaf spots, chlorosis, blights, deformities, defoliation, wilting, stunting and plant death can be common symptoms of both biotic and abiotic problems. Soil and root analysis is required to confirm the diagnosis and management of diseases. Diagnosing plant diseases requires careful examination of the entire plant specimen. Many abiotic stresss hown to weaken the defense mechanisms of plants and enhanced their susceptibility to pathogen infection. Nutrient deficiencies and toxicities reduce shoot growth and leaf size and cause leaf chlorosis, necrosis and dieback of plant parts. The macronutrients are carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. Iron, zinc, manganese, copper, boron, molybdenum and chlorine are essential for plant growth but are needed in relatively small amounts, these are known as micro-nutrients. Cobalt is essential for nitrogen fixation in both legumes and non-legumes. Deficiencies or excesses of these elements can result in plant damage. Nutrient deficiencies cannot be diagnosed on the basis of symptoms alone, because other plant problems can produce similar symptoms. The nutrient deficiencies usually confirm the problem by leaf tissue and soil sample analysis. Soil acidity or alkalinity is influences the availability of nutrients between 5.5 and 6.5pH, below and above this range some nutrient elements may toxic. Abiotic affects plants of various ages, often related to the environment, physical factors and cultural practices; relatively uniform and damage appears similar among plants, with no evidence of the pathogens to cause the symptoms, and not infectious commonly. It does not spread and is possibly associated with environmental conditions or cultural practices. The disorders occur of environmental restrictions too much or too little such as light, temperature, water, or wind. Sunburn is damage to foliage caused by too much light and heat and insufficient moisture. A yellow area develops on foliage, which dies between the veins. Frost damage causes shoots, buds and flowers to curl turn brown or black and die. Hailstones injure leaves, twigs, and chilling damage sensitive plants' development of dark water-soaked spots on leaves. Physical and mechanical injuries occur mishandled during transport and cultural practices. Plants exposed to toxic levels of ethylene gas, damaged, decaying, plants; and decaying fruit, ethylene gas cause premature abscission of flower buds, petals and leaves. The nursery plants by air pollutant gases such as ozone, carbon monoxide, nitrous oxides and sulfur dioxide can cause damage. Mutants in nursery beds such as Albino of seedlings, lack chlorophyll and quickly die. Sometimes plants exhibit sudden changes in colour producing markings of variegation, and new shoots such as a chimera as produce when a genetic mutation occurs. The Chimeras are often confused with nutritional or chemical disorders. “Chimera” is a term that describes a single plant with two genetically different tissue types. Sometimes variegation can be caused by viruses. Viruses usually cause non-uniform chlorosis, such as mosaics, while chimeras usually produce patterned forms such as variegation of colour on leaf margins, stripes, or complete loss of pigment. Diseases occur at any stage during the course of plant growth, the rapid and accurate diagnosis cause of a disease is essential to the protection of the crop. Herbicides are used to control weeds in crops, the mode of action of the herbicide can determinethe symptom.The herbicides are growth regulators, photosynthetic inhibitors and enzyme inhibitors such as 2, 4-D a growth regulatory, and glyphosate enzyme inhibitors. Insecticides and fungicides occasionally cause plant damage. Flower petals are more susceptible to damage from pesticides than leaves. The younger and tender leaves are more susceptible to pesticides, the active ingredients of pesticides can adversely affect the photosynthetic mechanism and physiological processes that cause general leaf chlorosis, interveinal chlorosis, leaf curling and stunting. Pesticides applied as soil drenches can cause poor germination, seedling death, and distorted plant growth.

Abiotic factors

Abiotic stresses unfavorable affect growth, and productivity that trigger a series of morphological, physiological, biochemical and molecularchanges in plants. Abiotic stresses include potentially adverse effects of Salinity, Drought, Flooding, Metal toxicity, Nutrient deficiency, High temperature and Low, UV exposure, Air pollution, Wind, Hail and Gaseous deficiency. In some cases, such as the supply of water in case of drought and flooding, both impose stress on plants (Fig. 1).

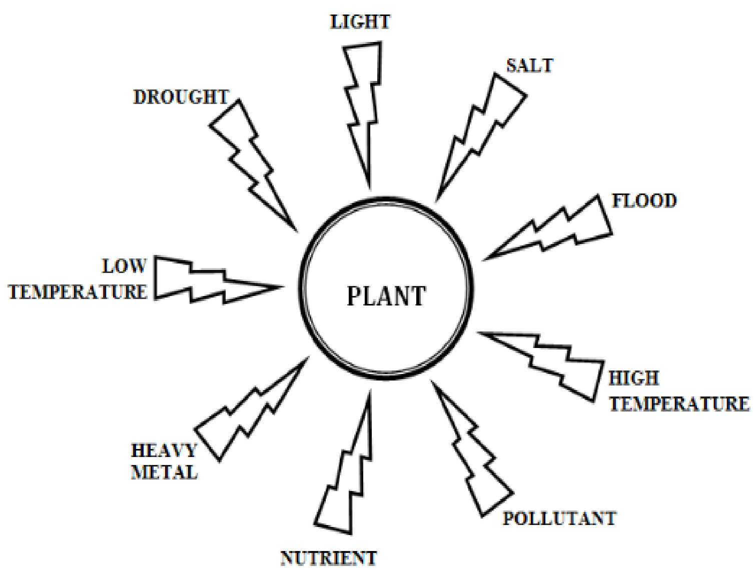

Fig.1. Abiotic factors that cause disorder in plants

Abiotic disorders

Diseases caused by non-living things are more difficult to diagnose. Abiotic plant problems are sometimes termed “physiological disorders”. The abiotic disorders are associated with non-living causal factors such as weather, soils, chemicals, mechanical injuries, cultural practices and genetic tendencies within the plant itself (Table 1). Abiotic disorders may be caused by a single extreme environmental incident such as a night severe cold following a warm complex of interrelated factors. They can also be caused by chronic conditions such as drought, and existing site conditions such as acid and alkaline soil. Abiotic stress factors affect plant growth and development and influence leads to the deterioration of the overall development of plants. Abiotic stresses usually reduce plant growth by slowing down photosynthesis. The primary metabolism of plants involves photosynthesis and related processes, respiration, sugars, and amino acid metabolism. Heat stress is the rise in temperature beyond a threshold level for a period sufficient to cause permanent damage to plant growth and development (Hasanuzzaman et al. 2013). Chilling stress by plants from 0 to 15°C causes major crop losses (Yadav 2010). Abiotic diseases occur through nutrient deficiencies, temperature extremes, abnormal lighting, and chemical application, changes in water uptake, mechanical damage and genetic mutations. Flowers that dry and drop from stems with no fruit formation are primarily caused by temperatures that are not conducive to effective pollination. Blossom drop occurs when daytime temperatures are above 90°F and nighttime temperatures above 72°F. Excessive heat desiccates pollen, resulting in poor fruit set and dried blossoms that eventually drop. Blossom-end rot is a disorder caused by a lack of calcium in the fruit. Calcium is a nutrient that contributes to healthy cell walls, and when deficient, cell breakdown occurs, leaving water-soaked spots on the bottom of the fruit. Blossom-end rot can occur on other crops, including summer squash, peppers, eggplant, and more. Blossom-end rot is most common during periods of intense heat or when irrigation management is less. The cat-facing refers to tomatoes that are generally distorted, misshapen, or dimpled. The damage usually results from injuries that cause the fruit's blossom scar to become enlarged. The damage by piercing-sucking insects' of tomato skin by piercing-sucking insects causes cat-facing symptoms. Cat-facing occurs when flowers are formed, and symptoms occur on fruit throughout the growing season.

Cracking and splitting occur due to changes in soil moisture, Cracking shows as vertical splits or circular patterns on the top of the fruit that reduce fruit quality and susceptibility to rotting organisms. Cold injury occurs by exposure between 33°F and 50°F temperatures, in combination with other factors, causing damage to leaf tissue that reduces flower formation and fruit production. Freeze damage occurs when temperatures drop below 32°F, causing leaf, stem, and fruit tissue to freeze, expand, and rupture. Edema is identified by watery blisters that form along the leaf veins and typically occur on the undersides of leaves, edema is induced by high relative humidity, overwatering, and low light quality. Edema most commonly occurs during prolonged cloudy and humid weather. Green shoulder of tomato fruit ripening disorder that appears, the top"shoulder" of the fruit remains green and yellow. It is caused by genetics, in some susceptible cultivars and also be caused by environmental conditions, such as temperatures above 90°F or below 60°F, high humidity, and exposure to direct sunlight. Herbicides damage the plant either directly or indirectly by residues in soil, such as small misshaped leaves, thick and tightly curled stunted growth, and dieback. “Legginess” occurs in newly germinated seedlings by weak stems with long internodes that are caused by little to no light available, seedlings stretch to reach a light source. Nose development in tomato fruits is a genetic mutation, during early fruit development few cells divide incorrectly, forming an extra fruitlocule. High temperatures during the night and day cause this mutation. A chimera is a genetic mutation characterized by foliage with distinct yellow and white patches, often leaf is delineated by veins, and it is a genetic abnormality that occurs spontaneously.

Nitrogen is a macronutrient for plant growth and development; nitrogen deficiency symptoms are expressed by light green to yellow colouration starting on the lower older foliage. Phosphorus is also macronutrients necessary for plant growth and development. It is a component of adenosine triphosphate (ATP) that forms during photosynthesis and stimulates root development, stem strength, flower formation, seed production, and overall crop quality. Phosphorus deficiency is expressed by small rigid leaf growth and erect and dark green, purplish-red discolouration on the underside of leaves. Potassium is a macronutrient necessary for plant growth and development and helps water movement and enzyme activation of plants, deficiency expressed on the leaf edges that veins remain green, and whitish, necrotic dots develop among the chlorotic areas. Iron is a micronutrient for plant growth and development, and the synthesis of chlorophyll, and it is important for maintaining chloroplast structure and function. Iron deficiency because of inter-veinal chlorosis, symptoms appear first on younger leaves of the plant. In high pH soils, iron is fixed to insoluble form, and unavailable to plant roots. Long-term standing water prevents the absorbing of oxygen by roots and the chance of infection with soil-borne pathogens. Heavy rain, hail, and strong winds can damage vegetable crops, strong winds and hail can tear through the foliage, removing leaves, and leaving the plant vulnerable to other problems such as sunburn to fruit or reduced photosynthesis. Upward curling or rolling is caused by herbicide, virus infection, and environmental stresses, it is also caused by physiological factors such as early planting, root damage, pruning, drought, heat, excess or shortage of nutrients, and excessive moisture.

Sunscald occurs on fruits when intensive sunlight damages the skin, expressing white or light-coloured, blister-like spots, and green and ripened fruit can be affected. Vivipary occurs when seeds sprout inside a ripe fruit and grow. It may cause over-ripening, deficiency and abundance of nutrients, which happens when the abscisic acid hormone reduces and the seed germinates in the fruit. Zippering is the presence of a thin, brown longitudinal scar extending from the stem to the blossom end of the fruit, resembling a zipper. It occurs when the flower anther sticks to the developing fruit as it grows. A single fruit may have multiple scars, but it does not affect overall yields and consumption quality.

Table.1. List of abiotic disorders of crops

Sl No.	Abiotic disorders	Cause of disorders
1	Edema of cabbage, Splitting and water injury of citrus	Water excess (poor drainage)
2	Black or hollow heart of potato	Oxygen deficiency
3	Greening of tubers	Exposure of tubers to sunlight
4	Sunscald of vegetables, sunburn	High light intensity
5	Etiolation	Low light intensity
6	Chilling and freezing injuries, Catface, Potato freezing necrosis, Blindness of cauliflower,	Low temperature
7	Water core of apple, Tip burn of leaf, Scorch of leaf	High temperature
8	Puffiness of tomato	Various abiotic factors
9	Crinkle leaf disease in cotton,	High concentration of manganese
10	Buttoning of caulislower, Pansukh/tip burn disease of paddy	Nitrogen deficiency
11	Tip burn and marginal necrosis of mango	Phosphorus deficiency
12	Tip drying of onion, Spongles of bidi tobacco, Marginal chlorosis of plum leaves	Potassium deficiency
13	Blossom end rot of tomato, Pitting of pepper , Blossom-end-rot of grape berries	Calcium deficiency
	Pahala blight of sugarcane, Top yellowing of gram	Manganese deficiency
13	Hollow stem (browning) of cauliflower, Black tip of mango	Boron deficiency
14	Khaira disease of rice	Zinc deficiency
15	Whip-tail of cauliflower	Molybdenum deficiency
16	Foliage distortion and malformation of tomato	Herbicide injury
17	Hail injury of cabbage	By Hail storm
18	Lightning injury of cabbage	By lightning
19	Silver leaf	Peroxyacyl nitrates (PAN)

Disorders management

Abiotic stress management is one of the most important challenges in agriculture. Abiotic stresses adversely affect the livelihoods of individual farmers and their families as well as national economies and food security. Crop tolerance to various abiotic stresses, they defend themselves by defense mechanisms activation of specific biosynthetic pathways (Caretto et al. 2015). Stress is the intense pressure that affects the normal functions of life in plants and prevents them from expressing their genetic potential for growth, development and reproduction (Levitt 1980). The abiotic stress factors cannot be mitigated by the plants, plants are developing mechanisms within their inner metabolism to balance the adverse impacts created by the outside environment (Sharma et al. 2019). Many such mitigation strategies are adopted by plants to overcome such abiotic stress factors (Sharma et al. 2019). The activation of the stress-responsive genes makes the plants much more tolerant and thus they can survive against such hazards. Identification of targeted genes is necessary as the overall mechanism depends upon such gene regulations (Zhang et al. 2021). The oxidative stress reduction increases the stress tolerance factors and long-term sustainability of the plants in adverse conditions (Zhang et al. 2021). The close relationship of abscisic acid (ABA) with SA and JA/ET-mediated defense signalling of plant-pathogen interaction in the field, as abiotic stress which leads to ABA accumulation is likely to suppress disease (Sivakumaran et al.2016). Abscisic acid increases plant-cause susceptibility to bacterial and fungal pathogens, and inhibition of ABA signalling increases plant defense against pathogens (Audenaert et al. 2002; Mohr &Cahill 2003; Anderson et al. 2004; Asselberghet al. 2007). Abscisic acid usually antagonizes SA and JA/ET defense signaling thereby interfering with plant responses (Ton et al. 2009; Lievens et al. 2017). Plants respond with changes in their pattern of gene expression and protein synthesis when exposed to low temperatures (Sanghera et al. 2011). The stress-responsive genes are expressed so that the plants can survive. The successful management of plant disease requires regular monitoring of plants detecting diseases early and selecting available options to manage the diseases. Nutritional imbalances limit growth by reducing photosynthetic rate, and physiological and metabolic processes which can be improved by application. The stress biotechnology research recently emphasizes on strength and stress-induced expression of the transgenes, combined with the regulatory machinery involving transcription factors, It is a genetic manipulation tool for controlling the expression of many stress-responsive genes.

Conclusion

The plant health problem needs accurate diagnosis, for recommendation disease management. Abiotic stressors cause symptoms in plants that are similar to diseases caused by biotic agents. Abiotic stressors also influence plants to pathogens and are linked to several biotic diseases in crops, the understanding of abiotic disorders for managing overall plant health. The differences in the plant show symptoms are difficult between biotic disease and abiotic disorder for effective management. Abiotic disorders are caused by nonliving factors, the understanding the difference between the two is vital to diagnosing the cause of plant injury. It is important to identify the cause and understand the climate, soil type, and management practices. The diagnosis of problems and suggest mitigate of abiotic injuries as they occur. The timely and accurately recognized plant problems help in early management of the developing diseases resulting in significant economic damage.

References

Andjelkovic V (2018) Introductory chapter: Climate changes and abiotic stress in plants. In: Plant, Abiotic Stress and Responses to Climate Change. *Intech Open*. p. 1.

Ashkavand P, Zarafshar M, Tabari M, Mirzaie J, Nikpour A andKazemBordbar S, et al. (2018) Application of SIO2 nanoparticles AS pretreatmentalleviates the impact of drought on the physiological performance of Prunusmahaleb (Rosaceae). *Boletin de la Sociedad Argentina de Botanica*. 53:207.

Audenaert K, De Meyer G B and Hofte MM (2002) Abscisic acid determines basal susceptibility of tomato to *Botrytis cinerea* and suppresses salicylic acid- dependent signalling mechanisms. *Plant Physiol.* 128: 491–501.

Anderson JP, Badruzsaufari E, Schenk PM, Manners JM, Desmond OJ andEhlert C, et al. (2004) Antagonistic interaction between abscisic acid and jasmonate-ethylene signalling pathways modulates defense gene expression and disease resistance in Arabidopsis. *Plant Cell* 16: 3460–3479.

Asselbergh B, Curvers K, Franca SC, Audenaert K, Vuylsteke M and Van Breusegem F et al. (2007) Resistance to Botrytis cinerea in sitiens, an abscisic acid-deficient tomato mutant, involves timely production of hydrogen peroxide and cell wall modifications in the epidermis. *Plant Physiol.* 144: 1863–1877.

Bockheim JG andGennadiyev AN (2000) The role of soil-forming processes in the definition of taxa in soil taxonomy and the world soil reference base. *Geoderma*. 95(1-2):53-72.

Bechtold U and Field B (2018) Molecular mechanisms controlling plant growth during abiotic stress. *Journal of Experimental Botany.* 69(11):2753-2758.

Chen L, Yin H, Xu J and Liu X (2011) Enhanced antioxidative responses of a salt-resistant wheat cultivar facilitate its adaptation to salt stress. *Afr J Biotechnol* 10(74):16887–16896.

Caretto S, Linsalata V, Colella G, Mita G and Lattanzio V (2015) Carbon fluxes between primary metabolism and phenolic pathway in plant tissues under stress. *Int. J. Mol. Sci.* 16 (11): 26378–26394.

Cairns JE, Sonder K, Zaidi PH, Verhulst N, Mahuku G andBabu R et al. (2012) Maize production in a changing climate. In: Advances in Agronomy [Internet]. Elsevier; pp. 1-58.

Cramer GR, Urano K, Delrot S, Pezzotti M and Shinozaki K (2011) Effects of abiotic stress on plants: A systems biology perspective. *BMC Plant Biology.* 11(1):163

Coakley SM, Scherm H and Chakraborty S (1999) Climate change and plant disease management. *Annu. Rev. Phytopathol.* 37: 399–426.

Devasirvatham Vand Tan D (2018) Impact of high temperature and drought stresses on chickpea production. *Agronomy;* 8(8):145

Dresselhaus T andHückelhoven R (2018) Biotic and abiotic stress responses in crop plants. *Agronomy*.;8(11):267

Enebe MC andBabalola OO (2018) The influence of plant growth-promoting rhizobacteria in plant tolerance to abiotic stress: a survival strategy. *Appl Microbiol Biotechnol* 102(18):7821–7835.

Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A andZohaib A et al. (2017) Crop production under drought and heat stress: Plant responses and management options. *Frontiers in Plant Science.*;29:8.

Fghire R, Anaya F, Ali OI, Benlhabib O, Ragab R andWahbi S (2015) Physiological and photosynthetic response of quinoa to drought stress. *Chilean Journal of Agricultural Research.* 75(2):174-183.

Gull A, Lone AA andWani NUI(2019) Biotic and abiotic stresses in plants. In: *Abiotic and Biotic Stress in Plants*.. pp. 1-19

Hasanuzzaman M, Bhuyan MHM, Zulfiqar F, Raza A, Mohsin SM and Mahmud JA, et al. (2020) Reactive oxygen species and antioxidant defense in plants under abiotic stress: Revisiting the crucial role of a universal defense regulator. *Antioxidants.* 9(8):681

Hasanuzzaman M, Nahar K, Alam MM, Roychowdhury R and Fujita M (2013) Physiological, biochemical and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences*. 14:9643-9684.

Kumar A andVerma JP (2018) Doesplant—microbe interaction confer stress tolerance in plants: a review? *Microbiol Res* 207:41–52.

LievensL, Pollier J, Goossens A, Beyaert R and Staal J (2017) Abscisic acid as pathogen effector and immune regulator. *Front. Plant Sci.* 8:587. doi: 10.3389/fpls.2017.00587

Levitt J (1980) Responses of plant to environmental stresses. 2nd. Ed Academic press.,NewYork.

Mohr PG and Cahill DM (2003) Abscisic acid influences the susceptibility of *Arabidopsis thaliana* to *Pseudomonas syringae*pv tomato and *Peronosporaparasitica*. *Funct. Plant Biol.* 30:461

Mittler R (2006) Abiotic stress, the field environment and stress combination. *Trends Plant Sci.* 11: 15–19.

Nadarajah KK (2020) ROS homeostasis in abiotic stress tolerance in plants. *International Journal of Molecular Sciences.* 21(15):5208

Ramegowda V and SenthilKM (2015) The interactive effects of simultaneous biotic and abiotic stresses on plants: mechanistic understanding from drought and pathogen combination. *J. Plant Physiol.* 176: 47–54.

Sanghera GS, Wani SH, Hussain W and Singh NB (2011) Engineering cold stress tolerance in crop planrs. *Current Genomics.* 12:30-43.

Suzuki N, Rivero RM, Shulaev V, Blumwald E and Mittler R (2014) Abiotic and biotic stress combinations. *New Phytol.* 203: 32–43.

Sivakumaran A, Akinyemi A, Mandon J, Cristescu SM, Hall MA andHarren FJM et al. (2016) ABA suppresses Botrytis cinerea elicited NO production in tomato to influence H2O2 generation and increase host susceptibility. *Front. Plant Sci.* 7:709

Shinwari ZK, Nakashima K, Miura S, Kasuga M, Seki M, Yamaguchi-Shinozaki K and Shinozaki K (1998) An Arabidopsis gene family encoding DRE binding protein involved in low tempera-ture – responsive gene expression. *Biochem Biophysical Res Commun* 250:161–170

Shinwari ZK, Nakashima K, Miura S, Kasuga M, Shinozaki KY and Shinozaki K (1998a) Identification of a gene family encoding dehydration-responsive-element (DRE) binding proteins in Arabidopsis thaliana and analysis of its promoter. *Plant Cell Physiol* 39:106–111.

Sharma A, Shahzad B, Rehman A, Bhardwaj R, Landi M and Zheng B(2019) Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. *Molecules.* 24(13):2452

Shavrukov Y, Kurishbayev A, Jatayev S, Shvidchenko V, Zotova L andKoekemoer F et al. (2017) Early flowering asa drought escape mechanism in plants: How can it aid wheat production? *Frontiers in Plant Science.;* 17:8.

Smertenko A, Draber P, Viklicky V andOpatrny Z (1997) Heat stress affects the organization of microtubules and cell division in *Nicotianatabacum* cells. *Plant, Cell & Environment.* 20(12):1534-1542

Shaheen T, Rahman M, ShahidRiaz M, Zafar Y and Rahman M (2016) Soybean production and drought stress. In: Abiotic and Biotic Stresses in Soybean Production [Internet]. Elsevier; pp. 177-196.

Takahashi D, Li B, Nakayama T, Kawamura Y and Uemura M(2013) Plant plasma membrane proteomics for improving cold tolerance. *Frontiers in Plant Science*. 4:90

Tabatabaei FS and Saeedizadeh A (2017)Rhizobacteriacooperative effect against *Meloidogynejavanica* in rhizosphere of legume seedlings. *Hellenic Plant Protection Journal* 10: 25–34

Ton J, Flors V and Mauch-Mani B (2009) The multifaceted role of ABA in disease resistance. *Trends Plant Sci.* 14: 310–317. doi: 10.1016/j.tplants.2009.03. 006

Yadav SK(2010) Old stress tolerance mechanisms in plants. A review. Agronomy for Sustainable Development. 30:515-527.

Zhang H, Zhu J, Gong Z and Zhu JK (2021) Abiotic stress responses in plants. *Nature Reviews Genetics.*1-16