E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(6): 545-549
Received: 02-03-2024
Accepted: 06-04-2024

Anmolpreet Kaur
MSc Scholar, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Gurpreet Singh
Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Sandeep Menon
Head of Department, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Kamini Kumara
Professor, Department of Soil science and soil chemistry, Lovely Professional University, Phagwara, Punjab, India

Haripriya Ngairangbam
MSc Scholar, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Shrikant Choudhary
MSc Scholar, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Gurpreet Singh
Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Elucidating the molecular mechanisms of plant stress responses: Deciphering the impacts of abiotic and biotic stressors and developing innovative mitigation strategies for sustainable agriculture

Anmolpreet Kaur, Gurpreet Singh, Sandeep Menon, Kamini Kumari, Haripriya Ngairangbam and Shrikant Choudhary

DOI: https://doi.org/10.33545/2618060X.2024.v7.i6h.922

Abstract
Crop stress, caused by abiotic factors or biotic agents, represents a major challenge for agricultural production worldwide. Abiotic stresses like drought, salinity, extreme temperature and nutrient imbalances disrupt plant physiology, leading to reduced growth, impaired photosynthesis, oxidative damage, and yield losses. Biotic stresses from pathogens (bacteria, fungi, viruses), pests (insects, nematodes) and competing plants impose additional constraints through tissue damage, nutrient depletion and disruption of physiological processes. Understanding the mechanisms by which these stresses impact plants is crucial for developing effective mitigation strategies. This review provides a comprehensive overview of abiotic and biotic stress factors affecting crops, their modes of action and their detrimental effects on plant growth, development and productivity. It further discusses various approaches to alleviate stress, including breeding for stress tolerance, optimized cultural practices, application of plant growth regulators and soil amendments, biological control methods and integrated pest management. Employing a combination of these mitigation strategies, tailored to specific stress factors and crop species, is vital to enhancing crop resilience and achieving sustainable food production amidst growing population demands and climate change challenges.

Keywords: Crop stress, abiotic stress, biotic stress, IPM, yield losses

Introduction

Any external element that causes an abnormality in the life cycle of agricultural crops is referred to as crop stress. An agricultural crop that experiences stress id prone to illness, deviating from its typical, healthy stage of growth and development Yadav *et al.*, 2020 [48]. One of the most significant issues facing agriculture today is abiotic stress. It decreases planted land and causes major losses in crop output globally Oshunsanya *et al.*, 2019 [28]. The complexity of this situation rises with an expanding and climate change. It is predicted that by 2050, there will be a 7-10 billion person world population, necessitating a 60-110% increase in global food production Tripathi *et al.*, 2019 [44]. Migration to cities has an impact on arable lands as well. As cities grow, they intrude further onto nearby, frequently fertile territory, which is another reason that forces agriculture into places that are not as suitable for growing crops Godoy *et al.*, 2021 [13]. Agricultural stress is the harmful shift in a plant's normal endogenic to exogenic activities. The disturbance of the plant's regular physiological processes and activities could be caused by it either directly or indirectly Sharma., 2023 [40]. Abiotic and biotic stress are the two categories of crop stress. The two types of biotic stress are physical attacks by herbivores and infections by disease causing microorganisms. Abiotic stress, on the other hand, encompasses circumstances such as water scarcity, nutrient imbalance, salinity, nutrient toxicity, drought and water logging Gupta *et al.*, 2021 [14]. Plant stress results in notable reduction in crop yields for every cropping season. To increase agricultural productivity, it is therefore necessary to recognize these distinct crop stresses and develop coping mechanisms for them Yadav *et al.*, 2020 [48]. Moreover, Among other consequences of climate change are extreme weather, which include extreme temperature changes, intense precipitation and drought Nehra *et al*., 2024 [27]. Production is being impacted and crop species are being exposed to more abiotic stress as a result. For instance, drought affects 45% of arable land Koyro *et al*., 2012 [20]. Additionally, salinity contributes significantly to crop productivity losses since most crop species are susceptible to salt stress (1.0-1.8 dsm^{-1}), which can reduce yield by 10% to 50% depending on the salt concentration Yadav *et al*., 2011 [47].

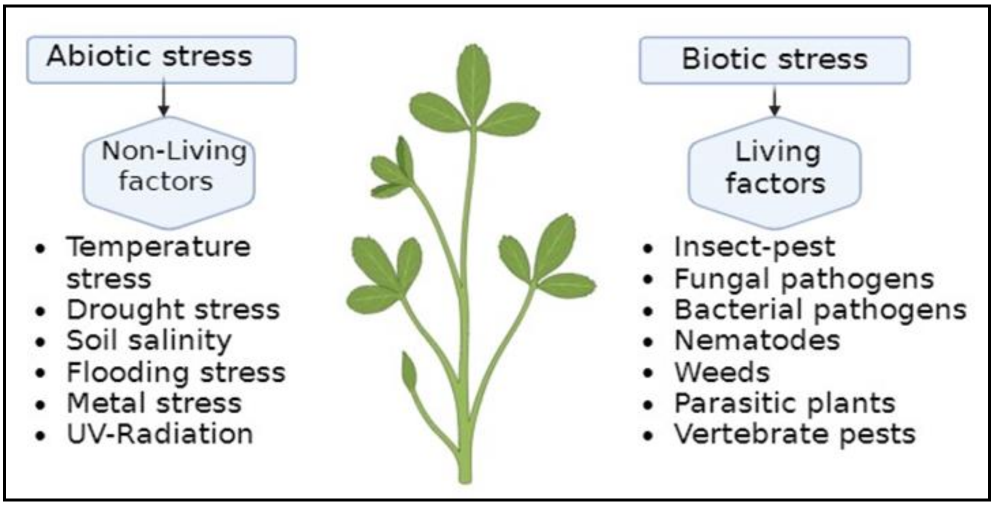

Fig 1: Abiotic and biotic stress in plants

1. Mechanism

Plants endure a multitude of environmental stresses as stationary organisms, affecting their growth, development, and productivity. These stresses fall into two main categories: abiotic stresses and biotic stresses.

1.1 Abiotic Stress

Abiotic stresses, like drought, salinity, extreme temperatures, and metal exposure, exert a significant impact on global crop production, reducing both quantity and quality. These stressors can lead to adverse changes in a plant's morphology, physiology, and biochemistry, ultimately decreasing crop yield (Kumar *et al*., 2020) [22].

Abiotic stresses stem from non-living factors in the environment, including:

1.1.1 Temperature Stress

- High Temperature (Heat Stress): Prolonged exposure to elevated temperatures can denature proteins, disrupt membranes, and deactivate enzymes, causing reduced photosynthesis and growth (Tiwari, *et al*., 2020) [43].
- Low Temperature (Cold Stress): Cold temperatures can disrupt cellular processes, cause chilling or freezing injury, and impede growth and development (Kumar *et al*., 2018) [21].

1.1.2 Drought Stress

Drought stress, a consequence of anthropogenic climate change, hinders crop production and distribution (Seleiman *et al*., 2021) [38].

1.1.3 Soil Salinity Stress

Excessive sodium chloride deposition in the soil leads to salinity stress, affecting crop plants due to osmotic and ionic stress (Khalid *et al*., 2023) [18].

1.1.4 Metal Stress

Metal stress inhibits plant growth and causes phytotoxicity by promoting reactive oxygen species production, oxidative stress, and cellular damage (Rasheed *et al*., 2021) [29].

1.1.5 UV-B Radiation Stress

UV-B radiation increases reactive oxygen species levels in plant cells, damaging DNA, chloroplast structure, and hindering various physiological processes (Correa *et al*., 2023) [9].

1.2 Biotic Stress

In contrast to abiotic stress, biotic stress originates from pathogens or pests like bacteria, fungi, viruses, insects, arachnids, and weeds. These stressors disrupt nutrient uptake in host plants, leading to nutrient deprivation and ultimately plant death. Biotic stresses result in pre- and post-harvest losses, with mechanisms like genetic resistance aiding plant defense (Umar *et al*., 2021) [45].

Various forms of biotic stress in plants include

1. **Insect Pests:** Aphids, whiteflies, mites, caterpillars, and beetles can damage plants by feeding on leaves, stems, roots, or fruits, causing defoliation and reduced yields (Kaur *et al*., 2022) [17].
2. **Fungal Pathogens:** Fungi like powdery mildews, rusts, and wilts infect plants, leading to diseases such as leaf spots, stem cankers, and root rots (Bardin *et al*., 2020) [3].
3. **Bacterial Pathogens:** Bacteria like Erwinia, Xanthomonas, and Pseudomonas cause diseases like leaf spots, blights, and wilts (Saxena *et al*., 2022) [37].
4. **Viral Pathogens:** Viruses like tobacco mosaic virus, cucumber mosaic virus, and potato virus Y induce symptoms such as stunting, mottling, and reduced growth (Reddy *et al*., 2016).
5. **Nematodes:** Nematodes feeding on plant roots result in root knots, galls, lesions, hampering water and nutrient uptake (Sivasubramaniam *et al*., 2020) [42].
6. **Weeds:** Unwanted plants competing with crops for resources impede growth and development by growing faster than the desired crop (Rathore *et al*., 2014) [32].
7. **Parasitic Plants:** Parasitic plants like dodder and broomrape weaken or kill host plants by drawing nutrients from them (Bhatla *et al*., 2018) [4].
8. **Vertebrate Pests:** Animals like rabbits, deer, birds, and rodents feed on plants, causing damage to leaves, stems,

fruits, or roots (Sarwar., 2023) [36].

2. Impact of Abiotic and Biotic Stress
2.1 Abiotic Stress
1. **Photosynthesis Inhibition:** Abiotic stresses disrupt photosynthesis, reducing a plant's ability to convert light energy into chemical energy, limiting access to essential carbohydrates and energy (Muhammad *et al.*, 2021) [26].
2. **Impaired Water Relations:** Drought, salinity, and extreme temperatures create water imbalances in plants, resulting in reduced water uptake, transpiration, and cell turgor pressure, leading to wilting and stunted growth (Farooq *et al.*, 2009) [12].
3. **Oxidative Stress:** Abiotic stresses generate reactive oxygen species (ROS) within plant cells, causing damage to proteins, lipids, and nucleic acids, disrupting cellular functions and compromising plant growth (Sachdev *et al.*, 2021) [33].
4. **Nutrient Imbalances:** Abiotic stresses interfere with nutrient uptake and utilization, resulting in deficiencies or toxicities that impair metabolic processes and growth (Farhan *et al*., 2024) [11].
5. **Altered Gene Expression:** Abiotic stresses trigger changes in gene expression, leading to the production of stress-responsive proteins that can help plants cope but may divert resources from growth and development (Mantri *et al.*, 2012) [24].
6. **Reduced Reproductive Success:** Abiotic stresses negatively impact flowering, pollination, seed or fruit development, resulting in reduced productivity in crops (Alqudah *et al*., 2011) [2].

2.2 Biotic Stress
1. **Tissue Damage:** Biotic stresses damage plant tissues through feeding or infection, reducing photosynthetic area, nutrient transport, and growth processes (Mostafa *et al.*, 2022) [25].
2. **Nutrient Depletion:** Pathogens and herbivorous insects deplete plants of essential nutrients, affecting plant growth and reproduction (Bittebiere *et al.*, 2020) [5].
3. **Physiological Disruption:** Biotic stresses interfere with physiological processes like photosynthesis and hormone signaling, leading to stunted growth, reduced yield, and plant death (Vandana *et al*., 2020) [46].
4. **Yield Losses:** Biotic stresses damage or destroy reproductive structures, reducing crop yield directly, or hampering the allocation of resources for reproductive growth (Al-Khayri *et al*., 2023) [1].
5. **Quality Deterioration:** Biotic stresses compromise the quality of plant products, introducing discoloration, deformities, or contamination (Rathore *et al*., 2024) [31].
6. **Secondary Infections:** Biotic stress-induced damage provides entry points for other pathogens or pests, leading to secondary infections and increasing overall stress on plants (Al-Khayri *et al*., 2023) [1].

3. Mitigation Strategies
3.1 Mitigation strategies for abiotic stress
1. **Breeding for stress tolerance:** Developing crop varieties resistant to specific abiotic stresses through selective breeding or genetic engineering enhances stress resilience (Cabusora., 2024) [6].
2. **Cultural Practices:** Practices like mulching, proper drainage, and optimized irrigation help mitigate abiotic stress impacts (Rathod *et al*., 2023) [30].
3. **Exogenous Application of Plant Growth Regulators:** Applying growth regulators aids plants in coping with abiotic stress by modulating physiological processes (Khan *et al*., 2024) [19].
4. **Soil Amendments:** Adding organic matter or soil amendments improves soil quality, enhancing plant resilience to abiotic stressors (Chi *et al*., 2024) [7].
5. **Antioxidant Treatments:** Applying antioxidants mitigates oxidative stress in plants caused by abiotic factors (Hasanuzzaman *et al*., 2012) [15].

3.2 Mitigation strategies for biotic stress
1. **Resistance Breeding:** Developing genetically resistant crop varieties mitigates specific pathogen, pest, or herbivore-related stresses (Mangena *et al.*, 2023) [23].
2. **Integrated Pest Management (IPM):** IPM combines various tactics to manage pests effectively, reducing environmental impacts (Singh *et al*., 2023) [41].
3. **Crop Rotation and Intercropping:** Rotating crops and intercropping minimize pest and disease build-up by disrupting cycles (Choudhary *et al.*, 2023) [8].
4. **Biological Control:** Introducing natural enemies helps control pest populations, reducing reliance on chemical pesticides (Costa *et al.*, 2023) [10].
5. **Plant-Derived Compounds:** Utilizing plant secondary metabolites with insecticidal properties aids in pest management as biopesticides (Ivănescu *et al*., 2021) [16].
6. **Quarantine and Sanitation Measures:** Strict quarantine and sanitation prevent pathogen and pest spread in agricultural settings (Sahu *et al*., 2023) [35].

Conclusion
Plants face significant challenges from both abiotic (environmental) stresses like drought, salinity, extreme temperatures, and nutrient imbalances, as well as biotic stresses from pathogens (bacteria, fungi, viruses), pests (insects, nematodes), and competing plants. These stresses can severely impact plant growth, development, and productivity through mechanisms such as photosynthesis inhibition, water imbalances, oxidative damage, tissue injury, nutrient depletion, and disruption of physiological processes. Ultimately, abiotic and biotic stresses lead to significant yield losses and quality deterioration in agricultural crop. To mitigate the detrimental effects of abiotic stress, strategies include breeding for stress tolerance, optimizing cultural practices (irrigation, fertilization, mulching), applying plant growth regulators and soil amendments, and utilizing antioxidant treatments. For biotic stress mitigation, key approaches involve resistance breeding, integrated pest management (IPM) combining biological, cultural, and chemical controls, crop rotation and intercropping, quarantine measures, and the use of plant-derived compounds with pesticidal properties.

References

1. Al-Khayri JM, Rashmi R, Toppo V, Chole PB, Banadka A, Sudheer WN, Rezk AAS. Plant secondary metabolites: The weapons for biotic stress management. Metabolites. 2023;13(6):716.
2. Alqudah AM, Samarah NH, Mullen RE. Drought stress effect on crop pollination, seed set, yield and quality. In: Mullen RE, ed. Alternative farming systems, biotechnology, drought stress and ecological fertilisation. Nova Science Publishers; 2011:193-213.

3. Bardin M, Gullino ML. Fungal diseases. In: Gullino ML, ed. Integrated Pest and Disease Management in Greenhouse Crops. Springer; 2020:55-100.
4. Bhatla SC, Lal A, Kathpalia R, Sisodia R, Shakya R. Biotic stress. In: Bhatla SC, Lal A, eds. Plant Physiology, Development and Metabolism. Springer; 2018:1029-1095.
5. Bittebiere AK, Benot ML, Mony C. Clonality as a key but overlooked driver of biotic interactions in plants. Perspectives in Plant Ecology, Evolution and Systematics. 2020;43:125-510.
6. Cabusora CC. Developing climate-resilient crops: adaptation to abiotic stress-affected areas. Technology in Agronomy. 2024;(tia-0024-0002):1-12.
7. Chi W, Nan Q, Liu Y, Dong D, Qin Y, Li S, Wu W. Stress resistance enhancing with biochar application and promotion on crop growth. Biochar. 2024;6(1):43.
8. Choudhary V, Kumar KK, Sahu BH, Muthappa SK, Das AD. Agronomic innovations in biotic stress management and its combined effect with abiotic stresses in crop production. Indian J Agron. 2021;66(5):237-257.
9. Correa MDSS, Saavedra MERR, Parra EAE, Ontiveros EN, Flores JDCB, Montiel JGO, *et al*. Ultraviolet Radiation and Its Effects on Plants. In: Saavedra MERR, ed. Abiotic Stress in Plants-Adaptations to Climate Change. Intech Open; 2023.
10. Costa CA, Guiné RP, Costa DV, Correia HE, Nave A. Pest control in organic farming. In: Guiné RP, ed. Advances in Resting-state Functional MRI. Woodhead Publishing; c2023. p. 111-179.
11. Farhan M, Sathish M, Kiran R, Mushtaq A, Baazeem A, Hasnain A, *et al*. Plant Nitrogen Metabolism: Balancing Resilience to Nutritional Stress and Abiotic Challenges. Phyton (0031-9457). 2024;93(3).
12. Farooq M, Wahid A, Kobayashi NSMA, Fujita DBSMA, Basra SM. Plant drought stress: effects, mechanisms and management. In: Sustainable agriculture. Springer; 2009:153-188.
13. Godoy F, Olivos-Hernández K, Stange C, Handford M. Abiotic stress in crop species: improving tolerance by applying plant metabolites. Plants. 2021;10(2):186.
14. Gupta A, Bano A, Pandey N, Rai S, Sharma S, Pathak N. Recent advances in biotic and abiotic stresses of *Solanum melongena* L. Solanum melongena: Prod Cultivat Nutri. 2021:151-71.
15. Hasanuzzaman M, Hossain MA, da Silva JAT, Fujita M. Plant response and tolerance to abiotic oxidative stress: antioxidant defense is a key factor. In: Fujita M, ed. Crop stress and its management: perspectives and strategies. Springer; 2012:261-315.
16. Ivănescu B, Burlec AF, Crivoi F, Roșu C, Corciovă A. Secondary metabolites from Artemisia genus as biopesticides and innovative nano-based application strategies. Molecules. 2021;26(10):3061.
17. Kaur A, Srivastava RM, Maurya SK, Phartiyal T. Insect Pests Infesting Major Vegetable Crops and Their Management Strategies-III. In: Srivastava RM, ed. Abiotic and Biotic Stress Management in Plants. CRC Press; 2022:95-113.
18. Khalid F, Asif K, Rasheed Y, Ashraf H, Maqsood MF, Rana S, *et al*. Nano priming for boosting growth and resilience in crops under abiotic stresses. Biocatalysis and Agricultural Biotechnology. 2023;53:102-892.
19. Khan S, Singh R, Kaur H, Kumar A, Vashishth A, Shahwan M, *et al*. Plant growth regulator-mediated response under abiotic stress: A review. J Appl Biol Biotechnol. 2024;12(2):13-21.
20. Koyro HW, Ahmad P, Geissler N. Abiotic stress responses in plants: an overview. In: Ahmad P, ed. Environmental adaptations and stress tolerance of plants in the era of climate change. Springer; 2012:1-28.
21. Kumar R, Singh PC, Singh S. A review report: Low temperature stress for crop production. Int J Pure Appl Biosci. 2018;6(2):575-598.
22. Kumar S. Abiotic stresses and their effects on plant growth, yield and nutritional quality of agricultural produce. Int J Food Sci Agric. 2020;4:367-378.
23. Mangena P, Adejumo SA. Biotic Stress and Breeding of Plants for Stress Resistance. In: Adejumo SA, ed. Advances in Legume Research: Physiological Responses and Genetic Improvement for Stress Resistance. Nova Science Publishers; 2023:1.
24. Mantri N, Patade V, Penna S, Ford R, Pang E. Abiotic stress responses in plants: present and future. In: Pang E, ed. Abiotic stress responses in plants: metabolism, productivity and sustainability. Springer; 2012:1-19.
25. Mostafa S, Wang Y, Zeng W, Jin B. Plant responses to herbivory, wounding, and infection. Int J Mol Sci. 2022;23(13):7031.
26. Muhammad I, Shalmani A, Ali M, Yang QH, Ahmad H, Li FB. Mechanisms regulating the dynamics of photosynthesis under abiotic stresses. Front Plant Sci. 2021;11:615-942.
27. Nehra A, Kalwan G, Gill R, Nehra K, Agarwala N, Jain PK, *et al*. Status of impact of abiotic stresses on global agriculture. In: Kalwan G, ed. Nanotechnology for Abiotic Stress Tolerance and Management in Crop Plants. Springer; 2024:1-21.
28. Oshunsanya SO, Nwosu NJ, Li Y. Abiotic stress in agricultural crops under climatic conditions. In: Nwosu NJ, ed. Sustainable agriculture, forest and environmental management. Nova Science Publishers; 2019:71-100.
29. Rasheed A, Hassan MU, Fahad S, Aamer M, Batool M, Ilyas M, *et al*. Heavy metals stress and plants defense responses. In: Hassan MU, ed. Sustainable soil and land management and climate change. Springer; 2021:57-82.
30. Rathod A, Verma NS. Impact of Abiotic Stress on Agronomical Crops. In: Verma NS, ed. Frontiers of Agronomy. Nova Science Publishers; 2023:27.
31. Rathore D, Naha N, Singh S. Phenolic Compounds and Nanotechnology: Application During Biotic Stress Management in Agricultural Sector and Occupational Health Impacts. In: Naha N, ed. Plant Phenolics in Biotic Stress Management. Springer; 2024:503-549.
32. Rathore M, Singh R, Choudhary PP, Kumar B. Weed stress in plants. In: Singh R, ed. Approaches to Plant Stress and their Management. CRC Press; 2014:255-265.
33. Sachdev S, Ansari SA, Ansari MI, Fujita M, Hasanuzzaman M. Abiotic stress and reactive oxygen species: Generation, signaling, and defense mechanisms. Antioxidants. 2021;10(2):277.
34. Saddique M, Kamran M, Shahbaz M. Differential responses of plants to biotic stress and the role of metabolites. In: Kamran M, ed. Plant metabolites and regulation under environmental stress. Springer; 2018:69-87.
35. Sahu B, Choudhary VK, Sahu MP, Kumar KK, Sujayanand GK, Gopi R, Ghosh PK. Biotic Stress Management. In: Trajectory of 75 years of Indian Agriculture after Independence. 2023:619-653.
36. Sarwar M. Avoid Sharing of Strawberries with Birds,

Rodents and Other Vertebrate Pests. In: Recent Studies on Strawberries. IntechOpen; 2023.
37. Saxena A, Rai D, Kalra A, Saxena MJ. Bacterial Diseases of Crops: Epidemiology, Symptoms and Management. International Journal of Current Microbiology and Applied Sciences. 2020;9(6):1483-1499.
38. Seleiman MF, Al-Suhaibani N, Ali N, Akmal M, Alotaibi M, Refay Y, Battaglia ML. Drought stress impacts on plants and different approaches to alleviate its adverse effects. Plants. 2021;10(2):259.
39. Shahzad A, Ullah S, Dar AA, Sardar MF, Mehmood T, Tufail MA, Haris M. Nexus on climate change: Agriculture and possible solution to cope future climate change stresses. Environmental Science and Pollution Research. 2021;28:14211-14232.
40. Sharma MK. Plants Stress: Salt Stress and Mechanisms of Stress Tolerance. Current Agriculture Research Journal. 2023;11(2).
41. Singh M, Pandey N, Sharma OP. IPM concept and strategies for sustainable agriculture. In: Integrated Pest Management in Diverse Cropping Systems. 2023:31-59.
42. Sivasubramaniam N, Hariharan G, Zakeel MCM. Sustainable management of plant-parasitic nematodes: an overview from conventional practices to modern techniques. In: Management of phytonematodes: Recent advances and future challenges. 2020:353-399.
43. Tiwari S, Patel A, Singh M, Prasad SM. Regulation of temperature stress in plants. In: Plant life under changing environment. 2020:25-45.
44. Tripathi AD, Mishra R, Maurya KK, Singh RB, Wilson DW. Estimates for world population and global food availability for global health. In: The role of functional food security in global health. 2019:3-24.
45. Umar OB, Ranti LA, Abdulbaki AS, Bola AL, Abdulhamid AK, Biola MR, Victor KO. Stresses in plants: Biotic and abiotic. In: Current Trends in Wheat Research. 2021:1-8.
46. Vandana P, Singh D, Guru GDR, Srivastava S. Plant response to the abiotic and biotic stresses: A review. Journal of Pharmacognosy and Phytochemistry. 2020;9(6S):457-461.
47. Yadav S, Irfan M, Ahmad A, Hayat S. Causes of salinity and plant manifestations to salt stress: a review. Journal of environmental biology. 2011;32(5):667
48. Yadav S, Modi P, Dave A, Vijapura A, Patel D, Patel M. Effect of abiotic stress on crops. Sustainable crop production. 2020;3(17):5-16.