Bioscene

Bioscene
Volume- 21 Number- 02
ISSN: 1539-2422 (P) 2055-1583 (O)
www.explorebioscene.com

The Climate Crisis: Navigating the Impact of Climate Change on Agriculture

Dr. Suhana Rao[1], Dr. Sushil Kumar[2], Dr. Sombir Singh[3] , Dr. Neeraj Kumar[4] & Dr. Vijay Kumar[5]

[1]Assistant Professor, Botany Department, Dyal Singh College, Karnal
[2]Associate Professor, Botany Department, RKSD College, Kaithal
[3]Assistant Professor, Botany Department, Pt. C.L.S. Govt. College, Karnal
[4]Assistant Professor, Biotechnology Department, Pt. C.L.S. Govt. College, Karnal
[5]Assistant Professor, Zoology Department, Pt. C.L.S. Govt. College, Karnal

Corresponding Author: **Dr. Sombir Singh**

Abstract:
Global food and nutritional security are under threat from climate change. Temperature increasecoincide with an increase in greenhouse gas production in the atmosphere due to the greenhouse effect. The climate change is the main factor fostering many stresses that negatively affect the efficiency of agriculture. Rising temperatures, irregular precipitation and growing greenhouse gas emissions are all threatening global agriculture, resulting in lower crop yields and increased food insecurity. This review investigates the implications of changing the climate on soil fertility, water availability, pest infestations, yields and food security. It explores novel strategies including climate-smart agriculture, traditional breeding and genomic tools to alleviate the effects of abiotic stresses on crops, including heat, salinity and drought. In order to ensure food production and handle the urgent problem of climate-induced agricultural vulnerabilities, the review highlights the necessity of adaptive methods.

Keywords: climate-smart farming, food security, global warming, genetic engineering, molecular breeding

1. Introduction:

Climate change is one of the world's most pressing concerns today. The past few decades have indicated that the primary driver of significant changes in the global climate has been elevated human activity, which has altered the planet's atmosphere (IPCC, 2007).Carbon dioxide, nitrous oxide and methane concentrations have increased dramatically since 1750 (IPCC, 2014). According to Sathaye (2006), carbon dioxide emissions are the most significant source of greenhouse gas output.

It increased from 22 billion metric tons in 1990 to 36 billion metric tons in 2014 (Abeydeera et al., 2019). Since 1975, the average planetary temperature has risen at a pace of around 0.20 °C every decade, and by 2021, an additional 5 °C is predicted (Arora et al., 2005). Catastrophic environmental changes had a significant impact on human health, agricultural productivity and ecological systems (Arunanondchai, 2018). As the world's population is growing rapidly, so does food demand, owing to worries about the global environment's stability. Agriculture production is significantly impacted by the pollution, fertility of the soiland water availability (Noya et al., 2018). As climatic conditions change abruptly, the adverse repercussions on plant production intensify due to effects of abiotic stresses. Varying rainfall has an undesirable effect on crops, particularly in developing states (Malhi et al., 2021). The worldwide food supply is going to be seriously threatened by global warming (Betts et al., 2018). It is widely acknowledged that climate change negatively affects agricultural output and estimates suggest that it will cut the world's cereal production of wheat and maize by around 5% (Lobell et al., 2011). Crop plants are subjected to several abiotic stresses, particularly salt, drought, heat stress and cold stressdue to variations in climate (Malhi et al., 2020). The primary adverse consequences of climate change are reduced soil fertility, agricultural insect infestations and water shortages (Baul and McDonald, 2015). According to IPCC-2014, the nineteenth and twenty-first centuries are thought to have seen catastrophic global warming (Pachauri et al., 2014). Extreme precipitation occurrences may generate floods, or scarcity of rainfall for over an extended amount of time which leads to drought stress (Khan et al., 2016). The global climate is constantly changing and industrialization is a major contributor to rising temperatures. According to Altieri & Nicholls (2017) compared to developing states, developed nations are more likely to experience climate change.

Food insecurity and climate change are the two main problems of 21st century. Sustainable development will have an additional challenge in achieving the global goal of ending hunger by 2030 because malnutrition affects more than 815 million people worldwide (Richardson et al., 2018. Globally, the productivity of main crops has clearly decreased with the increased temperature (Ito et al., 2018). By 2050, there will be roughly 9 billion people on the planet, and this will result in an 85% increase in food needs (FAOSTAT, 2017). According to Dhankher & Foyer (2018), it is predicted that the frequency of droughts, heavy rainfalls, temperature swings, salt stress and insect pest attacks will halt the crop productivity and raise the risk of famine. Severe environmental conditions have a significant impact on agricultural productivity, thus scientists have developed novel strategies to deal with these issues (Rosenzweig et al., 2014). To overcome these limitations and assure food security, new climate-conscious crop cultivars must be devised (Wheeler & Von Braun, 2013). This review addresses the consequences of climate change on food crops, as well as mitigation and adaptation strategies for combating climate change.

2. Climate change & agriculture

Earth's temperature fluctuates due to both natural and human-caused processes, which ultimately raises the level of greenhouse gasses. (Stern & Kaufmann, 2014). According to Montagka et al. (2021), anthropogenic activities cause the release of greenhouse gases such CO_2, methane and nitrous oxide in addition to other compounds that cause the depletion of atmosphere's ozone layer. The agricultural is particularly vulnerable to climate change because of its weather sensitivity, which would have a severe detrimental effect on the economy (Mendelsohn, 2009). Fluctuating precipitation, rising temperature and CO_2 fertilization negatively affects theagricultural crops (Malhi et al., 2021). Temperature surges are predicted to diminish agricultural yields by shortening their duration (Mahato, 2014). It is anticipated that the overall yield of the main cereals will decrease with every 2 °C increase in temperature(Challinor et al., 2014). Tropical regions are more affected by global warming because crops of tropical region are currently closer to the upper limit of their temperature tolerance range (Malhi et al., 2021). In most parts of the world, climate change is expected to increase the frequency of droughts, and by 2050, yields in drought afflicted zones are expected to drop around 50%(Li et al., 2009).

Lower harvests are predicted to cause a 0.3% annual loss in global GDP from agriculture by 2100, which could significantly impact agriculture worldwide and drive-up food prices(Stevanovic et al., 2016). These predicted changes could negatively impact the agriculture industry (Kumar &Gautam, 2014). It is anticipated that a 1 °C surge in the global mean temperature will worsen yield losses of key cereal grains by 10 to 25% (Deutsch et al., 2018). Temperature and precipitation variations have a significant impact on plant-water relations and physiological alterations and are more likely to be affected by abrupt shifts in these variables than by variations in the average climate (Reyer et al., 2012). Although C_3 crops are predicted to yield more but in the presence of stressful situations, both C_3 and C_4 crops are predicted to yield less (DaMatta et al., 2010).With higher CO_2 levels, non-leguminous C_3 crops have lower concentrations of nutrients (N, Zn, Fe, and S), which are mostly contained in proteins (Uddling et al., 2018). Human health is adversely influenced by the reduction in iron and zinc content of C3 crops owing to rising CO_2 levels(Myers et al., 2014).

The microbial community in the soil and its enzymatic activity are also impacted by climatic variations. Climate change also has an impact on crop weed infestation. C_3 weeds exhibit greater biomass and leaf area in response to elevated CO_2 concentrations. While C_4 weeds become less competitive in C_3 plants and C_3 weeds pose a significant threat to C_4 plants (Korreset al.,2016). Weeds contend with crops for both nutrients and water, because they demand more nutrients than agricultural crops (Malhi et al., 2020). As a result of climate change, weeds are expanding their geographic rangeand the only way to effectively control them is to develop new management strategies that take climate change into account. Climate change is expected to make pest infestations of different crops worse since warmer, more humid weather encourages the growth of pests. However, it will differ depending on the locality and how well-adapted the pests are to the changing environment ((Malhi et al., 2021).

2.1. Climate change & crop yield

Variability in the climate and harsh environmental conditions raised the possibility of different plant on crop plants(Thornton et al., 2014).According to a FAO (2007) report, climate change affects every agricultural region on the planet(Van Velthuizen, 2007). The impact of abiotic stresses on the efficiency of crops are challenging to quantify precisely but crop productivity is thought to be significantly impacted by these stresses, depending on how much of the entire cultivable region is damaged. It is predicted that in the future water scarcity, climate change and other factors will reduce the productivity of the world's major crops in many nations (Tebaldi&Lobell, 2018).Temperature extremes brought on by climate change have a significant impact on wheat production in many areas of world (Asseng et al., 2015). Two primary stresses with a considerable implication on crop yields are drought and high temperature (Barnabás et al., 2008).

Sorghum, maize and barley crops were studied for the cumulative impacts of drought and heat stress on cropsoutput and results showed that the combination of these stresseswas more detrimental than individual stresses (Wang& Huang, 2004). Water stress in cereals has been proven to have a deleterious impact on the development of flowers(Xu&Zhou,2006). Climate change is predicted to cause agricultural productivity to drop to 25.7% by 2080 (Hellin et al., 2014). In an investigation to look into the consequences of climate change on key crop yields, Zhao et al., (2017) found that maize, soybeans, rice and wheat all had showed significant yield losses. Drought stress has been shown to shrink the production of black gram from 31% to 57% during the flowering stage, and from 26% to 57% during the reproductive phase (Baroowa &Gogoi, 2014).According to Maleki et al. (2013), dry spell caused the 42% decrease in yield of soybean(Maleki et al. 2013). It was shown that the yield of maize was negatively impacted by every 1 °C upsurge in temperature (Lobell et al., 2011). Water scarcity is another keyproblem in sorghum, as noted by the majority of the leading producers (Otto et al., 2017).

2.2. Climate change & Food Security

Food safety may be jeopardized by climate variation because it can reduce the agricultural yields and increase competition for resources. According to Wang et al. (2018) by the end of the 2050s, nations like Egypt, Botswana,Myanmar and India and will face severe food insecurity. Furthermore, as a result of rising temperatures the majority of Asian and African regions will suffer from severe shortages of food by the close of 2080(Zewdie, 2014).Food availability is the amount of food that is produced domestically or imported and is of a satisfactory quality that is available for consumption. According to Zewdie (2014), this is one of the main variables used to evaluate food safety.Numerous studies have indicated that by the end of the 2050, climate change may result in reduced production in wheat (Gammans et al., 2017), maize (Li et al., 2014) and rice (Li, 2018).

It will be extremely difficult to sustain this fast-rising population due to a drop in agricultural productivity induced by mounting temperatures. This might end in a severely limited supply of food in the future, jeopardizing food security and safety. Recent findings indicate that global warming has a negative impact on agricultural outputwhich caused the food prices to rise by 20% (Trostle et al., 2010). According to a number of predictions, the expected surge in population growth and global warming will cause market prices of corn to increase by 42 to 131% by the end of the 2050s. According to Conforti (2011), the market price of rice is expected to increase by 11% to 78% as a result of the reduced yield brought on by climate change.Numerous research found that food quality, including nutritional content was negatively impacted by climate change. Grain characteristics such as starch concentration, granular size and gelatinization of wheat can be negatively influenced by a 2 to 4 °C rise in temperature(Williams et al.,1995). However, new pests, diseasesand weeds may also arise as a result of climate change, which potentially have an impact on human health, the food chain, agricultural productivity and quality (Rosenzweig et al., 2001).

Global warming can push our food systems to the verge of catastrophic levels by raising food prices (Nelson et al., 2010). Maintaining food system security is backbreaking, particularly in light of rising temperatures (Wheeler and Von Braun, 2013).

3. Approaches to Combat Climate Changes

Environmental variability has long-lastingeffects on agriculture and food safety around the world. The harsh weather conditions create a menace to the safety and security of foods, and this is not an entirely novel problem. Farmers can use climate-resilient solutions by combining traditional and agroecological management practices, such as biodiversity, soil management and rainwater harvesting (Altieri & Nicholls, 2017). These management strategies improve carbon sequestration, soil health, soil quality and reduce soil erosion, resulting in healthier soils and agricultural systems (Lal et al., 2011). Therefore, the most pressing issue in the world now is to adapt to these weather variations. The subsequent measures must be implemented for crops to adjust to fluctuating circumstances.

3.1. Cultural Approaches

Farmers employ variety of useful strategies, including asirrigation techniques,crop rotation, varying cropping patterns and short-cycle crops. Under climatic stress circumstances, all of these actions may improve crop adaptability (Deligios et al., 2019). Shifting the cultivation time, planting novel crops and utilizing drought resistant cultivars are some vital approaches to reduce the risk of climate unpredictability and boost crop plant adaptability to assure food security and safety(Ali & Erenstein, 2017).Utilizing crop-management strategies that can improve crop development under a range of environmental stresses is another way to increase plant adaptation. The timing of sowing, planting density and optimal irrigating techniques are critical approaches to deal with meteorological challenges (Battisti et al., 2018). Fertilizers are also essential for mitigating the effects of global warming and assisting plants in adapting more effectively. It delivers significant energy to plants which helps to maintain soil fertility and productivity. As a result, the role of fertilizer in sustaining the earth is undeniable (Henderson et al., 2018).

3.2. Traditional Methods

Plant breeding is an adaptable method for crop development and improvement under a range of environmental variables. In addition to helping plants survival from various challenges during a critical stage of plant growth, it ensures food security and safety amid extreme weather variations (Blum, 2018). Inbreeding selection, Polymorphism and recombination are used in genetic divergence analysis to produce the ideal plant. In order to establish innovative cultivars based on genetic variation and affinities, genetic divergence analysis is considered an essential tool(Raza et al., 2018).

3.3. Genetics and Genomics Strategies

Breeding programs in several crops are combined with genomic techniques to identify elite genes with multi-trait assembly and reach new heights in molecular breeding (Bevan &Waugh, 2007). With the introduction of sequencing and phenotyping, genomic-led breeding paved the path for identifying genes involved in various mitigation stress. (Kole et al., 2015). Collins et al., (2008) propose that the development of new cultivars with enhanced stress resistance is enabled by QTL dissection of yield-related factors in crops. Molecular plant Breeding is a key approach for enhancing crop yields and productivity in the presence of multiple environmental stresses. (Wani et al., 2018). Genomic selection (GS) is an intriguing approach for crop improvement that uses high-throughput phenotyping and marker density to screen elite genes, improve polygenic characteristics, and produce cost-effective breeding lines (Kumar et al., 2018).

3.4. Genetic Engineering

Genetic engineering is a powerful technique to modify the genetic makeup of the genome for the benefit of humans. Identification of stress-responsive transcription factors is a crucial breakthrough for developing stress-resistant agricultural varieties. These transcription factors can regulate gene phenotypes in genetically engineered crops exposed to various stresses (Reynolds et al., 2015). Genetic engineering has produced a large number of transgenic plants to combat biotic and abiotic stresses.These genetically altered plants are significantly more resistant to environmental fluctuations than conventional plants (Nejat & Mantri, 2017). Several transcription factors are recognized like the AP2/ERFBP group, which is important for several plant growth pathways and has roles in all stress responses (Licausi et al., 2010). Genetically modified tobacco with an overexpressed GmERF3 gene shows improved resistance to TMV, dehydration, and salinity stress (Zhang et al., 2009) [193]. WRKY is another significant family of TFs that is widely distributed in response to abiotic stresses (Muthamilarasan et al., 2015).

Genome editing (GE) is a decidedly effective approach for manipulating the plant genome using sequence-specific nucleases. On a global scale GE-assisted crop modification has the potential to combat food insecurity and create a climate-conscious farming system (Liu et al., 2013). The use of GE technologies and the development of novel techniques for quick and precise genome editing to enhance crop output and protect crops from various stresses have had a significant impact on plant breeding techniques (Taranto et al., 2018). Therefore, in order to improve crop varieties with a high potential for producing yielding crops, it is necessary to develop innovative alterations in the gene pool of plant germplasm under different stresses (Kamburova et al., 2017).Genome editing technique uses specific to the site endonucleases such as zinc-finger nucleases, CRISPR-Cas9 and transcription activator-like effector nucleases(Zhu et al., 2017). The CRISPR/Cas9 system is emerging as the most effective GE technique among the genome editing toolsdue to its affordability, speed, accuracy, and ability to edit many sites within the genome at once (Abdelrahman et al., 2018). Plant genome editing using CRISPR/Cas9 has been widely studied to adapt to biotic and abiotic challenges (Khurshid et al., 2017). Shen et al. (2017) used Osann3 gene knockout to study japonica rice ability to withstand cold stress and found that this enhanced the cold stress tolerance. The development of herbicide tolerance in mutant rice lines was achieved through the use of CRISPR/Cas9 to knock down the PmCDA1 gene (Shimatani et al., 2017).

Conclusion and Future perspective:

Climate change is an undeniable issue that poses serious difficulties to global agriculture, jeopardizing crop production, soil health, water supplies and food security. This review emphasizes the negative effects of climate change on agricultural productivity, such as reduced crop yields, soil degradation, water scarcity and increased pest and disease pressures, as well as the need for adaptive strategies, such as climate-smart agriculture, genetic engineering, molecular breeding, and traditional farming practices, to mitigate these consequences. Future efforts must focus on developing resilient crop varieties through genetic engineering, molecular breeding, implementing climate-smart agricultural practices for sustainable cropping systems and assuring strong regulatory and institutional support.

Addressing the complex difficulties faced by climate change requires collaborative research, knowledge exchange, and the creation of monitoring and early warning systems. Additionally, efforts to reduce greenhouse gas emissions from agriculture must be enhanced. Integrating these measures allows the agricultural industry to better adapt to climate change, assuring food security and sustainability for future generations. Continued investment in research, innovation and collaboration will be critical to developing a resilient agricultural system that can survive the effects of climate change.

References:

1. Abdelrahman, M.; Al-Sadi, A.M.; Pour-Aboughadareh, A.; Burritt, D.J.; Tran, L.-S.P. (2018). Genome editing using CRISPR/Cas9–targeted mutagenesis: An opportunity for yield improvements of crop plants grown under environmental stresses. Plant Physiology and Biochemistry, Volume 131: Pages 31–36.
2. Abeydeera, L.H.U.W.; Mesthrige, J.W.; Samarasinghalage, T.I. (2019). Global research on carbon emissions: A scientometric review. Sustainability, Volume 11: Page 3972.
3. Ali, A.; Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Climate Risk Management, Volume 16: Pages 183–194.
4. Altieri, M.A.; Nicholls, C.I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. Climate Change,
5. Arora, M.; Goel, N.K.; Singh, P. (2005). Evaluation of temperature trends over India. Hydrological Sciences Journal, Volume 50: Pages 81–93.

6. Arunanondchai, P.; Fei, C.; Fisher, A.; McCarl, B.A.; Wang, W.; Yang, Y. (2018). How does climate change affect agriculture.In The Routledge Handbook of Agricultural Economics; Routledge: Abingdon-on-Thames, UK.
7. Asseng, S.; Ewert, F.; Martre, P.; Rötter, R.P.; Lobell, D.; Cammarano, D.; Kimball, B.; Ottman, M.; Wall, G.; White, J.W. (2015). Rising temperatures reduce global wheat production. Nature Climate Change, Volume 5: Page 143.
8. Baroowa, B.; Gogoi, N. (2014). Biochemical changes in black gram and green gram genotypes after imposition of drought stress. Journal of Food Legumes, Volume 27: Pages 350–353.
9. Battisti, R.; Sentelhas, P.C.; Parker, P.S.; Nendel, C.; Gil, M.D.S.; Farias, J.R.; Basso, C.J. (2018). Assessment of crop-management strategies to improve soybean resilience to climate change in Southern Brazil. Crop and Pasture Science, Volume 69: Pages 154–162.
10. Baul, T.K.; McDonald, M. (2015). Integration of Indigenous knowledge in addressing climate change. Indian Journal of Traditional Knowledge, Volume 1: Pages 20–27.
11. Betts, R.A.; Alfieri, L.; Bradshaw, C.; Caeser, J.; Feyen, L.; Friedlingstein, P.; Gohar, L.; Koutroulis, A.; Lewis, K.; Morfopoulos, C.; et al. (2018). Changes in climate extremes, fresh water availability and vulnerability to food insecurity projected at 1.5 °C and 2 °C global warming with a higher-resolution global climate model. Philosophical Transactions of the Royal Society A, Volume 376: Article 20160452.
12. Bevan, M.; Waugh, R. (2007). In Applying Plant Genomics to Crop Improvement; BioMed Central: London, UK.
13. Blum, A. (2018). Plant Breeding for Stress Environments; CRC Press: Boca Raton, FL, USA.
14. Challinor, A.J.; Watson, J.; Lobell, D.B.; Howden, S.M.; Smith, D.R.; Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, Volume 4: Pages 287–291.
15. Collins, N.C.; Tardieu, F.; Tuberosa, R. (2008). Quantitative trait loci and crop performance under abiotic stress: Where do we stand? Plant Physiology, Volume 147: Pages 469–486.
16. Conforti, P. (2011). Looking Ahead in World Food and Agriculture: Perspectives to 2050; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy.
17. DaMatta, F.M.; Grandis, A.; Arenque, B.C.; Buckeridge, M.S. (2010). Impacts of climate changes on crop physiology and food quality. Food Research International, Volume 43: Pages 1814–1823.
18. Deligios, P.A.; Chergia, A.P.; Sanna, G.; Solinas, S.; Todde, G.; Narvarte, L.; Ledda, L. (2019). Climate change adaptation and water saving by innovative

irrigation management applied on open field globe artichoke. Science of the Total Environment, Volume 649: Pages 461–472.

19. Deutsch, C.A.; Tewksbury, J.J.; Tigchelaar, M.; Battisti, D.S.; Merrill, S.C.; Huey, R.B.; Naylor, R. (2018). Increase in crop losses to insect pests in a warming climate. Science, Volume 361: Pages 916–919.
20. Dhankher, O.P.; Foyer, C.H. (2018). Climate resilient crops for improving global food security and safety. Plant Cell and Environment, Volume 41: Pages 877–884.
21. FAOSTAT. (2017).
22. Gammans, M.; Mérel, P.; Ortiz-Bobea, A. (2017). Negative impacts of climate change on cereal yields: Statistical evidence from France. Environmental Research Letters, Volume 12: Article 054007.
23. Hellin, J.; Bellon, M.R.; Hearne, S.J. (2014). Maize landraces and adaptation to climate change in Mexico. Journal of Crop Improvement, Volume 28: Pages 484–501.
24. Henderson, B.; Cacho, O.; Thornton, P.; van Wijk, M.; Herrero, M. (2018). The economic potential of residue management and fertilizer use to address climate change impacts on mixed smallholder farmers in Burkina Faso. Agricultural Systems, Volume 167: Pages 195–205.
25. IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. In Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK.
26. IPCC. (2014). Climate Change 2014: Synthesis Report; Pachauri, R.K., Meyer, L.A., Eds.; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland; 151p.
27. Ito, R.; Vasconcelos, H.L.; Feeley, K.J. (2018). Global climate change increases risk of crop yield losses and food insecurity in the tropical Andes. Global Change Biology, Volume 24: Pages e592–e602.
28. Kamburova, V.S.; Nikitina, E.V.; Shermatov, S.E.; Buriev, Z.T.; Kumpatla, S.P.; Emani, C.; Abdurakhmonov, I.Y. (2017). Genome editing in plants: An overview of tools and applications. International Journal of Agronomy, Volume 2017: Pages 1–15.
29. Khan, A.; Ijaz, M.; Muhammad, J.; Goheer, A.; Akbar, G.; Adnan, M. (2016). Climate Change Implications for Wheat Crop in Dera Ismail Khan District of Khyber Pakhtunkhwa. Pakistan Journal of Meteorology, Volume 13: Pages 17–27.

30. Khurshid, H.; Jan, S.A.; Shinwari, Z.K.; Jamal, M.; Shah, S.H. (2017). Current Issues in Molecular Biology, An Era of CRISPR/Cas9 Mediated Plant Genome Editing. Volume 26: Pages 47–54.
31. Kole, C.; Muthamilarasan, M.; Henry, R.; Edwards, D.; Sharma, R.; Abberton, M.; Batley, J.; Bentley, A.; Blakeney, M.; Bryant, J. (2015). Application of genomics-assisted breeding for generation of climate resilient crops: Progress and prospects. Frontiers in Plant Science, Volume 6: Article 563.
32. Korres, N.E.; Norsworthy, J.K.; Tehranchian, P.; Gitsopoulos, T.K.; Loka, D.A.; Oosterhuis, D.M.; Gealy, D.R.; Moss, S.R.; Burgos, N.R.; Miller, M.R.; et al. (2016). Cultivars to face climate change on crops and weeds: A review. Agronomy for Sustainable Development, Volume 36: Pages 12–22.
33. Kumar, R.; Gautam, H.R. (2014). Climate change and its impact on agricultural productivity in India. Journal of Climatology and Weather Forecasting, Volume 2: Pages 1–3.
34. Kumar, S.; Muthusamy, S.K.; Mishra, C.N.; Gupta, V.; Venkatesh, K. (2018). Advanced Molecular Plant Breeding: Meeting the Challenge of Food Security;CRC Press: Boca Raton, FL, USA; p. 275.
35. Lal, R.; Delgado, J.A.; Groffman, P.M.; Millar, N.; Dell, C.; Rotz, A. (2011). Management to mitigate and adapt to climate change. Journal of Soil and Water Conservation, Volume 66: Pages 276–285.
36. Li, M. (2018). Climate Change to Adversely Impact Grain Production in China by 2030; IFPRI: Washington, DC, USA.
37. Li, X.; Takahashi, T.; Suzuki, N.; Kaiser, H.M. (2014). Impact of climate change on maize production in Northeast and Southwest China and risk mitigation strategies. APCBEE Procedia, Volume 8: Pages 11–20.
38. Li, Y.; Ye, W.; Wang, M.; Yan, X. (2009). Climate change and drought: A risk assessment of crop-yield impacts. Climatic Research, Volume 39: Pages 31–46.
39. Licausi, F.; Giorgi, F.M.; Zenoni, S.; Osti, F.; Pezzotti, M.; Perata, P. (2010). Genomic and transcriptomic analysis of the AP2/ERF superfamily in Vitis vinifera.BMC Genomics, Volume 11: Article 719.
40. Liu, W.; Yuan, J.S.; Stewart, C.N., Jr. (2013). Advanced genetic tools for plant biotechnology. Nature Reviews Genetics, Volume 14: Pages 781.
41. Lobell, D.B.; Bänziger, M.; Magorokosho, C.; Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change, Volume 1: Pages 42.
42. Lobell, D.B.; Schlenker, W.; Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, Volume 333: Pages 616–620.
43. Mahato, A. (2014). Climate change and its impact on agriculture. International Journal of Scientific Research and Publications, Volume 4: Pages 1–6.

44. Maleki, A.; Naderi, A.; Naseri, R.; Fathi, A.; Bahamin, S.; Maleki, R. (2013). Physiological performance of soybean cultivars under drought stress. Bulletin of Environmental Pharmacology and Life Sciences, Volume 2: Pages 38–44.
45. Malhi, G.S.; Kaur, M.; Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. Sustainability, Volume 13, Issue 3: Article 1318.
46. Malhi, G.S.; Kaur, M.; Kaushik, P.; Alyemeni, M.N.; Alsahli, A.; Ahmad, P. (2020). Arbuscular mycorrhiza in combating abiotic stresses in vegetables: An eco-friendly approach.Saudi Journal of Biological Sciences, Volume 28(2):Pages 1465-1476.
47. Malhi, G.S.; Rana, M.C.; Rana, S.S.; Kaushik, P. (2020). Effect of individual or combined application of herbicide imazethapyr on nutrient uptake by blackgram (Vigna mungo L.). Journal of Experimental Biology and Agricultural Sciences, Volume 8: Pages 441–446.
48. Mendelsohn, R. (2009). The impact of climate change on agriculture in developing countries. Journal of Natural Resources Policy Research, Volume 1: Pages 5–19.
49. Montzka, S.A.; Dlugokencky, E.J.; Butler, J.H. (2011). Non-CO2 greenhouse gases and climate change. Nature, Volume 476: Pages 43–50.
50. Muthamilarasan, M.; Bonthala, V.S.; Khandelwal, R.; Jaishankar, J.; Shweta, S.; Nawaz, K.; Prasad, M. (2015). Global analysis of WRKY transcription factor superfamily in Setaria identifies potential candidates involved in abiotic stress signaling. Frontiers in Plant Science, Volume 6: Article 910.
51. Myers, S.S.; Zanobetti, A.; Kloog, I.; Huybers, P.; Leakey, A.D.B.; Bloom, A.J.; Carlisle, E.; Dietterich, L.H.; Fitzgerald, G.; Hasegawa, T.; et al. (2014). Increasing CO2 threatens human nutrition. Nature, Volume 510: Pages 139–142.
52. Nejat, N.; Mantri, N. (2017). Plant immune system: Crosstalk between responses to biotic and abiotic stresses the missing link in understanding plant defence. Current Issues in Molecular Biology, Volume 23: Pages 1–16.
53. Nelson, G.C.; Rosegrant, M.W.; Palazzo, A.; Gray, I.; Ingersoll, C.; Robertson, R.; Tokgoz, S.; Zhu, T.; Sulser, T.B.; Ringler, C. (2010). Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options; IFPRI: Washington, DC, USA; Volume 172.
54. Noya, I.; González-García, S.; Bacenetti, J.; Fiala, M.; Moreira, M.T. (2018). Environmental impacts of the cultivation-phase associated with agricultural crops for feed production. Journal of Cleaner Production, Volume 172: Pages 3721–3733.
55. Otto, I.M.; Reckien, D.; Reyer, C.P.; Marcus, R.; Le Masson, V.; Jones, L.; Norton, A.; Serdeczny, O. (2017). Social vulnerability to climate change: A review of

concepts and evidence. Regional Environmental Change, Volume 17: Pages 1651–1662.

56. Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R.; Church, J.A.; Clarke, L.; Dahe, Q.; Dasgupta, P. (2014). Climate Change 2014: Synthesis Report; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland.
57. Raza, A.; Shaukat, H.; Ali, Q.; Habib, M. (2018). Assessment of RAPD markers to analyse the genetic diversity among sunflower (Helianthus annuus L.) genotypes. Turkish Journal of Agriculture, Food Science and Technology, Volume 6: Pages 107–111.
58. Reyer, C.P.O.; Leuzinger, S.; Rammig, A.; Wolf, A.; Bartholomeus, R.P.; Bonfante, A.; Lorenzi, F.D.; Dury, M.; Gloning, P.; Jaoude, R.A.; et al. (2012). A plant's perspective of extremes: Terrestrial plant responses to changing climatic variability. Global Change Biology, Volume 19: Pages 75–89.
59. Reynolds, M.; Tattaris, M.; Cossani, C.M.; Ellis, M.; Yamaguchi-Shinozaki, K.; Saint Pierre, C. (2015). Advances in Wheat Genetics: From Genome to Field;Springer: Berlin/Heidelberg, Germany; Pages 355–368.
60. Richardson, K.J.; Lewis, K.H.; Krishnamurthy, P.K.; Kent, C.; Wiltshire, A.J.; Hanlon, H.M. (2018). Food security outcomes under a changing climate: Impacts of mitigation and adaptation on vulnerability to food insecurity. Climate Change, Volume 147: Pages 327–341.
61. Rosenzweig, C.; Elliott, J.; Deryng, D.; Ruane, A.C.; Müller, C.; Arneth, A.; Boote, K.J.; Folberth, C.; Glotter, M.; Khabarov, N. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceedings of the National Academy of Sciences USA, Volume 111: Pages 3268–3273.
62. Rosenzweig, C.; Iglesias, A.; Yang, X.; Epstein, P.R.; Chivian, E. (2001). change and extreme weather events; implications for food production, plant diseases, and pests. Global Change and Human Health, Climate Volume 2: Pages 90–104.
63. Sathaye, J.; Shukla, P.R.; Ravindranath, N.H. (2006). Climate change, sustainable development and India: Global and national concerns. Current Science, Volume 90: Pages 314–325.
64. Shen, C.; Que, Z.; Xia, Y.; Tang, N.; Li, D.; He, R.; Cao, M. (2017). Knock out of the annexin gene OsAnn3 via CRISPR/Cas9-mediated genome editing decreased cold tolerance in rice. Journal of Plant Biology, Volume 60: Pages 539–547.
65. Shimatani, Z.; Kashojiya, S.; Takayama, M.; Terada, R.; Arazoe, T.; Ishii, H.; Teramura, H.; Yamamoto, T.; Komatsu, H.; Miura, K. (2017). Targeted base editing in rice and tomato using a CRISPR-Cas9 cytidine deaminase fusion. Nature Biotechnology, Volume 35: Pages 441.

66. Stern, D.I.; Kaufmann, R.K. (2014). Anthropogenic and natural causes of climate change.Climate Change, Volume 122: Pages 257–269.
67. Stevanovic, M.; Popp, A.; Campen, H.L.; Dietrich, J.P.; Muller, C.; Bonsch, M.; Schmitz, C.; Bodirsky, B.L.; Humpenoder, F.; Weindl, I. (2016). The impact of high-end climate change on agricultural welfare. Science Advances, Volume 2: Article e1501452.
68. Taranto, F.; Nicolia, A.; Pavan, S.; De Vita, P.; D'Agostino, N. (2018). Biotechnological and digital revolution for climate-smart plant breeding. Agronomy, Volume 8: Article 277.
69. Tebaldi, C.; Lobell, D. (2018). Estimated impacts of emission reductions on wheat and maize crops. Climate Change, Volume 146: Pages 533–545.
70. Thornton, P.K.; Ericksen, P.J.; Herrero, M.; Challinor, A.J. (2014). Climate variability and vulnerability to climate change: A review. Global Change Biology, Volume 20: Pages 3313–3328.
71. Trostle, R. (2010). Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices;DIANE Publishing: Collingdale, PA, USA.
72. Uddling, J.; Broberg, M.C.; Feng, Z.; Pleijel, H. (2018). Crop quality under rising atmospheric CO2. Current Opinion in Plant Biology, Volume 45: Pages 262–267.
73. Van Velthuizen, H. (2007). Mapping Biophysical Factors That Influence Agricultural Production and Rural Vulnerability; Food & Agriculture Organization: Rome, Italy.
74. Wang, J.; Vanga, S.K.; Saxena, R.; Orsat, V.; Raghavan, V. (2018). Effect of Climate Change on the Yield of Cereal Crops: A Review. Climate, Volume 6: Article 41.
75. Wang, Z.; Huang, B. (2004). Physiological recovery of Kentucky bluegrass from simultaneous drought and heat stress. Crop Science, Volume 44: Pages 1729–1736.
76. Wani, S.H.; Choudhary, M.; Kumar, P.; Akram, N.A.; Surekha, C.; Ahmad, P.; Gosal, S.S. (2018). Biotechnologies of Crop Improvement; Springer: Berlin/Heidelberg, Germany; Volume 3: Pages 1–23.
77. Wheeler, T.; Von Braun, J. (2013). Climate change impacts on global food security. Science, Volume 341: Pages 508–513.
78. Wheeler, T.; Von Braun, J. (2013). Climate change impacts on global food security. Science, Volume 341: Pages 508–513.
79. Williams, M.; Shewry, P.; Lawlor, D.; Harwood, J. (1995). The effects of elevated temperature and atmospheric carbon dioxide concentration on the quality of grain lipids in wheat (Triticum aestivum L.) grown at two levels of nitrogen application. Plant Cell and Environment, Volume 18: Pages 999–1009.

80. Xu, Z.Z.; Zhou, G.S. (2006). Combined effects of water stress and high temperature on photosynthesis, nitrogen metabolism and lipid peroxidation of a perennial grass Leymus chinensis.Planta, Volume 224: Pages 1080–1090.
81. Zewdie, A. (2014). Impacts of climate change on food security: A literature review in Sub-Saharan Africa. Journal of Earth Science and Climate Change, Volume 5: Article 225.
82. Zhang, G.; Chen, M.; Li, L.; Xu, Z.; Chen, X.; Guo, J.; Ma, Y. (2009). Overexpression of the soybean GmERF3 gene, an AP2/ERF type transcription factor for increased tolerances to salt, drought, and diseases in transgenic tobacco. Journal of Experimental Botany, Volume 60: Pages 3781–3796.
83. Zhao, C.; Liu, B.; Piao, S.; Wang, X.; Lobell, D.B.; Huang, Y.; Huang, M.; Yao, Y.; Bassu, S.; Ciais, P. (2017). Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences USA, Volume 114: Pages 9326–9331.
84. Zhu, C.; Bortesi, L.; Baysal, C.; Twyman, R.M.; Fischer, R.; Capell, T.; Schillberg, S.; Christou, P. (2017). Characteristics of genome editing mutations in cereal crops. Trends in Plant Science, Volume 22: Pages 38–52.