ISBN: 978-81-969534-8-5

16. Millet for Climate Resilience Agriculture

Pratikshya Paudel[1], Mamata Subedi[3]

[1,3] M.Sc. Scholor,
Department of Genetics and Plant Breeding,
School of Agriculture,
Lovely Professional University,
Phagwara, Punab, India.

Dr. Manoj Kumar Pandey[2]

[2]Associate Professor,
Department of Genetics and Plant Breeding,
School of Agriculture, Lovely Professional University,
Phagwara, Punab, India.

Abstract:

Millets are nutrient rich crops with unique potential to withstand extremities like drought, heat and several other abiotic as well as biotic stresses. The deep root structure of pearl millet allows it to thrive in a variety of ecological circumstances, including dry spells. It has great photosynthetic efficiency and can grow even under nutrient deprived soils by utilizing fewer chemical fertilizers compared to other cereals. This peculiar characteristic of millet may be utilized to combat the changing climate and has the capacity to elevate income as well as food security for the farmng communities and nation as a whole. Having an excellent nutrient profile, it has the ability to prevent malnutrition, which is prevalent around the globe and covert hunger. High-quality whole-genome sequencing and resequencing data of many lines are now available, which could facilitate the genetic analysis of stress tolerance and offer a promising avenue for further exploitation of resilience features and nutritional traits. Hence, additional work needs to be done to optimize inheritance and strengthen its genetic makeup in order to properly utilize it. Therefore, efforts must be focused on developing nutritionally dense hybrids or cultivars tolerant to drought utilizing various omics techniques making it the next-generation crop with the potential for nutritional richness and climate resilience.

Keywords:

Climate resilience, stresses, food security, genome, tolerance, omics.

16.1 Introduction:

Millets, popularly known as “Nutri-cereals” by the Ministry of Agriculture and Farmers Welfare, GOI. It ranks as the sixth most important cereal crop in the world, followed by rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), barley (Hordeum vulgare), and sorghum (*Sorghum bicolor*) that grows extensively over 30 million hectares in the dry and semi-arid parts of tropical Asia and Africa, and is a staple food for 90 million impoverished people. Nearly half of the millet produced worldwide is produced from it, and it is also utilized as feed and fodder (Srivastava et al., 2020a). Millets are a nutrient-dense, locally grown, high-fiber, low-GI (*Glycemic Index*), high-source of gluten-free protein, rich in bioactive compounds, and provide protection against diabetes and cardiovascular disease. They can also be used for brewing, biofuel production, food, feed, and fodder. Furthermore, it is an underutilized crop with enormous nutritional potential that needs to be completely utilized. It also has higher ceiling temperatures for grain output (Krishnan and Meera, 2018). It can be extremely helpful in ensuring food and nutritional security in the face of rapidly changing climate conditions, such as drought and water scarcity, and it is more resilient to harsh weather events compared to other cereal crops. This nutrient-rich, climate change-ready crop has a significant potential to produce improved economic returns in marginal conditions in contrast to other grains, even in the event of climate change having extreme weather conditions. Due to this peculiar nature, they are termed as the “miracle grains” or the “crops of the future”. Moreover, they are gluten free which makes them a perfect choice for people with celiac disease.

Being a C4 plant , it can account for about thirty percent of world terrestrial carbon fixation in addition to other C4 plants like sorghum and maize (Choudhary et al.,2020).Because of its special qualities, which include the C4 plant's high photosynthetic efficiency, greater capacity to produce dry matter, and ability to withstand harsh agroclimatic conditions with fewer inputs and greater financial returns, it outperforms all other cereals, including wheat, maize, rice, sorghum, and barley (Nambiar et al., 2011). C4 plants are more effective at using water and have a greater capacity to fix inorganic CO2 than C3 plants because of the leaf anatomy exhibiting "Kranz" characteristics. Small-holder farmers grow millets in many places with little water and perhaps no other inputs, such as fertilizers. Millets require 40% less energy and 70% less water when processing as compared to rice. Previously millet was limited only to certain groups of population, however its popularity is increasing these days because people around the globe are steadily realizing its innumerable health benefits.

16.2 Present Scenario:

As per the current context, consumption rate of cereal is soaring because of the rampant increment in population worldwide and millet is used as one of the prime sources of food because of rich nutritive profile and its ability to sustain ongoing changes in the climatic conditions. It is mostly grown on marginal terrain that faces rainfed conditions, and even in regions that are vulnerable to drought which receive an average annual precipitation of less than 250 mm (Nambiar et al., 2011).

A constant reliance on wheat and rice as food sources makes them unaffordable for locals and rural residents to live by on a daily basis, which leads to economic restraints. According to recent estimates (Godfray et al., 2010; Wheeler and Braun, 2013), 2-3 billion people may experience food insecurity and hunger by 2030 as a result of the decline in food production and the growing strain to feed a population that will surpass 9 billion. In addition, the current state of climate change is having a significant impact on agricultural productivity, which in turn affects food production and livelihoods. For instance, FAO data from 2019 show that over 820 million people worldwide were still experiencing hunger, highlighting the tremendous challenge of reaching the Zero Hunger target by 2030.

Under the current shifting climatic conditions, abiotic stresses pose a serious threat to plant growth and development under the current shifting climatic conditions, which can result in a 50% reduction in yield for common cereal crops (Bray et al., 2000). Only 10% of agricultural land is free from diverse abiotic pressures, while almost 90% of cultivable land worldwide is impacted by them (Dita et al., 2006).

Out of all the environmental challenges, heat and drought have a huge effect on production. In this context, a hardy crop species like pearl millet can be extremely important in meeting the world's expanding population's increased need for food due to rising temperatures and decreasing rainfall. Due to its innate ability to live in these conditions and tolerate abiotic stresses including heat, salinity, and drought, pearl millet is primarily grown on marginal lands that experience erratic and unexpected rainfall patterns (Serba and Yadav, 2016).

The crop is preferred because of its guaranteed productivity, short growing season, capable of sustaining in dry, hot weather enduring up to the temperature of 42 degrees Celsius during reproductive phase. Besides this it can also resist varied forms of biotic and abiotic stresses making it a climate resilient crop.

Given the current state of climate change, drought, and water scarcity, millets could be considered a highly promising and nutritious way to provide food security in a sustainable manner as in figure 16.1. The United Nations General Assembly recently proclaimed 2023 as the "International Year of Millets" in an effort to increase awareness of the benefits of farming millets and to highlight the importance of nutrient-rich crop for climate resilient agriculture.

This chapter mainly highlights the peculiar behavior of millets and how this neglected crop can be utilized as a climate ready crop in this undergoing climatic scenarios which is surging at a rapid rate. It also showcases the nutritional benefits of the crop addressing its role in ensuring food, nutritional and economic security of a nation.

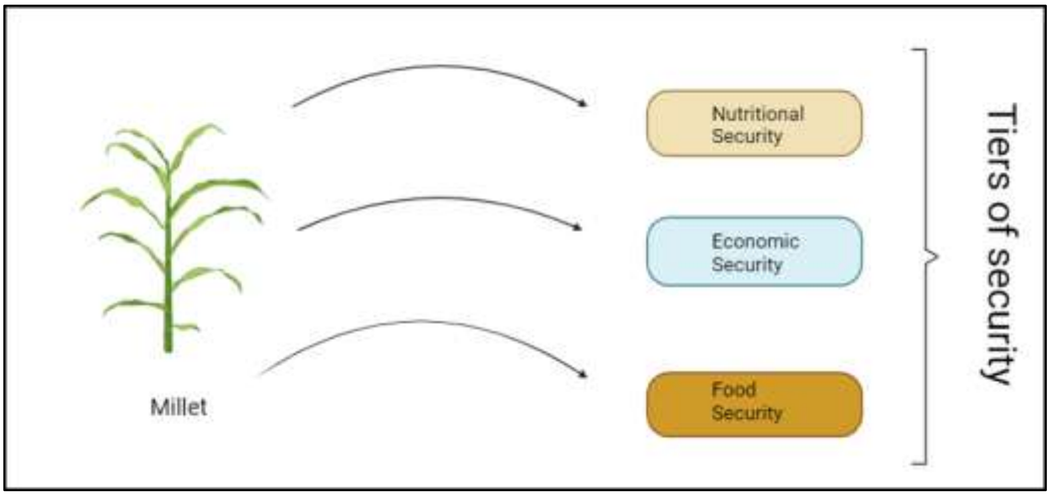

Figure 16.1: Illustration Depicting Millet as A Potential Source of Securities

16.3 Climate Resilience of Millets:

The yield of staple crops such as rice, wheat, and maize is severely threatened by environmental limitations. These crops need regular supplies of chemical fertilizers, well-manicured fields, and weed and insect control techniques. If extreme heatwaves and droughts persist throughout the growing season, there is a danger of 70–80% yield loss in these crops (Leng and Hall, 2019). A lack of sufficient water supply prevents rice from ever being grown. As of the end of the twenty-first century, Tollefson (2020) believes that wheat may vanish as the average global temperature is predicted to increase by 4-5 degree Celsius. Consequently, the notion of developing cereal crops like millets which are climate-smart has gained prominence. The capacity to tolerate elevated temperatures, endure in regions susceptible to drought, and be cultivated in some regions of Gujarat and eastern Uttar Pradesh of India in hot summers, makes millet adaptable to climate change and able to withstand its negative impacts (Gupta et al., 2015). Millets are physiologically sustainable in adverse environmental situations without sacrificing production because of their high water and nitrogen usage efficiency. By the end of the twenty-first century, numerous regions are predicted to experience more frequent and extended droughts, as well as a rise in the world average temperature and soil salinity. It is important to consider that important cereal crops like wheat and rice may experience negative effects on their yield, making them vulnerable under such circumstances. Therefore, it is imperative that we comprehend the genetic and molecular mechanisms governing the stress tolerance of naturally abiotic-tolerant minor cereal crops, such as millets. These mechanisms can then be engineered into other crops through various omics approaches to create climate-smart major cereal crops as illustrated in figure 16.2.

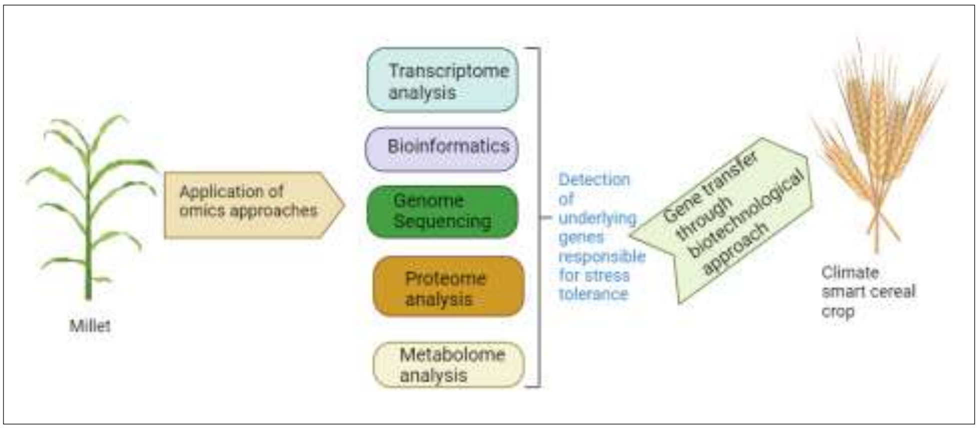

Figure 16.2: Diagrammatic Representation of Developing Climate Smart Cereal Crops with Millet Utilizing Omics Approaches

16.4 Genomic Resources:

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the National Agricultural Research System (NARS) in India have both played a key role in creating different enhanced breeding and parental lines of potential hybrids.

The ICRISAT Gene bank is home to 21,392 germplasm accessions, including 750 accessions of wild species of the genera Pennisetum and Cenchrus that were gathered from 50 nations.

The National Bureau of Plant Genetic Resources (NBPGR), located in New Delhi, India, is home to 8,284 accessions. A significant number of hybrids have been developed and commercialized using these lines in breeding programs run by the public and private sectors (in 2019, 105 hybrids were being cultivated by the business sector and 70 by the public sector).

A wide range of molecular markers like RFLP, AFLP, SSRs, SNPs and genomic tools have been developed and utilized for QTLs/genes identification, genetic diversity, and MAB (Marker Assisted Breeding) can improve pearl millet breeding (Serba and Yadav2016, Ambawat et al., 2020; Srivastava et al., 2020a, b; Anuradha et al., 2017; Bollam et al., 2018; Kumar et al., 2018; Singhal et al., 2018). Some of the genes encoding for various stress responses in different millets are briefly discussed below in Table-16.1.

Table 16.1: Genes Conferring Resistance to Various Forms of Stress in Millets

Millets	Stress Responses	Gene	References
Pearl millet	Tolerance to several abiotic stresses	Voltage dependent anion channel (VDAC)	Desai et al.,2006
	Involvement in stress responsive pathways	Glutathione reductase	Achary et al.,2015
Finger millet	Overexpression of NAC67 gene in rice confers tolerance to salinity and drought stress	NAC transcription factor	Rahman et al., 2016
	Cloning and characterization of four Pt genes which expresses their involvement in Pi stress	Phosphate transporters (Pt)	Pudake et al., 2017
	Overexpression of Dehydrin 7 gene in tobacco confers tolerance to drought stress	Dehydrin7	Singh et al.,2015
Foxtail millet	Tolerance to drought and oxidative stress	Abscisic acid stress ripening gene (ASR)	Feng et al.,2016
	Tolerance to salt, osmotic and drought stress	Late embryogenesis abundant protein (LEA)	Wang et al.,2014
	Regulate stress response in foxtail millet	Argonaute protein 1 encoding gene	Liu et al.,2016

16.4.1 Characterization of Gene Responsible for Varied Stresses in Different Millets:

These genes have played a vital role in making the crop thrive in various abiotic stress conditions like heat, drought, salinity as well as make them resist to several biotic stresses such as resistance to the attack of pests and diseases like Ergot, downy mildew and blast.

A. Stress Response Mechanisms:

A grain of resilience, millet shows various responses such as physiological, morphological, and biochemical responses to withstand multiple forms of stresses such as drought, heat, salinity and other biotic stresses.

The mechanisms by which the crop resist these stresses are briefed below:

a. Drought Tolerance: The deep root system in millets as well as the efficient water use system of the crop helps them to tolerate prolonged dry conditions (Shrestha et al.,2023). Pearl millet and finger millet may reach depths of up to 3.6 meters and 2.7 meters, respectively, in the soil, which is deeper than the root systems of many other crops. This enables them to access liquid that is hidden well below the surface in times of water scarcity when the superficial water sources dry up. In order to reduce water loss through evaporation, dense network of fine roots in topsoil layer effectively collects and absorbs any surface moisture that is available. Furthermore, certain millet species have developed adaptations such as hairy leaves and thicker cuticles which reduce loss of water by transpiration.

b. Heat Tolerance: Millets deep root system enables them to penetrate deep into nutrient rich layer of soil which are inaccessible to other crop plants. This trait provides access to minerals and nutrients accumulated in the deep soil strata to the plant which are crucial for their growth and development and to survive in nutrient deficient soil which is common in hot and arid regions. Similarly, the hardy seeds of millets enable them to germinate and thrive in scalding soil temperatures. Due to its ability to withstand heat, millet is able to establish itself quickly and gain a foothold on the hot ground in desert areas. This allows them to flourish in elevated temperatures where other crops simply would not take a chance.

c. Salinity Tolerance: Millets collect compatible solutes in their cells, such as proline, glycine, betaine while they are under salinity stress. Even in highly salinized conditions, these osmolytes work as osmoprotectants, assisting in the preservation of cell turgor and functionality. They preserve crucial physiological functions by selectively absorbing necessary minerals like potassium and calcium while limiting the uptake of detrimental sodium ions. Likewise, Reactive oxygen species (ROS), which harm plant cells, can be produced as a result of salinity stress. Millets have powerful antioxidant systems that neutralize reactive oxygen species (ROS) and shield cellular structures. These systems include enzymes like catalase and superoxide dismutase. Millet responds to various stresses through physiological, morphological and biochemical mechanisms as depicted in figure 16.3.

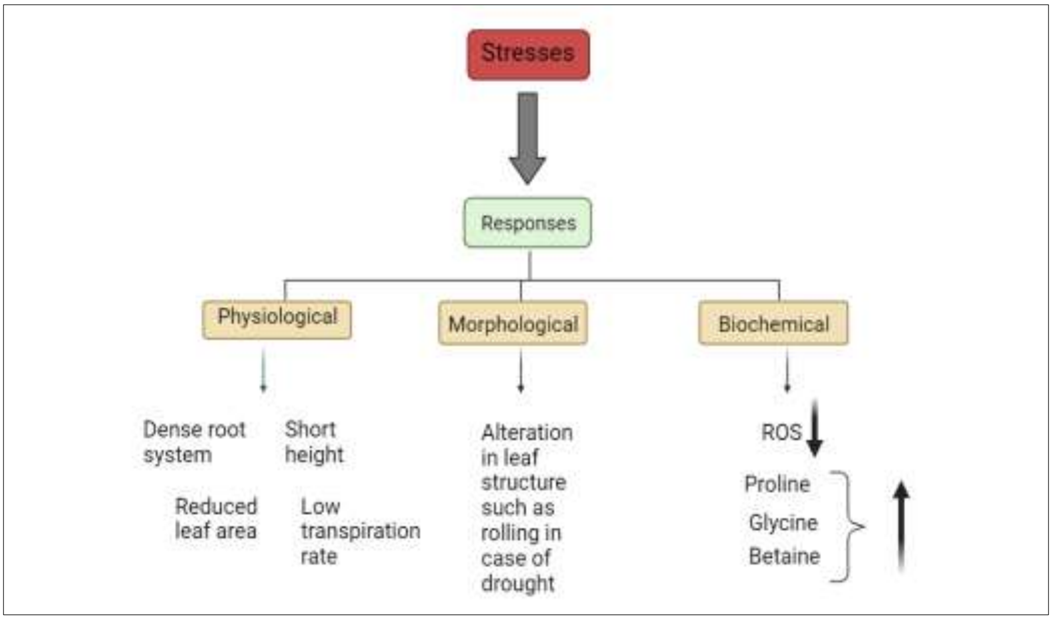

Figure 16.3: Various forms of responses to stress expressed by millet

B. Pests and Diseases Resistance:

As compared to other major crops like rice, maize and wheat, millets are generally less vulnerable to key insect pests such as armyworms, shoot flies, and stem borers. This is due to the presence of their waxy leaves, thick foliage, and chemical defense mechanisms. The crop withstands a number of fungal diseases that affect other cereals, such as blast, smut and mildews. For instance, pearl millet is naturally resistant to leaf blast, a serious rice disease. The high phenolic content of finger millet naturally guards against fungal diseases. Although no crop is impervious to diseases and pests completely, millets exhibit remarkable resilience in comparison to other important food crops. They are an excellent choice for sustainable agriculture due to their innate resilience, especially in areas with scarce resources or harsh weather circumstances.

C. Nutritional Value of Millets:

Millets have more diverse micronutrient profiles due to which they can sustainably supply the demand for cereal and also aid in nutritional security. Ensuring nutritional security is crucial in order to feed the world's expanding population and maintain public health in the current circumstances. Finger millet is highly rich in calcium and contains fiber and iron in enormous quantity as compared to rice and wheat. After major grains like wheat, rice, maize and sorghum pearl millet is the main source of energy for the semi-arid tropics and drought-prone areas of Asia and Africa because of its superior nutritional grain that is enhanced with significant levels of proteins, vitamins, minerals, and improved fat digestion. It also possesses polyphenols, anthocyanins, phytosterols, tannins, pinacosanols, and phytotates, which all contribute to its antioxidant properties and hence plays a major part in the aging process.

Obesity and diabetes are two common diseases, particularly in younger people and the issue can be addressed by including foods with a low glycemic index in a diet high in nutrients. Millets are low in glycemic index and include important vitamins like B2 (Riboflavin) and B1(Thiamine), fat, carbohydrates, crude fiber, amino acids, and trace minerals such as magnesium, iron, zinc, calcium, copper, and chromium at higher amounts than in rice and wheat (Muthamilarasan et al.,2016).

Due to its abundance in important nutrients in both good quantity and quality which are necessary for living a healthy and nutrient-dense life devoid of malnutrition, it is also known as the “Powerhouse of Nutrition.” Because of its exceptional nutritional qualities, it is becoming more and more popular worldwide, even in developed nations.

Epidemiological studies reveal that consumption of millet reduces the risk of heart disease, diabetes, enhances the digestive system, reduces the risk of cancer, detoxifies the body, and boosts immunity and respiratory health, increases vigor, and fortifies the neurological system and muscles. Moreover, millets could be used by those with celiac disease as a substitute for wheat flour. They are excellent model systems for examining how stress affects crop nutrient production and resource allocation because of their high nutritional content and resistance to environmental shocks.

16.5 Challenges and Opportunities for Millet Cultivation:

The grain millets are temperature resilient and full of nutrients, making them a promising weapon in the fight against climate change and address the issues related to food security. However, there are some loopholes that require attention. For instance, millets have a relatively poor yield; therefore, high yielding cultivars must be introduced (Grovermann et al.,2018). Also, they are sold at low prices, resulting in poor income, and even the minimum support price is not disclosed for them, which consequently affects the production. The globalization of millet production has been hampered by problems associated with domestication, such as seed shattering, low yield, lodging, and poor agronomic techniques, even though the crop is resilient to climatic change. Despite having better nutritional value in flour of Pearl millet, its consumption is restricted to certain regions around the globe due to its limited shelf life and the development of rancidity or an unpleasant odor whilst storage (Rani et al., 2018). Comparing modern millets to their wild and landrace ancestors, there is less seed breakage; yet grain shattering still causes significant yield losses, especially in small millets. Further, lodging is more common in smaller millets and has been linked to a 25% average production loss as well as decreased grain weight, grain yield per panicle, and seed germination (Chanyalew et al.,2019; Tian et al.,2018; Bayable et al.,2020).

Therefore, it is imperative that the areas mentioned below is given utmost attention in order to enhance its production as well as its utilization.

- Prolonging the shelf life of pearl millet flour and combating rancidity to advertise its goods.
- Creation of hybrids or varieties that are tolerant to high temperatures and salt.
- Creation of screening procedures and preventative measures against many diseases, including blast, rust, ergot, and smut.

- Development of pearl millet hybrids or cultivars with improved potential for regeneration upon the end of a dry spell for harsh environments and drought-prone regions.
- Value addition is also a great way to encourage consumption, and various value-added products are gaining popularity these days. It can be utilized to prepare a variety of traditional dishes like khichri, roti, sakarpare, gulgule, etc., however, industries in many countries also use it to make noodles, pasta, vermicelli, biscuits, bread, cookies, cakes, and puffs.

In Africa, malt and flour from millet are used to make a variety of traditional dishes and beverages that are higher in nutrients than those derived from other cereals.

16.6 Conclusion:

Millet, being a miracle grain with enormous benefits and ability to tackle stressful situations, has been facing a decline in production despite breeding efforts, lack of policies and thorough research. However, shift in focus for developing various food products from the crop can be a great solution to popularize it and make it acceptable as a substitute crop for the future. Production can be boosted unanimously from the efforts of breeders, concerned policy makers, agronomists and donors. With the effective application of genomic techniques, screening procedures, the creation of better genotypes has become quick and simple. It is projected that the kinds of crops grown will be significantly impacted by the changing environmental conditions.

Food security and the adverse effects of climate change can be addressed by taking advantage of their nutritional value and climate resilience in relation to food production. Promotion, branding, and improvement of millets can be done fully by utilizing the platform of International Year of Millets. By utilizing sophisticated novel genome sequencing method, QTL detection, candidate gene identification, and genomic selection can expedite the identification of allelic variations for the improvement of millets. Therefore, millets are pragmatic choice for guaranteeing both environmental resilience to climate change and food security. Hence, efforts should concentrate on enhancing yield related characteristics and reorienting the world's output toward these significant but underutilized crops. To recapitulate we can say that multidisciplinary methods encompassing breeding, genetics, nutrition, biotechnology, genomics, and bioinformatics are necessary for applying and harnessing the positive qualities of nutricereal millet in order to maintain nutritional security and combat climate change.

16.7 References:

1. Achary, V. M. M., Reddy, C. S., Pandey, P., Islam, T., Kaul, T., & Reddy, M. K. (2015). Glutathione reductase a unique enzyme: molecular cloning, expression and biochemical characterization from the stress adapted C 4 plant, Pennisetum glaucum (L.) R. Br. *Molecular Biology Reports*, *42*, 947-962.
2. Ambawat, S., Singh, S., Meena, R. C., & Satyavathi, C. T. (2020). Biotechnological applications for improvement of the pearl millet crop. In *Pearl Millet* (pp. 115-138). CRC Press.

3. Anuradha, N., Satyavathi, C. T., Meena, M. C., Sankar, S. M., Bharadwaj, C., Bhat, J., ... & Singh, S. P. (2017). Evaluation of pearl millet [Pennisetum glaucum (L.) R. Br.] for grain iron and zinc content in different agro climatic zones of India. *Indian Journal of Genetics and Plant Breeding*, 77(01), 65-73.
4. Bayable, M., Tsunekawa, A., Haregeweyn, N., Ishii, T., Alemayehu, G., Tsubo, M., ... & Masunaga, T. (2020). Biomechanical properties and agro-morphological traits for improved lodging resistance in Ethiopian teff (Eragrostis tef (Zucc.) Trottor) accessions. *Agronomy*, 10(7), 1012.
5. Bollam, S., Pujarula, V., Srivastava, R. K., & Gupta, R. (2018). Genomic approaches to enhance stress tolerance for productivity improvements in pearl millet. *Biotechnologies of Crop Improvement*, Volume 3: *Genomic Approaches*, 239-264.
6. Bray, E. A. (2000). Responses to abiotic stresses. *Biochemistry and molecular biology of plants*, 1158-1203.
7. Chanyalew, S., Ferede, S., Damte, T., Fikre, T., Genet, Y., Kebede, W., ... & Assefa, K. (2019). Significance and prospects of an orphan crop tef. *Planta*, 250, 753-767.
8. Choudhary, S., Guha, A., Kholova, J., Pandravada, A., Messina, C. D., Cooper, M., & Vadez, V. (2020). Maize, sorghum, and pearl millet have highly contrasting species strategies to adapt to water stress and climate change-like conditions. *Plant Science*, 295, 110297.
9. Desai, M. K., Mishra, R. N., Verma, D., Nair, S., Sopory, S. K., & Reddy, M. K. (2006). Structural and functional analysis of a salt stress inducible gene encoding voltage dependent anion channel (VDAC) from pearl millet (Pennisetum glaucum). *Plant Physiology and Biochemistry*, *44*(7-9), 483-493.
10. Dita, M. A., Rispail, N., Prats, E., Rubiales, D., & Singh, K. B. (2006). Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. *Euphytica*, 147, 1-24.
11. Feng, Z. J., Xu, Z. S., Sun, J., Li, L. C., Chen, M., Yang, G. X., ... & Ma, Y. Z. (2016). Investigation of the ASR family in foxtail millet and the role of ASR1 in drought/oxidative stress tolerance. *Plant cell reports*, *35*, 115-128.
12. Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... & Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science*, *327*(5967), 812-818.
13. Grovermann, C., Umesh, K. B., Quiédeville, S., Kumar, B. G., & Moakes, S. (2018). The economic reality of underutilised crops for climate resilience, food security and nutrition: Assessing finger millet productivity in India. *Agriculture*, 8(9), 131.
14. Gull, A., Jan, R., Nayik, G. A., Prasad, K., & Kumar, P. (2014). Significance of finger millet in nutrition, health and value-added products: a review. *Magnesium (mg)*, *130*(32), 120.
15. Gupta, S. K., Rai, K. N., Singh, P., Ameta, V. L., Gupta, S. K., Jayalekha, A. K., ... & Verma, Y. S. (2015). Seed set variability under high temperatures during flowering period in pearl millet (Pennisetum glaucum L. (R.) Br.). *Field Crops Research*, 171, 41-53.
16. K. Srivastava, R., Bollam, S., Pujarula, V., Pusuluri, M., Singh, R. B., Potupureddi, G., & Gupta, R. (2020b). Exploitation of heterosis in pearl millet: a review. *Plants*, 9(7), 807.
17. Krishnan, R., & Meera, M. S. (2018). Pearl millet minerals: effect of processing on bioaccessibility. *Journal of food science and technology*, 55, 3362-3372.

18. Kumar, S., Hash, C. T., Nepolean, T., Mahendrakar, M. D., Satyavathi, C. T., Singh, G., ... & Srivastava, R. K. (2018). Mapping grain iron and zinc content quantitative trait loci in an iniadi-derived immortal population of pearl millet. *Genes*, 9(5), 248.
19. Leng, G., & Hall, J. (2019). Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. *Science of the Total Environment*, *654*, 811-821.
20. Liu, X., Tang, S., Jia, G., Schnable, J. C., Su, H., Tang, C., ... & Diao, X. (2016). The C-terminal motif of SiAGO1b is required for the regulation of growth, development and stress responses in foxtail millet (Setaria italica (L.) P. Beauv). *Journal of experimental botany*, *67*(11), 3237-3249.
21. Muthamilarasan, M., Dhaka, A., Yadav, R., & Prasad, M. (2016). Exploration of millet models for developing nutrient rich graminaceous crops. *Plant Science*, *242*, 89-97.
22. Nambiar, V. S., Dhaduk, J. J., Sareen, N., Shahu, T., & Desai, R. (2011). Potential functional implications of pearl millet (Pennisetum glaucum) in health and disease. *Journal of Applied Pharmaceutical Science*, (Issue), 62-67.
23. Pudake, R. N., Mehta, C. M., Mohanta, T. K., Sharma, S., Varma, A., & Sharma, A. K. (2017). Expression of four phosphate transporter genes from Finger millet (Eleusine coracana L.) in response to mycorrhizal colonization and Pi stress. *3 Biotech*, *7*, 1-13.
24. Rahman, H., Ramanathan, V., Nallathambi, J., Duraialagaraja, S., & Muthurajan, R. (2016). Over-expression of a NAC 67 transcription factor from finger millet (Eleusine coracana L.) confers tolerance against salinity and drought stress in rice. *BMC biotechnology*, *16*, 7-20.
25. Rani, S., Singh, R., Sehrawat, R., Kaur, B. P., & Upadhyay, A. (2018). Pearl millet processing: a review. *Nutrition & Food Science*, 48(1), 30-44.
26. Serba, D. D., & Yadav, R. S. (2016). Genomic tools in pearl millet breeding for drought tolerance: status and prospects. *Frontiers in plant science*, 7, 1724.
27. Shrestha, N., Hu, H., Shrestha, K., & Doust, A. N. (2023). Pearl millet response to drought: A review. *Frontiers in Plant Science*, *14*, 1059574.
28. Singh, R. K., Singh, V. K., Raghavendrarao, S., Phanindra, M. L. V., Venkat Raman, K., Solanke, A. U., ... & Sharma, T. R. (2015). Expression of finger millet EcDehydrin7 in transgenic tobacco confers tolerance to drought stress. *Applied biochemistry and biotechnology*, *177*, 207-216.
29. Singhal, T., Satyavathi, C. T., Kumar, A., Sankar, S. M., Singh, S. P., Bharadwaj, C., ... & Singh, N. (2018). Genotype× environment interaction and genetic association of grain iron and zinc content with other agronomic traits in RIL population of pearl millet. *Crop and Pasture Science*, 69(11), 1092-1102.
30. Srivastava, R. K., Singh, R. B., Pujarula, V. L., Bollam, S., Pusuluri, M., Chellapilla, T. S., ... & Gupta, R. (2020a). Genome-wide association studies and genomic selection in pearl millet: Advances and prospects. *Frontiers in Genetics*, 10, 1389.
31. Tian, B., Luan, S., Zhang, L., Liu, Y., Zhang, L., & Li, H. (2018). Penalties in yield and yield associated traits caused by stem lodging at different developmental stages in summer and spring foxtail millet cultivars. *Field Crops Research*, 217, 104-112.
32. Tollefson, J. (2020). How hot will Earth get by 2100. *Nature*, *580*(7804), 443-445.
33. Wang, M., Li, P., Li, C., Pan, Y., Jiang, X., Zhu, D., ... & Yu, J. (2014). SiLEA14, a novel atypical LEA protein, confers abiotic stress resistance in foxtail millet. *BMC plant biology*, *14*(1), 1-16.
34. Wheeler, T. and Von Braun, J. (2013). Climate change impacts on global food security. *Science*, 341(6145):508-13.