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UNDERSTANDING THE RESILIENCE OF MILLETS TOWARDS CLIMATE CHANGE

AKSHITA PATWAL, ZIERA CHIGAM N SANGMA, SHEETAL, KAYNAT TABASSUM, NATASHA MWAZE and PRITESH VYAS*
School of Applied and Life Sciences, Uttaranchal University, Dehradun-248007, Uttarakhand INDIA
***Corresponding Author's Email**: pritesh2010@gmail.com

Change in climate is one of the most threatening aspects of the global environmental crisis. This aspect has not only bought change in the air quality index but also has changed the seasonal cycle. This variation in seasonal cycle has affected the timing and intensity of rainfall and similarly huge variations in the dry periods. Such kind of variations are now frequently increasing and therefore need of climate resilient crops is need of the hour. Millets has always been the climate resilient model among the crops and thus provides a strong gene pool against the climate change. The physiology and genetics of the millets is so robust that it grows efficiently in all kinds of harsh conditions. They grow in hills, foothills, and semi-arid tropics. This review article highlights the different types of millets and their fidelity of millets towards climate change.

Keywords: Agriculture, Climate resilient, Drought, Finger millet, Foxtail millet, Kodo millet

Introduction

Natural and human activities have enhanced the greenhouse emissions and it will continue to raise worldwide temperature in the 21th century. Global climate change and extreme weather variations are the most alarming challenge to agriculture sector and this is also unfavourable influence the Indian agricultural activities[1]. There has been a huge negative impact of climate changes on the crops, which includes reduction in crop yield as well as the nutrition in them, which have been shown in a study revealing production of maize and wheat under high greenhouse gas emissions scenario[2].

Millets have been grown by humans for about 10,000 years in tropical and warm regions, and millets are one of the earliest crops ever cultivated by humans[3]. According to the Food and Agriculture Organization, millets are tiny grains grown per year as human food and animal feed, with fewer rainfall areas[4]. Millets, which belong to the grass family (Poaceae), are also known as "Nutri-cereals" because of their high nutritional value[5]. Millets are known as "lost Crops" or "orphan Crops" because they are not produced as much as other common food crops like wheat and rice. Although some regions are still growing millets, their production is much lower than that of these popular crops. This is why the term lost is used[6].

Today, the world faces both climate change and nutritional deficiencies[7]. The millet play an important role as a sustainable and promising food source in relation with global climate variations and eliminating food security issues[8]. Millet domestication was rooted in adaptability and stability under poor conditions instead of increased yield, enabling superior stress tolerance compared to conventional grain crops[9]. This review focuses on the outlook for the enhancement of millet farming.

Diversity of Millets

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Millets are categorized into major and minor varieties depending on their cultivation area and grain size. The two main types of millets are Pearl millet (Bajra) and Sorghum (Jowar). The minor millets constitute of Barnyard millet (Sawan or Jhangora), Proso millet (Cheena or Common millet), Foxtail millet (kangni or Italian millet), Small millet (Kutki), Kodo millet, Finger millet (Ragi or Mandua), and Brown top millet[10]. Finger millets are majorly grown in Uttarakhand[11].

Finger millet (*Eleusine coracana*) is the most grown types of millet. India grows a large portion of the world's finger millet, making up about 41% of global production. Africa is the second-largest producer. Following Sorghum, pearl millet, and foxtail millet, finger millet is the fourth most important millet around the globe[12]. Finger millet is the best option for increasing climate smart-farming and improving food supplies for human beings. Its growing industrial demand because it can be turned into valuable and nutritious products[13].

Pearl millet is a tiny, healthy cereal grain that grows in harsh conditions (hot and dry places). Pearl millets are produced in mainly Asian and African countries, with India being the largest producer and highest yielder in the world[14]. Pearl millet is a crop that can grow in tough weather conditions. It helps reduce the adversities of climate change and improve food supplies with boosting income for farmers in dry conditions[15]. Pearl millet is a great substitute for other cereals that might struggle due to climate change because of its resilience to heat, drought, and poor soil conditions. Scientists are working on creating high-yield varieties that can be grown in different areas[16].

Proso millet (*Panicum milliaceum* L.) is an important crop grown all over the world for food, animal feed, and fodder. This crop grows fast and can adapt to different climates and conditions[17]. Proso millet is a member of the C_4 group of plants. These plants are very good at taking in carbon dioxide from the air and giving off oxygen[18].

Foxtail millet (*Setaria italica*) is an annual grass that grows only for one season. It is one of the oldest crops in the world and has been grown by people for over10,000 years[19]. Foxtail millet is a very adaptable crop that can be grown in very difficult climatic conditions[20].

Requirement of water for its growth falls around 25% and 30% of the annual rainfall needed for rice and sugarcane[21]. Foxtail millet, being the oldest cereals in China, is common between the Chinese consumers since it is not only high in nutrition, but also includes various healthcare functioning[22].India is known as the place where Kodo millet (also called Araka) was first grown and used. People started farming this millet, scientifically named *Paspalum scrobiculatum* L., about 3,000 years ago[23]. Minor millets have recently gained attention due to their ability to grow well in challenging soil and weather conditions[24]. It grows best in warm, tropical, and subtropical climates. It is commonly found in dry areas of India and Africa and can even grow in poor soil[25].

Impact of climate variations on agriculture

Extreme weather events driven by climate change like floods, droughts, extreme heat and cold, and storms—along with changing patterns in temperature and rainfall, are causing serious problems for agriculture in Asia. These conditions make it harder to grow crops, raise livestock, and maintain a stable food supply[26]. Climate change could have many lasting effects on farming. It might change how much food crops can produce, their quality, and how fast they grow. It can also affect how plants use sunlight and water, and how much water is available for farming. These changes could have a big impact on food production worldwide[27]. It leads to more diseases and pests, which lowers the amount of food we can grow. It also harms soil quality, makes it saltier, and causes pests and weeds to resist certain chemicals we use to control them. On top of that, it worsens the quality of water used for farming[28].

Climate resilient agriculture

Climate resilient agriculture is a sustainable approach for conversions and re-orientation of agricultural practices for supporting food security to address the new problems of climate changes, using various adaptation and mitigation strategies[31]. India has launched efforts at both state and national levels to make agriculture more resilient to climate change. For example, in 2011, the Indian Council of Agricultural Research (ICAR) carried out National Innovation in Climate Resilient Agriculture (NICRA) program to support this goal [32]. Climate-resilient crops have been recommended to help farmers adapt to climate change. These crops are better at handling extreme weather. However, even though they offer clear benefits, small farmers adopt them at very different rates[33]. Through better crop and animal management, climate-resilient agriculture achieves long-term increased production and farm revenues even with various climate uncertainties. Farmers can use it to help fight climate change, but many small farmers adopt it at different rates, even though it seems to have clear benefits. If the government and other organizations step up to promote Climate-Resilient Agriculture (CRA), it will be easier to cut down the impact of climate changes[34].

Millets as a climate resilient crop

A resolution establishing 2023 as the International Year of Millets was approved by the United Nations General Assembly (UNGA). This demonstrates the significance of millets and how they contribute to increased food security[35]. Crops and crop varieties consisting of improved resistance to biotic and abiotic stresses are known as climate-resilient crops. They serve as a way to adjust to declining crop yields against droughts, increased or decreased seasonal temperatures, and other climatic conditions by maintaining or increasing crop yields under stress conditions like fooding (submersion), heat, chilling, freezing, and salinity[36].The features of Millets which make them climate resilient consists of a broad spectrum including lower irrigation support, higher productivity under lower nutritional inputs, minimum dependency on synthetic fertilizers and less vulnerable under environmental stresses[37]. Due to its great water and nitrogen usage efficiency, millets can withstand harsh environmental conditions without compromising productivity[38]. Diversifying crop production in India to include more coarse grains, such sorghum and millets, can improve climate resilience, lower greenhouse gas emissions and resource demand, and increase the nutritional value of the country's food supply without lowering calorie production or requiring more land. Climate change-resilient food systems can benefit from millets. They are the greatest substitute for basic cereal crops due to their exceptional capacity to endure in harsh conditions and with little water availability[39].

Traits responsible for climate resilience

Millets are more resilient to environmental stressors than main cereals due to number of morpho-physiological, molecular, and biochemical virtues (Table 1). Since millets only need 12–14 weeks for completion of their life cycle (from seed to seed), compared to a maximum of 20–24 weeks for rice and wheat, their short life cycle primarily helps them avoid stress[40] . However, a number of characteristics,

Table-1 Diverse millets and their different aspects showing their resilience traits under different climatic changes[29,30].

Millet	Scientific Name	Common Name	Climate	Stress Tolerance	Major Area of production for grains	Climate-resilient traits
Sorghum	*Sorghum bicolor*	Jowar, Great millet, Guinea corn, Kafir corn, Milo in Spain, and kaolin in China	Tropical/ Temperate	Drought, Water logging, Salt tolerance	Nigeria, USA, Sudan, Mexico, Ethiopia, India	Resists moisture stress and high temperature compared to any other crops
Pearl millet	*Pennisetum glaucum*	Bajra, Cattail millet, Black millet, German millet	Arid Tropical	Drought and heat tolerance	India and Africa	The richest source of folic acid, drought-tolerant, grows in arid and semi-arid regions
Finger millet	*Eleusine coracana*	Ragi, Mandua, Nachni, Kapai, Nagli, Marua	Temperate	Drought and salt tolerance	Nepal, India, Ethiopia, Sri Lanka, Uganda, Burundi, and Malawi.	Wider adaptability, rich source of calcium
Foxtail millet	*Setaria italica*	Indian Pasapalum, Kangni, Italian millet	Tropical/ Temperate	Drought tolerance	China, Myanmar, India, Eastern Europe	Short duration. tolerate heat, drought, and low soil fertility
Proso millet	*Panicum milliaceum*	Cheena, Common millet, Broom millet	Arid, Tropical	Drought tolerance	USA, Russia, South Korea, Ukraine, Iran, Belarus, France, Kazakhstan	Drought Tolerance
Little millet	*Panicum sumatrense*	Kutki, Samai, Samaju, Hog millet	Tropical/ Temperate	Drought tolerance	India	Short duration, withstands both drought and waterlogging
Kodo millet	*Paspalum scrobiculatum*	Kodo, Ditch millet, Creeping paspalum	Tropical/ Temperate	Drought tolerance	India	Long duration, grown in shallow and deep soil with a high content of folic acid
Barnyard millet	*Echinochloa frumentacea*	Sawan, Jhingora, Kudraivali, Oodalu	Tropical/ Temperate	Drought tolerance	India, China, Japan, Malaysia	Drought Tolerance
Tef	*Eragrostis tef*	Teff, Lovegrass, annual-bunch grass, Williams	Tropical/ Temperate	Water logging and drought tolerance	Ethiopia, Eritrea, Australia	Water logging & Drought Tolerance
Fonio	*Digitaria exilis*	Fonio, Acha, Hungryrice	Tropical/ Temperate	Drought tolerance	Sudan, Ethiopia, Niger, West Africa	Drought Tolerance

including tiny leaf area, thickened cell walls, capacity to create deep root systems, and short stature, circumvent the occurrence of stress circumstances and their effect[41]. The C_4 mechanism raises the CO2 concentration in the bundle sheath, which depends on the temperature and reduces photorespiration by about 80% and raises Ribulose 1, 5-bisphosphate carboxylase/oxygenase (RuBisCO's) enzymatic activity in plants. Millets have a faster photosynthetic rate in warm climates and are more efficient at using water and nitrogen than C_3 plants because RuBISCO operates at higher CO2 levels. Apart from providing water use efficiency (WUE) and nitrogen use efficiency (NUE), C_4 photosynthesis offers millets additional advantages such as higher growth and ecological enactment in warm climates, more adaptable biomass allocation strategies, and decrease in hydraulic conduction per unit leaf area[42]. Millets contain natural substances that help protect them from pests. These natural defences reduce crop damage and the need for chemical pesticides, promoting more eco-friendly farming practices. In low soil conditions, millets' capacity to absorb nutrients is greatly influenced by their root architecture, especially by their longer and denser root systems. Millets need a lot less water and nutrients than typical crops like rice, maize and wheat[43].

Conclusion

The environment has already clearly been impacted by climate change, and the worldwide agriculture industry is facing difficulties. The strain on agricultural and food systems is increased by these extreme weather occurrences, such as drought, fluctuating rainfall, and rising temperatures. Numerous agricultural and supply chain operations have been interrupted by this outbreak, which has made food and nutrition security issues worse while also sustaining livelihoods. Because they exacerbate resource issues like pollution, land degradation, and water scarcity, their consequences are especially detrimental to developing nations. Although there are many landrace variants and vast genetic resources, little focus has been placed on how responsive the many millets are to different types of soil. As the demand for main grains like rice, wheat, and maize has increased during the past 20 years, the world's supply of millets has decreased. Despite this change, millets are among the grain crops with the highest degree of adaptability and climate resistance, and they can be extremely important for preserving cultural traditions and enhancing food security.

Future Scope

Climate-resilient crops' potential is essential to modify agricultural systems under climate change. For food availability to remain stable, sustainable, and equitable as the climate changes, these crops' development and broad adoption will be essential. Climate-resilient crops will be crucial to preserving food security and livelihoods for coming generations through a combination of creative breeding, biotechnology, and sustainable agricultural methods.

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Conflict of Interest

The authors declare that they have no conflict of interest for this work.

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