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3. Millets in Era of Climate Change

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Abstract:

An increasing population means an ever-increasing demand for food. This builds pressure on agriculture to increase productivity with limited resources. Climate change have now adversely affected agriculture system as it mostly weathers dependant. Irregular rainfalls, soil erosion, decreasing land productivity have now put question mark on food security. Most of the conventionally grown crops like rice, wheat, maize is affected by changing climate. To find a solution to it millets comes as a very good alternative as a climate-smart crop. Most of the major cereal crops have a higher global warming potential than millets, so they should be considered in mitigating global food insecurity. In this chapter, we are going to discuss how millets can mitigate the effects of climate change and ensure food security as well as sustainable agriculture along with financial security to farmers.

Keywords:

Climate-smart; Food security; Millets

3.1 Introduction:

As we inch towards 2030 we look forward to meet the deadline of Paris agreement to reduce the global temperature below 2˚C and continue our efforts to maintain it upto 1.5˚C, which is necessary to reduce the impact of climate change. The changing climate is now the burning scenario of the globe which can be felt by erratic rainfalls, increasing instances of natural calamities and alarming rate of temperature rise. This is affecting everyone around the planet and all sectors of life as well. But agriculture is one such area which is getting directly affected by the climatic irregularities. Increasing soil erosion, vagaries of monsoon, heat waves, increasing inundation of agricultural lands by sea etc., are some of the instances where agriculture is affected by climate change.

Increasing population and declining arable lands has put us in a difficult situation where by 2030 we need to ensure zero hunger under sustainable development goals (SDG). Moreover, we need to eradicate malnutrition and reduce poverty as well, in developing countries. As major developing countries' economy depends upon agriculture and allied sector, we need to find solution to it.

We need to search for climate resilient agricultural practices and crops to meet or needs. And the answer comes is "Millets". At this point the United Nation's General Assemble agreed on India's proposal and accepted the year of 2023 as International year of millets. We can take this scope as a chance to exploit the climate-resilience of millets.

In the present scenario where rising temperature due to global warming and irregularities in rainfall due to climate change is affecting the global food production, millets can act as a beacon of hope. Moreover, the sustainable development goals which are targeted to achieve by the year of 2030, four of them can managed by growing millets, those are No Poverty, Zero Hunger, Good Health and Well Being, and Climate Action. In this chapter we can see how these '*Sri Anna'* is a climate smart crop. Millets come as solution of increasing the income of marginal farmers of our country. As climate change affects the agriculture sector and small and marginal farmers are majority of our farmers, growing millets can avail them profit.

3.2 What Are Millets?

Millets are collective group of small seeded annual grasses that are grown as grain crops (FAO), which belongs to the family poaceae. Those are pearl millet (bajra), sorghum, finger millet (ragi), foxtail millet, barnyard millet, kodo millet, proso millet and little millet. Among these major millets are sorghum, pearl millet and finger millet while remaining are minor millets. These are also called as nutra-ceutical crops as they are rich in macronutrients and micronutrients, with higher levels of calcium, iron, zinc, potassium, protein and essential amino acids. These also have a low glycemic index (GI) property which can be helpful in reducing type 2 diabetes. In addition, their nutrients can help avert cardiovascular diseases, lower blood pressure and cholesterol and improve gut health. Because of these nutritional values they are being included in public distribution systems in many parts of the country.

Presently rice, wheat and maize are the major cereals grown around the world which is reducing the crop diversity. This will affect food production if there is a pest breakout or unfavorable climatic condition prolongs. In such scenario "miracle Grains-Millets" offer an exciting opportunity to enhance agrobiodiversity around the world as it can be grown in varied climatic and soil conditions. Most importantly millets are domesticated majorly in African and Indian subcontinent, it can tolerate extreme and erratic environments, and cultivation of these cereals can improve productivity of arid landscapes and establish food security under a changing climate.

3.3 Millets - Climate Smart Crop:

As we discussed above that millets are acting as miracle crop under changing climate, here we are going to see what makes this coarse cereal a climate smart crop under the following headings:

A. Can be cultivated in marginal lands
B. Low GHG emission and carbon foot print
C. C4 mechanism

D. stress management mechanism
E. High water use efficiency
F. Low external input
G. Nutritional security

3.3.1 Cultivation in Marginal Lands:

The increasing population is leading to per capita reduction in arable land availability. It is projected that by 2050 the world is going to hit 9 billion populations [1]. Along with that climate change is affecting arable land productivity. Increasing soil erosion and intensive use of chemical fertilizers is the reason for that. This is leading to reduction in yield of conventional crops. In this scenario millets come as miracle crop which can be grown in wasteland and provide nutritional security. Low nutrient and water requirement of millet crops makes them one of the most preferable crops for degraded land.

For example, finger millet is one such crop which can be grown in saline soils, alkali soils and in drought condition as well. Millets are the best choice as they can be grown on shallow, low fertile soils with a varied (ranging from 4.5 to 8.0) pH [2]. Millets can be an easy replacement for conventional crops like wheat and rice. Further, millets like pearl and finger millet can grow up to a soil salinity of 11–12 dS/m, while rice has poor growth and productivity on a soil having salinity higher than 3 dS/m [2]. Millets are adapted to wide range of ecological conditions often growing on skeletal soil that are less than 15cm deep. They are considered as a poor man's crop due to their significant contributions to a resource-limited population diet offering several opportunities for their cultivation in developing countries.

3.3.2 Low GHG Emission and Carbon Foot Print:

As we work to reduce greenhouse gas emission to reduce global temperature we need to reduce GHG emission from agriculture sector as well. Agriculture is the second largest emitter after energy sector. It emits about 14% from that 17.49% is from rice cultivation, followed by 15.88% from agriculture soil by N_2O emissions. Thus, reducing the greenhouse gas is necessary to ensure sustainable agriculture. Release of CO_2 by the fertilizer industry is also another major source. Intensive agriculture practices and declining soil health demands higher inputs leading to higher production causing higher GHG emissions. But millets with lower fertilizer demands and their ability to produce good yield even in marginal lands can provide solution to it leading to reduction in emission directly or indirectly.

If we look at global warming potential which refers to total contribution to global warming resulting from the emission of one unit of any gas relative to one unit of carbon dioxide [3], among all the major cereal crops, wheat has the highest global warming potential of around 4 tons CO_2 eq/ha followed by rice and maize (around 3.4 tons CO_2 eq/ha) whereas millets have 3.2 tons CO_2 eq/ha. These crops also have a high carbon equivalent emission of 1000, 956 and 935 kg C/ha for wheat, rice and maize, respectively. However, the carbon footprints of millets are comparatively lower [3]. Thus millet cultivation can play the role of an alleviator that could reduce carbon footprint in the world.

Moreover, for chemical nitrogen fertilizer production, CO_2 is generated and as per an estimate to fulfill the present requirement of chemical nitrogen fertilizers in the world, annually 300 tera-gram (Tg = 1012g) of CO_2 is released into the atmosphere [4]. Millets are less nutrient demanding crops and if grown in dryland, it doesn't even require any fertilizer. As millets have more tillers or branches than corn and sorghum, they provide better fodder too. Millet crops also have a good ability to sequester carbon and so help climate adaptation, considering the water needs and methane emission of rice fields [5].

3.3.3 C4 Mechanism:

All millets are C4 crops which use C4 pathway of photosynthesis, which has negligible photorespiration and high water use efficiency. In the C4 system, carbon dioxide (CO_2) is concentrated around ribulose-1,5- bisphosphate carboxylase/oxygenase (RuBisCO), which in turn suppresses ribulose 1,5-bisphosphate (RuBP) oxygenation and photorespiration (Aubry et al., 2011). Thus, C4 mechanism enhances the concentration of CO_2 in bundle sheath, which suppresses photorespiration (around 80%) depending on the temperature and increases the catalytic activity of RuBisCO [6] leading to higher photosynthesis. Additionaly, RuBisCO of C4 plants works at elevated CO_2 levels upto 360 ppm, and temperature upto 35-40˚C, so millets have enhanced photosynthetic rates at warm conditions. Thus in case of climate change with increasing CO_2 and temperature millets will ensure food security. This leads to higher water use efficiency (WUE) and nitrogen use efficiency (NUE) which are 1.5 to 4- fold higher than C3 photosynthesis [7]. For instance, foxtail millet requires just 257 g of water to produce a dry biomass of 1 g, whereas maize and wheat require 470 and 510 g, respectively [8].

3.3.4 Stress Management Mechanism:

Certain morphological features are there which provide stress tolerance to millets. They have unique dumbbell-shaped guard cells with two subsidiary cells. This modification allows for faster and more refined stomatal responses, resulting in higher water use efficiency [9,10,11]. Most grasses are amphistomatic, with stomata on both sides of their leaves. These isobilateral leaves held parallel to the axis of irradiance allow for more efficient CO_2 diffusion with low evapotranspiration rates [12]. Paired with their C4 physiology, deep and fibrous root systems establish quickly to enhance water availability and maintain stability during environmental changes. Overall, a high specific leaf area, net assimilation rate, and root to shoot ratio increase the relative growth rate of C4 millets [13, 14]. Pearl millet is an ephemeral crop with short life-cycle of 12–14 weeks, which enables it to escape drought and to complete its life-cycle (seed to seed) whereas rice and wheat requires a maximum of 20–24 weeks. But in case of Sorghum, it tolerates the drought being a camel crop. They several traits such as short stature, small leaf area, thickened cell walls, and the capability to form dense root system [8]. Compared to maize, pearl millet can modulate their membrane dynamics better for water permeability to attain better water status during osmotic stress [15]. An increase in leaf tensile strength and root length was reported in teff and little millet under drought [16]. Several biochemical events, e.g., reactive oxygen species (ROS) regulation, enhances ROS scavenging enzymes (catalase and superoxide), and other stress-related proteins are accumulated in response to abiotic stresses in millets [17].

3.3.5 High Water Use Efficiency:

As climate change is leading to worldwide water scarcity due to erratic rainfall, it is affecting water use in agriculture. In case of India agriculture sector accounts for about 80% of water use, target has been made to bring it down upto 60%. This has a major problem as rising temperature demands for more irrigation. But millets with C4 mechanism have high water use efficiency. Millets have evolved a unique set of adaptations to avoid, survive, tolerate, or recover from water deficit stress. Sorghum, finger millet, and teff have water use efficiencies (WUE) of 4.2-13.4 kg yield/hectare mm rain; several times higher than comparable C3 cereals and other grain crops [18]. Cultivated millets have generally low rainfall requirements of 200-500 mm, compared to 500-900 mm for winter wheat and maize, and high WUE helps preserve soil moisture content [19]. One rice plant requires nearly 2-5 times the amount of water required by a single millet plant of most varieties, according to the Crops Research Institute for Semi-Arid Tropics (ICRISAT). Some millets avoid drought altogether like fonio and barnyard millet, which can reach maturity within 8 weeks [20].

This short season enables millets to escape unpredictable late summer droughts, or serve as a rescue crop if another grain crop fails. Drought tolerance itself is linked to the evolutionary history of millets, and C4 grasses express a set of unique, likely ancestral dehydration pathways under severe drought stress that are typically specific to seed desiccation [21]. When combined with anatomic and physiological adaptations, these dehydration responses allow millets to survive low critical leaf water potential until conditions improve.

3.3.6 Low External Input and Income Security:

As we spoke in previous parts how millets can be cultivated with minimal external input. It makes them most suited crops for LEISA- low external input sustainable agriculture crop. Moreover, they can be easily incorporated in natural farming (ZBNF-Zero-budget natural farming) and organic agriculture as well. As they also provide fodder, we feed cattle as well. Millets are basically low input crops which can provide higher income to farmers. Presently government is providing MSP for some millets like jowar, ragi and bajra, so this will ensure farmer's income. As 2023 is declared as international year of millets and India being the largest producer of millets aims to popularize them round the globe. For that government have intiated to produce large number of processed products from them like- biscuits, chips, flour and ready to eat products. The products add value which can lead to provide higher income to millet growers and processors. In case of drought situations millets also work as contingent crops, can be used as mixed crops also can ensure farmer's income.

3.3.7 Nutritional Security:

We aim to achieve SDG by 2030, therefore we need to ensure no one goes to bed hungry based on SDG 2 – Zero Hunger. In the context of climate change with sustainable agriculture in limited arable land, millets can provide necessary nutrients to all with less price. They are called nutri-cereals for a reason. They are loaded with minerals like calcium, iron, zinc, magnesium, phosphorus and potassium. They can also solve the major health issue of the globe i.e, obesity and diabetes. With lower glycemic index it can reduce blood sugar levels of diabetic patients if it is replaced in place of white rice.

Finger millet is very rich in calcium, it is thirty times more than rice, while every other millet has at least twice the amount of calcium compared to rice. In iron content, little millet and Pearl millet are so rich that rice is nowhere in the race. They also contain appreciable amounts of dietary fibre, Vitamins, folic acid and high amounts of lecithin which are useful for strengthening of the nervous system.

3.4 Conclusion:

All good being said about the millets, it also has certain de-merits. Like high shattering, anti-nutritional properties and allelopathic effect. If these factors are managed by breeding and cropping practices, it can be widely adapted by the farmers.

The stress tolerance ability of this miracle crop has no comparison with other crops. With its nutri-rich grains it makes the crop climate smart. It requires significantly fewer input costs for cultivation and very less pest and disease attacks. These features accentuate millets as crops of choice for the world population amid growing concerns about climate change. With advantages loaded in its favour such as low-maintenance, disease and pest resistance, nutritional benefits, market demand, fodder value and ecological benefits, millet is being considered as a smart crop.

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