MILLETS: A LOW CARBON FOOTPRINT CROP FOR SUSTAINABLE AGRICULTURE

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INTRODUCTION

In contemporary times, agricultural practices have shifted their focus away from essential factors like nutrition, climate considerations, and environmental impact. Agricultural policies have primarily fixated on the singular objective of maximizing productivity. This exclusive emphasis on productivity has sidestepped the critical goals of sustainability within the food system, which include producing an ample supply of nutritious food while minimizing resource consumption, bolstering climate resilience, and fostering a positive environmental footprint. The agricultural sector has become one of the most influential human activities reshaping natural systems, causing a substantial surge in demand for natural resources and greenhouse gas (GHG) emissions.

Millets, a group of ancient, climate-resilient grains, are now recognized as a potential solution to these complex problems. Millets are generally grouped into two broad categories: Major millets, which are widely cultivated and consumed, and minor millets, which are grown and consumed locally on a smaller scale . Major millets include pearl millet, finger millet, and foxtail millet. Minor millets include proso millet, kodo millet, little millet, and barnyard millet.

Millets stand out due to their inherent climate resilience, as they demonstrate adaptability to a broad spectrum of ecological conditions. Millets are small-seeded drought-tolerant, rain-fed crops that thrive in arid climates despite of inadequate soil fertility

and moisture levels. These smart crops exhibit reduced irrigation requirements, enhanced growth and productivity even under low-nutrient conditions, reduced reliance on synthetic fertilizers, and minimal susceptibility to environmental stressors.

Additionally, the rich nutritional properties can help address dietary deficiencies and significantly contribute towards tackling malnutrition. They are a good source of energy, proteins, and dietary fibers. Millets are particularly high in micronutrients such as iron, zinc, and B vitamins, which are essential for human health but often deficient in many diets. Beyond nutrition, millets also have health-promoting properties. They have a low glycaemic index, which helps manage blood sugar levels and is beneficial for diabetes management. They are also gluten free, making them suitable for individuals with celiac disease or gluten sensitivity.

Given these attributes, it is imperative that we embark on an intensive exploration of millets, scrutinizing their agronomic, nutritional, and stress-tolerance qualities. By acknowledging their unique attributes and conducting rigorous research, we can bridge the gap between maximizing agricultural productivity and ensuring the long-term well-being of our environment, nutrition, and climate resilience.

MILLETS' ROLE IN ENHANCING RESILIENCE TO CLIMATE CHANGE

In the present era, agricultural practices have pivoted away from essential factors such as nutrition, climate considerations, and environmental impact. Agricultural policies have predominantly centered on a single-minded pursuit of maximizing productivity. This exclusive focus on productivity has, regrettably, overshadowed the critical imperatives of sustainability within our food systems. These imperatives encompass not only the production of an ample supply of nutritious food but also the judicious use of resources, the fortification of climate resilience, and the cultivation of a positive environmental footprint. Millets, however, emerge as pivotal players in enhancing resilience to climate change within agriculture and food systems. Here are several pivotal ways through which millets contribute to climate resilience:

Drought Tolerance:

Millets are well-known for their exceptional drought tolerance, thriving in arid and semi-arid regions with limited water resources. Given the increasingly unpredictable rainfall patterns and crop losses attributed to climate change, many farmers have returned to cultivating sorghum, little millet, and foxtail millet. These grains have proven their resilience to environmental stressors, consistently yielding crops even in the face of both insufficient and excess rainfall, all while maintaining an economical input cost structure. Kodo Millet, in particular, exhibits remarkable drought resistance, thriving in infertile lands with pebbles and adapting to various soil types. Additionally, its straw finds diverse applications, such as thatching roofs and making mud bricks. Small millets have gained popularity among farmers due to their reliability, yielding 8 -10 quintals per acre with minimal input costs, that prominently stands in contrast to resource-intensive staple crops like wheat and rice.

Low Water Requirements:

Millet crops demonstrate a remarkable frugality when it comes to water consumption, in stark contrast to major cereal crops like rice and wheat. This intrinsic ability to thrive on limited irrigation renders millets an eco-friendly choice in water-scarce regions where erratic rainfall patterns prevail. Reduced irrigation needs underscore the sustainability of millets. By way of a poignant comparison, the stark difference in water consumption between millets and rice cultivation becomes evident. Several millet cultivars exhibit substantially lower water requirements per plant compared to rice, which demands nearly 2.5 times more water per plant.

Adaptability to Varied Ecological Conditions: Millets exhibit a versatility that few crops can rival. They flourish across diverse climates and soil types, embodying resilience in the face of evolving environmental dynamics driven by climate change.

Shorter Growth Cycle:

The relatively brief growth cycles of millets confer an advantageous agility upon farmers. Their shorter maturation periods empower cultivators to harvest crops before extreme

weather events, such as late-season droughts or heavy rains, can inflict substantial damage. Barnyard millet distinguishes itself among millet varieties as the fastest growing, maturing in a mere six weeks and boasting tenfold the fiber content of wheat.

Reduced Reliance on Synthetic Inputs:

By and large, millets demand limited utilization of chemical fertilizers and pesticides in comparison to certain other crops. This dual benefit of reducing the environmental impact of chemical inputs while curbing production costs bolsters their sustainability.

Carbon Sequestration:

Some millet varieties, notably pearl millet, excel in sequestering carbon within their root systems. This phenomenon contributes significantly to the global effort to mitigate climate change by capturing carbon dioxide from the atmosphere.

Crop Rotation and Diversification:

Incorporating millets into crop rotation and diversification strategies fosters overall farm resilience. Diversifying crops spreads risk and diminishes vulnerability to climate-related disasters that disproportionately affect single-crop systems. During the Kharif season, farmers in the northern and southern regions of Karnataka judiciously intermingle millets with other staple crops like groundnut, ushering in a season of enhanced food security and crop diversification. Notably, millets lend themselves readily to intercropping or rotation with other food crops, a practice that safeguards food security, enhances soil health, and curtails disease and insect infestations. The millet's brief annual growth cycle (2.5–4 months) optimally utilizes agricultural space, while its root system rapidly sequesters carbon, thus ameliorating greenhouse gas emissions.

Nutritional Benefits:

Millets are a veritable powerhouse of nutrition, boasting high levels of vitamins, minerals, and dietary fiber. Their cultivation and consumption make substantial contributions to food security, especially in regions where climate change threatens traditional staple crops.

Traditional Knowledge and Indigenous Farming Practices:

Many communities boasting a rich heritage of millet cultivation have honed indigenous farming practices that elevate resilience in the face of climate variability. The preservation and dissemination of this traditional wisdom represent a linchpin in crafting climate-resilient agricultural systems.

In summation, millets stand as linchpins in the tapestry of climate-resilient agriculture and sustainable food systems. Their unique attributes, adaptability, and multifaceted contributions not only fortify resilience in the face of climate change but also address pressing concerns related to nutrition and the environment. The promotion of millet cultivation and consumption serves as a pivotal strategy, securing food security, championing environmental sustainability, and uplifting the well-being of communities on a global scale.

CARBON FOOTPRINT AND NITROGEN FOOTPRINT OF CEREAL GRAINS

The three most important food crops in the world are rice, wheat, and maize (corn). The three cereal grains directly contribute more than half of all calories consumed by human beings. In addition, other minor grains like sorghum and millet are particularly major contributors of overall calorie intake in certain regions of the world, particularly semi-arid parts of and India. Wheat and maize are cultivated globally using various forms of agri-management practices such as preparation of land, sowing, fertilizer, irrigation, pest management, harvesting which influences the emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) from agricultural soil, whereas methane emissions are very prominent in rice cultivation. Aeration, soil temperature, soil moisture, organic carbon (OC) supply, fertilizer, pH, and other environmental elements such as production and transport all have an impact on N_2O and CO_2 emissions in soil.

Rice: Rice accounts for roughly 21% of global per capita caloric intake and 27% of developing-country per capita calories. Rice cultivation emits CO_2, CH_4, and N_2O gases into the atmosphere, and these emissions are influenced by climate change. India and China accounts for approximately 20 to 28.5% of worldwide rice area. Perhaps irrigated rice fields serve as a primary source of CH_4 gas, which is generally produced in flooded or anaerobic conditions, in contrast to N_2O gas, which is created by nitrification and denitrification under aerobic and anaerobic conditions. Rice cultivation emissions are estimated to range between 20 and 150 Tg CH_4 per year.

Wheat: Wheat is more resistant to a variety of growing circumstances than other major cereal crops. Wheat carbon emissions are expected to rise by 70% by 2050. Summer fallowing, on the other hand, contributes significantly to carbon emissions. Furthermore, over time and with more frequent fallowing, the soil's organic matter can decrease at a faster rate, resulting in more degraded soil and increased soil erosion. It is estimated that about 0.027-0.0377kg CO_2 eq is sequestered in soil during production.

Maize: Maize is classified as an aerobic crop because it does not require submergence like rice. When compared to rice fields, decreased tillage activities require less water, resulting in fewer CH_4 emissions. As a result, maize is thought to be a better alternative for reducing groundwater depletion, soil degradation, and methane emissions.

Millet crops help to alleviate the consequences of climate change by having a carbon footprint of 3218 Kg CO_2 equivalent per hectare, as opposed to 3968 and 3401 Kg for wheat and rice, respectively. Millets crops can be used as a substitute for wheat and rice.

ROLE OF MILLETS IN CARBON SEQUESTRATION

Millets, classified within the C_4 group of cereals, play a crucial role in mitigating global warming by efficiently converting carbon dioxide into oxygen. The C4 photosynthetic trait is particularly advantageous for millets, as it facilitates this process. In the C_4 system, carbon dioxide (CO_2) is concentrated near the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), thereby preventing the undesirable oxygenation and photorespiration of ribulose 1,5-bisphosphate (RuBP).

The primary photosynthetic CO_2 reduction reaction catalyzed by rubisco is the conversion of atmospheric CO_2 into two molecules of 3-phosphoglycerate (3PGA). This reaction serves as the cornerstone for the photosynthetic fixation of carbon, vital for sustaining life's organic components. The C_4 mechanism enhances the CO_2 concentration in the bundle sheath cells, significantly reducing photorespiration (by approximately 80%) and enhancing the catalytic activity of RuBisCO within the plant. Millets exhibit remarkable water use efficiency (WUE) and nitrogen use efficiency (NUE), surpassing C_3 photosynthesis by 1.5 to 4 times. These advantages are especially pronounced in warm weather due to the elevated rates of photosynthesis in millets.

CONCLUSION

Millets are climate-resilient crop with high nutritional value, has the potential to improve nutritional quality and prevent malnutrition. It is almost disease and bug free and could be farmed with a fair harvest. As a result, the emphasis should be placed on the creation of food products from millet in order to make it acceptable as a future alternative crop. Scientists, government organizations, policy makers must refocus their attention on millet farming systems, and laws must be enacted to provide a viable environment for millet farmers. A sustainable supply chain also entails the management of material, information, and capital movements with the purpose of achieving simultaneous balancing of economic, environmental, and social goals through collaboration among the factors involved and meeting population demands.