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EFFECT ON CLIMATE CHANGE FOR CULTIVATION OF PEARL MILLET

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Abstract:

The C4 grass pearl millet is one of the most drought-tolerant cereals and is primarily grown in marginal areas where annual rainfall is low and intermittent. It was domesticated in sub-Saharan Africa, and several studies have found that it uses a combination of morphological and physiological traits to successfully resist drought. This review explores the short-term and long-term responses of pearl millet that enable it to either tolerate, avoid, escape, or recover from drought stress. The response to short-term drought reveals fine-tuning of osmotic adjustment, stomatal conductance, and ROS scavenging ability, along with ABA and ethylene transduction. Equally important are longer-term developmental plasticity in tillering, root development, leaf adaptations, and flowering time that can help avoid the worst water stress and recover some of the yield losses via asynchronous tiller production.

Introduction:

In common usage, climate change describes global warming—the ongoing increase in global average temperature—and its effects on Earth's climate system. Climate change in a broader sense also includes previous long-term changes to Earth's climate. The current rise in global average temperature is more rapid than previous changes and is primarily caused by humans burning fossil fuels Fossil fuel use, deforestation, and some agricultural and industrial practices add to greenhouse gases, notably carbon dioxide and methane Greenhouse gases absorb some of the heat that the Earth radiates after it warms from sunlight. Larger amounts of these gases trap more heat in Earth's lower atmosphere, causing global warming.

Materials and Methods:

Pearl millet responses to drought resistance in pearl millet, drought studies have been conducted in each of the three main phases: vegetative, panicle development, and grain filling (Shivhare et al., 2020a) and these studies have identified resistance mechanisms involving drought avoidance, tolerance, escape, and recovery. These mechanisms can be grouped into short and long-term responses, In addition, pearl millet is a C4 grass using the NADP-dependent malic enzyme (NADP-ME) pathway and is thus already preadapted for efficient water use in high-light environments (Pardo and VanBuren, 2021.

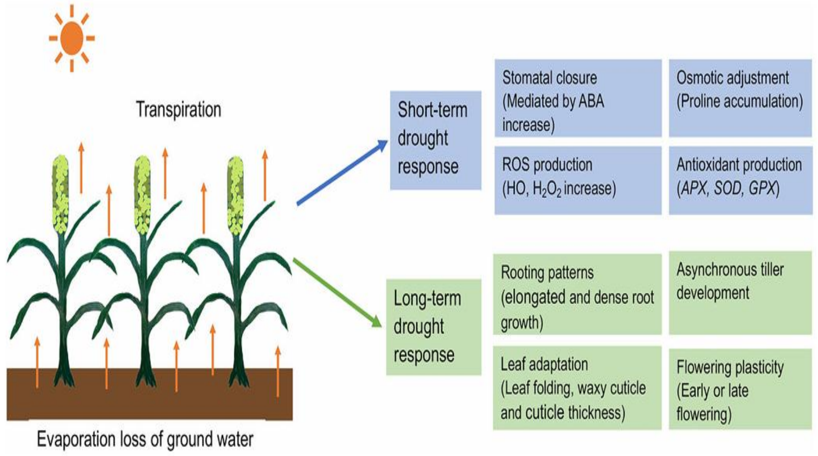

FIGURE 1

Short-term and long-term responses of pearl millet to adapt drought stress. ROS, Reactive oxygen species; HO, Hydroxyl radical; H_2O_2, Hydrogen peroxide; APX, *Ascorbate peroxide; GPX, Glutathione peroxidase; SOD, Superoxide dismutase.*

Short-term responses Stomatal conductance Stomata are vital to the plant's existence, as they provide passage for gas and water exchange to conduct photosynthesis and transpiration (Li et al., 2017). Generally, stomatal closure is highly influenced by environmental conditions and is the first step for avoiding water loss in water-stressed conditions.

Boosting Sustainability:

Through offering a reduced dependence on synthetic fertilizers and pesticides, millets cultivation may also help promote a shift towards sustainable agriculture, diversifying crop rotations and avoiding the promotion of mono-cropping systems. "The high carbon content of the crop residues makes them particularly important for maintaining and increasing soil carbon levels, important for sustainable cropping systems, and, where applicable, for providing forage, at the same time, for livestock.

Food System Divide:

Millets are believed to be among the earliest domesticated plants, which have long served as traditional staple crops for millions of farmers, particularly in India, China, and Nigeria.

Notwithstanding the wide range of benefits that millets provide, they have largely been missing from the global food security agenda. In fact, in recent years, their production has gradually declined.

Experts point towards market distortions, a lack of appreciation of the benefits of millets and policies that have favored the production of the so-called Big Three cereals - rice, wheat and maize, resulting in a "Food System Divide". Joanna Kane-Potaka of ICRISAT, gave the example of India where "during the green revolution, high yielding varieties of rice and wheat were introduced and supported to scale out on a massive scale, to improve food security, while arguably, inadequate attention was paid to nutrition or environmental factors." The problem is further compounded by changing dietary habits, high transaction costs and the challenges involved in accessing better markets; especially true for Africa. "Farmers have therefore shifted to more remunerative crops grown to sell for profit and moved away from subsistence agriculture responding to changing consumer preferences and markets inputs," said Dr. Aburto.

2023: The Year of Millets:

In declaring 2023 the International Year of Millets, the resolution calls on all stakeholders to provide support to "activities aimed at raising awareness of and directing policy attention to the nutritional and health benefits of millet consumption, and their suitability for cultivation under adverse and changing climatic conditions, while also directing policy attention to improving value chain efficiencies." Building on the experiences gained from past initiatives such as the 2016 International Year of Pulses and the 2021 International Year of Fruits and Vegetables, the UN agriculture agency is working to develop an action plan in partnership with external stakeholders, including farmers and research institutions. "Actions taken will be aligned and supported via existing initiatives, such as the UN decade of action on Nutrition, 2016-2025 that provides an umbrella for a wide group of actors to work together to address malnutrition and other pressing nutrition issues," Dr. Aburto added. In line with FAO's vision of a sustainable and food secure world for all, producing more and nutritious food for a growing population without overburdening land resources is a massive global challenge. In the search for climate resilient solutions, millets could be the crucial link in the sustainable food supply chain. Osmotic adjustment Osmotic adjustment is a major drought-tolerant mechanism in plants to maintain cell turgor, relative water content, cell expansion, photosynthesis, and continued stomatal conductance (Jones and Turner, 1980; Henson et al., 1982). Plants accumulate organic and inorganic cellular components as osmolytes for lowering osmotic potential. In field conditions, pearl millet has been reported to adjust its osmotic potential successfully in response to water stress (Henson et al., 1982), like other drought-tolerant C3 and C4 grasses, such as upland rice (Lum et al., 2014), wheat genotypes (Hong-Bo et al., 2006), and sorghum (Blum and Ebercon, 1976). The biochemical basis of osmotic adjustment has both inorganic as well as organic components,

Screening Techniques:

- Spray uredospores collected from infector rows, on 25-30 days old crop, twice, at 25 and 35 days after sowing.
- Spreading of uredinia-bearing leaves among test plants 25-30 days old.

Management:

- ○ Use of resistant hybrids/verieties.
- ○ Sow the crop with the onset of monsoon.
- ○ Destruction of collateral hosts like Ischaemum pretosum and Panicum maximum on the field bunds.
- ○ Dusting of fine sulphur @ 17kg/ and two sprays of 0.2% Mancozeb at 15 days intervals

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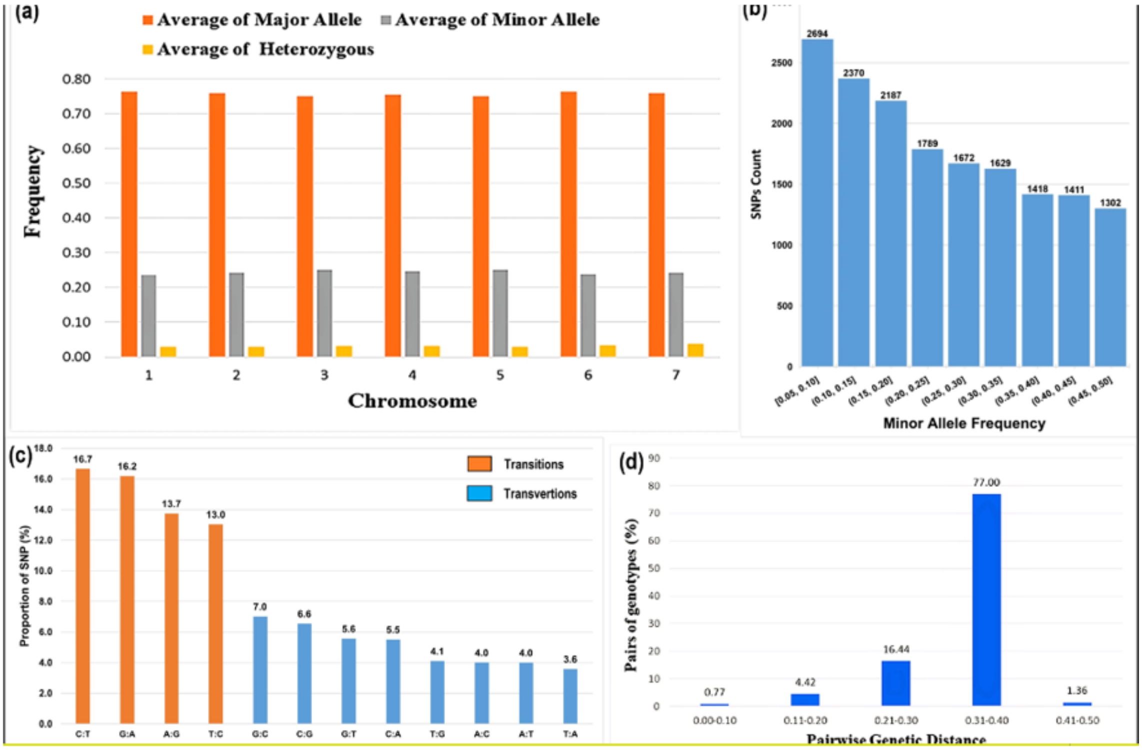

Fig: *(a) Frequency distribution of the 16,472 polymorphic SNPs across seven chromosomes; (b) Frequency distribution of the minor alleles for each SNP markers scored in a population sample of 109 genotypes; (c) Transition and transversion mutations of GBS-SNPs detected among 109 pearl millet hybrid parental lines; (d) Identity-by-state (IBS) based genetic distance between pairs of hybrid parental lines.*

Smut is widely distributed in all the pearl millet growing areas in the world. Systemic symptoms as chlorosis generally appear on the second leaf and all the subsequent leaves and panicles of infected plants show symptoms. Leaf symptoms begin as chlorosis at the base of the leaf lamina and successively higher leaves show a progression of greater leaf area coverage by the symptoms. Infected chlorotic areas produce massive amounts of asexual spores, generally on the lower surface giving the leaves a 'downy' appearance. Systemically infected plants remain stunted and either do not produce panicles or produce malformed panicles. In many affected plants 'green ear' symptoms appear on the panicles due to the transformation of floral parts into leafy structures that may be total or partial and such plants do not produce seeds or produce very few seeds. The infected leaves produce sexual spores (oospores) in the necrotic leaf tissue late in the season. Currently, in India, about 50% of the 9 million ha under pearl millet cultivation is grown with more than 70 hybrids in which DM incidence has been highly variable, with some hybrids showing more than 90%incidence at farmer's fields. This disease can be assuming alarming levels when a single genetically uniform pearl millet cultivar is repeatedly and extensively grown in a region. Yield losses within the region can reach 30-40%.

Flowering Plasticity:

Early flowering is an important drought escape mechanism in plants, and in wheat, early flowering after a relatively short vegetative period is a response for impending conditions of terminal stress (Shavrukov et al., 2017). Pearl millet is a short-day plant, but large genotypic differences exist in the photoperiodic requirement for flowering among pearl millet varieties depending upon the zone of latitude that they are adapted to. Almost 54.4% of total cultivated pearl millet germplasms have been found to flower irrespective of the day length, although most are facultatively photoperiod sensitive, showing a delay in flowering time with increasing day length (Rai et al., 1999). Germplasms originating from equatorial Africa are usually strictly photoperiod sensitive, needing comparatively short days to flower. Landraces with early flowering (33–40 days) are predominantly found in Pakistan, Ghana, Togo, and India; with very late flowering (121–159 days) in Sierra Leone and the Central African Republic (Upadhyaya et al., 2007).

Pearl millet grown under long day length together with midseason water stress was found to delay its flowering time but did not cause a significant effect on grain yield (Mahalakshmi et al., 1987). They suggested that later floral initiation is a drought escape mechanism adapted by pearl millet in early mid-season droughts, just as early floral initiation is adaptive for late-season drought. Varieties are adapted to time flowering close to the end of the rainy season, ensuring completion of maturation with remaining soil moisture (Vadez et al., 2012). However, climate change involving changes in rainfall patterns may mean that formerly adapted landraces no longer flower in sync with local conditions. QTL associated with the change in flowering time under drought stress have been found on LG2, colocalized with a major drought tolerant QTL (Tables 1, S1). Co-localized genes included transcription factors belonging to known flowering time gene families, including zinc finger CCCH type and MADS-box gene families (Sehgal et al., 2012). 3 Grain yield under drought stress Many genetic analyses have targeted variation in grain yield in pearl millet, which is a combination of number of productive tillers, size of the inflorescence, fertilization success, and effectiveness of seed development and maturation. 4 Insight into pearl millet drought tolerant mechanisms using transcriptomics the recent availability of the pearl millet draft genome has accelerated the transcriptomic study of drought stress tolerance (Varshney et al., 2017). Five papers have reported transcriptomics study on drought stress in pearl millet (Choudhary and Padaria, 2015; Dudhate et al., 2018; Jaiswal et al., 2018; Shivhare et al., 2020a; Shivhare et al., 2020b). The earliest transcriptomic studies exploring the genes responsible for drought tolerance were done using the suppressive subtraction hybridization technique on seedlings exposed to various stresses, including salt, drying, and cold (Mishra et al., 2007), and 30% polyethylene glycol 600 (Choudhary and Padaria, 2015).

Conclusions:

Pearl millet seems to be the solution for a future when temperatures will soar. Decoding and sequencing the pearl millet grain by a team comprising 65 scientists from across 30 research institutions have proved its adaptive capacity and increasing tolerance to drought. This research has been published in the journal, Nature Biotechnology. Research coordinated by the International Crops Research Institute for Semi-Arid Tropics, India, BGI-Shenzhen, China and the French National Research Institute for Sustainable Development used the latest innovations in DNA sequencing and analysis to identify new genetic tools like molecular markers related to drought and heat tolerance, as well as other important traits like better nutrition profile and pest resistance. This will help farmers grow the crop better in terms of productivity, as pearl millet is a staple food crop for millions of people living in the arid and semi-arid areas of Africa and Asia. As experts suggest, both these continents will see increasing incidents of droughts and high temperatures in the coming years due to climate change. Currently, pearl millet is grown on about 27 million hectares worldwide and is a daily food for more than 90 million people. It is also an important source of fodder for millions of farms. However, its yields have remained low over the last six decades, as the cereal is grown on poor soil.

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