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7. Millets Production in India: Constraints and Future Potential

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Abstract:

In dry lands of Africa and Asia millets are the staple food. Globally Africa and Asia contribute around 97 % of total production of the millets. Africa is the largest producer of the millets in the word followed by Asia. More than 75 % of the millet production in Asia comes from India and it contributes around 40 % in global millet production. Sorghum, Pearl millet, Finger millet and small millets are the major millets grown in the country. Maharashtra and Karnataka are the major producers of sorghum. Pearl millet has maximum area and production among all millets in India and about 99 % of its production comes from Rajasthan. Finger millet being the richest source of calcium is produced maximum in Karnataka followed by Tamil Nadu. Over the past seven decades area and production of small millets declined by 90 % and 80 %, respectively. Both biotic and abiotic factors cause hindrance in the production of millets. Outbreak of insect pests like stem borer and shoot fly, and grain mould, ergot and drought diseases cause reduce the production. Blast affects finger millet the most. Low soil fertility restricts the economic viability of millet. Green revolution led to the shift from the cultivation of millets towards rice and wheat. In near future the climate change will severely impact the Indian agriculture and one potential solution to this problem is promotion of millet cultivation as these are resilient crops and can withstand and endure severe weather. Due to millets high fibre content and mineral and vitamin content value addition of millet is necessary as it will boost household income and will made population available with healthy and nutritious products.

Keywords:

Millets, Staple food, production, biotic and abiotic factors, green revolution, household income, nutritious products.

7.1 Introduction:

Millets are the ancient nutritional grain and are the oldest food crops grown from early human civilization. It is the staple food of semi-arid tropics of Asia and Africa [1]. These crops are mostly cultivated under a variety of agro- ecological situations like plains, coast hills even diverse soil land with varying rainfall. Millets are a group of highly nutritious rich, drought tolerant crops. These small seeded grasses belonging to Poaceae family are an important source of food and fodder for millions of resource-poor farmers. These are grown as grain crops primarily on marginal lands in dry areas of temperate, sub-tropical and tropical regions thus are all-season crops cultivated round the year. They are considered as tough crops in terms of growth requirements as they withstand harsh climatic factors like nutrient deficit soils and unpredictable climate [2]. It plays vital role in ecological, economic, food and nutritional security of the country. Millets are the coarse cereals known as the “cereal of the poor”. Millets play important role in rainfed region of the country which contributes to 60 percent of the total area.

Millet is broadly categorised into two major groups (1) major millets viz., sorghum [Sorghum bicolour (L.)] and pearl millet [Pannisetum glaucum (L.)]; (2) minor or small millets, viz., finger millet [Eleusine coracana (L.) Gaertn.] proso millet [paspalum scobiulatum (L.)], barnyard millet (Echinochloa spp.), and little millet [Panicum sumatrense] [3]. Major millets Sorghum (Great millet), Bajra (Pearl millet), Ragi (Finger millet) and small millets viz., Korra (Foxatil millet), Little millet. Kodo millet, Proso millet and barnyard millet are the important millet crop grown in India. These are considered as the nutri-cereals after realising their nutrient richness. Millets are high in nutrition and dietary fibre. They serve as good source of proteins, minerals like iron, magnesium, phosphorous, potassium andvarious phytochemicals. The protein content in millets is 7-12 %, fat 2-5 %, carbohydrates 65-75 % and dietary fibre 15-20%. Finger millet is the richest source of calcium, which is 10 times more than rice or maize and 3 times more than milk. Millets are gluten free and non-allergic. Millet consumption decreases triglycerides and C-reactive proteins, thus prevents cardiovascular disease. India is the world’s largest producer of the millet during 2021 with a share of 43 %, followed by Niger (12%) and China (8 %). The government has taken various steps for the promotion of the millets in the nation. 2018 was declared as “National year of millets”. A sub mission on millets was run under National Food Security mission since 2018. Millets were included under the POSHAN MISSION Abhiyan by Ministry of Women & Child Development. ICAR released one variety Quinoa (Him Shakti). 13 high yielding varieties including 4 bio-fortified varieties of millets have been released. Further to create awareness and increase the production & consumption of millets, the United States at the behest of the Government of India, declared 2023 as the “International year of the Millet”.

7.2 History of millets:

Millets are as old as Human Civilization some of the studies has shown that the common millet was staple food around 100000 years ago in North China and some studies showed that some noodles are made of proso millet and foxtail millet around 4000 years ago [4;5]. One of the oldest plants in India is finger millet. Millets like Ragi (finger millet), Jowar (Sorghum) and Bajra (pearl millet) are of African descent, they have long been bred in India [6].

7.3 Global Scenario of millets:

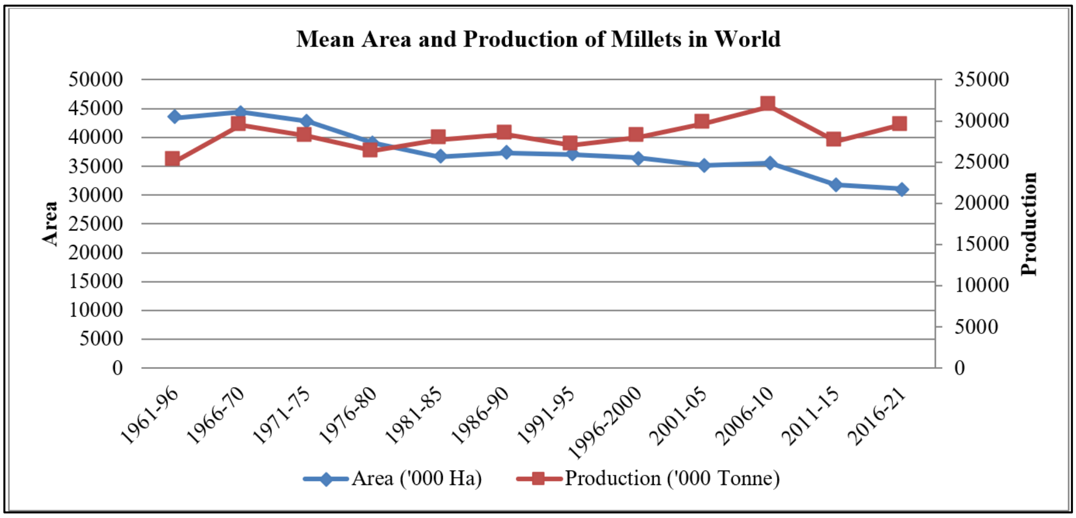
Millets cover 30934.72 thousand ha area globally with production of 30089.63 thousand tonnes. Globally millets are grown in more than 90 countries. Sorghum is the most widely grown crop with about 42100 thousand ha area in 105 countries. About 97 % of millets are produced and consumed in developing regions of Africa and Asia and these regions contribute around 98 % of the total area under millets.

Also, Africa is the largest producer of the millets in the world with the production of 12105 thousand tonne and area 18596 lakh ha [7]. Asia is the second largest producer of the millets followed by America. India contributes more than 75 % in millet production in Asia and 40 % in global millet production.

Table 7.1: Millet's area and production region wise (2021)

Regions	Area ('000 Ha)	Production ('000 tonne)
Africa	18596	12105
America	274	359
Asia	11661	16997
Europe	368	592
Australia & New Zealand	36	37

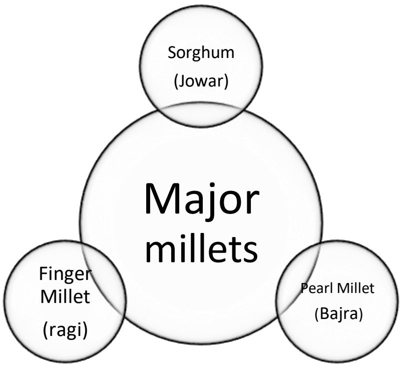
Source: FAOSTAT, 2021



Source: FAO STAT, 2021

7.4 Millet production in India:

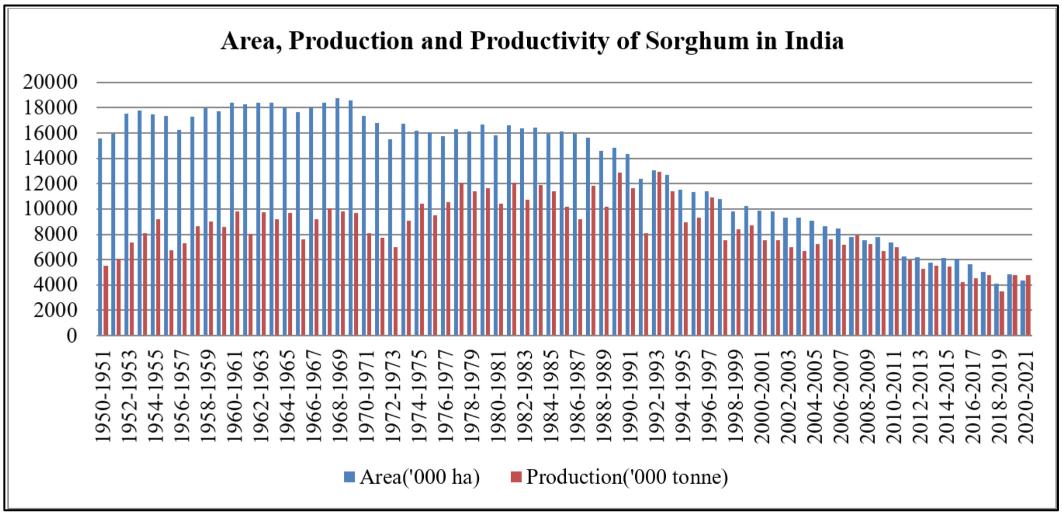
Looking into the production of the Nutri Cereals in India the production has declined from 21.32 million tonne during 2003-04 to 16 million tonnes during 2021-22. The Government of India has set a target of around 6 million tonnes to produce Jowar during 2022-23, likewise 11.3 million tonnes for Bajra, 2.5 million tonnes for Ragi and 7 million tonnes for small millets making total of 20.5 million tonnes of total millet production in the country. In India millets are the important integral part of tribal food in states of Madhya Pradesh, Odisha, Jharkhand, Rajasthan, Karnataka, and Uttarakhand. However, looking into their nutraceutical values, they have become popular in urban areas of the country as well [8]. The various millets found in India are foxtail millet, finger millet, Barnyard Millet, Brown top millet, little millet, kodo millet, pearl millet and sorghum.

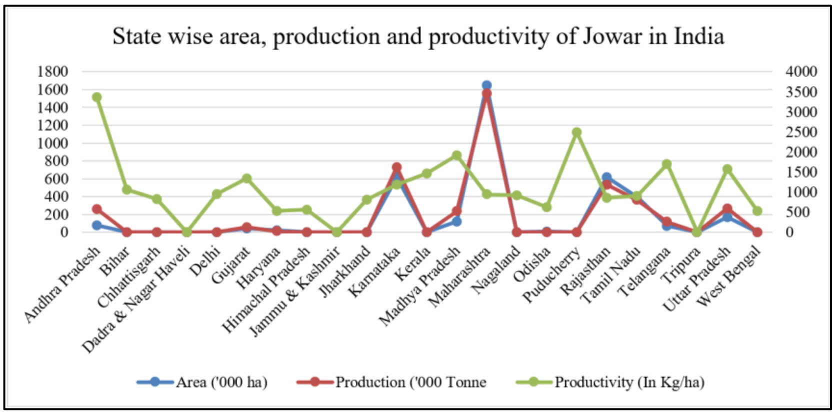


Sorghum (Jowar): Maharashtra is the largest producer of the sorghum followed by Karnataka in the country. The Productivity of the Sorghum is highest in Andhra Pradesh. The area under sorghum has declined by around 264 % from 15944 thousand ha to 4378 thousand ha during 1951-52 to 2020-21. And the production has declined by around 26 % during the same period. This decline in cultivated area under sorghum attributed to the shift of the farmers to more profitable cereals (rice, wheat, corn and pulses) and competing crops (oilseeds and cotton) and transformation in the consumption pattern towards fine cereals available through Public Distribution System (PDS).

Table 7.2: Area Production and productivity of Sorghum from 1951 -2021

	1951-52	1961-62	1971-72	1981-82	1991-92	2001-02	2011-12	2020-21
Area ('000 ha)	15944	18249	16777	16599	12360	9795	6245	4378
Production ('000 tonne)	6077	8029	7722	12062	8099	7557	5979	4812
Productivity (Kg/ha)	381	440	460	727	655	771	962	1099

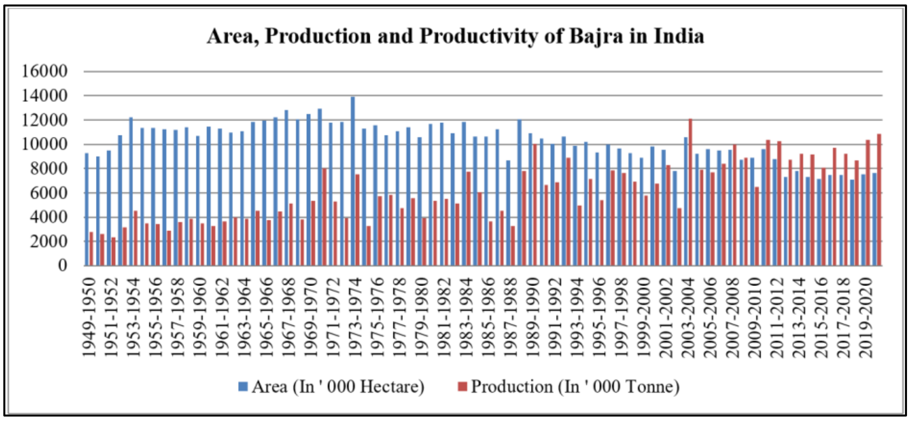


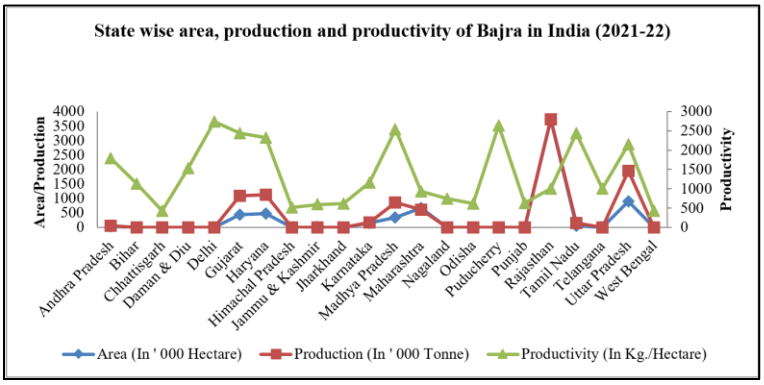


Pearl Millet: Pearl Millet, also known as Bajra, is one of the main Kharif crops in the arid and semi-arid farming regions of the country [9]. It is the first in the millet category in India in terms of production, productivity, and area. India is the largest producer of pearl millet in the world, which has an area of 6.84 million hectares and produces 9.78 million Tonne per year, with an average productivity of 1430 kg/ha throughout 2021–2022. Rajasthan has largest area under Bajra followed by Rajasthan i.e., 4.35 million ha and 0.91 million ha, respectively. 99 % of the Bajra production in country comes from Rajasthan, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, and Tamil Nadu. The area under pearl millet declined by -19.61 % from 9.52 million to 7.65 million ha during 1951-52 to 2020-21 and the production has increased from 2.35 million tonnes to 10.86 million tonnes during the same period.

Table 7.3: Area Production and productivity of Bajra from 1951 -2021

	1951-52	1961-62	1971-72	1981-82	1991-92	2001-02	2011-12	2020-21
Area (‘000 ha)	9519	11278	11773	11784	10027	9529	8777	7652
Production (‘000 tonne)	2346	3645	5319	5537	6894	8284	10276	10863
Productivity (Kg/ha)	246	323	452	470	465	869	1171	1420

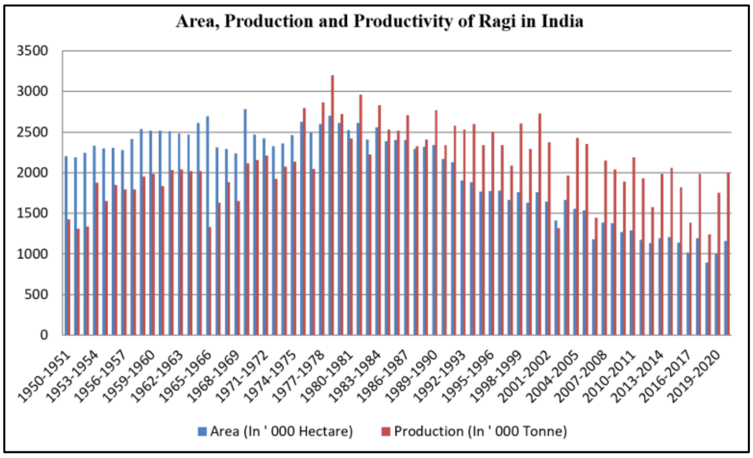


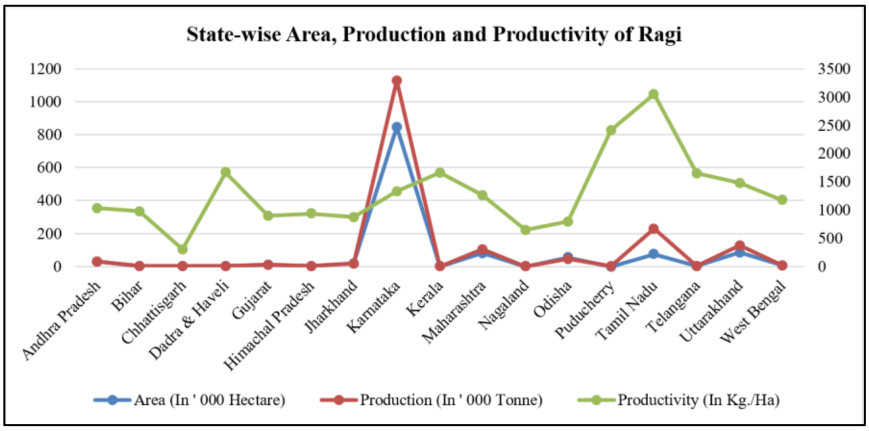


Finger Millet (Ragi): This crop is known for its ability to grow in the wide range of environmental conditions ranging from mean sea level to Hill regions over 2000 m above mean sea level. It is drought tolerant with longer storage life of the grains due to relatively. The increase in the productivity of the finger millet comes from the adoption of high yielding varieties and improved package of practices. Crop improvement efforts in finger millet have resulted in release of about 123 improved cultivars till now at national or state level [10]. It is the richest source of calcium (300-350 mg/100 g) and has highest mineral content. It also has high antioxidant activity. With continuing decline in the area under cultivation, there is a need to develop varieties resistant to blast disease, drought/heat stress and other biotic stress factors to sustain the growth in average productivity in the country.

Table 7.4: Area Production and productivity of Ragi from 1951 -2021

	1951-52	1961-62	1971-72	1981-82	1991-92	2001-02	2011-12	2020-21
Area ('000 ha)	2189	2511	2425	2611	2130	1647	1176	1159
Production ('000 tonne)	1312	2030	2208	2960	2582	2375	1929	1998
Productivity (Kg/ha)	599	808	911	1134	1212	1442	1641	1724

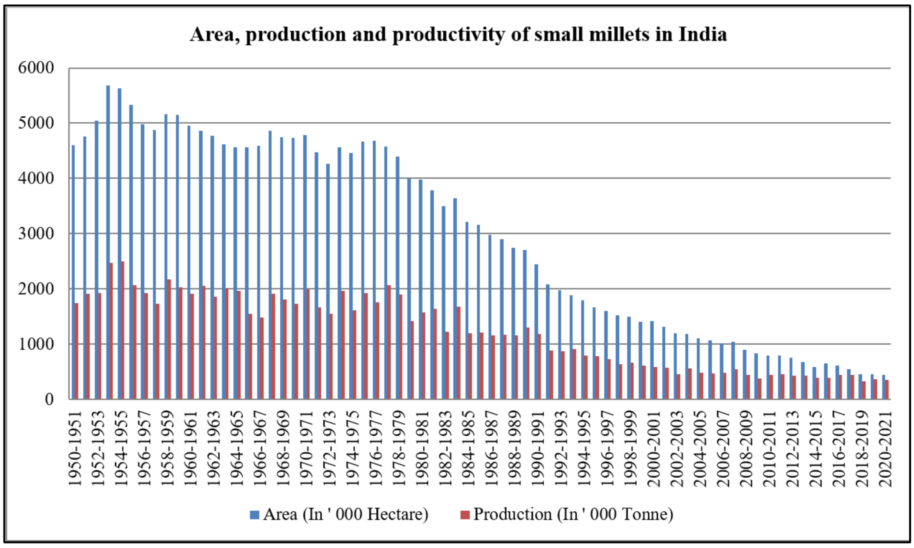


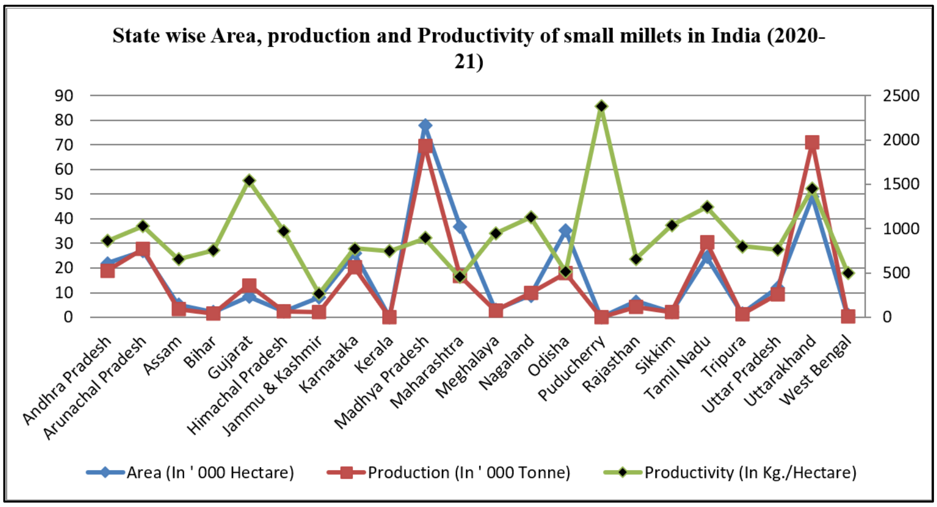


Small Millets: Foxtail millet, Kodo millet, Barnyard millet, little millet and Proso millet are minor millet. The area under small millets declined by 90 % from 4764 thousand ha to 444 thousand ha during 1951-52 to 2020-21. Around 80 % decline was observed in production of small millets from 1915 thousand tonne to 347 thousand tonne during the same period. Madhya Pradesh and Tamil Nadu with the contribution of 29 % of total production are the largest producers of small millets in the country.

Table 7.5: Area Production and productivity of Ragi from 1951 -2021

	1951-52	1961-62	1971-72	1981-82	1991-92	2001-02	2011-12	2020-21
Area ('000 ha)	4764	4868	4477	3787	2088	1311	798	444
Production ('000 tonne)	1915	2050	1669	1638	882	577	452	347
Productivity (Kg/ha)	402	421	373	433	423	440	565	781





7.5 Major Constraints in Millet Production:

Millet production like other crops is impacted by an array of constraints that have the potential to adversely influence production along with productivity. A variety of environmental variables such as drought, and direct damage from pests, weeds, and diseases can significantly hinder productivity.

The climate of a particular region impacts land topography, soil type, soil fertility, water availability, disease and pest prevalence, as well as the socioeconomic status of the farming community. Every single one of these factors is inextricably connected and all have a direct effect on the productivity and output of an agricultural production system. The following part discusses the major constraints to millet-based agricultural production systems.

7.5.1 Biotic Stresses as constraint:

While compared to other crops, millets are less negatively affected by biotic stresses since they are most often planted in dry areas. But one of the main causes millet's lower yields is an outbreak of insect pests like stem borer and shoot fly, as well as diseases like grain mould, ergot, and drought. The fungal diseases such as downy mildew and rust are the primary drivers for substantial production loss. A pearl millet hybrid, HB3, that was extensively utilized in India in then1960s, had to be removed from cultivation after being severely damaged by downy mildew. The downy mildew regularly causes the loss of as much as one third of the crop.

The most significant disease impacting finger millet is blast caused by the fungus *Magnoporthe grisea*. Due to the variety of fungal species involved, grain structure, lack of high-level resistance, complex genetic basis of resistance, as well as association of available resistance with hard grain texture and coloured pericarp, protecting grain from mould damage through conventional breeding is an enormous task. There have recently been reports of lethal variants of the bacterial soft rot triggered by *Erwinia chrysanthemi* emerging in the Tarai region of India [11;12].

There are over a hundred insect pests known to harm millet in the field and while it is being stored. Aphids, midges, headbugs, shootflies, stem borer, and others are significant insect pests of millets. A typical variety of frequently observed pests in millet includes stem borers and grain midges [13;14].

According to [15] typical pests include shoot flies, stemborers, armyworms, leaf beetles, leaf folders, flea beetles, leaf rollers, surface grasshoppers, and ants. These insects devour millet's shoots, leaves, and fruit, resulting in a considerable loss. Currently, millet growers are thought to be at risk from avian damage to millet grains. Small-grain crops are more vulnerable to severe avian damage than large-grain crops. Depending on the crop and the growing environment, the degree of damage varies, and in isolated and unprotected situations, the loss may reach 100%. Termites and cutworms are relatively minor pests among soil-dwelling insects that damage or feed on the roots of millet [13]. Contrarily, in arid and semi-arid environments, white grubs can cause severe feeding damage to pearl millet roots [16].

In India and Africa, millet plants are frequently attacked by lepidopterans such as armyworms (Noctuidae), leaf folders (Pyralidae), hairy caterpillars (Arctiidae), leaf caterpillars (Pyralidae) and leaf caterpillars (Noctuidae, Lymantriidae). The partial or complete defoliation caused by these insect's voracious feeding stops the growth of plants. Most defoliators are insignificant pests, but their irregular attacks may necessitate taking appropriate and prompt action against them. In southern India, a different species called *Atherigona pulla* (Wiedemann) is a major pest of tiny millet and common millet as well as a minor pest of ditch millet and foxtail millet [17]. In one study [18] and another [19], feeding of nymphs and adults of two common species, *Kraussaria angulifera* Krauss and *Oedaleus senegalensis* Krauss (Orthoptera: Acridiidae), reduced pearl millet yield by 56% and 90%, respectively. Neem trees in millet fields reportedly had a negative impact on grasshopper development [19].

Leaf bugs, grey weevils, and stem flies all infest seedlings. In India, numerous species of shoot flies (Diptera: Muscidae) attack all millets [15]. Early in their development, the shoot fly larvae eat through the leaf sheath, severing the growth point, which causes the seedling, sometimes known as "dead heart," to wilt, turn yellow, and die. Just above the cut, mature larvae eat decomposing matter. The yield loss caused by pest damage from these flies has been estimated to be between 20 and 50 percent for pearl millet (Kishore 1996), 36 percent for common millet [20], and 39 percent for small millet [21]. In southern Indian regions where the crop is grown in the winter, the pink borer, *S. inferens*, is a significant pest of finger millet [22]. Pearl millet, foxtail millet, barnyard millet, ditch millet, and common millet are also infrequently attacked by the borer. Despite the borer's economic significance, nothing is known about how to control it. Little study has been done since crop returns and market demand are poor.

Several pests harm the earhead during the flowering and grain development stages, reducing the yield. No millets have been recorded to develop thrips or earwigs over the past 20 years. The head miner, grain midge, and blister beetles are among these pests that are recognized as being particularly harmful to pearl millet. Millets with a short maturation cycle may be attacked by blister beetles if they are planted too late, whereas long-cycle varieties may be protected by late flowering.

7.5.2 Abiotic Stresses as constraint:

Both biotic and abiotic stresses have a substantial impact on a plant's ability to survive [23]. Millets are impacted by abiotic factors associated with soil and habitats that reduce yield and productivity. Inadequate soil moisture and precipitation, low soil fertility, light and heat stress, atmospheric drought, and high soil salinity are just a few of the factors which contribute to the abiotic stresses. Drought and water stress are regarded as one of the most significant pressures on millet production [24]. Millet has been mainly cultivated on sandy soils with poor nutrient status and limited water holding capacity; hence, low soil fertility is an additional problem that restricts the economic viability of millet. Predominantly poor in organic carbon and deficient in phosphorus and nitrogen, the soils are also low in organic carbon. Another significant obstacle to millet production is soil salinity. Saline soils include greater concentrations of soluble salts including sulphates, chlorides and carbonates that interfere with seed germination and lower yield of millet by inhibiting plant growth. One of the most prevalent environmental stresses is drought, which is defined as "a temporary reduction in wetness accessibility, in which the amount of available water is significantly below norm over a specified duration" [23]. Drought has already started to serve an essential part in reducing crop output worldwide due to a global shortage of water resources. In the regions of the world that cultivate millet, lack of moisture constitutes the main constraint. Water stress generally results in several morphological, physiological, biochemical, and molecular alterations that have a negative impact on plant growth, development, and productivity. The standing crop often gets no moisture and is vulnerable to drought because millets are usually grown in regions with unevenly distributed, sparse rainfall. Millets respond differently to moisture stress at different growth stages, and it has been demonstrated unequivocally that yield losses are highest when moisture is less. Millet yields very little grain or leaves when the rains quit abruptly. Water stress specifically exerts an immediate effect upon a plant's physiology, primarily the photosynthesis process. This circumstance negatively impacts agricultural growth and productivity. There is a substantial negative correlation between millet yield and temperature and a negative correlation between millet production and rainfall [25]. Crop production which needs an excessive amount of water is impacted by the frequency and severity of drought, which fluctuates from year to year [26]. Lack of soil moisture can affect plant growth, crop establishment, disruption of normal developmental processes, and ultimately, final production (27; 28).

Drought has been shown to have unfavourable effects on crop yield as well as grain nutrition, including the mineral and protein content (29; 30). When subjected to drought prior to blooming, a study on wild millet (*Setaria glauca*), foxtail millet (*Setaria italica*), small millet (*Panicum sumatrense*), and proso millet (*Panicum miliaceum*) found a significant loss in yield. After 4 weeks of seeding, full yield loss was documented in two landraces of finger millet that had been exposed to drought (30; 31). Due to terminal dryness that occurred during flowering until maturity, a yield loss of almost 60% was noted [32].

7.5.3 WEEDs as Constraint:

The existence of weeds or plants other than those sowed which emerge without human effort and inhibits from attaining maximum output, is one of the good difficulties with which a farmer must cope. In several cereal crop varieties, weeds have been a major cause of crop loss. Due to the favourable climatic conditions for their growth during the rainy season, weeds are a key barrier to enhancing millet's productivity and are a global concern in the agricultural sector. The foremost constraining elements are soil moisture and nutrients since millets flourish in a rainfed environment. Millets endure competition from weeds for light, soil moisture, and nutrients, which reduces the total amount of grain produced. In addition to the initial damages imposed by concurrence, weeds additionally bring about indirect losses by serving as additional hosts for pathogens. Due to increased humidity around the crop, the weed population provides a favourable microenvironment for blast development [33]. The grass weeds *Eleusine indica* (L.) Gaertn, *Digitaria* spp., *Setaria* spp., *Eleusine africana* (Benth.) Stapf, and *Dactyloctenium* spp are one of the most frequent alternate hosts for the fungus that causes blast of finger millet.

Most frequently emerging weeds in millet fields correspond to families Poaceae, Convolvulaceae, Asteraceae, Amaranthaceae, Commelinaceae, Compositae, Nyctaginaceae, Apparridaeceae, portolacaceae, Ehphorbiaceae, Tiliaceae, Alizoaceae, Zygophyllaceae, Asclepiadaceae, Cyperaceae and Scrophulaceae [34]. In accordance to crop cultivars, the type and degree of the weed invasion, management methods, and environmental conditions, uncontrolled weed infestation substantially decreases the production rate by 15 to 83% in sorghum, 16 to 94% in pearl millet, and 55 to 61% in finger millet [34].

7.5.4 Socioeconomic Constraints:

The agricultural sector is negatively impacted by an array of factors, including low levels of socioeconomic development, inadequate infrastructure, an outdated mentality, a higher reliance on natural resources, an inadequate marketing and a lack of consumer demand for the produce. Since millets are primarily farmed as a means of subsistence on marginal ground by the resource-poor farmers. The main driving force behind people giving up millet farming involves several factors like Green Revolution, the monocropping regime and the consumption of rice and wheat as a staple food which have resulted in the eradication of millets from farms. Low production is also a result of a lack of the necessary technology backup for raising millets' productivity. Other issues include low prices and insufficient demand for processed goods, which force small-scale agriculture owners to sell their goods on credit which ultimately proves to be unprofitable [35].

7.6 Future Prospects:

The foundation of the Indian economy is agriculture. The accelerating global warming, an acute shortage of water (that will reach terrifying proportions) and the projected malnutrition (that is expected to impact 70% of Indians, especially the poor and vulnerable groups) are the main global issues demands more attention to feed the world population. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), India will face some of the most severe effects of climate change, as a result, India should seek alternative crops that are more climate resilient. One potential solution to this problem is to promote millet cultivation as millets are resilient crops which can withstand and endure severe weather. They are therefore the perfect response to the issue of climate change. They are considered as healthy and diabetic foods.

However apart from nutrition, one of the key reasons for millet cultivation is its potential as a future crop as increase in global temperature can have a significant impact on agriculture and cereal productivity, threatening the food security of billions of people. Wheat, which is thermally sensitive, is predicted to struggle to thrive as a result of climate change. In addition, rice would also become completely unviable crop due to change in climatic conditions. Therefore, if we are concerned about finding a solution to this issue, we should consider millets. This ancient cereal has been recognized for its climate resilience, short cropping duration, to solve global nutritional security challenges, as a sustainable alternative to major cereals, its potential to generate livelihood, and thus increase farmer income. That is why it is considered as an excellent food crop. The collaborative research efforts in millet from agricultural research organisations, the industries, or even industrial research institutions would surely employ in a variety of ways to boost income and create demand for commercially viable products from millet. Due to their high fiber content, mineral and vitamin content, and nutritional value, value addition of millet is necessary as it will boost agricultural incomes and will provide customers with a variety of healthy and nutritious products. Additionally, improving the shelf life of items like flour, and other foods items made from millet will be a primary priority for value addition and long-term market prospects in addition to seeds and grains.

Future studies should concentrate on millet cultivation using high-yielding cultivars, resistance to abiotic (salinity and drought) and biotic stresses (grain mould, aphids, stem borer, etc.), enhanced quality of the produce, extended shelf life of grain, and pay attention to integrated pest and weed management. In order to develop genotypes with greater resilience, a trait-based strategy for genetic enhancement of millets would require the utilisation of the most recent advances of plant biotechnology and molecular biology.

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