



DECODING THE RESISTANCE IN MILLETS TOWARDS BIOTIC STRESS

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Environment presents various kinds of stress to the growing plants and plays an important role in determining the productivity specially in case of food crops. Amongst these stresses, biotic stress is the one which has got prominent role in deciding the productivity of a crop in a season. Biotic stress poses a serious threat to the crop productivity which enhances the use of insecticide and pesticide on the crops. Millets provides an ideal gene pool for its resistance against various diseases caused from the pathogens. This makes them the first choice amongst the farmers for their plantations and cultivations at various altitudes in different seasons. This review comprehensively provides an insight into the disease resistance in millets and various mechanisms and aspects associated with it.

Keywords: Biotic Stress, Disease Management, Millets, Pathogens, PGPR.

Introduction

Millets are small-seeded annual cereal crops grown as a source of food and fodder in different regions of the world with less rainfall and can also be grown on marginal land. Being rich in vitamins, minerals, and other bioactive compounds helps in the recovery and well-being of human health. It is frequently raised as a catch crop. Millets are also nutri-cereals¹.

Millets are divided into two categories- Major millets and Minor millets. Major millets include finger millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), and pearl millet (*Pennisetum glaucum*). Minor millets include foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), proso millet (*Panicum miliaceum*), browntop millet (*Urochloa ramosa*) and barnyard millet (*Echinochloa esculenta*). Millets are rich in proteins, vitamins, carbohydrates, and digestive fibres, and have high micronutrient content². In recent times, the nutritional advantages of millet have

created awareness among people. Several scientific shreds of evidence suggest that millet ingestion decreases prediabetes development, reduces body mass index, and results in the control of diabetes. Millet's high nutritional value and ancient history, dating back to the Indus Valley civilization, have contributed to its growing demand as a health-conscious food choice. It is also known as Cheenaka or kangus in Sanskrit, in India³.

Disease resistance is one of the most important features of a crop like millet due to the concern with food security, nutritional value, and sustainable agriculture. Millets are susceptible to many diseases (Table 1). These diseases are caused by various types of microorganisms like fungi, viruses, and bacteria, and can affect different parts of the plant, leading to issues like spots in leaves, wilting of leaves, discoloration, stunted growth of crops, and reduced grain quality. Common diseases include rusts, smuts, powdery mildew, leaf blight, maize streak virus, sorghum mosaic

virus, bacterial blight, and bacterial leaf streak⁴.

However, several studies on millet disease resistance have shown that millets have developed various defense mechanisms against pathogens. Disease resistance can be boosted by Plant-growth-promoting-bacteria (PGPR) interaction with plants which produces physiological and biochemical changes in plants like cell wall strengthening leading to restriction of pathogen activity. During the resistance induction, researchers have also quantitatively studied phytohormonal changes and signaling pathways that involve MAP kinase and *Lox* genes⁵.

Millet productivity can be increased by managing and understanding various diseases affecting them. By combining cultural, biological, and chemical methods we can achieve a significant approach⁶. Breeding for disease resistance varieties and assimilating resistance traits into new varieties are useful for resistance to diseases.

Moreover, molecular biology and genomics have aided scientists in identifying and developing 74 new millet varieties that are resistant to common diseases (Recent Advances in Millet Research, 2021). We can further improve disease resistance in millets by combining modern technology with traditional breeding⁵.

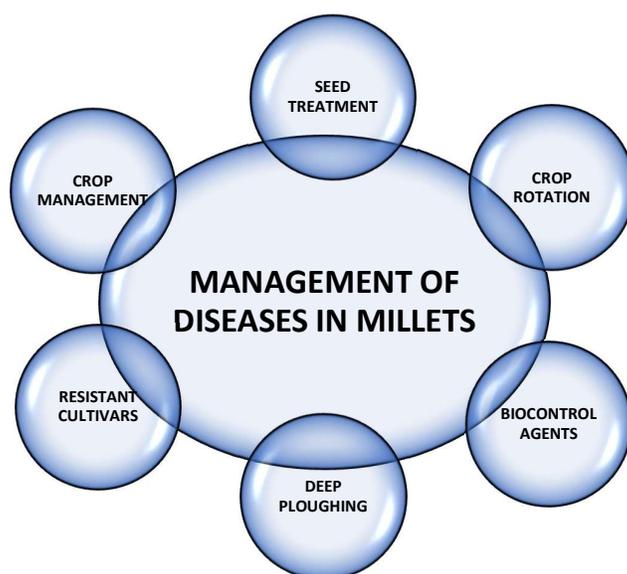


Fig 1: Different aspects associated with the management of diseases in millets.

Mechanism of Disease Resistance in Millets

Millets have developed different mechanisms to resist diseases. These mechanisms include physical and chemical defenses. Physical defense mechanism includes pericarp thickness which acts as the first line of defense against fungal infections. It also includes the texture of endosperm where the harder grains are more resistant to fungal attacks. Sorghum with high cysteine content

forms strong disulfide bonds, making the grain more resistant.

Chemical defense includes compounds like antifungal compounds which produce specific proteins, ferulic acid, and hydroxycinnamic acid. Proteins like chitinases, and thaumatin-like proteins also help inhibit fungal growth^{9,10}.

It also includes proteins like PR (pathogenesis-related) proteins and defense-related proteins. PR-1 and PR-6 are the proteins that are produced in

response to fungal infections and help inhibit fungal growth^{11,12}. Proteins like β -glucan hydrolases, chitinases, and thaumatin-like proteins also help inhibit fungal growth^{9,10}. The other protein that is involved in signaling pathways and activates defense mechanisms is defense-related protein and the gene coding for these are 'R' genes¹³.

Specific Resistance Mechanisms

Various mechanisms are there in millets which provides them resistance under diverse biotic stress (Table 2).

Downy Mildew Disease Resistance:

Downy mildew is a common disease that affects pearl millet. The millet uses lytic factors to inhibit fungus and then, it introduces a defense mechanism (induced systemic resistance), which activates some enzymes like chitinases and peroxidases to

fight against infection¹⁴.

Ethylene Signaling Pathway: Ethylene is a plant hormone that initiates defense responses in plants during fungal infection¹⁵. L- methionine is a precursor of ethylene and is essential in resistance by inducing the expression of defense-related genes¹⁶.

Mechanism of PGPR: Plant growth-promoting rhizobacteria (PGPR) plays an important role in defense against disease by forming barriers and producing chemicals that kill harmful microbes^{17,18}.

Role of BMR Gene: In millet-like sorghum a gene named bmr is present which is resistant to fungus like Fusarium. This gene affects the fungus by disintegrating lignin production¹⁹. With the help of these defense mechanisms, millets can be prevented from diseases.

Table 1: Common diseases associated with different kinds of millets.

Disease name	Disease-causing microorganisms	Host millet
Grain Mold ^{4,7}	<i>Fusarium spp.</i> , <i>C. lunata</i> , <i>A. alternate</i> , <i>P. sorghina</i> , <i>Bipolaris spp.</i> , <i>Aspergillus spp</i>	Sorghum, Pearl and Finger millet
Ergot OR Sugary Disease ⁸	<i>C. sorghi</i> , <i>C. africana</i>	Sorghum
	<i>C. fusiformis</i>	Pearl millet
Smut ^{4,7}	Head smut: <i>S. reilianum</i> Covered smut: <i>S. sorghi</i> Loose smut: <i>S. cruenta</i> Long smut: <i>T. ehrenbergi</i>	Sorghum, Pearl and Small millets
Downy Mildew OR Crazy Top ^{7,8}	<i>P. sorghi</i>	Sorghum, Pearl, and small millets
Blast ^{4,7}	<i>P. grisea</i>	Pearl millet, Finger, Foxtail, Barnyard, Proso & Little millets
Anthracnose ^{4,8}	<i>C. graminicola</i>	Sorghum
Rust ^{7,8}	<i>Puccinia purpurea</i>	Sorghum, Pearl and Small millets
	<i>E. turcicum</i> , <i>B. turcica</i> , <i>D. turcica</i>	Sorghum
Leaf Blight ⁷	<i>Alternaria spp.</i>	Kodo millet

Disease Management: The disease management includes following practises for the eradication of various disease in millets (Fig. 1).

Cultural Practices:

Deep ploughing summer fields, cleaning field bunds post-harvest, removing crop residue, and uprooting diseased plants and burning them can significantly reduce disease risk. Removing weeds, volunteer plants, and wild crop species can control diseases and various bacterial and viral infections. Destroying crop residue and rotating crops with non-host plants can reduce many common diseases like downy mildew, smut, charcoal rot, and certain fungal and bacterial leaf diseases⁴.

Resistant Cultivars:

Cultivars like CSH16, CSH27, CSH30, CSV20, and PVK801 are mold-tolerant. CSV19R, CSV216R, and DSV6 exhibit

good tolerance to charcoal rot. Recent pearl millet cultivars, such as HHB 67 and ICMH 356, tolerate downy mildew. Two widely used cultivars namely GPU 28 and GPU 48 are highly resistant to neck and finger blasts. In the case of barnyard millet genotypes PRB 402, TNAU 92, and VL 216 resist grain, head smut, and brown spot diseases. Foxtail millet lines GPUS 27, SiA 3039, SiA 3059, SiA 3066, SiA 3088, TNAU 213, and TNAU 235 remain unaffected by brown spots⁴.

Biological Control:

Biological control offers another effective method. Applying *Pseudomonas chlororaphis* SRB127 to seeds can reduce charcoal rot and lead to an increase in the weight of the seed. Two bio-control agents, particularly *Trichoderma* and *Pseudomonas* strains, are effective against sheath rot and foot rot in small millets⁴.

Table 2: Mechanism of disease resistance in millets.

Millet Name	Scientific Name	Resistant to Disease	Disease-Causing Organisms	Mechanism of Gene Responsible for Disease Resistance
Finger millet ^{5,20} (Ragi)	<i>E. coracana</i>	Blast Disease Grain Mold	<i>P. grisea</i> <i>Fusarium spp.</i> , <i>C. lunata</i> , <i>A. alternate</i> , <i>P. sorghina</i> , <i>Bipolaris spp.</i> , <i>Aspergillus spp</i>	Lipoxygenase (LOX) MAP Kinase SA, JA Polyphenols, tannins
Sorghum ²¹ (Jowar)	<i>Sorghum vulgare</i>	Grain Mold	<i>Fusarium spp.</i> , <i>C. lunata</i> , <i>A. alternate</i> , <i>P. sorghina</i> , <i>Bipolaris spp.</i> , <i>Aspergillus spp</i>	R2R3 MYB 3- Deoxyanthocyanidins
Foxtail millet ²² (Kangni)	<i>S. italica</i>	Blast	<i>P. grisea</i>	LOC- OsO8g10300 SHR-5 receptor-like kinase
Pearl millet ²³ (Bajra)	<i>Pennisetum typhoideum</i>	Downy Mildew	<i>P.sorghii</i>	PR Proteins PR1, PR5, POX, PAL & PPO
Barnyard ²⁴ millet (Sawa millet)	<i>Echinochloa frumentacea</i>	Blast	<i>Pyricularia grisea</i>	Avr-Pizt and Avr-Pia avirulence(Avr)

Chemical Control:

Chemical control is not commonly used for millet disease management due to the high costs of chemicals and labor. However, fungicides can be applied as seed treatments or foliar sprays.

Treat seeds and spray foliage with Ridomyl-MZ in case of downy mildew. For loose and covered smuts disease dress seeds with sulfur at a rate of 4 grams per kilogram of seed. Treat seeds with propiconazole at a rate of 1 milliliter per kilogram of seed for banded sheath blight. In case of blast disease spray with 0.1% of Carbendazim, 0.05% of Tricyclazole, or a combination of 63% of Mancozeb and 12% of Carbendazim. Plant-tolerant cultivars and spray panicles with fungicides such as Bavistin (0.1%), 0.2% of Tilt, or Mancozeb to minimize ergot incidence. Spray foliage with Mancozeb at a rate of 0.2% to control rust⁴.

Conclusion:

Millets are also known as nutri cereals due to their high nutritional value. It is resilient to adverse climatic conditions and can be found in marginal lands. They possess many health benefits which make them a valuable crop. However, various diseases like fungal, bacterial, and viral infections, cause threats to millet production. To solve this problem, we must understand how the diseases affect millets and also develop some effective measures to manage them. Millets have developed many defense mechanisms like physical chemical and genetic defenses to protect them from diseases.

Researchers are creating new millet varieties that are more resistant to diseases by uniting traditional breeding methods with advanced technologies like molecular biology and genomics. Crop rotation, biological controls, and chemical treatments are used to develop disease-free millets. Other methods like disease-resistant varieties and beneficial microbes like PGPR can be used to develop disease-free crops of millets. By continuing to

research and develop new methods for disease control, we can ensure that millet remains a healthy and important food source.

Future Prospects

Millets are the future crops, rich in nutrition, and need to be disease-free. The wild varieties of millets exhibit natural resistance against diseases but on the other hand, hybrid varieties lack the natural resistance and are more susceptible to diseases. By introducing disease resistance into hybrid varieties through advanced breeding techniques we can make millets as future crops. This is important for future aspects which ensures sustainable millet production and promotes healthier diets.

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Conflict of Interest

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

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