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A Review on Disease Management in Millets

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ABSTRACT

Millets, both major and minor, are important source of human diet. They are rich in proteins, carbohydrates, fat, fiber, micro nutrients including vitamins and minerals. Production of millets increase every year as they have high capacity to withstand biotic and abiotic stresses. However, in recent times, they are subjected to all type of bacterial, viral infections and fungal diseases. Blast, downy mildew, ergot, grain mold, smut, rust, bacterial leaf strike, bacterial leaf spot, Maize stripe virus (MStV-S), Maize streak virus, Maize mosaic virus (MMV-S) are common among all millets. Integrated crop management and pest control through agronomic cultural practices, use of resistant tolerant cultivars, chemical and biological control measures reduce the spread of diseases leading to high crop yield.

Keywords : Millets, blast, ergot, grain mold, downy mildew, resistant cultivars

I. INTRODUCTION

United Nations General Assembly and "Food and Agriculture Organization (FAO)" declared 2023 as the International year of Millets. One among the many goals of the international year of Millet is to attain sustainable production and achieve best millet quality. All millets Sorghum (*Sorghum bicolar*), kodo millet (*Paspalum scrobiculatum*), pearl millet (*Pennisetum typhoideum*),proso millet (*Panicum miliacem*), finger millet (*Eleusine coracana*), barnyard millet (*Eshinochloa crusgalli*), foxtail millet (*Setaria italica*) and little millet (*Panicum sumatrense*) possess nutritional superiority over other cereals. (Chandrashekar et al., 2016, Kumar et al., 2016)

Down the centuries, millets were considered to be vital part of human diet. Millets not only offer great health benefits but also help in regulating a clean and healthy surrounding and are less water consuming plants. They are resilient to adverse climate change. The production of millet increases year after year. Worldwide, 20% of millet production is contributed by India. (Nagaraja et al., 2016). Millets help to increase the hemoglobin level, presence of fiber in

millets helps to overcome constipation, reduces sugar level in diabetic patients and antioxidants and also inhibit the tumors. (Vanisha et al., 2011)

However, worldwide millets is under threat because of serious risks causes by the stresses of due to biotic and abiotic factors. Millets are not able to cope up with such stresses (Kumar et al., 2011, Bhosale et al., 2022). Apart from the changing climatic conditions, fungal, bacterial and viral diseases pose serious constraints towards the production of millets. (IK Das 2017) Phytopathogenic fungi cause severe damage to plant productivity and thereby reduce the annual grain yield (Baky et al., 2021). *Pyricularia grisea, Pyricularia setariae, Sclerophthora macrospora* and *Peronosclerospora sorghi* are some of the fungal pathogens that causes blast and downy mildew in millets. Other fungal diseases include grain mold, smut, anthracnose, ergot and rust (Das et al., 2017). Bacterial pathogens like *Pseudomonas* sp, *Xanthomonas* sp and *Erwinia* sp, causes the bacterial leaf spot, bacterial leaf stripe, bacterial leaf streak and bacterial stalk rot. (Sundin et al., 2016, Das et al., 2017).

Viral diseases in millets spread through vectors like Aphids and plant hoppers. The causal viruses include Maize stripe virus (MStV-S), Maize streak virus, Maize Mosaic Virus (MMV-S), Maize dwarf mosaic virus, Sugarcane Mosaic Virus (SCMV), and Ragi mottle streak virus (Das et al., 2017)

In this chapter, very important major diseases on millets are discussed in detail along with management strategy to combat such diseases.

II. Major Diseases on Millets

Various plant pathogens cause serious diseases in both major (Table 1) and minor millets (Table 2). The diseases on millets are broadly classified into three categories.

1. Fungal Disease
2. Bacterial Disease
3. Viral Disease

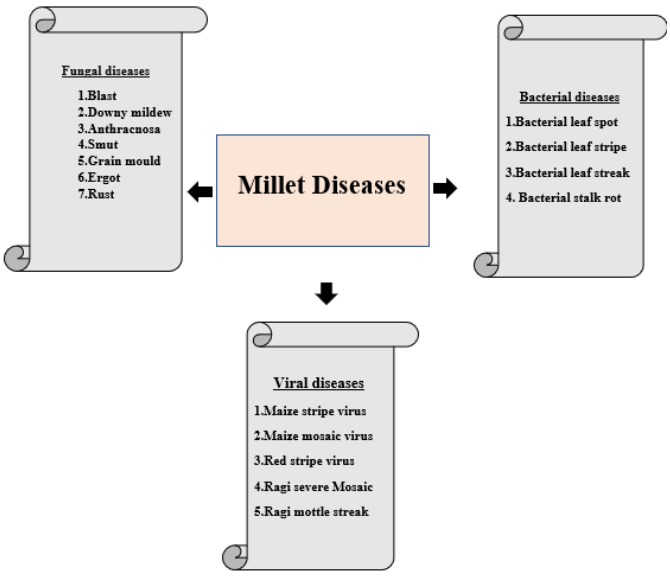

Figure 1: Different categories of millet diseases and their types

Fungal Disease

Blast

Blast is predominantly caused by fungal pathogens *Pyricularia grisea: Magnoporthe grisea* and *Pyricularia setariae* on proso millet, barnyard millet, pearl millet, little millets, foxtail millet, and finger millet (Mgonja et al., 2007, Das et al., 2016). Elliptically shaped lesions posing grey centers on the leaf is the characteristic feature of this disease. These lesions are surrounded by chlorotic halo in concentric rings. The critical condition of this disease known as the Neck Blast appears on the neck region resulting in the severe loss of production in terms of loss of weight number in the grain. In finger millet spikelet sterility is increased rapidly due to neck blast (Fig. 2. A). In pearl millet widespread chlorosis leads drying of the tender leaves before maturation. According to the stage and type of the crop, blast symptoms may be seen either on the leaf, stem, peduncle, leaf of the leaf and seedling. (Das et al., 2016 Das et al., 2017).

Downy mildew

This is a widespread disease that occurs on all small millets, pearl millet and sorghum. Downy mildew in finger millet is caused by *Sclerophthora macrospora* while in foxtail millet and pearl millet it is caused by *Sclerospora graminicola* (Bonde et al., 1982). The

pathogen *Peronosclerospora sorghi* causes the sorghum downy mildew (Das et al., 2017, Werder et al., 1992).

Sorghum downy mildew is observed by the presence of pale-yellow infected seedlings and undersized leaf with light color streaking. Although it first occurs on the leaf blade's lower side , it grows upward and the colour of the leaves completely changes to white. This change proves the occurrence of conidia and conidiophores of *Peronosclerospora sorghi.* This leads to the death of the plant (Das et al., 2017).

Pearl millet downy mildew are seen both in the earhead and leaves (Fig. 2. C). This disease is known by the color changes to yellow from green particularly in the lower leaves and then it spreads to the whole plant. Another important symptom of this is, the upper leaf (partly) remains without any symptom while the lower half shows symptoms of colour change due sporangia production. Hence, this phenomenon is also called as 'Half leaf" symptom. Earhead will not be produced by those plants which are severely infected by this disease. 'Green ear" disease is a peculiar type in which the earhead appears as leaf structure in infected plants (Jeger et al., 1998). The spikelet tissues turn into thread like leafy structure without producing grain. This leads to drying of the earhead and panicle becomes black (Das et al., 2017).

Finger millet Downy mildew otherwise known as crazy top downy mildew is a type of fungal infection on finger millet. The fingers are replaced by a leafy structure which are bushy (Nagaraja et al., 2016). The important symptom of this disease is the earheads get converted to leaf like appearance causing sterility. There is no white cottony growth as seen in other downy mildew disease (Nagaraja et al., 2016). This spreads to the spikelet from the base and later the earhead will look like a bush – 'green ear' (Das et al., 2017).

A. Blast Disease in Finger Millet Image Courtesy: Wikipedia

B. Ergot in Sorghum Image Courtesy: Agropedia

C. Downy Mildew in Pearl millet Image Courtesy: Wikipedia

D. Rust in Foxtail Millet Image Courtsey: Rajesh et al., 2020

E. Grain mold in Sorghum Image Courtesy: Wikipedia

F. Smut in Pearl Millet Image Courtesy: Agropedia

Figure 2: Fungal diseases in Millets

Anthracnose

Colletotrichum graminicola, C. sublineolum : Glomerella graminicola, are the causative agents of anthracnose in sorghum (Thakur et al., 2007). As mark of the initial characteristic symptom on sorghum, very small spots colored as straw appear on the leaf. The lesions that are produced in the margin may have varying colors of purple, red, black, orange due to cultivar pigment (Thakur et al., 2007, Das et al., 2017). These spots along with other leaf spots appear blight. The existence of a black dot at the necrotic spot center marks leaf anthracnose. Anthracnose can be seen in the leaf also on the leaf sheath, stalk, spikelet tissues and midrib. When the infection becomes severe, the seedlings droop will die when the leaf is young, and in the later phase, there will be defoliation and occurrence of death before maturity (Das et al., 2017).

Smut

The fungal disease smut could be observed on Sorghum, Pearl millet, small millets. In sorghum, there are different smut diseases namely Head smut caused by *Sporisorium reilianum* , Covered smut caused by *Sporisorium sorghi* Loose smut caused by *Sporisorium cruenta* and Long smut caused by *Tolyposporium ehrenbergii.* (Das et al., 2017).

Each smut is characterized by specific symptoms of its own. Plants that are infected by the loose smut experience stunt growth, premature flowering and stalks are very thin and fragile. Spikelet's become empty when there is a rupture and it leads to the blowing of the smut spores. Thus malformation of smut occurs (Das et al., 2017).

The emergence of a membrane in grayish white color membrane instead boot leaf panicle is the characteristic symptom of head smut. The masses of spores would be released when these membrane breaks open (Jain et al., 1999).

Cover smut is characterized by formation of fungal sorus instead of grain itself. However, the grains present in the earhead gets infected. Thick pale membrane covering the sorus marks Long smut (Das et al., 2017).

Pearl millet smut

Tolyposporium penicillariae (syn., Moesziomyces penicillariae) is the fungal pathogen of smut in the pearl millet. An interesting fact in this millet is, the sorus formation is from the floret ovary that is infected. Colour transition from green to brown also occurs. Grain becomes absent but enlarged body sized sorus are present instead (Fig. 2. F). When the sorus mature, they rupture and release spore balls which contain teleutospores. *Tolyposporium penicillariae* lives in the seed that is infected as teleutospore and on germination sporidia is produced causing severe infection (Das et al., 2017).

Small millet smut

Among all the small millets grain smut is caused by *Melanopsichium eleusinis* in finger millet, *Ustilago crameri* in foxtail millet and *Ustilago panici-frumentacei* in barnyard millet. In these millets, the grains contain randomly developed sori. The ovaries of these millets get transformed into large sized sori which resemble the velvety gall. A colour change from green to dark black could be easily observed when dried. The grains in the *Setaria italica* (foxtail millet) get affected completely (Das et al., 2017).

Sorosporium paspalithunbergii causes Head smut in Barnyard, Kodo & Proso millets. When kodo millet is affected by head smut, there is a great loss in the production of grains. There is a transformation of the panicle into sorus and in infected condition the panicle will not have complete emergence. It remains closed and darker spores get released when there is a breakage in the panicle (Das et al., 2017).

Grain mold

Sorghum, Pearl millet and Finger millet exhibit grain mold caused by *Fusarium* spp., *Curvularia lunata, Alternaria alternate, Phoma sorghina, Bipolaris* spp., and *Aspergillus* spp.

Among them sorghum fungal diseases grain mold is the major type. However, grain mold is also seen on finger and pearl millet. Grain mold in sorghum can be characterized by the coloration in spikelet tissues particularly in the palea and lemma (Das et al., 2017). In some cases, the anthers and filaments may have fungal growth. Due to severe infection, the production of grains gets affected in size reduction along with poor seed set. Colour changes from green to dark black on the grain can be observed (Thakur et al., 2007). The mature grains will exhibit colour variations like orange, pink, gray, white, or black on the surface of the grain. The fungal growth takes place and spreads to the pericarp from the end of hilar. Pinkish or white growth of the fungus exhibited on the mature grains indicate the grain mold on pearl millets while finger millets exhibit the black colour (Das et al., 2017).

Table 1: Diseases on Major millets

Types of Millets	**Diseases**	**Pathogens**	**References**
Finger Millet	Rust	*Uromyces eragrostidis*	Nagaraja et al., 2016
	Green ear	*Sclerophthora macrospora* (Sacc.) *Sclerospora macrospora* (Sacc.)	Nagaraja et al., 2016, Kumar et al., 2016
	Blast	*Pyricularia grisea* *Magnaportha grisea* *Magnaportha oryzae*	Kumar et al., 2011, Gashaw et al., 2014, Gashaw et al., 2016, Lenne et al., 2007 Mbinda et al., 2021
	Leaf blast	*Pyricularia setariae*	Chandrashekar et al., 2006,
	Leaf blight	*Cochliobolus nodulosus*	
	Downy mildew	*Sclerophthora macrospora*	Das et al., 2017, Nagaraja et al., 2016
	Bacterial leaf spot	*Xanthomonas eleusinae*	
	Bacterial leaf stripe	*Pseudomonas eleusinae*	
Pearl Millet	Green ear	*Sclerospora graminicola* (Sacc.)	Bonde et al., 1982
	Ergot	*Claviceps fusiformis* *Claviceps microcephala*	Lubadde et al., 2014, Miedaner et al., 2015, Nene et al., 1976,
	Downy mildew	*Sclerospora grmainicola*	Jeger et al., 1998, Sudisha et al., 2011
	Blast	*Pyricularia oryzae* *Magnaportha grisea*	Chandrashekar et al., 2006, Das et al., 2016,
	Smut	*Moesziomyces penicillariae*	Das et al., 2016, Lubadde et al., 2014
	Rust	*Puccinia subtriata*	Lubadde et al., 2014
	Leaf blast	*Pyricularia grisea*	
	Top rot	*Fusarium moniliforme*	Das et al., 2017, Nagaraja et al., 2016
	Bipolaris leaf spot	*Bipolaris setariae*	
	Phyllosticta leaf blight	*Phyllosticta penicillariae* Speg	
Sorghum	Downy mildew	*Peronosclerospora sorghi*	Bonde et al., 1982, Jeger et al., 1998, Thakur 2007
	Anthracnose	*Colletotrichum sublineolum*, *Colletotrichum graminicola*	Chandrashekar et al., 2006, Das et al., 2016, Thakur 2007
	Grain mould	*Fusarium loniliforme*, *Curvularia lunata*, *Alternaria alternata*, *Phoma sorghilla*	Das, 2016, Das et al., 2017
	Ergot	*Claviceps sorghi*, *Claviceps*	Medaner et al., 2015,

		sorghicola, Claviceps Africana	Thakur 2007
	Charcoal rot	*Macrophomina phaseolina*	Das et al., 2017, RP Thakur 2007
	Leaf blight	*Exserohilum turcicum* (Pass.) *Bipolaris turcica*	Thakur et al., 2007 Das et al., 2017
	Head smut	*Sporisorium reilianum*	
	Long smut	*Sporisorium ehrenbergii*	
	Viral diseases	*Maize Stripe Virus* (MStV) *Maize Mosaic Virus* (MMV)	
	Bacterial leaf stripe	*Pseudomonas andropogonis*	Das et al., 2017

Sugary disease/ Ergot

Ergot affects sorghum and pearl millet. Sorghum ergot is spread by *Claviceps sorghi, C. africana* while Pearl millet ergot is caused by *C. fusiformis* (Miedaner et al., 2015)

The viscous droplet like the honeydew transudation from the infected floret is the earliest characteristic symptom of ergot infection (Miedaner et al., 2015). As ergot infection becomes severe, viscous droplets could be noticed either in all or few florets. After the infection has appeared, a fungal growth called sphacelium takes place. Sclerotium – a fungal structure like similar to a lump will appear instead of grain (Fig 2. B). The sclerotia possess different shape, colour and texture based on the millet that is infected. In sorghum, sclerotia is purple or black coloured, elongated, large sized than sorghum and possesses hard texture, while in pearl millet it is pink or dark brown colored, round sometimes elongated possessing hard texture (Das et al., 2017)

Rust

The bacterial disease rust affects Sorghum, Pearl millet and Small millets .*Puccinia purpurea* is the pathogen that causes rust in sorghum. The appearance of reddish brown pustules on the lower leaves on both surfaces indicate rust on sorghum (Thakur et al., 2007). The lower half of the leaves get less infected when compared to the upper half and in advanced infected conditions, rust spread to younger leaves as well. Small pustules amalgamate to form larger patches on the leaves resulting unhealthy appearance of the plant. Premature leaf death takes place due to pustule formation. Pustules are observed in peduncle, midrib, stem and in rest of the plant parts. In the pustules two kinds of spores namely urediniospore and teleutospore are produced by *Puccinia purpurea* (Das et al., 2017).

Pearl millet Rust

Pearl millet rust is caused by *Puccinia substriata var. indica (Syn., P. substriata var. penicillariae*). The appearance of a reddish and round pustule on the leaves indicate rust. Pustules affects the leaves farther half and then spreads to both the surfaces. Rusty sores will be released when the pustule mature. Rust can also be seen in the stem of the plant (Das et al., 2017).

Small millet rust

Rust in kodo millet in caused by *Puccinia substriata*, while *Uromyces eragrostidis* causes rust in finger millet. Foxtail millet rust is caused by *U. setariae-italiae* and the rust in Little millet is caused by *U. linearis* The rust symptoms in small millets is the occurrence of very small brown pustules on the top leaves particularly in the upper surface (Fig 2. D). Rust in small millets are seen fewer in the lower surface and more on the upper surface. Teleutospores are produced by *U. setariae-italicae* and *U. linearis* with yellow and black color respectively. The upper surface of of the leaves in kodo millet possess small brown but oval spots developed by *P. substriata* indicating rust formation (Das et al., 2017).

Bacterial Disease

Bacterial leaf spot

Bacterial leaf spot is a bacterial disease mostly found on Sorghum, Pearl millet, Finger millet. *Pseudomonas syringae pv. syringae* cause bacteria leaf spot disease (BLS) on sorghum and pearl millet while *Xanthomonas eleusinae* causes on finger millet (King et al., 1992, das et al., 2017). These spots are often found the leaves leading to colour changes particularly straw color. Very small and asymmetrical cryptic shaped spots having a

darker margin with straw colored center are seen in the sorghum leaf. In contrast, linear spots are seen in finger millet. It is present on the dual surfaces of the leaf. When the disease gets advanced, the color varies to dark brown from light colour can be observed. The leaves get affected completely leaving a tattered appearance. (Das et al., 2017).

Bacterial leaf stripe

Pseudomonas species, in particular, *Pseudomonas andropogoni, Pseudomonas avenae* and *Pseudomonas eleusinae* cause the bacterial leaf stripe in Sorghum, Pearl millet and Finger millet respectively (King et al., 1992, Das et al., 2017). These bacteria will endure in the soil on the residues from the crop. The affected sorghum leaves will possess red stripes which will be narrow and long. These stripes can be noted in the interveinal leaf part (William et al., 1978). The lesions present can be noted with transudes from *Pseudomonas andropogoni*. In the case of finger millet, the leaf sheath will be brown in the base part and moves upwards. The leaf midrib will be straw colored and run to the tip of the leaf. On some occasions, it could be noted on the margins as well vacating the leaf's central part. On the one side of the leaf there is discoloration extending to the base of the leaf sheath (Das et al., 2017).

Bacterial leaf streak

Sorghum, Pearl millet and small millets are subjected to bacterial leaf streak disease. Bacterias like *Xanthomonas axonopodis pv. holcicola, Xa. pv. Pennamericanum, Xa. pv. coracanae* and *Pseudomonas avenae* cause bacterial leaf streak in sorghum, pearl millet, Finger millet and small millets (Foxtail, Barnyard, Proso millets) respectively. Infected sorghum exhibits the streaks that are water soaked showing reddish margins and tan centers. These are seen in between the leaf veins. Bacterial oozes could be noted coming from the lesions (Das et al., 2017, King et al., 1992). Similarly, in finger millet, there appears streaks which are characterized by color changes from pale yellow to green-brownish, radiant and water-soaked. These symptoms can be noted all along the lamina midrib in a parallel pattern. Premature withering can be noted in the primordial infection stage and in the later stage of infection this will turn to complete brown and causes death and grain loss. (Das et al., 2017).

Bacterial stalk rot

Bacterial stalk rot is also termed as *Erwinia* soft rot. This sorghum bacterial disease is spread by the bacteria *Erwinia chrysanthemi*. The infected sorghum will exhibit leaf withering at a premature stage, as it possesses this infection in the longitudinal patches on the leaf in the upper part. Due to this, the leaf starts drying leading to colour changes to brown from green. The stalk base changes to shaddy reddish brown colour. It is exciting to note that bacterial oozes emerge as white threads when the cut stalk is put in the clean water. The plant stem emits foul smell and the symptoms of stalk rot can be observed. These rots will turn the stalk completely brown. Due to this, the plant withers and dries and forms ragged fibrous tissue. At the initial infectious stage, the plant experiences premature death while crop lodging occurs during the later infectious stage (Das et al., 2017).

Table 2 : Diseases on Minor Millets

Type of Millet	**Disease**	**Pathogen**	**Reference**
Foxtail Millet	Udbatta	*Ephelis sp.*	Nagaraja et al., 2016
	Grain smut	*Ustilago crameri Koem*	Nagaraja et al., 2016
	Blast	*Pyricularia oryzae* *Pyricularia setariae* *Pyricularia grisea*	Pordel et al., 2018 Kumar et al., 2016, Hariprasanna et al., 2017 Sharma et al., 2014
	Leaf blight	*Cochliobolus setariae*	Kumar et al., 2016
	Smut	*Ustilago crameri*	Kumar et al., 2016, Kumar et al., 2011

	Rust	*Uromyces setariae italicae*	Chandrashekar et al., 2006
	Leaf and Sheath brown spot	*Bipolaris australiensis*	Mirezaee et al., 2010
	Bacterial blight	*Xanthomonas coracanae* Desai	Nyyall Robert et al., 1989
	Bacterial Stripe	*Xanthomonas panici*	
	Bacterial spot	*Pseudomonas alboprecipitans*	
	Bacterial leaf spot	*Pseudomonas syringae* van Hall	
Kodo millet	Udbatta	*Ephelis oryzae* Syd. *Balansia oryzae sativae*	Nagaraja et al., 2016
	Sheath rot	*Sarcoladium oryzae*	
	Leaf blight	*Alternaria alternate Drechsler asp.*	
	Head smut	*Sorosporium paspali*	Jain et al., 1999
	Rust	*Puccinia subtriata*	Das et al., 2017, Nagaraja et al., 2016
Barnyard Millet	Head Smut	*Ustilago crusgalli*	Nagaraja et al., 2016, Kumar et al., 2016
	Leaf spot	*Helminthosporium monoceros* Drec. *Colletotrichum frumentacei*	Nagaraja et al., 2016, Kumar et al., 2016 Upadhyaya et al., 2016
	Leaf blight	*Helminthosporium crusgalli*	Nagaraja et al., 2016
	Sheath blight	*Rhizoctonia solani*	Kumar et al., 2009, Kumar et al., 2016
	Grain smut Kernel smut	*Ustilago panici-frumentacei*	Kumar et al., 2016, Upadhyaya et al., 2016, Das et al., 2017, Nagaraja et al., 2016
Proso Millet	Sheath blight	*Rhizoctonia solani*	Kumar et al., 2016
	Head smut	*Phacelotheca destruens*	Das et al., 2017, Nagaraja et al., 2016, Das et al., 2016
	Bacterial leaf blight	*Pseudomonas avenae*	Das et al., 2017, Nagaraja et al., 2016
	Blast	*Pyricularia grisea*	Das et al., 2016
Little Millet	Grain smut	*Tolyposporium sp. Macalpinomyces sharmae V*anky.	Nagaraja et al., 2016
	Leaf blight	*Alternaria alternata*	Praveen et al., 2021
	Rust	*Uromyces linearis*	Das et al., 2017, Nagaraja et al., 2016

Viral Diseases

Maize stripe (MStV-S)

Maize Stripe Virus is a viral disease that affects sorghum. It is propagated by plant hopper *Peregrinus maidis. Maize stripe virus disease* and *Sorghum stripe disease (SStD).* The leaf veins of the infected plant will demonstrate bands or chlorotic stripes in between the vein (Thakur et al., 2007). As the spread of disease takes place from the base to the tip there is variation of colour to yellow from being green. The hallmark feature in the infected plant is the failure to produce earhead along with improper growth (Das et al., 2017).

Maize mosaic (MMV-S)

Peregrinus maidis – a plant hopper is vector of Maize mosaic virus on sorghum. Maize Mosaic Virus infected sorghum will exhibit stunted growth. The veins will possess chlorotic streaks along with lesions which on the disease progression necrotic leading to non-emergence of earhead and plant death (Thakur et al., 2007, Das et al. 2017). If this virus attacks the plant in the later stage, the plant might develop earhead but the grain emergence in such plants would be scanty or nil (Das et al., 2017).

Sorghum Red Stripe virus Disease (SRSD)

Sorghum red stripe virus is primarily transmitted by Aphids on sorghum. The sorghum that are affected display necrotic red stripe along with the reddish colour of the leaves. However, this condition is preceded with the symptoms of mosaic virus as seen in sugarcane. This virus is a potyvirus which is similar to sugarcane mosaic virus. **(Das et al., 2017).**

Ragi severe mosaic

Longiunguis sacchari (Aphid) is known to transmit Ragi severe mosaic virus on small millets. This virus causes stunt growth in the infected plants. The symptoms become quite clear and visible in the newly formed and young leaves. The ears looks to be pale yellow in colour or may be slightly brown or whitish with very minute seeds indicating ear malformation. As the plant grows in age the disease decreases. (Das et al., 2017).

Ragi mottle streak

The spread of Ragi mottle streak virus on Finger millet is carried out by Leaf hopper, *Cicadulina bipunctella* and *Cicadulina chinai.* When the plants that are infected by this virus attains a growth of 6 weeks will display a pattern of shaddy-green areas along the leaf veins. If on the lower leaves, one notices the white specks, that marks that the plants are struck by Ragi mottle streak virus. The diseased plants do possess streak and leaf chlorosis along with stunted growth producing small ears. (Das et al., 2017).

Ragi streak

Ragi streak is a viral disease transmitted by Leaf hopper, *Cicadulina chinai.* Ragi streak is known by the presence of either pale stripes or pale specks on the fresh and young leaves. Away from this symptomatic condition, parallelly running chlorotic bands could be observed in the infected leaf particularly in the midrib portion. The plants that are severely infected yield tillers. Shriveled seeds could be easily detected on the yellowish ears in the affected plants. (Das et al., 2017).

Disease Management in millets

Although millets are rich in nutrient supplements, they are prone to various fungal, bacterial and viral infections leading to complete or partial damage of grains. Proper management of diseases are necessary to increase their productivity and high crop yield. Management strategy includes agronomic measures, use of resistant cultivars, chemical and biological control measure (Figure: 2, Table: 3) (Miedaner et al., 2015, Das 2017)

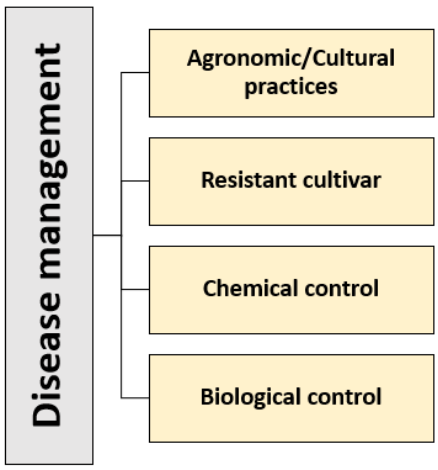

Figure 3: Methods of disease management in millets

Table 3: Important Disease Management in Millets

III.CONCLUSION

Millets are promising crops to combat food sacristy in many famine hit countries. They are easily cultivable as they can survive any extreme climatic conditions, require minimum water and provide clean environment. The disease-causing pathogens, their life cycle, their virulence, host plant interactions, mode of transmission of disease have to be carefully studied by researchers and experts to achieve appropriate management strategy of the diseases adopting integrated approach and bring sustainable development. Methods like resistant cultivars, chemical and biological control measures are adopted to eradicate diseases in millets along with the agronomic cultural practices. This improves the productivity and yield of millets which will contribute to zero hunger in the world.

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