REVIEW

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Emerging Diseases : Need for Focussed Research in small millets

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Finger millet, foxtail millet, kodo millet, little millet, barnyard millet and proso millet together are grouped into 'small millets'. Owing to their nutritional superiority over major food crops like maize, rice and wheat they are now called nutri-cereals. Small millets are rich in crude fibre and are very good sources of iron and calcium (especially ragi). These millets contribute towards balanced diet, and can hence ensure nutritional security more easily through regular consumption along with keeping the environment safe as they are low input crops mostly adapted to marginal lands. Small millets are tolerant to drought and other abiotic stresses particularly high temperatures and poor soils and hence are climate smart. These crops have traditionally been the indispensable component of dry farming system in India and elsewhere. As with other crop species, small millets also are prone for attack by various pathogens causing different diseases. An attempt in this article has been made to cover diseases that are once thought minor becoming major; diseases that are new to crops or those that were reported long back in sporadic form but at times are alarming as 'Emerging diseases' and need for detailed studies on survival and spread, host range, epidemiology *vis-a-vis* management aspects.

Key words: Banded blight, Green ear, Foot rot, Rust, Smuts, Sheath rot, Udbatta

INTRODUCTION

Small millets as a group include several grain crops namely; finger millet (*Ragi*), foxtail millet (*Kangni*), kodo millet (*Kodo*), little millet (*Kutki*), barnyard millet (*Sawan*), and proso millet (*Cheena*). With a long history of cultivation of more than 5000 years, these crops, grown in many states of the country, are quite important in areas of their production as dry land crops, as well as for tribal and hill agriculture.

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They are important components of traditional cropping and food systems contributing significantly to regional food security and diversity in the national food basket. They require small quantity of water, mature early and are well suited for cultivation under scarcity conditions. The resilience exhibited by these crops is helpful in their adjustment to different ecological situations making them ideal crops for climate change and contingency plantings.

Small millets are known for their unique nutritional properties particularly high fibre content, quality protein and mineral composition and contribute sig-

nificantly to nutritional security of some of the most disadvantaged groups. They contain 7-12% protein, 75-85% carbohydrates, 1- 4% fat, 2-3% minerals and 15-20% dietary fibre, besides being rich sources of phyto-chemicals, micronutrients and hence are aptly termed as 'nutri-cereals'. They are known for their nutraceuticular qualities and health benefits besides their nutritional advantages. These small millet grains have long storage life and hence may be termed as 'famine reserves'. Epidemiologically millets are known to be beneficial towards prevention and management of diabetes mellitus, cardiovascular diseases and gastro-intestinal tract related disorders.

Globally, India is the leading producer of small millets with about 20 per cent of the area under these crops. Annual planting area under small millets is around 2.5 m ha. Owing to poor management practices, crops succumb to various biotic and abiotic stresses. Under vulnerable conditions of biotic stresses *viz*.; diseases like Blast, Cercospora leaf spot, Brown spot, Downy mildew/green ear, Smut, Rust and many viral diseases can cause heavy yield losses (Anil Kumar *et al*, 2003; Kumar *et al*, 2007a). Besides these several new diseases, reappearance of diseases that were prevailing in the past and a minor disease in the past that has become major hindering in the production of different millets have been reported and are presented as emerging problems for strengthening the research needs.

Fig.1a: Symptoms of Banded Blight

Banded blight on finger millet and other small millets

Banded blight of finger millet was first recorded in a severe form at Vellayani, Kerala, India (Das and Girija, 1989). Subsequently, the disease was recorded in a severe form in the experimental plots of Birsa Agricultural University, Ranchi, mostly on exotic genotypes (Dubey, 1995). The disease was also observed at Agricultural Research Station, Vizianagaram in a very severe form on varieties KM 252 and RAU-8 (Patro, 2008). Recently during 2006 *kharif*, in Karnataka also the disease was noticed on popular Ragi variety GPU 28 in Narasapur village, Kolar district (Nagaraja and Anjaneya Reddy, 2010a). However during *Kharif* 2009 at Ranchi the disease incidence varied with

Fig. 1b: Colony Morphology of R. solani

variety and highest was recorded on TNAU 1089.

Pathogen

Rhizoctonia solani Kuhn. [Basidial Stage: *Thanatephorus cucumeris* (Fr.) Donk] as described by Dubey (1995). According to Kannaiayan and Prasad (1978), rice sheath blight pathogen *Rhizoctonia solani* can infect finger millet crop, but the finger millet banded blight pathogen *R. solani* AG1 cannot infect rice crop.

Symptoms

The disease is characterized by oval to irregular light grey to dark brown lesions on the lower leaf

and leaf sheath. The central portions of the lesions subsequently turn white with narrow reddish brown boarder. These spots at later stages are distributed irregularly on leaf lamina. Infection may occur in the temperature range from 23-30^{O}C and a relative humidity of 80 per cent or above favours rapid disease development where these lesions enlarge rapidly and coalesce to cover large portions of the sheath and leaf lamina. At this stage the disease symptom is characterized by a series of copper or brown colour bands across the leaves giving a very characteristic banded appearance (Fig. 1a). The mycelial growth along with white to brown sclerotia can be observed on and around the lesions. Later on, the leaves dry up and plants appear blighted. The pathogen was isolated on potato dextrose agar medium and sclerotial bodies were observed (Fig. 1b) (Nagaraja and Anjaneya Reddy, 2010a).

Fig. 1c: Banded blight on foxtail millet, little millet, proso millet, barnyard millet and kodo in sequence

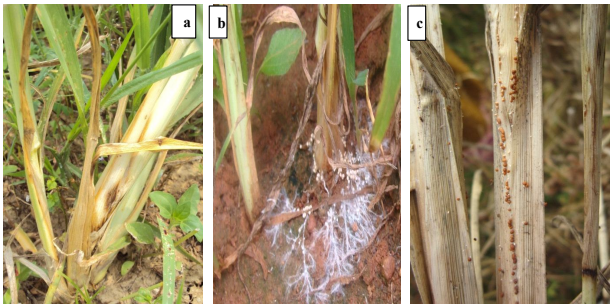

Fig. 2a : Water soaked brown lesion **(b)** Mycelium and **(c)** Mustard seed like sclerotia

In severe cases, symptoms appear on peduncles, fingers and glumes as irregular to oval, dark brown to purplish to brown necrotic lesions. Early infection on peduncle is similar to neck rot resulting in poor grain filling. Infected glumes produce smaller and shrivelled grains. The symptoms produced on every part of the plant, give a very characteristic banded appearance, hence the name 'Banded blight' (Dubey, 1995).

Recently the disease has been reported on all the small millet crops (Fig. 1c) at different AICRP centres situated in different states.

Foot rot on finger millet

Coleman (1920) was the first in India to record the occurrence of *Sclerotium rolfsii* from the princely state of Mysore. Subsequently, it was reported from the former Madras Presidency, Coimbatore (Anon, 1954), Odisha (Narain, 1972), Madhya Pradesh (Jain *et al*, 1994), Uttarakhand (Bhatt *et al*, 1985; Kumar and Prasad, 2010) and Gujarat (Waghunde *et al*, 2011).

The disease is on the rise and especially severe in heavy rainfall areas of Maharashtra and Gujarat states and irrigated Ragi in Mandya district of Karnataka.

Symptoms

The disease appears randomly in the field. The infection occurs around the collar region and the infected area being restricted to 5 to 7.5 cm above ground level. Normally, at a stage when plants are flowering or setting seeds, the plants are attacked due to the debility of the stem as the movement of photosynthetic material is towards sink.

The basal portion of affected plant immediately above the ground initially appears water soaked due to infection by the pathogen (Fig. 2a). Later on it turns brown and subsequently dark brown with a concomitant shrinking of the stem in the affected region. Profuse white cottony mycelial growth occurs in this area. Soon small roundish white velvety grain like structures starts appearing in the fungal matrix (Fig 2b). They grow, become mus-

Fig. 3a: Severely rust infected finger millet crop

tard seed like, turn brown and develop into sclerotial bodies (Fig. 2c**)**. Meanwhile the leaves loose their lustre, droop and dry. Ultimately, the plant dries up prematurely.

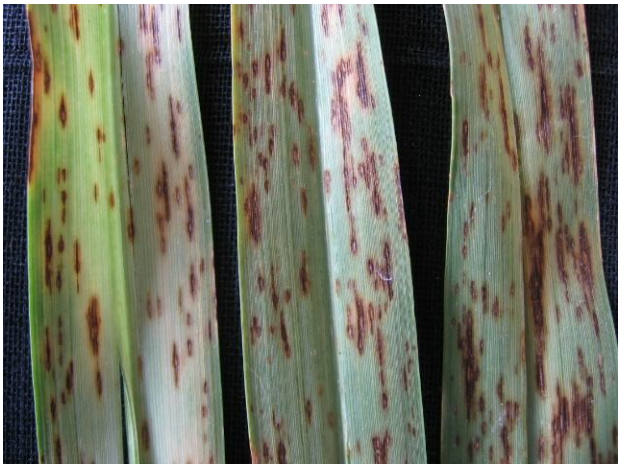

Fig. 3b : Rust pustules on ragi leaves

Causal fungus is described as *Sclerotium rolfsii* (Sacc.) Curzi. (Perfect Stage *Pellicularia rolfsii*) which is for wide host range (>500) and thus is present in almost all soils. At the end of the crop season, enormous sclerotial bodies are produced from the growth that had occurred on the host plant. The sclerotia find their way to soil, move through rainwater from field to field.

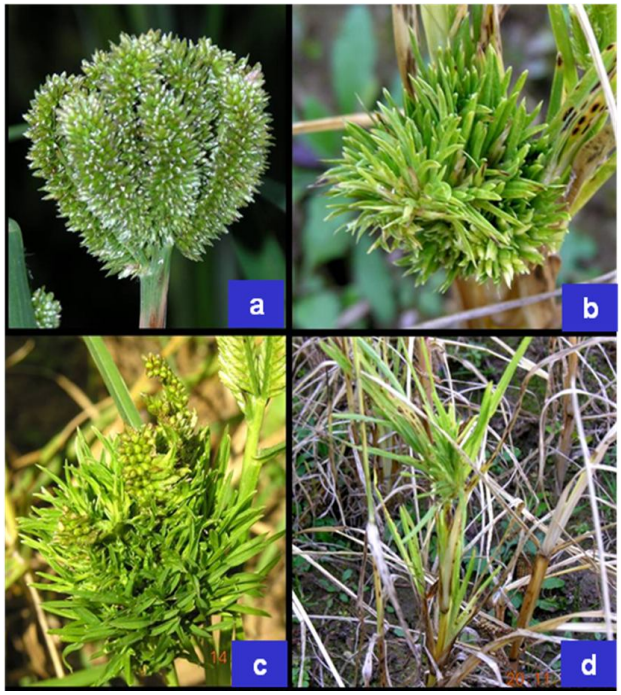

Fig. 4 : Symptoms of downy mildew or green ear disease: **(a)** healthy ear; **(b)** fully affected ear converted into green ear; **(c)** partially affected ear; **(d)** proliferation of foliage from auxiliary internodes

Rust on Finger millet

Rust in finger millet was reported from Karnataka (Lucy Channamma *et al*, 1996) and tribal belts of Andhra Pradesh (Patro and Rani, 2008) in severe form hitherto it was considered as a minor men-

Fig. 5a : Symptoms of Udbatta on Kodo

Fig. 5b: Colony morphology of Ephelis sp

ace on finger millet. Symptoms on leaf appeared as a small, cinnamon colour pustules, linearly arranged on the upper surface of the top leaves (Fig. 3a and b). The uredospores were pedicillate, ellipsoidal, thick, smooth walled with four equatorial germpores and the pathogen was identified as *Uromyces eragrostidis* with HCIO No.46,915 at Division of Plant Pathology, IARI, New Delhi. on ragi leaves

Fig. 6a : Gall like swellings on leaf axils **b)** on stem **c)** on ear exposing spores

Green Ear or Downy Mildew or Crazy Top of finger millet

The disease was reported for the first time in India by Venkatarayan (1947) from old Mysore state. Subsequently, the disease has also been reported from Tamil Nadu and more recently from Uttarakhand (Kumar *et al*, 2007b). Though reported to occur in a sporadic manner but may lead to total crop failure as the affected ears are malformed, it appeared with very severe intensity (~50%) during 2014 *Kharif* season in Gubbi taluk, Tumkur dist., Karnataka on GPU 28 and PR 202 varieties.

Fig. 7a : Healthy ear and **(b)** Udbatta affected panicle

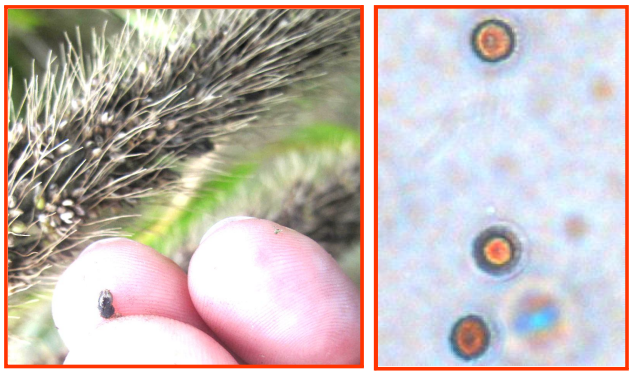

Fig. 8a : Smutted foxtail millet grains;**b**) Echinulated spores

Fig. 9: Lesions of kodo sheath rot

Symptoms

Affected plants are generally stunted with shortened internodes and profuse tillering. The plant assumes a bunchy and bushy appearance. Often, pale yellow translucent spots are seen on leaves of affected plants. The white cottony growth, characteristic of

many downy mildews, is generally not seen in the downy mildew of finger millet. As a result, the asexual phase quite often goes unnoticed.

The green ear manifests itself at the time of grain formation and completely converts the ear heads into green narrow leafy structures causing complete sterility. Partial or whole ear including lemma, palea and glumes convert into narrow leafy structures. The proliferation takes place first in the basal spikelets and afterwards others get affected. Finally the whole ear gives a bush-like appearance displaying typical 'green ear' symptom (Fig. 4). Partially infected ears also fail to produce grains. However, leaves of infected plants does not show any change in their external morphology. Growth of auxiliary leafy structures from internodes has also been observed (Kumar *et al*, 2007b).

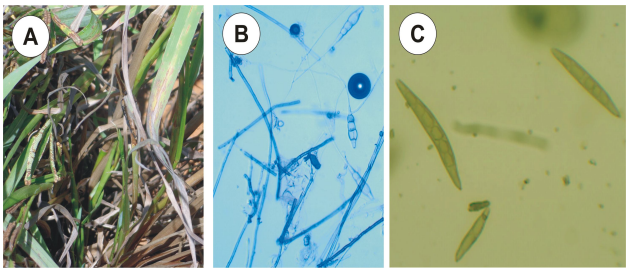

Fig. 10 a : Leaf blight of kodo millet; **b)** Alternaria and **c)** Drechslera conidia

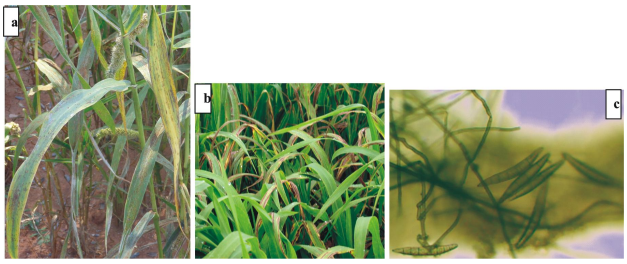

Fig. 11 a : Leaf spot and **b)** leaf blight symptoms of barnyard millet; **c)** Conidia

Pathogen

Sclerophthora macrospora (Sacc.) Thirum., Shaw and Naras. Syn. *Sclerospora macrospora* Sacc.

Udbatta on Kodomillet

Udbatta disease was earlier noticed as pandemic and of minor importance in certain paddy growing areas by Butler and Bisby (1931), is incited by *Ephelis oryzae* Syd. has its perfect stage in *Balansia oryzae sativae* Hashioka. The disease was noticed on several host plants such as grasses *Cynadon dactylon*. *Pennisetum sp* and *Ergostis tenufolia* (Govindu and Thirumalachar, 1961; Ranganathaiah, 1972) and little millet (Mohanti *et al*, 1969).

During rainy season of 2008, the disease was found in sporadic way on Kodo millet in the experimental plots of All India Coordinated Research Project on Small Millets, GKVK farm, Bengaluru, Karnataka. Kodo millet Variety RBK 155 has recorded highest disease incidence of 19.56 per cent (Nagaraja *et al*, 2010).

Symptoms

The disease symptoms appeared during panicle initiation stage. In the panicle, the grains get infected and the entire panicle converts into hard dirty/silver coloured cylindrical spike resembling that of udbatta disease in paddy (Fig. 5a). White mycelium and conidia form narrow stripes on the flag leaves along the veins before the panicle emerges. No grains are formed on the affected panicle.

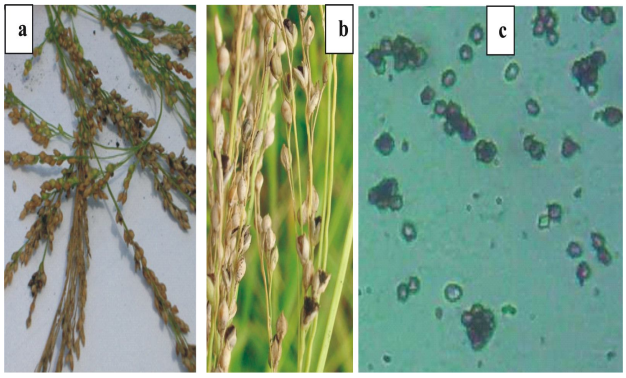

Fig. 12 : Grain smut of little millet: **a and b)** Infected panicles **c)** Teliospores

Colony morphology of Causal fungus Ephelis sp.

Culture established on potato dextrose agar medium within 15 days after inoculation. The colony appears dull white with dull brown specks. The surface of the colony was thin, flat and waxy having edges with lobate margin (Fig. 5b) (Nagaraja *et al*, 2010).

Head smut on barnyard millet

Barnyard millet grown for both grain and fodder purposes in India, is quite popular in the hills of Uttarakhand as a component of tribal agriculture. In major growing areas, the crop suffers from grain smut disease. The head smut disease (*Ustilago*

crusgalli) on this crop has been recorded from Madhya Pradesh (Mundkur, 1943) and more recently from Uttarakhand (Kumar *et al*, 2008) and Bengaluru, Karnataka **(**Nagaraja and Anjaneya Reddy, 2010b).

Symptoms

The disease appeared as deformation of the inflorescence with gall like swellings on the stem, the nodes of young shoots, in the axils of the older leaves and in the ear (Fig. 6a, b and c). The disease is occurred late in the season at grain filling stage. The smuts are the important diseases, which cause considerable losses to barnyard millet. However, the details of etiology, mode of transmission, and management may have to be initiated.

Udbatta on foxtail millet- Reappearance of a forgotten disease in Karnataka

In India, Udbatta on foxtail millet was reported by Venkatakrishniah (1952), later on the disease was also reported from madhya Pradesh (Mishra and Pall, 1975). The Udbatta disease causes significant yield losses in areas where it is endemic, but its occurrence is generally sporadic and of minor importance.

Symptoms

Spikes infected by *Ephelis* sp. become somewhat mummified with partially formed buds and, in time, become darker in colour and more stromatic as conidial acervuli develop on the surface. When wet, these conidial acervuli appear gelatinous and produce a saucer-shaped fructification bearing a palisade of conidiophores. Infected plants are usually stunted and occasionally the white mycelium and conidia form narrow stripes on the flag leaves along the veins prior to panicle emergence. The flag leaf and sheath of infected tillers are sometimes slightly distorted and the upper leaves (including the flag leaf) may appear silvery. Symptoms first become evident at the time of panicle emergence. While still within the sheaths, panicles become matted together by the mycelium of the fungus (Fig. 7a and b). They emerge as single, small, cylindrical rods, covered with white mycelium that becomes hard and sclerotium-like, bearing many black dots. An erect, greyish-white axis emerges from the leaf sheath in place of a normal inflorescence.

Grain smut of foxtail millet

Grain smut disease of foxtail millet has been reported from Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra (Pall *et al*, 1980), however, in Uttarakhand, the disease has been recorded for the first time in 2010 (Kumar, 2011) in a routine survey for incidence of diseases of small millets in the district Tehri-Garhwal, during 2010. At Hill campus, Ranichauri (UK), the incidence of disease was recorded from 0.0 to 75% in different varieties with the highest incidence in RAU 2 followed by 60 % in PS 4 and TNAU 264.

Symptoms

The disease manifested itself at the time of ear formation. Pale greyish to dark brown sori were seen in the flowers initially which later turned black. The fungus is known to affect most of the grains in an ear but sometimes terminal portion of the spike may escape, producing sori in the flowers and basal parts of the palea. After the rupture of sori dark black powdery mass of spores could easily be seen on the infected ear heads (Fig. 8a).

Pathogen

The disease is known to be caused by the basidiomycetous fungus *Ustilago crameri* Koem. In microscopic examination, the spores were dark brown, echinulated and angular or round in shape (Fig. 8b).

Sheath rot of Kodo millet

In Vrudhachalam area of Tamil Nadu kodo millet is taken as rabi / summer crop after paddy and sheath rot is of very common occurrence. The disease reduces grain yield by retarding or aborting panicle emergence, and producing unfilled seeds and sterile panicles. Sheath Rot also reduces grain quality by causing panicles to rot and grains to become discoloured.

Symptoms

The typical sheath rot lesion starts at the uppermost leaf sheath enclosing the young panicles. It appears oblong or as irregular spot with dark reddish, brown margins, and gray center or brownish gray throughout. Usually several spots are observed and these spots enlarge and coalesce or grow together and can cover most of the leaf sheath (Fig. 9). Panicles remain within the sheath or may partially emerge. Affected leaf sheaths may have abundant whitish powdery fungal growth

(mycelium) visible on the outer surface. Unemerged panicles rot and florets turn red-brown to dark brown.

Pathogen

Sarocladium oryzae (Sawada) W. Gams & D. Hawksworth Infected seeds and mycelium carried by the rice crop residue play an important role as primary source of inoculum.

Leaf blight of Kodo

The disease was reported for the first time in India from Kanpur (U.P.) during 1980 by Gupta *et al,* (1982) and further observed in 20 districts of Uttar Pradesh with higher severity in Allahabad, Faizabad, Gorakhpur and Varanasi regions (Gupta *et al*, 1994). During *Kharif* 2013 it appeared in a severe form on Kodo millet Advanced variety RK 58 and local check RK 390-25 showing 4.5 and 4 grades respectively. During 2014 *Kharif* also the disease was noticed in moderate to severe intensity both at Bengaluru (Karnataka) and Dindori (MP).

Symptoms

Pale and straw coloured small scattered lesions are formed on the leaf blade. Severely affected plant showed a blighted appearance causing premature drying of leaves from tip to downwards (Fig. 10a). Although, *Alternaria alternata* (Fr.) Keissl. is reported as the cause, isolation studies have revealed the presence of both *Alternaria* (Fig. 10b) and *Drechslera* (Fig. 10c) species.

Leaf spot and leaf blight of barnyard millet

Leaf spot or blight was first reported in 1923 by Drechsler from the USA. The disease is also reported from Japan, China and India. The disease is most common under humid conditions. This is a serious problem in cultivation of barnyard millet in Uttarakhand.

Symptoms

The disease appears as isolated, dark brown or chocolaty, scattered and spindle shaped spots, measuring 0.3 to 1mm on leaves (Fig. 11a). Later on, these spots increase in their size, measuring 1.5 to 5mm long. Afterwards, several such spots coalesce, cover the entire leaf, which becomes grey, and dry up. The spots are dark brown to grey in colour and surrounded by yellow halo. Just after the appearance of the lesions, dark points are visible in the centre. Under humid conditions, fungal growth is visible on these spots. In severe form the leaves show blightening (Fig. 11b). Similar spots can also be seen on the leaf sheath.

Pathogen

Helminthosporium monoceros Drec. [Syn. *Helminthosporium crusgalli* Nisikado and Miyake] Conidiophores emerge either through stomata or outer wall of the epidermal cells, singly or in clusters of two to five. They are slightly swollen at the base, septate, dark olivaceous brown in colour, produce 4-6 conidia. The condia are slightly curved or straight, thin walled, fusoid, yellowish, 3-11 septate and 49-158µm x 10-15.5µm in size (Fig. 11c).

Grain smut of little millet

In India, the disease was first reported by Sharma and Khare (1987) from Dindori district of Madhya Pradesh. Later on, the disease reported in severe form in early maturing varieties (Jain, 2003). The disease was also recorded in the states of Tamil Nadu and Jharkhand. Up to 9.8 to 53.5 per cent reduction in grain yield per plant, 4.2 to 16.6 per cent in plant height and 6.4 to 38.9 per cent in panicle length were reported due to grain smut.

Symptoms

Characteristic symptoms of grain smut appear at grain formation stage. A few to all grains of a panicle are transformed into smut sori. The affected ovary is converted into smut sorus, but does not increase in size than the normal grain (Fig. 12a and b). The sorus is covered by thin dull delicate membrane, which is easily pushed away leaving the sorus exposed. The spores are easily blown away leaving nothing inside the glumes. Some of the late developing grains remain greenish and increase in size slightly over the normal grains.

Pathogen

Earlier the causal organism was identified as *Tolyposporium* sp. (Sharma and Khare, 1987) later on Vanky (1995) confirmed it as *Macalpinomyces sharmae* Vanky. Teliospores of the fungus are agglomerated into dark reddish brown spore balls. Individual spores are sub-globose, ovoid, yellowish brown, thin balled, finely and densely punctu-

ate-verruculose (Fig. 12c).

Conclusion

Small millets are important poor man's crops and the occurrence of these new diseases and their increasing level of severity affect crop production. Hence, research should focus on these diseases to understand the aetiology, nature of survival and spread of the pathogen, epidemiological aspects of the disease including host range and cross infectivity *vis-a-vis* location of resistant sources to develop suitable management strategies especially through an integrated approach.

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