Golden Jubilee Publication Series

अ.भा.स.अ.प. (चारा)
AICRP Forage

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Technological Advances in Forage Crop Protection

All India Coordinated Research Project on Forage Crops & Utilization

(Indian Council of Agricultural Research)

ICAR-IGFRI, Jhansi-284 003 (U.P.)

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अखिल भारतीय समन्वयित अनुसंधान परियोजना
चारा फसलें एवं उपयोगिता
(भारतीय कृषि अनुसंधान परिषद)
भा.कृ.अनु.प.-भा.च.चा.अनु.सं., झाँसी-284 003 (उ.प्र.)

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Authors

N. R. Bhardwaj, D. K. Banyal, Ashlesha Atri, Arabinda Dhal, Sandeep Langde, Annasaheb Tambe, Pravasini Behra, Ritu Mawar, R. B. Bhaskar, Subhash Chand, R. K. Agrawal and A. K. Roy

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Project Coordinator
AICRP on Forage Crops & Utilization,
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भाकृअनुप
ICAR

Indian Council of Agricultural Research
Ministry of Agriculture and Farmers Welfare
Govt. of India, Krishi Bhavan
New Delhi 110001, India

डॉ. तिलक राज शर्मा
उप महानिदेशक (फसल विज्ञान)
Dr. T. R. Sharma, Ph.D
FNA, FNAAS, FNASc, JC Bose National Fellow
Deputy Director General (Crop Science)

Message

Crop losses inflicted by different diseases and insect-pests are major constraints in achieving the targeted and sustainable productivity of forage crops. Thus, it is essential that suitable crop protection technologies be generated for minimizing these crop losses in the forage crops. ICAR-All India Coordinated Research Project on Forage Crops and Utilization through its multilocation experiments and trials has generated many protection technologies against major insect-pests and diseases in different forage crops growing in various agro-climatic conditions.

I am glad to know that ICAR-All India Coordinated Research Project on Forage Crops and Utilization on the occasion of its Golden Jubilee year has made an effort to compile forage crop protection technologies developed through concerted efforts of scientist located in different places in the country in the form of a bulletin. The bulletin contains information about causal organism, symptoms, and protection technologies on 10 major fodder crops along with high quality photographs for its practical use. I am sure that this compilation of forage crop protection technologies will help stakeholders in augmenting forage production and maintaining the quality of the produce as well as end products.

I extend my heartiest congratulation to Dr. A.K. Roy, Project Coordinator, All India Coordinated Research Project on Forage Crops and Utilization and his team for preparing this important bulletin.

(T.R. Sharma)

E-mail: ddgcs.icar@nic.in Phone: 91-11-23382545 Fax: 91-11-23097003

Preface

At present, the country faces a net deficit of 11.24% in green fodder, 23.4% in dry crop residue, and 28.9% in concentrated feed ingredients. In addition to the above-mentioned problems, pests and diseases causes a significant effect on the establishment, yield, and longevity of grass and forage crops. Practicing intensive fodder production systems to produce maximum forage per unit area because of limited availability of land for forage crops provides more favorable conditions for multiplication of pests. Moreover, climate change conditions are becoming even more congenial for reproduction and development of these pests. Various forage crops are grown in different parts of the country which varies as per agro-ecological conditions as well as season. Therefore, it is very important to develop suitable location as well as region specific and feasible crop protection technologies for the benefit of the farmers. During last two decades, various technologies aimed at different disease and insect-pests in different forages have been generated in AICRP on Forage Crops and Utilization by multilocation testing. In this bulletin, efforts have been made to provide information on description of major pests and diseases in forage crops along with the recommended technology for their management. We express our sincere thanks and gratefulness to ICAR for providing guidance, funds and support to AICRP on Forage Crops and Utilization for developing these technologies.

Authors

Contents

1. Need of forage crop protection technologies

Introduction

India accounts for around 17% of human population and 15% of world's livestock population on just 2% of the world's total geographical area, which indicates enormous biotic pressure on the land. Indian livestock population is 536.76 million at present showing an increase of 4.8% over the livestock census-2012 (Anonymous, 2019). In order to sustain this vast livestock population and to meet the growing demand for milk and meat of ever increasing human population, fodder crops will certainly play a very important role. At present, the country faces a net deficit of 11.24% in green fodder, 23.4% in dry crop residue, and 28.9% in concentrated feed ingredients (Roy *et al*., 2019). In addition to the above-mentioned problems, pests and diseases can have a significant effect on the establishment, yield, and longevity of grass and forage crops. As with other agricultural crops, forage crops are subject to damage from pests and diseases that hamper crop establishment, impair forage quality, and reduce green fodder and seed yield. Pests and diseases also cause indirect losses, such as reduced nodule formation in legumes, eventually resulting in the reduction of nitrogen fixation capacity.

Major diseases and pests in forage crops

Prevalence of pests and diseases lead to reduction in fodder production seed production and also deterioration in nutritive quality and ultimately profitability of farmer. Severe problem may even lead to the abandonment of cultivated species. A large number of pests have been found associated with a variety of fodder crops grown in different parts of the country (Table 1). In addition, grasslands normally support and can tolerate large number of pests and recent evidence suggests that there are some situations where damage is more likely to occur especially during the establishing period of young seedlings. Moreover, grasslands act as reservoir of pests which later can infect/infest cultivated food crops.

Table 1 : Major diseases and insect-pests of forage crops (Modified from Saxena *et al*., 2002)

Berseem (*Trifolium alexandrinum*)	
Diseases	Stem rot (*Sclerotinia trifoliorum*)
Insect-pests	Hairy caterpillars (*Euproctis virguncula* and *E. lunata*), Semilooper (*Plusia nigrisigna, P. orichalcea*), Pod borer (*Helicoverpa armigera*),

	Red pumpkin beetle (*Raphidopalpa favcicollis*), Red cotton bug (*Dysdercus koenigii*), Aphid (*Aphis craccivora*), Stunt nematode (*Tylenchorhynchus vulgaris*)
Oat (*Avena sativa*)	
Diseases	Leaf blotch (*Drechslera avenae*), Crown rust (*Puccinia coronata*), Stem rust (*Puccinia graminis* f. sp. *avenae*), Powdery mildew (*Blumeria graminis* f. sp. *avenae*)
Insect-pests	Aphid (*Rhapalosiphum padi*), Cyst nematode (*Heterodera avenae*), Root-knot nematode (*Meloidogyne javanica*), Stunt nematode (*Tylenchorhynchus* sp.)
Lucerne (*Medicago sativa*)	
Diseases	Downy mildew (*Peronospora trifoliorum*), Rust (*Uromyces striatus*), Common leaf spot (*Pseudopeziza medicaginis*), Anthracnose (*Colletotrichum trifolii*), Crown wart (*Physoderma alfalfae*), Leaf spot (*Cercospora medicaginis, Stemphylium botryosum, Alternaria medicaginis, Xanthomonas alfalfae*), Powdery mildew (*Erysiphe polygoni*), Mosaic (*Alfalfa mosaic virus*), Wilt (*Fusarium* sp.), Crown and root rot (*Sclerotinia trifoliorum*), Damping off or Root rot (*Phytophthora megasperma*)
Insect-pests	Leaf hoppers (*Exitianus indicus, Austroagalia* sp., *Macrosteles* sp. and *Empoasca* sp.), Alfalfa weevil, (*Hypera postica*), Grey weevil, (*Myllocerus mosolosus*), Alfalfa caterpillar, (*Spodoptera exigua*), Tobacco caterpillar (*S. litura*), Semilooper, (*Plusia nigrisigna, P. orichalcea*), Clover cyst nematode (*Heterodera trifolii*)
White Clover (*Trifolium repens*)	
Diseases	Powdery mildew (*Erysiphe trifolii*), clover rot/crown & stem rot (*Sclerotinia trifoliorum*)

Cowpea (*Vigna unguiculata*)	
Diseases	Anthracnose (*Colletotrichum lindemuthianum*), Bacterial blight (*Xanthomonas campestris* pv. *vignicola*), Root rot (*Macrophomina phaseolina*), Seedling rot (*Rhizoctonia solani, Pythium, Sclerotium, Phytophthora*), cowpea mosaic virus, Powdery mildew (*Erysiphe polygoni*)
Insect-pests	Leafhoppers (*Empoasca kerri*), Flea beetle (*Pagria signata, Modurasia* sp), Tobacco caterpillar (*Spodoptera litura*), Semilooper (*Plusia nigrisigna*), Aphid (*Aphis craccivora*), Grasshoppers (*Colemania sphenarioides, Chrotogonus trachyapterus and Attractomorpha crenulata*), Blister beetle (*Mylabris postulata*)
Sorghum (*Sorghum bicolor*)	
Diseases	Anthracnose (*Colletotrichum graminicola*), Sooty stripe (*Ramulisporia sorghi*), Zonate leaf spot (*Gloeocercospora sorghi*), Gray leaf spot (*Cercospora sorghi*), Downy mildew (*Scleropsora sorghi*)
Insect-pests	Shoot fly (*Atherigona soccata*), Stem borer (*Chilo partellus*), Aphids (*Rhopalosiphum maydis*), Sorghum midge (*Contarinia sorghicola*), Army worm (*Mythimna separata, Spodoptera exigua*) Sorghum cyst nematode (*Heterodera sorghi*)
Maize (*Zea mays*)	
Diseases	Brown stripe downy mildew (*Sclerophthora rayssiae* var. *zeae*), Turcicum leaf blight (*Exserohilum turcicum*), Maydis leaf blight (*Bipolaris maydis*), Bacterial stalk rot (*Erwinia carotovora* var. *zeae*)
Insect-pests	Shoot fly (*Atherigona soccata*), Fall armyworm (*Spodoptera frugiperda*), Stem borer (*Chilo partellus*), Aphids (*Rhopalosiphum maydis*), Maize cyst nematode (*Heterodera zeae*)
Pearl millet (*Pennisetum glaucum*)	
Diseases	Downy mildew (*Sclerospora graminicola*), Ergot (*Claviceps fusiformis*), Blast (*Magnaporthe grisea*)

Insect-pests	Shoot fly (*Atherigona soccata*), Stem borer (*Chilo partellus*)
Guar (*Cyamopsis tetragonoloba* Linn. Taub.)	
Diseases	Leaf spot (*Alternaria cyamopsidis*), Blight (*Xanthomonas campestris* pv. *cyamopsidis*), Powdery mildew (*Erysiphe polygoni*), Root rot (*Rhizoctonia solani*), Anthracnose (*C. lindemuthianum*)
Insect-pests	Flea beetle (*Pagria signata*), Leaf roller (*Anarsia epipias*), Leafhoppers (*Empoasca* sp.), Root-knot nematode (*M. incognita*), Reniform nematode (*Rotylenchulus reniformis*)
Range grasses	
Diseases	Rust (*Puccinia* and *Uromyces* spp.), Leaf spots (*Curvularia, Pyricularia, Colletotrichum* spp.)
Insect-pests	Grasshoppers (*Hieroglyphus nigrorepletus, Catantops pinguis, Oedaleus abruptus, Chrotogonus trachypterus, Aelopus tamulus, Colemania* sp., *Oxya* sp., *Locusta migratoria, Attractomorpha* sp.)

Forage crop protection scenario in fodder crops:

In order to meet the growing demand borne out of increasing livestock population, the productivity of the fodder crops and efficient utilization of the arable land becomes essential factors. Moreover, for the sustainability of any fodder production system, level of plant diseases and pests should be contained below a threshold value. Pests as a whole are responsible for yield losses ranging between 20 and 40% of global agricultural productivity with diseases in particular accounting for losses between 9.7% to 15.7% (Oerke *et al*., 1994; Oerke, 2006). In major fodder crops also, quantitative and qualitative losses caused by these biological stress factors have been reviewed (Ahmed *et al*., 1996; Saxena *et al*., 2002). Disease/insect-pest management in forages is not given that much importance. But, in this era of climate change, epidemics could take its toll on forages and it can lead to significant losses in terms of forage production, aggravating the present deficit of green and dry fodder as mentioned above. Varieties possessing effective resistance against diseases and insect-pests are lacking in forages due to complex nature of these diseases. Thus, there is a need of generation of suitable crop protection technologies in forage crops. In ICAR-AICRP on Forage crops

and Utilization efforts are made in the past on generation of suitable crop protection technologies against major diseases and insect-pests. These technologies along with appropriate disease/insect-pest illustration will be discussed in this bulletin.

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2. Technologies generated in fodder Cowpea

Collar rot of cowpea

Symptoms: The first visible symptom is a progressive, yellowing and wilting of the foliage beginning from the lower leaves resulting in plant death. Brown, vascular discoloration inside the affected stem extending several inches above the soil line is also observed. During favorable conditions, white mycelium makes characteristic fan-shaped patterns of growth on the stem at the soil line in which numerous smooth, round, light-tan to dark-brown mustard seed-like sclerotia are formed.

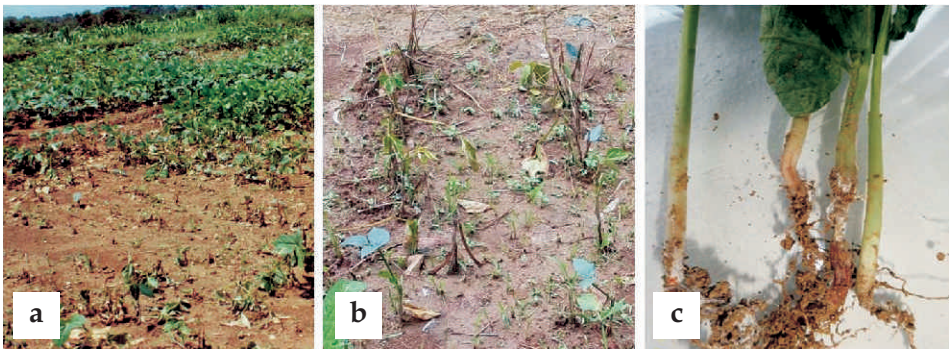

Fig. 1: Cowpea severely affected by collar rot (a, b) and close up view of collar region of cowpea showing mycelia of the fungus (c)

Pathogen: *Sclerotium rolfsii* Sacc.

Favourable conditions for development: Disease is favoured by warm, moist soil conditions.

Charcoal rot

Symptoms: The seedlings become stunted and develop rot in the hypocotyls region extending downwards. Leaves become blighted with numerous small microsclerotia visible on the blighted portion. Roots also shows rotting and seedlings get dried. In mature cowpea plants, grayish black sunken lesions appear on the lower stem and roots containing small black sclerotia.

Pathogen: *Macrophomina phaseolina* (Tassi) Goid

Favourable conditions for development: *M. phaseolina* survives as microsclerotia in the soil and on infected plant debris. The microsclerotia serve as the primary source of inoculum and have been found to persist within the soil up to three years. Hot, dry weather promotes infection and development of charcoal rot.

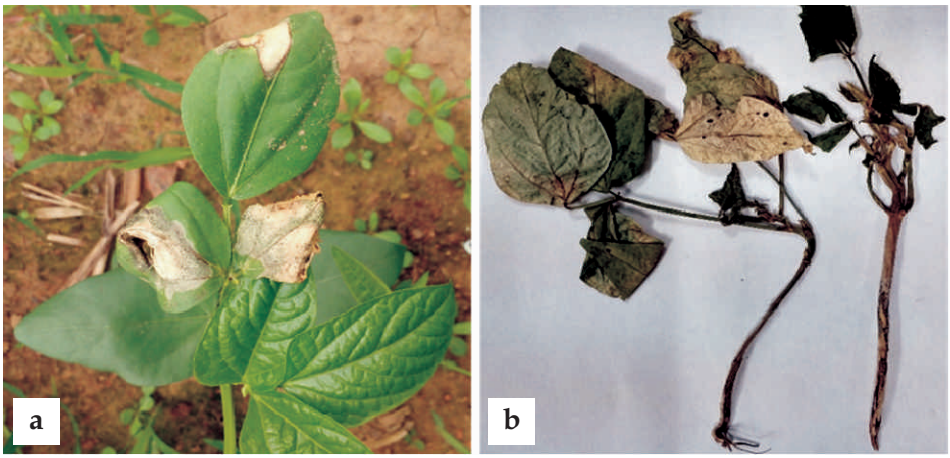

Fig. 2: Leaf blight (a) and charcoal rot of Cowpea (b)

Recommended technologies for collar and charcoal rot management:

1. Use of resistant varieties such as UPC-5286, UPC-607, UPC-622 and UPC-628.
2. Seed treatment with *Trichoderma viride* @ 5 g/kg seed (CFU 10^6/gm of formulation) + FYM @ 2 t/ha.
3. Seed treatment with tebuconazole 2DS @ 1g/kg seed + NSKP (50 g/kg seed) followed by two foliar sprays of 0.1 per cent propiconazole at 15 day interval.

Anthracnose

Symptoms: Brown sunken lesions with dark red margins develop on the stems, branches, peduncle, petiole, pods and leaves. Elongated lesions appear on the leaf veins and tannish red spots with yellow halo on the leaf surface. Severely affected pods are curled and do not contain normal size seeds.

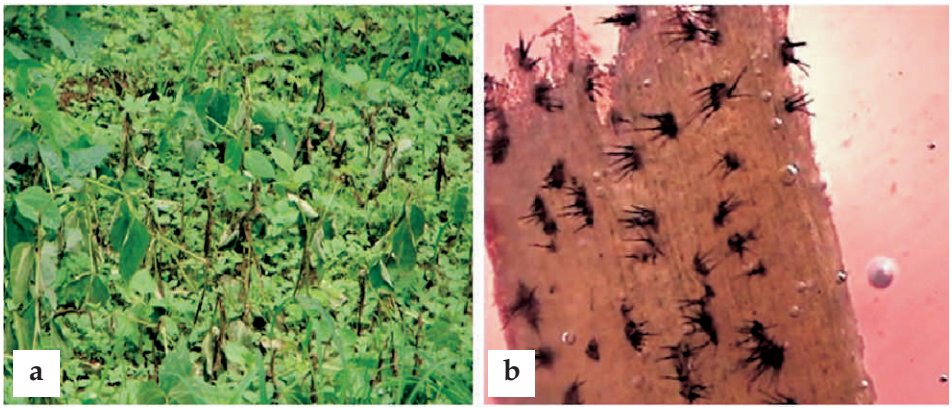

Fig. 3: Cowpea crop severely affected by anthracnose (a) and close up of acervulii showing numerous setae of the pathogen on the affected plant part (b)

Pathogen: *Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri. and Cav.

Favourable conditions for development: Disease spread is rapid during cool, wet weather.

Septoria leaf spot

Symptoms: Small, pinhead size, reddish brown, circular, water soaked scattered spots on both the surface of leaves. Spots later turn light brown with dark brown margins and rapidly enlarge to irregular lesions.

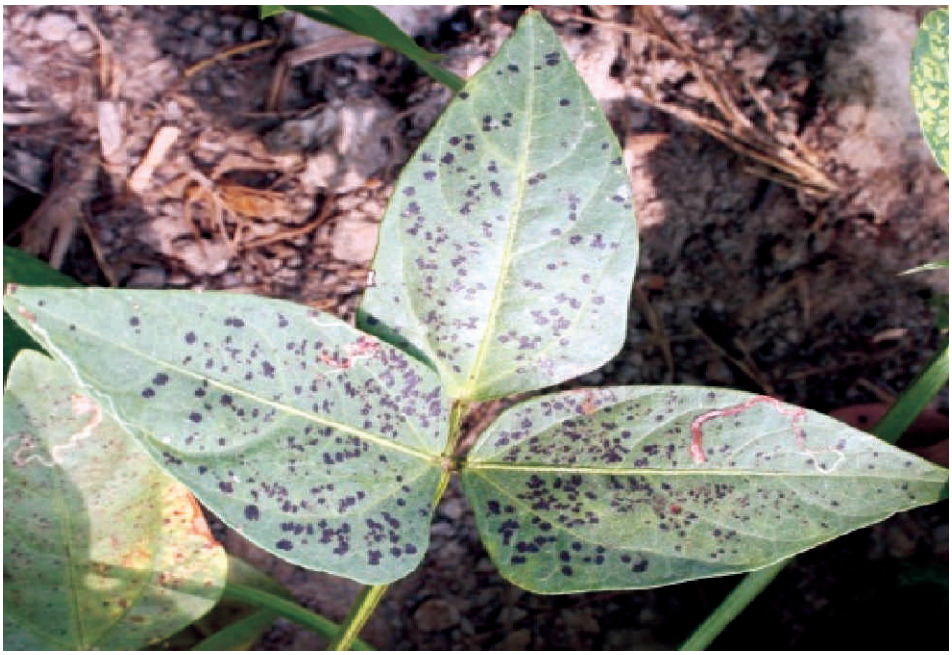

Fig. 4: Septoria leaf spot of cowpea

Pathogen: *Septoria vignae* P. Henn.

Favourable conditions for development: Disease spread is rapid during cool, wet weather.

Recommended technologies for anthracnose and septoria leaf spot management:

1. Use of resistant varieties such as UPC-5286, UPC-607, UPC-622 and UPC-628.
2. Seed treatment with tebuconazole 2DS @ 1g/kg seed + NSKP (50 g/kg seed) followed by two foliar sprays of 0.1 per cent propiconazole at 15 day interval.

Cowpea mosaic

Symptoms: Several viruses cause disease in cowpea. These viruses produce a mosaic pattern (intermixing of green and yellow patches) on

leaves. They may be found singly or in combination with others. Some viruses cause thickened, malformed and distorted leaves. The mosaic patterns are best observed on the younger foliage. If the disease attacks plants at the early growth stage, no pods should be expected. The most common virus disease on cowpeas is cowpea aphid borne mosaic. It is transmitted by aphids.

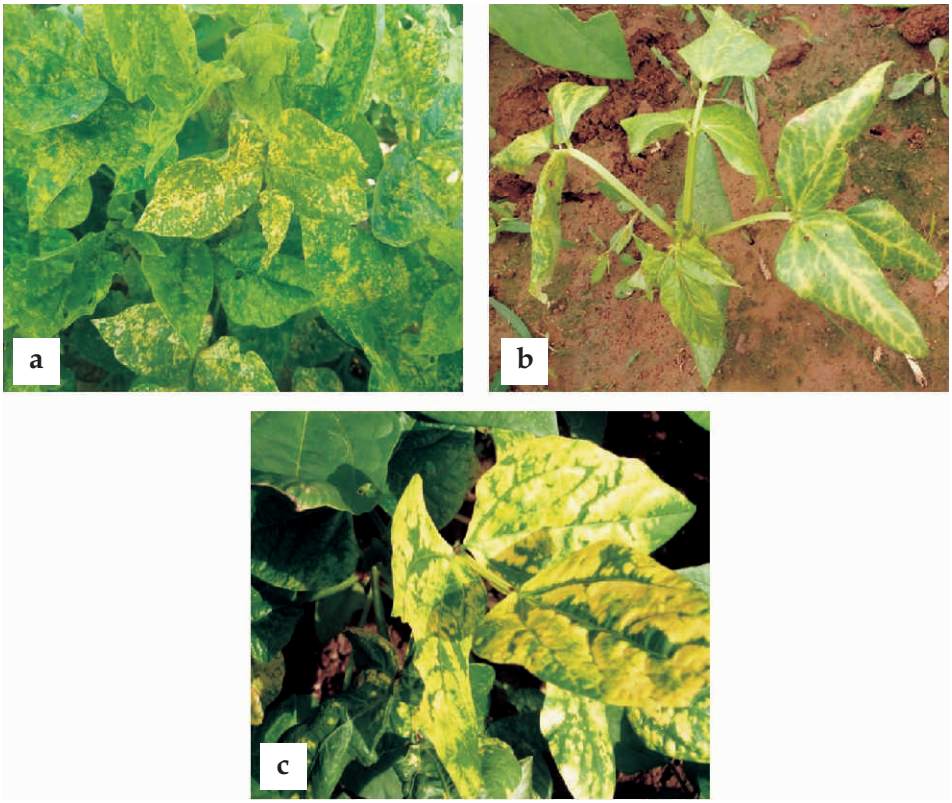

Fig. 5: Different manifestations (a, b, c) of mosaic virus in cowpea

Pathogen: Cowpea mosaic virus

Favourable conditions for development: Infection from infected seeds plays an important role in initiation of the disease, whereas aphids are important in the secondary spread of the disease under field conditions. Cultivation of virus-susceptible cowpea cultivars in a large area is another factor which favors disease spread

Recommended technologies for cowpea mosaic management:

1. Use of resistant varieties such as UPC-5286, UPC-607 and UPC-622.
2. Two sprays of imidacloprid 17.8 SL @ 0.3 ml/lit at 15 days interval followed by two sprays of *Veticillium lecani* @ 5 g/lit at 10 days interval.

Cowpea aphids

Damage symptoms: Aphids live in dense colonies on cowpea plants causing considerable damage. Severe aphid infestation causes plant depletion, leaf deformation, early defoliation and seedling decay. In addition to these direct attacks, aphids also transmit cowpea mosaic virus and secrets honeydew which attracts saprophytes to the plant and disrupt photosynthesis.

Fig. 6: Cowpea aphids feeding on cowpea leaves and branch

Causal agent: *Aphis craccivora* Koch

Favourable conditions for development: Cowpea aphids favour legume hosts and can tolerate warm dry weather. They can cause severe damage to water stressed plants.

Recommended technologies for cowpea aphid management:

1. Use of resistant varieties such as UPC-5286, UPC-607 and UPC-622.
2. Two sprays of imidacloprid 17.8 SL @ 0.3 ml/lit at 15 days interval followed by two sprays of *Veticillium lecani*@ 5 g/lit at 10 days interval.

Cowpea defoliators

Damage symptoms: Defoliators make holes on the leaves and in case of severe infestation complete defoliation and skeletonization of the leaves can be there.

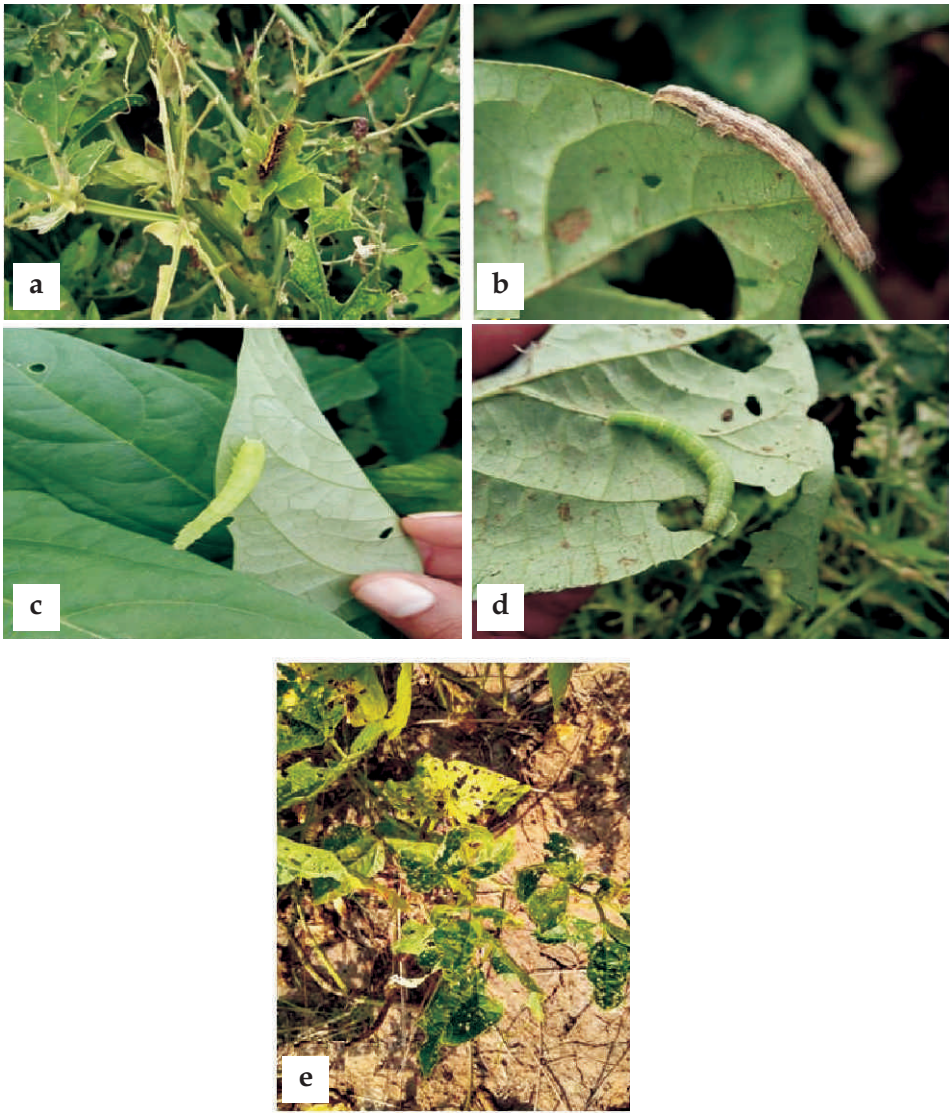

Fig. 7: Cowpea defoliators feeding on cowpea (a, b, c, d) and severely infested cowpea plant (e)

Causal agent: Insects belonging to Acrididae and Lepidopteran larvae have been reported feeding on cowpea leaves, "skeletonizing" and sometimes defoliating the entire plant. Other foliage defoliators of cowpea belong to the family Chrysomelidae.

Favourable conditions for development: Cowpea defoliators favour warm dry weather. They can cause severe damage to water stressed plants.

Recommended technology for cowpea defoliators management:

Foliar application of *B. bassiana* @ 5g/lit. (1 X 10^7 cfu/ml) for ecofriendly management of defoliators in forage cowpea.

3. Technologies generated in fodder Maize

Maydis leaf blight/Southern leaf blight

Symptoms: Young lesions are small and diamond shaped which elongate on maturation. Growth is limited by adjacent veins, so final lesion shape is rectangular and 2 to 3 cm long. Lesions may coalesce, producing a complete burning of large areas of the leaves.

Fig. 8: Maize leaf with symptoms of Maydis leaf blight

Causal organism: *Bipolaris maydis* (Nisikado et Miyake) Shoem

Favourable conditions for development: Maydis leaf blight is prevalent in warm humid temperate to tropical regions where the temperature ranges from 20-30^{0}C during cropping period.

Recommended technologies for leaf blight management:

1. Use of resistant varieties such as African tall and Pratap Makka Chari 6.
2. Seed treatment with Vitavax power @ 2 g/kg seed followed by two sprays of mancozeb @ 0.25%.

Banded leaf and sheath blight

Symptoms: The disease develops on leaves, sheaths, stalks and can spread to the ears. Leaves and sheaths develop characteristic symptoms of concentric bands and rings that are discolored, brown, tan or grey in color. Ear rot is characterized by light brown, cottony mycelium on the ear and the presence of small, round, black sclerotia.

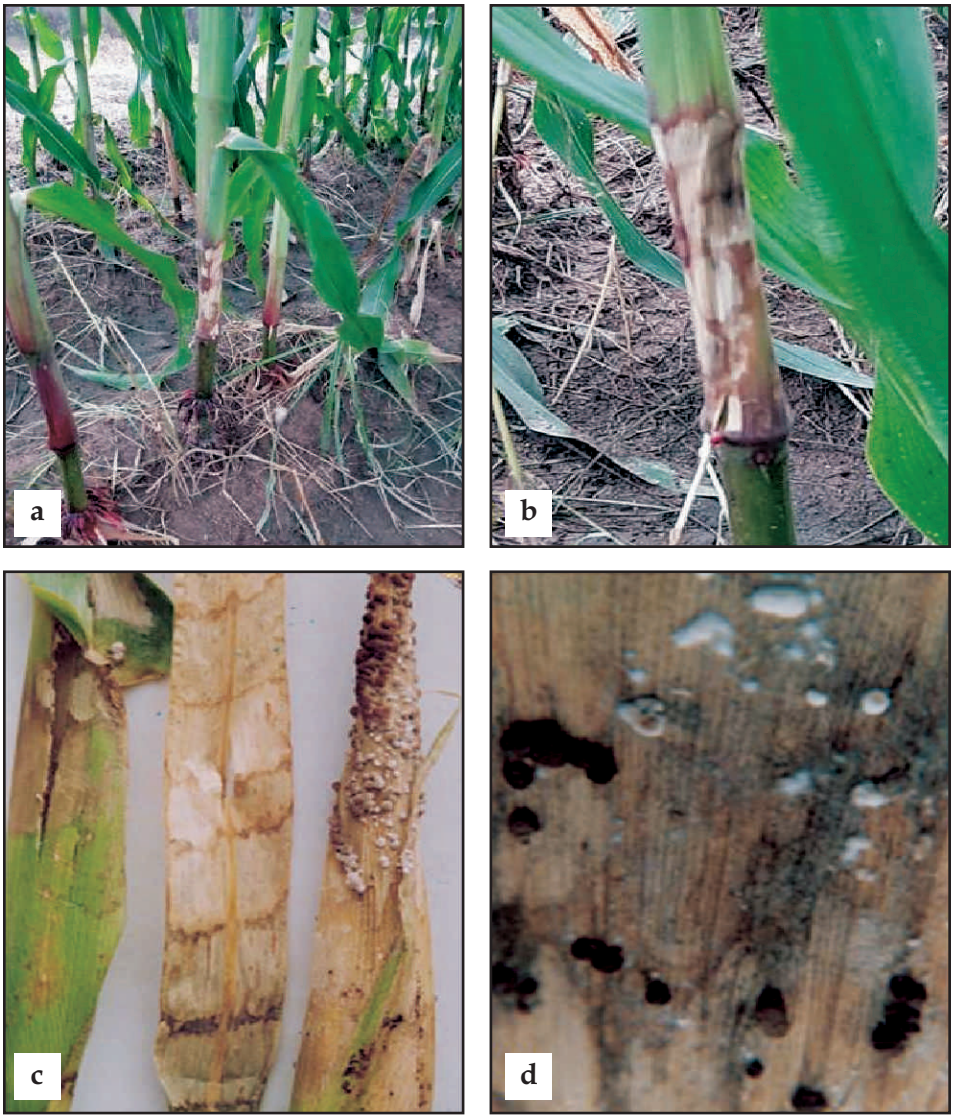

Fig. 9: Symptoms of Banded leaf and sheath blight on stalk (a,b), ear (c) and presence of sclerotia on the affected ear (d)

Pathogen: *Rhizoctonia solani* f. sp. *sasakii* Exner

Favourable conditions for development: Banded leaf and sheath blight is a serious problem in hot and humid environment of the tropics and subtropics. High relative humidity and rainfall significantly favours development and spread of this disease.

Recommended technologies for banded leaf and sheath blight management:

1. Use of resistant varieties such as African Tall and Pratap Makka Chari 6.

2. Seed treatment with Vitavax power @ 2 g/kg seed followed by two sprays of mancozeb @ 0.25%.
3. Seed treatment with *T. viride* @ 5g/kg seed + two foliar sprays with trifloxystrobin +tebuconazole @ 1g/l at 10 days interval starting from disease onset.

4. Technologies generated in fodder Sorghum

Zonate leaf spot

Symptoms: Small spots of red to brown color accompanied by water-soaked tissue followed by semi-circular to circular bull's-eye spots occurring later on. Spots range from small spots to 3 inches or more in diameter. Rings of purple and brown appear alternately. Early infection can result in defoliation and death of plant.

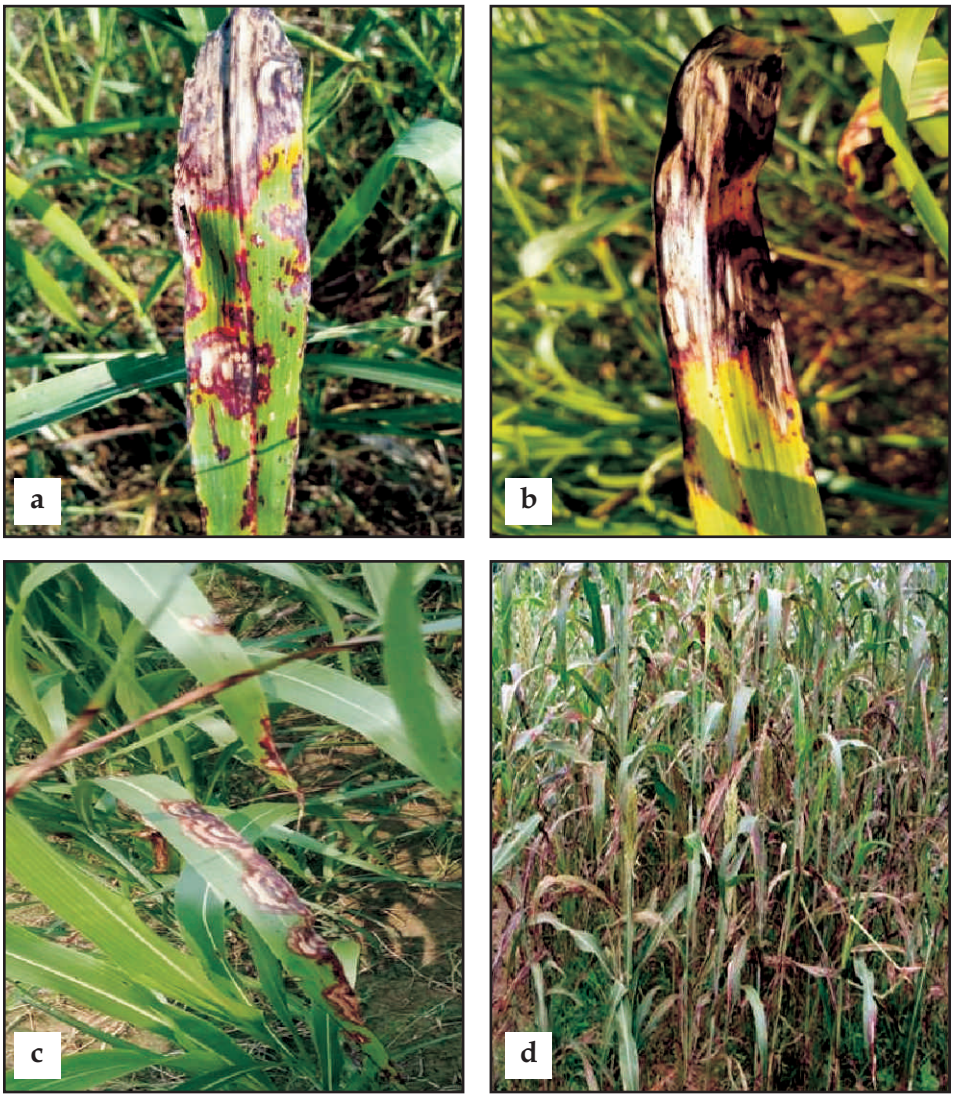

Fig. 10: Sorghum leaves with zonate leaf spot symptoms (a, b, c) and severely infected sorghum crop (d)

Pathogen: *Gloecercospora sorghi* Bain and Edgerton ex Deighton

Favourable conditions for development: Damage to the photosynthetic area of the leaf can be as as high as 85% under humid and cloudy weather conditions.

Recommended technology for zonate leaf spot management:

Seed treatment with *T. viride* @ 5g/kg followed by two foliar sprays with propiconazole @ 1g/l at 10 days interval starting from disease onset.

Gray leaf spot

Symptoms: Small red spots that enlarge to form narrow, rectangular lesions delimited by veins. Lesions may coalesce to form longitudinal stripes or irregular blotches and possibly cause leaf death. Lesion color can vary from dark red, purple to straw colored. Lesions may have a grayish cast due to sporulation.

Fig. 11: Sorghum leaves with gray leaf spot symptoms

Pathogen: *Cercospora sorghi* Ellis and Everh.

Favourable conditions for development: Disease is favoured by moderate temperature (22-31 ^{0}C) coupled with moderate humidity (60-80%).

Anthracnose

Symptoms: Circular to oval young lesions which are reddish to purple and appear as small dots. Mature lesions have distinct dark purple margins with lighter colored centers. Lesions are often more distinct along midrib. Numerous small black dots like acervuli are seen on the light colored centre of the lesions.

Fig. 12: Sorghum leaves with anthracnose symptoms along the midrib

Pathogen: *Colletotrichum graminicola* (Ces.) Wils.

Favourable conditions for development: Disease is favoured by continuous rain along with temperature of 28-30°C and high humidity.

Recommended technologies for gray leaf spot and anthracnose management:

1. Seed treatment with *T. viride* @ 5g/kg followed by one spray each with neem bio –pesticide (Achook) @ 3% and propiconazole @ 1g/l at 10 days interval starting from disease onset for management of gray leaf spot and anthracnose disease in fodder sorghum.

or

2. Seed treatment with carbendazim @ 2 g/kg seed followed by two foliar sprays of propiconazole @ 0.1 per cent at 10 days interval starting from disease onset for management of gray leaf spot and anthracnose disease in fodder sorghum.

Shoot fly

Damage symptoms: Shootfly larvae migrates to the upper side of the leaf, and moves along the leaf whorl until it reaches the growing point where the larvae cut the growing point. As a result the central leaf dries up forming a dead heart, which can be pulled out easily and produces a rotting smell. Normally the damage occurs 1 to 4 weeks after seedling emergence. Damage at the seedling stage will lead to the typical dead heart symptoms. 5 to 30 days old seedlings are generally more susceptible to shoot fly damage. Late infestations may also damage the panicle, resulting in rotting or drying up of a portion of the panicle affected by shoot fly damage. The damage plants produce side tillers.

Causal agent: *Atherigona soccata* L. Moench

Favourable conditions for development: The late sown crops generally suffer greater shoot fly damage because of high humidity and moderate temperature. Temperature higher than 35^{0}C and less than 18^{0}C reduces shoot fly survival.

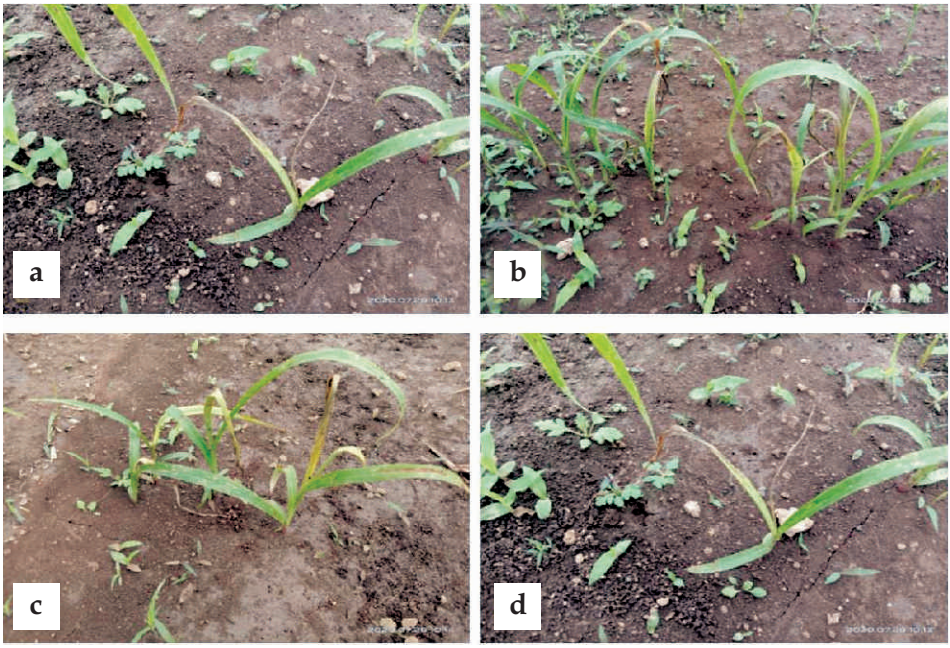

Fig. 13: Sorghum plants affected with shootfly damage

Recommended technology for shootfly management:
Seed treatment with Thiomethoxam (2 g/kg seed).

5. Technologies generated in fodder Pearl millet

Downy mildew

Symptoms: Pale, chlorotic broad streaks extending from base to tip of leaves. As the disease progresses, the leaf streaks turn brown and the leaves become shredded longitudinally. In severe infection, the downy fungal growth can be seen on the upper as well as lower surface of the leaves. The infected plants fail to form ear but if formed, they are malformed to green leafy structures. As the disease advances, the malformed floral structures of ears become brown and dry.

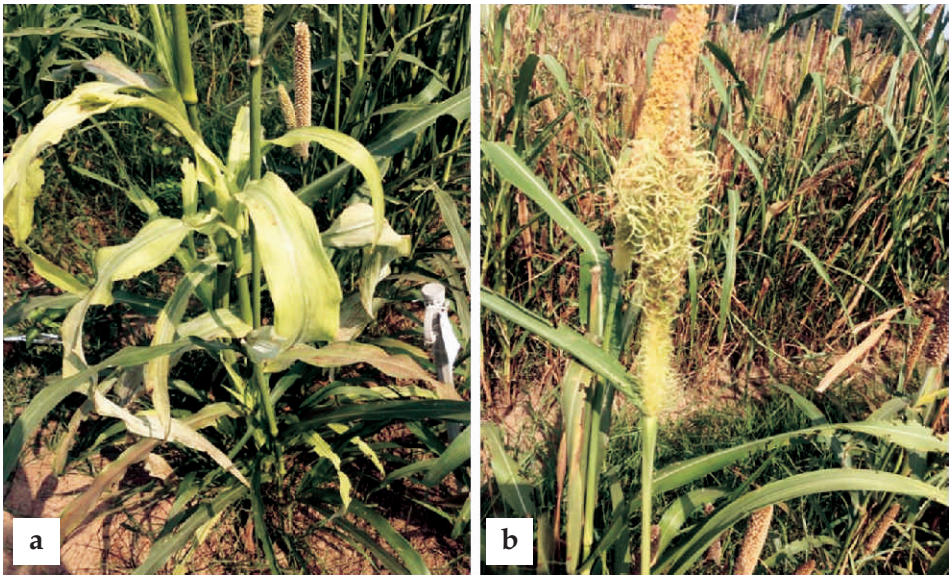

Fig. 14: Pearl millet leaves with Pale, chlorotic broad streaks (a) and green ear (b) symptom on the infected ear

Pathogen: *Sclerospora graminicola* (Sacc.) J. Schrot

Favourable conditions for development: Disease is favoured by temperature between 15-25 °C and relative humidity above 85 per cent. Light rainfall along with cool weather is highly favorable for downy mildew development.

Recommended technology for downy mildew management:

1. Seed treatment with *Bacillus subtilis* @ 5g/kg seed followed by two foliar sprays of *Bacillus subtilis* @ 5g/l at 10 days interval starting from disease onset.

6. Technologies generated in Berseem

Stem rot

Symptoms: The leaves turn olive-greyish-brown before they wither and become covered with mycelium. The mycelia grow through the petioles and stems into the crown and eventually down into the taproot. Clover rot infection may also spread between plants by means of mycelial growth, thus creating patches of dead plants in the field. Infected and dead plants are covered by greyish mycelia, with black sclerotia forming in dead plant tissue at soil level, or in the soil close to dead plants.

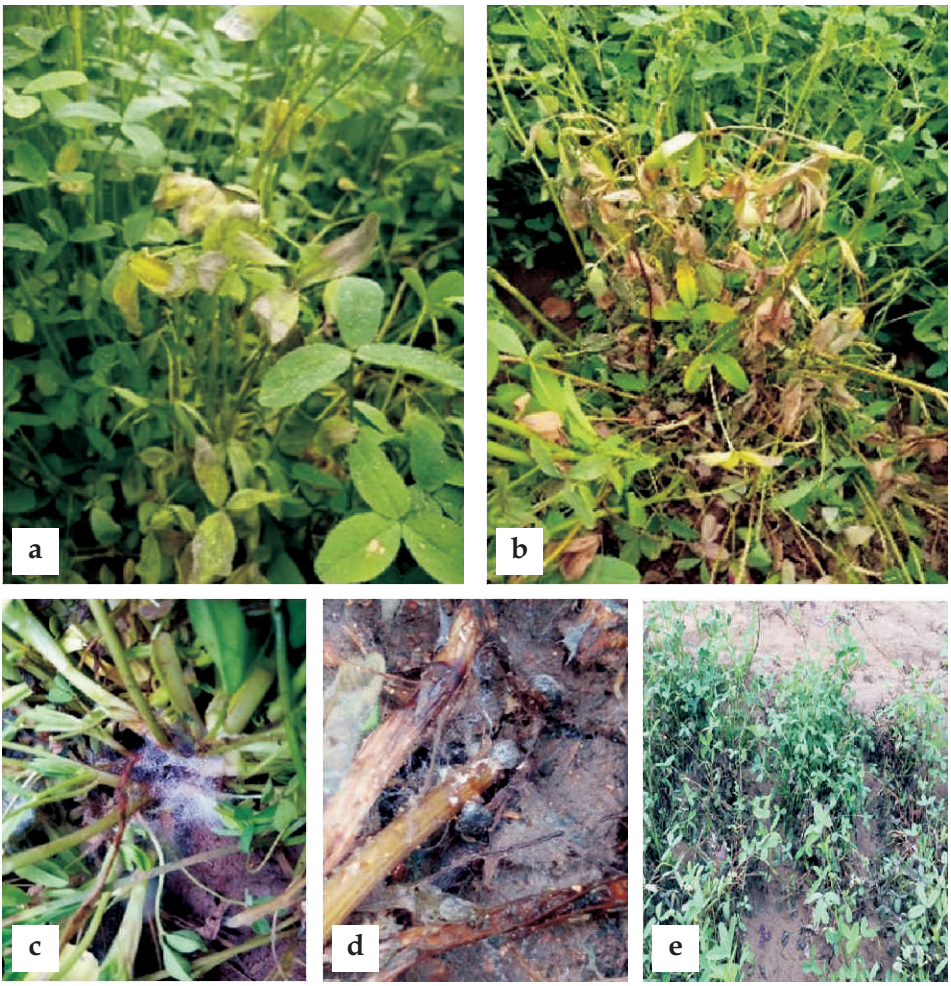

Fig. 15: Initial symptoms of stem rot with leaves turning olive-greyish-brown (a, b) followed by appearance of white mycelium (c) and black sclerotia (d) on the affected stem and ultimately rotting of entire affected plants (e)

Pathogen: *Sclerotinia trifoliorum* Erikks.

Favourable conditions for development:

Disease is favoured by relatively cold temperature (12-25^{0}C) along with mild winds and intermittent frost especially during the month of January and February in central and north India.

Recommended technologies for stem rot management:

1. Use of resistant varieties such as Bundel Berseem-3 (moderately resistant to stem rot).
2. Foliar application of carbendazim @1 kg/ha after first and second cut.

7. Technologies generated in fodder Oat

Leaf blotch

Symptoms: The symptoms of leaf blotch appear as small grayish brown, necrotic elongated spots on the leaf blade and sheath, which coalesce to form larger spots or lesions of irregular shape and size. The lesions are mostly limited by veins, but they spread and coalesce to form elongated large dark brown to grey blotches. As the disease advances, the tissues become necrotic and dry up.

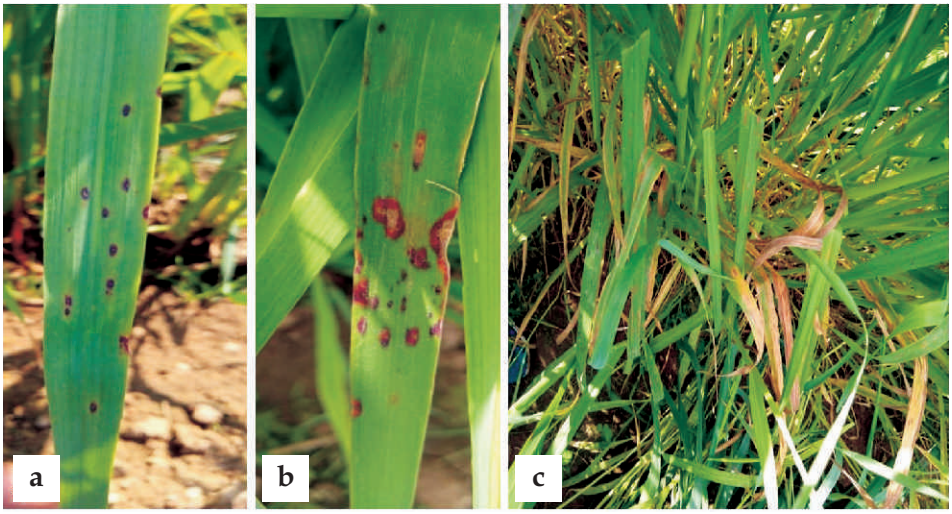

Fig. 16: Initial (a, b) and advanced symptoms (c) of leaf blotch in Oat

Pathogen: *Drechslera avenae* (Eidam) Scharif

Favourable conditions for development: Disease is favoured by moderate temperature (15- 28^{0}C) along with moderate humidity during the month of January to March.

Recommended technologies for leaf blotch management:

1. Use of resistant varieties such as OS-6, UPO-94, JO-03-91, JO-03-93, OS-377 and JHO-2010-1.
2. Seed treatment with carbendazim@ 2g/kg seed followed by foliar application of propiconazole @1ml/lit after 21 days after sowing.

Powdery mildew

Symptoms: Colonies of fluffy white to light grey superficial mycelium on the upper surfaces of the leaf blades. The mycelium darkens to yellowish grey with age. The undersides of affected leaves have yellowish necrotic

spots at infection sites. Late in the season, black spherical fruiting structures (cleistothecia) develop in the mycelial mats.

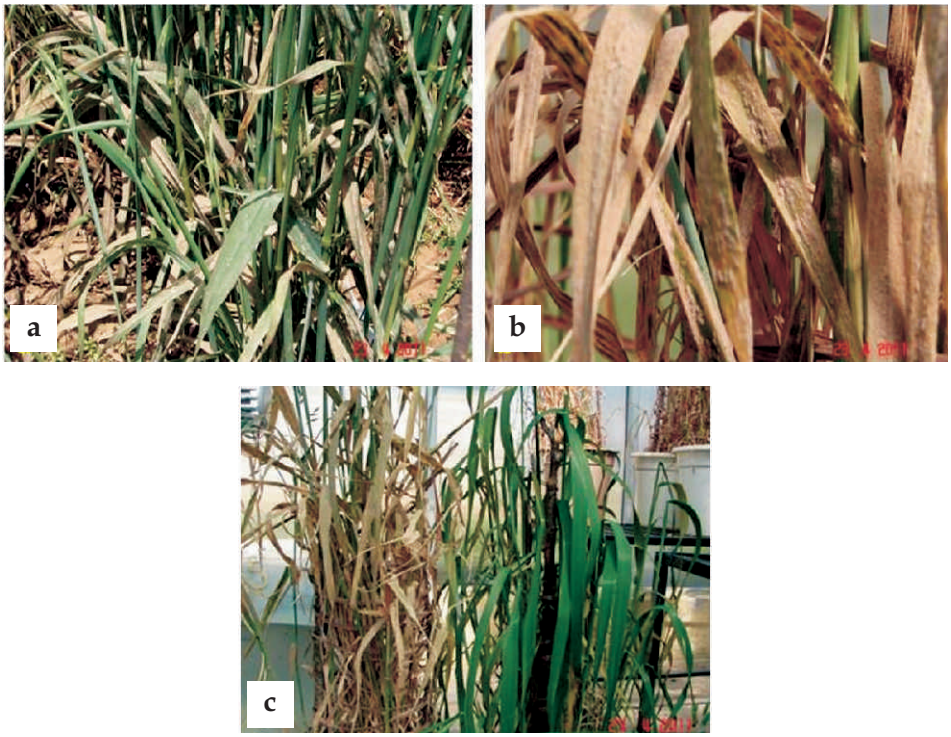

Fig. 17: Symptoms (a, c) and signs (b) of powdery mildew in oat

Pathogen: *Blumeria graminis* f.sp. *avenae* Em. Marchal

Favourable conditions for development: Disease emergence is favoured by heavy nitrogen fertilization, high humidity and cool temperatures.

Recommended technologies for powdery mildew management:

1. Use of resistant varieties such as OS-6, JO-03-91 and JO-03-93.
2. Spray of hexacanozole @ 0.05% and Propacanazole @ 0.05% at 15 days interval at disease onset.

8. Technologies generated in Lucerne

Rust

Symptoms: Small, round, powdery, reddish brown to dark brown pustules form, mostly on the undersides of the leaves. Pustules may also appear on the petioles and stem. Severely infected leaves may turn yellow, wither, and drop prematurely.

Fig. 18: Rust disease of Lucerne

Pathogen: *Uromyces striatus* J. Schrot.

Favorable conditions for development: Disease is favored by warm, humid weather.

Recommended technologies for rust management:

1. Use of resistant varieties such as Chetak, Anand Lucerne-3 and RRB-07-1.
2. Spraying of mancozeb (2.5 g/lit) and tebuconazole (0.5 ml/lit) alternately at 15 days interval is recommended for superior seed yield.

Helicoverpa armigera Hubner

Damage symptoms: *H. armigera* has a preference for feeding on the floral parts of host plants although young foliage is also frequently attacked. *H. armigera* will initially start feeding on tender leaves, but eventually their movements on plants will primarily take them to the reproductive organs.

Favourable conditions for development: *H. armigera* on Lucerne favours relatively moderate temperature and lower humidity levels for infestation. Monocropping of Lucerne over large areas can lead to severe outbreak.

Fig. 19: *H. armigera* larva feeding on leaves (a) and flower (b) of Lucerne

Recommended technologies for *H. armigera* management:

1. Foliar application of HaNPV @1 ml/lit and *B. bassiana* @ 5 g/lit of water in evening.

2. Spraying of *Bacillus thuringensis* @1 kg/ha or release of *T. chilonis* @100,000 parasites/week/ha synchronizing first release with the appearance of *H. armigera* larvae (minimum 2 release) followed by spraying of HaNPV @ 250 LE/ha after last release of *T. chilonis* and installation of 'T' shaped bird perches stands for birds @15 /ha.

Spodoptera litura Fabricius

Damage symptoms: Singular, or closely grouped circular to irregularly shaped holes in foliage. Heavy feeding by young larvae can leads to skeletonized leaves.

Fig. 20: *S. litura* larva feeding on leaves of Lucerne

Favourable conditions for development: *S. litura* on Lucerne favours relatively moderate temperature and lower humidity levels for infestation. Monocropping of Lucerne over large areas can lead to severe outbreak.

Recommended technology for *S. litura* management:

Foliar application of *SlNPV* @ 1 ml/L and *B. bassiana* @ 5g/L of water at 8 pm.

9. Technologies generated in Red clover

Powdery mildew

Symptoms: Small patches of fine, white to pale gray powdery growth develop on the leaf surface. These patches later enlarge and merge. The fungus may also grow on the lower surface of the leaves and on the stems. Severe attacks can make entire fields appear white. Infected leaves turn yellow and drop prematurely.

Fig. 21: Powdery mildew of red clover

Pathogen: *Erysiphe trifolii* Grev.

Favourable conditions for development: Disease is most prevalent when nights are damp and cool and days are warm and dry. Long periods of relatively dry weather favour its development and spread.

Recommended technology for powdery mildew management:

Seed treatment with carbendazim @ 2 g/kg seed followed by three foliar spray of hexaconazole @ 0.1% starting from disease onset.

Stem rot

Symptoms: The leaves turn olive-greyish-brown before they wither and become covered with mycelium. The mycelia grow through the petioles and stems into the crown and eventually down into the taproot. Clover rot

infection may also spread between plants by means of mycelial growth, thus creating patches of dead plants in the field. Infected and dead plants are covered by greyish mycelia, with black sclerotia forming in dead plant tissue at soil level, or in the soil close to dead plants.

Fig. 22: Stem rot of red clover

Pathogen: *Sclerotinia trifoliorum* Erikks.

Favourable conditions for development: Disease is favoured by relatively cold temperature (12-20 ^{0}C) along with mild winds and moist conditions.

Recommended technology for stem rot management:

Seed treatment with carbendazim @ 2 g/kg seed followed by three foliar spray of hexaconazole @ 0.1% starting from disease onset.

10. Technologies generated in White clover

Powdery mildew

Symptoms: Small patches of fine, white to pale gray powdery growth develop on the leaf surface. These patches later enlarge and merge. The fungus may also grow on the lower surface of the leaves and on the stems. Severe attacks can make entire fields appear white. Infected leaves turn yellow and drop prematurely.

Fig. 23: Powdery mildew of white clover

Pathogen: *Erysiphe trifolii* Grev.

Favourable conditions for development: The disease occurs severely in the cool and dry condition, and the damage becomes large when sunshine is insufficient under the cloudy weather.

Recommended technology for powdery mildew management:

Seed treatment with carbendazim @ 2 g/kg and *Trichoderma viride* @ 5g/kg seed followed by alternate sprays of carbendazim @ 0.1% and hexaconazole @ 0.05%.

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