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Insect, Pest and Disease Management in Rice

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Abbreviations: D: days; DT: Days After Transplanting; Wk: Week; H: Hrs; %: Percent; Sp: Specie; @: At The Rate Of; Ha: Hectare; Kg: Kilo; Gram; Ml: Milli Liter; Ipm: Integrated Pest Management; Sq.M: Square Meter; E.G: For Example; 2.4.D: 2,4-Dichlorophenoxyacetic acid; Bt: Bacillus thuringiensis

1. Introduction

Insect, pest and disease management is vital in attaining sustainable rice production. Rice serves as a staple diet for about half of the world's population and it is cultivated in 110 countries of the world, covering about one-fifth of world's cropland under cereals. But its production is affected largely by insects, pests and disease attacks. Reduction in rice yield due to insects, pests, and diseases is recorded to be about 21 % in North and Central America and about 31.5% in Asia (excluding mainland China). Yield loss varies within production conditions. In utter terms, yield losses of about 1.2 to 2.2 tons/ha have been recorded due to weed, insect, pest and disease injuries in Asia. More than 800 rice insect's species have been reported in the worldwide ecosystems. From these, about 700 species did not cause damage to rice and are considered friendly insects while about 100 species attack rice. Almost 20 insects act as rice pests that include defoliators, stem borers, gall midge and vectors like planthoppers and leafhoppers that cause direct damages and also transmit several diseases at different growth stages (**Table 7-1**). Management practices are needed to control the loss carried out by different diseases and insects and pests. Most common practices include agronomic practices, biological and chemical control.

Agronomic practices include; growing of resistant and early maturing varieties, early sowing of seeds, proper/close plant spacing, avoiding rice hotspot areas of viruses especially of grassy stunt virus and tungro virus, crop and field sanitation/hygiene, ploughing after harvesting that helps to bring eggs to soil surface and abolish them, judicious use of fertilizers, flooding of fields in order to save irrigated crops and after forecasting etc. For biological control of insects and pests, numerous natural enemies (predators, parasites, pathogens, and microbial insecticides) of insects and pests are used. These living entities attack insects and pests and destroy them. A wide variety of insecticide and pesticides are used as chemical control, according to the extent of attack and crop growth stages.

Several viral, bacterial and fungal diseases have been noticed. Disease damage can greatly affect growth and yield of rice crops and can sometimes completely destroy the crop. It is observed that destructive viral diseases are not present in any of the rice-growing regions of the world, but fungal and bacterial diseases are widely spread and are very destructive. Some effects of diseases as direct losses include the spotted kernels, low number of grains, lodging, reduction in plant stands and a general plant efficiency reduction while indirect losses include the application costs of fungicides used to control the disease, yield reduction along with special agronomic practices that not only decrease the disease effect but may not be conducive to higher yield production. Diseases and their causal agents are listed in **Table 7-1**. The physiological disorders such as zinc deficiency, straight ahead, salt damage, cold injury and nutrient deficiencies are sometimes misunderstood as disease symptoms. Management is necessary in order to avoid damage caused by the diseases. Toward disease management, the first step is the identification of disease followed by field scouting so that extent of disease can be determined. Determination of varietal resistance to diseases can be helpful in determining the chances of having problems warranting preventive management measures.

Table. 7-1: Growth stages of rice attacked by insect pests

Growth stages	Insect pests
Vegetative Stage	Seedling maggots
	Rice seed midge
	Rice caseworms
	Rice leaf beetles
	Rice gall midge
	Grasshoppers, katydids, and field crickets
	Rice stem borers
	Black bugs
	Rice mealybugs
	Rice thrips
	Rice leaffolders
	Mealy bugs
	Rice hispa
	Armyworms and cutworms
	Stalked-eyed flies
	Colaspis
Reproductive Stage	Rice Skippers
	Leafhoppers
	Greenhorned caterpillars
	Planthoppers
	Lady bird beetle
Ripening stage	Stink bugs
	Ripening seed bugs
	Rice Chinch bug
	Panicle rice mite
Soil Inhabiting pests	Ants
	White grubs
	Mole crickets
	Root aphids
	Root-feeding mealybugs
	Termites
	Field cricket
	Root weevil
	Wire worm

Table. 7-2: Rice diseases and their pathogen

Plant growth Stage	Common name	Pathogen name	Cause
Seed and Seedling:	Seedling Blight	*Sclerotium rolfsii, Cochliobolus miyabeanus, Fusarium* sp., *Curvularia sp., Athelia rolfsii, Rhizoctonia solani, Athelia rolfsii*, and other pathogenic fungi.	Fungi
	Water Mold	*Achlya*sp. *Pythium* sp.	Fungi
Roots and Crown	Crown Rot	Erwinia chrysanthemi	Bacteria
	Root Rot	*P. dissotocum, Fusarium* sp., *P. spinosum,* and *Pythium* sp.	Fungi
	Root Knot	Meloidogyne sp.	Nematode
Leaf Blades:	Rice Blast	*Pyricularia oryzae*	Fungi
	Brown spot	*Bipolaris oryzae*	Fungi
	Narrow brown leaf spot	*Cercospora oryzae*	Fungi
	Leaf smut	*Entyloma oryzae*	
	Leaf scald	*Sarocladium oryzae*	Fungi
	Bacterial leaf blight	*Xanthomonas campestris* pv. *oryzae*	Bacteria
	Stackburn	Alternaria *padwickii*	Fungi
	White leaf streak	*Mycovellosiella oryzae*	Fungi
	White tip	*Aphelenchoides besseyi*	Nematode
Stem and leaf sheath:	Sheath spot	*Rhizoctonia oryzae*	Fungi
	Sheath blight	*Rhizoctonia solani*	Fungi
	Sheath blotch	*Pyrenochaeta oryzae*	Fungi
	Sheath rot	*Sarocladium oryzae*	Fungi
	Crown sheath rot	*Gaeumannomyces graminis*	Fungi
	Stem Rot	*Magnaporthe salvinii*	Fungi
	Flag leaf collar blast	*Pyricularia oryzae*	Fungi
	Node blast	*Pyricularia oryzae*	Fungi
	Tungro	Rice tungro bacilliform virus (RTBV)	Virus
	Grassy stunt	Rice Grassy stunt virus (RGSV)	Virus
Panicle, Florets, and Grain:	Rotten neck blast	*Pyricularia oryzae*	Fungi
	Head blight	Various fungi	Fungi
	Panicle blast	*Pyricularia oryzae*	Fungi
	Bacterial panicle blight	*Burkholderia glumae*	Bacteria
	Downy Mildew	*Sclerophthora macrospora*	Fungi
	Grain spotting or Pecky rice	*Fusarium* sp., *Cochliobolus miyabeanus, Microdochium oryzae, Sarocladium oryzae, Curvularia* sp. and bacteria	Fungi and Bacteria
	Kernel smut	*Tilletia barclayana*	Fungi
	False smut	*Ustilaginoidea virens*	Fungi
	Bakanae	*Fusarium moniliforme*	Fungi
	Black kernel	*Curvularia lunata*	Fungi

2. Insect, Pest of Rice and their Management

Stem Borers

Description: Stem borers are the most severe rice pests in the world. Three families; Noctuidae, Diopsidae, and Pyralidae, have been documented as rice stem borers. The pyralid borers possess high host specificity. They are most common and destructive. In Asia, the most destructive and widely distributed are *Scirpophaga incertulas*, *Chilo suppressalis*, *Sesamia inferens, Scirpophaga innotata*, and *Chilo polychrysus*. In Asia, *Chilo suppressalis* and *Scirpophaga incertulas* cause a damage of 5-10% of the total rice crop. *Scirpophaga incertulas is* distributed in the temperate and tropics areas. It is the dominant species in Pakistan, Malaysia, In the Republic of Korea, Bangladesh, Sri Lanka, India, Philippines, Vietnam, Thailand, and some parts of Indonesia.

Damage: The underlying feeding and boring by hatchlings in the leaf sheath cause vast, longitudinal, whitish, stained zones at bolstering destinations, however just infrequently do they bring about shriveling and drying of the leaf-cutting edges. At the point in the middle of the vegetative period of the plant, the focal leaf whorl does not unfurl, but rather turns tanish and gets dry, in spite of the fact that the lower leaves stay green. This situation is recognized as the dead heart, and the infected tillers dry off without panicles.

Management

Agronomic Methods: Crop agronomic practices show an intense effect on the population of stem borer. High rates of nitrogen fertilizer will provide more plant nutrition and result in higher yield. However, it also increases the incidence of bacterial and fungal diseases by increasing tiller density and tissue susceptibility and boosts the stem borer's multiplication. Insects generally grow larger and faster, produce more offspring by completing more generations per crop and cause more damage when high nitrogen is applied. Stem borer moth's oviposition occurs favorably under high nitrogen fertilizers. For its management, nitrogen is applied as a split application at optimal rates. Splitting the nitrogen application, and use of slow nitrogen release forms of fertilizers(e.g. sulfur-coated urea, urea super-granules) helps to attain higher crop yields and lower chances of pest attack. Silica application helps to increase crop resistance against stem borer. Slag application increases the silica content and makes it resistant to stem borer attack.

Clipping the seedlings tip before transplantation is done to eradicate the egg masses. This method is used only for mature seedlings. Crop harvest at ground level reduces the number of larvae. Harvested crop height is an important factor that determines the larvae percentage, left in stubble. Removal and destruction of stubbles from rice field, which will help in the destruction of egg masses. To destroy those remaining eggs, flooding and plowing of fields, and burning and decomposition of rice stubble are suggested. For decomposition, calcium cyanide is used in low amount. Plowing and flooding are most effective apparently. Uniform burning of stubble is also difficult in a field. Burning of stubbles is effective only when larvae migrate to subsurface soils.

In many countries, postponing of sowing and transplanting time is considered a good practice in escaping moth's first-generation and it can also decrease the density as well as damage of stem borers both in directly seeded and transplanted rice fields. Changing planting time is not always effective because of other agronomic attention. In Pakistan, planting date is scheduled by canal water release only after the emergence of *Scirpophaga incertulas* moths. This late-planted crop is less affected by moths than early field plantation receiving tubewell irrigation.

Delayed planting is an effective practice against *Scirpophaga incertulas* since emergence is also delayed with planting date. The number of generations of stem borer is dependent on the crop growth period. Thus, change in planting time has a slight effect in areas where rice cropping is practiced continuously.

Light traps are used for collection and destruction of moths. Catching of moths by Light-traps shows a variation from a uni-modal to a bi-modal pattern in first and second broods. The frequency-vibration-based pest lamps used to kill the stem borers. They are installed at 200 m distance from each other in a checkerboard pattern and 1.3–1.5 m above the ground. These lamps are switched on during the light period when immigration of stem borers occur. However, a disadvantage of these lamps is that it will also cause damage to beneficial insect pests. High insecticidal activities of Bt rice are observed against stem borers.

Chemical Methods: Stem borers are difficult to control with insecticides because larvae are exposed only for a few hours before they enter the tiller or plant. So when an economic threshold of the dead heart reaches at about 10% in the nursery and in the vegetative stage and 1 moth /sq.m. has reached, implementation of the chemical control method is suggested. Chemicals that are recommended at these stages are chlorpyriphos, fenitrothion, monocrotophos, cartap hydrochloride, etofenprox, phosalone, endosulfan, fenthion, phenthoate, and fipronil. Seedlings root dipping in chlorpyriphos (0.02%) for 12-14 h before transplanting gives safety against stem borer for up to 30 d.

Successful control involves repeated foliar applications. Granular insecticides, particularly diazinon and gamma BHC, are most effective than foliar sprays, specifically in high rainfall environments. Gamma BHC is a fumigant that kills inactive moths. In the dead hearts of young crops, granules fertigation is effective in preventing stem borer. The insecticide is dissolved partially in the water and is transported between the stem and leaf sheath by capillary action, to make contact with young larvae. The limitation in the use of this method is cost and water supply. Granules are costly to transport. Stable and deep water levels are required for control. A combination of chemo-sterilant and sex attractant (pheromones) also shows the potential of pest control. Sex pheromone application can decrease the insecticide use by 1–2 sprays, and the input costs can be decreased than insecticides.

Biological Methods: Biological control of stem borers in Africa and tropical Asia mostly comes from native parasites, predators, and entomo-pathogens. Over 100 species of these parasitoids have been recognized. The management and protection of these parasitoids are essential in the development of successful and stable integrated pest management (IPM) systems against stem borer. The essential genera include; *Trichogramma, Telenomus,* and *Tetrastichus, Telenomus* wasps parasitize stem borer eggs before the eggs are covered by the hair while the moth is in the oviposition stage. The wasp detects the female moth, gets attached near ovipositor. Many predators, crickets; *Anaxipha longipennis,* and *Metioche vittaticollis*, and mirid; *Cyrtorhinus lividipennis* feed on *Chilo suppressalis.* The long-horned grasshopper preys rapaciously on yellow stem borer eggs. Some important predators are carabid beetles such as *Ophionea* sp., coccinellid beetles; *Micraspis crocea* and *Harmonia octomaculata* that attack small larvae of stem borers. *Mesovelia vittigera* and *Microvelia douglasi atrolineata* prey on young larvae when they fall on the water. Ants and many other predators prey on larvae of stem borer.

Several fungal species can attack the larvae and ingest them at the stem base — the *Cordyceps sp.* Fungus feeds on the body of stem borers. Spiders attack adult moths when resting on foliage. Bats are effective at dusk while birds and dragonflies are active predators at daytime. Spinetoram, Spinosad, *Empedobacter brevis* and *Beauveria bassiana* possess greater insecticidal effects on stem borers. Another popular biological insecticide, Bt agent, is recommended in China to control rice stem borers.

Armyworms and cutworms

Description: The hatchlings of a few types of field noctuids are called armyworms and cutworms. They feed extrovertly on rice plants. They are comparable in propensities, however, can be comprehensively recognized by the attacking habits. The armyworm hatchlings grow on the over-the-ground plant's parts, frequently leaving just midribs. The cutworm hatchlings grow on the underground parts. The common armyworm, *Mythimna* (*Pseudaletia*) *unipuncta*, periodically cause crop losses. *M. unipuncta;* being polyphagous is also a severe pest of wheat, rice, barley, oats, and non-graminaceous crops, cereals, and grasses. The species is native to North America, but it is diverse in the allocation and documented throughout Asia, Europe, and Australia.

Armyworms and cutworms that are described in this chapter are; rice warming caterpillar, fall armyworm, and common cutworm.

Rice swarming caterpillar

Description: The rice swarming caterpillar (*Spodoptera mauritia acronyctoides*) infrequently makes substantial losses to rice crops. A preferred host of this polyphagous insect is upland rice, but it also infects weeds and graminaceous crops. It is standout amongst the most genuine creepy crawly bugs in South India and widely distributed in Southeast and East Asia. It is the most damaging pest of the armyworms in rice regions of Asia.

Damage: The swarming caterpillars appear unexpectedly in multitudes and move from field to field. They generally affect the nursery of rice, and the transplanted crop is not sternly affected by their attack. Newly hatched larvae give the plant a sickly look with cut leaves and withered tips while older larvae attack and feed wholly and ravenously defoliate the plant.

Fall armyworm

Description: The fall armyworm (*Spodoptera frugiperda*) causes economic losses to rice crops though it comes about only periodically. It is also known as southern armyworm grass worm and overflow worm. It also attacks cereals, grasses, tobacco, cotton, legumes, and cabbage. It has been noticed in Central and North America but is common in Central and, southern USA, and in neotropical areas.

Damage: The hatchlings feed on leaves, leaving the epidermis undamaged. At first, they eat just delicate parts of leaves, as they develop they eat up all foliage, leaving just the hard plant parts. Harm becomes obvious around 3-4 d after the invasion, and overwhelming defoliation ends up after the hatchlings assemble on the plants.

Common cutworm

Description: The common cutworm, *Spodoptera litura*, is also known as tobacco caterpillar or tobacco cutworm, grass cutworm, and vegetable cutworm. It is a common polyphagous insect of various agricultural crops. It is found sporadically and causes economic losses to rice, cabbage, maize, castor, smaller millets, jute, tobacco, sweet potato, and in many other crops. It is found generally in Pakistan, India, Australia, East Asia, Turkey, China, and several African countries.

Damage: The common cutworm needs dry land for pupation, and for causing damage, so it is a problem only on upland rice. Larvae migrating from grassy areas adjacent to low land rice usually cause massive damage. Young caterpillars feed on soft leaves, but fully-grown can consume the whole plant. Their effect is serious on seedlings where they cause damage at the base. Fully grown caterpillar severely defoliates the rice crop during late crop growth.

Management:

Control measures for all cutworms and armyworms are similar.

Agronomic Methods: Seedbeds should be made away from grasses and weeds areas to avoid cutworms and armyworms migration to alternate hosts. Plowing fallow land and weed removal from areas outside the fields helps to control cutworms and armyworms. Use of resistant rice varieties is recommended. Several wild kinds of rice have moderate resistance to *Mythimna separate* and *Spodoptera mauritia acronyctoides.*

Chemical Methods: Insecticides; Sevin (@ 0.15 to 0.25%) and Furadan (@ 10 kg/ha) are used to control armyworm and cutworms. These insecticides are suggested to be applied as sprays because of their effectiveness over granular form.

Since insecticides rapidly break down in high temperature and sunlight. Insecticide spray should be done in the late afternoon to make sure that larvae are in their resting places because after that larvae climb up the plants. To destroy large cutworm and armyworm larvae, higher doses are required, because of direct positive linkages between insecticide toxicity and insect body weight.

Biological Methods: Cutworms have several natural enemies. They colonize the crop in the rainy season immediately after land preparation. At this stage, populations of the natural enemy are low. Armyworms controlled at the egg and larval stage by parasites. Because of drought, these parasites fail then armyworms become epidemic. Larvae are parasitized by Tachinid flies, eulophid wasps (*Euplectrus chapadae*), chalcid wasps (*Brachymeria lasus*) and braconid wasps (*Cotesia* sp. and *Ropalidia fasciata*). Ants (*Odontoponera transversa* and *Chelonus formosanus*) are reported as larval and egg parasites. Moths are parasitized by spiders, *Oxyopes javanus* and *Pardosa pseudoannulat*.

Soil-inhabiting insect pests

Soil-inhabiting insect pests do not create the problem in irrigated rice fields because these pests attack and feed on underground plant parts. Non-puddled, Well-drained, upland rice soils are suitable sites for these pests.Soil-inhabiting pests described in this chapter are; Ants, Termites, Crickets, White grubs, Rice root weevil, and Rice root Apids.

Ants

Description: The ant is a social insect and is distributed widely but commonly found in dry-seeded rice fields in rain-fed wetlands and in upland rice. The most common species of soil-inhabiting ants that cause significant damage in Asia are *Pheidologeton diversus*, *Pheidole* sp., *Solenopsis geminata* and *Munomorium pharaonis.*

Damage: These harvester and fire ants feed on un-germinated rice seeds, and cause rice plant's destruction. Their nests are built on levees or below the soil surface in upland fields. If un-germinated seeds are not available, they attack germinated seeds. Damage by ants results in a patchy, reduced, plant stand. Ants help aphids in penetrating the soil by making the tunnels along with the root systems.

Management:

Agronomic Methods: Ants usually attack at seeds after sowing so in order to reduce loss, an increased rate of seeds is used.

Chemical Methods: Seed coating with powdered insecticides helps to control ants in rice fields.

Termites

Description: Termites belonging to family Termitidae, are subterranean and are commonly known as white ants as they also possess workers caste system, king, queen, soldiers, body shape, and wings. They cannot digest cellulose because of the lack of protozoans. Termites culture fungi in special underground cells that break down cellulose. Termites are a problem in upland rice areas, but can also occur in light textured soils in rainfed wetland areas. In Africa, *Macrotermes* and *Microtermes* termites have been recorded as rainfed upland rice pests. Termites are a serious problem in Africa and Latin America.

Damage: Soil texture and moisture content are important factors that affect the rate of infiltration. Light textured soils having low moisture receive more infiltrations. They preferably attack older plants with greater cellulose content but also attack a drought-stressed crop. They make a burrow all the way through plant stems and then eat roots.

Management:

Agronomic Methods: Provide another host at planting time for termites like crop residues that diverts termites from growing crops. Pulling out of damaged plants from the fields will reduce the dissemination of termites.

Chemical Methods: Insecticides are used to control termites in rice fields. Granular insecticide applications in seed hills and furrows and seed treatment with insecticides at planting time are the two most commonly used methods for termite control.

Crickets

Description: Four species of mole crickets are reported to attack rice; *Gyllotalpa africana* in Africa, *Gryllotalpa orientalis* in Asia, and *Scapteriscus didactylus* and *Neocurtilla hexadactyla* in Latin America. Several field cricket species are identified as rice pests; *Plebeiogryllus plebejus*, *Teleogryllus occipitalis*, *Gryllus assimilis*, *Brachytrupes portentosus*, *Teleogryllus testaceous*, *Loxoblemmus haani*, *Velarifictorus aspersus membranaceus* and *Gryllus bimaculatus*.

Damage: They live in branched burrows that are 8-10 cm below the soil surface. Under lowland fields, burrow making is common in non-submerged areas and near the levees while in upland fields, burrows are more in moist patches. These burrows lie near the soil surface and crickets feed on plant roots. That results in the complete separating of roots from the aerial parts. Some field cricket species remove the central portion of leaves and defoliate rice plants.

Management:

Agronomic Methods: Only agronomic practice for controlling crickets is the maintenance of standing water in the field. Standing water will prevent crickets to form tunnels in soil and ultimately cannot damage the plant roots.

Chemical Methods: The main control measure in deep water areas is the chemical treatment of soil as well as seeds at planting. Another measure that is recommended is poisoned bait made from powdered or liquid insecticide and from moistened rice bran can be placed on rice bunds or in a rice field to kill night-foraging field and mole crickets.

Biological Methods: Sphecid species; *Motes manila*, *Liris aurulenta*, *Motes loboriosus* and *Motes subtessellatus*, parasitize the field crickets. Mole crickets are cannibalistic and regulate their own numbers. Eggs of *Gryllotalpa africana* are preyed by *Pheropsophus jessoensis* larvae*.* Other parasites are Sphecid wasps (*Larva luzonensis*, *Larva carbonaria,* and *Larva sanguinea*) that parasitize nymphs and adults. Nymph and adults of mole crickets are parasitized by the nematode, *Mermis igrescens,* and the fungus *Beauveria bassiana.*

White Grubs

Description: The term white grubs are actually the large larvae of a scarab beetle. White grub larvae feed on the roots and they are also known as the chafers. White grubs are a serious damage causing pests of rice and they are distributed widely. They infiltrate the roots of sugarcane, cereals, vegetables, millets, and many other crops.

Management

Agronomic Methods: Delaying land preparation escapes the egg-laying phase of adults or they may die. Weeding also helps to reduce the chances of attack by reducing egg laying by females.

Chemical Methods: The only practical and effective insecticidal control measure is the application of granular insecticides against white grubs. Insecticides should be applied in crop hills or furrows at sowing.

Biological Methods: Mermithid nematodes and *Psammomermis* sp. parasitize the grub larvae. Several scoliid wasps, e.g. *Campsomeris marginella modest,* parasitize the white grubs.

Rice root aphids

Description: The rice root aphid, *Tetraneura nigriabdominalis,* is a major upland rice pest. It is reported in Pakistan, Bangladesh, India, Sri Lanka, Indonesia, Fiji, Republic of Korea, Japan, Malaysia, Nepal, Tonga, Philippines, Central America, Africa, New Zealand, the Caribbean, and Australia.

Damage: The rice root aphids affect rice crops at different stages. Aphid causes heavy damage at the tillering while light damage at the seedling stage. Rice root aphid causes deformed plant growth. Yellowing also occurs. These aphids reside in plant roots The main damage is caused by the nymphs and adults feeding, they suck the plant roots sap.

Management

Agronomic Methods: Increased plant density reduces the chances of Aphid attack so increasing plant density will help reduce the Aphid attack.

Chemical Methods: The usual prophylactic seed or soil treatment with appropriate chemicals or spraying formothion or oxydemeton methyl or phosphamidon (@ 250 ml/ha) will prevent the buildup of rice root aphids. Acephate and Carbofuran are also used as a chemical treatment.

Biological Methods: Several natural enemies are documented. Lady beetles (*Harmonia octomaculata*, *Coccinella repanda,* and *Menochilus sexmaculatus*), a mermithid nematode (*Mermis* sp.) and a braconid wasp (*Aphidius* sp.) are recorded parasites of nymphs and adults.

Rice root weevils

Description: Rice root weevil is the most damaging rice pest in Asia. They are widely distributed in Asia specifically in the Republic of Korea, Japan, and China, and in India.

Damage: Adults attack transplanted rice but rarely cause economic loss. Larvae cause real damage by attacking the roots and rootlets of young rice plants. They attack the redeveloping roots and restrict their development. The leaves give rusty appearance with yellow color and then plants die. The heavy attack in fields leaves large patches of dry plants. Tillering stage affected severely compared to other stages.

Management

Agronomic Methods: Late planting of the crop is recommended. This helps to escape the time of the highest larval attack. In flooded rice, growing of another crop along with rice can kill larvae. Dense planting decreases populations of rice root weevil.

Chemical Methods: Insecticides as a foliar spray and granular insecticides helps to control larvae, but granular insecticides show promising effects in controlling adults compared to foliar spray and dipping of rice seeds for 6 h before transplanting is an effective method for controlling larvae in highly infested areas. Leaf extract of the mahogany tree is used in research, and it affected the progeny production of rice weevil.

Rice mealybugs

Description: Mealybugs are immobile, plant-sucking insects. They are distributed widely all over the world and are economically important pests for rice, sorghum, potato, cassava, yam, coffee, citrus, and cacao. To cover themselves, they secrete white filaments of wax. Mealybugs are root, stem, or leaf feeders. *B. rehi* occasionally causes rice crop losses in Thailand, India, and Bangladesh.

Damage: They suck sap from a stem. This results in yellowing, abnormal tillering, and stunted plant growth. Because the young nymphs have restricted movement, damage occurs in patches. Under heavy infestation, panicle does not fully exert from the boot. Mealybug numbers vary between hills that cause several spots of depressed growth in the field which are identified as Sooraj and Chakdhora disease. Drought provides favorable conditions for the attack, and rice plants can least tolerate sap loss in this situation.

Management

Agronomic Methods: Agronomic control measures includes early or late planting to skip the timing of peak infestation. Flooding of the field throughout the crop growth period at 5-cm depth helps to reduce the damage because drought condition favors the epidemic. Removal and destruction of infected plants are done. No resistant varieties to *B. rehi* are commercially available.

Chemical Methods: Granular insecticides are operative in standing water. If there is no standing water in damaged fields, broadcasting the granules is an impractical practice. The waxy discharge covering the mealy bugs protects them from insecticidal effect. In that case, foliar sprays are effective.

Biological Methods: Main natural enemies of the mealybug are lady beetle species (such as *Harmonia octomaculata*, *Coccinella repanda* and *Menochilus sexmaculatus*). Dipterous predators of *B. rehi* are two chloropids (*Mepachymerus ensifer* and *Anatrichus pygrnaeus*) and one drosophilid (*Gitona perspicax*). Hymenopterous parasites of *B. rehi* recorded include; Encyrtidae *(Specie of Cheiloneurus, Gyranusa, Doliphocerus, Parasyrphophagus, Adelencyrtus, Xanthoencyrtus,* and *Mayeridia*), Eulophidae *(Species of Tetrastichus, Aprostocetus, Chrysocharis,* and *Desostenus*), Mymaridae (*Lymaemon sp.*), Ceraphronidae (*Cerapkron sp*.), Thysanidae (*Thysanus sp*.) and Pteromalidae *(Diparini* sp.and *Callitula sp*.).

Grain-sucking insects

Description: Several bugs feed on developing spikelets. They live on grasses or in the rice fields or in the surrounding areas where they reside and multiply in their vegetative stage. Then they move to flowering rice fields. In Asia, *Leptocorisa sp.* and in America, *Oebalus pugnax* are the important grain-sucking pests.

Rice bugs and Stink bugs

Damage: Rice bugs adults cause more damage because of a longer feeding period in spite of the fact that nymphs are more active feeders than adults. Rice bugs attack at the milk, dough making and even ripening stage of seed. Both nymphs and adult bugs feed on the endosperm of developing grains. In heavily infested fields, rice panicles contain unfilled grains. Rice bugs attacks on soft endosperm in a solid state and infuse enzymes to predigest it that results in kernel weakness and discoloration of mature grain. Damage during the milk and dough stage causes yield loss and poor grain quality, respectively.

Management

Agronomic Methods: Several agronomic and mechanical methods are being used to control grain-sucking rice bugs. Late planting is usually used as an agronomic practice especially for early maturing varieties. This is done in a synchronous pattern in order to make sure that all crops mature concurrently. During rice free periods, alternate hosts eradication from fields, from leaves and from surrounding areas is a good practice in controlling the bug multiplication.

Mechanical control measures include the use of sticky traps, hand picking of nymphs and adults, and smoking the field.

Chemical Methods: Granular insecticides are usually futile in controlling grain sucking bugs. Dust formulations or spraying the insecticides are sometimes suggested. Use of chemicals (e.g., Acephate) is recommended in some rice growing areas. Dusting carbaryl @ 10 %, for *Leptocorisa sp.* is sufficient and if there is the severity of the infestation, it is repeatedly used.

Biological Methods: As a biological control, several predators and parasites are recognized to outbreak the rice bug. A typical natural enemy of stink bug is *Nabis stenoferus*, called the assassin bug. A number of spider's species, e.g., *Tetragnatha* *javana*, *Neoscona thesis* and *Argiope catenulate,* target on nymphs and adults of rice bug. Eggs of *Leptocorisa sp.* are destroyed by small scelionid wasps (*Gryon Nixon*). Stink bugs are parasitized by several wasps species. The meadow grasshopper, *Conocephalus longipennis,* preys on rice bug eggs. A fungus, *Beauveria bassiana*, preys on both nymphs and adults.

Rice leafhoppers and planthoppers

Description: Leaf and planthoppers not only cause feeding damage, but they also cause viral diseases by acting as vectors. The more damaging species in Asia are the zigzag leafhopper *Recilia dorsalis*, green leafhoppers *Nephotettix sp.,* the white-backed planthopper *Sogatella furcifera*, the small brown planthopper *Laodelphax striatellus*, and the brown planthopper *Nilaparvata lugens* and *Tagosodes orizicolus*. The rice delphacid *Tagosodes orizicolus* is found in the north-central region of South America and the southern USA. Three *Nephotettix* species; *Nephotettix nigropictus* and *Nephotettix virescens* are found in tropical and temperate Asia.

Damage: Leaf and planthoppers damage plants by plugging phloem and xylem through sucking the sap. Similar effects appeared due to excessive oviposition. The ovipositional and feeding marks incline plants to be a bacterial and fungal infection. Honeydew boosts sooty molds due to a toxin injected during feeding on plants infested with *Cicadulina bipunctella.* Leaf and planthoppers are also vectors of rice viral diseases. *Nephotettix virescens* is a vector of tungro viruses, *Nilaparvata lugens* spreads grassy and ragged stunt virus in South Asia and Southeast Asia, *Laodelphax striatellus* act as a vector of a most dangerous disease, rice stripe in East Asian countries and *Tagosodes orizicolus* causes the spreading of 'Hoja Blanca' virus.

Management

Agronomic Methods: Nitrogen application in three split doses is effective in minimizing the population rate of *Sogatella furcifera and Nilaparvata lugens.* Silicon application is positively connected to reduce the planthopper population in rice fields. Water favors the growth of planthoppers and leafhoppers so 3 or 4 d fields draining during invasion have been endorsed for reducing *Sogatella furcifera* and *Nilaparvata lugens* populations. For *Nilaparvata lugens,* closer plant spacing is considered as an important factor favoring hopper build-up. Lower plant portion is slightly cooler due to low sunshine, humidity and provides a favorable microclimate for pest population build-up.

Field sanitation for control of leaf and planthoppers is used in many rice growing areas. Volunteer rice and ratoons may act as a source for the spread of a virus.

Rice crop rotation is an economical control measure. For this purpose, legumes are usually grown in most areas of Asia for reducing leaf and planthopper infestations.

Use of trap crop to control *Nephotettix virescens* and *Nilaparvata* lugens is suggested in a study conducted at IRRI. Trap crop transplanted 20 d before crop transplanting and it reduced the attack of *Nilaparvata lugens* on the main crop. Similarly, The banker plant system is also used in some countries, and it can boost the population of *A. nilaparvatae that* helps to control rice planthoppers. In the Jiaxing City of China, the incidence of planthopper transmitted viral diseases is considerably decreased by delayed sowing and non-significant variation in the grain yield is observed.

The frequency-vibration-based pest lamps used to kill the planthoppers. They are installed at 200 m distance from each other in a checkerboard pattern and 1.3–1.5 m above the ground. These lamps are switched on during the light period when immigration of planthoppers occurs. However, a disadvantage of these lamps is that it will also cause damage to beneficial insect pests.

Host-plant resistance is helpful in decreasing the damages. In a study in China, about 29 dominant resistance genes for planthoppers have been recognized from wild rice species and indica rice varieties. The transgenic rice plants with snowdrop Lectin (*Galanthus nivalisagglutinin*) have reduced the fecundity and survival rate by postponing the development of planthoppers because of there by an antifeedant activity.

Chemical Methods: For the control of leaf and planthopper vectors, insecticides application is used that not only reduces the effect of leaf and planthopper but also reduces the spread of the virus. The strategies used in chemical control of leaf and planthopper vector successfully are linked to vector behavior and virus transmission characteristics. With *Nephotettix virescens,* direct feeding is more damaging than the tungro virus transmitted by the vector. Tungro is a non-persistent virus and spread during a short feeding period, whereas grassy stunt and ragged stunt viruses are persistent and require more time. Therefore, rapid knockdown and prevention of feeding of the leafhopper are important. In tungro epidemic areas, prophylactic procedures are used for protection against this virus.

For *Nilaparvata lugens,* insecticide application at young nymph stage is inefficient because young nymphs do not cause damage to the crop. The insecticide should be applied only at an economic threshold level of population.

Leafhoppers are more responsive to insecticides than planthoppers. Most commonly recommended insecticides are chlorinated hydrocarbons, organophosphates, and carbamates in the Republic of Korea and Japan, but organophosphates have the highest selectivity against *Laodelphax striatellus, Nilaparvata lugens,* and *Sogatella furcifera.* Organophosphates have a lower level of ovicidal activity than carbamates.

Buprofezin is extremely discerning molting-inhibitor for *Nephotettix cincticeps, Nilaparvata lugens, Nephotettix virescens, Laodelphax striatellus,* and *Sogatella furcifera,* Buprofezin is found nontoxic to fish, or mammals.

For tungro virus control, systemic granules of insecticides are suggested for soil incorporation before seedbed sowing. Soil incorporated granules are advantageous than sprays or broadcast granules in the seedbed.

Broadcasting or soil incorporation of systemic granules provides protection to crop for 40 d whereas, seed soaking in insecticide solution before transplanting for 6-12 h gives protection for 20 d.

Insecticide sprays are more effective than a granular application for control of *Nilaparvata lugens.* However, in many countries, leafhoppers and planthoppers developed resistance against organophosphates carbamates and carbofuran.

Biological Methods: Several pathogens, parasites, and predators attack at all stages of leaf and planthopper. Inappropriate insecticides application may destroy the population of natural enemies that results in a striking outbreak of pest. Most effective parasites of *Nilaparvata lugens* eggs are; trichogrammatid (*Paracentrobia andoi*), mymarid (*Anagrus optabilis*), and eulophid wasps (*Tetrastichus formosanus*). Parasites of *Nilaparvata lugens* nymphs and adults are; dryinid wasp (*Echthrodelphax bicolour*), elenchid strepsipteran (*Elenchus yasumatsui*), fungal pathogens (*Hirsutella citriformis* and *Beauveria bassiana*), and nematode parasite (*Hexamermis sp.*). Underwater aquatic predators (e.g., *Cybister sp.*) and surface predators (e.g. *Ranatra dimidiate*, *atrolineata*, *Mesovelia vittigera* and *Microvelia douglasi)* prey on hoppers in water bodies.

The beetle, *Ophionea,* actively explore foliage for *Nilaparvata lugens* nymphs and adults. Damselfly and dragonfly prey on adults and nymphs. In laboratory tests, a single *Pardosa pseudoannulata* used up about 45 planthoppers/d. A white fungus, *Beauveria bassiana*, grows and covers the body of dead leafhoppers and grows inside it.

Common predators of eggs are *Cyrtorhinus lividipennis.* Parasites of nymphs and adults are dryinid wasp (*Echthrodelphax fairchildii*), pipunculid flies (*Tomosvaryella oryzaetora, Pipunculus mutillatus*), and strepsipteran. Greater than 50% parasitization of green leafhoppers by pipunculids is reported. Biological insecticide, 9% 12 α-hydroxy rotenone EW, shows greater insecticidal effects on planthoppers.

Rice gall midge

Description: The rice gall midge *Orseolia oryzae* (Wood-Mason) is one of the most damaging pests of rice in South and Southeast Asia. It also occurred in several parts of Pakistan, India, Sri Lanka, Cambodia, Laos, Nepal, Myanmar, Indonesia, Vietnam, and northern Thailand. It also occurs in Ghana, Ivory Coast, Cameroon, Liberia, Mali, Nigeria, Niger, Sudan, and Senegal.

Damage: The gall formed by the activity this fly is popularly known as 'anaikomban' 'onion shoot' or 'silver shoot'. Hollow pink or purple, pale green or dirty white tubes at the tip of the leaf, a reduced green leaf blade with auricles and ligules are formed. It also invades the rice nursery but tillers are ideal for their attack. It may cause up to 50% rice yield loss in a heavily infested crop.

Management

Agronomic Methods: The use of suitable amounts of nitrogen fertilizer in split doses on different growth stages is suggested. Field sanitation helps a lot to control the spread of gall midge. Removal of alternate hosts from fields is recommended controlling the pest population. Keeping land fallow free of off-season host plant and field plowing after harvest is recommended. Planting should not be done in neighboring fields within 3 wk to avoid staggered ages crops. Delaying planting of photoperiod-sensitive varieties helps decrease rice gall midge infestation because the vegetative stage is more prone to gall midge attack.

Chemical Methods: Insecticides are not recommended for gall midge control because larvae reside and protect inside the gall and plant. However, granular insecticides are applied sometimes. Granular insecticide applications at any rate in standing water in the field are usually effective than foliar sprays. Seed treatment with chlorpyriphos (0.2%) emulsion for 3 h is suggested in some rice-growing areas of the world. Seed mixing with either imidacloprid (0.5 kg /100 kg seeds) or chlorpyriphos (0.75 kg/100 kg seeds) provides protection for 30 d in the nursery. Seedling root dipping for 12 -14 h in 0.02% chlorpyriphos emulsion before transplanting provides 30 d protection.

Biological Methods: Numerous predators and parasites attack at gall midges. The natural enemies, controlling the African and Asian rice gall midge are diverse. Several platygasterid wasps are parasitoids of larvae and they start laying eggs on silver shoot walls when they first sting the larva from inside. The new hatchlings attack on the gall midges. A phytoseiid mite, *Amblyseius imbricatus, and Bracon sp., aff. annulicornis*, *Platygaster pachydiplosisae*, *Anisopteromalus camerunus, and Neanastatus tenuis platygasteri,* attacks on eggs of Asian and African rice gall midges. Several pupal parasitoids e.g., *Neanastatus cinctiventris* and *Neanastatus* oryzae, and solitary larval parasitoids, e.g., *Obtusiclava oryzae* are also known. Adult midge is preyed by many spiders species, e.g., *Neoscona theisi*, *Argiope catenulata* and *Tetragnatha mandibulata*.

Rice leaf folder

Description: Larvae of eight pyralid moths' species roll or fold the leaves of graminaceous plants. They are *Marasmia exigua*, *Cnaphalocrocis medinalis*, *Marasmia bilinealis* Hampson, *Marasmia patnalis*, *Marasmia suspicalis*, *Marasmia ruralis*, *Marasmia venilialis,* and *Marasmia trapezalis*. They are found in the rice-growing tracts of 29 temperate and humid tropical countries of Asia, Australia, and Africa.

Damage: Several epidemics of leaf folders have been reported in the Republic of Korea, Fiji, Bangladesh, Philippines, China, India, Sri Lanka, Japan, Nepal, Vietnam, and Malaysia.

Under favorable conditions, several generations of leaf folders are produced. Only 1 larva/leaf is found. After feeding for about 2-3 d, larvae move to another leaf. Thus, each larva destroys more than one leaves during its growth period. The high insect population causes rice plants to dry up and appear scorched. The larvae longitudinally fold the leaves before feeding and fasten the leaf margins with threadlike silk stitches. Feeding affects the photosynthetic ability and vigor of the infected rice plant. The damaged leaves are the entry points for bacterial and fungal infections. Feeding on flag leaf by leaf folders caused maximum yield loss.

Management

Agronomic Methods: Nitrogen fertilizer management is highly recommended. N fertilizer plays an important role in improving the yield, in increasing the nutrition of the rice plant but it also helps to greater insect feeding rates, survival, and reproduction which in turn leads to greater damage. Nitrogenous fertilizer application in split doses is helping to reduce the growth, reproduction and surviving ability. Other fertilizers such as phosphorus, potassium and necessary elements should be applied in balanced amounts. They can enhance the rice plant vigor and improve the resistance of rice plants to leaf folders.

Removal of the alternate host plant is recommended e.g. grassy weeds removal from rice fields and surrounding borders that prevent the rice leaf folders build-up on alternate hosts. Varietal resistance can be used to reduce the damage caused by leaf folders. Bt rice posses first-rate insecticidal activities against leaf folders. Sex pheromone application can decrease the insecticide use by 1–2 sprays and the input costs can be decreased than insecticides.

Chemical Methods: In order to control severe leaf folder influx, chemical control is done. A most effective method of applying an insecticide is foliar sprays. Foliar sprays are needed to be repetitive because of washing off insecticides by frequent rains. Granular insecticides application by the broadcast method is ineffective. However, insecticide created resurgence of *ilaparvata lugens* acts as hindrances to successful chemical control. Fields should be monitored weekly because leaf folders can attack the crop at any growth stage.

Biological Methods: Several natural enemies of rice leaf folders normally push them underneath economic threshold levels. Several species of nematode (*Agamermis sp.*), Diptera (e.g., *Argyrophylax sp.* and *Megaselia sp.*), Coleoptera (*Coccinella sp.* and *Chlaenius sp.*), Orthoptera *(Metioche sp.* and *Anaxipha sp.*), Hymenoptera *(Apanteles sp., Trichogramma sp., Goniozus sp.,* and *Bracon sp.*) and Araneae *(Tetragnatha sp., Argiope sp.* and *Pardosa sp.*) have been reported as parasites and predators of leaf folders in Asia. Spinetoram, Spinosad, *Empedobacter brevis* and *Beauveria bassiana* possess grater insecticidal effects on stem borers. A few viral, fungal and bacterial pathogens and toads and frogs also parasitize the larvae, when the pest population is high. The biological insecticide 9% 12 α-hydroxy rotenone EW show greater insecticidal effects on leaf folders. Microbial insecticides, e.g. *Bacillus thuringiensis*, are effective against larvae.

Rice water weevil

Description: The rice water weevil (*Lissorhoptrus oryzophilus*) was originally found in the Mississippi River basin., but it is now one of the most destructive rice pests in all rice growing areas.

Damage: Adults feed on young rice plants and cause damage to leaves. Longitudinal strips are formed on the leaf surface. Maggots cause the main injury. They feed on the roots, severely pruning them in heavy infestations and causing vigor loss, reduced yields and plant lodging.

Management

Agronomic Methods: Early planting of rice can skip the time of pest attack and reduce the yield loss. In Japan, early transplanting of rice seedlings early reduces yield loss. Losses can also be decreased by transplanting middle-aged or mature seedlings. Intermittent rice fields flooding and draining at 15 d intervals reduces the damage. However, this practice has a limitation in areas where water availability is low and the loss of fertilizers also occur due to drainage. Removal of alternate hosts plants e.g. aquatic grasses, reduce the pest population. Areas receiving higher doses of fertilizers are more sternly infested. Rice resistance varieties to rice root weevil are recommended. Several rice varieties with low or moderate levels of resistance are recognized.

Chemical Methods: Granular insecticides are suggested and applied at the appropriate time.

Biological Methods: The fungus, *Beauveria bassiana,* attack on rice water weevil. A mermithid parasitized the female weevils in the USA. Several frogs and bird species are recognized to feed on the rice weevils. Tettigoniid grasshoppers such as *Orchelimum agile*, *Conocephalus fasciatus* and *eoconocephalus triops* prey on adult weevils.

Rice thrips

Description: The two most common species associated with rice are *Haplothrips aculeatus* and *Stenchaetothrips biformis*. *S. biformis* is a major rice pest in India, Sri Lanka, Japan, Bangladesh, Indonesia, and China. *S. biformis* is also known as rice paddy thrips, oriental rice thrips, and rice leaf thrips. The first specimen collected from watercourses.

Damage: Larvae, as well as adults, possess scratchy mouthparts. Thrips species with leaf-feeding habit possess a punch and suck feeding technique. Symptoms of damage include; leaves rolling inward along the margins, stunting and wilting. Fine, silvery or yellowish streaks appear. In a severe epidemic, plant death occurs, resulting in a low plants number/unit area. The damage is severe in dry land rice fields.

Management

Agronomic Methods: For rice thrips control, flooding the field for 2 d to submerge plants is an effective practice. Use of resistant varieties can reduce the chances of thrips attack. Many rice varieties resistance to thrips have been identified. Wild rice with resistance to thrips includes; *Oryza glaberrima. Oryza eichingeri, Oryza minute, Oryza officinalis, Oryza nivara, Oryza perennis, Oryza sativa f. spontanea* and *Oryza rufipogon.*

Chemical Methods: Insecticides as sprays, as systemic granules or dust controls pest build-up. In china seed treatment with methoxam reduces the trips infestation more effectively compared to the foliar application. Imidacloprid, carbosulfan, thiamethoxam, and thiacloprid are the insecticides most commonly used as seed treatments against rice thrips.

Rice caseworm

Description: The rice caseworm, *Nymphula depunctalis,* is an important insect pest of rice. It occurs in Africa, in Australia, South America, and many tropical countries. Among related species are; *Paraponyx fluctuosalis*, which occurs in Australia, Japan, India, Philippines, Sri Lanka, China, Malaysia, Thailand and in some African countries, *Nymphula fengwhanalis* and *Nymphula vittalis*, which occur in China and *P. diminutalis*, which occurs in India, Japan, China, Indonesia, Philippines, Thailand and Sri Lanka.

Damage: The freshly hatched larvae attack and feed on the tender leaf surfaces, but larvae at later stages, feed on the surfaces of the older leaves. Larvae caused the damage by feeding and cutting off the leaf tips forming a case. Removed leaf tissue gave the ladder-like appearance, while upper epidermis gave the papery appearance. They gave smaller panicles and less number of tillers and delayed maturity. If other pests such as stem borer or whorl maggot infest the crop within first 30 d of transplanting, yield loss occurs and plants' ability to recover is decreased.

Management

Agronomic Methods: Agronomic methods involving older seedlings transplant helps in limiting the period of larvae attack. Water management is also effective in controlling larvae of rice caseworm. Field draining for about 3 ds will exterminate most of the larvae because of low supply of oxygen. A non-flooded seedbed is protected from caseworm attack. However, this practice favors weed growth.

Chemical Methods: Larvae of rice caseworm are sensitive to insecticides. So, the foliar spray is recommended. They have controlled readily with granules application in floodwater or with foliar sprays. Within one week of transplanting, the insecticidal foliar spray is recommended.

Biological Methods: A tabanid fly; *Tabanus sp.* and a braconid wasp; *Dacnusa sp.* parasitize the caseworm larvae. The hydrophilids (e.g. *Berosus sp.*), *Cybister tripunctatus orientalis Gschwendther* and *dystiscids Laccophilus difficilis* are reported predators of caseworm larvae. Algae and snails foraging such as *Radix* sp. and *Pila sp.* may remove caseworm eggs from rice leaves. Red ants attack the larvae in infested dry field rice. Several spiders of Araneidae; *Araneus inustus,* and *Neoscona theisi,* one species of Clubionidae; *Clubiona japonicola*; one species of Tetragnathidae; *Tetragnatha nitens*; one species of Lycosidae; *Pardosa pseudoannulata* prey on the moth.

Whorl maggots

Description: Whorl maggots consist of a composite of several species of genus *Hydrellia.* All members of the genus are a leaf or stem miners. They prefer living in damp areas or near water. In the field, rice whorl maggots resemble with other flies. Because of this resemblance, rice whorl maggots are difficult to identify.

Rice whorl maggot/South American Rice Miner

Description: The rice whorl maggot, *Hydrellia philippina,* was first documented in the Philippines in 1962, as a serious pest of rice. The insect attacks only rice plants usually at the vegetative stage, in the irrigated fields. It feeds on the central whorl of the leaf. It is a semi-aquatic pest.

Damage: The fly maggots attack unfurled leaves. The hatchlings move to the center and feed on the mesophyll tissue. Chewed-up and discolored areas appear. These areas ultimately dry up and leave often droop.

Management

Agronomic Methods: Crop establishment methods result in insignificant damage because plants cover the water surface. Water surface covering with Azolla helps to restrict invasion. Recommended agronomic control is rice fields draining because adults are attracted to standing water. It is good to use mature seedlings to curtail the crop vegetative stage. Draining should be done during the first 30 DT at intervals of 3-4 d. Drained fields allow more growth of weeds. Direct-seeded seedbeds or fields are not striking to adults so direct seeding is recommended. Use of resistant varieties is recommended however only a few resistant varieties are available against whorl maggots.

Chemical Methods: Soil application of systemic granules before transplanting or broadcasting of non-systemic granules in standing water are usually more effective methods for whorl maggots' control. However, foliar sprays can be done 1 or 2 wks after transplanting.

Biological Methods: Wasps *Trichogramma sp.* parasitized the exposed eggs of whorl maggots on leaves and braconids parasitized the whorl maggot larvae. Another parasite of whorl maggots includes; araneid (*Neoscona theisi*), lycosid (*Pardosa pseudoannulata, Oxyopes javanus*) and a fungus of the genus *Entomophthora.* Adult whorl maggots are preyed upon by ephydrid flies (*Ochthera brevitibialis*).

Ladybird beetle

Description: The ladybird beetles are oval, convex, small, insects. A large number of these species act as predators. They grow on planthoppers, leafhoppers, aphids, and mealy bugs and on the eggs of many other insects. The most common and widely distributed are *Micraspis crocea* and *Micraspis discolor*.

Damage: Ladybird beetle has variable feeding habits. Adults and nymphs of ladybird beetles usually feed on planthopper, aphid and leafhopper nymphs, and adults, eggs of mealy bugs, thrips, and stem borer. In the absence of prey, they attack pollen and leaf blades (leaving small chewed areas) and recurrently damage grains.

Management

Organophosphate insecticides spray helps to control rice beetles. These beetles are predators of several harmful insects. Controlling or reducing prey population helps to control beetles.

Rice black bugs

Description: The two most important and common species of black bugs are the Japanese rice black bug, *Scotinophara lurida* and Malasyan rice black bug, *Scotinophara coarctata* that attack rice plants. They are also known as rice pentatomid bugs. *Scotinophara lurida* occurs in Japan, Taiwan, China, Sri Lanka, and India while *Scotinophara coarctata* occurs in Taiwan, China, Indonesia, India, Malaysia, Thailand, Vietnam, Philippines, and Cambodia.

Damage: Both nymph and adults of rice black bug cause damage to plant by feeding the sap. They usually reside at the plant base. At the start of the day, they feed on upper parts of plants. But when sunlight intensity is high, they invade to undersides of stem and leaves and continue feeding there. At night, they become active and incessantly feed throughout the night.

Management

Agronomic Methods: Destroying the host plants usually b plowing the field is an important agronomic practice to control black bugs. Black bugs persist in the rice stubbles even after harvest, plowing is done to control the pests. Sunlight plays an important role in destroying black bugs. Weed removal allows more sunlight to arrive at the rice plants bases and kills the bugs.

Chemical Methods: Spraying the insecticides at the plant base is a most effective way to control black bugs. This practice is done because black bugs stay at the base of plants.

Biological Methods: Several natural enemies of the rice black bug are reported. These include; gryllid (*Metioche vittaticollis*), coccinellid (*Micraspis crocea*), carabid (*Agonum daimio),* nabid bug (*Stenonabis tagalicus*) and spiders (*Pardosa pseudoannulata*, *Oxyopes javanus*, *Tetragnatha virescens*, and *amaricus formosus).* Some fungi also act as a predator of black bugs e.g. *Paecilomyces lilacinus*, *Beauveria bassiana,* and *Metarhizium anisopliae*.

Colaspis

Description: Two species of colaspis; *Colaspis louisianae,* and *Colaspis brunnea,* are found throughout rice-growing areas. This pest usually causes damage to dry- seeded rice fields in a soybean-rice rotation.

Damage: Colaspis larvae start feeding on the plant roots when rice or any other crop is sown into a field. Fine root hair feeding by larvae may result in the death of the plant. The larvae will then pupate and develop into adults. Adults will not lay eggs on rice crop but will migrate to a nearby soybean field. Clumped larval distribution in the soil and patches of reduced plant stand loss are commonly found.

Management

Application of permanent flooding is the only agronomic practice that helps to minimize the pest attack. These pests do not live in water and they cannot survive continuous flooding. This is why they are not a serious problem in water-seeded rice.

Panicle Rice Mite

Description: The panicle rice mite (PRM), *Steneotarsonemus spinki*, is a pest of commercially produced rice in Asia, the Caribbean and Central America. This pest causes significant damage to rice crop, especially in the presence of bacterial panicle blight and sheath rot.

Damage: The panicle rice mite attack and damages the plants both directly by feeding on rice leaves, kernels, and stems and indirectly by acting as a vector of viral, fungal, and bacterial pathogens. Feeding destruction can cause the sterile grain syndrome, which is designated as a brownish, loose flag leaf sheath, damaged grain development with un-filled grains and brown spots, a twisted panicle neck, and erect panicles standing.

Management

All the control methods used for sheath rot and bacterial panicle blight will help to reduce the effect of this pest.

Chinch Bug

Description: Chinch bugs (*Blissus leucopterus leucopterus*) hibernate as adults in leaf litter, grass clumps, and other protected areas. They emerge in early to mid-spring for feeding and mating on grass hosts and on rye, wheat, barley, and oats grains.

Damage: Chinch bugs are sporadic and create more damage in drill-seeded rice because of the delayed application of permanent flood. Economic damage to rice usually occurs when different production practices and favorable weather conditions sanction chinch bugs to reside on wheat, corn and sorghum fields. When these crops are harvested at maturity, chinch bugs may migrate to young rice plants in nearby fields. Crop stand is reduced.

Management

Agronomic and chemical control methods are available. Agronomic control consists of flooding the fields, force the chinch bugs to migrate to rice foliage where they can be controlled with an insecticide. This practice necessitates that rice plants be large and levees be in place to resist a flood. Agronomic control is usually more costly than chemical control.

Rice Leaf Miner

Description: The rice leaf miner (*Hydrellia griseola*) is a sporadic problem in rice growing areas. Leaf miner attacks on the crop in the early spring and epidemic occur usually in the deep water, on the upper side of levees. Rice leaf miner is usually not a problem in 4 to 6 inches deep water.

Damage: The attack is more severe in continuously flooded rice fields with more than 6 inches deep water. Larvae make a tunnel between leaf layers. Leaf miner usually attacks and kills the leaves that are close to the water. Under heavy infestations, the entire plant may die and severely reduce the plant stand.

Management

Rice leafminer management involves agronomic control or insecticide application, perhaps both. Important agronomic practice is maintaining the water depth at 4-6 inches. Lowering of water level in rice fields helps to prevent injury.

Rice Seed Midge

Description: Adult rice seed midges (*Chironomus sp.*) always occur in flocks on levees, rice fields, and roadside ditches and in other water bodies.

Damage: Midge usually attacks water-seeded rice. Larvae injure rice by feeding on the seeds of very young seedlings, on germinating seed embryo and on the developing roots. In flooded fields, the potential of infestation increases. Midge infestation can be from insignificant (not economically important) to very severe.

Management

Most important agronomic method to control rice seed midge is field draining as this pest grows better in flooded fields. Draining the field will reduce the midge number. Sometimes, reseeding in highly infested fields is required. Methods that encourage rapid seedling growth and seed germination, such as avoiding cool weather planting and using pre-sprouted seed will help to escape vulnerable midge attack stage and reduce serious damage.

3. Rice diseases and their management

Seedling Blight

Description: Seedling blight, or damping off, is caused by several soil-borne and seed-borne fungi, including species of *Curvularia*, *Cochiobolus*, *Fusarium, Sarocladium*, *Sclerotium,* and *Rhizoctonia*. Brown thin and irregular spot on growing point or coleoptiles of rice appear. Fungi penetrate the undeveloped seedlings and injure them. Blighted seedlings that come out of the soil, dies out suddenly after surfacing.

Management

Suitable agronomic practices, such as sowing of early maturing varieties will decrease the effect of fungi. Draining the field and seed planting under optimum temperature, are the best control measures for this disease. Treating seed with seed-protectant fungicides (e.g. mefenoxam, metalaxyl, thiram, and mancozeb) effectively decreases the seedling blight and gives satisfactory stand.

Water Mold

Description: It is a fungal (*Achlya* sp. and *Pythium sp.*) disease. Water mold is noticed as a fungal ball strand around seeds on the surface of the soil. Seeds are rotted after draining seeding flood. This result in a greenish-brown or copper-brown spots on soil surfaces or above, about a dime size with central rotted seed. The color is due to green algae and bacteria, mixed with fungal hyphae.

Management

Draining and flushing the seeding helps prevent water mold. Pin-point flooding helps in reducing damage caused by water-mold. Sowing should not start till the mean daily temperature reaches 65 ^{o}C. Seed treatment with suggested fungicides helps to reduce the damage.

Crown Rot

Description: It is a minor disease of rice caused by *Erwinia sp*. This disease is observed rarely. During tillering, symptom first appears. The crown area is rotten and becomes soft that extends into lower internodes with a fetid odor. Tiller starts dying, one at a time. Roots die and turned black, with discolored streaks. A similar crown discoloration is caused by misapplication of a hormonal herbicide (e.g. 2, 4 –D.).

Management

No specific control practices are generally recommended.

Root rot

Description: Root rot is a fungal disease also called as feeder root necrosis, caused by *Phytium dissotocum*, *Pythium spinosum,* and other *Pythium sp.* This disease causes black discoloration of roots. As the root deterioration occurs, absorption of nutrient is reduced. The leaves become yellow and plants lack vigor.

Management

Proper fertilization reduces the disease symptoms however nutrient use is reduced. Control of rice root weevil can help to reduce root rots. Field draining enhances root growth but can create problems with nutrient use efficiency, blast, and weeds.

Root knot

Description: Root-knot is caused by nematode *Meloidogyne* sp., found only under dry-land conditions. Symptoms include swollen areas of the roots and formation of knots or galls. Plants are a yellow color, dwarf, and lack vigor.

Management

The disease is rare and yield losses are low. Prolonged flooding of field is recommended as nematode becomes inactive.

Rice blast

Description: A most important disease of rice worldwide and occupies the first position in terms of causing damage in intense rice cultivation areas. The causative agent of this disease is *Pyricularia oryzae*. This disease is also named as rotten-neck blast, node blast, leaf blast, collar blast and panicle blast depending on the portion of the plant affected. The disease disseminates through seeds, wild grasses and diseased plant debris lying in the field. Small spots appear on grains, leaves, nodes, and panicles and sometimes on leaf sheaths. The spots start as small, greyish, bluish or whitish, water-soaked dots. These spots rapidly multiply and their center turns grey. Black and brown spots also grow on glumes and inflorescence. In later stages, diseased heads blasted, and color becomes white. Grain development is affected and the panicles droop.

Management

If the disease is not widespread in an area, the blast can be controlled by burning and destroying the diseased plant debris and stubble, avoid over nitrogen fertilization as this increases the plant's receptiveness to the disease. Early planting, use of healthy seed, dusting the seed with the seed dressing organic mercurial fungicides, spray the crop with organo-mercurial, cultivation of resistant varieties, avoid excessive application of irrigation water and utilize good water management to ensure that plants do not experience water stress. Also avoid and control the excessive population of plants, grasses, and weeds. The disease might be successfully controlled by systemic fungicides when they are available. In a study in Nepal, Tricyclazole 22% + Hexaconazole 3% fungicide proved effective in controlling rice blast when applied at weekly intervals starting from the booting stage. Silicon application to rice crops showed a positive effect in combating rice blast disease.

Brown spot

Description: Brown spot is caused by the fungus, *Cochiobolus miyabeanus* and it is one of the most prevailing rice diseases around the world. It is also known as Helmintho-sporium leaf spot. This is another leaf spot disease that frequently occurs. The main cause of this disease is poor soil conditions. Round, brown lesions having a yellow halo appeared on leaves. Size of lesions fluctuates from the size of a pin-head to rice grain. As lesion grows, they remained round with necrotic grey center and reddish-brown to dark brown margin. These brown spots cause severe damage and ultimately leaf dies.

Management

Sowing of good quality seed and good land preparation helps to reduce the disease incidence. Destruction of stubble, sanitation and crop rotation are mostly used agronomic practices. Chemical seed treatments like appropriate fungicides are effective in reducing the prevalence of the disease. Copper fungicides spray in the right amount and at right time will reduce the damage. Disease resistant varieties are also grown to reduce chances of disease occurrence. Plants must be provided with correct nutrients, at the proper time and in the proper dose. Avoiding water stress in field reduces the propagation of disease.

Narrow brown leaf spot

Description: The causative agent of this disease is called *Cercospora janseana*. This disease differs in rigorousness from year to year and becomes more rigorous as rice plants mature. The disease occurs in major rice-growing regions in Africa, North, Central and South America, tropical Asia and Australia. Long narrow reddish-brown or brown lesions appear that are parallel with leaf veins. These lesions usually constrained between veins. The lesion may expand across veins that can kill leaves. The lesion can also appear on the leaf sheath.

Management

Treating seeds with appropriate fungicides or sometimes with hot water, before planting, can diminish the prevalence of the disease. However, chemical application is not currently suggested for this disease. Use of resistant varieties is also recommended.

Leaf smut

Description: Leaf smut is a distributed widely and is caused by a fungus, *Entyloma oryzae*. Lesions appeared on leaf blade that is small, black, and linear and may have a light brown or dark gold halo. Leaf tip dries up and becomes gray as plants reach maturity. Lesions are usually present on the upper sheath.

Management

Foliar fungicides (e.g. trifloxystrobin and propiconazole) are usually applied. Leaf smut attacks in the late rice growing season and causes minor losses.

Leaf Scald

Description: This disease is caused by a pathogen, *Gerlachia oryzae* and it is severe in West Africa and Latin America.

Damage may vary depending on growth stage, plant density, and cultivar. Leaves gave the scalded appearance. The lesion is consisting of a different zone of alternating wide bands of grey color with light tan and dark brown narrow bands from leaf tips or edges. Lesions often are tan marks with golden or yellow borders at leaf edges. Light brown halos appear as the lesions mature. Leaf tips and margins are translucent.

Management

Application of only recommended amount of nitrogen fertilizer in split dose helps to reduce the disease susceptibility. Growing of resistant rice varieties is an important preventive measure. Foliar fungicides (trifloxystrobin and propiconazole) application is recommended. But these fungicides are not applied after the rice seedhead emergence. Treat the seeds with suitable fungicide (e.g. iprodine and propiconazole).

Bacterial leaf blight

Description: Bacterial leaf blight is caused by a bacterium called *Xanthomonas campestris*. This is a serious rice disease during the rainy season. Elongated lesions appear near the tips of leaves or edges that are several inches long and water soaked in appearance. Leaf tips or edges turn firstly into white, then yellow and finally gave grey color due to fungi (Saprophytic fungi). Leaf edges become wavy. Death of leaf and plant occur, and grains remain empty.

Management

Bacterial blight can be managed effectively by plowing the straw and stubble into the soil after crop harvest. The burning of diseased stubble helps to reduce the chances of disease transfer. Appropriate land preparation and sowing good quality seed reduce the chances of disease manifestation. Resistance varieties are also used to avoid this disease. Excessive nitrogen application in the field increases the chances of disease manifestation. To avoid this situation, nitrogen application is done in split doses.

Stack burn

Description: It is also called Alternaria leaf spot, caused by a fungus, *Alternaria padwickii*. It is common in rice growing areas of the world. White or pale tan, round or oval spot appear with marrow reddish-brown margin. Two adjacent spots merge and form a double oval spot. In the center of the spot, a small black fruiting structure appears.

Management

Seed treatment with fungicides will decrease the seedling blight and in turn, will reduce the chances of leaf infections by reducing the number of available spores.

White leaf streak

Description: White leaf streak is caused by a fungal pathogen, *Mycovellosiella oryzae*. It is very similar to narrow brown leaf spot except that the spots are a little broad and have white centers. White leaf streak is widespread in West Africa and tropical Asia. Lesions are long, narrow with brown border and white center appears on leaves. Pathogen lives on infected straw and seed. The pathogen may go through the plant from cuts and bacterial exudates can blow out in irrigation water. High temperatures and humidity are favorable conditions for disease emergence.

Management

Planting of treated seed with fungicides can reduce the disease outburst. Use of resistant rice varieties may suppress the attack. Control of field moisture content also is used as a remedy.

White Tip

Description: A nematode; *Aphelenchoides besseyi* caused this disease. Leaf tips become white with yellow strips between diseased and healthy tissue and leaf edges become white sometimes.

Management

Use of resistant varieties is recommended but resistant varieties are not proved effective and still, a loss in yield occurs. Storage seed fumigation can reduce the population of the nematode.

Sheath spot

Description: This is a fungal disease caused by *Rhizoctonia oryzae*. The disease looks like sheath blight but is less severe.

The lesions appear on leaf blades or on sheaths midway up the tiller. Lesions are oval, cream color or white in the center and broad dark reddish-brown margin. The pathogen attacks and deteriorates the culm below the sheath lesion on susceptible varieties. The weakened culm breaks over where it was infected.

Management

Fungicides used to control sheath blight are also effective in reducing the sheath spot. Foliar application of recommended fungicides is done to control sheath spot (e.g. azoxystrobin, propiconazole)

Sheath blight

Description: The disease is caused by a fungus, *Rhizoctonia solani*, a pathogen of both soybeans and rice. This disease occurs in all rice growing areas of the world and it occupies the second place after rice blast in term of causing damage. It causes severe damage in areas where rice is intensively cultivated with excessive nitrogen fertilizer application and rapidly spread through irrigation. Alternating narrow bands of reddish-brown or brown with wide bands of greenish grey, white to tan, appears at the base of leaf blade. Under moist conditions, spreading of lesions from infection points of leaf sheath may occur. Fungal survival structure formed on the leaf surface is called sclerotia. Bird nest area of dead tissue may form under favorable conditions.

Management

Foliar application of appropriate fungicides (e.g. azoxystrobin, propiconazole, trifloxystrobin and propiconazole, iprodine) is carried out to control sheath blight. Higher rates of these fungicides are recommended when the attack is severe. Normally two applications, one at the time of early internodes elongation and second at 10-14 days after panicle emergence, are required to control this disease. Excessive nitrogen application increases the susceptibility to disease, avoiding the excessive application of nitrogen fertilizer to plants decrease the susceptibility to disease. Seed treatment with trifloxystrobin or azoxystrobin or carboxin + thiram is also used to control sheath blight.

Sheath blotch

Description: This fungal *(Pyrenochaeta oryzae*) disease distresses the leaf sheaths, especially the flag leaf sheath near the collar. The lesion starts usually at the sheath edge and expands to form a rhombus blotch that increases in size and it eventually covers the whole sheath. The lesion is generally restricted and turns out to be in a zonate form. This discriminates it from sheath rot.

Management

This disease is normally not severe or widespread enough to warrant control measures.

Sheath rot

Description: *Sarocladium oryzae* is the causative agent of this disease. Symptoms appear during the booting stage on the leaf sheath in which young panicles are enclosed. Irregular oval-shaped spots with brown centers and a diffuse reddish-brown margin appear. This disease causes partial emergence of panicle, grain discoloration and white powdery growth inside of the sheath.

Management

Usually, the fungicidal spray is recommended but fungicides showed little effect on these pathogens. Fungicidal sprays help to lessen the damage in a disease management process, but it was observed that many bacteria also sow similar symptoms on rice plant.

Crown sheath rot

Description: A fungus, *Gaeumannomyces graminis* var. *graminis*, is the causative agent of crown sheath rot. It is also called Arkansas foot rot, brown sheath rot, and black sheath rot. Mycelial mats of reddish-brown color are formed in the inner side of infested sheaths. Dark perithecia are formed on the sheath. This disease can be easily muddled with stem rot. Under severe conditions, lodging occurs.

Management

As this fungus survives on plant residues and is wind-borne in moist conditions, management practices do not work for this disease. However, foliar application of appropriate fungicides (e.g. azoxystrobin) is somewhat effective in controlling this epidemic.

Stem Rot

Description: Fungus (*Sclerotium oryzae*) subsists even after harvest in crop residues and fruiting bodies and then they are brought to the soil surface due to flooding and they infect leaf sheaths. Infested soil helps the organism for its survival. Symptoms generally start to appear at tillering or initial stage jointing growth. Black angular lesions appear on leaf sheath. These lesions expand and start to blight leaf sheaths from inside and then culm starts to rot. Culms have black or dark brown streaks. At maturity, culms may collapse and black round sclerotia form in dead tissues. This infection can cause unfilled panicles, plants lodging and death of tillers.

Management

Avoid excessive nitrogen fertilizer application. Try to apply nitrogen in split doses. In potassium deficient soils, potassium application will decrease the disease severity. An important agronomic practice is burying of crop residues in the soil after harvest. Growing resistant rice varieties is also helpful to reduce disease susceptibility. Stem rot does not cause damage to early maturing varieties. Fungicides (trifloxystrobin and propiconazole) are applied as a foliar spray. Higher rates of fungicides are applied in case of disease severity. These fungicides are not applied after seedhead emergence. Destroy the sclerotia by tillage, by burning the stubbles and by crop rotation. Use of antagonistic organisms also helps to reduce the damage.

Tungro disease

Description: A virus, Rice tungro bacilliform virus (RTBV), is the causative agent of tungro disease. It is the severely destructive rice virus in South Asia and Southeast Asia. Leafhoppers spread this virus. Plants are stunted and change color from green to yellow then orange. Numbers of tillers are reduced, and brown colored lesions appear on the leaf. Leaves are striped, mottled or show inter-venial necrosis.

Management

To control the tungro virus, many rice resistant varieties have been used and controlled the disease effectively. But intensive farming has collapsed the impact in some potent leafhopper strain. In Indonesia, this virus is controlled effectively by obtaining synchronous plant development through scheduling the planting time and practicing crop rotation with resistant varieties. To reduce the chances of virus infection, rice seedlings should be cultured far away from areas where rice virus diseases occur every year.

Grassy stunt

Description: It is a viral disease (Rice grassy stunt virus (RGSV)) and transmitted by leafhoppers. It is pervasive in rice cultivated areas of South Asia, Southeast Asia, Japan, China, and Taiwan.

This virus causes narrow yellow or pale green leaves. Dark brown irregular blotches appeared on leaves. On newly unfolded leaves, the striped or mottled pattern appears. Plant growth is stunted and few or no panicles produced.

Management

Suitable insecticides spray can reduce infestation by decreasing the vector populations. A spray of fenthinon or phosphamidon or monocrotophos helps to control the damage. Many rice resistant varieties to the leafhopper vectors have developed but leafhoppers have overcome the resistance in some countries due to a favorable environment for virus vectors. To reduce the chances of virus infection, rice seedlings should be cultured far away from areas where rice virus diseases occur every year.

Bacterial panicle blight

Description: It is caused by bacteria, *Burkholderia gladioli,* and *Burkholderia glumae.* Lesions are formed on flag leaf sheath that extends to leaf collar. The lesion is discretely having a necrotic and gray color in the center with reddish-brown border. The lesion length may reach several inches. The panicle may have unfilled or aborted florets.

Management

Avoiding excessive nitrogen application helps to reduce the damage caused by this disease. Early planting can reduce disease by escaping the favorable period of disease attack. Some rice varieties are partially resistant while most are susceptible to disease. An important control measure is to not plant infected seed from previous year seriously affected rice fields. To test seed lots, the procedure has been developed but they are not widely available. No pesticides are currently recommended to control this disease.

Downy mildew

Description: Causative agent of downy mildew is a fungus called *Sclerophthora macrospora*. Due to mildew, panicles do not come out of the leaf sheath and become irregular and twisted. Their size remains small with no seeds.

Management

This disease is extremely rare. No control measures are recommended.

Grain Spotting or Pecky Rice

Description: The fungus infects the developing grain and causes discoloration of the kernels or hulls. Rice stink bug also cause kernel discoloration. Kernel discoloration caused by fungal infections or insect damage is called pecky rice. Single or several florets/panicles appear with reddish-brown spots. Grain discolored due to fungal growth and stink bugs feedings. Similar symptoms also appeared by high winds at early heading stage.

Management

Management practices used to control stink bugs reduces the extent of this disease

Kernel smut

Description: It is a fungal disease, caused by *Neovossia barclayana.* It is distributed in all rice growing areas. Symptoms appeared shortly before maturity. A black smut spores mass replaces a part or all of the grain endosperm. In an ear, few grains are affected partially or wholly. If severe infestation not occurs, seeds germinate but seedling growth is stunted.

Management

Use of healthy seed, sowing of resistant and early maturing varieties, collection and burning of diseased ear heads and avoid threshing and winnowing of the diseased crop in the field are useful agronomic practices. Nitrogen application in split doses is recommended. At booting stage, fungicide applications can be effective for controlling this disease. Seed treatment with suitable chemicals is used in many rice growing areas.

False smut

Description: The causative agent of this disease is *Ustilaginoidea Virens*. It is usually a minor disease but it causes an epidemic sometimes in many rice cultivating areas. Large orange fungal fruiting structure appears on rice grains panicle. The orange membrane of this orange fruiting structure bursts and a mass of spores is exposed. These spores turn dark green to black with time and grain is then replaced by fungal structure sclerotia.

Management

Seed treatment is recommended. Seeds are treated with hot water at 52 °C for 10 min. Field sanitation helps a lot in reducing the chances of disease occurrence. Keep the rice field and its surrounding clean. Roughing of infected plants from the field is suggested in some rice growing areas. Use of resistant varieties is helpful in some areas. Maintain moisture content in the field by alternate wetting and drying process. As increased nitrogen application increases the incidence of the disease, balanced amount of fertilizer should be applied. Recommended fungicides application at booting can hinder the disease.

Black Kernel

Description: The fungus, *Curvularia lunata,* causes black kernel disease. Severe discoloration of grains occur, and kernels appear black after milling. In case of severe infection, the fungus can cause weakened seedlings or seedling blights.

Management

Use of the right amount of fertilizer, maintaining good soil drainage, hatch layer management, and soil compaction reduction are effective agronomic practices for the reduction of black kernel disease. Proper insect (stink bug), nematode and fungus control practices help to reduce the damage. Seed treating for managing other diseases will diminish the seedling damage. No other management measures are necessary.

Bakanae Disease

Description: The causative agent of Bakanae disease is *Fusarium moniliforme*, also called white stalk disease and distributed in all rice growing areas. Contaminated seedlings are chlorotic, thin and sometimes die when they are transplanted. In the field, leaves of affected plants die out in short time and plants have only a few tillers. Live plants have unfilled panicles. Many affected plants sometimes become elongated. Abnormal elongation of these infested plants in the field and in seedbed is a common disease symptom.

Management

Cultivation of resistant varieties and seed treatment with effective chemicals helps to reduce the damage caused by this disease. Do not plant the infected seed that comes from an infected field. Stubble destruction of the previous crop either by plowing or uprooting of infected plants before sowing. Biological control is also available for the control of *Gibberella sp.* Biological product namely Tri-Cure (*Trichoderma harzianum* isolate MIT04), is used mainly in Africa.

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