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Field Problems of Tropical Rice

REVISED EDITION

International Rice Research Institute

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Director general

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Whorl maggot *Hydrellia philippina* — Typical damage is degenerated tissue along the inner margins of emerging leaves (Photo 1). As leaves expand, yellow damaged areas become conspicuously visible. Tillering is reduced and maturity may be delayed. Damage occurs from seedling through maximum tillering stages. Whorl maggots attack fields with standing water.

The adult fly, 2 mm long (Photo 2), lays single eggs on the leaf surface (Photo 3). Larvae move to the center of the plant and feed on inner margins of developing leaves. Greenish-yellow larvae (Photo 4) in the center of a leaf whorl are the same color as the young leaf. Pupae are found outside the stem. The insect has a 4-week life cycle.

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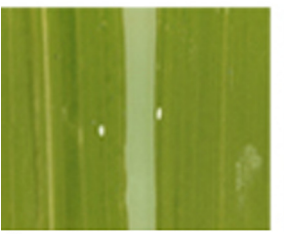

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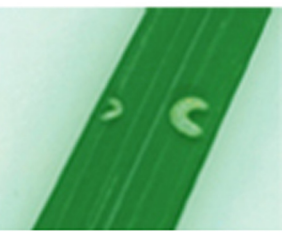

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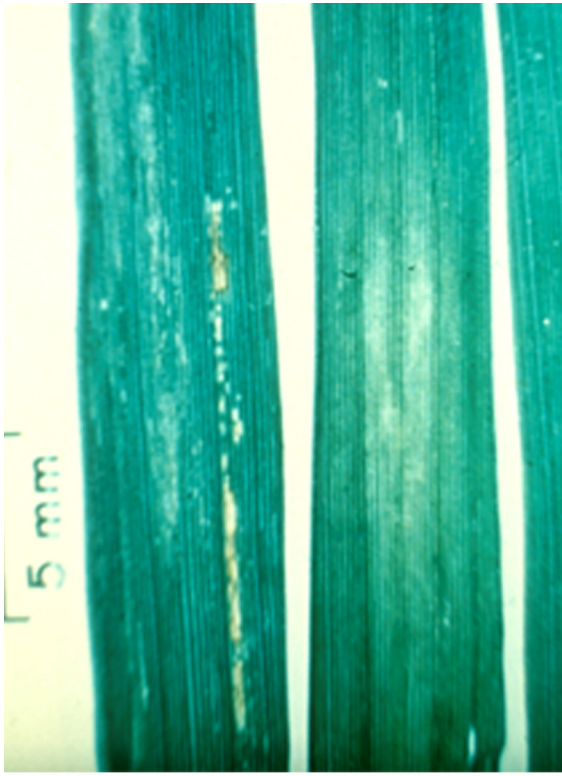

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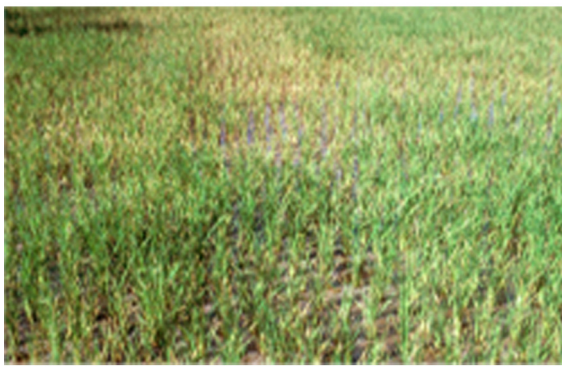

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Thrips *Baliothrips biformis* — Thrips adults and nymphs slash the plant tissue and feed on sap. Damage causes yellow-to-red plant discoloration (Photo 5) and makes the leaf blade roll. Spikelets may have unfilled grains or completely empty heads. Plants may be damaged at seedling and tillering stages and at flowering. Thrips attack fields without standing water (Photo 6).

Thrips. The minute, slender-bodied insects are usually 1-2 mm long, with 5-8 segmented antennae (Photo 7). They can be winged or wingless. If winged, both pairs are elongated, narrow, and fringed with long hairs. Eggs are uniform and laid individually in slits cut in leaf blade tissues by the saw-like ovipositors of the female. Eggs are tiny, about 0.25 mm long and 0.1 mm wide, limpid when freshly laid, but turn pale yellow before hatching. Freshly hatched nymphs are colorless.

Nymphs remain stationary shortly after hatching but soon migrate to feed on the soft tissues of unopened young leaves, under rolled leaf areas near the leaf rim, on basal parts of the leaf sheath, and on developing panicles. Larval and pupal periods are completed at these sites, where emerging adults also feed.

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Stem borers *Chilo suppressalis* (striped) (Photo 8), *C. polychrysus* (dark-headed) (Photo 9), *Rupela albinella* (South American white) (Photo 10), *Scirpophaga incertulas* (yellow) (Photo II), *S. innotata* (white), and *Sesamia inferens* (pink) — Damage results from larvae feeding within the stem, severing the vascular system. Deadheart is damage to the tiller before flowering. When damage occurs before maximum tillering, the plant partially compensates by producing additional tillers.

Stem borers. Deadheart damage (Photo 12) may occasionally be mistaken for kresek or rat damage. But the leaf of a plant with deadhearts is easily pulled from the tiller. Feeding damage and sometimes frass can be seen at the base of a pulled leaf.

"Whitehead" is damage caused after flowering (Photo 13). It causes the entire panicle to dry. Rats and drought can cause similar symptoms.

If the culm is not completely cut before maturity, damage is restricted to leaf sheaths and a small portion of the stem at ground level. Some spikelets in the lower portion of the panicle will be sterile.

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Stem borer damage is indicated by larvae within the stems, signs of a stem being cut by larval feeding, frass in a culm, or external discoloration and exit holes on the leaf sheath and culm.

Egg masses are a sign (Photo 14) that plant damage will occur. Eggs of the yellow, white, and striped borers are usually laid on the upper half of a leaf; those of the pink borer on the inner side of the leaf sheath. Eggs of yellow and white borers are covered with a mat of light brown hairs. Eggs of the striped borer are scalelike and turn dark just before hatching.

Stem borer larvae migrate to between the leaf sheaths (Photo 15). In early stages, larvae of pink and striped borers may concentrate in one tiller; larvae of yellow and white borers are found singly. Larvae and pupae are usually found within the leaf sheath or culm at any height from below ground to the panicle. The larvae and pupae of the white borer and yellow borer are similar.

Large numbers of adult stem borer moths around lights indicate that large numbers of eggs will be laid that evening.

Chilo zacconius and *Scirpophaga* sp. occur in West Africa. Damage is similar to that caused by the Asian species.

Diopsis macrophthalma (stalk-eyed borer) (Photo 16) is also found in West Africa. Adults prefer an aquatic habitat. The larva is a yellowish maggot with two abdominal protrusions that have black hooks on the ends.

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Gall midge *Orseolia oryzae* — Typical damage is a tubular gall resembling an onion leaf, sometimes called an “onion leaf gall” (Photo 17). It is also known as “silvershoot,” because of its light, shiny appearance. Galls may be as long as a leaf and easy to see or short and difficult to detect. Tillers with galls do not produce panicles. Once panicle initiation occurs, larvae no longer cause damage.

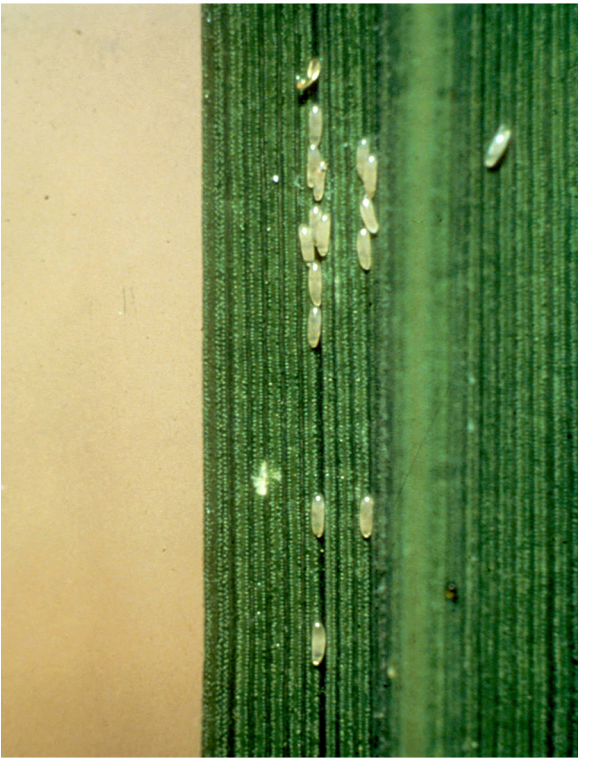
Gall midge larvae feeding at the growing point cause gall development. Pupation occurs in the gall. The midge emerges from the gall tip, leaving only the pupa’s skin.

Gall midge adults are the size of mosquitoes but females have bright red abdomens (Photo 18). Adults are active at night. Eggs usually are laid on the underside of a leaf blade (Photo 19) but some may be laid on the leaf sheath.

The annual cycle is governed by season. During dry season, the inactive midge is found in wild rice or weeds as a prepupa. The adult becomes active at the onset of wet season and often completes one or more life cycles on alternate hosts.

Life cycles range from 9 to 14 days on alternate hosts; 9 to 26 days on rice. If rice infestation occurs in the nursery, the midge may complete several life cycles before panicle initiation.

Where dry and wet seasons occur, early wet season rice may escape damage. Rice planted later in the season may be affected severely. Irrigated dry season crops where there was heavy infestation during wet season will be damaged.



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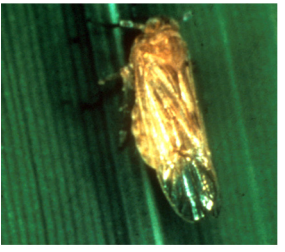

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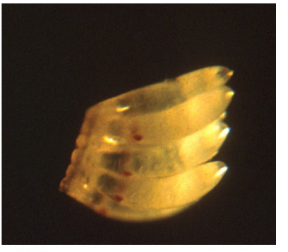

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Brown planthopper *Nilaparvata lugens* - Often attack susceptible rice varieties in large numbers, causing hopperburn. Infested plants yellow and die (Photo 20). Hoppers transmit grassy stunt, ragged stunt, and wilted stunt virus diseases. Fields are invaded by long-winged adults (Photo 21) that lay eggs in leaf sheaths or midribs. Eggs have broad flat egg caps (Photo 22). Nymphs hatch in 7-9 days. There are 5 nymphal instars. Nymphal period lasts 13-15 days. First-instar nymphs are white, later stages are brown. Short-winged and long-winged adults are produced. Short-winged adults (Photo 23) dominate before flowering, and the females are found among tillers at the extreme base of hills. As the crop ages, long-winged forms capable of migrating are produced.

Whitebacked planthopper *Sogatella furcifera* — Frequently occurs with brown planthopper and the two are often confused. Nymphs are white to a strongly mottled dark grey or black and white (Photo 24). Adults are 5 mm long, and have a white stripe on their back (Photo 25). Only females are short-winged. Whitebacked planthopper does not transmit disease and rarely causes hopperburn. because populations usually decline by flowering stage. Heavy infestations may cause outer leaves of a hill to show burn symptoms (Photo 26).

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Smaller brown planthopper *Laodelphax striatellus* (Photo 27) — Is most abundant in temperate subtropical regions. It transmits black streaked dwarf and stripe viruses. Adults have two wing forms, long and short.

Rice delphacid *Sogatodes oryzicola* (Photo 28) — Occurs in the Americas and is the principal vector of hoja blanca or white leaf virus. Adults have two wing forms, long and short.

Green leafhopper *Nephotettix* spp. (Photo 29) – Are widely distributed. They are important vectors of viruses that cause rice dwarf, transitory yellowing, tungro, and yellow dwarf diseases. Adults are 3-5 mm long, bright green, with variable black markings. Eggs are deposited in the midrib of a leaf blade or sheath. There are 5 nymphal stages, also with variable markings.

Zigzag leafhopper *Recilia dorsalis* (Photo 30) – Transmits gall dwarf, tungro, and orange leaf viruses and sucks plant sap. The wings of adults have a zigzag pattern. Nymphs are yellowish brown.

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Leaffolder *Cnaphalocrocis medinalis* (Photo 31) — Damage appears as white feeding areas in a field. Severely damaged plants appear burned. Leaf diseases, especially bacterial leaf streak, can start at the edges of damaged leaves.

Adults lay eggs on the leaf surfaces near the midrib (Photo 32). Larvae (Photo 33) feed on leaf tissue and, as they become older, fold the leaf to form a tube (Photo 34). Pupation occurs within the folded portion.

Caseworm *Nymphula depunctalis* — Defoliates rice plants before maximum tillering. Larvae scrape the leaf tissues, leaving only the papery upper epidermis. Characteristic leaf damage has horizontal rows of green material, giving a ladder-like appearance. Severely attacked fields have a whitish appearance because of damaged plant tips, especially in nurseries (Photo 35).

Adults are 6 mm long with a wing spread of 15 mm (Photo 36). They are nocturnal and strongly attracted to light. Eggs are laid on the undersides of leaves floating in the water. The larvae are common on older rice seedlings in seedbeds and on newly transplanted seedlings. They cut leaves and wrap themselves in a section (Photo 37). Cut leaves found at the side of the paddy, where they may be blown or carried by the water, appear as if snipped off with scissors.

A life cycle takes about 35 days.

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Rice bug *Leptocorisa oratorius* — One of several species of true bugs that feed on ripening rice grains. Both adults and nymphs pierce rice grains between the lemma and palea. Feeding during milk stage results in empty grains. Feeding during the soft dough stage results in lower grain quality and broken grains (Photo 38).

Adults are brown and slender with long legs and antennae (Photo 39). Eggs are deposited in rows on leaves and panicles. Both green nymphs and adults have a characteristic foul odor.

Armyworm *Mythimna separata* (Photo 40) - The several species of armyworms get their name from their habit of appearing in large numbers. As food supplies are exhausted, they move in search of fresh fields. Armyworms feed on many grass species. Damage is caused by larvae feeding on leaves. They feed from the edges, leaving only the midribs and stems. *Mythimna separata* also cuts the panicle at the base and is known as an earhead-cutting caterpillar.

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Cutworm *Spodoptera litura* (Photo 41) - The common cutworm is primarily a problem on dry-land rice because it needs dry soil to complete its life cycle. Wetland rice suffers damage from larvae which migrate from adjacent grassy areas. Young caterpillars eat only the leaves; mature larvae (Photo 42) eat the entire plant. They cut seedlings at the base.

Greenhorned caterpillar *Melanitis leda ismene* — Adults (Photo 43) lay eggs on leaves. The larvae (Photo 44) have two pair of horns, one projecting from the tip of the head and the other from the abdomen.

Green semilooper *Naranga aenescens* (Photo 45) — Larvae are similar in size and habit to the green hairy caterpillar. They are most abundant from seedbed to maximum tillering. Larvae move like inchworms, arching their backs as they go.

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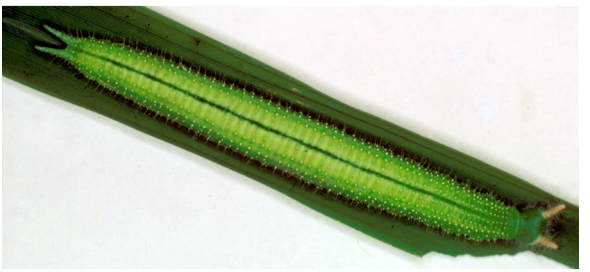

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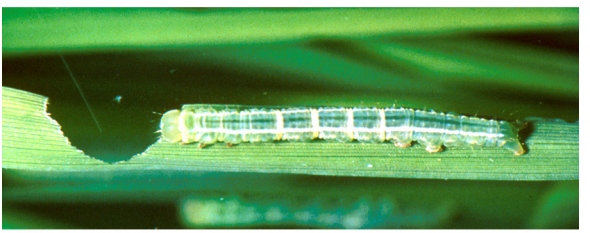

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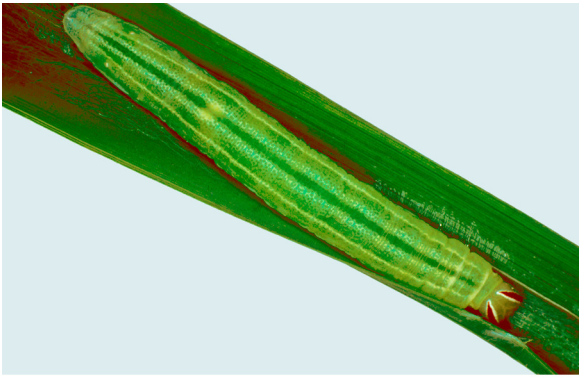

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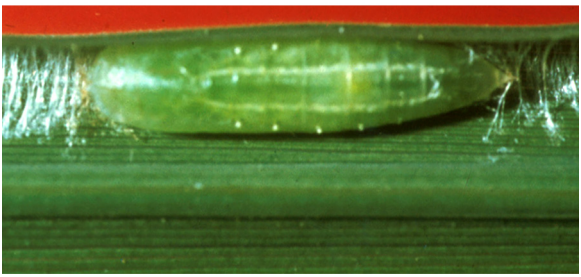

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Rice skipper *Pelopidas mathias* — Larvae feed on the leaf blade from the margin inward, then parallel to the midrib (Photo 46). Damage by the skipper and greenhorned and green hairy caterpillars and semilooper is similar.

Adults have hook-like antennae (Photo 47). They fly fast and erratically. Pupae are attached to folded leaves by silken threads (Photo 48).

Crickets *Euscyrtus concinnus* (Photo 49) — Feed on leaves, leaving holes while keeping leaf margins intact. Leaves appear ragged.

Short-horned grasshopper *Oxya* spp. (Photo 50) — Transmits yellow mottle. Defoliates rice plants by removing large sections near the edges of leaves. Swarming grasshoppers are called locusts.

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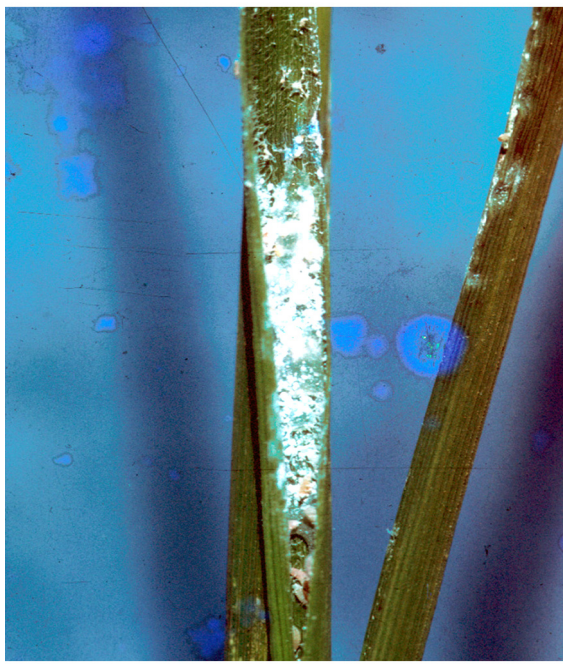

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Ants *Solenopsis geminata* (Photo 51) — Remove seeds from nonpuddled rice fields between sowing and seedling emergence, resulting in sparse and uneven stands.

Mealybugs *Brevennia rehi* (Photo 52) — Common in well-drained rainfed environments. Suck plant sap and stunt growth. High infestations inhibit panicle emergence. Infested fields show isolated patches of stunted plants.

Mealybugs are small, reddish white, soft-bodied, wingless insects covered with white filamentous material. They are found in colonies attached to the stem and leaf sheath of a plant.

Hispa *Dicladispa armigera* (Photo 53) — Narrow white areas on a leaf are the typical damage. Severely damaged fields appear hopperburned.

Both the adult and grub injure plants. The adult beetles are fringed with spines. They feed on the upper leaf surface, eating down to the lower epidermis. Many adults will be visible in an obviously-damaged field. Adult beetles often migrate from volunteer or ratoon rice to young rice, causing severe damage along the edges of fields.

The beetle usually disappears when plants mature.

Female hispa beetles lay their eggs on the lower surface of a leaf. The grubs mine the leaf material between the epidermal layers, creating irregular tunnels. Both larvae and pupae are found in the leaf tissue.

The hispa life cycle is 3-4 weeks.

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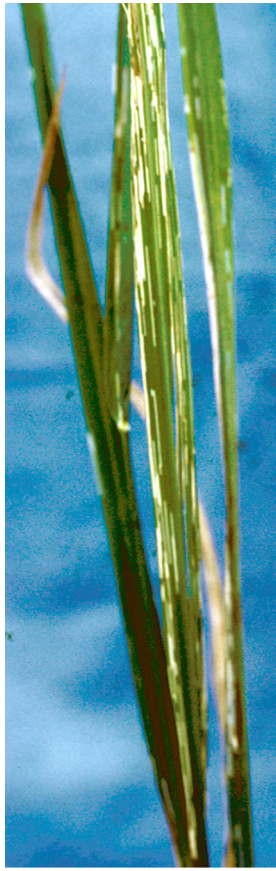

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Leptispa *Leptispa pygmaea* — Causes damage similar to that of hispa (Photo 54), but the feeding lines are narrower. Yellow larvae also feed on leaves.

The adult is a small, elongated beetle (Photo 55). Leptispa and hispa are often found in the same field.

Mole cricket *Gryllotalpa africana* (Photo 56) — Kills plants by cutting them off at the base. The damage can be mistaken for stem borer damage, but mole crickets feed on young roots and basal portions of plants below the ground.

Mole crickets are a problem in nonflooded rice fields. Flooded rice becomes infested only after being drained or in patches when the water level varies and soil is exposed. Flooding a field makes the cricket migrate to the levees, where it lays eggs in hard earthen shells below ground. Mole cricket tunnels look like disturbed soil areas.

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Black bugs *Scotinophara* spp. (Photo 57) — Damage plant by sucking sap. The area around a feeding hole turns brown with dark-brown margins, resembling a blast lesion. Leaf tips or margins, the center leaves, or an entire plant may dry and center leaves may roll longitudinally.

Black bugs are moisture loving and become dormant in dry weather or when the temperature is cool or hot. In favorable conditions, adults migrate to rice fields and feed on the leaves or leaf sheaths of young plants. On older plants, they feed on the leaf sheaths near the plant base.

Eggs are arranged in 2-4 rows on the surface of leaves and leaf sheaths of rice and some grasses. Newly laid eggs are light, but turn deep orange before hatching in 6 days. Newly hatched nymphs feed first near the egg masses, then migrate toward the plant base.

Rats — Eat rice plants at any stage but do the greatest damage after panicle initiation, when they may eat the base of the young panicle shoot or completely cut off the stem to eat the grain. Signs of feeding at the base of the plant distinguish rat damage from stem borer damage.

Rats range widely across rice fields and may completely destroy a crop except around the edges of the field (Photo 58). If damage occurs early, affected plants may produce new tillers, so that a field has young panicles in the center and mature panicles at the edges. Plants may not re - cover from damage late in the growing season.

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Birds (Photo 59) — Can damage rice shortly after flowering, but damage most severely between the milk and late dough stages. They squeeze the milky grains and feed on the contents so that grains are partially covered with a milky white substance. Empty grains result. Near maturity, birds remove entire grains. Bird damage in the milky stage is distinguishable from the whiteheads caused by stem borers because usually not all the grains in a panicle are chaffy. In stem borer damaged panicles, all grains in a panicle are chaffy and the panicle can be pulled out easily.

Bacterial leaf blight caused by *Xanthomonas campestris* pv. *oryzae* (*X. oryzae*) (Photo 60) — Yellow to white lesions begin as water-soaked stripes at the margins of a leaf blade. Lesions may start on one or both edges of a leaf, or at any point on injured blades, and advance to cover the entire blade (Photo 61). On susceptible cultivars, lesions may reach the lower end of the leaf sheath.

Bacteria invade the vascular system of the rice plant during transplanting, when seedlings are pulled from the seedbed and roots are broken, or when leaves are damaged.

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Bacterial leaf blight. When blight bacteria cells invade rice plants through the roots and basal stem, plants may show kresek (Photo 62). Leaves or entire plants wilt during seedling to early tillering stages. Sometimes affected leaves of susceptible cultivars turn pale yellow. Older leaves appear normal and green, younger leaves are either a uniform pale yellow or have yellow or green-yellow stripes.

Sources of bacteria are diseased straw, stubble, ratoons of infected plants, seed, and weed hosts. Blight is spread by dew, irrigation water, rain, flooding, and strong winds. Bacterial cells form small beads in the morning, which harden and adhere to the leaf surfaces of a host plant (Photo 63). Moisture on the leaf surface dissolves the beads and bacterial cells spread freely.

High nitrogen fertilizer rates favor blight epidemics, especially where susceptible cultivars are grown.

Leaf streak caused by *Xanthomonas campestris* pv. *oryzae translucens*/f. sp. *oryzicola.* — Infection usually is restricted to the leaf blades. Symptoms appear as narrow, translucent lesions between leaf veins (Photo 64). As the disease develops, lesions enlarge, turn brown, and advance laterally over the larger veins. Entire leaves of susceptible cultivars may turn brown and die. Under ideal conditions for infection, plants throughout a field may be yellowish orange (Photo 65).

The bacterium enters the plant through mechanical injuries or natural cell openings. Bacterial beads will appear on the leaf surface. Rain and wind help to spread the disease.

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Foot rot caused by a strain of *Erwinia chrysanthemi* (Photo 66) — The primary symptoms are yellow leaves and dark-brown tiller decay. Early infection begins on individual young tillers. In the early stages, the leaf sheath rots and turns brown. Lesions quickly extend down to the nodes, culms, and crowns. The stalk becomes soft and rots and has an unpleasant odor. At advanced stages, so many tillers decay that the entire plant lodges or can be easily pulled up. Foot rot is usually observed from maximum tillering to reproduction, but damages rice at all growth stages when the field is flooded.

Stripe caused by *Pseudomonas setariae* — The first symptoms are dark-green longitudinal stripes that look water-soaked near the base of seedling leaf sheaths (Photo 67). In humid conditions, lesions elongate and extend the length of the sheath and onto the leaf blade. They turn dark brown. Lesions usually are 3-10 cm long and 0.5-1 mm wide, but sometimes join to form wider stripes. When infection is light, seedlings grow but suffer a great deal of damage (Photo 68). Heavier infections cause stunting and seedling death.

Infection on young, unfolding leaves is called bud rot. If that happens, the plant eventually dies. Infection on mature plants is common, but may occur on ratoon tillers.

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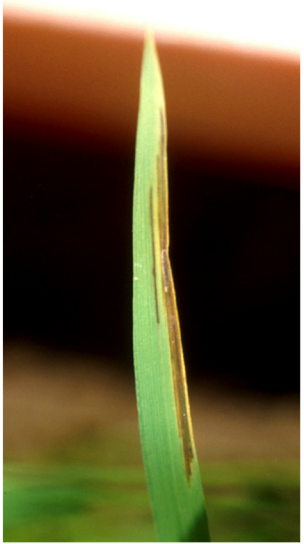

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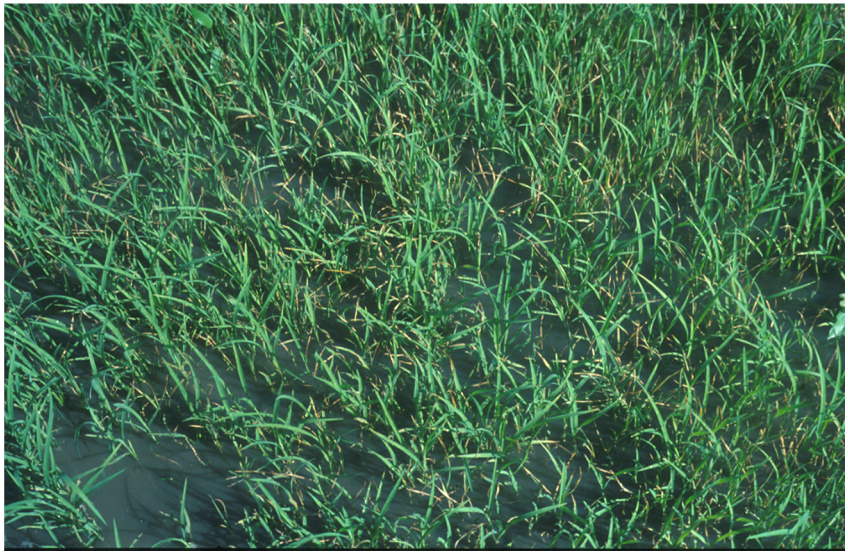

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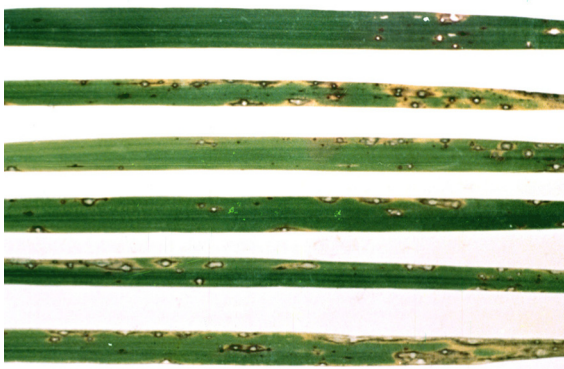

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Blast caused by *Pyricularia oryzae* Cav. (Photo 69) — This fungus can infect rice plants at any growth stage. Typical leaf lesions are spindle-shaped — wide in the center and pointed toward either end (Photo 70). Large lesions (1 to 1.5 × 0.3 to 0.5 cm) usually develop gray centers. Leaves of susceptible varieties may be killed. Pinhead-size brown lesions, indicating a resistant reaction, may be difficult to distinguish from the symptoms of brown spot.

Rice blast may attack the stem at the nodes (Photo 71). The sheath pulvinus rots, turns blackish, and breaks easily. Lesions may occur on the panicle neck. Infected necks turn blackish and break over. When neck rot occurs, few or no seeds in the panicle fill (Photo 72). High nitrogen levels and wet leaves favor infection.

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73

Sheath blight caused by *Rhizoctonia solani* Kuhn (*Thanatephorus cucumeris* [FR] Donk) — First symptoms are greenish gray spots that develop on the leaf sheaths near the waterline. The elliptical or oval, about 1-cm-long spots enlarge, lengthen to 2 or 3 cm, and join. The border of each lesion and the color variation of the lesions give a distinct pattern to the infected area (Photo 73). Under favorable humid conditions, leaf blades in contact with adjacent infected stems also become infected. Symptoms are usually distinct during flowering or maturing stages. Severe infection results in poor grain filling.

False smut caused by *Ustilaginoidea virens* (CK) Tak. (Photo 74) — Symptoms become visible as grains start to mature. Individual grains of the panicle are transformed into a mass of spores that are greenish outside and yellow orange on the inside (Photo 75). Young spore balls measure 1 cm and longer when mature. Chlamydospores cannot be easily freed from the smut balls because of the presence of a sticky material. Usually only a few spikelets in a panicle are infected.

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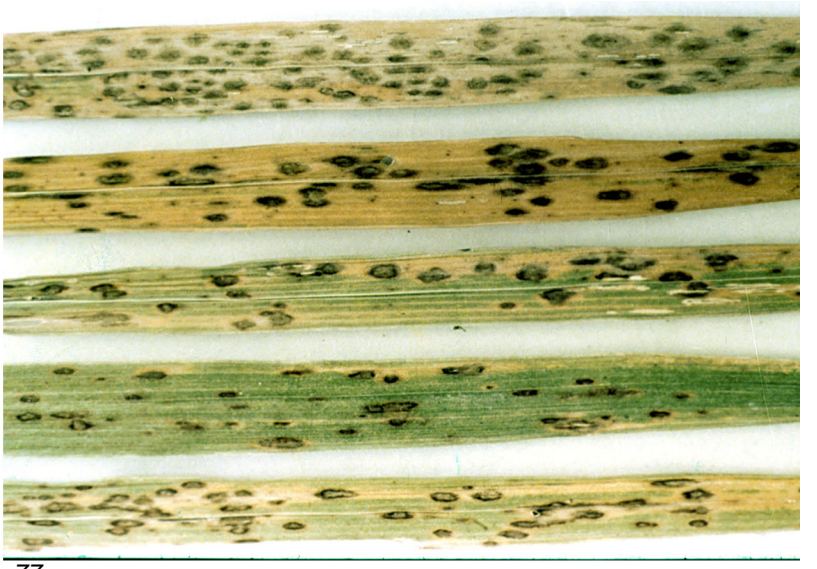

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Brown spot caused by *Helminthosporium oryzae* Breda de Haan (Cochliobolus *miyabeanus* Drech ex Dastur) (Photo 76) — The most conspicuous symptoms are found on leaves and glumes. Typical spots on the leaves are oval, about the size and shape of sesame seeds (Photo 77). They are relatively uniform and fairly evenly distributed over the leaf surface. Young spots are small, circular, 0.05 to 0.1 cm in diameter, and usually dark brown. Fully developed lesions 0.4-1 cm by 0.1-0.2 cm are brown with gray or whitish centers. Most spots have a light-yellow halo around their margins. The spots are larger and not as linear as those of narrow brown leaf spot.

Narrow brown leaf spot caused by *Cercospora oryzae* Miyake (*Sphaerulina oryzina* Hara) (Photos 78, 79) — Short, narrow, linear brown lesions on leaves may occur on the sheath, pedicles, and glumes. The long axis of each spot is parallel with the leaf vein. Lesions are 2-10 mm long by 1 mm wide, narrow, short, and dark brown on resistant varieties; slightly wider, light brown, with a light narrow center, on susceptible varieties. Usually narrow brown spots are red brown with the color fading at the edges.

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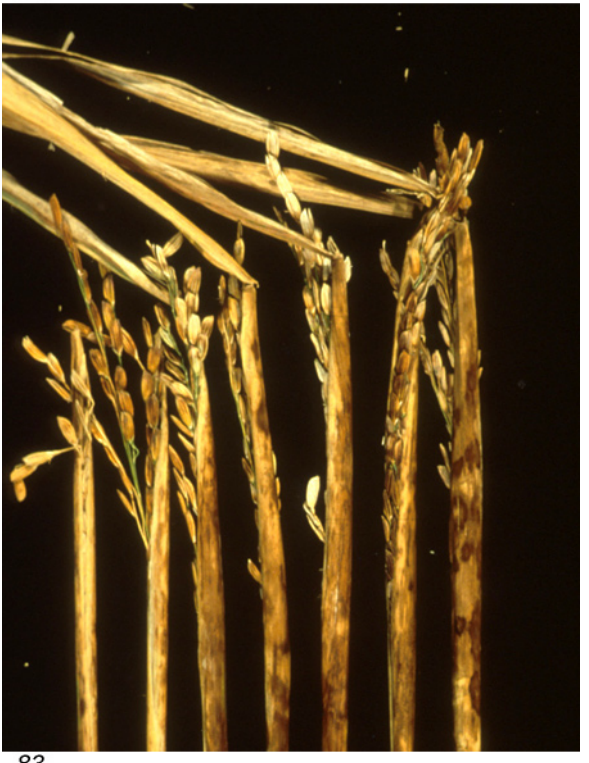
Stem rot caused by *Helminthosporium sigmoideum* (*Leptosphaeria salvinii* or *Magnaporthe salvinii*) (Photo 80) — Infection usually occurs near the waterline, entering through wounds and injuries. It starts as blackish, dark, irregular lesions on the outer leaf sheath and gradually enlarges. Eventually, the fungus penetrates into the culm and weakens the stems and leads to lodging (Photo 81).

Sheath rot caused by *Sarocladium oryzae* (Sawada) Gums and Hawksworth (Photo 82) — Infection occurs on the uppermost leaf sheath at late booting stage. Early symptoms are oblong to irregular spots, 0.5-1.5 cm long, with gray centers and brown margins or gray brown throughout. Lesions enlarge, often connect, and may affect the entire leaf sheath. Severe infection may cause panicles to be only partially exserted (Photo 83). Unemerged panicles are rotted and show abundant powdery fungus growth inside the leaf sheath. Partially emerged panicles may produce poorly filled grains. Infected plants may be infested with stem borers or have other injuries on the lower stems. The disease is associated with virus-infected plants.

82



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Leaf scald, a seedborne disease caused by *Rhynchosporium oryzae* Has. and Yokogi (*Metasphaeria albescens* [Von Thumen] Wei) (Photo 84) — Usually occurs on the tips of mature leaves. Sometimes occurs along the margin or other parts of the leaf blade. Lesions are oblong or diamond-shaped, 1-5 cm long by 0.5 cm wide, water-soaked blotches. Lesions develop into large ellipsoid or oblong olive areas encircled by dark narrow bands and light brown halos. Successive bands of dark-brown margins and lighter inner areas have a characteristic zonation. Badly affected leaves dry and turn a bleached straw color with brown margins and faint zonation.

Continuous enlargement of lesions may cover most of the leaf blade (Photo 85). Leaf scald can be identified by immersing cut leaves in clear water for 5-10 minutes. If an ooze or milky substance comes out of the cut portion, it is bacterial leaf blight. If no ooze comes out, it is leaf scald.

Bakanae and foot rot diseases, seedborne diseases caused by Fusarium moniliforme Shel (*Gibberella fujikuroi* Saw.) — Infected seedlings are sometimes nearly twice the height of normal plants, with thin yellow green leaves (Photo 86). Elongated plants die. Stunting and foot rotting or seedling death are symptoms.

Infected plants have tall, lanky tillers. Pale-green flag leaves are conspicuous above the general level of the crop and may develop adventitious roots from the lower nodes (Photo 87). Infected plants that survive until maturity bear only partially filled grains or empty panicles. High nitrogen applications and a temperature range of 30 to 35°C favor the disease.

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Gall dwarf — Infected plants are stunted with reduced tillering. Leaves are short, often twisted at the tip, and green to dark green (Photo 88). Flowering is delayed and blossoms do not have nodal branches. Plants may produce small panicles.

Vein swellings or galls on the outer surfaces of leaf blades and sheaths are symptoms. Galls are pale green to translucent white, 0.4-0.5 mm wide, 0.4-8 mm long, but usually less than 2 mm long. The leaf epidermal layer may be broken (Photo 89).

It is often difficult to observe galls, but they can be felt by sliding the leaf blade from base to tip between thumb and forefingers. A leaf may have more than 10 galls.

Gall dwarf virus is transmitted by the green leafhopper and the zigzag leafhopper. Virus-vector interaction is persistent with transovarial passage.

Grassy stunt — Infected plants are severely stunted with excessive tillering, producing a grassy or rosette appearance (Photo 90). Leaves are narrow, short, stiff, pale green to green, and sometimes have rusty spots (Photo 91). Infected plants usually live until maturity, but produce few panicles. Panicles produced are small with dark-brown, unfilled grains.

When infection occurs late in plant growth, symptoms may not develop before harvest, but may occur on regenerated growth of ratooned plants.

Grassy stunt virus is transmitted by the brown planthopper. Virus-vector interaction is persistent with no transovarial passage.

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Hoja blanca (white leaf) (Photo 92)— Infected plants are stunted but new leaves can unfold normally. Stunting is higher the younger the plant is when infection occurs. The most striking symptom is one or more yellowish white to white stripes on leaf blades, whitening of the entire leaf blade, or leaves mottled in a mosaic pattern (Photo 93). Panicles of diseased plants are reduced in size and often are not exserted from the sheaths. The lemma and palea show brownish discoloration, dry rapidly, and frequently have a distorted shape. Because panicles have few or no seeds, they remain upright. Infected plants usually are not killed but may die if infection occurs at a very early growth stage. The virus is transmitted by delphacids. Virus-vector interaction is persistent with transovarial passage.

Orange leaf (Photo 94) — Infected plants are slightly stunted with reduced tillering. Leaves are golden yellow to deep orange. Initial symptoms appear near the tip of the leaf blade. Well-defined stripes run parallel to the veins. As the disease progresses, discolored leaves roll inward and dry, starting from the tip. infected plants die quickly, especially when infected at early growth stages. Plants infected later may develop panicles but they are not completely exserted and are mostly sterile.

This disease is self-eliminating because infected plants often die prematurely. Dead plants are not inoculum sources for the vector insect.

The infective agent is transmitted by the zigzag leafhopper. Agent-vector interaction is persistent with no transovarial passage.

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Ragged stunt — Infected plants are stunted. Other symptoms vary with growth stage. Healthy and diseased plants have similar numbers of early tillers but diseased plants remain green at maturity and have more tillers than healthy plants.

During early growth stages ragged leaves are the predominant symptom (Photo 95). Irregular edges or breakings can be seen before the leaf unfurls. The ragged area usually is chlorotic, becomes yellow or brownish yellow, and disintegrates. As plants grow, fewer ragged leaves develop. Often twisting occurs at the apex or the base of the leaves.

Ragged stunt. Vein swellings resulting from the outward growth of the phloem cells appear on leaf blades and leaf sheaths, particularly near the collar. Pale yellow or white to dark brown vein swellings range from 1 mm to over 10 cm long and from 0.2 to about 1 mm wide and protrude from 0.1 to 1 mm from the surface.

During late growth stages, symptoms are short and twisted, malformed, or ragged flag leaves (Photo 96). Diseased plants often flower late and panicle emergence may be incomplete. Tillers generate branches from the upper nodes which often bear small panicles. Diseased plants have more panicles and spikelets than healthy ones, but fewer filled grains.

Ragged stunt virus is transmitted by the brown planthopper. Virus-vector interaction is persistent with no transovarial passage.

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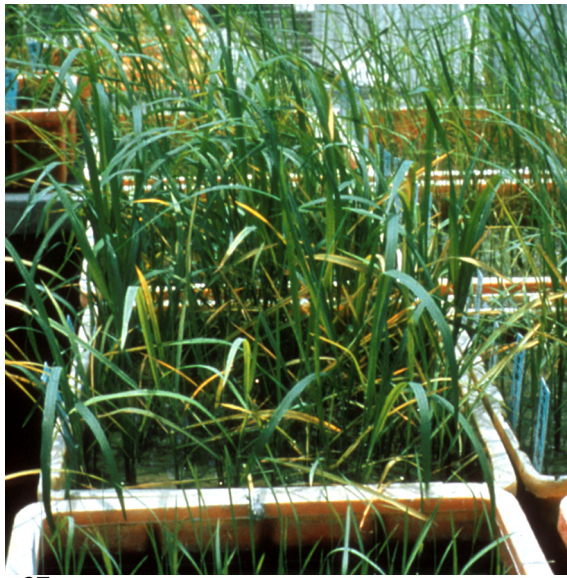

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Transitory yellowing (yellow stunt) (Photo 97) — Infected plants are stunted. Yellow leaf discoloration usually starts from the tip of the lower leaves. Brown rusty flecks or patches may appear on the discolored leaves. After acute leaf yellowing, infected plants may appear to recover by producing green leaves, but leaf yellowing can reappear. Plants infected early produce no panicles or poor panicles.

Symptoms of transitory yellowing and tungro are similar. They are transmitted by rice green leafhoppers. Diseases are identified by virus particle appearance and by virus-vector interaction. The virus is transmitted by *Nephotettix cincticeps, N. nigropictus,* and *N. virescens.* Virus-vector interaction is persistent with no transovarial passage.

Tungro (Photo 98) — Infected plants are stunted and the number of tillers is slightly reduced. Both leaf sheath and leaf blade are shortened. The young, unfolded leaf blade is clasped by the outer leaf sheath and the leaves twist or roll slightly. Leaf color changes from green to light yellow to orange-yellow to brown-yellow, starting from the tips of older leaves. Young leaves often are mottled or have pale green to white stripes of different lengths running parallel to the veins. Leaf yellowing varies during the growth period.

Infected plants usually live until maturity. Delayed flowering may delay maturity. Panicles often are small, sterile, and incompletely exserted. Dark brown blotches cover the grains, which weigh less than those from healthy plants. Low yields result mainly from fewer filled grains per plant. Plants infected late may not develop symptoms before harvest but ratooned regenerated growth may show symptoms.

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Tungro. The younger the plant and the more susceptible the variety, the more severe the infection. Tungro is the most important virus disease of rice in tropical Asia. Outbreaks destroy plants in a large area in a short time (Photo 99).

Tungro virus agents are *Nephotettix malayanus, N. nigropictus, N. parvus, N. virescens,* and the zigzag leafhopper. Virus-vector interaction is transitory with no transovarial passage.

Yellow dwarf (Photo 100) — Infected plants have yellowing of newly emerged and young leaves. Leaf color varies from yellow-green to white-green or pale yellow. As the disease progresses, infected plants show general chlorosis and become severely stunted, tillering increases markedly, and leaves become soft and droop. Diseased plants may die but often live to maturity.

Infected plants produce few or no panicles. Plants infected during later growth stages may not show characteristic symptoms but symptoms are conspicuous on regenerated growth when diseased plants are ratooned.

The causal agent is transmitted by *Nephotettix cincticeps, N. malayanus, N. nigropictus, N.* par*vus,* and *N. virescens.* Causal agent-vector interaction is persistent with no transovarial passage.

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Yellow mottle — Infected plants are characterized by stunting and reduced tillering; crinkling, mottling, and yellowish streaking of leaves; malformation and partial panicle emergence, and sterility (Photo 101). In severe cases, infected plants die.

The first symptoms are a few yellow-green spots on the youngest leaves. Spots enlarge along the veins, giving the characteristic streaking (Photo 102). Such leaves sometimes turn yellow and later become necrotic. The leaf sheath also becomes mottled. Panicles do not emerge from the sheaths and are malformed, with small, usually empty, spikelets.

In the field, the diseased plants yellow 3-4 weeks after transplanting (Photo 103). Mottling or a mild yellow-green streaking appears on the youngest leaves. Yellow mottle virus is transmitted by beetles.

Stem nematode (*Ditylenchus angustus*) — Is a soilborne foliar nematode that feeds ectoparasitically on the tissues of unfurled leaves and growing panicles. The first symptom appears as tiny whitish dots on the youngest leaf of a plant. The dots widen and gradually spread, until the entire unfurled leaf collapses (Photo 104). Some emerging leaves are crinkled and most emerging panicles are crinkled, with empty glumes (Photo 105). Some panicles do not emerge. The disease is spread by water flowing from one field to another, especially in deepwater rice (Photo 106).

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Root-knot nematode (*Meloidogyne graminicola*) — Attacks rice plants in dry soils during early growth. Leaves become orangish yellow, then dry, resulting in yellow patches in the field (Photo 107). Affected plants show galls on the roots.

Other nematodes cause similar damage. The **root nematode** causes root browning (Photo 108), uniform plant stunting, and loss of crop vigor. The **root lesion nematode** causes yellowing, stunting, reduced tiller numbers, and spotted patches of dead seedlings. The **cyst nematode** causes leaf chlorosis, patches of stunting, reduced tiller numbers, and root browning. The seedborne **white-tip nematode** damages foliage and panicles.

Cyprus difformis L. (Photo 109) — is an erect, smooth, densely tufted annual sedge 20-70 cm tall. Stems are smooth, triangular at the top, and 1-4 mm thick. The leaf sheath is tubular and united at the base. Lower leaf sheaths are straw-colored to brown. The 3-4 basal leaves are flaccid and linear, 10-40 cm long and 2-3 mm wide.

The inflorescence is a dense, globose, simple or compound umbel, 5-15 mm in diameter. It is subtended by 2-4, but usually 3, leaf-like bracts 15-30 cm long and 6 mm wide (Photo 110). The primary rays of the umbels are 2-4 cm long, the secondary rays are about 1 cm long. Some are sessile and some are long peduncled. Rays end in globose or ovoid masses about 6 mm in diameter. The masses are composed of crowded green spikelets that are linear to oblong linear, 2-5 mm long and 1-1.5 mm wide, with 10-30 flowers.

The fruit is a brownish achene which is elliptical to slight obovate, 0.6 mm long, and slightly pitted. Propagation is by seed.

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Cyperus iria L. (Photo 111) — is a smooth, tufted annual sedge 20-60 cm tall with triangular stems. Roots are yellow-red and fibrous. The leaf sheath envelopes the stem at the base and is membranous. The leaf blade is linear, lanceolate, shorter than the flowering stem, and about 5 mm wide.

The inflorescence is a compound umbel with primary rays about 10 cm long and secondary rays about 2 cm long, subtended by 3-5, occasionally 7, bracts (Photo 112). The lowest bract is longer than the inflorescence. The 2-4-cm-long spike is elongate and loose at the ends of the branches. The numerous yellow-brown to green spikelets are erect-spreading, 3-10 mm long and 1.5-2 mm wide. The obovate glume is 1-2 mm long.

The yellow-brown fruit is an achene, obovate, triangular, and 1-1.5 mm long. Propagation is by seed.

Cyperus rotundus L. (Photo 113) — is an erect, rhizomatous, tuber-forming, perennial sedge 15-20 cm tall. Stems are erect, unbranched, smooth, and triangular, with swollen tuberous bases. Rhizomes are spreading, slender, white, and fleshy. They are covered with scale leaves when young, turning fibrous when old. Tubers are irregularly shaped, 1-2.5 cm long. They are white and succulent when young, turning fibrous, brown or almost black, when old. Dark-green leaves are linear, basal and involucral, 5-15 cm long and up to 5 mm wide.

The inflorescence is a simple or compound umbel subtended by 2-4 leafy bracts (Photo 114). Flowers in red-brown spikelets are arranged in the terminal umbels. The 3-8 primary rays are 2-5 cm long and end in short spikes of 3-10 spikelets, sometimes on short branches and sometimes with 1-2 short secondary rays at the base of the spike. Spikelets are 1-2.5 cm long and 1.5-2 mm wide, flattened and acute at the tip. They are composed of 10-40 closely overlapping florets which are red-brown when mature. The outer scales are 3-4 mm long with blunt tips.

The fruit is an ovate or oblong-ovate, 3-angled achene 1.5 mm long. It is black when ripe. Propagation is by rhizome, tuber, and seed.

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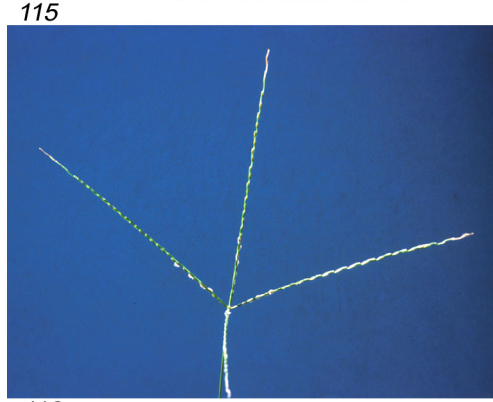

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Digitaria ciliaris (Retz.) Koel. [synonym *D. adscendens* (H.B.K.) Henr.] (Photo 115) — is a decumbent or prostrate annual or short-lived perennial 20-60 cm tall. It branches freely and roots at the lower nodes. The leaf sheath is usually hairy. Leaf blades are flat and linear, 5-15 cm long and 3-8 mm wide. Leaves are usually hairless and have scabrous, undulate margins. The ligule is membranous, 1-3 mm long, and truncate.

The inflorescence is a panicle of 3-8 racemes 5-15 cm long (Photo 116). They often occur in a whorl at the top of the central stalk but are sometimes arranged along a short common axis up to 2 cm long. The rachis is slender, winged, and hairless. Spikelets, which are suppressed in two rows along one side of the axis, are about 3 mm long. The triangular lower glume is about 2 mm long; the lanceolate upper glume is 1/2 to 4/5 the length of the spikelet. The lower lemma is broadly lanceolate, 5-7 nerved, and variously pubescent.

The fruit is a variously elliptical caryopsis. Propagation is by seed.

D. sefigera Roth ex R & S (Photo 117)— is similar to *D. ciliaris,* but usually taller (1 m or more). The leaf sheath normally is hairless. The 6-15 racemes are arranged in whorls along a common axis up to 6 cm long. The lower glume is absent or reduced to a tiny veinless scale.

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Echinochloa colona (L.) Link (Photo 118) — is a smooth, tufted annual grass 70-75 cm tall. It is usually decumbent and roots at the lower nodes. The stem is flattened, often red-purple at the base, and usually swollen at the nodes. The leaf sheath is smooth and often flattened. The margins of the leaf sheaths are free in the upper part and the basal portion is often tinged with red. The leaf blade is smooth, flat, linear-lanceolate, rather flaccid, up to 25 cm long and 3-7 mm wide. It sometimes has transverse purple bands.

The green-to-purple inflorescence is an ascending panicle 6-12 cm long with 4-8 simple short, compact branches 1-3 cm long and 3-4 mm wide (Photo 119). The branches are ascending or appressed about half their own length apart, usually solitary but occasionally two together. Short spikes are arranged alternately on the main axis. Spikelets are ovate to broad ovate, acute, 2-3 mm long and crowded into 4 rows along one side of the branch. They are nearly sessile, sometimes with an awn point about 1 mm long.

The fruit is an elliptical caryopsis. Propagation is by seed.

Echinochloa crus-galli (L.) Beauv. ssp. *hispidula* (Retz.) Honda (Photo 120) — is an erect annual grass up to 2 m tall with thick roots and stout spongy stems. The lower part of the stem is often compressed. The leaf is linear, up to 40 cm long and 5-15 mm wide.

The pink to purple, occasionally green, inflorescence is a soft nodding panicle 10-25 cm long with dense spikelets (Photo 121). The lowest branches are the longest, occasionally reaching 10 cm in length. Panicles often rebranch by maturity and are spread. Nodes of the rachis are usually bearded. Spikelets are elliptical and pointed, 3-3.5 mm long, and are usually slightly hairy. They shed readily at maturity. The lower glume is 1/3 to 3/5 the length of the spikelet. Awns are usually red or purple and 2.5 cm long. The lemma of the first floret is flat or slightly convex and dull.

The fruit is a caryopsis about 2 mm long. Propagation is by seed.

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E. glabrescens Munro ex Hook f. (Photo 122) — is similar to *E. crus-galli* but is only 0.5-1 m high. The leaf blade is acuminate. Leaf sheaths are almost closed and often flattened. Spikelets are ovate and about 3 mm long. The lemma of the first floret is convex and shining. Awns, if present, are about 1 cm long.

Eleusine indica (L.) Gaertn. (Photo 123) — is a smooth or slightly hairy, tufted, prostrate to ascending annual grass 30-90 cm tall. The white or pale green stem is laterally flattened, smooth or with a few long hairs along the edges. The leaf sheath is 6-9 cm long, flattened laterally, with a few long hairs at the collar. The leaf blade is flat or folded, linear-lanceolate, 10-30 cm long and 3-6 mm wide with almost parallel margins and a rather blunt tip. It has a few scattered hairs on the upper surface. The ligule is membranous with a jagged edge. Long hairs occur on the margins at the junction of the blade and sheath.

The inflorescence is digitate, profusely branching at the base (Photo 124). It occasionally roots at the lower nodes. The terminal whorl of 3-6 spikes is 4-8 cm long and 3-6 mm wide. It often has 1-2 additional spikes slightly below the others. The numerous spikelets are sessile, awnless, 4-5 mm long, laterally compressed, and crowded into 2 rows along the underside of the flattened rachis.

The fruit is a red-brown caryopsis about 1.5 mm long, oblong-ovate with conspicuous ridges. Propagation is by seed.

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Fimbristylis miliacea (L.) Vahl [synonym *F. littoralis* Gaud] (Photo 125) — is an erect, tufted, annual sedge 20-70 cm tall. The stem is weak, flattened at the base, and has 4-5 strong angles at the top. The flowering stem is 0.5-1.5 mm thick and bears 2-4 unequal bracts that are shorter than the inflorescence. Basal leaves are up to 35 mm long and 1-2.5 mm wide with broadly overlapping leaf sheaths. Stem leaves have very short blades.

The inflorescence is a decompounded, rather lax, diffuse umbel 6-10 cm long and 2.5-8 cm wide. Its solitary spikelets are numerous, globular, brown or straw-colored, and 2-2.5 mm in diameter (Photo 126).

The pale ivory to brown fruit is a 3-angled achene, 0.5-1 mm long and 0.75 mm wide, with 3 heavy ridges on each side. Propagation is by seed.

Ipomoea aquatica Forsk. (Photo 127) — is a smooth, widely spreading perennial vine. The stems creep or sometimes twine on mud but become hollow and slightly inflated when they float on water. They form roots at the nodes. Leaves are simple, 7-15 cm long and about 3.5 cm wide, and oblong-ovate to oblong-cordate with a prominent point tip. Leaf margins are either entire or sublobed. Stalks are 2.5-15 cm long. White to cream or purple flowers are solitary, arising from the axils, and have 5-15-cm-long stalks (Photo 128).

The fruit is an ovoid capsule about 1 cm long with 2 cells and 4 seeds. The light-brown seed is about 4 mm long and 5-7 mm wide, either smooth or with short, dense, gray hairs. Propagation is by seed and cuttings.

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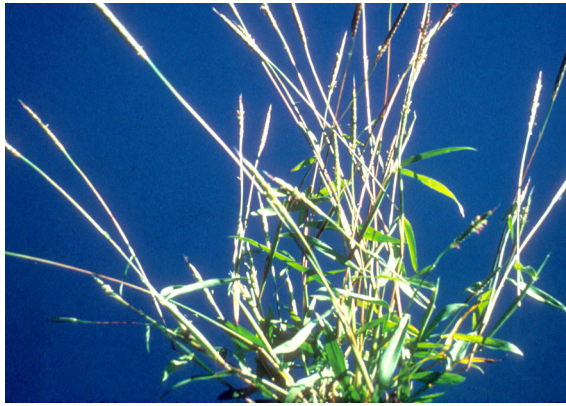

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Ischaemum rugosum Salisb. (Photo 129) — is an aggressive, erect or straggling, tufted annual grass 0.6-1.2 m tall, with 2 long-awned, spikelike racemes and conspicuously ridged spikelets. Stems are purple with bearded nodes. Flowering stems have long hairs at the nodes. Leaf blades are linear-lanceolate, 10-30 cm long and 5-13 mm wide, with scattered hairs on both surfaces. The green or purple leaf sheath is loose, with hairy margins.

The inflorescence separates at maturity into two racemes 5-10 cm long (Photo 130). Yellow-green spikelets are up to 6 mm long, paired, with one sessile and the other on a stalk up to 6 mm long. Awns are 1.5-2.5 cm long, slender, and twisted at the base. Lower glumes have 3-6 prominent transverse ridges.

The fruit is a red-brown caryopsis, oblong-lanceolate, pointed at the tip, and 1.5-2 mm long. Propagation is by seed.

Leptochloa chinensis (L.) Nees (Photo 131) — is a strongly tufted aquatic or semiaquatic annual or short-lived perennial grass 30 cm-1 m high. It is common in East, South, and Southeast Asia Slender to stout stems ascend from a branching base. Foliate and panicles are sometimes red or purple. Leaf blades are flat and linear with an acute tip, 10-30cm long and 0.3-1 cm wide. The ligule is 1-2 mm long and deeply divided into hair-like segments. The inflorescence is a panicle with a straight main axis 10-40 cm long (Photo 132). Its numerous simple, straight, spreading branches are 5-15 cm long. Spikelets 2.5-3.5 mm long have 4-6, usually 5, flowers and a short stalk 0.5-0.7 mm long. The inflorescence is pale green or red.

The fruit is an ellipsoid caryopsis about 0.8 mm long. Propagation is by seed.

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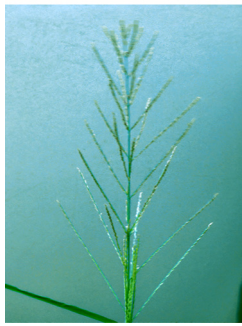

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Monochoria vaginalis (Burm. f.) Presl. (Photo 133) — is an annual, semiaquatic broadleaf 40-50 cm tall. This monocotyledonous weed has short, fleshy stems and very short roots. Leaves are shiny, deep green, oblong-ovate to broad ovate, and sharply acuminate. The cordate or rounded base is 10-15 cm long and 3.5 cm wide. Stalks are long, soft, and hollow, 10-20 cm long, with longitudinal veins.

The inflorescence is a 3- to 6-cm spike with a few blue flowers about 1 cm long arising from a leaf-like sheath. Flower stalks are less than 1 cm long (Photo 134).

The fruit is a capsule about 1 cm long, splitting into 3 valves. Seeds are oblong and about 1 mm long. Propagation is by seed.

Oryza sativa L. (red rice) (Photo 135) — is closely related to cultivated rice, with which it may naturally cross. But, unlike cultivated rice, the seeds of most ecotypes shatter readily before they are fully mature and panicles remain erect. However, some nonshattering ecotypes have drooping panicles. Spikelets may or may not have awns and awn length varies widely. Mature hulls may be straw-colored or dark. The pericarp is pigmented and changes from grey to red with maturity and age of seed. Seeds have a prolonged dormancy in the soil, but if harvested and handled as cultivated rice, dormancy will be broken.

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Sphenoclea zeylanica Gaertn. (Photo 136) — is an erect annual broadleaf with smooth, stout, fleshy, hollow, many-branched stems 0.3-1.5 m tall. Spirally-arranged leaves are simple, oblong to lanceolate, up to 10 cm long and 3 cm wide. Leaves narrow to a point at the tip. They have short stalks and entire margins.

The green inflorescence is a cylindrical, dense, terminal spike up to 7.5 cm long and 12 mm wide on a stalk up to 8 cm long. Crowded white to green flowers are about 2.5 mm long and 2.5 mm wide (Photo 137).

The fruit is a globular capsule, 4-5 mm wide, splitting transversely. Its numerous seeds are yellow-brown, 0.5 mm long. Propagation is by seed.

Nitrogen deficiency (Photo 138) — Symptoms vary with the growth stage at which nitrogen availability becomes limiting. Deficiency during early growth is shown in yellow to yellowish-green leaves, stunted and spindly growth, and reduced tillering (Photo 139). If deficiency persists to maturity, the number of grains per head is reduced.

When nitrogen is adequate during early growth but limiting later, yellowing occurs first on older leaves; new leaves appear most normal. The entire crop eventually will appear uniformly yellow.

Excessive nitrogen may cause lodging and disease susceptibility.

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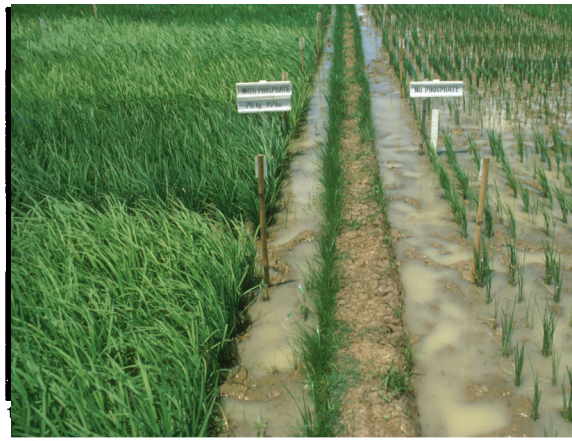

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Phosphorus deficiency (Photo 140) — Symptoms include reduced tillering, stunted growth, and decreased grain formation. Deficient plants usually have darker green, more erect leaves than normal. In some varieties, older leaves show orange or purplish discoloration (Photo 141).

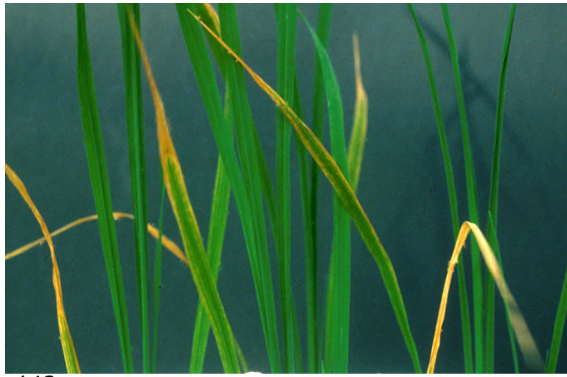
Phosphorus deficiency can occur in strongly acid, acid sulfate, peat, and alkali soils. Phosphorus is more available in flooded soils than in dryland soils.

Potassium deficiency (Photo 142) — Symptoms of mild deficiency are dark-green leaves, low tillering, and stunting. Symptoms of severe deficiency include a yellowish-orange to yellowish-brown discoloration starting at the tip of older leaf blades and gradually moving toward the base. Necrotic spots may appear on the leaf blade. Grain size and weight may be reduced.

Potassium deficiency usually occurs in coarse, sandy, or peat soils and in soils rich in potassium-fixing clays.

Sulfur deficiency (Photo 143) — Symptoms are chlorosis of younger leaves, followed by yellowing of older leaves, stunted growth, and reduced tillering. Sulfur deficiency affects the whole plant; nitrogen deficiency affects older leaves.

Sulfur deficiency occurs in soils low in organic matter in humid regions. Flooding aggravates sulfur deficiency by converting soluble sulfates into insoluble sulfides.



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BO. BANIKAL, IBA, ZAMBALES
WITHOUT SULFUR
WITH SULFUR
IR 42 7 WAT

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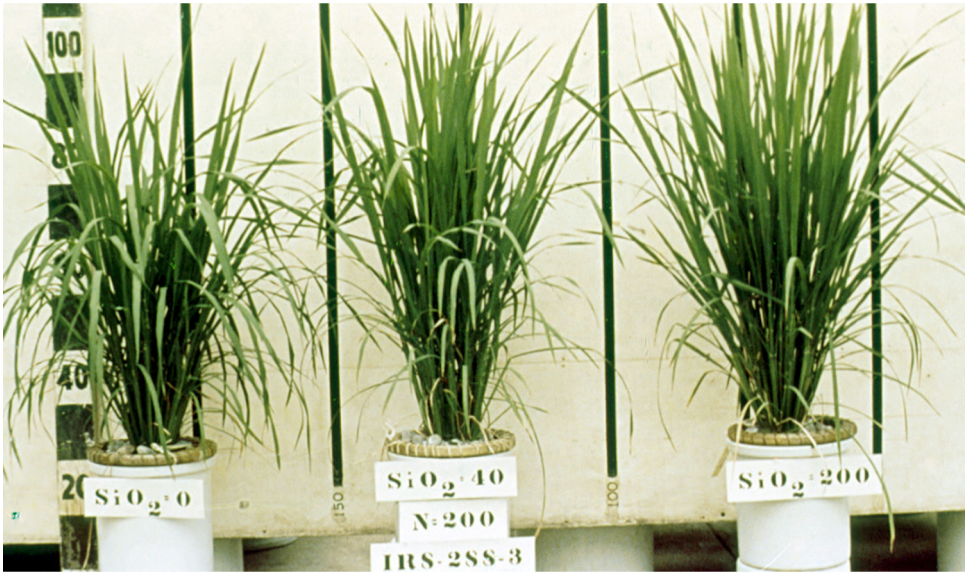
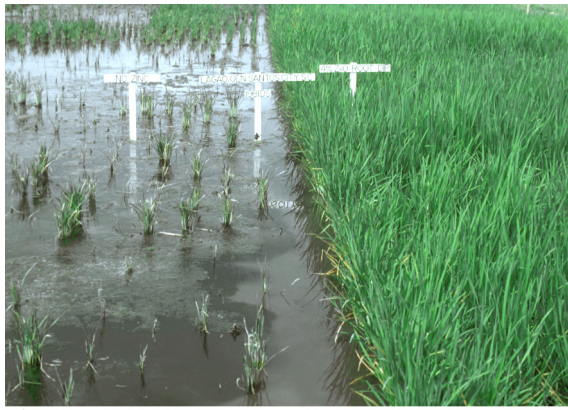


144

Silicon deficiency (Photo 144) — The typical symptoms are drooping leaves. This results in reduced absorption of sunshine, hence, reduced yields. Increased absorption of silicon makes rice leaves more erect, so that they make better use of sunlight. Silicon appears to increase resistance of rice to certain diseases and insect pests. Less than 5% silicon content in rice straw indicates deficiency.

Zinc deficiency (Photo 145) — Symptoms appear 2-4 weeks after sowing, as blanching of the midrib of the emerging leaf, especially at the base. Brown spots appear on the older leaves. The spots enlarge and coalesce, giving the leaf a brown color (Photo 146). Tillering and growth are depressed. In severe deficiency, the plant dies. In moderate deficiency, maturity is delayed and yield reduced.

Zinc deficiency is associated with calcareous, alkali, peat, and volcanic soils and soils that are wet or waterlogged most of the year. Incidence is more severe when high rates of nitrogen and phosphorus are applied.



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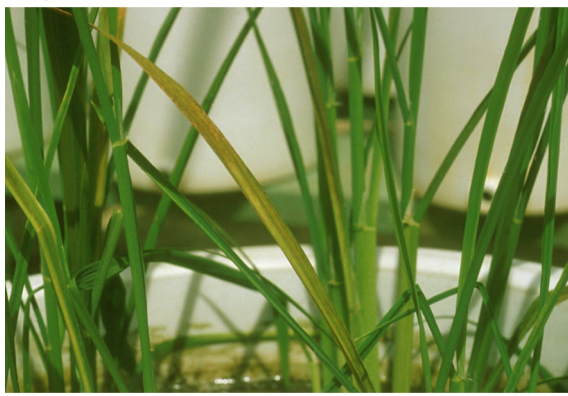

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Salinity (Photo 147) — Symptoms include white rolled upper leaf, browning of the older leaves, and retarded growth and tillering (Photo 148). Salinity occurs in arid regions where drainage is poor and evaporation exceeds precipitation. Humid saline soils are alluvial soils in delta, estuaries, and low-lying coastal areas subject to flooding by sea water.

Alkalinity (Photo 149) — Symptoms include discoloration of the leaves ranging from white to reddish brown starting from the leaf tips. In more susceptible plants the discoloration spreads down the leaf giving the plant a scorched appearance (Photo 150). Growth and tillering are depressed. Alkalinity occurs in semiarid region soils and is associated with salinity. Strongly alkaline soils can also be phosphorus deficient.

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Iron toxicity (Photo 151) — Symptoms are small brown spots on the lower leaves, starting at the tips. Later the entire leaf turns brown, purple, yellow, or orange (Photo 152). In severe iron toxicity, leaves turn brown and the lower leaves die. Growth and tillering are depressed and the root system is coarse, scanty, and dark brown.

Iron toxicity is caused by a high iron content in flooded acid soils. It limits yields on Oxisols, Ultisols, some Histosols, and acid sulfate soils.

Peat (organic) (Photo 153) — Symptoms include stunting, reduced tillering, yellowing or browning of the leaves, and reduced grain formation.

Peat soils are rich in organic matter, or humus, and are slightly acidic. They are deficient in zinc and copper.

Boron toxicity (Photo 154) — Symptoms are the appearance of a yellow discoloration of the leaf tips that spreads along the margins. Large brown elliptical spots appear along the leaf margins (Photo 155). Affected parts turn brown and wither. Vegetative growth is not depressed unless toxicity is severe.

Boron toxicity occurs on coastal soils, arid-region soils, soils irrigated with high-boron water, and in geothermal areas.

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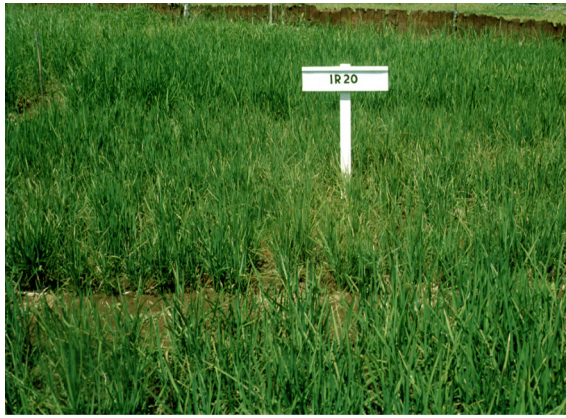

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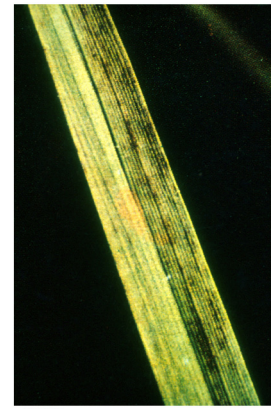

158

Aluminum toxicity (Photo 156) — Symptoms are white or yellow interveinal blotches on the leaves. The leaves dry out and die (Photo 157). Roots are short and scanty. Plants are stunted.

Aluminum toxicity is caused by excess water-soluble and exchangeable aluminum. It limits growth of wetland rice on acid sulfate soils and of dryland rice on strongly acidic soils.

Manganese toxicity (Photo 158) — Symptoms are brown spots on older leaves, leaf tip drying, and high sterility. Vegetative growth is not appreciably depressed. Manganese toxicity is a disorder of dryland rice on acid soils.

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