RiceDoctor

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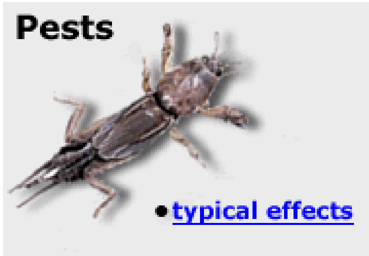
Welcome to Rice Doctor

Rice Doctor is a field diagnostic for identifying factors limiting rice crop growth in the Tropics. Before starting, you must know your problems and pests and their usual symptoms. Determine these by exploring the following links. When satisfied, explore the links from the left side of the screen to further your diagnosis.



Seed and Grain Symptoms

Symptom	Possible Cause	Confirmation
Smell – urine / feces	Rodents	Look for other symptoms of rodents – e.g., droppings, scattered grain, foot prints in dust, sacks damaged, etc.
Smell – musty	Fungus due to high moisture content	Discoloration of grain and husk, Check moisture content.
Color - Darkening or spotting of husks; grain yellowing	High moisture and high temperature	Check if grain moisture content and temperature too high (e.g., above 14% MC for 2-3 weeks)Yellowing can occur in 2-3 days if high moisture and temperature prior to threshing.
Observed pests (e.g., insects. Moths, rodents)	Pests – moths, insects, rodents, birds	Look for other symptoms of rodents or birds – e.g., smell (rodents), droppings, tracks in dust, sacks damaged (rodents), dust (insects) etc.
Spillage – gain scattered	Rodents or birds	Look for other symptoms of rodents or birds – e.g., droppings, foot prints in dust, sacks damaged, etc.
Damaged grain	Rodents, birds, or insects	Look for other symptoms of rodents or birds – e.g., smell (rodents), droppings, tracks in dust, sacks damaged (rodents), dust (insects) etc.
Dust or powder beside stack or mixed with grain	Insects	Look for other symptoms of rodents or birds – e.g., smell (rodents), droppings, tracks in dust, sacks damaged (rodents), dust (insects) etc.
Poor grain germination	Loss of viability	High moisture and temperature during storage (e.g., Moisture above 10% in seed held for > 12 months).

Fact Sheets

Deficiencies and Toxicities

Alkalinity

Discoloration spreads down the leaf (IRRI).

Diagnostic summary

Effects on plants	• impairs plant growth • obstructs root development • restricts water supply to the roots • results in deficiencies in phosphorus and zinc • Iron deficiency and boron toxicity may also occur
Signs	• discoloration of leaves starting at tip • scorched appearance in more susceptible plants • depressed tillering and growth • pattern of damage is patchy
Importance/Occurrence	• with high levels of exchangeable sodium • relatively rare especially in irrigated rice systems • occurs in semiarid region soils • often associated with salinity • damage occurs throughout the growth cycle of the rice crop

Full fact sheet

Symptoms	• Discoloration of leaves ranging from white to reddish brown starting from the leaf tips • Discoloration spreads down the leaf giving the plant a scorched appearance in more susceptible plants and in severe alkaline conditions • Growth and tillering depressed

Plant stand is patchy and has a poor growth (IRRI).

Confirmation

Soil and plant tests can be used to detect alkalinity. However, there is no direct test available for plants. The soil can be checked for potential alkalinity if the exchangeable sodium > 15% and a soil pH > 8.

Problems with similar symptoms

Strongly alkaline soils can also be phosphorus and zinc deficient.

Why and where it occurs

Alkalinity is relatively rare especially in irrigated rice systems. Alkaline soils have high levels of exchangeable sodium usually more than 15%.

Alkalinity occurs in semiarid region soils and is often associated with salinity. Thus, a number of combinations can occur:

	Saline soil	Alkali soil	Saline-Alkali
EC_e x 10^{-3}	Above 4	Below 4	Above 4
ESP	Below 15	At least 15	At least 15
PH paste	Below 8.5	8.5-10.0	usually < 8.5

EC_e = Electrical conductivity of soil extract with water
ESP = Exchangeable sodium percentage

Mechanism of damage

The high percentage of sodium in alkaline soils usually causes soil structural problems, which can be a problem in aerobic or upland crop systems. The high percentage of sodium can also have a direct effect on some cultivars. Alkalinity impairs plant growth and obstructs root development. It also restricts water supply to the roots. The strong basic properties of alkaline soils result in deficiencies in phosphorus and zinc. Iron deficiency and boron toxicity may also occur in these soils.

When damage is important

The damage caused by alkalinity occurs throughout the growth cycle of the rice crop.

Economic importance

Alkalinity is relatively rare, especially in irrigated rice systems.

Management principles

The objective of rehabilitating alkaline soils is to replace the sodium ions in the soil with calcium ions. This is a long-term process. Sources of calcium to be applied include:

Name	Formula	Content	Comments
Lime	$CaCO_3$	40% Ca	
Dolomite	$MgCO_3 + CaCO_3$	13% Mg, 21% Ca	Slow-acting, content of Ca and Mg varies
Gypsum	$CaSO_4 . 2 H_2O$	23% Ca, 18% S	Slightly soluble, slow-acting
Partly acidulated rock phosphate	$Ca_3(PO_4)_2$	10–11% P	>1/3 water-soluble
Rock phosphate, finely powdered	$Ca_3(PO_4)_2$	11–17% P, 33–36% Ca	Very slow acting (25–39% P_2O_5)
Single superphosphate	$Ca(H_2PO_4)_2 . H_20 + CaSO_4 . 2H_20$	12% S, 7-9% P, 13-20% Ca	Soluble, quick acting

Source

1. International Rice Research Institute. 1983. Field problems of tropical rice. Los Baños, Laguna, Philippines. 172 p.

2. Ilaco BV. 1985. Compendium for agricultural development in the tropics and subtropics. Elsevier Science Publishing Co., New York. 2nd edition.

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Aluminum Toxicity


Stunting with leaf scorching.

Diagnostic summary

Effects on plants	• inhibits root growth • inhibits shoot growth by inducing nutrient (Mg, Ca, P) deficiencies, drought stress, and phytohormone imbalances
Signs	• orange-yellow to white interveinal chlorosis on leaves • poor growth or stunted growth • yellow to white mottling of interveins is followed by leaf tip death and leaf margin scorch • necrosis of chlorotic areas during severe Al toxicity • stunted and deformed roots in susceptible cultivars
Importance/Occurrence	• one of the major factors in limiting crop production on acid upland soils • rare especially in irrigated rice systems • associated with strong P fixation and P deficiency • occurs in acid upland soils and acid sulfate soils • occurs throughout the growth cycle of the rice crop

Full fact sheet

Symptoms	• Orange-yellow interveinal chlorosis on leaves • Poor stunted growth • Yellow to white mottling of interveins is followed by leaf

tip death and leaf margin scorch

- Necrosis of chlorotic areas during severe Al toxicity
- Stunted and deformed roots in susceptible cultivars

Orange-yellow interveinal chlorosis (IRRI).

Scorching of leaf margins (IRRI).

Confirmation

Both the soil and plant can be tested for Al toxicity.

For plant—Optimal range and critical level for occurrence of Al toxicity:

Growth stage	Plant part	Optimum (mg kg^{-1})	Critical level for toxicity (mg kg^{-1})
Tillering-PI	Shoot	15-18	>100

The tillering capacity (total number of tillers per plant) of the plant appears to be a useful, early indicator for assessment of

	the effect of Al on grain production. Al-resistant and Al-sensitive varieties cannot be differentiated by biomass production or mineral concentrations (K, Ca, Mg, P, Al) in the shoots and roots of rice plants. A soil with potential Al toxicity has Al saturation of >30%, soil pH (H_2O) <5.0, and >1-2 mg Al L-1 in soil solution.
Problems with similar symptoms	No other damage exhibits these symptoms except for Al toxicity.
Why and where it occurs	Al toxicity is relatively rare especially in irrigated rice systems. Excess Al3+ concentration in soil solution is caused by low soil pH (<5). The concentration of Al in soil solution depends on soil pH as well as the concentration of organic and inorganic compounds that can form complexes with Al. Al toxicity rarely occurs in lowland rice except in some soils where soil reduction after flooding proceeds very slowly. Aluminum toxicity is one of the major factors limiting crop production on acid upland soils, and is often associated with strong P fixation and P deficiency. Al toxicity occurs on the following soils: • Acid upland soils (Ultisols, Oxisols) with large exchangeable Al content. Al toxicity often occurs together with Mn toxicity. • Acid sulfate soils, particularly when rice is grown as an upland crop for a few weeks before flooding (e.g., Thailand). • Flooded soils with pH <4 before Fe toxicity symptoms appear.
Mechanism of damage	Aluminum accumulates preferentially in the root tips at sites of cell division and cell elongation. The most important symptom of Al toxicity is the inhibition of root growth. This can be due to the effect of Al on cell walls, as well as the toxic effects of Al on the plasma membrane of younger and outer cells in roots or on the root symplasm. Al affects plasma-membrane functions and decreases the influx of Ca2+ and Mg2+. Some varieties are resistant to large Al concentrations by excluding Al from the root apex or through plant tissue tolerance of Al in the symplasm. Long-term exposure of plants to Al also inhibits shoot growth by inducing nutrient (Mg, Ca, P) deficiencies, drought stress, and phytohormone imbalances. Genotypic differences in susceptibility to Al toxicity in rice are as follows: • Al stress avoidance, due to the exclusion of Al from sensitive sites or reduced Al3+ activity in the rhizosphere, thus reducing the Al inhibition of Ca2+ and Mg2+ influx.

	• Al stress tolerance, due to high tissue tolerance of Al, immobilization of Al in nontoxic forms, or high internal nutrient use efficiency for P.
When damage is important	Al toxicity occurs throughout the growth cycle of the rice crop.
Economic importance	Aluminium toxicity is relatively rare especially in irrigated rice systems. It is more common in upland acid soil rice environments and can be a major source of yield loss.
Management principles	There are general measures to prevent Al toxicity. These are as follows: • **Varieties:** Plant Al-tolerant cultivars, which accumulate less Al in their foliage and take up and use Ca and P efficiently in the presence of Al. Al-tolerant cultivars include IR43, CO 37, and Basmati 370 (India), Agulha Arroz, Vermelho, and IAC3 (Brazil), IRAT 109 (Côte d'Ivoire), and Dinorado (Philippines). • **Crop management:** Delay planting until pH has increased sufficiently after flooding (to immobilize Al). • **Water management:** Provide crops with sufficient water to maintain reduced soil conditions. Prevent the topsoil from drying out. • **Fertilizer management:** On acid upland soils with Al toxicity, pay special attention to Mg fertilization. Al toxicity decreases when sufficient Mg is supplied. Liming with CaCO3 may not be sufficient, whereas the application of dolomite instead of CaCO3 not only raises the pH but also supplies Mg. Kieserite and langbeinite can be part of an integrated management strategy on acid upland soils to reduce Al toxicity, but are less cost-efficient than finely ground dolomite. Small amounts of kieserite and langbeinite (50 kg ha-1) may have an effect similar to that of liming with more than 1,000 kg CaCO3. • **Straw management:** Recycle straw or ash in the field to replenish Si removed. There are various options for treating Al toxicity. The options are: • Apply 1-3 t lime ha-1 to raise pH. Determine the exact amount needed based on a lime requirement test. • Ameliorate subsoil acidity to improve root growth below the plow layer by leaching Ca into the subsoil from lime applied to the soil surface. Supply anions SO42- or NO3- to accompany Ca2+ moving into the subsoil by applying gypsum, green manure crop, or urea with additional lime to neutralize the acidity generated in nitrification. Cl- is not an effective counter ion.

- On acid upland soils, install soil erosion traps and incorporate 1 t ha-1 of reactive rock phosphate to alleviate P deficiency.

Materials for treating Al toxicity in rice are:

Name	Formula	Content	Comments
Lime	$CaCO_3$	40% Ca	
Dolomite	$MgCO_3 + CaCO_3$	13% Mg, 21% Ca	Slow-acting, content of Ca and Mg varies
Gypsum	$CaSO_4 . 2 H_2O$	23% Ca, 18% S	Slightly soluble, slow-acting
Kieserite	$MgSO_4$. 7 H20	23% S, 16% Mg	Quick-acting
Langbeinite	K2SO_4 . $MgSO_4$	18% K, 11% Mg, 22% S	Quick-acting
Partly acidulated rock phosphate	Ca3(PO_4)2	10-11% P	>1/3 water-soluble
Rock phosphate, finely powdered	Ca3(PO_4)2	11-17% P, 33-36% Ca	Very slow acting (25-39% P_2O_5)
Single superphosphate	Ca(H2PO_4)$_2$. H20 + $CaSO_4$ .2$H_2$0	12% S, 7-9% P, 13-20% Ca	Soluble, quick acting

Source

Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute (IRRI). 191 p.

Boron Toxicity

Field damage caused by Boron toxicity (Dobermann and Fairhurst).

Diagnostic summary

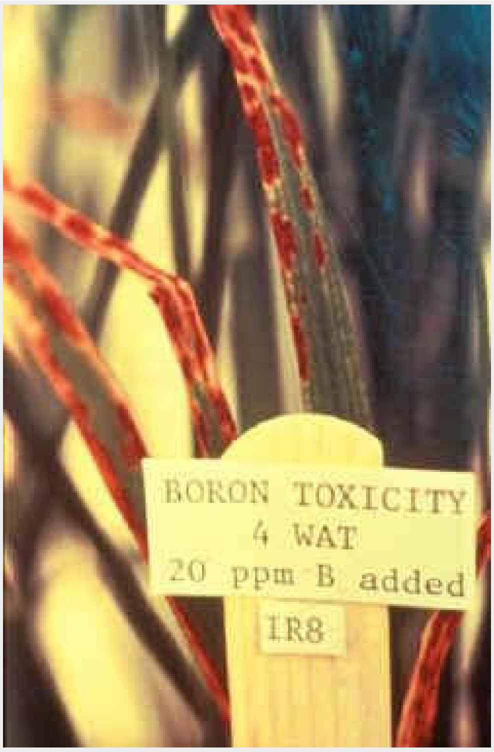
Effects on plants	• inhibits the formation of starch from sugars • affects the formation of B-carbohydrate complexes
Signs	• chlorotic leaf tips and margins of older leaves • dark brown elliptical spots on discolored areas of leaves • necrotic spots at panicle initiation • depressed vegetative growth
Importance/Occurrence	• important throughout the growth cycle of the rice crop • common in arid and semiarid regions • occur in soils formed on volcanic parent material, associated with the use of irrigation water pumped from deep wells and some coastal saline soils

Full fact sheet

Symptoms	• Chlorosis of tips and margins of older leaves as initial symptoms • Dark brown elliptical spots on discolored areas two to three weeks later followed by browning and drying up • Necrotic spots prominent at panicle initiation • Brownish leaf tips and dark brown elliptical spots on leaves • Vegetative growth is not markedly depressed

Stunting and yellowing (Dobermann and Fairhurst).

Large brown spots (Dobermann and Fairhurst).



Elliptical spots (Dobermann and Fairhurst).

Confirmation

Both the soil and plant can be tested for B deficiency.
The optimal toxicity limits of B in leaves have to be interpreted with caution.

- There is a steep concentration gradient of B within a leaf blade, from low values at the leaf base to high values at the tip.
- Critical toxicity levels in field-grown rice are lower than those of plants grown in the greenhouse because of B leaching from leaves due to rain.
- The effect on yield differs significantly among rice varieties.

The critical toxicity limits of B in the soil are as follows:

- >4 mg B kg^{-1}0.05N HCl
- >5 mg B kg^{-1}hot water- soluble B
- >2.5 mg B L^{-1}soil solution

In irrigation water, the B concentration is hazardous at > 2 mg B L^{-1}.

Problems with similar symptoms

No other damage exhibits these symptoms except for B deficiency.

Why and where it occurs

B toxicity is relatively rare - especially in irrigated rice systems. It is caused by:

- Large B concentration in soil solution because of the use

	of B-rich groundwater and high temperature (e.g., in arid regions, very deep tube wells, or wells in areas affected by geothermal activities). • Large B concentration in soil solution because of B-rich parent material. B content is high in some marine sediments, plutonic rocks, and other volcanic materials (e.g., tuff), but the content in igneous rocks is low. • Excess application of borax or large applications of municipal waste (compost). B toxicity is most common in arid and semiarid regions, but has also been reported in rice in other areas. Soils prone to B toxicity include the following types: • Soils formed on volcanic parent material, usually associated with the use of irrigation water pumped from deep wells containing a large B concentration (e.g., IRRI farm, Los Baños, and Albay, Philippines). • Some coastal saline soils.
Mechanism of damage	The physiology of B tolerance and B toxicity is not well understood. B uptake is closely related to the B concentration of the soil solution and the rate of water transpiration. When the B concentration in the soil solution is large, B is distributed throughout the plant in the normal transpiration stream, causing the accumulation of B in leaf margins and leaf tips. Excess B appears to inhibit the formation of starch from sugars or results in the formation of B-carbohydrate complexes, resulting in retarded grain filling but normal vegetative growth. Varieties with a large B requirement are less susceptible to B toxicity and vice versa.
When damage is important	The damage is important throughout the growth cycle of the rice crop.
Economic importance	B toxicity is relatively rare - especially in irrigated rice systems - being more common in arid and semiarid regions.
Management principles	The general measures to prevent B toxicity are as follows: • **Varieties:** Plant B-toxicity tolerant varieties (e.g., IR42, IR46, IR48, IR54, IR9884-54). B-toxicity tolerant varieties can yield up to 2 t ha-1 more than susceptible varieties. • **Water management:** Use surface water with a low B content for irrigation. Groundwater must be monitored regularly if used for irrigation. If the B concentration is too great, dilute the water with water from a different source containing a small amount of B. • **Soil management:** Plow when the soil is dry so that B accumulates in the topsoil. Leach with water containing a small amount of B. B toxicity soil can be treated by leaching with low-B irrigation

	water if percolation is sufficient and a suitable water source is available.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Calcium Deficiency

Leaf discoloration (IRRI)

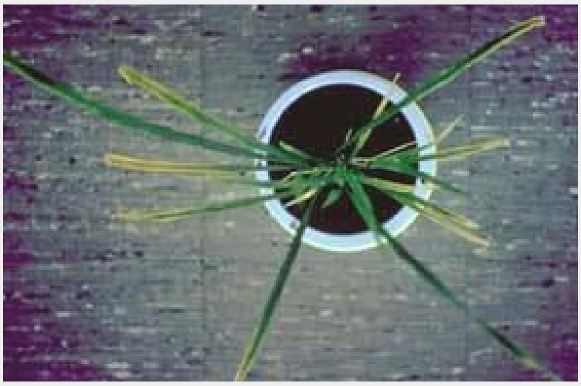
Diagnostic summary

Effects on plants	• affects cell wall constituents in biomembrane maintenance • impairs root function • predisposes the rice plant to Fe • may resemble B deficiency
Signs	• white or bleached, rolled, and curled tips of youngest leaves • necrosis along the lateral margins of leaves • old leaves turn brown and die • stunting and death of growing points
Importance/Occurrence	• relatively rare especially in irrigated rice systems • common in acid, strongly leached, low-CEC soils in uplands and lowlands, soils derived from serpentine rocks, coarse-textured sandy soils with high percolation rates and leaching, and leached, old acid sulfate soils with low base content • important throughout the growth cycle of the rice crop

Full fact sheet

Symptoms	**NOTE:** visible only under severe Ca deficiency like pot experiments, exhaustion experiments • Tips of youngest leaves become white or bleached, rolled, and curled • Necrotic tissue may develop along the lateral margins of leaves and old leaves eventually turn brown and die • Stunting and death of growing point during extreme

deficiency



Stunting and death of growing points (IRRI)

Confirmation

Both the soil and plant can be tested for Ca deficiency.
The optimal ranges and critical levels of Ca in plant tissue are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering-PI	Y leaf, shoot	0.2-0.6	<0.15
Maturity	Straw	0.3-0.5	<0.15

In a plant, a Ca:Mg ratio of 1-1.5:1 in rice shoots at tillering to panicle initiation stages is considered optimal. White leaf tips may occur when Ca:Mg is <1.

In the soil, Ca deficiency is likely when soil exchangeable Ca is <1 cmolc kg-1 or when the Ca saturation is <8% of the CEC. For optimum growth, Ca saturation of the CEC should be >20%.

For optimum growth, the ratio of Ca:Mg should be > 3-4:1 for exchangeable soil forms and 1:1 in soil solution.

Problems with similar symptoms

Ca deficiency may resemble B deficiency, and plant tissue analysis may be required to distinguish the cause of symptoms.

Why and where it occurs

Ca deficiency is relatively rare especially in irrigated rice systems. It can be caused by one or more of the following:

- Small amounts of available Ca in soil (degraded, acid, sandy soils)
- Alkaline pH with a wide exchangeable Na:Ca ratio resulting in reduced Ca uptake. Use of irrigation water rich in $NaHCO_3$.
- Wide soil Fe:Ca or Mg:Ca ratios resulting in reduced Ca uptake. Long-term irrigated rice cultivation may lead to higher Mg:Ca and Fe:Ca ratios.
- Excessive N or K fertilizer application resulting in wide NH_4:Ca or K:Ca ratios and reduced Ca uptake.

	- Excessive P fertilizer application, which may depress the availability of Ca (due to formation of Ca phosphates in alkaline soils). Ca deficiency is very uncommon in lowland rice soils because there is usually sufficient Ca in the soil, from mineral fertilizers, and irrigation water. Soils particularly prone to Ca deficiency occurs on the following soil types: - Acid, strongly leached, low-CEC soils in uplands and lowlands - Soils derived from serpentine rocks - Coarse-textured sandy soils with high percolation rates and leaching - Leached, old acid sulfate soils with low base content
Mechanism of damage	Calcium is a constituent of Ca pectates, important cell wall constituents also involved in biomembrane maintenance. It helps in cell wall stabilization as an enzyme activator, in osmoregulation, and in the cation-anion balance. Ca is less mobile in rice plants than Mg and K. Because Ca is not retranslocated to new growth, deficiency symptoms usually appear first on young leaves. Ca deficiency also results in impaired root function and may predispose the rice plant to Fe toxicity. An adequate supply of Ca increases resistance to diseases such as bacterial leaf blight (caused by *Xanthomonas oryzae*) or brown spot (caused by *Helminthosporium oryzae*). The rate of Ca uptake is proportional to the rate of biomass production.
When damage is important	The damage is important throughout the growth cycle of the rice crop.
Economic importance	Ca deficiency is relatively rare especially in irrigated rice systems.
Management principles	These are the general measures to prevent Ca deficiency: Crop management: Apply farmyard manure or straw (incorporated or burned) to balance Ca removal in soils containing small concentrations of Ca. Fertilizers: Use single superphosphate (13-20% Ca) or triple superphosphate (9-14% Ca) as a Ca source. Ca fertilizer sources for rice are:

Name	Formula	Content	Comments
Calcium chloride	$CaCl_2 . 6 H_2O$	18% Ca	Soluble, quick-acting, does not raise pH

Gypsum	$CaSO_4 . 2 H_2O$	23% Ca, 18% S	Slightly soluble, slow-acting, for saline and alkaline soils
Dolomite	$MgCO_3 + CaCO_3$	13% Mg, 21% Ca	Slow acting , content of Ca and Mg varying
Lime	$CaCO_3$	40% Ca	Slow-acting, for acid soils

Ca deficiency can be treated using the following:

- Apply $CaCl_2$(solid or in solution) or Ca-containing foliar sprays for quick treatment of severe Ca deficiency.
- Apply gypsum on Ca-deficient nonacidic soils, e.g., on sodic and high-K soils.
- Apply lime on acid soils to raise pH and Ca availability.
- Apply Mg or K in conjunction with Ca because Ca may cause deficiencies in these nutrients.
- Apply pyrites to mitigate the effects of $NaHCO_3$-rich water on Ca uptake.

Source

Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Copper Deficiency

Affected crop (IRRI)

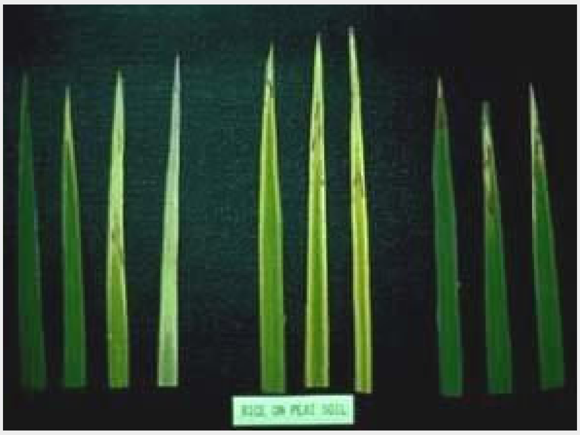
Diagnostic summary

Effects on plants	• affects metabolic processes like photosynthesis and respiration • reduction in pollen viability and increase in spikelet sterility and many unfilled grains
Signs	• either side of midrib of leaves with chlorotic streaks • leaf tips with dark brown necrotic lesions • bluish green leaves appearing chlorotic near leaf tip • needlelike appearance of new leaves • reduced tillering
Importance/Occurrence	• rare especially in irrigated rice systems • important throughout the growth cycle of the crop • more common on young leaves • occurs in high organic matter status soils, lateritic, highly weathered soils, soils derived from marine sediments, sandy textured soils, and calcareous soils

Full fact sheet

Symptoms	• Leaves develop chlorotic streaks on either side of the midrib • Dark brown necrotic lesions on leaf tips • Leaves often bluish green and chlorotic near the leaf tip

- New leaves do not unroll and the distal parts of leaves maintain a needlelike appearance, while the proximal portion of the leaf appears normal
- Reduced tillering
- Pollen viability is reduced under Cu deficiency thus increasing spikelet sterility and many unfilled grains



Leaf chlorosis (IRRI)

Needle-like leaves (IRRI)

Confirmation

There are tests used for both plant and soil to detect Cu deficiency.
The optimal ranges and critical levels of Cu in plant tissue are:

Growth stage	Plant part	Optimum (mg kg^{-1})	Critical level for deficiency (mg kg^{-1})

	Tillering-PI	Y leaf	7-15	<5
	Maturity	straw	-	<6

The critical soil levels for occurrence of Cu deficiency are:

- 0.1 mg Cu kg^{-1} 0.05N HCl
- 0.2-0.3 mg Cu kg^{-1} DTPA + $CaCl_2$, pH 7.3

Problems with similar symptoms

Only Cu deficient plants exhibit these symptoms.

Why and where it occurs

Cu deficiency is relatively rare especially in irrigated rice systems. It is caused by the following:

- Small amountof available Cu in soil.
- Strong adsorption of Cu on humic and fulvic acids (peat soils).
- Small amounts of Cu in parent materials (sandy soils derived from quartz).
- High NPK rates, causing rapid plant growth rate and exhaustion of Cu in soil solution.
- Overliming of acid soils, causing increased amount of Cu complexed by organic matter or adsorbed and occluded by hydroxides and oxides.
- Excessive Zn in the soil, inhibiting Cu uptake.

Cu deficiency occurs on the following soils:

- High organic matter status soils (Histosols, humic volcanic ash soils)
- Lateritic,highly weathered soils (Ultisols, Oxisols)
- Soils derived from marine sediments (limestone)
- Sandy textured soils
- Calcareous soils

Mechanism of damage

Copper is required for lignin synthesis (and thus cellular defense mechanisms) and is a constituent of ascorbic acid, the enzymes oxidase and phenolase, and plastocyanin. It is a regulatory factor in enzyme reactions (effector, stabilizer, and inhibitor) and a catalyst of oxidation reactions. It plays a key role in the following processes:

- N, protein, and hormone metabolism.
- Photosynthesis and respiration.
- Pollen formation and fertilization.

The mobility of Cu in rice plants depends partly on leaf N

	status. Little retranslocation of Cu occurs in N-deficient plants. Cu deficiency symptoms are more common on young leaves.
When is damage important	It is important throughout the growth cycle of the crop.
Economic importance	Cu deficiency is relatively rare especially in irrigated rice systems.
Management principles	The following are recommended for Cu deficiency: • Crop management: Dip seedling roots in 1% $CuSO_4$ suspensions for 1 h before transplanting. • Soil management: Avoid overliming of acid soils because it may reduce Cu uptake. • Fertilizer management: On Cu-deficient soils, apply CuO or $CuSO_4$ (5-10 kg Cu ha^{-1} at 5-year intervals) for long-term maintenance of available soil Cu (broadcast and incorporate in soil). Cupric sulfate is hygroscopic, i.e., it cannot blend with macronutrient fertilizers and may form insoluble compounds if mixed with P fertilizers. Cu applied to the soil has a high residual value.

Cu fertilizers for rice are:

Name	Formula	Content (% Cu)	Comments
Cupric sulfate	$CuSO_4 \cdot H_2O$ $CuSO_4 \cdot 5\ H_2O$	35 25	Soluble, quick-acting, low cost
Cu oxide	CuO	75	Insoluble, slow-acting

Cu deficiency can be treated by:

- Apply $CuSO_4$ (5-10 kg Cu ha^{-1}) for rapid treatment of Cu deficiency (solid or liquid form). For soil application, fine $CuSO_4$ material is either broadcast (or banded) on the soil or incorporated as a basal application.
- Foliar Cu can be applied during tillering to panicle initiation growth stages, but may cause leaf burn in growing tissues. Apply cupric sulfate solution or Cu chelates as foliar spray only for emergency treatment of Cu deficiency.
- Avoid applying excessive Cu because the range between Cu deficiency and toxicity levels is narrow.

Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Iron Deficiency

Iron deficient crop (IRRI)

Diagnostic summary

Effects on plants	• affects photosynthesis • decreased dry matter production
Signs	• interveinal yellowing • chlorosis of whole leaves and emerging leaves • entire plants becomes chlorotic
Importance/Occurrence	• mainly a problem in upland soils • relatively rare especially in irrigated rice systems • can be a source of yield loss in alkaline or calcareous soils • important throughout the growth cycle of the rice crop.

Full fact sheet

Symptoms	• Interveinal yellowing and chlorosis of emerging leaves • Whole leaves become chlorotic and then very pale • Entire plant becomes chlorotic and dies if deficiency is very severe • Decreased dry matter production

Leaf interveinal yellowing (IRRI)

Stunted plant with narrow leaves (right) (IRRI)

Confirmation

The plant and the soil can be tested for Fe deficiency.

The optimal ranges and critical levels of Fe in plant tissue are:

Growth stage	Plant part	Optimum (mg kg^{-1})	Critical level for deficiency (mg kg^{-1})
Tillering-PI	Y leaf	75-150	<70
Tillering-PI	Shoot	60-100	<50

Active Fe content may be more useful than total Fe content as an indicator of Fe nutritional status in leaves. The critical limit of ferrous Fe at 40 DAT is 45 mg kg^{-1} leaf tissue. The critical Fe deficiency contents are much higher in fast-growing merismatic and expanding tissues (e.g., shoot apices), perhaps around 200 mg Fe kg-1 for total Fe and 60-80 mg Fe kg^{-1} for active Fe.

	The soil is Fe deficient if soil Fe concentration is either: • <2 mg Fe kg^{-1} NH_4^-acetate, pH 4.8, or • <4-5 mg Fe kg^{-1} DTPA-CaC_{l2}, pH 7.3.
Problems with similar symptoms	No other rice crop exhibits these symptoms except for a Fe deficient plant.
Why and where it occurs	Fe deficiency is relatively rare, especially in irrigated rice systems. One or more of the following can cause Fe deficiency in rice: • Low concentration of soluble Fe^{2+} in upland soils. • Inadequate soil reduction under submerged conditions (e.g., low organic matter status soils). • High pH of alkaline or calcareous soils following submergence (i.e., decreased solubility and uptake of Fe because of large bicarbonate concentration). • Wide P:Fe ratio in the soil (i.e., Fe bound in Fe phosphates, possibly because of excess application of P fertilizer). • Excessive concentrations of Mn, Cu, Zn, Mo, Ni, and Al. • In upland soils, cultivars with low potential for excretion of organic acids to solubilize Fe. • Increased rhizosphere pH after the application of large amounts of NO_3-N fertilizer (rare case and is relevant for upland crops only). The soils, which are particularly prone to Fe deficiency include the following types: • Neutral, calcareous, and alkaline upland soils • Akaline and calcareous lowland soils with low organic matter status • Lowland soils irrigated with alkaline irrigation water • Coarse-textured soils derived from granite.
Mechanism of damage	Iron is required for electron transport in photosynthesis and is a constituent of iron porphyrins and ferredoxins, both of which are essential components in the light phase of photosynthesis. Fe is an important electron acceptor in redox reactions and an activator for several enzymes (e.g., catalase, succinic dehydrogenase, and aconitase), but inhibits K absorption. On alkaline soils, immobilization of Fe in plant roots occurs because of Fe precipitation. Because Fe is not mobile within rice plants, young leaves are affected first.

When is damage important	This deficiency is important throughout the growth cycle of the rice crop.
Economic importance	Fe deficiency is relatively rare - especially in irrigated rice systems. It can be a source of yield loss in alkaline or calcareous soils (especially in the Uplands).

Management principles

The following are general measures to prevent Fe deficiency:

- **Varieties:** Screen and breed for tolerance for low soil Fe availability. Grow Fe-efficient cultivars. Selection of high-Fe rice cultivars is in progress to improve Fe nutrition in children and pregnant women in developing countries.
- **Soil management:** Apply organic matter (e.g., crop residues, manure). Apply waste materials from mining and other industrial operations provided that they do not contain other pollutants at toxic concentrations.
- **Fertilizer management:** Use acidifying fertilizers (e.g., ammonium sulfate instead of urea) on high-pH soils. Use fertilizers containing Fe as a trace element.

Fe fertilizer sources for rice:

Name	Formula	Content (% Fe)	Comments
Ferrous sulfate	$FeSO_4 . H_2O$, $FeSO_4 . 7H_2O$	33 20	Quick-acting, soluble
Ferrous ammonium sulfate	$(NH_4)2SO_4 . FeSO_4 . 6H_2O$	14	Quick-acting, soluble
Fe chelate	NaFeDTPA	10	Quick-acting
Fe chelate	NaFeEDTA	5-14	Quick-acting
Fe chelate	NaFeEDDHA	6	More stable in neutral soils

Fe deficiency is the most difficult and expensive micronutrient deficiency to correct. Soil applications of inorganic Fe sources are often ineffective in controlling Fe deficiency, except when application rates are large.
Fe deficiency should be treated as follows:

- Apply solid $FeSO_4$ (about 30 kg Fe ha^{-1}) next to rice rows or broadcast (larger amount needed).
- Foliar applications of $FeSO_4$ (2-3% solution) or Fe chelates. Because of low Fe mobility in the plant, two or three repeated applications at 2-wk intervals starting at tillering are necessary to support new plant growth.

Source

Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate

Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Iron Toxicity


Tiny brown spots on leaves (IRRI)

Diagnostic summary

Effect on plants	• increased polyphenol oxidase activity, leading to the production of oxidized polyphenols • caused leaf bronzing • reduced root oxidation power
Signs	• lower leaves with tiny brown spots from tip and spread toward the base or whole leaf is orange-yellow to brown • spots combine on leaf interveins and leaves turn orange-brown and die • leaves narrow but often remain green • leaf tips become orange-yellow and dry up in some varieties • leaves appear purple-brown if Fe toxicity is severe • stunted growth, extremely limited tillering • dark brown to black coating on the root surface and many dead roots • fresh uprooted rice hills have many black roots
Importance/Occurrence	• occur on a wide range of soils, but generally in lowland rice soils with permanent flooding during crop growth • occur on soils that remain waterlogged • can affect the rice crop throughout its growth cycle

Full fact sheet

Symptoms

- Tiny brown spots on lower leaves starting from tip and spread toward the leaf base or whole leaf colored orange-yellow to brown
- Spots combine on leaf interveins and leaves turn orange-brown and die
- Leaves narrow but often remain green
- In some varieties, leaf tips become orange-yellow and dry up
- Leaves appear purple-brown if Fe toxicity is severe
- Stunted growth, extremely limited tillering.
- Coarse, sparse, damaged root system with a dark brown to black coating on the root surface and many dead roots
- Freshly uprooted rice hills often have poor root systems with many black roots

Leaf browning (IRRI)


Bronzing (IRRI)

Confirmation

Both the plant and soil can be tested for Fe toxicity.

The optimal ranges and critical levels for occurrence of Fe toxicity in plants are:

Growth stage	Plant part	Optimum (mg kg^{-1})	Critical level for toxicity (mg kg^{-1})
Tillering-PI	Y leaf	100-150	>300-500

Fe content in affected plants is usually (but not always) high (300-2,000 mg Fe kg^{-1}), but the critical Fe content depends on plant age and general nutritional status. The critical threshold is lower in poor soils where nutrition is not properly balanced.

Fe-toxic plants have low K content in leaves (often <1% K). A K:Fe ratio of <17-18:1 in straw and <1.5:1 in roots may indicate Fe toxicity.
The critical concentration for the occurrence of Fe toxicity is >300 mg Fe L-1soil. Critical Fe solution concentrations for the occurrence of Fe toxicity vary widely. Reported values range from 10 to 1,000 mg Fe L-1, which implies that Fe toxicity is not related to the Fe concentration in soil solution alone. The difference between critical solution Fe concentrations is caused by differences in the potential of rice roots to resist the effects of Fe toxicity, depending on crop growth stage, physiological status of the plant, and variety grown (root oxidation power).

No critical levels for soil test results have been established, but

	soils with pH <5.0 (in H_2O) are prone to Fe toxicity. Similarly, soils containing small amounts of available K, P, Ca, and Mg contents are prone to Fe toxicity.
Problems with similar symptoms	Only Fe-toxic plants exhibit these symptoms.
Why and where it occurs	Fe toxicity tends to occur on soils that remain waterlogged. The principal causes of Fe toxicity are as follows: • Large Fe^{2+} concentration in soil solution because of strongly reducing conditions in the soil and/or low pH. • Low and unbalanced crop nutrient status. Poor root oxidation and Fe^{2+} exclusion power because of P, Ca, Mg, or K deficiency. K deficiency is often associated with low soil base content and low soil pH, which result in a large concentration of Fe in the soil solution. • Poor root oxidation (Fe^{2+} exclusion) power because of the accumulation of substances that inhibit respiration (e.g., H_2S, FeS, organic acids,). • Application of large amounts of undecomposed organic matter. • Continuous supply of Fe into soil from groundwater or lateral seepage from hills. • Application of urban or industrial sewage with a high Fe content Fe toxicity occurs on a wide range of soils, but generally in lowland rice soils with permanent flooding during crop growth. The common features of Fe-toxic sites are poor drainage and low soil CEC and macronutrient content, whereas Fe toxicity occurs over a wide range of soil pH (4 to 7) Soils, which are prone to Fe toxicity, include the following types: • Poorly drained soils (Aquents, Aquepts, Aquults) in inland valleys receiving inflow from acid upland soils (Philippines, Sri Lanka) • Kaolinitic soils with low CEC and small amounts of available P and K (Madagascar) • Alluvial or colluvial acid clayey soils (Indonesia, Philippines) • Young acid sulfate soils (Sulfaquepts in Senegal, Thailand) • Acid lowland or highland peat (swamp) soils (Burundi, Liberia, Madagascar)
Mechanism of	Iron toxicity is primarily caused by the toxic effect of excessive

damage	Fe uptake due to high solution Fe concentrations. Recently transplanted rice seedlings may be affected when large amounts of Fe^{2+} accumulate immediately after flooding. In later growth stages, excessive Fe2+ uptake due to increased root permeability and enhanced microbial Fe reduction in the rhizosphere affects rice plants. Excessive Fe uptake results in increased polyphenol oxidase activity, leading to the production of oxidized polyphenols, the cause of leaf bronzing. Large amounts of Fe in plants can give rise to the formation of oxygen radicals, which are highly phytotoxic and responsible for protein degradation and peroxidation of membrane lipids. Varieties differ in susceptibility to Fe toxicity. The major adaptive mechanisms by which rice plants overcome Fe toxicity are as follows: • Fe stress avoidance because of Fe^{2+} oxidation in the rhizosphere. The precipitation of Fe3+ hydroxide in the rhizosphere by healthy roots (indicated by reddish brown coatings on the roots) prevents excessive Fe2+ uptake. In strongly reduced soils containing very large amounts of Fe, however, there may be insufficient oxygen at the root surface to oxidize Fe^{2+}. In such cases, Fe uptake is excessive and roots appear black because of the presence of Fe sulfide. Root oxidation power includes the excretion of O2 (transported from the shoot to the root through aerenchyma) from roots and oxidation mediated by enzymes such as peroxidase or catalase. An inadequate supply of nutrients (K, Si, P, Ca, and Mg) and excessive amounts of toxic substances (H2S) reduce root oxidation power. Rice varieties differ in their ability to release O2 from roots to oxidize Fe^{2+} in the rhizosphere and protect the plant from Fe toxicity. • Fe stress tolerance may be due to the avoidance or tolerance of toxin accumulation. Another mechanism involves the retention of Fe in root tissue (oxidation of Fe^{2+} and precipitation as Fe^{3+}). • Fe toxicity is related to multiple nutritional stress, which leads to reduced root oxidation power. The root of plants deficient in K, P, Ca, and/or Mg exude more low molecular weight metabolites (soluble sugars, amides, amino acids) than plants with an adequate nutrient supply. In periods of intense metabolic activity (e.g., tillering), this results in an increased rhizoflora population, which in turn leads to increased demand for electron acceptors. Under such conditions, facultative and obligate anaerobic bacteria reduce Fe3+ to Fe2+. The continuous reduction of Fe3+ contained in Fe2O3 root coatings may result in a breakdown in Fe oxidation, leading to an uncontrolled influx of Fe2+ into the rice plant roots. A black stain of Fe sulfide (a diagnostic

	indication of excessively reduced conditions and Fe toxicity) may then form on the root surface.
When is damage important	Fe toxicity can affect the rice crop throughout its growth cycle.
Economic importance	Fe toxicity occurs on a wide range of soils, but generally in lowland rice soils with permanent flooding during crop growth.
Management principles	The following are general measures to prevent Fe toxicity: • **Varieties:** Plant rice varieties tolerant of Fe toxicity (e.g., IR8192-200, IR9764-45, Kuatik Putih, Mahsuri). If nutrients are supplied in sufficient amounts, hybrid rice varieties have a more vigorous root system and higher root oxidation power, and do not tend to absorb excessive amounts of Fe from Fe-toxic soils. • **Seed treatment:** In temperate climates where direct seeding is practiced, coat seeds with oxidants (e.g., Ca peroxide at 50-100% of seed weight) to improve germination and seedling emergence by increasing the O_2 supply. • **Crop management:** Delay planting until the peak in Fe^{2+} concentration has passed (i.e., not less than 10-20 d after flooding). • **Water management:** Use intermittent irrigation and avoid continuous flooding on poorly drained soils containing a large concentration of Fe and organic matter. • **Fertilizer management:** Balance the use of fertilizers (NPK or NPK + lime) to avoid nutrient stress. Apply sufficient K fertilizer. Apply lime on acid soils. Do not apply excessive amounts of organic matter (manure, straw) on soils containing large amounts of Fe and organic matter and where drainage is poor. Use urea (less acidifying) instead of ammonium sulfate (more acidifying). • **Soil management:** Carry out dry tillage after the rice harvest to enhance Fe oxidation during the fallow period. This reduces Fe^{2+} accumulation during the subsequent flooding period, but will require machinery (tractor). Preventive management strategies (see above) should be followed because treatment of Fe toxicity during crop growth is difficult. The following are options for treating Fe toxicity: • Applying additional K, P, and Mg fertilizers. • Incorporating lime in the topsoil to raise pH in acid soils.

	- Incorporating about 100-200 kg MnO2 ha-1 in the topsoil to decrease Fe3+ reduction. - Carrying out midseason drainage to remove accumulated Fe^{2+}. At the midtillering stage (25-30 d after planting/sowing), drain the field and keep it free of floodwater (but moist) for about 7-10 d to improve oxygen supply during tillering.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Magnesium Deficiency


Interveinal chlorosis caused by Mg deficiency (IRRI)

Diagnostic summary

Effects on plants	• affects CO_2 assimilation and protein synthesis • affects several enzymes activities • affects cellular pH and the cation-anion balance activation
Signs	• pale-colored plants with orange-yellow interveinal chlorosis on older leaves and later on younger leaves • chlorosis progresses to yellowing and finally necrosis in older leaves in severe cases • greater leaf number and length • wavy and droopy leaves • reduced number of spikelets • reduced grain quality
Importance/Occurrence	• damage is important throughout the growth cycle of the rice crop • relatively rare especially in irrigated rice systems • more common in rainfed lowland and upland rice • may also be induced by large applications of K fertilizer on low Mg status soils • occurs on acid, low-CEC soils in uplands and lowlands, coarse-textured, highly weathered acid

	soils, coarse-textured sandy soils with high percolation rates and leaching losses, and leached, old acid sulfate soils with low base content

Full fact sheet

Symptoms

- Orange-yellow interveinal chlorosis on older leaves
- Plants pale-colored with interveinal chlorosis first appearing on older leaves and later on younger leaves as deficiency becomes more severe
- Green coloring appears as a "string of beads" in which green and yellow stripes run parallel to the leaf
- In severe cases, chlorosis progresses to yellowing and finally necrosis in older leaves
- Leaf number and leaf length are greater in Mg-deficient plants, and Mg-deficient leaves are wavy and droopy due to an expansion in the angle between the leaf sheath and leaf blade
- With moderate deficiency, plant height and tiller number are not affected greatly.
- Reduced number of spikelets and reduced 1,000-grain weight.
- May reduce grain quality (% milled rice, protein, and starch content).
- Fe toxicity may be more pronounced where Mg is part of multiple nutrient deficiency stress involving K, P, Ca, and Mg.

Confirmation

Both plant and soil can be tested for Mg deficiency.

The optimal ranges and critical levels of Mg in plant tissue are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering-PI	Y leaf	0.15-0.30	<0.12
Tillering-PI	Shoot	0.15-0.30	<0.13
Maturity	Straw	0.20-0.30	<0.10

In rice shoots, the Ca:Mg ratio of 1-1.5:1 between tillering and panicle initiation is considered optimal.

On soil, a concentration of <1 $cmol_c$ Mg kg^{-1} soil indicates very low exchangeable Mg content, whereas values of >3 cmolc Mg kg^{-1} are generally sufficient for rice.

For optimum growth, the ratio of Ca:Mg should be 3-4:1 for exchangeable soil forms and not exceed 1:1 in soil solution.

Problems with similar symptoms

No other plants exhibit these symptoms except for a Mg deficient plant.

Why and where it occurs	Mg deficiency is relatively rare especially in irrigated rice systems. Mg deficiency can be caused by either of the following: • Low available soil Mg. • Decreased Mg uptake due to a wide ratio of exchangeable K:Mg (i.e., >1:1). Mg deficiency is not frequently observed in the field because adequate amounts are usually supplied in irrigation water. Mg deficiency is more common in rainfed lowland and upland rice where soil Mg has been depleted because of the continuous removal of Mg in crop products without recycling crop residues or replacing removed Mg with mineral fertilizer. Many rainfed rice soils are inherently deficient in Mg. Mg deficiency occurs on the following soil types: • Acid, low-CEC soils in uplands and lowlands, e.g., degraded soils in North Vietnam and coarse-textured, highly weathered acid soils in northeast Thailand, Lao PDR, and Cambodia • Coarse-textured sandy soils with high percolation rates and leaching losses • Leached, old acid sulfate soils with low base content, e.g., in Thailand
Mechanism of damage	Magnesium activates several enzymes. It is a constituent of chlorophyll, and thus is involved in CO_2 assimilation and protein synthesis because it activates several enzymes and is a constituent of chlorophyll. Mg also regulates cellular pH and the cation-anion balance. It is very mobile and is retranslocated easily from old leaves to young leaves. Deficiency symptoms therefore tend to occur initially in older leaves.
When damage is important	The damage is important throughout the growth cycle of the rice crop.
Economic importance	Mg deficiency is not very common in irrigated rice and thus tends to be of little economic significance.
Management principles	• **Crop management:** Apply sufficient Mg fertilizer, farmyard manure, or other materials to balance removal in crop products and straw. • **Water management:** Reduce percolation rates (leaching losses) on coarse-textured soils by subsoil compaction. • **Soil management:** Reduce losses from erosion and surface runoff by appropriate soil conservation measures in upland systems.

The following are recommended for treating Mg deficiency:

- Apply Mg-containing fertilizers. Rapid correction of Mg deficiency symptoms is achieved by applying a soluble Mg source such as kieserite or Mg chloride.

Mg Fertilizers for Rice:

Name	Formula	Content	Comments
Kieserite	$MgSO_4 \cdot H_20$	17% Mg, 23% S	Soluble, quick-acting
Langbeinite	K_2SO_4, $MgSO_4$	18% K, 11% Mg, 22%S	Quick-acting
Magnesium chloride	$MgCl_2$	9% Mg	Soluble, quick-acting
Magnesium oxide	MgO	42% Mg	Slow-acting, for foliar application
Magnesite	$MgCO_3$	25-28% Mg	Slow-acting
Dolomite	$MgCO_3 \cdot CaCO_3$	13% Mg, 21% Ca	Slow-acting, content of Ca and Mg varying

- Make a foliar application of liquid fertilizers containing Mg (e.g., $MgCl_2$).
- On acid upland soils, apply dolomite or other slow-acting Mg sources to supply Mg and increase soil pH (prevent Al toxicity)

Source

Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Manganese Deficiency

Chlorosis is youngest leaves (IRRI)

Diagnostic summary

Effect on plants	• affects photosynthesis and protein synthesis • Mn-deficient plant is often deficient in P
Signs	• pale grayish green interveinal chlorosis from leaf tip to base • necrotic brown spots develop later and leaf becomes dark brown • newly emerging leaves short, narrow, and light green • plants shorter with fewer leaves and smaller root system at tillering • affected plants more susceptible to brown spot • symptoms of bronzing
Importance/Occurrence	• relatively rare especially in irrigated rice systems • important throughout the growth cycle of the rice crop • common problem in upland systems • occurs in acid upland soils, alkaline and calcareous soils, degraded paddy soils, leached sandy soils, old acid sulfate soils, alkaline and calcareous organic soils, and highly weathered soils

Full fact sheet

Symptoms	• Pale grayish green interveinal chlorosis spreads from the tip to the leaf base • Necrotic brown spots develop later and leaf becomes

dark brown

- Newly emerging leaves short, narrow, and light green
- Deficient plants shorter, with fewer leaves, weigh less, and smaller root system at tillering
- Plants stunted but tillering is not affected
- Affected plants more susceptible to brown spot (caused by *Helminthosporium oryzae*)
- Mn-deficient rice plants often deficient in P
- In soils where both Mn deficiency and Fe toxicity occur, Mn-deficient rice plants contain a large concentration of Fe, and may also show symptoms of bronzing

Interveinal chlorosis (IRRI)

Confirmation

Both plant and soil can be tested for Mn deficiency.

The optimal ranges and critical levels of Mn in plant tissue are:

Growth stage	Plant part	Optimum (mg kg-$^{-1}$)	Critical level for deficiency (mg kg^{-1})
Tillering-PI	Y leaf	40-700	<40
Tillering	Shoot	50-150	<20

In plants, an Fe: Mn ratio >2.5:1 in the shoot during early growth (tillering) indicates Mn deficiency.

On soil, the critical soil levels for occurrence of Mn deficiency are as follows:

	• 1 mg Mn kg^{-1}, TPA + $CaCl_2$, pH 7.3 • 12 mg Mn kg^{-1}, 1N NH_4-acetate + 0.2% hydroquinone, pH 7 • 15-20 mg Mn kg^{-1} , 1N H_3PO_4 + 3N $NH_4H_2PO_4$ The application of Mn is unnecessary in soils with >40 mg kg^{-1} 0.1 M HCl extractable Mn. The optimum concentration of Mn in soil solution is in the range of 3-30 mg L^{-1}.
Problems with similar symptoms	Only rice crops, which are Mn deficient exhibit these symptoms.
Why and where it occurs	Mn deficiency is relatively rare especially in irrigated rice systems. The following are causes of Mn deficiency: • Small available Mn content in soil. • Fe-induced Mn deficiency, due to a large concentration of Fe in the soil. Increased Fe absorption reduces Mn uptake in rice plants, resulting in a wide Fe:Mn ratio. • Reduced Mn uptake because of large concentrations of Ca^{2+}, Mg^{2+}, Zn^{2+}, or NH^{4+} in soil solution. • Excessive liming of acid soils, causing an increase in the amount of Mn complexed by organic matter or adsorbed and occluded by Fe and Al hydroxides and oxides. • Reduced Mn uptake, due to hydrogen sulfide accumulation. Mn deficiency occurs frequently in upland rice, but is uncommon in rainfed or lowland rice because the solubility of Mn increases under submerged conditions. Soils particularly prone to Mn deficiency include the following types: • Acid upland soils (Ultisols, Oxisols) • Alkaline and calcareous soils with low organic matter status and small amounts of reducible Mn • Degraded paddy soils containing large amounts of active Fe • Leached sandy soils containing small amounts of Mn • Leached, old acid sulfate soils with low base content • Alkaline and calcareous organic soils (Histosols) • Highly weathered soils with low total Mn content
Mechanism of damage	Manganese is involved in oxidation-reduction reactions in the electron transport system, O_2 evolution in photosynthesis, and activates certain enzymes (e.g., oxidase, peroxidase, dehydrogenase, decarboxylase, kinase). Mn is required for the

	following processes: • Formation and stability of chloroplasts. • Protein synthesis. • NO_3- reduction. • TCA (tricarboxylic acid) cycle. Mn^{2+} catalyzes the formation of phosphatidic acid in the phospholipid synthesis for cell membrane construction. Mn helps to alleviate Fe toxicity. It is required to maintain a low O_2 supply in the photosynthetic apparatus. Mn accumulates in roots before it moves to aboveground shoots. There is some translocation of Mn from old to young leaves.
When damage is important	The damage is important throughout the growth cycle of the rice crop.
Economic importance	Mn deficiency is not very common in irrigated or rainfed rice, but it can be a common problem in Upland systems.
Management principles	There are general measures to prevent Mn deficiency. These are as follows: • **Crop management:** Apply farmyard manure or straw (incorporated or burned) to balance Mn removal and enhance Mn(IV) reduction in soils containing small amounts of Mn and low organic matter status. • **Fertilizer management:** Use acid-forming fertilizers, e.g., ammonia sulfate [$(NH_4)2SO_4$] instead of urea. Manganese deficiencies can be corrected by foliar application of Mn or by banding Mn with an acidifying starter fertilizer. Broadcast Mn undergoes rapid oxidation so that high rates are required (>30 kg Mn ha^{-1}). High rates of Mn and Fe may be antagonistic and reduce yield. Mn deficiency should be treated as follows: • Apply $MnSO_4$ or finely ground MnO (5-20 kg Mn ha^{-1}) in bands along rice rows. • Apply foliar $MnSO_4$ for rapid treatment of Mn deficiency (1-5 kg Mn ha^{-1} in about 200 L water ha^{-1}). Multiple applications may be required, starting at tillering when sufficient foliage has developed. • Chelates are less effective because Fe and Cu displace Mn. **Mn fertilizer sources for rice:**

Name	Formula	Content (% Mn)	Comments
Mn sulfate	$MnSO_4 . H2O$	24-30	Soluble, quick-acting
Mn chloride	$MnCl_2$	17	Soluble, quick-acting

	Mn carbonate	$MnCO_3$	31	Insoluble, slow-acting
	Mn chelate	$Na_2MnEDTA$	5-12	Quick-acting
	Mn oxide	MnO2	40	Insoluble, slow-acting
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.			

Nitrogen Deficiency


Field damage (IRRI)

Diagnostic summary

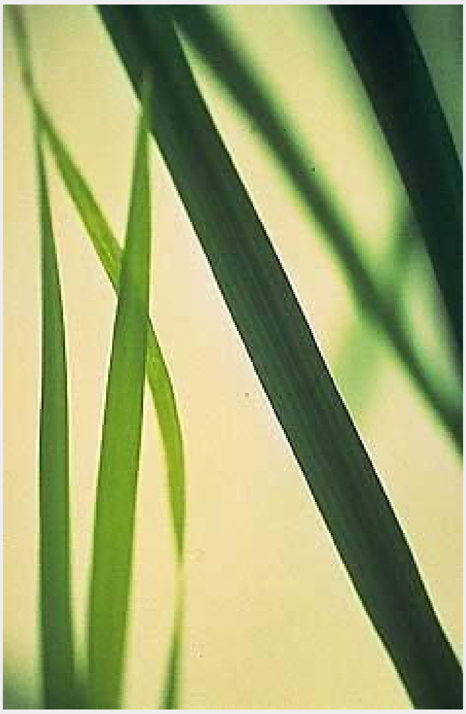
Effect on plants	• affects all parameters contributing to yield
Signs	• stunted • older leaves or whole plants yellowish green • sometimes all leaves become light green and chlorotic at the tip • leaves die under severe N stress • all leaves are narrow, short, erect, and lemon-yellowish green except for young leaves, which are greener • entire field may appear yellowish • reduced tillering • reduced grain number
Importance/Occurrence	• most common in rice in Asia • common in all rice-growing soils where modern varieties are grown without sufficient mineral N fertilizer • occurs at critical growth stages such as tillering and panicle initiation

Full fact sheet

Symptoms	• Stunted • Older leaves or whole plants yellowish green • Old leaves and sometimes all leaves become light green and chlorotic at the tip • Leaves die under severe N stress

- Except for young leaves, which are greener, leaves are narrow, short, erect, and lemon-yellowish green
- Entire field may appear yellowish
- Reduced tillering, small leaves, and short plants
- Reduced grain number

Stunting and reduced tillering (IRRI)


Smaller leaves (IRRI)

Confirmation

Both the plant and soil can be tested for N deficiency.
The optimal ranges and critical levels of N in plant tissues are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering to panicle initiation	Y leaf	2.9-4.2	<2.5
Flowering	Flag leaf	2.2-3.0	<2.0

	Maturity	Straw	0.6-0.8	

To reach maximum potential yield, leaf N must be maintained at or above 1.4 g m^{-2} leaf area, which is equivalent to a chlorophyll meter reading (SPAD) of 35 or a leaf color chart reading of 4. A SPAD reading of 35 or LCC 4 for the uppermost fully expanded leaf is used as a threshold for N deficiency (i.e., the need to apply N) in transplanted high-yielding indica rice. A SPAD threshold of 32-33 or LCC 3 should be used in direct-seeded rice with high tiller density. Note that SPAD or LCC values are poorly correlated with leaf N content expressed on a leaf dry weight basis, but closely correlated with leaf N content expressed on a leaf area basis (g N m-2).

In direct-seeded rice in southern Australia, fast tissue N testing in the shoot at panicle initiation is commonly practiced to determine the requirement for N topdressing at the panicle initiation stage. N rates are adjusted as a function of tiller density and N content in the shoot. For example, topdressed N is not recommended at the panicle initiation stage when:

- 800-1,000 shoots m-2 and shoot N at PI stage >2%
- 1,000-1,200 shoots m-2 and shoot N at PI stage >1.75%

On soil,

- Crop-based estimates provide the most reliable estimates of the indigenous N supply in intensive rice systems. In irrigated lowland rice systems, most commonly used soil tests are incapable of predicting soil N supply under field conditions and therefore reliable, general critical levels or ranges cannot be given. Soil organic C or total soil N content cannot be used as a reliable index of soil N supply in irrigated rice systems, but is more useful in upland rice systems.

Soil N supply can be measured by incubating soil under anaerobic conditions (2 wk at 30 ºC) and the results used to predict N requirements. This method should be used with caution because it may underestimate the true soil N-supplying capacity and because adequate field calibration is missing. It is also not practical for routine soil analysis.

Problems with similar symptoms

The visual symptoms of N deficiency can be confused with those of S deficiency, but S deficiency is less common and tends to first affect younger leaves or all leaves on the plant. Mild N deficiency can be confused with Fe deficiency, but the latter affects the emerging leaf first.

Why and where it occurs

N deficiency is one of the most common problems in rice in Asia. It can be caused by one or more of the following:

- Low soil N-supplying power.

- Insufficient application of mineral N fertilizer.
- Low N fertilizer use efficiency (losses from volatilization, denitrification, incorrect timing and placement, leaching, and runoff).
- Permanently submerged conditions that reduce indigenous soil N supply (i.e., in triple cropping systems).
- N loss caused by heavy rainfall (leaching and seepage).
- Temporary drying out of the soil during the growing period.
- Poor biological N_2 fixation because of severe P deficiency.

N deficiency is common in all rice-growing soils where modern varieties are grown without sufficient mineral N fertilizer. Significant yield responses to N applied in mineral and/or organic forms are obtained in nearly all lowland rice soils where irrigation and other nutrients and pests are not limiting. N deficiency may also occur where a large amount of N fertilizer has been applied but at the wrong time or in the wrong way. Soils particularly prone to N deficiency include the following types:

- Soils with very low soil organic matter content (e.g., <0.5% organic C, coarse-textured acid soils).
- Soils with particular constraints to indigenous N supply (e.g., acid sulfate soils, saline soils, P-deficient soils, poorly drained wetland soils where the amount of N mineralization or biological N2 fixation is small).
- Alkaline and calcareous soils with low soil organic matter status and a high potential for NH_3 volatilization losses.

Mechanism of damage

N is an essential constituent of amino acids, nucleic acids, nucleotides, and chlorophyll. It promotes rapid growth (increased plant height and tiller number) and increased leaf size, spikelet number per panicle, percentage filled spikelets in each panicle, and grain protein content. Thus, N affects all parameters contributing to yield. Leaf N concentration is closely related to leaf photosynthesis rate and crop biomass production. N drives the demand for other macronutrients such as P and K.

NO_3-N and NH_4-N are the major sources of inorganic N uptake. Most absorbed NH_4-N is incorporated into organic compounds in roots, whereas NO3-N is more mobile in the xylem and is also stored in the vacuoles of different plant parts. NO_3-N may also contribute to maintaining the cation-anion balance and

	osmoregulation. To fulfil essential functions as a plant nutrient, NO_3-N must be reduced to ammonia through the action of nitrate and nitrite reductases. N is required throughout the growth period, but the greatest requirement for it is between the early to midtillering and panicle initiation stages. Sufficient N supply during ripening is necessary to delay leaf senescence, maintain photosynthesis during grain filling, and increase protein content in the grain. N is very mobile within the plant and, because N is translocated from old senescent leaves to younger leaves, deficiency symptoms tend to occur initially in older leaves. Compared with conventional (inbred) rice varieties, hybrid rice has important specific characteristics: • Greater potential to absorb and use N from the soil because of a more vigorous root system (many superficial roots, greater root oxidation power). • Higher efficiency of N translocation from sources (stem, leaf) to the sink (grain). • N uptake peaks at tillering and grain filling stages. • Greater NO_3- uptake and use during reproductive growth. Larger yield response to topdressed NO_3-N because of the large number of superficial roots.
When damage is important	N deficiency often occurs at critical growth stages such as tillering and panicle initiation when the demand for N is large. The damage is important throughout the growth cycle of the crop.
Economic importance	N deficiency is probably the most common problem in rice and tends to be of large economic significance. Fertilizer as a percent of costs per ha varies considerably—being from 10 to 20% in irrigated rice in a range of countries.
Management principles	Treatment of N deficiency is easy and response to N fertilizer is rapid. Apply N fertilizer and follow the guidelines given below. The response may already be evident after 2-3 d (greening, improved vegetative growth) but this depends on the rice variety, soil type, weather conditions, N fertilizer used, amount applied, and time and method of application. Dynamic soil- and plant-based management is required to optimize N use efficiency for each season. The adjustment of the quantity of N applied in relation to variation in indigenous N supply is as important as the timing, placement, and source of applied N. Nitrogen management must focus on improving the congruence between N supply and demand within a cropping season. Unlike for P and K fertilizer, residual effects of N fertilizer are negligible, but long-term management of indigenous N sources must also be considered. General crop management measures to improve N use

efficiency are as follows:

- **Varieties:** Do not apply large amounts of N to less responsive varieties, e.g., traditional (tall) varieties with low harvest index grown in rainfed lowland and upland environments. Conventional modern rice varieties do not differ much in their potential nutrient recovery efficiency and internal nutrient efficiency. Hybrid rice absorbs mineral N (particularly NO_3- during later growth stages) more efficiently than inbred rice varieties such that a late N application supplied in nitrate form may lead to a significant yield increase.

- **Crop establishment:** Choose a suitable plant spacing for each cultivar. Crops with suboptimal plant densities do not use fertilizer N efficiently. Adjust the number of splits and timing of N applications according to the crop establishment method (see below). Transplanted and direct-seeded rice require different N management strategies.

- **Water management:** Maintain proper water control, i.e., keep the field flooded to prevent denitrification but avoid N losses from water runoff over bunds immediately following fertilizer application. Fluctuating moisture conditions cause higher N losses due to nitrification-denitrification. Fields can be kept moist but without standing water during early vegetative growth (e.g., during emergence and early tillering in direct-seeded rice before N has been applied). Rice, however, requires flooded conditions, particularly during the reproductive growth stages, for optimum growth, nutrient uptake, and yield.

- **Crop management:** Optimal response to N fertilizer depends on proper overall crop management. Establish a dense, healthy rice crop by using high-quality seed of a high-yielding variety with multiple pest resistance and a suitable plant density. Control weeds that compete with rice for N. Control insects and diseases (damage reduces canopy efficiency and thus rice productivity). At the end of the rice season, losses of residual soil NO3-N can be reduced if a dry-season crop is planted to recover residual N or if weeds are allowed to develop and then are incorporated into the soil in the subsequent cropping cycle.

- **Soil management:** Correct deficiencies of other nutrients (P, K, Zn) and solve other soil problems (shallow rooting depth, toxicities). Response to applied N will be small on acid, low-fertility rainfed lowland and upland soils unless all existing soil fertility problems (acidity, Al toxicity, deficiencies of P, Mg, K, and other materials to increase CEC (capacity to adsorb NH4+) on low-CEC soils. If cost-effective sources are available, zeolite (CEC 200-300 cmol+ kg-1) or vermiculite (CEC 100-200 cmol+ kg-1) can be used to increase N use efficiency on low-CEC soils (acid Ultisols, Oxisols, degraded paddy soils). These materials can be applied directly to the soil or mixed with N fertilizer (e.g., 20% of the total N application rate can be replaced with zeolite).

- **Organic matter management:** Over the long term, maintain or increase the supply of N from indigenous sources through proper organic matter management:
    - Apply available organic materials (farmyard manure, crop residues, compost) on soils containing a small amount of organic matter, particularly in rainfed lowland rice and intensive irrigated rice systems where rice is rotated with other upland crops such as wheat or maize.
    - In irrigated rice-rice systems, carry out dry, shallow tillage (5-10 cm) within 2 wk of harvest. Early tillage enhances soil oxidation and crop residue decomposition during fallow and increases N availability up to the vegetative growth phase of the succeeding rice crop.
    - Increase the indigenous N-supplying power of permanently submerged soils by periodic drainage and drying. Examples are a midseason drainage of 5-7 d at the late tillering stage (about 35 d after planting) or occasional thorough aeration of the soil by substituting an upland crop for one rice crop, or omitting one rice crop.
- **Fertilizer management:** Application of N fertilizer is standard practice in most rice systems. To achieve yields of 5-7 t ha-1, fertilizer N rates typically range from 80 to 150 kg ha-1. Factors affecting the amount and timing of N applications in rice include:
    - Variety grown.
    - Crop establishment method.
    - Soil N-supplying capacity (indigenous N supply), including residual effects of preceding crops or fallow periods.
    - Water management.
    - Type of N fertilizer used.

  - Method of application.
  - Soil physical and chemical properties affecting fertilizer N transformations.

Excessive N or unbalanced fertilizer application (large amounts of N in combination with small amounts of P, K, or other nutrients) may reduce yield because of one or more of the following:

- Mutual leaf shading caused by excessive vegetative growth. Increased number of unproductive tillers that shade productive tillers and reduce grain production.
- Lodging caused by the production of long, weak stems.
- Increased number of unfilled grains.
- Reduced milling recovery and poor grain quality.
- Increased incidence of diseases such as bacterial leaf blight (caused by *Xanthomonas oryzae*), sheath blight (caused by *Rhizoctonia solani*), sheath rot (caused by *Sarocladium oryzae*), stem rot (caused by *Helminthosporium sigmoideum*), and blast (caused by *Pyricularia oryzae*) because of greater leaf growth and dense crop stand.
- Increased incidence of insect pests, particularly leaffolder, *Cnaphalocrocis medinalis*.

Some general recommendations can be made for N fertilizer use in rice:

- Apply about 15-20 kg N t-1 grain yield target. The N fertilizer requirement is smaller in rainy-season crops (less sunshine, smaller potential yield) and larger in dry-season crops (more sunshine, greater potential yield) where larger N application rates result in more tillers and leaf area, and ultimately larger grain yield.
- Divide N fertilizer recommendations larger than 60 kg N ha-1 into 2-3 (wet-season crop) or 3-4 (dry-season crop) split applications. Use more splits, especially with long-duration varieties and in the dry season when crop yield potential is greater.
- Identify the need for a basal N application depending on soil N release dynamics, variety, and crop establishment method. Apply more basal N in these situations:
  - Soils with low INS (<40 kg N ha-1).
  - Where the plant spacing is wide (<20 hills m-2) to enhance tillering.

- In areas with low air and water temperature at transplanting or sowing.
- Soils with high INS (>50 kg N ha-1) often do not require basal N incorporated into the soil. Hybrid rice always requires basal N. Avoid large basal N fertilizer applications (i.e., >50 kg N ha-1) in transplanted rice where growth is slow during the first 3 wk after transplanting. Incorporate basal N into the soil before planting or sowing. Use NH4-N and not NO_3-N as a basal N source.

- Monitor plant N status to optimize timing and amount of split applications in relation to crop demand and soil N supply. Use a chlorophyll meter (SPAD) or leaf color chart (LCC) to guide N management. N fertilizer should be applied when the crop has the greatest need for N and when the rate of uptake is large. The highest recovery efficiency of applied N is achieved during late tillering to heading stages. Use NH4 fertilizers as an N source for topdressed N applications.
- Apply a late N dose (at flowering) to delay leaf senescence and enhance grain filling, but only to healthy crops with good yield potential. Source-limited and panicle-weight-type varieties (e.g., hybrid rice) usually need N application at flowering. To reduce the risk of lodging and pests, do not apply excessive amounts of N fertilizer between panicle initiation and flowering, particularly in the wet season.
- In planted fields, lower or remove the floodwater before applying topdressed N and then reirrigate to enhance movement of N into the soil. Do not apply topdressed N when heavy rainfall is expected. Do not apply urea onto standing water under windy conditions before canopy closure and at midday when the water temperature is highest.
- Use other means of increasing N use efficiency if they are economically viable. Examples include:
    - N fertilizer placement in the reduced soil layer about 8-10 cm below the soil surface (deep placement of urea supergranules, tablets, briquettes, mudballs), and
    - slow-release N fertilizer (S-coated urea) or poly-olefin coated urea incorporated as a basal dressing before planting.

N fertilizer sources for rice:

Name	Formula	Content	Comments

Ammonium nitrate	NH_4NO_3	33-34% N	Non-acidifying, apply to upland rice only
Ammonium chloride	NH_4Cl	28% N	Non-acidifying
Ammonium sulfate	$(NH_4)_2SO_4$	21% N, 24% S	Acidifying
Ammonium bicarbonate	NH_4HCO_3	17% N	Non-acidifying, low-quality N
Urea	$CO(NH_2)_2$	46% N	Non-acidifying
Monoammonium phosphate (MAP)	$NH_4H_2PO_4$	11% N, 22% P	Soluble, quick-acting, acidifying
Diammonium phosphate (DAP)	$(NH4)_2HPO_4$	18-21% N, 20% P	Soluble, quick-acting, acidifying
Urea phosphate	$CO(NH_2)_2$ + H_3PO_4	18% N, 20% P	Soluble, quick-acting

Site-specific N management in irrigated rice
Liquid fertilizers such as urea ammonium nitrate solution (UAN, 28% N) are used in some mechanized rice-growing areas. Averaged over the whole growth period, the recovery efficiency of N from UAN is lower (~50%) than for granular urea (~70%), but rice can efficiently use NO_3-N from applications made at the panicle initiation stage or later, when a dense superficial root system has formed.
Ammonia volatilization from different N fertilizer sources increases in the order ammonium sulfate < urea < ammonium bicarbonate.

Various special fertilizer products have become an important part of N management strategies in rice, particularly in rainfed and irrigated lowland systems. At present, however, their use is restricted by the high cost or additional labor required to place these materials in the reduced soil layer. So far, controlled-release fertilizer use increased only in Japan. Examples include:

- Urea supergranules, briquettes, tablets
- Urea-formaldehyde (UF, 38% N)
- S-coated urea (SCU, 30-40% N, 6-30% S)
- Polymer-coated urea (40-44% N, e.g., Osmocote, Nutricote, Polyon)
- Neem-coated urea (locally produced in India but not used widely)

SCU costs twice as much as conventional urea, whereas UF or polymer-coated materials usually cost 3-5 times as much. Although these materials may result in reduced N requirement and yield increases of about 10%, at current prices their use is not economical for rice farmers in South and Southeast Asia. This may change, however, when new technologies allow less

	costly production of coated materials. Nitrification and urease inhibitors have been investigated thoroughly, but increases in N efficiency achieved are usually too small to justify their use in rice farming.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.
Related links	Leaf Color Chart

Nitrogen Excess

Overly green crop (IRRI)

Diagnostic summary

Effect on plants	• causes excessive growth • plants become more attractive to insects and diseases • reduces stem strength
Signs	• plants look overly green • may be healthy, but also may be lodged • may have thin stems • may have increased disease or insects • plants in patchy pattern across the field
Importance/Occurrence	• negative implications on the environment • decrease farm profits • it is used where fertilizers are relatively cheap and where farmers don't understand the amount of nitrogen required relative to their yield goals

Full fact sheet

Symptoms	• Plants look overly green • May be healthy, but also may be lodged at maturity

	(especially in direct-seeded rice) • May have thin stems • May have increased disease (e.g., bacterial leaf blight, sheath blight, blast) or insects (leaffolder) • Patchy pattern resulting from uneven application across the field
Confirmation	Check the field and/or ask farmer about the rate of N applied.
Problems with similar symptoms	P deficiency will produce dark green leaves that may be confused with excessive N application; however P deficient plants produce less tillers and have stunted growth.
Why and where it occurs	Excess nitrogen is typically used where fertilizers are relatively cheap and where farmers don't understand the amount of nitrogen required relative to their yield goals and the right time of N application.
Mechanism of damage	Excessive nitrogen causes "luxuriant" growth, resulting in the plant being attractive to insects and/or diseases/pathogens. The excessive growth can also reduce stem strength resulting in lodging during flowering and grain filling.
When damage is important	Damage can be important if it results in lodging during heading or grain fill or if the attack from diseases or insects is increased at vegetative phase. The excessive use of N also has negative implications for the environment and lowers farm profits.
Economic importance	Excess N does not tend to be a widespread problem. Where it does occur, it can increase pest and disease problems, requiring higher pesticide use to control them. Pesticide-related health risks are also high. If crops lodge, harvest cost increases and grain quality is poor. If excess N moves to the environment then the indirect costs can be quite high.
Management principles	Farmers should apply sufficient N to meet the plants needs. On average this equates to around 20 kg N for each t of grain produced. The farmer needs to know how much N is coming from the soil and other sources (e.g., water or bacteria in the soil or water) and then apply the additional N to meet the yield goal. The Leaf color chart is a simple tool ensuring that sufficient but not excessive N is applied. It helps farmers to determine the right time of N application based on crop need and soil N supply.
Selected references	1. Balasubramanian V, Morales AC, Cruz RT, Abdul Rachman S. 1999. On-farm adaptation of knowledge-intensive nitrogen management technologies for rice systems. Nut. Cycl. Agroecosyst. 53:59-69. 2. FFTC (Food and fertilizer technology center). 1994. Fertilizer use and sustainable food production. FFTC for the Asian and Pacific region, 14 (June 1994):4-5. 3. IRRI-CREMNET. 2000. Progress report for 1998 and 1999. IRRI, Los Baños, Philippines.
Contributors	V Balasubramanian and M Bell

Related Links	Leaf Color Chart

Phosphorous Deficiency

Stunting and reduced tillering (IRRI)

Diagnostic summary

Effect on plants	• affects the major functions in energy storage and transfer and membrane integrity • affects tillering, root development, early flowering, and ripening
Signs	• stunting • reduced tillering • older leaves are narrow, short, very erect, and dark green • stems are thin and spindly • reduced number of leaves, panicles, and grains per panicle • young leaves appear to be healthy but older leaves turn brown and die • red and purple colors may develop in leaves if the variety has a tendency to produce anthocyanin • leaves appear pale green when P and N deficiency occur simultaneously
Importance/Occurrence	• widespread in all major rice ecosystems • common in irrigated rice • major growth-limiting factor in acid upland soils where soil P-fixation capacity is often large • occurs throughout the growth cycle of the crop • occurs in coarse-textured soils, highly weathered, clay, acid upland soils with high P-fixation capacity, degraded lowland soils, calcareous, saline, and sodic soils, volcanic soils with high P-

	sorption capacity, peat soils, and acid sulfate soils • associated with Fe toxicity at low pH, Zn deficiency, Fe deficiency, and salinity in alkaline soils

Full fact sheet

Symptoms	• Stunted plants • Reduced tillering • Leaves, particularly older ones, are narrow, short, very erect, and "dirty" dark green • Stems are thin and spindly and plant development is retarded • The number of leaves, panicles, and grains per panicle is also reduced • Young leaves appear to be healthy but older leaves turn brown and die • Red and purple colors may develop in leaves if the variety has a tendency to produce anthocyanin • Leaves appear pale green when P and N deficiency occur simultaneously • Mild to moderate P deficiency is difficult to recognize in the field • P deficiency is often associated with other nutrient disorders such as Fe toxicity at low pH, Zn deficiency, Fe deficiency, and salinity in alkaline soils Other effects of P deficiency include • Delayed maturity (often by 1 week or more). When P deficiency is severe, plants may not flower at all. • Large proportion of empty grains. When P deficiency is very severe, grain formation may not occur. • Low 1,000-grain weight and poor grain quality. • No response to mineral N fertilizer application. • Low tolerance for cold water. • Absence of algae in floodwater. • Poor growth (small leaves, slow establishment) of green manure crops.

Stems thin and spindly (IRRI)

Leaf discoloration (IRRI)

Confirmation

Both plant and soil can be tested for P deficiency.

The optimal ranges and critical levels of P in plant tissue are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering-PI	Y leaf	0.20-0.40	<0.10
Flowering	Flag leaf	0.20-0.30	<0.18

Maturity	Straw	0.10-0.15	<0.06

In plants, during vegetative growth (before flowering), P supply is sufficient and further response to P is unlikely when P leaf concentration is 0.2-0.4%. Yields greater than 7 t ha^{-1} require >0.06% P in the straw at harvest and >0.18% P in the flag leaf at flowering.
On soil, numerous soil P tests are in use and critical levels generally depend on soil type and targeted yield level. Olsen-P (0.5 M $NaHCO_3$ at pH 8.5) and, to a lesser extent, Bray-1 P (0.03 M NH_4F + 0.025 M HCl) are used as indicators of available P in flooded rice soils. Critical levels for Olsen-P reported for rice range from 5 mg P kg^{-1} in acid soils to >25 mg P kg^{-1} in calcareous soils.
For lowland rice soils with little or no free $CaCO_3$, Olsen-P test results can be classified as follows:

<5 mg P kg^{-1}	(low P status) > response to P fertilizer certain
5-10 mg P kg^{-1}	(medium P status) > response to P fertilizer probable
>10 mg P kg^{-1}	(high P status) > response to P fertilizer only at very high yield levels (>8 t ha^{-1})

For lowland rice soils with little or no free CaCO3, Bray-1 P test results can be classified as follows:

<7 mg P kg^{-1}	(low P status) > response to P fertilizer certain
7-20 mg P kg^{-1}	(medium P status) > response to P fertilizer probable
>20 mg P kg^{-1}	(high P status) > response to P fertilizer only at very high yield levels (>8 t ha^{-1})

Other critical soil levels for occurrence of P deficiency are:

Bray-2 P <12-20 mg P kg^{-1}	acid soils, 0.03 M NH_4F + 0.1 M HCl
Mehlich-1 P <5-7 mg P kg^{-1}	upland rice, 0.05 M HCl + 0.0125 M H_2SO_4
Mehlich-3 P <28 kg P ha^{-1}	lowland rice, Arkansas

Olsen-P measured on a dried soil sample is a more versatile soil test for irrigated lowland rice soils because it can be used for a wider pH range and it measures the amount of P available through plant-induced P solubilization in the rhizosphere under anaerobic conditions. Acid extractions (e.g., Bray-1, Bray-2, Mehlich-1) are more suitable for measuring the amount of available P in acid rainfed lowland and upland soils.
Various resin-P measurement techniques have been proposed. Generally, they predict P uptake by rice better than static soil tests. They are not yet used routinely, however, except in Brazil.

	In upland soils, immobilization of P occurs by diffusion to adsorption sites within soil aggregates so that conventional soil tests using dried, crushed soil samples may give misleading results. The Hedley procedure can be used for the sequential fractionation of soil P pools.
Problems with similar symptoms	tbd
Why and where it occurs	The common causes of P deficiency are as follows: • Low indigenous soil P-supplying power. • Insufficient application of mineral P fertilizer. • Low efficiency of applied P fertilizer use due to high P-fixation capacity or erosion losses (in upland rice fields only). • P immobilization in Ca phosphates due to excessive liming. • Excessive use of N fertilizer with insufficient P application. • Cultivar differences in susceptibility to P deficiency and response to P fertilizer. • Crop establishment method (P deficiency is more likely in direct-seeded rice due to high plant densities and shallow root systems). P deficiency is widespread in all major rice ecosystems and is the major growth-limiting factor in acid upland soils where soil P-fixation capacity is often large. Soils particularly prone to P deficiency include the following types: • Coarse-textured soils containing small amounts of organic matter and small P reserves (e.g., sandy soils in northeast Thailand, Cambodia) • highly weathered, clayey, acid upland soils with high P-fixation capacity (e.g., Ultisols and Oxisols in many countries • Degraded lowland soils (e.g., North Vietnam) • Calcareous, saline, and sodic soils • Volcanic soils with high P-sorption capacity (e.g., Andisols in Japan and parts of Sumatra and Java) • Peat soils (Histosols)

	• Acid sulfate soils in which large amounts of active Al and Fe result in the formation of insoluble P compounds at low pH
Mechanism of damage	Phosphorus is an essential constituent of adenosine triphosphate (ATP), nucleotides, nucleic acids, and phospholipids. Its major functions are in energy storage and transfer and membrane integrity. It is mobile within the plant and promotes tillering, root development, early flowering, and ripening (especially where the temperature is low). It is particularly important in early growth stages. The addition of mineral P fertilizer is required when the rice plant's root system is not yet fully developed and the native soil P supply is small. P is remobilized within the plant during later growth stages if sufficient P has been absorbed during early growth.
When damage is important	The damage caused by P deficiency occurs throughout the growth cycle of the crop.
Economic importance	P deficiency is fairly common in irrigated rice.
Management principles	P management should be considered as a long-term investment in soil fertility, and it is more effective to prevent P deficiency than to treat P deficiency symptoms (in contrast to N deficiency, for which treatment and prevention are equally important). P requires a long-term management strategy because P is not easily lost or added to the root zone by biological and chemical processes that affect N supply. The residual effect of P fertilizer application can persist for several years, and management must emphasize the buildup and maintenance of adequate soil-available P levels to ensure that P supply does not limit crop growth and N use efficiency. General measures to prevent P deficiency and improve P use efficiency area as follows: • **Varieties:** Use rice cultivars that use P efficiently, particularly on acid upland soils. P-efficient rice cultivars have either greater P acquisition (increased external efficiency because of better root morphology or increased excretion of organic acid or O_2) or higher internal efficiency of P use (larger grain yield when P uptake is small). Examples are IR20, IR26, IR64, and IR74. • **Soil management:** In rice-rice systems, carry out dry, shallow tillage (10 cm) within 2 weeks after harvest. Early tillage enhances soil oxidation and crop residue decomposition during the fallow period and increases P availability during vegetative growth of the succeeding rice crop. This practice is not recommended for rice-upland crop systems because early tillage after harvesting the rice crop may decrease the availability of P in the succeeding upland crop (e.g., wheat). On acid,

low-fertility rainfed lowland and upland soils, all existing soil fertility problems (acidity, Al toxicity, deficiencies of Mg, K, and other nutrients) must be corrected before a response to P is obtained.

- **Phosphobacteria application:** In field trials with irrigated rice in southern India, an increase in P availability was found after the application of phosphobacteria to the soil, as seed coating, or as seedling dip.
- **Crop management:** Establish a healthy plant population by using high-quality seed of a high-yielding variety with multiple pest resistance planted at the correct density with proper water and pest management.
- **Straw management:**Incorporate rice straw. Although the total amount of P recycled with the straw is small (1 kg P t-1 straw), it will contribute to maintaining a positive P balance in the long term.
- **Fertilizer management:** Apply optimum doses of N and K and correct micronutrient deficiencies. Replenish P removed in crop products by applying P fertilizers, farmyard manure, or other materials (night soil, compost). If P-deficiency symptoms are already evident, there may be no response to P applied to the current crop. Factors affecting P application rates and response to P fertilizer include:
    - Type of P fertilizer used
    - Timing and method of application
    - Soil P-supplying capacity (indigenous P supply)
    - Soil physical and chemical properties that affect applied P
    - Supply of other nutrients (e.g., N, K)
    - Water management, temperature, and availability
    - Variety grown, and
    - Cropping system and cropping history

Application of P fertilizer is standard practice in most irrigated rice systems. To maintain yields of 5-7 t ha-1 and replenish P removed with grain and straw, fertilizer P rates should be in the range of 15 to 30 kg P ha-1. It is necessary, however, to correct deficiencies of other nutrients (N, K, Zn), fix other soil problems (shallow rooting depth, toxicities), and ensure proper overall crop management before a response to P fertilizer can be expected.

Some general recommendations can be made for P fertilizer use in rice:

- If most of the straw is retained in the field (e.g., after combine harvest or harvest of panicles only) and the P input from manure is small, apply at least 2 kg P ha-1 per t grain harvested (e.g., 10 kg P for a yield of 5 t ha-1) to replenish P removed with grain.
- If most of the straw is removed from the field and P input from other sources (manure, water, sediments) is small, apply at least 3 kg P ha-1 per grain harvested (e.g., 15 kg P for a yield of 5 t ha-1) to replenish P removed with grain.
- Large amounts of P fertilizer are required to recapitalize soil stocks where soil P has been severely depleted because of P removal over a long time (e.g., degraded paddy soils). Large ameliorative applications of 200-500 kg P ha-1 are required where acid soils are brought into production in newly developed irrigated rice fields.
- In upland rice systems on strongly P-sorbing soils, large initial P applications or repeated smaller P applications may be required. The adsorption of additional P decreases as the quantity of P already adsorbed increases. Therefore, crop response to P increases with continuous smaller P additions. In acid upland soils in the humid tropics (Ultisols, Oxisols), when the Mehlich-1 P is <10 mg kg-1, about 20 kg P ha-1 is required to increase the amount of Mehlich 1 soil P by 1 mg P kg-1. When the Mehlich-1 P is >10 mg kg-1, only 10-15 kg P ha-1 is required to increase Mehlich-1 soil P by 1 mg P kg-1. In upland rice systems, P fixation can be reduced by applying P fertilizer in a band beneath the seed. Root proliferation in and close to the band increases with increased soluble-P concentration near the root surface.
- P applied to either rice or wheat has a residual effect on the succeeding crop, but direct application to each crop is more efficient.
- Rock phosphate should be broadcast and incorporated before flooding when soil pH is low to allow reactions between the soil and fertilizer that release P for plant uptake.

In some soils, excessive application of soluble-P sources may, under conditions of poor aeration, induce Zn deficiency.

Site-specific P management in irrigated rice

P fertilizer sources for rice include:

Name	Formula	Content	Comments
Single superphosphate	$Ca(H_2PO_4)_2 \cdot H_2O + CaSO_4 \cdot 2H_2O$	7-9% P, 13-20% Ca, 12% S	Soluble, neutral (16-21% P_2O_5)
Triple superphosphate	$Ca(H_2PO_4)_2 \cdot H2O$	18-22% P, 9-14% Ca, 1.4% S	Soluble, neutral (41-50% P_2O_5)
Monoammonium phosphate (MAP)	$NH_4H_2PO_4$	22% P, 11% N	Soluble, acidifying (51% P_2O_5)
Diammonium phosphate (DAP)	$(NH_4)_2HPO_4$	20-23% P, 18-21% N (most common 20% P)	Soluble, acidifying (46-53% P_2O_5)
Urea phosphate (UP)	$CO(NH2)_2 + H_3PO_4$	20% P, 18% N	Soluble (46% P_2O_5)
Partly acidulated rock phosphate	$Ca_3(PO_4)_2$	10-11% P	>1/3 water-soluble (23-26% P_2O_5)
Rock phosphate, finely powdered	$Ca_3(PO_4)_2$	11-17% P, 33-36% Ca	Very slow acting (25-39% P_2O_5)

All commercially available P sources are suitable for irrigated rice (enumerated above), so the choice of fertilizer material should be based on:

- the cost per kilogram of P_2O_5,
- other nutrient content, and
- solubility or reactivity of the P fertilizer in the soil.

P fertilizers can also provide S. Care should be taken to ensure a sufficient supply of S from other sources when changing from S-containing (e.g., single superphosphate) to S-free P fertilizers (e.g., triple superphosphate). Note that the solution produced from the dissolution of superphosphate in soil has a pH approaching 1:

- $Ca(H_2PO_4)_2 \times H_2O + H_2O$ -----» $CaHPO_4 \times H_2O + H+ + H_2PO_4^-$

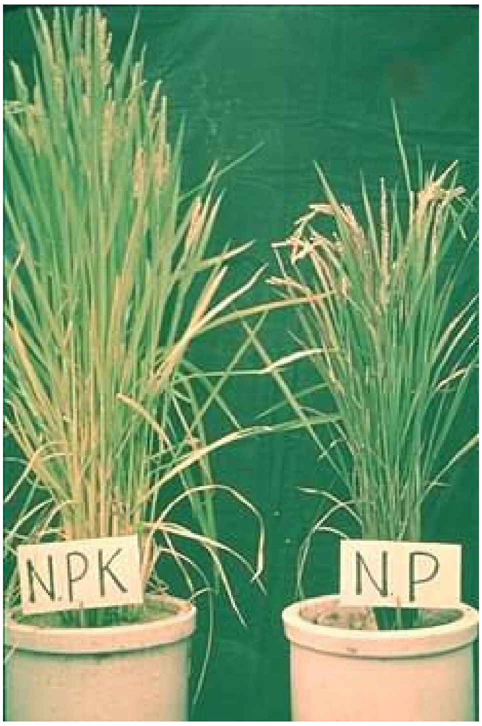
whereas that from diammonium phosphate has a pH approaching 8:

- $(NH_4)_2HPO_4 + H+$ -----» $2NH_4+ + H_2PO_4^-$

Finely ground rock phosphate is an effective (and often the least costly) P fertilizer source for very acid rainfed lowland and upland soils (pH <4.5). The effectiveness of rock phosphates in tropical environments, however, depends on the extent to which the required P uptake rate of the crop plant can be maintained by the dissolution of rock phosphate P in the soil. Rock phosphate also contains Ca, which may help to alleviate subsoil acidity and Ca deficiency in highly weathered tropical

	soils.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Potassium Deficiency



Effect of potassium deficiency on yield (IRRI)

Diagnostic summary

Effect on plants	• affects canopy photosynthesis • affects crop growth
Signs	• dark green plants with yellowish brown leaf margins or dark brown necrotic spots appearing first on the tip of older leaves, then along the leaf edge, and finally on the leaf base • upper leaves short, droopy, and dark green • drying of leaf tips and margins • yellow stripes along leaf interveins • lower leaves may bend downward • pattern of damage is patchy • irregular necrotic spots may also occur on panicles • stunted plants with smaller leaves, short and thin stems • tillering is reduced under very severe deficiency • lodging • early leaf senescence, leaf wilting, and leaf rolling

	when temperature is high and humidity is low • unhealthy root system • increased incidence of diseases
Importance/Occurrence	• important throughout the growth cycle • occur in coarse-textured soils, highly weathered acid soils, acid upland soils, lowland clay soils, soils with a large K content but very wide, leached, "old" acid sulfate soils, poorly drained and strongly reducing soils, and organic soils

Full fact sheet

Symptoms	• Dark green plants with yellowish brown leaf margins or dark brown necrotic spots appearing first on the tip of older leaves • Leaf tips yellowish brown under severe K deficiency • Symptoms appear first on older leaves, then along the leaf edge, and finally on the leaf base • Affected plants with upper leaves short, droopy, and "dirty" dark green • Older leaves change from yellow to brown • Discoloration gradually appears on younger leaves if deficiency is not corrected • Leaf tips and margins may dry up • Yellow stripes may appear along leaf interveins and lower leaves may bend downward • General pattern of damage is patchy within a field, affecting single hills rather than the whole field • Rusty brown spots on tips of older leaves and later spread over the whole leaf causing it to turn brown and dry if K deficiency is severe • Irregular necrotic spots may also occur on panicles. • Stunted plants with smaller leaves, short and thin stems • Tillering is only reduced under very severe deficiency • Greater incidence of lodging. • Early leaf senescence, leaf wilting, and leaf rolling when temperature is high and humidity is low. • Large percentage of sterile or unfilled spikelets caused by poor pollen viability and retarded carbohydrate translocation. Reduced 1,000-grain weight. • Unhealthy root system (many black roots, reduced root length and density), causing a reduction in the uptake of other nutrients. Reduced cytokinin production in roots.

- Poor root oxidation power, causing decreased resistance to toxic substances produced under anaerobic soil conditions, e.g., Fe toxicity caused by K deficiency.
- Increased incidence of diseases, particularly brown leaf spot (caused by *Helminthosporium oryzae*), cercospora leaf spot (caused by *Cercospora spp.*), bacterial leaf blight (caused by *Xanthomonas oryzae*), sheath blight (caused by *Rhizoctonia solani*), sheath rot (caused by *Sarocladium oryzae*), stem rot (caused by *Helminthosporium sigmoideum*), and blast (caused by *Pyricularia oryzae*) where excessive N fertilizer and insufficient K fertilizer have been used.

Dark brown spots on leaves (IRRI)

Confirmation

Both the plant and soil can be tested for K deficiency.

The optimal ranges and critical levels of K in plant tissue are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering-PI	Y leaf	1.8-2.6	<1.5
Flowering	Flag leaf	1.4-2.0	<1.2
Maturity	Straw	1.5-2.0	<1.2

During the vegetative growth up to flowering stage of the rice crop, the K supply is usually sufficient and a response to additional K is unlikely when the leaf concentration is between 1.8% and 2.6%. To produce the maximum number of spikelets per panicle, the K content of mature leaves should be >2% at the booting stage.

The critical level for K in straw at harvest is between 1.0% and 1.5%, but yields greater than 7 t ha^{-1} require >1.2% K in the straw at harvest and >1.2% K in the flag leaf at flowering. For optimum growth, the N:K ratio in straw should be 1:1 to 1:1.4.

On lowland rice soils, the 1N NH4OAc-extractable K ranges from 0.05 to 2 cmol kg-1 (× 391 = mg kg^{-1}). A critical concentration of 0.2 cmol K kg^{-1} soil is often used. Depending on soil texture, clay mineralogy, and K input from natural sources, however, critical levels of NH4OAc-extractable K can vary from 0.1 to 0.4 cmol K kg^{-1}. The amount of tightly bound or "fixed" K increases with clay content so that critical levels are larger in soils containing large amounts of 2:1 clay minerals. Critical ranges with general applicability are as follows:

Exchangeable K <0.15 cmol kg^{-1}	low K status > response to K fertilizer certain
Exchangeable K 0.15-0.45 cmol kg^{-1}	medium K status > response to K fertilizer probable
Exchangeable K >0.45 cmol kg^{-1}	high K status > response to K fertilizer only at very high yield levels (>8 t ha^{-1})

On lowland rice soils with high K "fixation" and release of nonexchangeable K (e.g., vermiculitic soils), 1N NH_4OAc-extractable K is often small (<0.2 cmol kg^{-1}) and not a reliable soil test for assessing K supply.
K saturation (% of total CEC) is often a better indicator of soil K supply than the absolute amount of K extracted with 1N NH_4OAc because it takes into account the relationship between K and other exchangeable cations (Ca, Mg, Fe). The proposed ranges are as follows:

K saturation <1.5%	low K status > response to K fertilizer certain
K saturation 1.5-2.5%	medium K status > response to K fertilizer probable
K saturation >2.5%	high K status > response to K fertilizer unlikely

Other critical soil levels where K deficiency is likely to occur are as follows:

0.05 cmol K kg^{-1}	Electroultrafiltration (EUF) K
0.12 cmol K kg^{-1}	0-10 min EUF K
0.25 cmol K kg^{-1}	0-35 min 1N HNO_3 (slow-release K) 196 kg K ha^{-1} Mehlich III, Arkansas

A (Ca + Mg):K ratio of >100 (all measured as exchangeable cations) may indicate low soil K availability for rice.

Problems with similar symptoms

Leaf symptoms of K deficiency, particularly the yellowish brown leaf margins, are similar to those of tungro virus disease. Unlike K deficiency, tungro occurs as patches within a field, affecting single hills rather than the whole field.

Why and where it occurs

The following are the common causes of K deficiency:

- Low soil K-supplying capacity.
- Insufficient application of mineral K fertilizer.
- Complete removal of straw.
- Small inputs of K by irrigation (irrigation water low in

K).

- Low recovery efficiency of applied K fertilizer because of high K-fixation capacity or leaching losses.
- Presence of excessive amounts of reduced substances in poorly drained soils (e.g., H_2S, organic acids, Fe^{2+}), resulting in retarded root growth and reduced K uptake.
- Wide Na:K, Mg:K, or Ca:K ratios in soil, under sodic/saline conditions. Excess Mg in soils derived from ultrabasic rocks. Bicarbonate is high in irrigation water.

K deficiency in rice is more common under the following crop management practices:

- Excessive use of N or N and P fertilizers with insufficient K application.
- In direct-sown rice during early growth stages, when the plant population is large and root system is shallow.
- Cultivar differences in susceptibility to K deficiency and response to K fertilizer. The K requirement of hybrid rice is greater than that of inbred modern rice varieties; hybrid rice requires a narrower N:K ratio in the plant. Additional K is required to sustain the vigorous root system, increase the formation of superficial roots, and improve grain filling in hybrid rice.

Soils, which are particularly prone to K deficiency include the following types:

- Soils inherently low in K:
    - Coarse-textured soils with low CEC and small K reserves (e.g., sandy soils in northeast Thailand, Cambodia).
    - Highly weathered acid soils with low CEC and low K reserves, e.g., acid upland soils (Ultisols or Oxisols) and degraded lowland soils (e.g., North Vietnam, northeast Thailand, Cambodia, Lao PDR).
- Soils on which K uptake is inhibited:
    - Lowland clay soils with high K fixation because of the presence of large amounts of 2:1 layer clay minerals (e.g., illitic clay soils in India, vermiculitic clay soils in the Philippines).
    - Soils with a large K content but very wide (Ca + Mg)/K ratio (e.g., some calcareous soils or soils derived from ultrabasic rocks). Wide (Ca +

	o Mg)/K ratios result in stronger K adsorption to cation exchange sites and reduce the concentration of K in the soil solution. o Leached, "old" acid sulfate soils with a small base cation content. K deficiency may occur on acid sulfate soils even when the soil K content is large (Thailand, South Vietnam). o Poorly drained and strongly reducing soils where K uptake is inhibited by the presence of H2S, organic acids, and an excessive concentration of Fe^{2+}. o Organic soils (Histosols) with small K reserves (e.g., Kalimantan, Indonesia).
Mechanism of damage	Potassium has essential functions in osmoregulation, enzyme activation, regulation of cellular pH, the cation-anion balance, regulation of transpiration by stomata, and the transport of assimilates (the products of photosynthesis). K provides strength to plant cell walls and is involved in the lignification of sclerenchyma—tissues with thickened cell walls. On the whole-plant level, K increases leaf area and leaf chlorophyll content, delays leaf senescence, and therefore contributes to greater canopy photosynthesis and crop growth. Unlike N and P, K does not have a pronounced effect on tillering. K increases the number of spikelets per panicle, percentage of filled grains, and 1,000-grain weight. K deficiency results in an accumulation of labile low-molecular-weight sugars, amino acids, and amines that are suitable food sources for leaf disease pathogens. K improves the rice plant's tolerance of adverse climatic conditions, lodging, insect pests, and diseases. Deficiency symptoms tend to occur in older leaves first, because K is very mobile within the plant and is retranslocated to young leaves from old senescing leaves. Often, yield response to K fertilizer is only observed when the supply of other nutrients, especially N and P, is sufficient.
When damage is important	The damage on the crop is important throughout the growth cycle.
Economic importance	K deficiency is becoming increasingly important throughout Asia.
Management principles	K management should be considered part of long-term soil fertility management because K is not easily lost from or added to the root zone by the short-term biological and chemical processes that affect the N supply. K management must ensure that N use efficiency is not reduced due to K deficiency. The following are general measures to prevent K deficiency and improve K use efficiency: • **Natural inputs:** Estimate K input from indigenous sources to assess site-specific K requirements. In most

irrigated rice areas, K input from irrigation water ranges between 10 and 50 kg K ha^{-1} per crop, which is insufficient to balance crop removal and leaching losses at current average yield levels of 5-6 t ha^{-1}. The K concentration in irrigation water tends to follow the order shallow-well water (5-20 mg K L^{-1}, near human settlements) > deep-well groundwater (3-10 mg K L^{-1}, up to 20 mg K L^{-1} in volcanic layers) > surface water (1-5 mg L^{-1}, canal, river). K inputs in irrigation water can be calculated where the amount of irrigation water used per season is known, e.g., if the average K concentration in irrigation water is 3 mg K L^{-1}, 30 kg K ha^{-1} is added in 1,000 mm of irrigation water. The K content of irrigation water can vary considerably from place to place and from year to year. Irrigation water with low in K content will add to the depletion of soil K and induce severe K deficiency, whereas water rich in K is often sufficient to meet K requirements of high-yielding crops. (NOTE: If the site-specific K management approach described below is used, K input from irrigation and other natural sources is already included in the crop-based estimate of the indigenous K supply).

- **Soil management:** Increase K uptake by improving soil management practices on root health (e.g., deep tillage to improve percolation to at least 3-5 mm d^{-1} and to avoid excessively reducing conditions in soil).
- **Crop management:** Establish an adequate population of healthy rice plants by using high-quality seed of a modern variety with multiple pest resistance, and optimum crop maintenance (water and pest management).
- **Straw management:** Incorporate rice straw. If straw burning is the only option for crop residue management, spread the straw evenly over the field (e.g., as it is left after combine harvest) before burning. Ash from burnt straw heaps should also be spread over the field.
- **Balanced fertilizer management:** Apply optimum doses of N and P fertilizers and correct micronutrient deficiencies. Apply K fertilizers, farmyard manure, or other materials (rice husk, ash, night soil, compost) to replenish K removed in harvested crop products.

Some general recommendations for K fertilizer use in rice are as follows:

- Correct deficiencies of other nutrients (N, P, Zn), correct other soil problems (restricted rooting depth, mineral toxicities), and ensure proper overall crop management to maximize the response to K fertilizer. To maintain yields of 5-7 t ha-1 and replenish K removed with grain and straw, fertilizer K rates may range from 20 to 100 kg K ha^{-1}. The required application rate depends on many factors: the soil's buffer capacity for K (large in vertisols and other soils containing lattice clays), soil texture, availability of other nutrients, variety, yield target, straw management, cropping intensity, and the amount of K in the irrigation water. In any case, it is necessary to correct deficiencies of other nutrients (N, P, Zn), fix other soil problems (restricted rooting depth, mineral toxicities), and ensure proper overall crop management to maximize the response to K fertilizer. On many lowland soils in Asia, a significant response to fertilizer K is only achieved where all other factors are properly managed and yields are greater than 6 t ha^{-1}.

- If most of the straw remains in the field (e.g., after combine harvesting or harvest of panicles only) and K inputs from animal manure are small, apply 3 kg K ha^{-1} per ton grain harvested (e.g., 15 kg K for a 5 t ha^{-1} yield) to replenish K removal.

- Where straw is removed from the field and the K input from other sources (animal manure, water, sediments) is small, apply at least 10 kg K ha^{-1} per ton grain harvested (e.g., 50 kg K for a 5 t ha^{-1} yield) to replenish most of the K removed. To avoid long-term soil K depletion, and if budgets allow, attempt to replenish completely the K removed by applying 15 kg K ha^{-1} per ton grain harvested.

Hybrid rice always requires larger applications of K (50-100 kg K ha^{-1} on most soils) than inbred modern varieties.

K fertilizer sources for rice are:

Name	Formula	Content	Comments
Potassium chloride	KCl	50% K	Muriate of potash (60% K_2O)
Potassium nitrate	KNO_3	37% K, 13% N	In compounds (44% K_2O)
Potassium sulfate	K_2SO_4	40-43% K, 18% S	In compounds (50% K_2O)
Langbeinite	K_2SO_4, $MgSO_4$	18% K, 11% Mg, 22% S	Quick-acting
Compound fertilizers	N + P + K	Variable	Common in rice

Sodium can substitute for some nonspecific functions of K in the plant (e.g., turgor control), but not specific functions such as enzyme activation. NaCl (common salt) can be used as a substitute for K fertilizer where:

	• K fertilizers are not available or too costly • soils contain small amounts of available K, and • yield levels are low to moderate (<5 t ha^{-1}). Farmers in Cambodia often apply low-cost sea salt to their poor soils. During World War II, Farmers in Japan partially replaced K fertilizer with NaCl when K fertilizer was not available.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Salinity


Whitening and browning of leaves (IRRI)

Diagnostic summary

Effect on plants	• affects respiration and photosynthesis processes • decreased biological N_2 fixation and soil N mineralization
Signs	• affected leaves with white tips • some leaves with chlorotic patches • stunting • reduced tillering • patchy field growth
Importance/Occurrence	• important throughout the growth cycle of the rice plant • associated with poor irrigation practice or insufficient irrigation water, alkaline soils in inland areas, increase in the level of saline groundwater, and intrusion of saline seawater in coastal areas • may be accompanied by P deficiency, Zn deficiency, Fe deficiency, or B toxicity

Full fact sheet

Symptoms	• Tips of affected leaves turn white • Chlorotic patches appear on some leaves • Plant stunting and reduced tillering • Patchy field growth • Symptoms first manifest themselves in the first leaf, followed by the second, and then in the growing leaf • Salinity or sodicity may be accompanied by P deficiency,

	Zn deficiency, Fe deficiency, or B toxicity Further effects on rice growth: • Reduced germination rate • Reduced plant height and tillering • Poor root growth • Increased spikelet sterility • Excess Na uptake decreases 1,000-grain weight and total protein content in grain, but does not alter major cooking qualities of rice • Decreased biological N_2 fixation and soil N mineralization  Patchy field (IRRI)  White leaf tips (IRRI)
Confirmation	Plant and soil can be tested to confirm salinity. Increased Na content in rice plants may indicate salinity injury,

which may lead to yield loss. The critical concentration of salt (NaCl) in leaf tissue at which toxicity symptoms appear, however, differs widely between varieties. Varieties showing the greatest tolerance for salt within plant tissues are not necessarily those showing the greatest overall phenotypic resistance to salinity.

The correlation between Na:K ratio and salinity tolerance has been established; however, no absolute critical levels in plant tissue are known. A Na:K ratio of <2:1 in the grain may indicate salt-tolerant rice varieties.

The Na:Ca ratio in plant tissue does not seem to be a good indicator of salinity. No effects on growth or NaCl concentration in the shoot were found over the range of Na:Ca ratios (5-25:1) commonly found in the field.

On soil, EC in saturation extract or soil solution: For rice growing in flooded soil, EC is measured in the soil solution or in a saturation extract (EC_e). For upland rice grown at field capacity or below, EC in soil solution is about twice as great as that of the saturation extract. A rough approximation of the yield decrease caused by salinity is:

Relative yield(%) = 100 - [12(EC_e - 3)]

- EC_e <2 dS m-1 optimum, no yield reduction
- EC_e >4 dS m-1 slight yield reduction (10-15%)
- EC_e >6 dS m-1 moderate reduction in growth and yield (20-50%)
- EC_e >10 dS m-1 >50% yield reduction in susceptible cultivars

Exchangeable Na percentage (ESP):

- ESP <20% no significant yield reduction
- ESP >20-40% slight yield reduction (10%)
- ESP >80% 50% yield reduction

Sodium adsorption ratio (SAR):

- SAR >15 sodic soil (measured as cations in saturation extract)

Irrigation water has:

- pH 6.5-8, EC <0.5 dS m^{-1} high-quality irrigation water
- pH 8-8.4, EC 0.5-2 dS m^{-1} medium- to bad-quality irrigation water
- pH >8.4, EC >2 dS m^{-1} unsuitable for irrigation
- SAR <15 high-quality irrigation water, low Na

- SAR 15-25 medium- to bad-quality irrigation water, high Na
- SAR >25 unsuitable for irrigation, very high Na

Notes:

- Measurement of EC as an indicator of salinity is rapid and simple. EC alone, however, is insufficient to assess the effects of salinity on plant growth because salt concentrations at the root surface can be much greater than in the bulk soil. In addition, EC only measures the total salt content, not its composition. Na and B must be considered as well. Salinity is highly variable in the field, both between seasons and within individual fields. Individual EC values must be treated with caution unless they are based on representative soil samples.
- From EC, the osmotic potential of the saturation extract can be estimated as:
    - Osmotic potential (MP_a) = EC × 0.036
- If the samples do not contain much gypsum, EC measurements can be converted as follows:
    - EC_e = 2.2 × EC1:1 EC1:1 measured in 1:1 soil:water suspension
    - EC_e = 6.4 × EC1:5 EC1:5 measured in 1:5 soil:water suspension

Problems with similar symptoms

No other deficiency exhibits these symptoms but salinity.

Why and where it occurs

Plant growth on saline soils is mainly affected by high levels of soluble salts (NaCl) causing ion toxicity, ionic imbalance, and impaired water balance. On sodic soils, plant growth is mainly affected by high pH and high HCO_3^- concentration. The major causes of salinity or sodicity are as follows:

- Poor irrigation practice or insufficient irrigation water in seasons/years with low rainfall.
- High evaporation. Salinity is often associated with alkaline soils in inland areas where evaporation is greater than precipitation.
- An increase in the level of saline groundwater.
- Intrusion of saline seawater in coastal areas (e.g., Mekong Delta, coastal India)

Salt-affected soils (~11 million ha in South and Southeast Asia) are found along coastlines or in inland areas where evaporation is greater than precipitation. Salt-affected soils

	vary in their chemical and physical properties, but salinity is often accompanied by P and Zn deficiency, whereas Fe toxicity is common in acid sulfate saline soils. Salt-affected soils can be grouped into: • saline soils (EC >4 dS m^{-1}, ESP <15%, pH <8.5) • saline-sodic soils (EC 4 dS m^{-1}, ESP >15%, pH ~8.5) • sodic soils (EC <4 dS m^{-1}, ESP >15%, pH >8.5, SAR >15) Examples of salt-affected soils include: • saline coastal soils (widespread along coasts in many countries) • saline acid sulfate soils (e.g., Mekong Delta, Vietnam) • neutral to alkaline saline, saline-sodic, and sodic inland soils (e.g., India, Pakistan, Bangladesh) • acid sandy saline soils (Korat region of northeast Thailand)
Mechanism of damage	Salinity is defined as the presence of excessive amounts of soluble salts in the soil (usually measured as electrical conductivity, EC). Na, Ca, Mg, Cl, and SO_4 are the major ions involved. Effects of salinity on rice growth are as follows: • Osmotic effects (water stress) • Toxic ionic effects of excess Na and Cl uptake • Reduction in nutrient uptake (K, Ca) because of antagonistic effects The primary cause of salt injury in rice is excessive Na uptake (toxicity) rather than water stress, but water uptake (transpiration) is reduced under high salinity. Plants adapt to saline conditions and avoid dehydration by reducing the osmotic potential of plant cells. Growth rate, however, is reduced. Antagonistic effects on nutrient uptake may occur, causing deficiencies, particularly of K and Ca under conditions of excessive Na content. For example, Na is antagonistic to K uptake in sodic soils with moderate to high available K, resulting in high Na:K ratios in the rice plant and reduced K transport rates. Sodium-induced inhibition of Ca uptake and transport limits shoot growth. Increasing salinity inhibits nitrate reductase activity, decreases chlorophyll content and photosynthetic rate, and increases the respiration rate and N content in the plant. Plant K and Ca contents decrease but the concentrations of NO^{3-}N, Na, S, and Cl in shoot tissue increase. Rice tolerates

	salinity during germination, is very sensitive during early growth (1-2-leaf stage), regains tolerance during tillering and elongation, but becomes sensitive again at flowering. Several factors affect the tolerance of different rice varieties to salinity: • Transpiration rate and potential for osmotic adjustment. • Differences in nutrient uptake under Na stress. Tolerant cultivars have a narrower Na:K ratio (higher K uptake) and greater leaf Ca^{2+} content than susceptible cultivars. • Efficient exclusion of Na^{+} and Cl^{-}. Salt-tolerant rice varieties have a reduced Na^{+} and Cl- uptake compared with less tolerant cultivars. • Rapid vegetative growth results in salt dilution in plant tissue.
When damage is important	Rice is more tolerant of salinity at germination, but plants may become affected at transplanting, young seedling, and flowering stages. Thus, this problem occurs throughout the growth cycle of the rice crop.
Economic importance	Salinity can be a major problem in localized areas - tending to occur in low coastal regions and semi-arid inland saline areas.
Management principles	Varieties that tolerate salinity are available, but their use does not substitute for proper water and irrigation management. Breeders will unlikely be able to produce varieties with ever-increasing tolerance of salinity. A variety adapted to present levels of salinity may not survive if salinity increases because water management practices have not been corrected. Rice is a suitable crop for the reclamation of both sodic and saline soils. On sodic soils, rice cultivation results in a large cumulative removal of Na caused by mobilization of insoluble $CaCO_3$. On saline soils, cultivation practices lead to the loss of salts by leaching. Management of salinity or sodicity must include a combination of measures. Major choices include the following: • **Cropping system:** In rice-upland crop systems, change to double-rice cropping if sufficient water is available and climate allows. After a saline soil is leached, a cropping pattern that includes rice and other salt-tolerant crops (e.g., legumes such as clover or *Sesbania*) must be followed for several years. • **Varieties:** Grow salt-tolerant varieties (e.g., Pobbeli, Indonesia; IR2151, Vietnam; AC69-1, Sri Lanka; IR6, Pakistan; CSR10, India; Bicol, Philippines). This is a short-term solution that may result in increased salinity over the longer term if other amelioration measures are not implemented. • **Seed treatment**: In temperate climates where rice is

direct seeded, coat seed with oxidants (e.g., Ca peroxide at 100% of seed weight) to improve germination and seedling emergence by increased Ca and O2 supply. Alternatively, treat rice seeds with CaCl2 to increase seed Ca2+ concentration.

- **Water management:** Submerge the field for two to four weeks before planting rice. Do not use sodic irrigation water or alternate between sodic and nonsodic irrigation water sources. Leach the soil after planting under intermittent submergence to remove excess salts. Collect and store low saline rainwater for irrigation of dry-season crops (e.g., by establishing reservoirs). In coastal areas, prevent intrusion of salt water.

- **Fertilizer management:** Apply Zn (5-10 kg Zn ha^{-1}) to alleviate Zn deficiency. Apply sufficient N, P, and K. The application of K is critical because it improves the K:Na, K:Mg, and K:Ca ratios in the plant. Use ammonium sulfate as N source and apply N as topdressing at critical growth stages (basal N is used less efficiently on saline and sodic soils). In sodic soils, the replacement of Na by Ca (through the application of gypsum) may reduce P availability and result in an increased requirement for P fertilizer.

- **Organic matter management:** Organic amendments facilitate the reclamation of sodic soils by increasing the partial CO_2 pressure and decreasing pH. Apply rice straw to recycle K. Apply farmyard manure.

The following are options for treatment of salinity:

- **Saline soils:** Salinity can only be reduced by leaching with salt-free irrigation water. Because rice has a shallow root system, only the topsoil (0-20 cm) requires leaching. Cost, availability of suitable water, and soil physical and hydraulic characteristics determine the feasibility of leaching. To reduce the level of salinity in affected soils, electrical conductivity in the irrigation water should be <0.5 dS m^{-1}). Where high-quality surface water is used (EC ~0), the amount of water required to reduce a given EC_e to a critical-level EC_c can be calculated as follows:
    - $A_{iw}=A_{sat[}(EC_e\ /ECc)+1]$
    - where A_{iw} represents the amount of irrigation water (in cm) added during irrigation and A_{sat} is the amount of water (cm) in the soil under saturated conditions. For example, to lower an initial EC_e of 16 dS m^{-1} to 4 dS m^{-1} in the top 20 cm of a clay loam soil (A_{sat} = 8-9 cm), about

	40 cm of fresh water is required. Subsurface drains are required for leaching salts from clay-textured soils. • **Sodic soils:** Apply gypsum ($CaSO_4$) to reduce Na saturation of the soil (ESP, Na:K ratio). Because of complex chemical and physical interactions, it is difficult to calculate the exact amount of gypsum required. The amount of Ca^{2+} contained in gypsum required to reduce the ESP to a target level can be estimated as follows: o Ca (kg ha-1) = $(ESP_0 - ESP_d) \times CEC \times B \times D \times 20.04$ o where ESP_0 is the original and ESP_d is the target ESP value (% of CEC), CEC is in cmolc kg^{-1}, B is the bulk density (g cm^{-3}), and D is the soil depth (m) to be reclaimed. • Foliar application of K, particularly if a low-tolerance variety is grown on saline soil. Spray at the late tillering and panicle initiation stages.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Silicon Deficiency

Droopy leaves (IRRI)

Diagnostic summary

Effect on plants	• affects the development of strong leaves, stems, and roots • affects the formation of a thick silicated epidermal cell layer • affects the rice plant's susceptibility to fungal and bacterial diseases and insect and mite pests • increases mutual shading • reduces photosynthetic activity
Signs	• soft and droopy leaves and culms • increased occurrence of diseases • keep leaves erect • reduction in the number of panicles and filled spikelets per panicle • smaller grain yields • lodging
Importance/Occurrence	• important throughout the growth cycle of the rice crop • low Si content in rice plants indicates poor soil fertility • not very common in irrigated rice • common in old and degraded paddy soils, organic soils with small mineral Si reserves, and in highly weathered and leached tropical soils in the rainfed

	lowland and upland areas

Full fact sheet

Symptoms	• Leaves and culms become soft and droopy thus increasing mutual shading • Reduces photosynthetic activity • Lower/reduced grain yields • Increased occurrence of diseases such as blast (caused by *Pyricularia oryzae*) or brown spot (caused by *Helminthosporium oryzae*) • Severe Si deficiency reduces the number of panicles m^2 and the number of filled spikelets per panicle • Si-deficient plants are particularly susceptible to lodging  Brown spots on leaves (IRRI).
Confirmation	There are plant or soil tests to show Silicon deficiency. On plant, the optimal ranges and critical levels of Si are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering-PI	Y leaf		<5
Maturity	Straw	8-10	<5

	On soil, the critical soil level for occurrence of Si deficiency is 40 mg Si kg^{-1} (1M sodium acetate buffered at pH 4).
Problems with similar symptoms	No other symptom exhibits this kind of disorder except for a Si deficient plant.
Why and where it occurs	One or more of the following can cause Si deficiency: • Low Si-supplying power because the soil is old and strongly weathered. • Parent material contains small amounts of Si.

	• Removal of rice straw over long periods of intensive cropping results in the depletion of available soil Si. Low Si content in rice plants indicates poor soil fertility (Si is very susceptible to leaching). Soils containing a small amount of Si are usually depleted of other nutrients and vice versa. Si status is an indicator of general plant nutrient status except in volcanic soils, which often contain a large concentration of Si but small amounts of P, Ca, and Mg. Si deficiency is not yet common in intensive irrigated rice systems of tropical Asia. Because application of Si is not common, however, and large amounts of straw are removed, Si balances are often negative (-150 to -350 kg Si ha^{-1} per crop) and Si deficiency may become more widespread in these systems in the future. Soils, which are particularly prone to Si deficiency include the following types: • Old, degraded paddy soils in temperate (e.g., Japan, Korea) or subtropical (e.g., North Vietnam) climates • Organic soils with small mineral Si reserves [e.g., peat soils in Florida (USA), Indonesia, and the Madagascar highlands] • Highly weathered and leached tropical soils in the rainfed lowland and upland areas (e.g., northeast Thailand)
Mechanism of damage	Silicon is a 'beneficial' nutrient for rice but its physiological functions are not clearly understood. It is required for the development of strong leaves, stems, and roots. The formation of a thick silicated epidermal cell layer reduces the rice plant's susceptibility to fungal and bacterial diseases and insect (stem borers, planthoppers) and mite pests. Rice plants adequately supplied with Si have erect leaves and growth habit and this contributes to efficient light use and thus high N use efficiency. Water use efficiency is reduced in Si-deficient plants due to increased transpiration losses. Si increases P availability in soil, increases the oxidation power of roots, and alleviates Fe and Mn toxicity by reducing the uptake of these elements.
When damage is important	The damage caused by Silicon deficiency is important throughout the growth cycle of the rice crop.
Economic importance	Si deficiency is not very common in irrigated rice and thus to date tends to be of little economic significance.
Management principles	General measures to prevent Si deficiency are as follows: • **Natural inputs:** Substantial input of Si from irrigation water occurs in some areas, particularly if groundwater from landscapes with volcanic geology is used for irrigation. Assuming average concentrations of 3-8 mg Si L^{-1} and about 1,000 mm water crop-1, Si input from irrigation is usually 30-80 kg ha-1 crop-1.

- **Straw management:** In the long term, Si deficiency is prevented by not removing the straw from the field following harvest. Recycle rice straw (5-6% Si) and rice husks (10% Si).
- **Fertilizer management:** Avoid applying excessive amounts of N fertilizer, which increases yield and total uptake of N and Si, but also decreases the Si concentration in straw because of excessive biomass growth.
- **Postharvest measures:** If rice hulls or rice hull ash are available, recycle them to replenish Si in soil.

Treatment of Si deficiency includes application of calcium silicate slags regularly to degraded paddy soils or peat soils at a rate of 1-3 t ha^{-1}.
For more rapid correction of Si deficiency, granular silicate fertilizers should be applied:

- Calcium silicate120-200 kg $ha\text{-}^{1}$
- Potassium silicate40-60 kg ha^{-1}

Calcium silicate fertilizers are prepared from various kinds of slags, which are by-products of the iron and alloy industries.

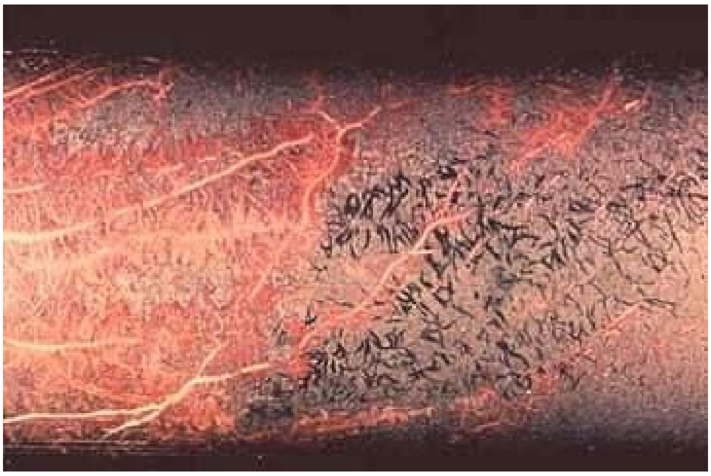
Si fertilizers for rice include:

Name	Formula	Content	Comments
Blast furnace slag	$CaSiO_3$, $MgSiO_3$	14-19% Si, 25-32% Ca, 2-4% Mg	
Convertor slag	$CaSiO_3$, $MgSiO_3$	4-10% Si, 26-46% Ca, 0.5-9% Mg	
Silico-manganese slag	$CaSiO_3$, $MgSiO_3$	16-21% Si, 21-25% Ca, 0.5-2% Mg	
Fused magnesium phosphate		9% Si, 9% P, 7-9% Mg	Granular
Calcium silicate	Si, Ca, Mg	14-19% Si, 1-4% Mg	Granular, slow-release fertilizer
Potassium silicate	K, Si	145% Si, 17% K, 2.5% Mg	Granular, slow-release fertilizer

Source

Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Sulfide Toxicity


Coarse and sparse roots (IRRI)

Diagnostic summary

Effect on plants	• reduces nutrient uptake by reducing root respiration • has an adverse effect on metabolism when an excessive amount is taken up by the rice plant
Signs	• interveinal chlorosis of emerging leaves • coarse, sparse, dark brown to black roots • fresh uprooted rice have poorly developed root systems with many black roots • increased occurrence of diseases
Importance/Occurrence	• associated with low-Fe soils • not very common in rice • can occur throughout the growth cycle of the rice • occur in well-drained sandy soils, degraded paddy soils, poorly drained organic soils, and acid sulfate soils

Full fact sheet

Symptoms	• Interveinal chlorosis of emerging leaves • Coarse, sparse, dark brown to black root system • Freshly uprooted rice hills often have poorly developed root systems with many black roots (stains of Fe sulfide) unlike healthy roots, which are covered with a uniform and smooth orange-brown coating of Fe^{3+} oxides and hydroxides

- Increased occurrence of diseases, such as brown spot (caused by *Helminthosporium oryzae*), because of unbalanced plant nutrient content caused by H_2S toxicity

Confirmation

No critical levels have been established to test Sulfide toxicity. Sulfide toxicity depends on the concentration of sulfide in soil solution relative to the oxidation power of rice roots. H_2S toxicity can occur when the concentration of H_2S >0.07 mg L_{-1} in the soil solution.

Problems with similar symptoms

Leaf symptoms of sulfide toxicity are similar to those of chlorosis caused by Fe deficiency. Other diagnostic criteria are similar to those of Fe toxicity, (but which has, however, different visual leaf symptoms.

Why and where it occurs

Sulfide toxicity can be caused by one or more of the following:

- Large concentration of H_2S in the soil solution (due to strongly reducing conditions and little precipitation of FeS).
- Poor and unbalanced crop nutrient status, causing reduced root oxidation power (due to deficiencies of K in particular but also P, Ca, or Mg).
- Excessive application of sulfate in fertilizers or urban or industrial sewage on poorly drained, strongly reducing soils.

If sufficient amounts of free Fe (Fe_{2+}) are present, the concentration of H2S is usually low due to the formation of insoluble FeS. Toxicity is therefore associated with low-Fe soils. Because the bacteria that reduce SO_4^{2-} to H2S become active when the soil pH is >5, H_2S toxicity mainly occurs after prolonged flooding. H_2S toxicity occurs on the following soil types:

- Well-drained sandy soils with low active Fe status
- Degraded paddy soils with low active Fe status
- Poorly drained organic soils
- Acid sulfate soils

Soils prone to sulfide toxicity and Fe toxicity are similar in containing a large amount of active Fe, small CEC, and small concentration of exchangeable bases. Plant tissues contain small concentration of K, Mg, Ca, Mn, and Si content.

Mechanism of damage

An excessive concentration of hydrogen sulfide in the soil reduces nutrient uptake by reducing root respiration. Hydrogen sulfide has an adverse effect on metabolism when an excessive amount is taken up by the rice plant.

Rice roots release O_2 to oxidize H_2S in the rhizosphere. H_2S

	toxicity therefore depends on the strength of root oxidizing power, H_2S concentration in the soil solution, and root health as affected by nutrient supply. Young rice plants are particularly susceptible to sulfide toxicity before the development of oxidizing conditions in the rhizosphere. Physiological disorders attributed to H_2S toxicity include "Akiochi" in Japan and "straighthead" in the southern United States.
When damage is important	The symptoms of Sulfide toxicity can occur throughout the growth cycle of the rice.
Economic importance	Sulfide toxicity is not very common in rice and thus tends to be of little economic significance.
Management principles	The following are the preventive strategies for sulfide toxicity management: • **Varieties:** Grow rice varieties that tolerate sulfide toxicity because of their greater capacity to release O_2 from roots. For example, hybrid rice varieties have a more vigorous root system and greater root oxidation power if sufficient nutrients (NPK) have been applied. • **Seed treatment:** In temperate climates, coat seeds with oxidants (e.g., Ca peroxide) to increase the O_2 supply and improve seed germination. • **Water management:** Avoid continuous flooding and use intermittent irrigation in soils that contain large concentrations of S, have high organic matter status, and are poorly drained. • **Fertilizer management:** Balance the use of fertilizer nutrients (NPK or NPK + lime) to avoid nutrient stress and improve root oxidation power. Apply sufficient K fertilizer. Avoid using excessive amounts of organic residues (manure, straw) in soils containing large amounts of Fe and organic matter, and in poorly drained soils. • **Soil management:** Carry out dry tillage after harvest to increase S and Fe oxidation during the fallow period. This technique slows down the decrease in soil redox potential and the accumulation of Fe^{2+} and H_2S during the subsequent period of flooding, but requires machinery (tractor). The above preventive management strategies should be followed because treatment of sulfide toxicity during crop growth is difficult. The following are options for treating of sulfide toxicity: • Apply K, P, and Mg fertilizers.

	• Apply Fe (salts, oxides) on low-Fe soils to increase immobilization of H_2S as FeS. • Carry out midseason drainage to remove accumulated H_2S and Fe^{2+}. Drain the field at the midtillering stage (25-30 d after planting/sowing) and maintain floodwater-free (but moist) conditions for about 7-10 d to improve oxygen supply during tillering.
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Sulfur Deficiency

Reduced plant height and tillering (IRRI)

Diagnostic summary

Effect on plants	• affects chlorophyll production, protein synthesis and plant function and structure • affects some oxidation-reduction reactions • reduces cysteine and methionine content in rice • delayed plant development and maturity • affects yield if deficiency occurs at vegetative stage
Signs	• yellowing or pale green whole plant • chlorotic young leaves with necrotic tips • lower leaves do not show necrosis • reduced plant height • reduced number of tillers and spikelets • fewer and shorter panicles
Importance/Occurrence	• important throughout the growth cycle of the crop • not particularly common in irrigated rice • common in soils containing allophane, soils with low organic matter status, highly weathered soils containing large amounts of Fe oxides, and sandy soils

Full fact sheet

Symptoms	• Yellowing or pale green whole plant • Young leaves chlorotic or light green colored with the tips becoming necrotic

- Lower leaves not showing necrosis
- Leaves paler yellow
- Effect on yield is more pronounced when S deficiency occurs during vegetative growth

Other symptoms and effects on growth include the following:

- Reduced plant height and stunted growth (but plants are not as dark-colored as in P or K deficiency)
- Reduced number of tillers, fewer and shorter panicles, reduced number of spikelets per panicle
- Delayed plant development and maturity by 1-2 weeks
- Yellowish seedlings in nursery beds with retarded growth
- High seedling mortality after transplanting
- S-deficient rice plants have less resistance to adverse conditions (e.g., cold)

Leaf chlorosis (IRRI)

Confirmation

Plant or soil can be tested for S deficiency.
The optimal ranges and critical levels of S in plant tissue are:

Growth stage	Plant part	Optimum (%)	Critical level for deficiency (%)
Tillering	Y leaf		<0.16
Tillering	Shoot	0.15-0.30	<0.11
Flowering	Flag leaf	0.10-0.15	<0.10
Flowering	Shoot		<0.07
Maturity	Straw		<0.06

Plant

- During vegetative growth before flowering, a shoot concentration of >0.15% S indicates that a response to applied S is unlikely.
- Between tillering and flowering, <0.10% S in the shoot or an N:S ratio of >15-20 indicates S deficiency. At maturity, an S content of <0.06% or an N:S ratio of >14 in the straw (>26 in grain) may indicate S deficiency.

Soil

- Soil tests for S are not reliable unless they include inorganic S as well as some of the mineralizable organic S fraction (ester sulfates).
- Critical soil levels for occurrence of S deficiency:
    - <5 mg S kg^{-1} 0.05 M HCl
    - <6 mg S kg^{-1} 0.25 M KCl heated at 40 ºC for 3 hours, and
    - <9 mg S kg^{-1} 0.01 M $Ca(H_2PO_4)_2$

Problems with similar symptoms

S deficiency is often not properly diagnosed, as foliar symptoms are sometimes mistaken for N deficiency.

Why and where it occurs

S deficiency can be caused by:

- Low available S content in the soil.
- Depletion of soil S as a result of intensive cropping.
- Use of S-free fertilizers (e.g., urea substituted for ammonium sulfate, triple superphosphate substituted for single superphosphate, and muriate of potash substituted for sulfate of potash).
- In many rural areas of developing countries, the amount of S deposition in precipitation is small due to low levels of industrial pollution.
- Sulfur concentrations in groundwater, however, may range widely. Irrigation water contains only small quantities of SO_4^{2-}.
- S contained in organic residues is lost due to burning.

Soils particularly prone to S deficiency include the following types:

- Soils containing allophane (e.g., Andisols)
- Soils with low organic matter status.

	• Highly weathered soils containing large amounts of Fe oxides. • Sandy soils, which are easily leached. It often occurs in upland rice, but is also found in the lowland rice areas of Bangladesh, China, India, Indonesia, Myanmar, Pakistan, Philippines, Sri Lanka, and Thailand.
Mechanism of damage	Sulfur is a constituent of essential amino acids (cysteine, methionine, and cystine) involved in chlorophyll production and is thus required for protein synthesis, and plant function and structure. It is also a constituent of coenzymes required in protein synthesis. It is contained in the plant hormones thiamine and biotine, both of which are involved in carbohydrate metabolism. S is also involved in some oxidation-reduction reactions. It is less mobile in the plant than N so that deficiency tends to appear first on young leaves. S deficiency affects human nutrition by causing a reduction in cysteine and methionine content in rice.
When damage is important	S deficiency is important throughout the growth cycle of the crop.
Economic importance	S deficiency is not particularly common in irrigated rice and thus tends to be of little economic significance.
Management principles	On most lowland soils, S supply from natural sources or S-containing fertilizer is similar to or exceeds S removal by rice. The concentration of S in rainwater varies widely and generally decreases with increasing distance from the coast or from industrialized areas. In Asia, the annual S deposition in rainfall ranges from 2 to 50 kg S ha^{-1}. Irrigation water typically provides 10-30 kg S ha^{-1} per crop in sulfate form. S deficiency is easily corrected or prevented by using S-containing fertilizers. General crop management measures to prevent S deficiency are as follows: • **Natural inputs:** Estimate S input from the atmosphere to identify needs for S management. • **Nursery:** Apply S to the seedbed (rice nursery) by using S-containing fertilizers (ammonium sulfate, single superphosphate). • **Fertilizer management:** Replenish S removed in crop parts by applying N and P fertilizers that contain S (e.g., ammonium sulfate [24% S], single superphosphate [12% S]). This can be done at irregular intervals. Calculate the cost-effectiveness of S supplied as S-coated urea or compound fertilizers containing S. • **Straw management:** Incorporate straw instead of completely removing or burning it. About 40-60% of the S contained in straw is lost during burning.

- **Soil management:** Improve soil management to enhance S uptake, as follows:
    - maintain sufficient percolation (~5mm per day), to avoid excessive soil reduction, or
    - carry out dry tillage after harvesting, to increase the rate of sulfide oxidation during the follow period.

Treatment of S deficiency is that the requirement for S fertilizer and manure inputs depends on soil S status and S inputs from other sources such as irrigation and the atmosphere. If S deficiency is identified during early growth, the response to S fertilizer is rapid and recovery from S deficiency symptoms can occur within five days of S fertilizer application
S deficiency should be treated as follows:

- Where the soil S fertility status is high and water contains large amounts of S (i.e., near industrial and urban centers), no additional S input is required. Emphasis should be given to the preventive measures described earlier.
- Where moderate S deficiency is observed, apply 10 kg S ha^{-1}.
- On soils with severe S deficiency (e.g., parts of China, India, Indonesia, and Bangladesh), an application of 20-40 kg S h^{a-1} is sufficient for large yields.
- Applying 15-20 kg S ha^{-1} gives a residual effect that can supply the S needed for two subsequent rice crops.
- Usually, S is added as a constituent of fertilizers applied to correct other nutrient deficiencies. Water-soluble S forms such as kieserite and langbeinite are the most efficient fertilizers for treating S deficiency in growing crops. Use slow-acting S forms (gypsum, elemental S) if leaching is likely to be a problem.

S fertilizers for rice

Name	Formula	Content	Comments
Ammonium sulfate	$(NH_4)_2SO_4$	24% S	Quick-acting
Single superphosphate	$Ca(H2PO_4)_2 . H_2O + CaSO_4 . 2 H_2O$	12% S, 7-9 % P, 13-20% Ca	Soluble, quick-acting
Potassium sulfate	K_2SO_4	18% S	Quick-acting
Magnesium sulfate (Epsom salt)	$MgSO_4 . 7 H_20$	13% S, 10% Mg	Very quick-acting
Kieserite	$MgSO_4 . H_20$	23% S, 17% Mg	Quick-acting
Langbeinite	$K_2SO_4 . MgSO_4$	18% K, 11% Mg, 22% S	Quick-acting

	Gypsum	$CaSO_4 \times 2\ H_2O$	17% S	Slow-acting
	Elemental S	S	97% S	Slow-acting
	S-coated urea	$CO(NH_2)_2 + S$	6-30% S, 30-40% N	Slow-acting
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.			

Zinc Deficiency

Crop yellowing (IRRI)

Diagnostic summary

Effect on plants	• affects several biochemical processes in the rice plant, such as • cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity • growth is severely affected
Signs	• dusty brown spots on upper leaves of stunted plants • uneven plant growth • decreased tillering • increased spikelet sterility in rice • chlorotic midribs particularly near the leaf base of younger leaves • leaves lose turgor and turn brown as brown blotches and streaks appear on lower leaves, enlarge, and coalesce • white line sometimes appears along the leaf midrib • leaf blade size is reduced
Importance/Occurrence	• important throughout the growth cycle of the rice crop • occurs in neutral and calcareous soils, intensively cropped soils, paddy soils and very poorly drained soils, sodic and saline soils, peat soils, soils with high available P and Si status, sandy soils, highly weathered, acid, and coarse-textured soils, soils derived from serpentine and laterite, and leached,

	old acid sulfate soils with a small concentration of K, Mg, and Ca • associated with S deficiency

Full fact sheet

Symptoms

- Symptoms appear between two to four weeks after transplanting
- Dusty brown spots on upper leaves of stunted plants
- Uneven plant growth and patches of poorly established hills in the field, but the crop may recover without intervention
- Tillering decreases and can stop completely and time to crop maturity increases under severe Zn deficiency
- Increase spikelet sterility in rice
- Chlorotic midribs, particularly near the leaf base of younger leaves
- Leaves lose turgor and turn brown as brown blotches and streaks appear on lower leaves, enlarge, and coalesce
- White line sometimes appears along the leaf midrib
- Leaf blade size is reduced

Other effects on growth include the following:

- Symptoms may be more pronounced during early growth stages because of Zn immobilization (due to increased bicarbonate concentration in the soil under strongly reducing conditions following flooding). If the deficiency is not severe, plants can recover after 4-6 wk, but maturity is delayed and yield reduced.

Confirmation

There are plant or soil tests to show Zinc deficiency.

The optimal ranges and critical levels of Zn in plant tissue are:

Growth stage	Plant part	Optimum	Critical level for deficiency
Tillering	Y leaf	25-50	<20
Tillering	Shoot	25-50	<10

On plant, the ranges of Zn deficiency in the whole shoot during vegetative growth (tillering) are as follows:

- <10 mg kg^{-1} definite Zn deficiency
- 10-15 mg kg^{-1} very likely
- 15-20 mg kg^{-1} likely
- >20 mg kg^{-1} unlikely (sufficient)

The ratios of P:Zn and Fe:Zn in the shoot at tillering to the PI stage are good indicators of Zn deficiency. Values should not exceed:

- P:Zn20-60:1in shoots 6 wk after planting
- Fe:Zn5-7:1in shoots 6 wk after planting

Leaf Zn concentration is a less reliable indicator of Zn deficiency, except in extreme cases (leaf Zn <15 mg kg^{-1}).
On soil, the critical soil levels for occurrence of Zn deficiency are as follows:

- 0.6 mg Zn kg^{-1} 1N NH4-acetate, pH 4.8
- 0.8 mg Zn kg^{-1} DTPA methods
- 1.0 mg Zn kg^{-1} 0.05N HCl
- 1.5 mg Zn kg^{-1} EDTA methods
- 2.0 mg Zn kg^{-1} 0.1N HCl

Calcareous soils (pH >7) with moderate to high organic matter content (>1.5% organic C) are likely to be Zn-deficient due to high HCO3- in solution.
A ratio of >1 for exchangeable Mg:Ca in soil may indicate Zn deficiency.

Problems with similar symptoms

The symptoms of Zinc deficiency may resemble those of Fe deficiency, which also occurs on alkaline soils. On alkaline soils, Zn deficiency is often associated with S deficiency. They may also resemble Mn deficiency and Mg deficiency.

Leaf spots may resemble Fe toxicity in appearance but the latter occurs on high organic status soils with low pH.

Zn deficiency symptoms may resemble symptoms of grassy stunt and tungro virus diseases.

Why and where it occurs

Zn deficiency can be caused by one or more of the following factors:

- Small amount of available Zn in the soil.
- Planted varieties are susceptible to Zn deficiency (i.e., Zn-inefficient cultivars).
- High pH (close to 7 or alkaline under anaerobic conditions). Solubility of Zn decreases by two orders of magnitude for each unit increase in pH. Zn is precipitated as sparingly soluble $Zn(OH)_2$ when pH increases in acid soil following flooding.
- High HCO^{3-} concentration because of reducing conditions in calcareous soils with high organic matter content or because of large concentrations of HCO^{3-} in

irrigation water.

- Depressed Zn uptake because of an increase in Fe, Ca, Mg, Cu, Mn, and P after flooding.
- Formation of Zn-phosphates following large applications of P fertilizer. High P content in irrigation water (only in areas with polluted water).
- Formation of complexes between Zn and organic matter in soils with high pH and high organic matter content or because of large applications of organic manures and crop residues.
- Precipitation of Zn as ZnS when pH decreases in alkaline soil following flooding.
- Excessive liming.
- Wide Mg:Ca ratio (i.e., >1) and adsorption of Zn by $CaCO_3$ and $MgCO_3$. Excess Mg in soils derived from ultrabasic rocks.

Zn deficiency is the most widespread micronutrient disorder in rice. Its occurrence has increased with the introduction of modern varieties, crop intensification, and increased Zn removal. Soils particularly prone to Zn deficiency include the following types:

- Neutral and calcareous soils containing a large amount of bicarbonate. On these soils, Zn deficiency often occurs simultaneously with S deficiency (widespread in India and Bangladesh).
- Intensively cropped soils where large amounts of N, P, and K fertilizers (which do not contain Zn) have been applied in the past
- Paddy soils under prolonged inundation (e.g., when three crops of rice are grown in one yr) and very poorly drained soils with moderate to high organic matter content
- Sodic and saline soils
- Peat soils
- Soils with high available P and Si status
- Sandy soils
- Highly weathered, acid, and coarse-textured soils containing small amounts of available Zn. Soils derived from serpentine (low Zn content in parent material) and laterite.

	• Leached, old acid sulfate soils with a small concentration of K, Mg, and Ca
Mechanism of damage	Zinc is essential for several biochemical processes in the rice plant, such as: • Cytochrome and nucleotide synthesis • Auxin metabolism • Chlorophyll production • Enzyme activation • Membrane integrity Zn accumulates in roots and can be translocated from roots to developing plant parts. Because little retranslocation of Zn occurs within the leaf canopy, particularly in N-deficient plants, Zn deficiency symptoms are more common on young or middle-aged leaves.
When damage is important	The damage brought about by Zn deficiency is important throughout the growth cycle of the rice crop.
Economic importance	In Japan, Zn deficiency is the cause of the "Akagare Type II" disorder in rice.
Management principles	Preventing Zn deficiency is an intricate part of general crop management. The following are the general measures to prevent Zn deficiencies: • **Varieties:** Grow Zn-efficient varieties that are tolerant of high HCO^{3-} and low plant-available Zn content. Early modern varieties (e.g., IR26) were prone to Zn deficiency, but new lines are now screened for tolerance to low-Zn environments and some cultivars are particularly adapted to Zn stress (e.g., IR8192-31, IR9764-45). Tolerant varieties may not respond to Zn application on soils with only slight Zn deficiency. • **Nursery:** Broadcast ZnSO4 in nursery seedbed. • **Crop establishment:** Dip seedlings or presoak seeds in a 2-4% ZnO suspension (e.g., 20-40 g ZnO L^{-1} H2O). • **Fertilizer management:** Use fertilizers that generate acidity (e.g., replace some urea with ammonium sulfate). Apply organic manure. Apply 5-10 kg Zn ha^{-1} as Zn sulfate, Zn oxide, or Zn chloride, prophylactically either incorporated in the soil before seeding or transplanting or applied to the nursery seedbed a few days before transplanting. The effect of Zn applications can persist up to five years depending on the soil and cropping pattern. On alkaline soils with severe Zn deficiency, the residual effect of applied $ZnSO_4$ is small, and therefore Zn must be applied to each crop. On most

other soils, blanket applications of $ZnSO_4$ should be made every two to eight crops, but soil Zn status should be monitored to avoid accumulating toxic concentrations of Zn.

- **Water management:** Allow permanently inundated fields (e.g., where three crops per year are grown) to drain and dry out periodically. Monitor irrigation water quality. pH is an approximate indicator for possibly excessive HCO_3- supply:
    - pH 6.5-8.0 - good-quality water
    - pH 8.0-8.4 - marginally acceptable, but check for HCO3-
    - pH >8.4 - do not use for irrigation unless diluted with water that has pH<6.5

Zn deficiencies are most effectively corrected by soil Zn application. Surface application is more effective than soil incorporation on high pH soils. Because of its high water solubility, Zn sulfate is the most commonly used Zn source, although ZnO is less expensive. The following measures, either separately or in combination, are effective but should be implemented immediately at the onset of symptoms:

- If Zn deficiency symptoms are observed in the field, immediately apply 10-25 kg ha^{-1} $ZnSO_4$.7 H_2O. Uptake of $ZnSO_4$ is more efficient when broadcast over the soil surface (compared with incorporated) particularly in direct-sown rice. To facilitate more homogeneous application, mix the Zn sulfate (25%) with sand (75%).
- Apply 0.5-1.5 kg Zn ha-1 as a foliar spray (e.g., a 0.5% $ZnSO_4$ solution at about 200 L water ha-1) for emergency treatment of Zn deficiency in growing plants. Start at tillering (25-30 DAT), two or three repeated applications at intervals of 10-14 d may be necessary. Zn chelates (e.g., Zn-EDTA) can be used for foliar application, but the cost is greater.

Zn fertilizers for rice:

Name	**Formula**	**Content (% Zn)**	**Comments**
Zinc sulfate	$ZnSO_4 \cdot H_2O$ $ZnSO_4 \cdot 7 H_2O$	36 23	Soluble, quick-acting
Zinc carbonate	$ZnCO_3$	52-56	Quick-acting
Zinc chloride	$ZnCl_2$	48-50	Soluble, quick-acting
Zinc chelate	Na_2Zn-EDTA	14	Quick-acting
	Na_2Zn-HEDTA	9	Quick-acting

	Zinc oxide	ZnO	60-80	Insoluble, slow-acting
Source	Dobermann A, Fairhurst T. 2000. Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.			

Diseases

Bacterial Leaf Blight


Small streaks caused by Bacterial Leaf Blight

Diagnostic summary

Damage to plants	• wilting of seedlings • yellowing and drying of leaves • reduced yield
Signs and symptoms	• leaf blight o Water-soaked to yellowish stripes on leaf blades or starting at leaf tips then later increase in length and width with a wavy margin o Appearance of bacterial ooze that looks like a milky or opaque dewdrop on young lesions early in the morning o Lesions turn yellow to white as the disease advances o Severely infected leaves tend to dry quickly o Lesions later become grayish from growth of various saprophytic fungi • seedling wilt or kresek o Observed 1-3 weeks after transplanting o Green water-soaked layer along the cut portion or leaf tip of leaves as early symptom

	- Leaves wilt and roll up and become grayish green to yellow - Entire plant wilt completely • yellow leaf or pale yellow mature plants - Youngest leaf is uniform pale yellow or has broad yellow stripe - Older leaves do not show symptoms • Panicles sterile and unfilled but not stunted under severe conditions
Factors favoring disease development	• presence of weeds • presence of rice stubbles and ratoons of infected plants • presence of bacteria in the rice paddy and irrigation canals • warm temperature, high humidity, rain and deep water • over fertilization • handling of seedlings at transplanting

Full fact sheet

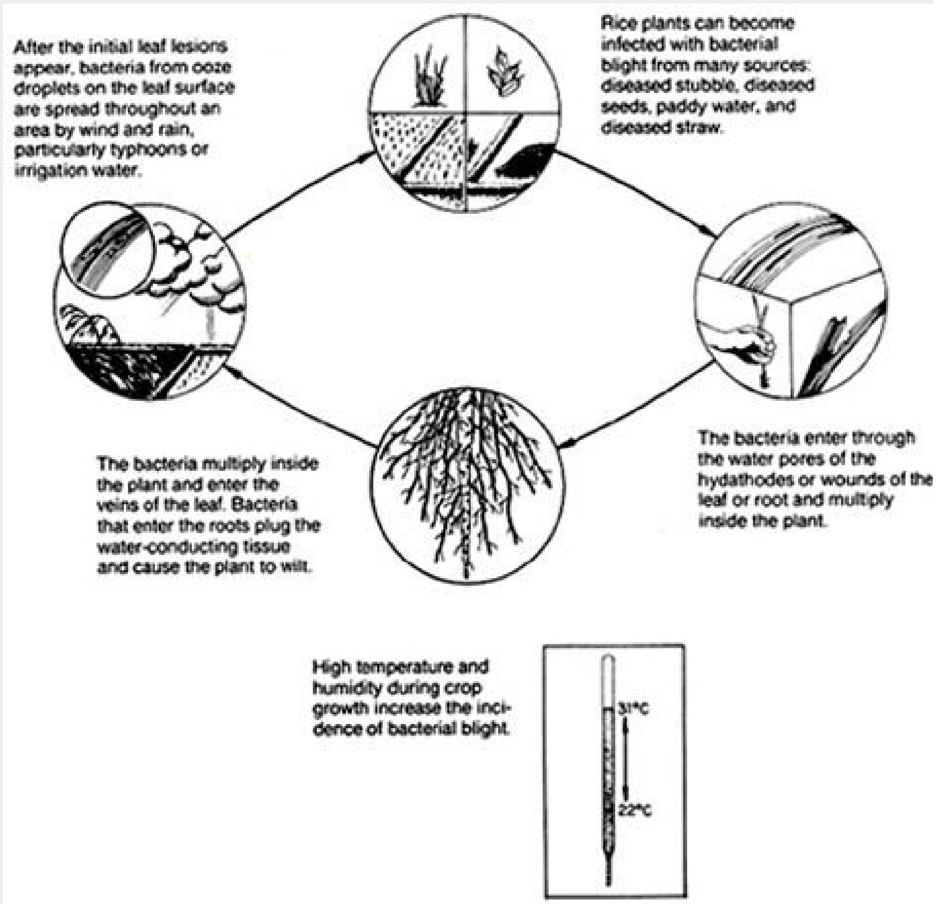
Disease name	Bacterial leaf blight (BB)
Pathogen	*Xanthomonas oryzae* pv. *oryzae* (Ishiyama) Swings et al.
Symptoms	• Water-soaked to yellowish stripes on leaf blades or starting at leaf tips then later increase in length and width with a wavy margin • Appearance of bacterial ooze that looks like a milky or opaque dewdrop on young lesions early in the morning • Lesions turn yellow to white as the disease advances • Severely infected leaves tend to dry quickly • Lesions later become grayish from growth of various saprophytic fungi • Seedling wilt or kresek • Observed 1-3 weeks after transplanting • Green water-soaked layer along the cut portion or leaf tip of leaves as early symptom • Leaves wilt and roll up and become grayish green to yellow • Entire plant wilt completely • Yellow leaf or pale yellow of mature plants • Youngest leaf is uniform pale yellow or has broad yellow stripe • Older leaves do not show symptoms • Panicles sterile and unfilled but not stunted under severe conditions

Seedling wilt (IRRI)

Leaf blight (IRRI)

Confirmation	In the field, diseased leaves can be collected and cut near the lower end of the lesions. The cut diseased leaves can be placed in a test tube with water for a few minutes. The cut portion can be observed against the light to see the bacterial ooze streaming out from the cut ends into the water. After 1-2 hours, the water becomes turbid.

	To distinguish kresek symptoms from stem borer damage, the lower end of the infected seedling can be squeezed between the fingers. Yellowish bacterial ooze may be seen coming out of the cut ends.
Problems with similar symptoms	Infected plants show kresek, which resemble rice stem borer damage.
Why and where it occurs	The presence of weeds around the field, the rice stubbles, and ratoons of infected plants sustains survival of the disease. They become sources of initial inoculum. Likewise, the bacteria in the rice paddy and irrigation canals encourage new infection on leaves. Warm temperature (25-30° C), high humidity, rain and deep water favor the disease. Wetland areas also encourage the presence of the disease. Severe winds, which cause wounds, and over fertilization are suitable factors for the development of the disease. Irrigation water and splashing or windblown rain can disseminate the bacterium from plant to plant. The use of trimming tools for transplanting and by handling during transplanting can also trigger new infection. For example, the kresek symptom is associated with seedling infection, which was damaged during transplanting operations.
Causal agent or factor	The bacteria causing the disease are rods, 1.2 x 0.3-0.5 µm. They are single, occasionally in pairs but not in chains. They are Gram negative, non-spore-forming, and devoid of capsules. Their colonies on nutrient agar are pale yellow, circular, and smooth with an entire margin. They are convex and viscid.
Host range	*Leersia sayanuka* Ohwi, *L. oryzoides* (L.) Sw., *L. japonica*, and *Zizania latifolia* are alternate hosts of the disease in Japan. In the tropics, the disease is found to infect *Leptochola chinensis* (L.) Nees, *L. filiformis* (Lam.) *P. Beauv.*, and *L. panicea* (Retz.) Ohwi. *Cyperus rotundus L.* and *C. difformis L*. are recorded as alternate hosts of the disease in India. In Australia, the disease is known to survive on wild rice, *Oryza rifopogon* and *O. australiensis*.

Life cycle	
Mechanism of damage	Leaf tips of seedlings cut before transplanting and leaf injuries serve as important sources of inoculum especially for kresek. The bacterium or pathogen enters the leaf tissues through natural openings such as water pores on hydathodes or stomata on the leaf blade, growth cracks caused by the emergence of new roots at the base of the leaf sheath, and on leaf or root wounds. Once the bacterium enters the water pore or any opening, it multiples in the epitheme, into which the vessel opens. When there is sufficient bacterial multiplication, some bacteria invade the vascular system and some ooze out from the water pore.
When damage is important	Bacterial blight is one of the most serious diseases of rice, which is known worldwide. It is common in both tropical and temperate countries. Strains in tropical areas are more virulent than that of in the temperate region. Yield loss due to this disease corresponds to the plant growth stages at which the rice plants were infected. The earlier the disease occurs, the higher the yield loss. Infection at booting stages does not affect yield but results in poor quality and a high proportion of broken kernels.
Economic importance	Bacterial blight is reported to have reduced Asia's annual rice production by as much as 60%. For example, in Japan, about 300,000

	to 400,000 hectares of rice were affected by the disease in recent years. There were 20% to 50% yield losses reported in severely infected fields. In Indonesia, losses were higher than those reported in Japan. In India, millions of hectares were severely infected, causing yield losses from 6% to 60%.
Management principles	Practicing field sanitation such as removing weed hosts, rice straws, ratoons, and volunteer seedlings is important to avoid infection caused by this disease. Likewise, maintaining shallow water in nursery beds, providing good drainage during severe flooding, plowing under rice stubble and straw following harvest are also management practices that can be followed. Proper application of fertilizer, especially nitrogen, and proper plant spacing are recommended for the management of bacterial leaf blight. The use of resistant varieties is the most effective and the most common management practices adopted by farmers in most growing countries in Asia. When different strains of bacteria are present, it is recommended to grow resistant varieties possessing field resistant genes. Fallow field and allow to dry thoroughly is recommended. Seed treatment with bleaching powder (100µg/ml) and zinc sulfate (2%) reduce bacterial blight. Control of the disease with copper compounds, antibiotics and other chemicals has not proven highly effective.
Selected references	• International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, FA dela Peña, and IP Oña

Bacterial Leaf Streak

Crop yellowing (IRRI)

Diagnostic summary

Damage to plants	• browning and drying of leaves • reduced 1000-grain weight under severe condition
Signs and symptoms	• initial symptoms are dark-green and water-soaked streaks on interveins from tillering to booting stage • streaks later enlarge to become yellowish gray and translucent • bacterial exudates on surface of lesions • lesions turn brown to grayish white then dry • browning and drying of entire leaves
Factors favoring disease development	• presence of the bacteria on leaves and in the water or those surviving in the debris left after harvest • high temperature and high humidity • early stage of planting from maximum tillering to panicle initiation

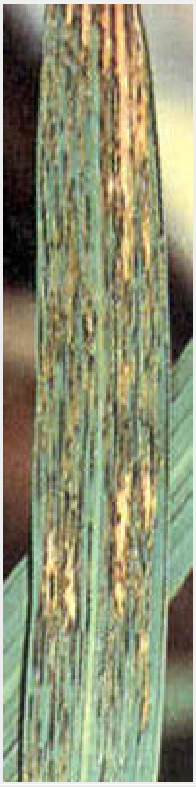
Full fact sheet

Disease name	Bacterial leaf streak
Pathogen	*Xanthomonas oryzae* pv. *oryzicola* (Fang et al.) Swings et al.

Symptoms

- Initially, small, dark-green and water-soaked streaks on interveins from tillering to booting stage
- Streaks dark-green at first and later enlarge to become yellowish gray and translucent
- Numerous small yellow beads of bacterial exudates on surface of lesions on humid conditions
- Very small yellow beads instead of bacterial exudates during dry season
- Lesions turn brown to grayish white then dry when disease is severe
- Yellow halo around lesions on susceptible cultivars
- Browning and dying of entire leaves
- Bleached and grayish white leaves


Yellow streaks (IRRI)


Brown streaks (IRRI)

Confirmation

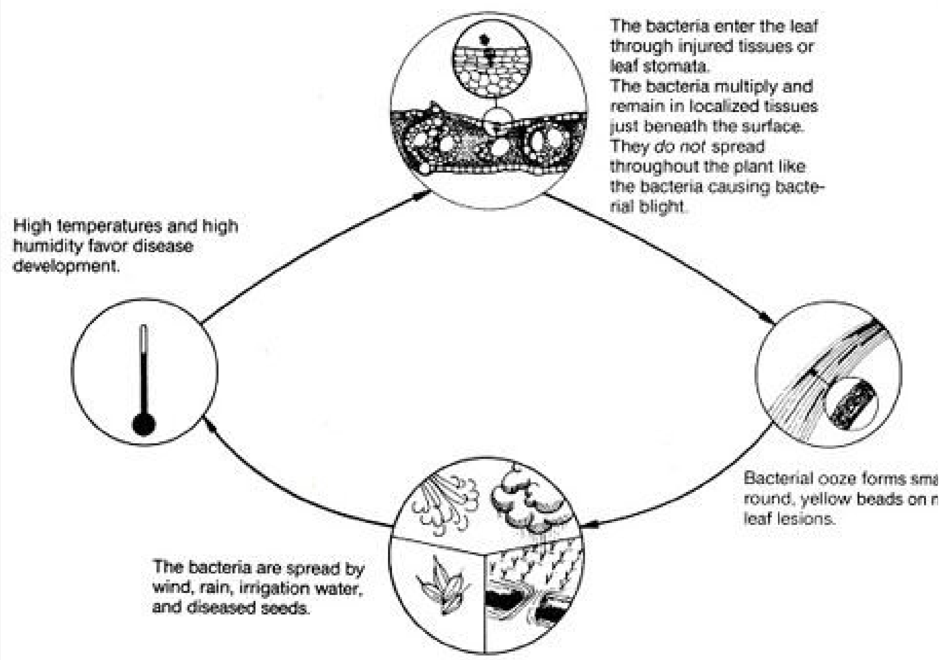
The linear streaks or narrow transparent streak can be seen against the sunlight. When the advancing part of the streaks are cut and placed in a glass with water, mass of bacterial cells would be seen coming out from the leaf making the water turbid after 5 minutes.

Problems with similar symptoms

BLS is the only leaf spot disease with transparent narrow streaks as compared with other leaf diseases like brown spot, narrow brown spot, and bacterial blight.

At an early stage, the symptom looks similar to that of the narrow brown leaf spot. At a later stage, when the streaks coalesced, the

	symptoms of bacterial leaf streak look the same as those of bacterial blight. Bacterial leaf streak can be distinguished from bacterial blight by its thinner translucent lesions with the yellow bacterial ooze.
Why and where it occurs	The disease is transmitted through seeds to the next planting season. Planting of infected seeds, which are collected from diseased fields produce diseased seedlings. The bacteria, which is present in the water or those surviving in the debris left after harvest, are also sources of inoculum in the next planting season. The bacterial cells in beads on leaves when moistened by dew or rain disperse and spread by wind cause new infection or damage on the same leaves or other leaves. High temperature and high humidity also favor new infection and development of lesions. The disease usually occurs during the early stage of planting from maximum tillering to panicle initiation. Older plants are more resistant to the disease.
Causal agent or factor	The bacteria causing the disease *X. oryzae* pv. *oryzicola* occur as rods. They are 1.2 x 0.3-0.5 µm in dimension. They are single, occasionally in pairs but not in chains. The bacteria have no spores and no capsules. They move with the aid of a single polar flagellum. They are Gram-negative and aerobic and can grow favorably at 28 °C. The bacterial colonies on nutrient agar are pale yellow, circular, smooth, convex, and viscid and have an entire margin. Their growth on slant is filiform. Growth in nutrient broth is moderate with a surface ring growth without a definite pellicle.
Host range	Species of wild rice such as *Oryza spontanea*, *O. perennis balunga*, *O. nivara*, *O. breviligulata*, *O. glaberrima*, and *Leersia hexandra* Sw. (southern cutgrass) are alternate hosts of the disease.

Life cycle	
Mechanism of damage	The bacterium penetrates the leaf through natural openings (such as stomata and hydatodes), leaf injuries or artificial wounds due to wind, insect bites, or others. Initial infection is observed only on the parenchyma cells in between the veins of the leaf. Highest infection occurs at midday, during which the leaf stomata are fully opened. After gaining entrance, the bacterium multiplied in the substomatal cavity and progressed intercellularly in the parenchyma. Soon after lesions develop, bacterial exudates form on the surface of the lesions under moist conditions during the night. Under dry conditions, these exudates become small, yellow beads that eventually fall into the irrigation water. When the leaves are wet from dew or rain, with the aid of wind, the bacteria is carried from field to field by irrigation water.
When damage is important	The disease is usually observed during the tillering stage of the rice crop. The rice plant can easily recover at the later growth stages and grain yield losses are minimal.
Economic importance	Bacterial leaf streak is widely distributed in Taiwan, southern China, Southeast Asian countries, India, and West Africa. The disease is not reported to occur in temperate countries including Japan. Losses as high as 32.3% in 1000-grain weight due to BLS were reported. At three disease intensities, the estimated yield losses were 8.3%, 13.5%, and 17.1% in the wet season and 1.5%, 5.9%, and 2.5% during the dry season.
Management principles	The disease can be controlled by proper application of fertilizers and proper planting spacing, the use of resistant varieties, and hot water treated seeds. Practicing field sanitation is important. Ratoons, straws and volunteer seedlings left after harvest can be destroyed to minimize the initial

	inoculum at the beginning of the season. Providing good drainage system especially in seedbeds can also manage this disease. Planting of resistant varieties, which are available at IRRI and at National Research Institute, is the most effective method of controlling bacterial leaf streak. Fallow field and allowing to dry thoroughly is also recommended.
Selected references	• Benedict AA, Alvarez AM, Berestecky J, Imanaka W, Mizumoto CY, Pollard LW, Mew TW, Gonzalez • CF. 1989. Pathovar-specific monoclonal antibodies for Xanthomonas campestris pv. oryzae and for Xanthomonas campestris pv. oryzicola. Phytopathol. 79:322-328. • Ho BL. 1975. Effects of bacterial leaf streak infection on rice plant and yield in relation to different nitrogen levels and times of inoculation. MARDI Bulletin 3:32-43. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Opina DS, Exconde BR. 1971. Assessment of yield loss due to bacterial leaf streak of rice. Philippine Phytopathol. 7:35-39. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Shakhomat GS, Srivastava DN. 1971. Control of bacterial leaf streak of rice (Oryza sativa). Ind. J. Agric. Sci. 41:1098-1101. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, and IP Oña

Bakanae

Reduced tillering due to Bakanae

Diagnostic summary

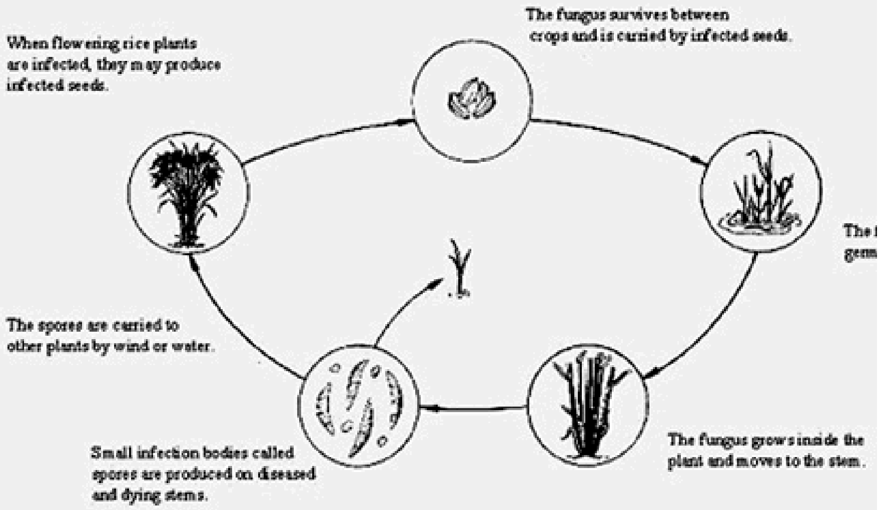
Damage to plants	• abnormal plant growth
Signs and symptoms	• abnormal elongation of plants in seedbed and field - thin plants with yellowish green leaves • reduced tillering and drying of leaves at late infection - dying seedlings at early tillering • partially filled grains, sterile, or empty grains for surviving plant at maturity
Factors favoring disease development	• presence of infected seeds • soilborne pathogens • high nitrogen application • temperature ranging from 30 to 35° C • presence of wind or water that carries the spores from one plant to another • seedling and tillering stages of the rice crop

Full fact sheet

Disease name	Bakanae disease
Pathogen	*Gibberella fujikuroi* Sawada Wollenworth (teleomorph)

	Fusarium fujikuroi Nirenberg (anamorph) *F. moniliforme* J. Sheld. (synonym)
Symptoms	• Infected plants several inches taller than normal plants in seedbed and field • Thin plants with yellowish green leaves and pale green flag leaves • Dying seedlings at early tillering • Reduced tillering and drying leaves at late infection • Partially filled grains, sterile, or empty grains for surviving plant at maturity • In the seedbed, infected seedlings with lesions on roots die which may die before or after transplanting  Infected plant (IRRI)
Confirmation	White powdery growth of conidiophores can be seen at the base or on the lower portions of the diseased plants. Not all infected seedlings exhibit the visible bakanae symptoms; sometimes they may be stunted or appear normal. Under a stereobinocular microscope, infected seeds on a blotter paper show moderate to heavy growth of white, fluffy mycelia, often covering the entire seed. Later, growth appears powdery due to microconidia formation.
Problems with similar symptoms	There is no other disease with similar symptoms as the bakanae disease of rice.
Why and where it occurs	Bakanae is primarily a seedborne disease. Sowing ungerminated seeds in infested soil gives rise to infected seedlings. Soil temperature of 35^{o}C is most favorable for infection.

	Application of nitrogen favors the development of the disease. Wind or water easily carries the spores from one plant to another. High temperature, ranging from 30 to 35ºC favors the development of the disease. Wind or water easily carries the conidia from one plant to another. The bakanae disease is primarily seedborne and the fungus survives under adverse conditions in infected seeds and other diseased plant parts.
Causal agent or factor	The pathogen sexually produces ascospores that are formed within a sac known as ascus. Asci are contained in fruiting bodies called ascocarps which are referred to as perithecia. The perithecia are dark blue and measure 250-330 x 220-280 µm. They are spherical to ovate and somewhat roughened outside. The asci are cylindrical, piston-shaped, flattened above, and are 90-102 x 7-9 µm. They are 4- to 6-spored but seldom 8-spored. The spores are one-septate and about 15 x 5.2 µm. They are occasionally larger, measuring 27-45 x 6-7 µm. The anamorph form produces gibberellin and fusaric acid. Biological studies of the two substances showed that fusaric acid cause stunting and giberrellin causes elongation. Hyphae are branched and septate. The fungus has micro- and macroconidiophores bearing micro- and macroconidia, respectively. The microconidiophores are single, lateral, and subulate phialides. They are formed from aerial hyphae. The microconidia are more or less agglutinated in chains and remain joined or cut off in false heads. They are later scattered in clear yellowish to rosy white aerial mycelia as a dull, colorless powder. They are 1-2-celled and fusiform-ovate. The macroconidiophores have basal cells with 2-3 apical phialides, which produce macroconidia. The macroconidia are delicate, awl-shaped, slightly sickle-shaped, or almost straight. They narrow at both ends and are occasionally somewhat bent into a hook at the apex and distinctly or slightly foot-celled at the base. The sclerotia are 80 x 100 µm. They are dark blue and spherical. The stroma are more or less plectenchymatous and yellowish, brownish, or violet.
Host range	In Japan, the disease is found to develop in *Panicum miliaceum* L., barley, maize, sorghum, and sugarcane. Other alternate hosts of the disease include *Leucaena leucocephala*, *Lycopersicon esculentum* Mill. (tomato), *Musa* sp. (banana), *Saccharum officinarum* L. (sugarcane), *Vigna unguiculata* (cowpea), and *Zea mays* L. (maize).

Life cycle	
Mechanism of damage	The seeds are usually infected during the flowering stage of the crop. Severely infected seeds are discolored because of the conidia of the pathogen. Seed infectrion occurs via airborne ascospores and also from conidia that contaminate the seed during harvesting. Discolored seeds give rise to stunted seedlings, whereas infected seeds without discoloration produce seedlings with typical bakanae symptoms. Infection may also take place through spores and mycelium, which are left in the water used for soaking seeds. The fungus infects plants through roots or crowns. It later becomes systemic, i.e., it grows within the plant but does systemically infect the panicle. The microconidia and mycelium of the pathogen are found to be concentrated in the vascular bundles, particularly the large pitted vessels and lacunae of the xylem vessels.
When damage is important	Infection usually occurs during seedling and tillering stages of the rice crop.
Economic importance	Crop losses caused by the disease may reach up to 20% in outbreak cases. For example, in Japan, a 20% to 50% loss was observed. Yield losses of 15% and 3.7% were reported in India and Thailand, respectively.
Management principles	Clean seeds should be used to minimize the occurrence of the disease. Salt water can be used to separate lightweight, infected seeds from seed lots and thereby reduce seedborne inoculum. Seed treatment using fungicides such as thiram, thiophanate-methyl, or benomyl is effective before planting. Benomyl or benomyl-t at 1-2% of seed weight should be used for dry seed coating. However, rapid development of resistance against benomyl and carbendazim have been observed which

	may be caused by successive applications as a seed disinfectant. Triflumizole, propiconazole and prochloraz were found to be effective against strains that are resistant to benomyl and combination of thiram and benomyl.
Selected references	• Ahmed MI, Raza T. 1992. Survey of Pakistan's rice crop for bakanae. Int. Rice Res. Newsl. 17(1):23. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986
Contributors	Suparyono, JLA Catindig, NP Castilla, and F Elazegui

Brown Spot

Crop infected with brown spot (IRRI)

Diagnostic summary

Damage to plants	• seedling mortality • quality and number of grains affected
Signs and symptoms	• seedlings manifest seedling blight • infected seedlings become stunted or die • infected leaves with numerous oval spots and wither • young or underdeveloped spots are small, circular, dark brown or purplish brown dots • fully developed spots are brown with gray or whitish centers • infected panicles with brown spots • infected young roots with blackish lesions
Factors favoring disease development	• presence of infected seeds, volunteer rice, rice debris, and several weeds • poorly drained or nutrient deficient soils • abnormal soils, which are deficient in nutrient elements • temperature ranging from 25-30oC • water stress and high humidity • maximum tillering up to the ripening stages of the crop

Full fact sheet

Disease	Brown spot

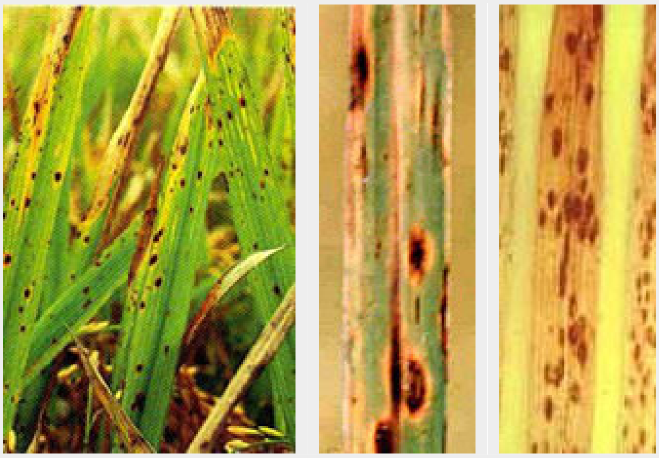
name

Pathogen

Bipolaris oryzae (Breda de Haan) Shoemaker (anamorph) *Drechslera oryzae* (Breda de Haan) Subramanian & P. C. Jain (synonym)
Helminthosporium oryzae Breda de Haan (synonym)
Cochliobolus miyabeanus (Ito & Kuribayashi) Drechsler ex Dastur (teleomorph)

Symptoms

- Infected seedlings have small, circular or oval, brown lesions, which may girdle the coleoptile and cause distortion of the primary and secondary leaves (symptom is called seedling blight)
- Infected seedlings become stunted or die
- Young or underdeveloped lesions on older leaves are small and circular, dark brown or purplish brown
- A fully developed lesion on older leaves is oval, brown with gray or whitish center with reddish brown margin
- Lesions on older leaves of moderately susceptible cultivars are tiny and dark
- When infection is severe, the lesions may coalesce, killing large areas of affected leaves.
- Infected glumes with black or dark brown spots
- Velvety appearance of lesions on infected glumes under severe conditions
- Infected grains with black discoloration or with brown lesions
- Infected young roots with black discoloration



Brown spots on leaves

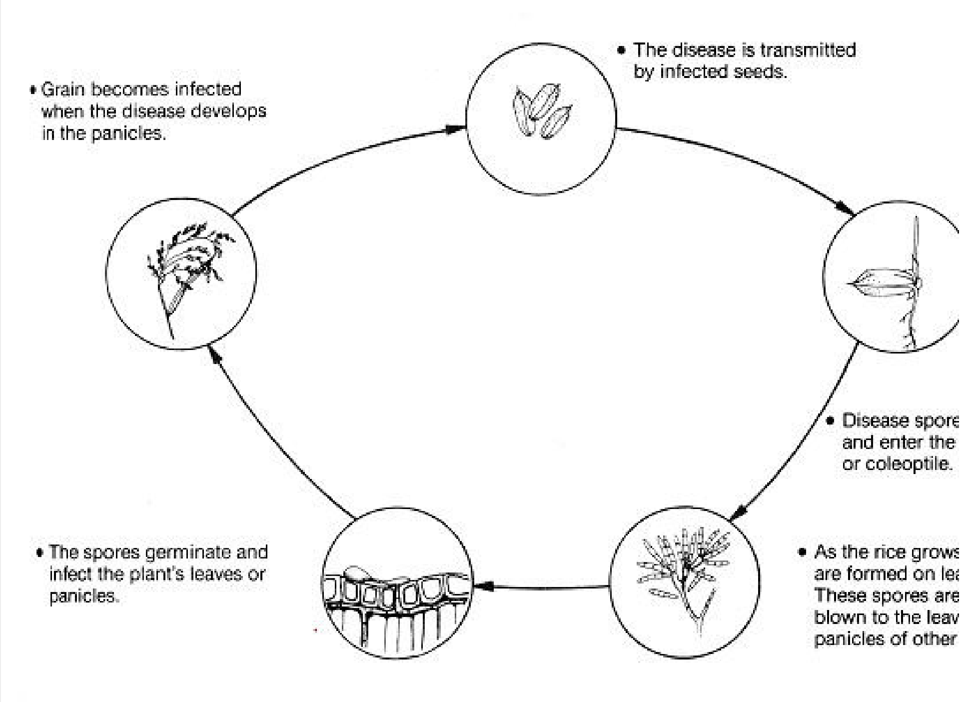
Confirmation

Brownish, circular to oval spots lesions that have a light brown to gray center surrounded by a reddish brown margin. are the most common identifying features to confirm the disease. Mycelial mats, which are black and velvety, are visible on the glumes of affected spikelets.

Problems with similar symptoms

The lesions can be similar to blast lesions in certain rice varieties.

Why and where it occurs	The fungus can survive in the seed for more than 4 years. Infected seeds, volunteer rice, infected rice debris, and several weeds are the major sources of inoculums in the field. Infected seeds give rise to infected seedlings. The fungus can spread from plant to plant and in the field by airborne spores. The disease is common in nutrient-deficient soils and unflooded soil but rare on rice grown on fertile soils. Abnormal soils, which are deficient in nutrient elements, or soils in a much-reduced condition in which toxic substances accumulate favor the development of the disease. Disease development is favored by high relative humidity (86-100%) and optimum temperature between 16 and 36°C. Leaves must be wet for 8-24 hours for infection to occur. Yield losses due to brown spot epidemic in Bengal in 1942 was attributed to continuous temperature of 20-30°C for two months, unusually cloudy weather, and higher-than-normal temperature and rainfall at the time of flowering and grain-filling stages.
Causal agent or factor	The fungi causing the disease occur in two states or stages. These are the asexual stage, which is called anamorph or imperfect stage and the sexual stage, which is called teleomorph or the perfect stage. The somatic structures of the fungus consist of black velvety mycelial mats which are made up of prostrate hyphae and erect sporophores. The hyphae are abundant, branching, and anastomosing. They are dark brown or olivaceous and measure 8-15 µm or more in diameter. The sporophores arise as lateral branches from the hyphae. They change from olivaceous at the base to light ferruginous and the tip to subhyaline. The sporophores are 150-600 x 4-8 µm. Their geniculations are not always well defined. The conidia measure 35-170 x 11-17 µm. Typical conidia are slightly curved, widest at the middle and tapering toward the hemispherical apex, where their width approximates half the median width. Mature conidia are brownish with a moderately thin peripheral wall.
Host range	Aside from the rice plant, the disease also infects barley, oats, *Cynodon dactylon* (L.) Pers., *Digitaria sanguinalis* (L.) Scop., *Eleusine coracana* (L.) Gaertn., *Leersia hexandra* Sw., *Panicum colonum* (L.) Link, *Setaria italica* (L.) P. Beauv., *Triticum aestivum* L. em. Thell. (wheat), *Zea mays* L. (maize), and *Zizania aquatica* (wild rice).

Life cycle	
Mechanism of damage	The infection processes start at the formation of appressoria. During this time, there is an increase in protoplasmic streaming in the host cells and the cell nuclei moved near the appressorium. It is followed by the hyphae attacking the middle lamella and penetrating the cells. The middle lamella started to separate and caused the formation of yellowish granules. Then, 2 or 3 cells died and mycelia developed in the cells. Appearance of minute spots followed. Another observation showed that the spores or conidia germinate by germ tubes from the apical and basal cells. Germ tube is covered with mucilaginous sheath and at its tip, an appressorium is formed. The fungus directly penetrates the epidermis by the infection pegs formed under the appressoria. The germ tubes also penetrate the leaf through the stomata without producing any appressorium.
When damage is important	It is observed during the maximum tillering up to the ripening stages of the crop. Damage is important when infection occurs in the seed, causing the formation of either unfilled grains or spotted or discolored seeds giving rise to infected seedlings. Numerous spots or big spots on a leaf may result in blight, thus killing the whole leaf.
Economic importance	The disease causes blight on seedlings, which are grown from heavily infected seeds, and can cause 10-58% seedling mortality. It also affects the quality and the number of grains per panicle and reduces the kernel weight. The reduction in yield can be as high as 45% in severe infection and 12% in moderate infection. There is no loss in yield in light infection. The disease was considered to be the major factor contributing to the "Great Bengal Famine" in 1942 resulting to yield losses of 50% to 90% and caused the death of 2 million people. Epidemics in India have resulted in 14-41% losses in high yielding varieties. Under favorable environment, yield loss estimates ranging

	from 16 to 40% in Florida, USA was reported.
Management principles	The use of resistant varieties is the most economical means of control. There are cultivars in Thailand, which are found to be resistant to the disease. Proper management of fertilizer by using silicon fertilizers (e.g., calcium silicate slag) in poor soil conditions can be used to reduce disease intensity. Since the fungus is seed transmitted, a hot water seed treatment (53-54°C) for 10-12 minutes may be effective before sowing. This treatment controls primary infection at the seedling stage. Presoaking the seed in cold water for 8 hours increases effectivity of the treatment. Seed treatment with captan, thiram, chitosan, carbendazim, or mancozeb has been found to reduce seedling infection. Seed treatment with tricyclazole followed by spraying of mancozeb + tricyclazole at tillering and late booting stages gave good control of the disease. Application of edifenphos, chitosan, iprodione, or carbendazim in the field is also advisable.
Selected references	• International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, and IP Oña

False Smut


Infected panicle (IRRI)

Diagnostic summary

Damage to plants	• reduction in seed germination • chalkiness of grains - reduction in grain weight
Signs and symptoms	• individual rice grain transformed into a mass of yellow fruiting bodies • growth of velvety spores that enclose floral parts • immature spores slightly flattened, smooth, yellow, and covered by a membrane • growth of spores result to broken membrane • mature spores orange and turn yellowish green or greenish black • only few grains in a panicle are usually infected and the rest are normal
Factors favoring disease development	• presence of rain and high humidity • presence of soils with high nitrogen content • presence of wind for dissemination of the spores from plant to plant • presence of overwintering fungus as sclerotia and chlamydospores • flowering stage of the rice crop

Full fact sheet

Disease name	False smut
Pathogen	*Ustilaginoidea virens* (Cooke) Takah (anamorph), *Claviceps oryzae-sativae* Hashioka (teleomorph)
Symptoms	• Individual rice grain transformed into a mass of velvety spores or

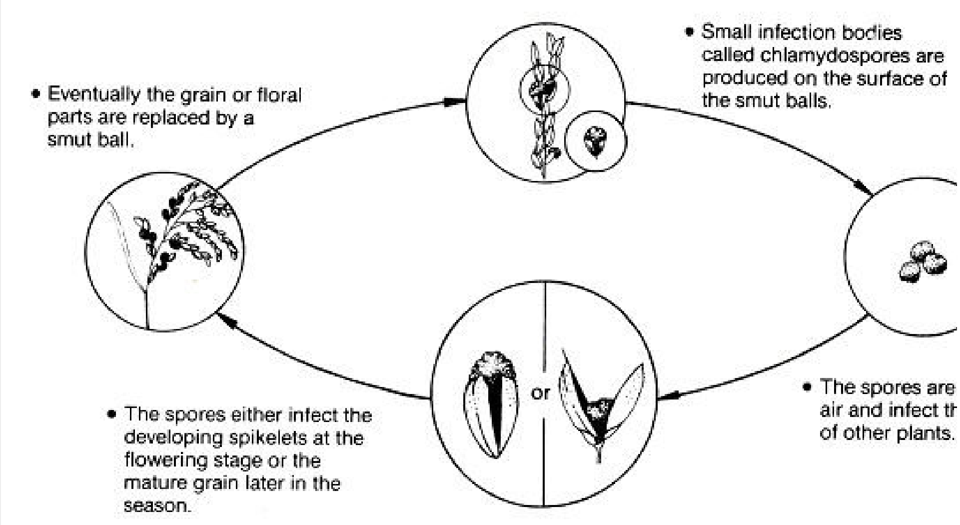
yellow fruiting bodies

- Growth of velvety spores enclose floral parts
- Immature spores slightly flattened, smooth, yellow, and covered by a membrane
- Growth of spores result to broken membrane
- Mature spores orange and turn yellowish green or greenish black
- Only few grains in a panicle are usually infected and the rest are normal

Severely infected panicle (IRRI)

Infected grains (on left) (IRRI)

Confirmation	Velvety mass of spores replaces individual grains of the panicle. The mass is greenish outside and yellow orange on the inside. In a panicle, only few grains are infected and the remaining grains are normal.
Problems with similar symptoms	The symptom of the disease is very specific, therefore no other disease exhibits this symptom.

Why and where it occurs	The disease is favored by periods of rain, high humidity, and soils with high nitrogen content. Wind causes dissemination of the spores from plant to plant. The fungus overwinters as sclerotia and chlamydospores. The primary infection of rice plants begins from the ascospores that are produced from sclerotia, whereas the secondary infection comes from chlamydospores.
Causal agent or factor	The causal organism is a fungus. The chlamydosphores or the conidia of the fungus are spherical to elliptical. They are pale and almost smooth when young, olivaceous and warty when mature, and measure 3-5 x 4-6 µm. They are formed along the hyphae on tiny sterigmata. In culture, the conidia form small and ovoid secondary conidia. Stipitate stromata with globose heads grow from the sclerotia. At the periphery, the heads are embedded with perithecia. The perithecia contain cylindrical, eight-spored asci. Ascopores are filiform, hyaline, and nonseptate.
Host range	In India, the pathogen was found to develop on *Oryza officinalis* Wall. and on a wild species of *Oryza*. It was also reported on *Digitaria ciliaris* (Retz.) Koel. (tropical finger grass), *Panicum trypheron* Schult., and *Zea mays* L. (maize).
Life cycle	
Mechanism of damage	There are two types of infection. One type occurs at flowering stage when the ovary is destroyed but the style, stigmas, and anther lobes remain intact and are buried in the spore mass. The second infection occurs when the grain is already mature. The spores accumulate in the glumes. The spores absorb moisture, swell, and force the lemma and palea to open. The fungus contacts the endosperm and growth is observed. The whole grain is replaced with a mass of spores.
When damage is important	The disease affects the early flowering stage of the rice crop when the ovary is destroyed. The second stage of infection occurs when the spikelet nearly reaches maturity.
Economic importanc	The disease causes chalkiness and can reduce 1,000-grain weight. It also causes a reduction in seed germination of up to 35%. In damp

e	weather, the disease can be severe and losses can reach 25%. In India, a yield loss of 7-75% was observed.
Management principles	No special control measures are necessary. There are varieties that are found to be resistant or tolerant against the disease in India. Among the cultural control, destruction of straw and stubble from infected plants is recommended to reduce the disease. In areas where the disease may cause yield loss, applying captan, captafol, fentin hydroxide, and mancozeb can be inhibited conidial germination. At tillering and preflowering stages, spraying of carbendazim fungicide and copper base fungicide can effectively control the disease.
Selected references	• International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Seth LN. 1945. Studies on the false smut disease of paddy caused by Ustilaginoides virens (Cke.) Tak. Ind. J. Agric. Sci. 15:53-55. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, NP Castilla, and FA Elazequi

Leaf Scald

Scalded leaf (IRRI)

Diagnostic summary

Damage to plants	• scalded appearance of leaves
Signs and symptoms	• zonate lesions from leaf tips or edges • lesions oblong with light brown halos in mature leaves • continuous enlargement and coalescing of lesions result in blight of a large part of the leaf blade • affected areas dry out giving the leaf a scalded appearance • translucent leaf tips and margins • infected leaf tips also split near the midrib especially when there are strong winds
Factors favoring disease development	• high nitrogen • wet weather - close spacing of plants • wounded leaves - sources of infection such as seeds and crop stubbles

Full fact sheet

Disease name	Leaf scald
Pathogen	*Microdochium oryzae* (Hashioka & Yokogi) Samuels & I.C. *Gerlachia oryzae* (Hashioka & Yokogi) W. Gams (synonym) *Rynchosporium oryzae* Hashioka & Yokogi (synonym) *Monographella albescens* (Thumen) Parkinson, Silvanesan & Booth (teleomorph) *Metasphaeria albescens* Thumen

	(synonym)
Symptoms	• Zonate lesions of alternating light tan and dark brown starting from leaf tips or edges • Lesions oblong with light brown halos in mature leaves • Individual lesions 1-5 cm long and 0.5-1 cm wide or may almost cover the entire leaf • Continuous enlargement and coalescing of lesions result in blighting of a large part of the leaf blade • The affected areas dry out giving the leaf a scalded appearance • Translucent leaf tips and margins • In some countries, lesions rarely develop the zonate pattern and only the scalding symptom is evident • In Costa Rica, the disease has been reported to cause decay of coleoptiles, with red brown infection, root rot, and a head blight that caused considerable sterility, flower deformation and glume discoloration • Infected leaf tips also split near the midrib especially when there are strong winds  Infected leaf tips (Suparyono, RIR)
Confirmation	A visible scalded appearance of the leaf easily distinguishes the disease from the other diseases. Immersing cut leaves in clear water for 5-10 minutes can identify leaf scald. It is a leaf scald if no ooze comes out.

Problems with similar symptoms	Leaf scald can be confused with bacterial leaf blight.
Why and where it occurs	Disease development usually occurs late in the season on mature leaves and is favored by wet weather, high nitrogen fertilization, and close spacing. Results of artificial inoculation using the conidial stage showed that the disease developed faster in wounded than unwounded leaves indicating that the fungus is a weak pathogen. The sources of infection are seeds and crop stubbles. Wet weather and high doses of nitrogenous fertilizer favor the disease.
Causal agent or factor	A fungus causes the leaf scald disease. The conidia are borne on superficial stromata (compact masses of specialized vegetative hyphae) arising from lesions. They are bow to new-moon shaped, single-celled when young and 2-celled when mature, occasionally 2-3 septate. They appear pink in mass and hyaline under the microscope. The teleomorph produces brown, globose perithecia that are embedded in the leaf tissue, except for the opening called ostiole. Perithecia embedded in the leaf tissues are spherical or slightly depressed. They are dark brown with an ostiole and measure 50-180 x 40-170 µm. Asci are cylindrical to club-shaped and unitunicate (an ascus wherein both the inner and outer walls are more or less rigid and do not separate during spore ejection). The asci often measure 40-65 x 10-14 µm. The ascospores are fusoid (tapering towards each end), straight or somewhat curved, 3-5 septate. They have long, slender, and colorless paraphyses (sterile, upward growing, basally attached hyphal filament or cell in a hymenium).
Host range	The hosts of the fungus include *Echinochloa crus-galli* (L.) P. Beauv. (cockspur) and *Oryza sativa* L. (rice). The infected weed may serve as a source of inoculum.
Life cycle	There is no available information on the life cycle of the disease.
Mechanism of damage	The conidia germinate and produce appressorium-like structures of various sizes upon contact with stomata. The fungus gains entry through the stomatal slits, thereby causing swelling of the stomata cavities. The substomatal hyphae grow profusely into the intercellular spaces and then into the mesophyll cells. About three days after inoculation, short-branched conidiophores grow out from the stomata and produce spore masses.
When damage is important	The fungal disease is important during the tillering and stem elongation stages of the rice crop.
Economic importance	In India and Bangladesh, yield losses of 23.4% and 20-30% were reported respectively. The disease has caused considerable losses in Latin America and West Africa.

Management principles	The only cultural control practice, which is applicable for the disease is to avoid high use of fertilizer. There are some cultivars from India with resistance to the disease. Chemicals such as benomyl, carbendazim, quitozene, and thiophanate-methyl can be used to treat the seeds to eliminate the disease. In the field, spraying of benomyl, fentin acetate, edifenphos, and validamycin significantly reduce the incidence of leaf scald. Foliar application of captafol, mancozeb, and copper oxychloride also reduces the incidence and severity of the fungal disease.
Selected references	• Bakr MA, Miah SA. 1975. Leaf scald of rice, a new disease in Bangladesh. Plant Dis. Rep. 55:909. • Chin KM. 1974. The leaf scald disease of rice. MARDI Research Bulletin 2:13-18. • Das SR. 1976. Screening of rice varieties for resistance to leaf-scald disease. Ind. J. Agric. Sci. 46:424-425. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Naito H, Koshimizu Y. 1974. Morphology and hyphal growth temperature of brown leaf fungus of rice (rice scald fungus). Ann. Phytopathol. Soc. Jpn. 20:319-328. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, and IP Oña

Narrow Brown Leaf Spot


Infected panicle (IRRI)

Diagnostic summary

Damage to plants	• premature death of leaves • premature ripening of grains
Signs and symptoms	• short, narrow, elliptical to linear brown lesions usually on leaf blades but may also occur on leaf sheaths, pedicels, and glumes or rice hulls • lesions narrower, shorter, and darker brown on resistant varieties • lesions wider and lighter brown with gray necrotic centers on susceptible varieties • leaf necrosis may also occur on susceptible varieties • lesions occur in large numbers during the later growth stages
Factors favoring disease development	• presence of rice crops grown on problem soil deficient in potassium • temperature from 25-28° C • susceptibility of the variety to the fungus • late growth stages of the rice crop

Full fact sheet

Disease name	Narrow brown leaf spot
Pathogen	*Cercospora janseana* (Racib.) O. Const. (anamorph) *Cercospora oryzae* Miyake *Sphaerulina oryzina* K. Hara (teleomorph)
Symptoms	• Short, narrow, elliptical to linear brown lesions usually on leaf blades but may also occur on leaf sheaths, pedicels, and glumes or rice hulls

- Lesions about 2-10 mm long and 1 mm wide
- Lesions narrower, shorter, and darker brown on resistant varieties
- Lesions wider and lighter brown with gray necrotic centers on susceptible varieties
- Leaf necrosis may also occur on susceptible varieties
- Lesions occur in large numbers during the later growth stages

Linear brown lesions on leaf (IRRI)

Linear spots on leaf (IRRI)

Confirmation

The linear form of the lesions of narrow brown leaf spot makes the disease distinct from other leaf diseases.

Problems with similar symptoms

The symptoms are similar to white leaf streak, which is caused by *Mycovellosiella oryza* and early stage of bacterial leaf streak caused by *Xanthomonas oryzae* pv. *oryzicola*.

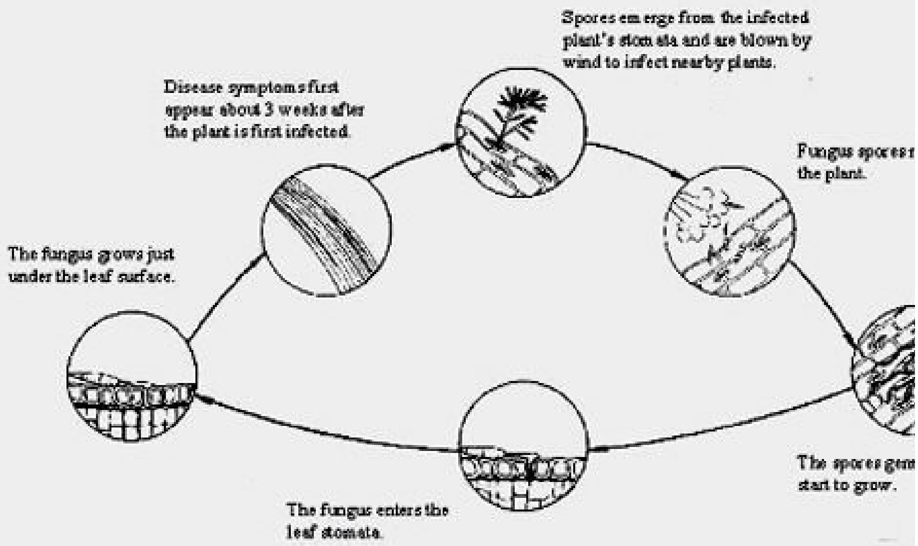
Why and where it occurs

The disease is observed on rice crops grown on soil deficient in potassium.

Temperature ranging from 25-28° C is favorable for the optimum growth of the disease. Susceptibility of the variety to the fungus and the growth stage of the rice crop are other factors that affect the development of the disease. Although rice plants are susceptible to the fungus at all stages of growth, they are more susceptible from panicle emergence to maturity, thus, becoming more severe as rice approaches maturity.

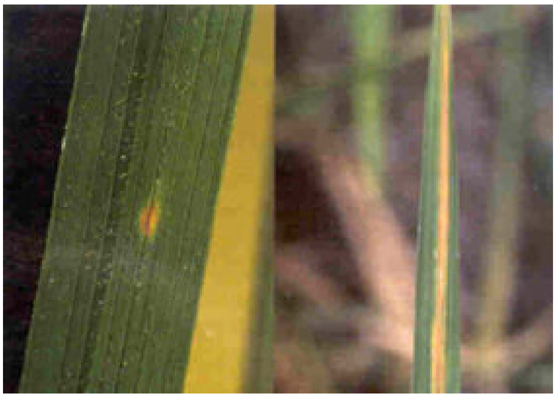
Causal agent or factor

The narrow brown leaf spot is caused by a fungus, which is commonly found in its sclerotial state.

	Its conidiophores appear singly or in fascicles of 1-7 and rarely up to 15. They are pale brown to medium brown. Conidiophores are unbranched, geniculate, and multiseptate. They measure 80-140 x 4-9 µm. Geniculations may be absent. Conidiophores often emerge from the host stomata. The conidia are hyaline, cylindrical to obclavate, and straight to mildly curved. They have 3-10 septa. The conidia measure 15-60 x 4 µm. A conidial scar is present. The teleomorph has perithecia, globose or subglobose, black, with a papiliform mouth (minute, rounded, blunt projection through which spores escape), immersed in the epidermal tissues of the host plant and which measure 60-100 µm in diameter. Asci cylindrical or club-shaped, round at the top, stipitate (having a stipe or stem) with ascospores biseriate (in two series) spindle-shaped, straight or slightly curved, 3-septate, hyaline, 20-23 x 4-5 µm.
Host range	Aside from the rice plant, the fungus can survive on *Panicum maximum* Jacq. (guinea grass), *P. repens* L. (torpedo grass), and *Pennisetum purpureum* K. Schum. (elephant grass).
Life cycle	
Mechanism of damage	The fungus penetrates the host tissue through the stomata. It becomes stable in the parenchyma where it stays beneath the stomata and spreads longitudinally in the epidermal cells.
When damage is important	Narrow brown leaf spot usually occurs during the late growth stages of the rice crop.
Economic importanc	Premature death of leaves and leaf sheaths, premature ripening of kernels and lodging of plants are observed during severe infection. It

e	decreases the market value of the grains because it causes grain discoloration and chalkiness, and reduces the milling recovery. A 40% loss in yield was reported in Suriname during the 1953 and 1954. The disease has been reported in several countries in Asia, Africa, Australia, and Papua Guinea.
Manageme nt principles	Cultural practices, such as the use of potassium and phosphorus fertilizers, and planting of early maturing cultivars early in the growing season, are recommended to manage the narrow brown leaf spot. The use of resistant varieties is the most effective approach to manage the disease. However, the resistant varieties and lines are only grown in United States and India. Spraying of fungicides such benomyl, propicanazole, carbendazim, propiconazole, and iprodione, when the disease is observed in the field is effective.
Selected references	• International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributo rs	Suparyono, JLA Catindig, NP Castilla, and FA Elazequi

Red Stripe



Lesion of red stripe disease (N Catilla, IRRI)

Diagnostic summary

Damage to plants	• formation of lesions on leaves
Signs and symptoms	• initial symptom is pin-sized orange spot at any place on leaf blade • transparent stripe that advances from the spots upward to leaf tip and never downward • lesions become necrotic and coalesce forming a blight appearance on the leaves
Factors favoring disease development	• high temperature and high relative humidity • high leaf wetness - high nitrogen • flowering to ripening stages of the rice crop

Full fact sheet

Disease name	Red stripe
Pathogen	Unknown
Symptoms	• Initial symptoms are pin-sized lesions, often yellow green to light orange • Older lesions appear as orange spots with an upward stripe, which advances towards the tip of the leaves • Lesions become necrotic and coalesce forming a blight appearance on the leaves • Lesions more common on the leaves and, less common on the sheaths

Translucent lesions (N Castilla, IRRI)

Close-up of red stripe lesion on rice

Confirmation	The shape, size and color of lesions easily distinguishes red stripe from other fungal diseases of rice. An advanced lesion is characterized by an orange spot with a stripe, which advances towards the tip of the leaf.
Problems with similar symptoms	The disease can be confused with orange leaf blight disease. It is hardly distinguishable from the bacterial leaf blight disease at severe and advanced stage of disease development.
Why and where it occurs	The disease usually occurs when the plants reach the reproductive stage, starting from the panicle initiation. High temperature, high relative humidity, high leaf wetness and high nitrogen supply favor disease development. The disease was first reported in Indonesia as bacterial red

	stripe in 1988. It was later reported to occur in the Philippines, Vietnam, Malaysia and Thailand. Red stripe has not been observed in temperate rice-growing countries.
Causal agent or factor	No literature is available to describe the causal agent of the red stripe disease.
Host range	The hosts other than the rice plant of the disease are not known.
Life cycle	The life cycle of the red stripe disease is not known.
Mechanism of damage	The mechanism of damage is unknown.
When damage is important	Disease intensity is high from flowering to ripening stages of the crop.
Economic importance	Red stripe of rice is common in Indonesia, Malaysia, Philippines, Thailand and Vietnam. It is a potential threat to rice production in Southeast Asia. However, no reliable quantification of yield losses has been done yet.
Management principles	Benzimidazole fungicides, such as benomyl, carbendazim, and thiophanate methyl, are effective against the disease. The application of nitrogen based on the actual requirements of the crop can manage red stripe without reducing yield. Optimum seeding rate and wider plant spacing also appear to reduce the disease. Initial studies in Indonesia suggest that intermittent drainage when plants reach panicle initiation can reduce the disease. One local improved glutinous rice variety was found to be resistant to the disease in Indonesia.
Selected references	• Du PV, Lan NTP, Dinh HD. 1991. Red stripe, a newly reported disease of rice in Vietnam. Int. Rice Res. Newsl. 16(3):25. • Du Pv, Dinh HD, Lan NTP, Sau TT, Ba DX. 1991. Field evaluation to control "red stripe", a new rice disease in Vietnam. Int. Rice Res. Newsl. 16(5):21-22. • Mew TW, Castilla NP, Elazegui FA, Vera Cruz CM. 2001. The etiology of red stripe of rice: current status and future directions. Int. Rice Res. Newsl. 26(1):4-10. • Suparyono. 1999. An overview on the study of bacterial orange leaf blight of rice in Indonesia. Paper presented at the Planning Workshop on Red Sripe, 15-18 March, Ho Chi Minh City, Vietnam.
Contributors	Suparyono, JLA Catindig, NP Castilla, and FA Elazequi

Rice Blast


Infected leaves (IRRI)

Diagnostic summary

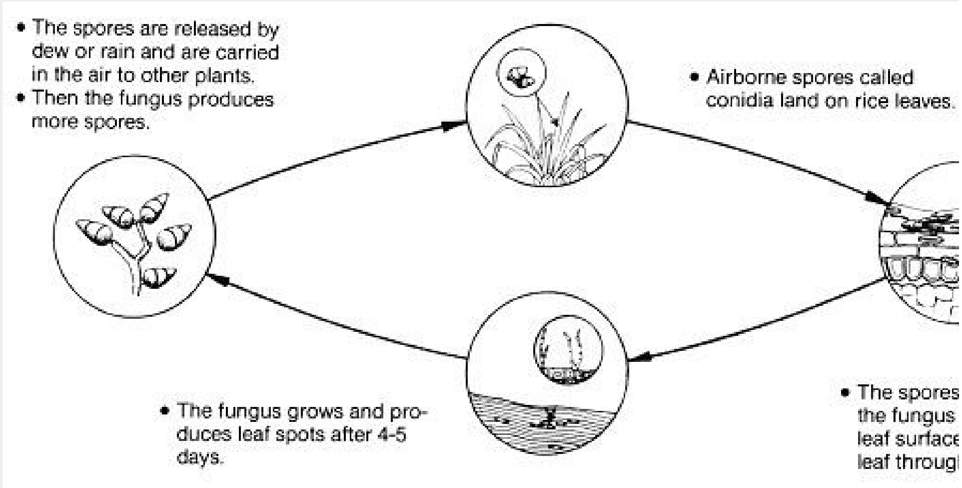
Damage to plants	• production of spores • penetration of infection
Signs and symptoms	• initial symptoms are white to gray-green lesions or spots with darker borders produced on all parts of shoot • older lesions elliptical or spindle-shaped and whitish to gray with necrotic borders • lesions wide in the center and pointed toward either end • lesions may enlarge and coalesce to kill the entire leaves • symptoms also observed on leaf collar, culm, culm nodes, and panicle neck node • internodal infection of the culm occurs in a banded pattern • nodal infection causes the culm to break at the infected node • few, no seeds, or whiteheads when neck is infected or rotten
Factors favoring disease development	• presence of the blast spores in the air throughout the year • upland rice environment • cloudy skies, frequent rain, and drizzles • high nitrogen levels • high relative humidity and wet leaves • growing rice in aerobic soil in wetlands where drought

	stress is prevalent

Full fact sheet

Disease name	Rice Blast
Pathogen	**Pathogen:** *Pyricularia oryzae* Cavara (anamorph), *Magnaporthe grisea* (T. T. Hebert) Yaegashi & Udagawa (teleomorph)
Symptoms	• Initial symptoms white to gray-green lesions or spots with darker borders produced on all parts of shoot • Older lesions elliptical or spindle-shaped and whitish to gray with necrotic borders • Lesions wide in the center and pointed toward either end • Lesions may enlarge and coalesce to kill the entire leaves • Larger lesions (2 cm long) at reproductive stage on younger plants (< 1 cm long) • Symptoms also observed on leaf collar, culm, culm nodes, and the panicle neck node • Internodal infection of the culm occurs in a banded pattern with a 3-cm blackened necrotic culm and 3-cm healthy tissue in succession • Nodal infection causes the culm to break at the infected node • Few, no seeds, or whiteheads when neck is infected or rotten  Severely infected panicle (IRRI)
Confirmation	The lesions are elongated and pointed at each end.
Problems with similar symptoms	The pinhead-size brown lesions can be confused from the symptoms of brown spot disease caused by *Helminthosporium oryzae*. The whiteheads symptom looks the same as the whiteheads produced by the stem borer.
Why and where it occurs	In the tropics, blast spores are present in the air throughout the year, thus favoring continuous development of the disease. The infection brought about by the fungus damages upland rice severely than the irrigated rice. It rarely attacks the leaf sheaths. Primary infection starts where seed is sown densely in seedling boxes for mechanical transplanting.

	In the temperate countries, it overseasons in infested crop residue or in seed. Cloudy skies, frequent rain, and drizzles favor the development and severity of rice blast. High nitrogen levels, high relative humidity, and wet leaves encourage infection caused by the fungus. The rate of sporulation is highest with increasing relative humidity of 90% or higher. For leaf wetness, the optimum temperature for germination of the pathogen is 25-28 °C. Growing rice in aerobic soil in wetlands where drought stress is prevalent also favors infection.
Causal agent or factor	A fungus causes rice blast. Its conidiophores are produced in clusters from each stoma. They are rarely solitary with 2-4 septa. The basal area of the conidiophores is swollen and tapers toward the lighter apex. The conidia of the fungus measure 20-22 x 10-12 µm. The conidia are 2-septate, translucent, and slightly darkened. They are obclavate and tapering at the apex. They are truncate or extended into a short tooth at the base.
Host range	Aside from the rice plant, the fungus also survives on *Agropyron repens* (L.) Gould, *Agrostis palustris*, *A. tenuis*, *Alopecurus pratensis*, *Andropogon* sp., *Anthoxanthum odoratum*, *Arundo donax* L., *Avena byzantina*, *A. sterilis*, *A. sativa*, *Brachiaria mutica* (Forssk.) Stapf, *Bromus catharticus*, *B. inermis*, *B. sitchensis*, *Canna indica*, *Chikushichloa aquatica*, *Costus speciosus*, *Curcuma aromatica*, *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *C. compressus* L., *Dactylis glomerata*, *Digitaria sanguinalis* (L.) Scop, *Echinochloa crus-galli* (L.) P. Beauv., *Eleusine indica* (L.) Gaertn., *Eragrostis* sp., *Eremochloa ophiuroides*, *Eriochloa villosa*, *Festuca altaica*, *F. arundinacea*, *F. elatior*, *F. rubra, Fluminea* sp., *Glyceria leptolepis*, *Hierochloe odorata*, *Holcus lanatus*, *Hordeum vulgare*, *Hystrix patula*, *Leersia hexandra* Sw., *L. japonica*, *L. oryzoides*, *Lolium italicum*, *L. multiflorum*, *L. perenne*, *Muhlenbergia* sp., *Musa sapientum*, *Oplismenus undulatifolius* (Ard.) Roem. & Schult., *Panicum miliaceum* L., *P. ramosum* (L.) Stapf, *P. repens* L., *Pennisetum typhoides* (L.) R. Br., *Phalaris arundinacea* L., *P. canariensis*, *Phleum pratense*, *Poa annua* L., *P. trivialis*, *Saccharum officinarum*, *Secale cereale*, *Setaria italica* (L.) P. Beauv., *S. viridis* (L.) P. Beauv., *Sorghum vulgare*, *Stenotaphrum secundatum*, *Triticum aestivum*, *Zea mays* L., *Zingiber mioga*, *Z. officinale*, and *Zizania latifolia*.

Life cycle	
Mechanism of damage	Conidia are produced on lesions on the rice plant about 6 days after inoculation. The production of spores increases with increase in the relative humidity. Most of the spores are produced and released during the night. After spore germination, infection follows. Infection tubes are formed from the appressoria and later the penetration through the cuticle and epidermis. After entering the cell, the infection tube forms a vesicle to give rise to hyphae. In the cell, the hyphae grew freely.
When damage is important	Rice blast infects the rice plant at any growth stage. Rice seedlings or plants at the tillering stage are often completely killed. Likewise, heavy infections on the panicles usually cause a loss in rice yields.
Economic importance	Rice blast is one of the most destructive diseases of rice because of its wide distribution and its destructiveness. In India, more than 266,000 tons of rice were lost, which was about 0.8% of their total yield. In Japan, the disease can infect about 865,000 hectares of rice fields. In the Philippines, many thousand hectares of rice fields suffer more than 50% yield losses. A 10% neck rot causes yield loss of 6% and 5% increases in chalky kernels.
Management principles	There are some cultural practices that are recommended against the rice blast. For example, manipulation of planting time and fertilizer and water management is advised. Early sowing of seeds after the onset of the rainy season is more advisable than late-sown crops. Excessive use of fertilizer should be avoided as it increases the incidence of blast. Nitrogen should be applied in small increments at any time. Water management practices in rainfed areas lessen the likelihood of stress, which also aid in blast control. Planting resistant varieties against the rice blast is the most practical and economical way of controlling rice blast. Systemic fungicides such as pyroquilon and tricyclazone are possible chemicals for controlling the disease.
Contributors	Suparyono, JLA Catindig, and IP Oña

Rice Grassy Stunt Virus (RSGV)

Plant damage (IRRI)

Diagnostic summary

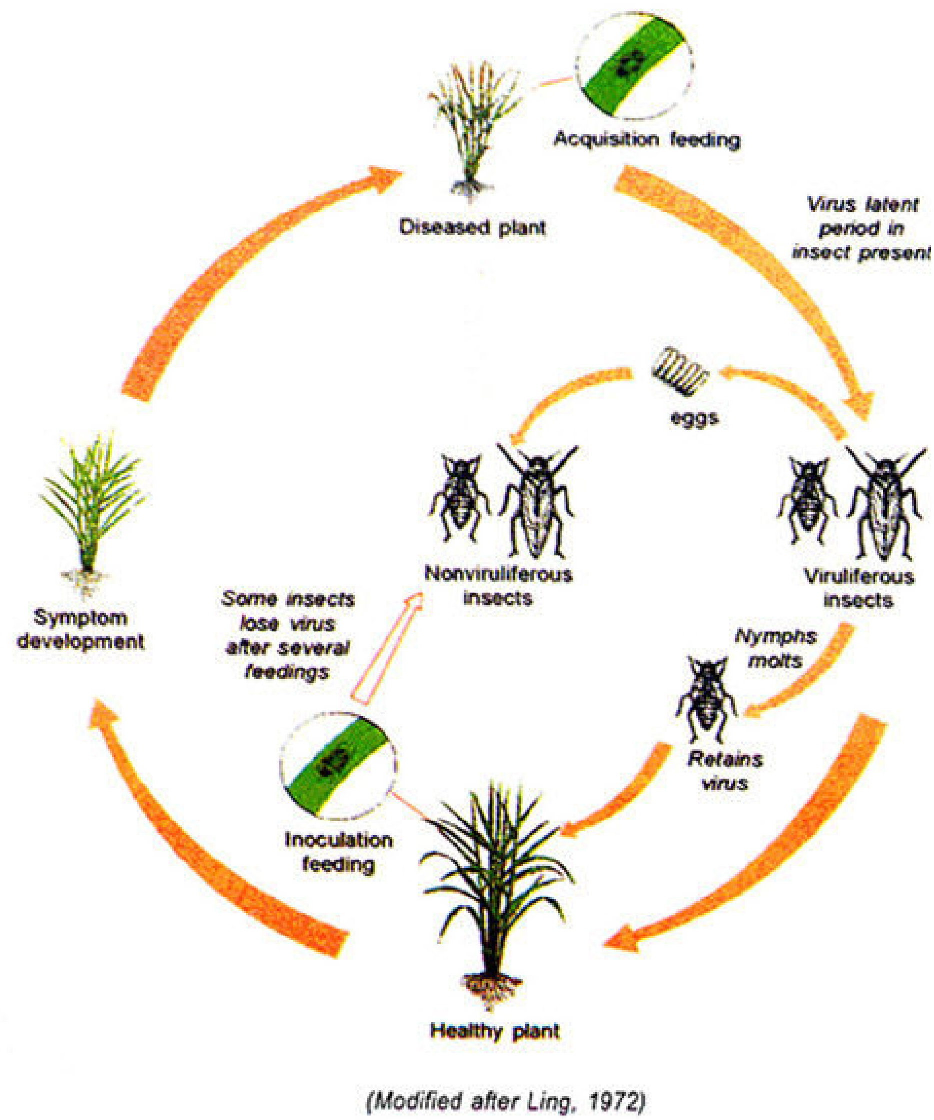
Damage to plants	• symptoms of virus infection • no panicle production
Signs and symptoms	• stunting • excessive tillering • very upright growth habit • grassy and rosette appearance • leaves short, narrow, and yellowish green with numerous • small rusty spots or patches, which form blotches • infected plants usually survive until maturity, but produce no panicles • the symptom develops 10-20 days after infection
Factors favoring disease development	• availability of the vector • all growth stages especially the tillering stage of the rice crop

Full fact sheet

Disease name	Rice grassy stunt virus (RGSV)
Symptoms	• Diseased hills are severely stunted with excessive tillering and

	a very upright growth habit • Diseased hills has a grassy and rosette appearance • Leaves short, narrow, and yellowish green with numerous small rusty spots or patches, which form blotches • Retention of green coloration of the leaves after application of sufficient nitrogenous fertilizers • Infected plants usually survive until maturity, but produce no panicles • The symptom develops 10-20 days after infection  Infected plants (IRRI)  Infected plant (IRRI)
Confirmation	The grassy or rosette appearance of the infected plant easily distinguishes the diseased plant from the normal plants. Severe stunting with yellow and rusty spots on leaves is prominent.
Problems with similar symptoms	Stunting and increased tillering symptoms can be confused with the rice yellow dwarf and rice dwarf disease.

Why and where it occurs	The virus exists in the vector and in the rice crop. Brown planthopper nymphs and adults transmit it where rice is grown year-round. RGSV is generally endemic. The macropterous forms or the long winged adults of the insect are important in spreading the disease than the short winged forms. They feed on the diseased plant for at least 30 minutes to pick-up the virus. Higher infection is attained after prolonged inoculation feeding periods of up to 24 hours. The availability of the vector encourages the damage.
Causal agent or factor	The grassy stunt virus is transmitted by the brown planthopper *Nilaparvata lugens* Stal. The disease can also be transmitted by *Nilaparvata bakeri* Muir and *N. muiri* China. The interaction between the virus and its vector is persistent without transovarial passage. The insect acquires the virus during at least 30 minutes of feeding period. The plants can be infected in as little as 9 minutes of feeding. Incubation in the insect takes around 5-28 days with an average of 11 days, whereas in plants, incubation ranges from 10 to 19 days. Viruliferous insects remain infective for life. Rice grassy stunt virus (RGSV) is a member of the Tenuiviruses. It has fine filamentous particles, which are 6-8 nm in diameter. It has a nodal contour length of 950-1,350 nm. The particles have one capsid protein and the genome is made up of four single-stranded RNA.
Host range	The disease is only found in the rice crop.

Life cycle	
Mechanism of damage	Both nymphs and adults of brown planthopper transmit grassy stunt virus. The insects can get the virus by feeding on diseased plants in a 6 hr-acquisition access period (minimum of 30 minutes). Longer feeding periods of up to 24 hours caused higher percentage of infected insects. After a latent period of 5-28 days (average of 10-11 days), the brown planthoppers can transmit the virus in an inoculation access period of several minutes to 24 hr (minimum of 5-15 minutes). The infected insects can transmit the virus until they die.
When damage is important	The disease affects all growth stages of the rice crop. Infected plants live until maturity, however, the most vulnerable plant growth stage is tillering, and at which infected hills produced no panicles.
Economic importance	The grassy stunt virus is not a widespread problem. It became a serious problem during brown planthopper outbreaks in 1975 to 1977 in Indonesia. During sporadic outbreaks, it can cause serious damage in limited areas. For example, yield loss is higher when infection

	occurs early in the season.
Management principles	A single dominant gene governs resistance. A strain of wild rice, *Oryza nivara* Sharma & Shastry, was found to be resistant to the pathogen. The control of brown planthopper, either with chemical, resistant varieties, or other control measures, result in the control of RGSV.
Selected references	• Cabauatan PQ, Hibino H. 1991. Monoclonal antibodies for detection of rice viruses: grassy stunt, dwarf, gall dwarf, and ragged stunt. In: Maramorosch K, editor. Biotechnology for biological control of pests and vectors. Boca Raton, Florida (USA): CRC Press, Inc. p 119-131. • Hibino H, Usugi T, Omura T, Tsuchizaki T, Shohara K, Iwasaki M. 1985. Rice grassy stunt virus: a planthopper-borne circular filament. Phytopathology 75:849-899. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Ling KC. 1972. Rice virus diseases. Manila (Philippines): International Rice Research Institute. 134 p.
Contributors	Suparyono, JLA Catindig, and PQ Cabauatan

Rice Ragged Stunt Virus (RRSV)

Infected panicle

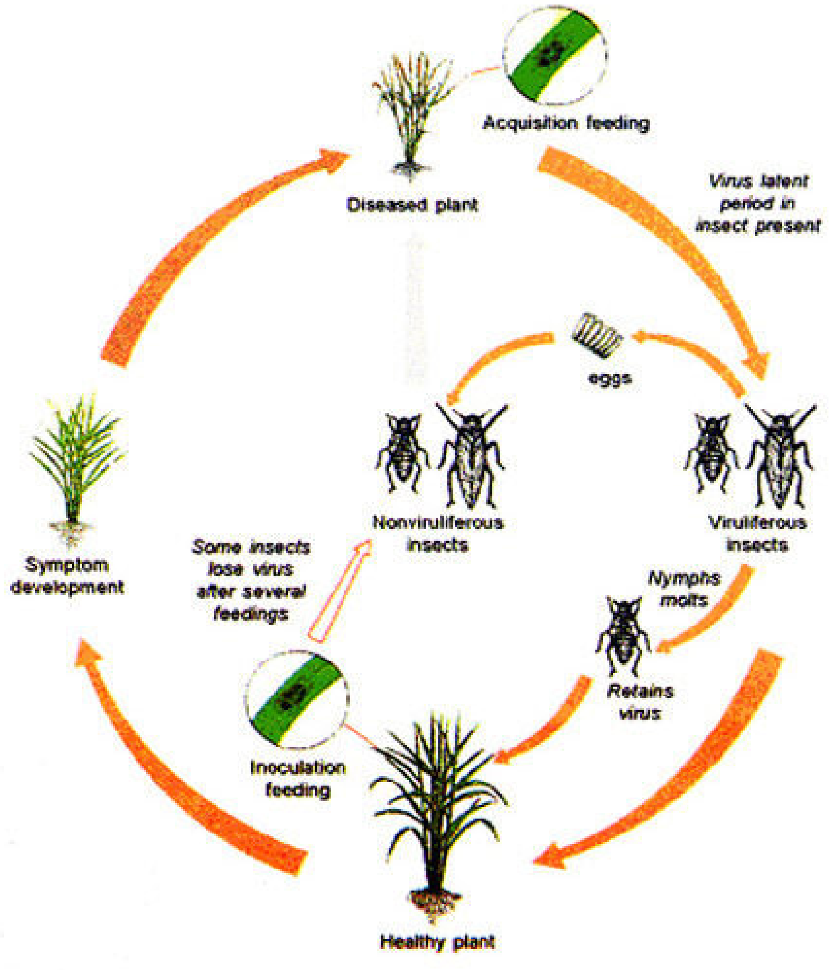
Diagnostic summary

Damage to plants	• partially exserted panicles and unfilled grains • there are spaces between too few plants
Signs and symptoms	• stunting during early growth stages of the crop • leaves short and dark green with serrated edges • leaf blades twisted at the apex or base • leaf edges uneven and the twisting give the leaves a ragged appearance • ragged portions of the leaves are yellow to yellow-brown • vein swellings develop on the leaf blades and sheaths • swellings pale yellow or white to dark brown • flag leaves twisted, malformed, and shortened at booting stage • flowering is delayed • incomplete panicle emergence • nodal branches produced at upper nodes • partially exserted panicles and unfilled grains
Factors favoring disease development	• presence of the vector and the host • tillering, reproductive, and maturity growth stages of the rice plant

Full fact sheet

Disease name	Rice ragged stunt virus (RRSV)
Symptoms	• Infected plants severely stunted during early growth stages of

	the crop • Leaves short and dark green with serrated edges • Leaf blades twisted at the apex or base, which result in the spiral shape of the leaves • Leaf edges uneven and the twisting give the leaves a ragged appearance • Ragged portions of the leaves are yellow to yellow-brown • Vein swellings develop on the leaf blades and sheaths • Swellings pale yellow or white to dark brown • Flag leaves twisted, malformed, and shortened at booting stage • Flowering is delayed • Incomplete panicle emergence • Nodal branches produced at upper nodes • Partially exserted panicles and unfilled grains
Confirmation	Leaves show various symptoms like ragged appearance, twisted leaves, and vein swelling. Severely infected plant is stunted and greener in color. Presence of the vector *Nilaparvata lugens* (Stal) is an indication of RRSV disease.
Problems with similar symptoms	The ragged appearance and twisted leaf symptoms can be confused with the damage caused by rice whorl maggot and nematodes.
Why and where it occurs	The infection and the vector density are very high in tropical regions where rice is planted year-round.
	The presence of the vector and the host continuously support the development of infection or pathogen.
Causal agent or factor	The brown planthopper transmits the disease. The early instar nymphs of the insect are more efficient in transmitting the disease than older ones. Five-day-old nymphs are the most efficient transmitters. The virus is acquired within a feeding period of 24 hours. Viral particles are 63-65 nm in diameter and consist of five proteins. They are mostly found in phloem and gall cells. The genome consists of ten double-stranded RNA segments. The virus is circulative and propagative in the insect vectors.
Host range	Aside from the rice plant, the virus also infects *Oryza latifolia* Desv. and *O. nivara* Sharma & Shastry.

Life cycle	 (Modified after Ling, 1972)
Mechanism of damage	The brown planthoppers can pick up the virus from infected plants in a 1 day acquisition access period. The latent period is 3-35 days (with an average of 8-6 days). The vectors transmit the disease in a 6 hour-inoculation access period (minimum of 1 hour). The vector retains the virus after each molt and remains infective for life.
When is damage important	The disease is important during the tillering, reproductive, and maturity growth stages of the rice plant.
Economic importance	The rice crop infected with the disease has partially exserted panicles and unfilled grains. Infected plants produce few or no grains at all depending on the extent of damage. In Indonesia, a field survey showed yield losses of 53-82% after 34-76% of the plants were affected. Some fields in the central plain region had 90% infection and the yield was less than 10% of the normal crop.
Management principles	There are no specific control measures for the ragged virus disease except for the use of resistant varieties. Because some rice varieties

	are resistant to the brown planthopper, to the virus, and to both. Cultivars resistant to the vector have low disease incidence. The application of insecticides to migratory planthoppers is being used in temperate countries to reduce disease incidence.
Selected references	• Cabauatan PQ, Hibino H. 1991. Monoclonal antibodies for detection of rice viruses: grassy stunt, dwarf, gall dwarf, and ragged stunt. In: Maramorosch K, editor. Biotechnology for biological control of pests and vectors. Boca Raton, Florida (USA): CRC Press, Inc. p 119- 131. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Ling KC, Tiongco ER, Aguiero VM, Cabauatan PQ. 1978. Rice ragged stunt disease in the Philippines. Philippine Phytopathology 14:38-57. • Mariappan V, Yesuraja I, Gomathi N. 1998. Viral, mycoplasmal and bacterial diseases of rice and their integrated management. In: Paul SM, editor. Pathological problems of economic crop plants and their management. Jodhpur (India): Scientific Publishers. 47 p.
Contributors	Suparyono, JLA Catindig, and PQ Cabauatan

Sheath Blight

Infected sheath (IRRI)

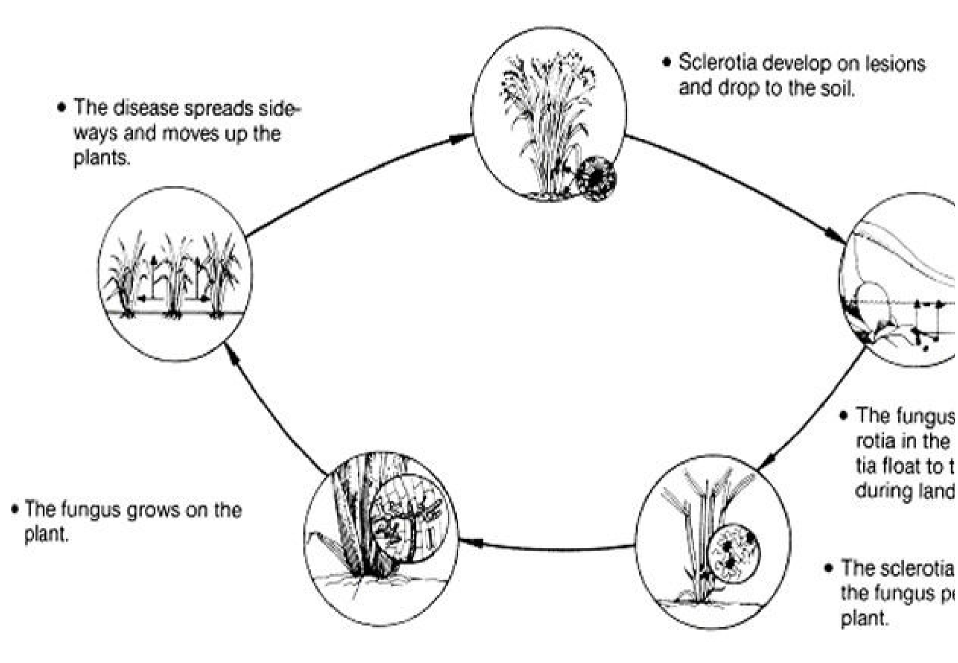
Diagnostic summary

Damage to plants	• formation of lesions - production of empty grains
Signs and symptoms	• initial lesions are water-soaked to greenish gray and later becomes grayish white with brown margin • lesions on leaf sheaths near waterline and on leaves • presence of sclerotia • lesions may coalesce to form bigger lesions • death of the whole leaf • filled or empty grains, especially those on the lower portion of the panicles
Factors favoring disease development	• presence of the disease in the soil • presence of sclerotia or infection bodies floating on the water • relative humidity from 96 to 100% • temperature from 28-32 °C • high levels of nitrogen fertilizer • presence of irrigation water • growing of high yielding improved varieties • late tillering or early internode elongation growth stages

Full fact sheet

Disease name	Sheath blight
Pathogen	*Rhizoctonia solani* Kunh (anamorph), *Thanatephorus cucumeris* (Frank) Donk (teleomorph)
Symptoms	• Initial lesions are small, ellipsoidal or ovoid, greenish-gray and water-soaked and usually develop near the water line in lowland fields • Older lesions are elliptical or ovoid with a grayish white center and light brown to dark brown margin • Lesions may reach the uppermost leaf under favorable conditions • Lesions may coalesce forming bigger lesions with irregular outline and may cause the death of the whole leaf • Severely infected plants produced poorly filled or empty grains, especially those on the lower portion of the panicles  Bigger lesions (Suparyono, RIR) 

	Older lesions on sheath (IRRI)
Confirmation	The disease is easily distinguished by the irregular lesions, which are initially water-soaked to greenish gray and later becomes grayish white with brown margin. These lesions are usually found on the leaf sheaths near the waterline and on the leaves. The disease can be confirmed by the presence of sclerotia. Sclerotia and mycelia may be produced on the lesions. Sclerotia are compact masses of mycelia, which are irregular, hemispherical, flattened at the bottom, white when young, and turn brown or dark brown when mature.
Problems with similar symptoms	Lesions on the stem are sometimes confused with those caused by stem rot. Lesions on the stem resulting from stemborer infestation can be sometimes confused with sheath blight lesions.
Why and where it occurs	The disease is soilborne. It usually starts at the base of the plant near the water level. Later, the symptoms are observed on the upper leaf sheath and on the leaf blade. The disease usually infects the plant at late tillering or early internode elongation growth stages. Disease may spread from one hill to another through leaf-to-leaf or leaf-to-sheath contacts. It is commonly assumed that the critical factors for disease development are relative humidity and temperature. Relative humidity ranging from 96 to 100% and temperature ranging from 28-32°C have been reported to favor the disease. High supply of nitrogen fertilizer, and growing of high-yielding, high-tillering, nitrogen-responsive improved varieties favor the development of the disease. High leaf wetness and high frequency of tissue contacts among plants also favor the disease. The pathogen can be spread through irrigation water and by movement of soil and infected crop residues during land preparation.
Causal agent or factor	The young mycelium of the fungus is colorless. With age, it turns yellowish to brown and measures 8-12 µm in diameter with infrequent septations. There are three types of mycelium produced: runner hyphae, lobate hyphae, and monilioid cells. The runner hyphae have thick, parallel walls and spread rapidly over the sheath and leaf surfaces of the rice plant. The runner hyphae give rise to lobate hyphae or appressoria. Monilioid cells are short, broad cells involved in the formation of sclerotia. Sclerotia consist of compact masses of mycelia. They are irregular, hemispherical, flattened at the bottom, white when young, and turn brown or dark brown when older. Individual sclerotia are 1-6 mm in diameter. They may unite to form a larger mass. Large sclerotia are significantly more virulent than smaller ones.
Host range	Aside from the rice plant, the disease survives in citrus, cruciferous vegetables, legumes, cucurbits, *Arachis hypogaea* L. (groundnut), *Capsicum annum* L. (chilli), *Daucus carota* L. (carrot), *Glycine max* (soyabean), *Gossypium* sp. (cotton), *Hordeum vulgare* (barley), *Lactuca sativa* L. (lettuce), *Lycopersicon esculentum* Mill. (tomato), *Sorghum bicolor* (sorghum), *Triticum* sp. (wheat), *Tulipa* sp. (tulips), and *Zea mays* L. (maize).

Life cycle	
Mechanism of damage	The sclerotia germinate and initiate infection once they get in contact with the rice plant. The fungus penetrates through the cuticle or the stomatal slit. Infection pegs are formed from each lobe of the lobate appressorium of infection cushion. The mycelium grows from the outer surface of the sheath going through the sheath edge and finally through the inner surface. Primary lesions are formed while the mycelium grows rapidly on the surface of the plant tissue and inside its tissue. It proceeds upwards and laterally to initiate formation of the secondary lesions.
When damage is important	The disease starts during the maximum growth stage of the rice crop. Under favorable conditions, the disease increases as the plant grows older. The damage caused by the disease depends on the infection of the plants at plant growth stages.
Economic importance	Sheath blight is considered to be an important disease next to rice blast. Rice sheath blight is an increasing concern for rice production especially in intensified production systems. In Japan, the disease caused a yield loss of as high as 20% and affected about 120,000-190,000 hectares. A yield loss of 25% was reported if the flag leaves are infected. In the United States, a yield loss of 50% was reported when susceptible cultivars were planted. Studies at IRRI showed that sheath blight causes a yield loss of 6% in tropical Asia.
Management principles	Seeding rate or plant spacing should be optimized to avoid closer plant spacing or dense crop growth which favors the horizontal spread of the disease. Need-based or real-time application of nitrogen fertilizer is recommended in fields known to have a high amount of inoculum. Sanitation, specifically removing of weeds, can help control sheath

	blight considering that the pathogen also attacks weeds which are commonly found in rice fields. Removal of infected stubbles or crop residues from the field is also recommended to reduce the amount of inoculum for the succeeding cropping season. Spraying infected plants with fungicides, such as benomyl and iprodione, and antibiotics, such as validamycin and polyoxin, is effective against the disease.
Selected references	• Castilla, NP, Elazegui FA, Savary S. 1995. Inoculum efficiency in sheath blight as affected by contact frequency, leaf wetness regime, and nitrogen supply. Int. Rice Res. Notes 20(1):38-39. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Agricultural Bureau 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Roy AK, Saikia UN. 1976. Chemical control of sheath blight of rice. Indian Phytopathol. 29:354-356.
Contributors	Suparyono, JLA Catindig, NP Castilla, and FA Elazequi

Sheath Rot

Infected sheaths (IRRI)

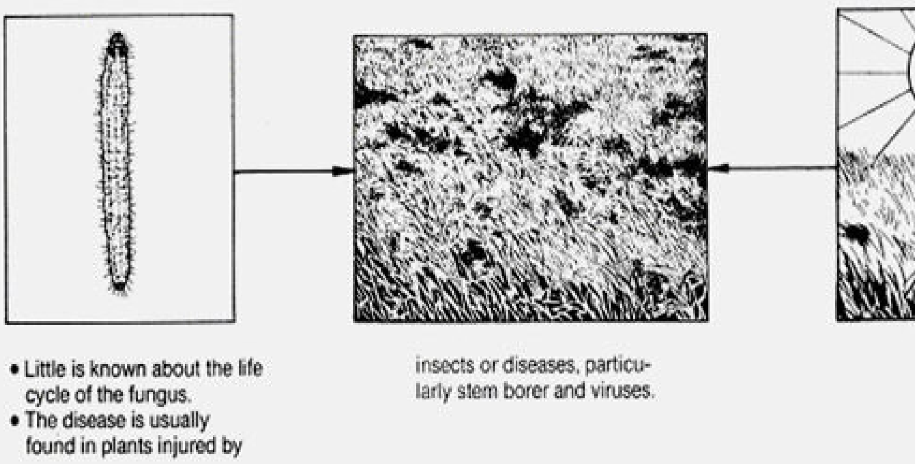
Diagnostic summary

Damage to plants	• development of spots or lesions • unfilled and discolored panicles
Signs and symptoms	• irregular spots or lesions, with dark reddish brown margins and gray center • discoloration in the sheath • lesions enlarge and often coalesce and may cover the entire leaf sheath • severe infection causes entire or parts of young panicles to remain within the sheath • unemerged panicles rot and florets turn red-brown to dark brown • whitish powdery growth inside the affected sheaths and young panicles • infected panicles sterile, shrivelled, or with partially filled grain
Factors favoring disease development	• associated with insect injury • presence of entry points • high amount of nitrogen • high relative humidity • dense crop growth

	• temperature from 20 to 28°C - heading to maturity rice crop stages

Full fact sheet

Disease name	Sheath rot
Pathogen	*Sarocladium oryzae* (Sawada) W. Gams & D. Hawksw
Symptoms	• Infection occurs on the uppermost leaf sheath enclosing the young panicles at late booting stage • Initial symptoms are oblong or somewhat irregular spots or lesions, 0.5-1.5 cm long, with dark reddish brown margins and gray center • Lesions may also consist of diffuse reddish brown discoloration in the sheath • Lesions enlarge and often coalesce and may cover the entire leaf sheath • Severe infection causes entire or parts of young panicles to remain within the sheath • Unemerged panicles rot and florets turn red-brown to dark brown • Visible abundant whitish powdery growth inside the affected sheaths and young panicles • Infected panicles are discolored, sterile, shrivelled, or with partially filled grain  Infected sheath with panicles (IRRI)
Confirmation	Lesions develop on the uppermost leaf sheaths that enclose the panicles. Some panicles do not emerge or emerge partially. Rotting of

	the sheath and the development of whitish powdery fungal growth is usually observed.
Problems with similar symptoms	Sheath rot lesions are sometimes confused with sheath blight lesions.
Why and where it occurs	High amount of nitrogen, high relative humidity, and dense crop growth favors sheath rot development. The fungus grows best at 20 to 28°C.
Causal agent or factor	A fungus causes the disease. The mycelium of this fungus is white and sparsely branched with septate hyphae. It measures 1.5-2 µm in diameter. Conidiophores arising from the mycelium are slightly thicker than the vegetative hyphae. They are branched once or twice and each time with 3-4 branches in a whorl. The main hyphal axis is 15-22 x 2-2.5 µm. It has the terminal branches tapering toward the tip and measures 23-45 µm long and 1.5 µm at the base. Conidia are borne simply on the tip. They are produced consecutively. Conidia are hyaline, smooth, single-celled, and cylindrical. They measure 4-9 x 1-2.5 µm.
Host range	The disease is host to *Oryza sativa* L. Its alternate host includes maize, pearl millet, sorghum, *Echinochloa colona* (L.) Link (jungle grass), *Eleusine indica* (L.) Gaertn. (goosegrass), *Leptochloa chinensis* (L.) Nees (red sprangletop), *Oryza rufipogon* (red rice), *Zizania aquatica* (annual wild rice), and *Zizaniopsis miliaceae* (giant cutgrass).
Life cycle	
Mechanism of damage	No information on the mechanism of damage is available.
When damage is important	The disease is important during the heading towards the maturity stages of the rice crop. It usually attacks the uppermost leaf sheath that encloses the panicles and causes rotting of the panicles.
Economic importance	The disease appears late during the growing season of the rice crop. It causes yield losses from 20% to 85% in Taiwan and 30% to 80% in Vietnam, the Philippines, and India. In Japan, areas infected range from 51,000 to 122,000 hectares and annual losses are estimated to be 16,000-35,000 tons.

Management principles	Removal of infected stubbles after harvest and optimum plant spacing are among the cultural practices that can reduce the disease. Application of potash at tillering stage is also recommended. Foliar spray of calcium sulfate and zinc sulfate was found to control sheath rot. At booting stage, seed treatment and foliar spraying with carbendazim, edifenphos, or mancozeb was found to reduce sheath rot. Foliar spraying with benomyl and copper oxychloride were also found to be effective.
Selected references	• International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p. • Nair R. 1976. Incidence of sheath rot in rice: a potential problem for Sambalpur, Orissa. Int. Rice Res. Newsl. 1:19.
Contributors	Suparyono, JLA Catindig, NP Castilla, and EA Elazequi

Stem Rot

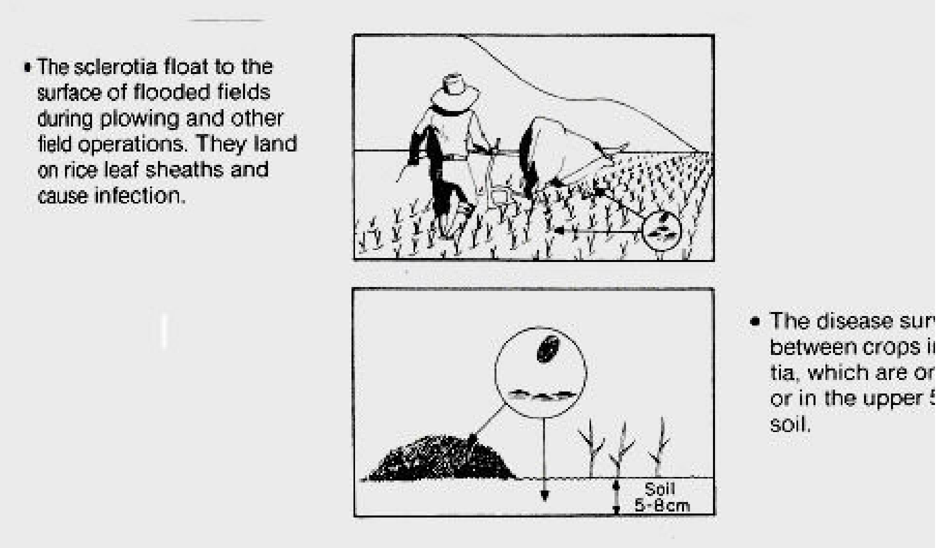
Stem lesions (IRRI)

Diagnostic summary

Damage to plants	• formation of lesions • production of chalky grains and unfilled panicles
Signs and symptoms	• small and irregular black lesions on the outer leaf sheath near water level • infected stem rots • tiny white and black sclerotia and mycelium inside the infected culms • infected culm lodges and caused unfilled panicles and chalky grain • death of tiller
Factors favoring disease development	• presence of infection bodies or sclerotia in the upper soil layer or on irrigation water • presence of wounds as entry points of the fungus • panicle moisture content • nitrogen fertilizer • presence of the white tip nematode, which has synergistic effect with the disease • from milking to ripening stages of the crop

Full fact sheet

Disease name	Stem rot
Pathogen	*Sclerotium oryzae* Cattaneo (anamorph), *Magnaporthe salvinii* (Cattaneo) R.A. Krause & R. K. Webster (teleomorph)
Symptoms	• Initial symptoms are small, irregular black lesions on the outer leaf sheath near water level • Lesions expand as the disease advances • Infected stem rots • Visible numerous tiny white and black sclerotia and mycelium inside the infected culms • Infected culm lodges and caused unfilled panicles and chalky grain • Severe infection causes tiller death • The disease aggravates the plants to lodge  Stem rot (IRRI)
Confirmation	Blackish, dark, irregular lesions are visible on the outer leaf sheath. The lesion later expands and affects the inner culm. If infected culm is dissected, it reveals dark gray masses of fungi and small white and black sclerotia or infection bodies.
Problems with similar symptoms	Only this disease exhibits the above-described symptoms.
Why and where it occurs	The infection bodies or sclerotia are found in the upper soil layer. They survive in air-dry soil, buried moist rice soil, and in tap water. They can also survive on straw, which is buried in the soil. The sclerotia float on irrigation water and infect newly planted rice during land preparation. Infection is high on plants with wounds as a result of lodging or insect

	attack. The panicle moisture content and nitrogen fertilizer also influence disease development. The presence of the white tip nematode is reported to have a synergistic effect with the disease and incidences become higher.
Causal agent or factor	The perithecia are dark, globose, and embedded in outer tissues of the sheath. They are 202-481 µm. They have a short beak, 30-70 µm, which is not protruding. The asci are narrowly clavate with almost invisible walls and deliquescing by the time the spores mature. They have a short stalk and measure 90-128 x 12-14 µm. Mature ascospores are biserate and three-septate. There are normally eight ascospores in an ascus, rarely only four. The ascospores are usually constricted at the septa, particularly at the middle septum. They are brown, with two end cells lighter in color, and the contents are less granular than the middle cells. The ascospores are fusiform and somewhat curved. They measure 38-53 x 7-8 µm or mostly 44 x 8 µm. The sclerotia are black and globose or near globose and smooth. They measure 180-280 µm. The conidiophores are dark, upright, and septate. They measure 100-175 x 4-5 µm. Conidia are fusiform, three-septate, curved, and measure 29-49 x 10-14 µm. They are produced on pointed sterigmata.
Host range	Aside from the rice plant, the fungus can also develop on *Echinochloa colona* (L.) Link (jungle grass), *Eleusine indica* (L.) Gaertn. (goosegrass), *Leptochloa chinensis* (L.) Nees (red sprangletop), *Zizania aquatica* (annual wild rice), and *Zizaniopsis miliaceae* (giant cutgrass).
Life cycle	
Mechanism of damage	The sclerotia or floating bodies in the rice field come in contact with the rice leaf sheaths and then germinate. They form appressoria or infection cushions. The formation of appressoria or infection cushions is affected by environmental conditions. The infected stem lesions have disorganized parenchymatous tissue. The lignified tissue or the vascular bundles become separated from the epidermis. The fungus or the pathogen showed enzymic action because the pectic substances in the middle lamella showed a change in the

	staining reaction and the viscosity has decreased.
When damage is important	The pathogen infects leaves and panicles during the milking to ripening stages.
Economic importance	The infection is seen on the rice crop during early heading and grain filling. The leaf sheaths decay and cause lodging and lower grain filling. It can cause heavy losses in many countries. For example, in Japan, there are 51,000 to 122,000 hectares infected and estimated annual losses of 16,000-35,000 due to this disease. In Vietnam, the Philippines, and India, losses from 30% to 80% were recorded.
Management principles	Among the cultural control practices, burning straw and stubble or any crop residue after harvest or letting the straw decompose and draining the field can reduce sclerotia in the field. A balanced use of fertilizer or split application with high potash and lime to increase soil pH reduces stem rot infection and increases yield. The use of resistant cultivars may be the best control measure for stem rot. There are reported resistant cultivars from USA, India, Sri Lanka, Philippines, and Japan. Chemicals such as fentin hydroxide sprayed at the mid-tillering stage, thiophanate-methyl sprayed at the time of disease initiation can reduce stem rot incidence in the rice field. The use of other fungicides such as Ferimzone and validamycin A also show effectivity against the fungus.
Selected references	• Ahuja SC, Srivastava MP. 1990. Stem rot of paddy, a review. Agric. Rev. 11(2):61-78. • International Rice Research Institute (IRRI). 1983. Field problems of tropical rice. Manila (Philippines): IRRI. 172 p. • Nyvall RF. 1999. Field crop diseases. Iowa State University Press, USA. 1,021 p. • Ou SH. 1985. Rice diseases. Great Britain (UK): Commonwealth Mycological Institute. 380 p. • Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. • Webster RK, Gunnell PS. 1992. Compendium of rice diseases. St. Paul, Minnesota (USA): The American Phytopathological Society. 62 p.
Contributors	Suparyono, JLA Catindig, NP Castilla, and FA Elazequi

Tungro

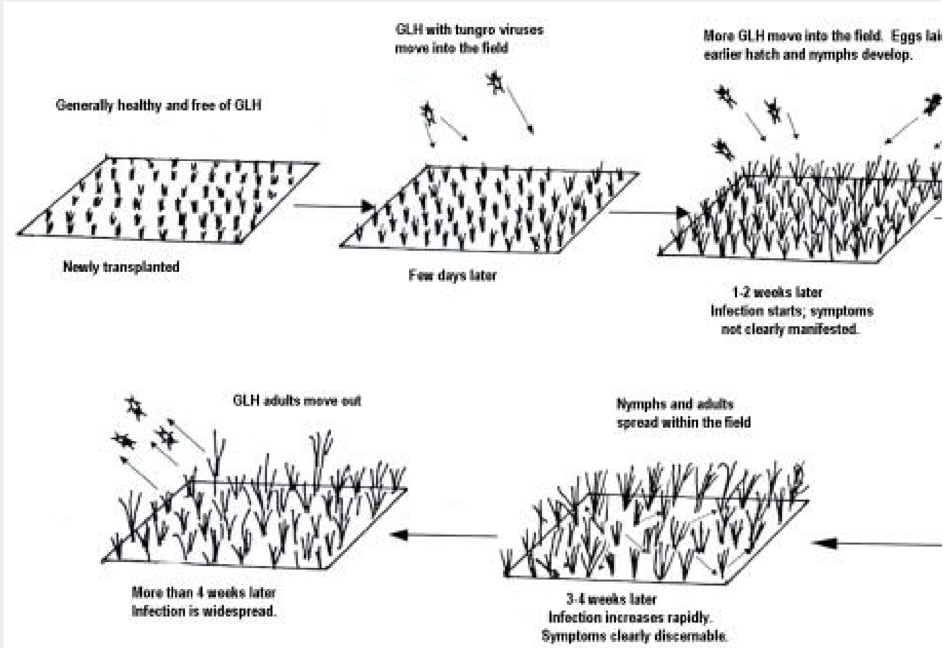
Leaf symptoms of Tungro (IRRI)

Diagnostic summary

Damage to plants	• leaf discoloration - partially filled grains
Signs and symptoms	• discoloration begins from leaf tip and extends down to the blade or the lower leaf portion • infected leaves may also show mottled or striped appearance - stunting • reduced tillering • delayed flowering, which may delay maturity - panicles small and not completely exserted • most panicles sterile or partially filled grains and covered with dark brown blotches
Factors favoring disease development	• presence of the virus sources • presence of the vector • age and susceptibility of host plants • synchronization of the three above factors • all growth stages of the rice plant specifically the vegetative stage

Full fact sheet

Symptoms	 Tungro in the field
Confirmation	There are some serological tools to detect tungro viruses. These are Latex agglutination test, Enzyme Linked Immunosorbent Assay or ELISA, and Rapid Immunofilter Paper Assay or RIPA. The presence of the vector *Nephotettix* spp. is indicative of the disease.
Problems with similar symptoms	The yellowing of the plant and its stunted height is often confused with 1) physiological disorders such as nitrogen and zinc deficiencies and water stress; 2) pest infestation such as stem borer infestation, planthopper infestation, and rat damage; and 3) other diseases such as grassy stunt virus disease and orange leaf disease.
Why and where it occurs	Tungro incidence depends on the availability of the virus sources, population and composition of the vector, age and susceptibility of host plants, and synchronization of the three factors mentioned.
Causal agent	Tungro virus disease is transmitted by leafhoppers, wherein the most efficient vector is the green leafhopper, *Nephotettix virescens* (Distant). The disease complex is associated with rice tungro baciliform virus (RTBV) and rice tungro spherical virus (RTSV). RTBV cannot be transmitted by leafhoppers unless RTSV is present. Insects could acquire the virus from any part of the infected plant. After acquiring the virus, the vector can immediately transmit to the plants. RTBV particles are rod-shaped and 100-300 nm in length and 30-35 nm in width. It contains DNA of 8.3 kb. RTSV particles are isometric and 30 nm in diameter. It has a polyadenylated single-stranded RNA of about 12 kb.
Host range	Under artificial (experimental) conditions, rice tungro viruses infect *Echinochloa colona* (L.) Link, *E. crus-galli* (L.) *P. Beauv.* ssp. *hispidula* (Retz.) Honda, *Eleusine indica* (L.) Gaertn., *Dactyloctenium aegyptium* (L.) Beauv., *Ischaemum rugosum* Salisb., *Hydrolea zeylanica* (L.) Vahl, *Hemarthia compressa* (L. f.) R. Br., *Fimbristylis miliacea* (L.) Vahl, *Leersia hexandra* Sw., and *Panicum repens* L. Only rice and some wild relatives are infected under natural conditions.

Life cycle	
Mechanism of damage	The insect acquires the virus by feeding on the plant for a short time in an 8-hr acquisition access period (minimum of 30 minutes). It can transmit the virus immediately after feeding. Either or both viruses can be transmitted during a 1 hour inoculation access period (minimum of 7 minutes). The virus does not remain in the vector's body. After feeding on a diseased plant, the insect can transmit the virus for about 5 days and the longest is about a week. The insect becomes reinfective after re-acquisition feeding.
When is damage important?	Tungro virus disease affects all growth stages of the rice plant specifically the vegetative stage.
Economic importance	Tungro is one of the most damaging and destructive diseases of rice in countries in Southeast Asia. Outbreaks of the disease can affect thousands of hectares in many countries. Plant infected with the virus at the early crop growth stage could have as high as 100% yield loss in severe cases. The damage caused by the disease depends on the variety used, the plant stage when infection occurs, the virus particles, and the environmental conditions.
Management principles	There are three limitations of effective tungro management: 1) the absence of symptoms at early growth stage of the disease development, 2) lack of resistant varieties to the tungro viruses, and 3) vector adaptation on GLH-resistant variety. Planting of resistant varieties against tungro virus disease is the most economical means of managing the disease. There are resistant varieties from the Philippines, Malaysia, Indonesia, India, and Bangladesh, which are available.

	Among the cultural management practices, adjusting the date of planting is recommended. Likewise, observing a fallow period of at least a month to eliminate hosts and viruses and vectors of the disease and plowing and harrowing the field to destroy stubbles right after harvest in order to eradicate other tungro hosts are also advisable.
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Contributors	Suparyono, JLA Catindig, PQ Cabauatan, and HX Troung

In the Field

Cloddy Soil


Seeds fall between cracks in cloddy soil (IRRI)


Cloddy soil (IRRI)

Diagnostic summary

Effects on plants	• the seed becomes covered by too much soil • the seed has problem of emerging • with poor soil-seed contact • limiting the seed to absorb water for germination
Signs	• soil clods much larger than seed size • poor crop emergence in dry seeded fields • pattern of damage is usually general across the field
Importance/Occurrence	• problem in all dry direct sown fields • greatly reduce crop stand in dry direct seeded fields • important at the time of crop establishment

Full fact sheet

Symptoms	• Soil clods much larger than seed size at planting • Poor crop emergence in dry seeded fields • Pattern of damage is usually general across the field
Confirmation	Check or ask farmer if clod size much larger than seed size at the time of dry seeding.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting).
Why and where it occurs	Cloddy soil can be a problem in all dry direct sown fields and generally occurs because the soil is tilled when it is too dry.
Mechanism of damage	The seed falls down the cracks in between the clods. As the soil clods break up due to the action or rain or irrigation, the seed becomes covered by too much soil and has problems emerging. In addition, there may be poor soil-seed contact limiting the extent to which the seed can absorb water to begin the germination process.
When damage is important	The damage is important at the time of crop establishment. Good crop establishment lays the foundation for good yield.
Economic importance	Cloddy soil can greatly reduce crop stand in dry direct seeded fields. It's economic effect can be direct in terms of stand and yield reduction or indirect in terms of increased tillage costs to break down clod size.
Management principles	When soil is tilled too dry, it will typically result in large dry hard clods, which are difficult to break down. For dry direct seeding, tillage is best done when soil moisture is below field capacity and well above permanent wilting point. If the soil is too wet, the soil will seal and smear - too dry and large clods form. Sandy soils can be tilled at a higher percent of available moisture than clayey soils. Secondary tillage should follow primary tillage within a day or two for clayey soils with a little wider window of opportunity for sandy soils. For best results, there should be a range of sizes of soil clods. If the clod size is much larger than the seed, then problems are likely. Rainfall or irrigation can break clod size down.
Contributors	J Rickman and M Bell

Crop is Too Dense


Plant count is high (IRRI)

Diagnostic summary

Effect on plants	• poor crop stand • plants too close together • plant count is high
Signs	• the stems can be thin and weak • lodging during heading • differences in grain maturation
Importance/Occurrence	• problem in direct seeded fields • problem in establishing a satisfactory crop stand

Full fact sheet

Symptoms	• Plant count is high (e.g., > 250 plants per m^2) • Plants too close together with thin stems and possibly lodged or may lodge
Confirmation	Check or ask farmer about seed rate.
Problems with similar symptoms	High plant density can result from high seed rates or uneven seed distribution in the field. Various problems can cause low plant stands (e.g., cloddy soil, seed too deep, soil too soft at seeding, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Crop density is a problem of direct seeded fields, especially when broadcast seeded. Crops can be surface broadcasted (wet or dry), drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Pre-germinated seed is typically used when wet direct seeding. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. When broadcast, fields can have patches

	of either too many or too few plants depending on the skills of the broadcaster and the soil conditions where the seed lands. Farmers often use high seed rates due to poor seed quality, to compensate for losses to rats, birds and snails and to increase crop competition with weeds.
Mechanism of damage	If the crop stand is too dense, then the stems can be thin and weak resulting in lodging during heading and differences in grain maturation.
When damage is important	When plants are too close together the stems are often weak which can result in lodging and yield loss during heading.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to poor crop stand (too many or too few plants) or through the increased cost of seed when high seed rates are used.
Management principles	There is a relatively wide range of crop stands that will give good yields. For good establishment, the fields have to have good water management and be more level. Ensure an appropriate seed rate with even distribution of seed. In transplanted fields, 25 to up to 100 hills per m^2 are typical ranges. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are sufficient (e.g., pest problems and seedbed preparation) are adequate.
Contributors	J Rickman and M Bell

Direct Seeded

Direct seeding (IRRI)

Weeds grow in spaces where there are few rice plants (IRRI)

Diagnostic summary

Effect on plants	• plant count too high or too low • groundcover can be low
Signs	• problems of lodging • plants that are too close can have thin stems and possibly lodge • weeds grow when plants are few and there are spaces in the crop • uneven patches of growth of the plants
Importance/Occurrence	• uneven seed distribution in the field • there is a problem in establishing a satisfactory

	crop stand

Full fact sheet

Symptoms	• Plant count too high (e.g. > 250 plants per m^2) or too low (e.g. < 75) • When too close, plants can have thin stems and possibly lodge. • When too few plants, there are spaces in the crop, weeds can grow and yield potential can be lost. • The pattern of crop stand tends damage tends to be uneven across the field.
Confirmation	Check or ask farmer about seed rate.
Problems with similar symptoms	High plant density can result from high seed rates or uneven seed distribution in the field. Various problems can cause low plant stands (e.g., cloddy soil, seed too deep, soil too soft at seeding, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Crop density is a problem of direct seeded fields, especially when broadcast seeded. Crops can be surface broadcasted (wet or dry), drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Pre-germinated seed is typically used when wet direct seeding. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. When broadcast, fields can have patches of either too many or too few plants depending on the skills of the broadcaster and the soil conditions where the seed lands. Farmers often use high seed rates due to poor seed quality, to compensate for losses to rats, birds and snails and to increase crop competition with weeds.
Mechanism of damage	If the crop is too dense, then the stems can be thin and weak resulting in lodging during the heading and grain maturation. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. If a low seed rate results in a low crop stand, then groundcover can be low. Thus yield potential can be lost directly and/or indirectly due to greater weed pressure resulting from the lack of crop-weed competition.
When damage is important	When plants are too close together the stems are often weak which can result in lodging and yield loss during heading.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to poor crop stand (too many or too few plants) or through the increased cost of seed when high seed rates are used.
Management principles	For good establishment, the fields have to have good water management and be more level. Ensure an appropriate seed

	rate with even distribution of seed. In transplanted fields, 25 to up to 100 hills per m^2 are typical ranges. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are sufficient.
Contributors	J Rickman and M Bell

Drought

Drought (IRRI)

Diagnostic summary

Effect on plants	• the plant has less ability to extract essential nutrients from the soil • the symptoms can be confused with N deficiency and high spots in the field
Signs	• stunting • leaf rolling • burning of leaf tips • leaf senescence • flowering delayed • may cause whitehead
Factors affecting development of the pest	• major source of yield and economic loss in rice production • a problem in rainfed areas with poor rainfall distribution or within irrigated areas with poor water delivery

Full fact sheet

Symptoms	• Plants stunted • Leaves roll • Flowering delayed

	• Tip burn • Leaf senescence • May cause whitehead (though the tiller will still be attached to the stem)  Drought (IRRI)
Confirmation	Check the field and/or ask farmer about weather conditions - check for high spots in field or soil cracking.
Problems with similar symptoms	The symptoms can be confused with N deficiency and high spots in the field.
Why and where it occurs	Water stress is a problem in rainfed areas with poor rainfall distribution or within irrigated areas with poor water delivery. Permeable soils (i.e., high infiltration rates) and soils with low moisture retention increase the probability of water stress. Poorly leveled fields often result in patches of higher soil with water stress.
Mechanism of damage	The lack of water in the soil reduces the ability of the plant to extract essential nutrients from the soil. The lack of water in the plant reduces cell expansion.
When damage is important	Water stress is most critical around flowering (from three weeks before flowering up to one week after anthesis).
Economic importance	Water stress is a major source of yield and economic loss in rice production throughout Asia. As soon as fields drop below saturation, yield potential in most cases is being lost. The exception is with some varieties of aerobic rice being grown in parts of China and Brazil.
Management principles	Water stress can be reduced by ensuring fields are well leveled, by choosing an appropriate cultivar and planting date that increases the probability of moisture being available during the critical flowering period. The ability of cultivars to tolerate water stress depends on direct tolerance or avoidance based on the length of their growth period. To the extent possible, periods of probable

	moisture stress should be identified and the cultivar selected to avoid these probable periods of stress.
Contributors	R Lafitte and M Bell

Dry Winds


Dried leaf tips (IRRI)

Diagnostic summary

Effect on plants	• burning effects on leaves • effect varies with cultivar
Signs	• plant looks healthy • necrotic upper tips of leaves • general pattern of damage across the field
Importance/Occurrence	• no real effect on yield potential

Full fact sheet

Symptoms	• Plant look healthy except that upper tips of leaves are necrotic (i.e., dead) • The effect varies with cultivar • Pattern of damage is general across the field
Confirmation	Check the field and/or ask farmer about wind patterns and wind characteristics.
Problems with similar symptoms	May be confused with diseases or nutrient deficiencies that dry the leaf tips.
Why and where it occurs	The wind burn effect results from the leaf tips drying faster than water can be provided for evapotranspiration. Thus the leaves essentially cook their tips as they can't keep them cool enough.
Mechanism of damage	The wind burn effect results from the leaf tips drying faster than water can be provided for evapotranspiration. Thus the leaves essentially cook their tips as they can't keep them cool enough.
When damage is important	Damage has no real effect on yield potential.

Economic importance	Dry winds have no significant economic effect.
Management principles	No management is really required. If some yield loss is expected then a new cultivar may not have the same problem.
Contributors	V Balasubramanian and M Bell

Heavy Rainfall

Poor germination (IRRI)

Diagnostic summary

Damage to plants	• poor seed distribution • poor seed germination • poor seed emergence
Signs	• poor plant stand • pattern of damage is general across the entire field, but may be more obvious in low spots
Importance/Occurrence	• important during crop emergence • occurs in wet direct seeded and in heavy textured soils • it happens when heavy rain falls on freshly seeded fields and is worse if the field has been wet direct seeded • tends to be worse in heavy textured soils

Full fact sheet

Symptoms	• Poor plant stand on direct seeded fields - especially if wet direct seeded • Pattern of damage is usually general across the entire field, but may be more obvious in low spots
Confirmation	Check rainfall, if field was direct-seeded and when field was seeded relative to the rainfall.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as

	ants, birds and rats that remove seed at planting.
Why and where it occurs	The problem happens when heavy rain falls on freshly seeded fields and is worse if the field has been wet direct seeded. The problem tends to be worse in heavy textured soils.
Mechanism of damage	Seed is washed deeper into the anaerobic layers of the soil creating problems in germination and growth for emergence (i.e., oxygen not available for growth).
When damage is important	Rainfall heavy is important during crop emergence.
Economic importance	Heavy rainfall during crop establishment is becoming an increasingly important problem as wet direct seeding spreads throughout Asia. Because of the nature of the problem it tends to be seasonal and can not really be reliably predicted. However, when it does occur, then fields often have to be reploughed and then reseeded.
Management principles	The problem tends to be worse in heavy textured soils. The critical period is the first 1-2 days after sowing - with the problem being much worst in wet-direct seeded fields. Surface seeding or good field drainage may help.
Contributors	J Rickman and M Bell

Herbicide Toxicity

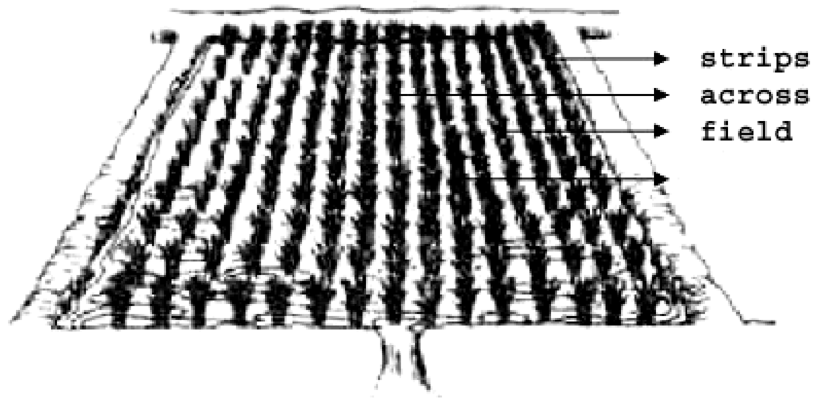
Whiteheads (IRRI)

Diagnostic summary

Effect on plants	• poor crop emergence • root damage
Signs	• whiteheads
Importance/Occurrence	• becomes sporadic when either new products or farmers inexperienced with a product make the application • damage occurs at the time of or shortly after product application

Full fact sheet

Symptoms	• Poor crop emergence (e.g., if pendamethalin comes into contact with the seed) • Root damage (e.g., possibly 2,4-D) • Whitehead (e.g., possibly Phenoxyprop)

	 Stripes across field (IRRI)
Confirmation	Check what products were applied and when relative to crop growth stages.
Problems with similar symptoms	Problems of crop establishment can be confused with other problems such as cloddy soil, seed too deep, soil too soft at seeding, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	The problems typically happen if products are not used according to their recommendations - e.g., at the wrong rate, the wrong stage of crop growth, or sometimes if the product is carried into contact with the emerging seed (e.g., water infiltration moves the product into the soil). Plants vary in their susceptibility both in terms of variety and growth stage.
Mechanism of damage	The effect varies, but damage may occur due to contact or due to translocation within the plant.
When damage is important	Damage occurs at the time of or shortly after product application.
Economic importance	Herbicide toxicity does not tend to be a major economic problem. It tends to be sporadic when either new products or farmers inexperienced with a product make the application. However, misuse of products and potential impact on the users and the environment requires great attention.
Management principles	The primary management requirement is to firstly determine the pest whether an application is required. Then, carefully read the label of the product and follow the recommendations carefully.
Contributors	J Hill and M Bell

Mixed Variety

Plants with different heights, caused by mixed variety (IRRI)

Planting of mixed variety (IRRI)

There is low crop establishment in a muddy field (IRRI).

Diagnostic summary

Effect on plants	• plants have different maturity periods • differences in grain filling and moisture at the time of harvest

	• direct losses of seeds due to shattering • shading of nearby plants by tall plants causing the - lowering of yield potential of the surrounding plants • symptoms similar to replanting and early rat damage
Signs	• different heights of plants • plants are uniformly spread across the field
Importance/Occurrence	• problem arises because farmers keep their own seed and do not tend to do any seed processing to ensure purity • important throughout the cycle of the crop

Full fact sheet

Symptoms	• Plants (off types) in field have different height, maturity, color and/or other characteristics (e.g., grain characteristics) • The pattern of off types tends to be reasonably uniformly spread across the field, but may be patchy  Planting of mixed variety (IRRI)
Confirmation	Compare plants. Check or ask farmer about seed source and quality.
Problems with similar symptoms	The symptoms are similar to the symptoms affected by replanting and early rat damage-causing differences in plant development.
Why and where it occurs	The problem arises primarily as most farmers in Asia keep their own seed and do not tend to do any seed processing to ensure varietal purity or seed quality. The increase in direct seeding can also be a

	factor as the number of volunteer plants (i.e., those germinating from fallen seed) increase with continuous cropping and direct seeding.
Mechanism of damage	Mixed varieties differ in height and maturity leading to differences in grain filling and moisture at the time of harvest. Differences in maturity may also result in direct losses with seed being lost due to shattering. Tall plants can shade nearby plants lowering yield potential of the surrounding plants.
When damage is important	It is important throughout the cycle of the crop.
Economic importance	Poor seed quality in general (including mixed varieties) is a major problem throughout Asia. Yields are reduced due to poor vigor, diseases and weeds introduced in the seed. Yield increases of around 10% are not uncommon, although the benefit or good seed depends on the starting point - i.e., how bad the farmers seed is.
Management principles	Good quality seed increases yields with the effect being greater the poorer the seed. Seed sources should have high viability, high germination rates, varietal purity and seed should be full (i.e., high thousand grain weight for the variety) and free of insects, diseases and weed seeds. The problem of poor seed arises as most farmers in Asia keep their own seed and do not tend to do any seed processing to ensure varietal purity or seed quality. Ensure volunteers from previous crops are not allowed to develop.
Contributors	J Rickman and M Bell

Muddy Water

Diagnostic summary

Damage to plants	• low crop establishment • reduction of oxygen supply for the germinating seed
Signs	• plants are usually uniform across the field
Importance/Occurence	• important at the time of seed sown directly into standing water • occur due to seed trying to germinate and or grow in muddy water • only occur in direct seeded fields

Full fact sheet

Symptoms	• The resulting crop establishment is low • The pattern of damage is usually general across the field
Confirmation	Check or ask farmer about watercolor at the time of crop establishment (direct seeding only).
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	The problem occurs due to seed trying to germinate and/or grow in muddy water. The problem only occurs in direct seeded fields. Crops can be surface broadcasted (wet or dry), drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Pre-germinated seed is typically used when wet direct seeding. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. Some fields are sown into standing water, or the water enters the field shortly after seeding.
Mechanism of damage	Muddy water reduces the oxygen content of the water and thus reduces the oxygen supply for the germinating seed.
When damage is important	Muddy water is important at the time of seed sown directly into standing water. The problem occurs at the time of crop establishment.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasingly important in direct seeded fields. Economic costs can be direct in terms of yield lost due to poor crop stand (too few plants) or through the increased cost of seed when high seed rates are used to compensate for establishment problems.

Management principles	For good establishment, the fields have to have good water management and be more level and sometimes allowing water to settle. Ensure an appropriate seed rate with even distribution of seed. In transplanted fields, 25 to up to 100 hills per m^2 are typical ranges. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2 . A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2 . Seed rates between 40 to 100 kg per ha are sufficient.
Contributors	J Rickman and M Bell

Poor Transplanting


Missing plants (IRRI)

Diagnostic summary

Effects on plants	• greater weed pressure • low crop stand • low groundcover
Signs	• inadequate plant stand • variable pattern of damage in the field
Importance/Occurrence	• it is a problem where labor supplies are becoming limited • important in laying foundation for good yields

Full fact sheet

Symptoms	• Inadequate or uneven plant stand (e.g., plants too far apart or missing) • Variable pattern of this problem in the field
Confirmation	Check or ask farmer about planting practices.
Problems with similar symptoms	This should not be confused with factors affecting crop stand (e.g., low seed rate, or poor seed distribution), pest damage during establishment (e.g., rats, birds, snails or possibly crabs).
Why and where it occurs	Poor transplanting is typically a problem where labor supplies are becoming limited.
Mechanism of damage	Yield potential can be lost directly and/or greater weed pressure can result from the lack of crop-weed competition. If a low seed rate results in a low crop stand, then groundcover can be low. Thus yield potential can be lost directly and/or

	indirectly due to greater weed pressure resulting from the lack of crop-weed competition.
When damage is important	Low plant stands are important throughout growth. A good plant stand lays the foundation for good yields. The absence of a good stand automatically lowers yield potential.
Economic importance	As labor for rice transplanting becomes increasing scarce, farmers experience greater problems of good transplanting practices. At this point direct seeding for establishing a satisfactory crop stand becomes increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to a poor crop stand with too few plants.
Management principles	If labor supplies are inadequate, then a shift to mechanized transplanting or direct seeding may be required. Both of these crop establishment options requires that fields have good water management and are well leveled. Ensure an appropriate seed rate with even distribution of seed. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are usually sufficient, if other factors (e.g., pest problems and seedbed preparation) are not problematic.
Contributors	J Rickman and M Bell

Replanting

Different stages of development (IRRI)

Diagnostic summary

Effects on plants	• differences in maturity rates • differences in grain filling and moisture at the time of harvest • direct losses of seeds due to shattering or lower head rice recovery at milling • shading of nearby plants by tall plants and lower yield potential of the surrounding plants
Signs	• uneven plant heights and are slightly at different stages of development • general pattern of damage is patchy across the field
Importance/Occurrence	• important throughout the growth cycle of the rice crop

Full fact sheet

Symptoms	• Plants in the field have different height and are at slightly different stages of development • General pattern is patches across the field (often low spots or high spots where there were problems of crop establishment)

Different plant heights (IRRI)

Confirmation	Compare plants. Check or ask farmer about crop establishment and the extent of replanting and when replanted.
Problems with similar symptoms	Mixed varieties and/or early rat damage causing differences in plant development.
Why and where it occurs	The problem arises where there are problems of crop establishment (e.g., low seed rate, poor seed quality, poor seed distribution or the loss of plants due to pests such as rats, snails or birds, or problems of crop emergence in direct seeded fields due to low spots or seed too deep, or a seeder clogged, etc.).
Mechanism of damage	Plants at different stages differ in height and maturity leading to differences in grain filling and moisture at the time of harvest. Differences in maturity may also result in direct losses with seed being lost due to shattering or lower head rice recovery at milling. Tall plants can shade nearby plants lowering yield potential of the surrounding plants.
When damage is important	It is important throughout the growth cycle of the rice crop.
Economic importance	Many crops throughout Asia have parts of the field replanted.
Management principles	Ensure good crop establishment practices including good seed quality, good water management and land leveling.
Contributors	J Rickman and M Bell

Seed - High Rate


Seedlings too dense (IRRI)

Diagnostic summary

Effect on plants	• crop stand is too dense • high plant count
Signs	• plants that are too close have thin stems • plants possibly lodged • pattern of damage is uneven in patches across the field
Importance/Occurrence	• problem in crop establishment

Full fact sheet

Symptoms	• High plant count (e.g., > 250 plants per m^2) • Plants too close together with thin stems and possibly lodged • Number of seed in each 10 cm x 10 cm square multiplied by the thousand grain weight equates to the estimated seed rate (kg per ha) • Seed rates are typically adequate between 40 to 100 kg per ha • Pattern of damage is uneven in patches across the field
Confirmation	Check or ask farmer about seed rate.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Farmers often use high seed rates due to poor seed quality, to compensate for losses to rats, birds and snails and to increase crop competition with weeds. Crops can be surface broadcast

	(wet or dry); drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Higher seed rates are usually used if seed is broadcast. Pre-germinated seed is typically used when wet direct seeding. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. For good establishment, the fields have to have good water management and be more level. When broadcast, fields can have patches of either too many or too few plants depending on the skills of the broadcaster and the soil conditions where the seed lands.
Mechanism of damage	If the crop stand is too dense, then the stems can be thin and weak resulting in lodging during heading and grain maturation.
When damage is important	When plants are too close together the stems are often weak which can result in lodging and yield loss during heading.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to poor crop stand (too many or too few plants) or through the increased cost of seed when high seed rates are used.
Management principles	For good establishment, direct seeded fields have to have good water management and be well leveled. Ensure an appropriate seed rate with even distribution of good quality seed (i.e., high germination and vigor). In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m2. Seed rates between 40 to 100 kg per ha are usually sufficient, if other factors (e.g., pest problems and seedbed preparation) are not problematic.
Contributors	J Rickman and M Bell

Seed - Poor Distribution

Weeds grow in spaces where there are few rice plants (IRRI)

Plant count is either too high or too low in a direct-seeded field (IRRI)

Diagnostic summary

Effect on plants	• too dense crop stand • there are spaces between too few plants • weeds grow and compete with the crop for nutrients
Signs	• too high or too low plant count • too close plants have thin and weak stems • growth of plants are usually uneven across the field • lodging during heading and grain maturation

Importance/Occurrence	• may cause a problem in crop establishment • a problem in direct seeded fields

Full fact sheet

Symptoms	• Plant count too high (e.g., > 250 plants per m^2) or too low (e.g., < 75) in direct seeded fields • When too close, plants can have thin stems and possibly lodge • When too few plants, there are spaces in the crop, weeds can grow and yield potential can be lost • Pattern of damage is usually uneven across the field
Confirmation	Check or ask farmer about seed rate and how crop was established.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Crop density is a problem of direct seeded fields, especially when broadcast seeded. Crops can be surface broadcast (wet or dry), drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Pre-germinated seed is typically used when wet direct seeding. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. When broadcast, fields can have patches of either too many or too few plants depending on the skills of the broadcaster and the soil conditions where the seed lands. Farmers often use high seed rates due to poor seed quality, to compensate for losses to rats, birds and snails and to increase crop competition with weeds.
Mechanism of damage	If the crop stand is too dense, then the stems can be thin and weak resulting in lodging during heading and grain maturation. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown.
When damage is important	When plants are too close together the stems are often weak which can result in lodging and yield loss during heading.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to poor crop stand (too many or too few plants) or through the increased cost of seed when high seed rates are used.
Management principles	For good establishment, the fields have to have good water management and be more level. Ensure an appropriate seed rate with even distribution of seed. In transplanted fields, 25 to up to 100 hills per m^2 are typical ranges. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per

	m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are sufficient.
Contributors	J Rickman and M Bell

Seed - Poor Quality

Seeds of different colors and sizes (IRRI)

Diagnostic summary

Effect on plants	• low seedling vigor • poor growth • mixed varieties differing in height and maturity • prone to weeds, insects and diseases
Signs	• low germination • seed source may be discolored • seeds may be of different sizes and varieties • seed sources may contain inert, weeds or other matter • pattern of damage is usually general across the field
Importance/Occurrence	• a problem on crop establishment • this problem arises because farmers keep their own seed

Full fact sheet

Symptoms	• Low germination, mixed varieties, low plant vigor, diseased plants or the introduction of weeds • Seed source may be discolored • Seeds may be of different sizes and varieties • Seed sources may contain inert, weeds or other matter • Pattern of damage is usually general across the field

Confirmation	Check or ask farmer about seed source and quality. It may be necessary to check germination, thousand-grain weight, seed purity and the extent of non-seed materials (e.g., inert matter or weeds).
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	The problem arises as most farmers in Asia keep their own seed and do not tend to do any seed processing to ensure varietal purity or seed quality.
Mechanism of damage	Poor seed results in lost yield due to a variety of reasons including: low seedling vigor and poor growth, mixed varieties differing in height and maturity, the introduction of weeds, insects and diseases.
When damage is important	The damage is important at the time of crop establishment. Good crop establishment lays the foundation for good yield.
Economic importance	Poor seed quality is a major problem throughout Asia. Yields are reduced due to poor vigor, diseases and weeds introduced in the seed. Yield increases of around 10% are not uncommon, although the benefit or good seed depends on the starting point - i.e., how bad is the farmer's seed?
Management principles	Good quality seed increases yield - with the effect being greater the poorer the seed. Seed sources should have high viability, high germination rates, seed should be full (high thousand grain weight for the variety) and free of insects, diseases and weed seeds. The problem of poor seed arises as most farmers in Asia keep their own seed and do not tend to do any seed processing to ensure varietal purity or seed quality.
Contributors	T Mew, J Rickman and M Bell

Seed - Rate Too Low


Low seedling rate (IRRI)

Diagnostic summary

Effect on plants	• low crop stand • low groundcover • greater weed pressure due to lack of crop-weed competition
Signs	• plant growth is uneven across the field
Importance/Occurrence	• problem of crop establishment • occurs due to uneven distribution or insufficient seed used

Full fact sheet

Symptoms	• Insufficient plants and groundcover • Seed rates are typically adequate between 40 to 100 kg per ha • Pattern of damage is often uneven across the field
Confirmation	Check or ask farmer about seed rate. The number of seed in each 10 cm x 10 cm square multiplied by the thousand grain weight equates to the estimated seed rate (kg per ha).
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Low seed rates can occur due to uneven distribution or insufficient seed used. Crops can be surface broadcast (wet or dry), drill seeded (using machines) or broadcast and incorporated when sown on dry fields. Pre-germinated seed is

	typically used in wet direct seeding. When broadcast, fields can have patches of either too many or too few plants depending on the skills of the broadcaster and the soil conditions where the seed lands. Direct seeded fields tend to have greater problems of lodging, especially when the seed is surface sown. For good establishment, the fields have to have good water management and be more level.
Mechanism of damage	If a low seed rate results in a low crop stand, then groundcover can be low. Thus yield potential can be lost directly and/or indirectly due to greater weed pressure resulting from the lack of crop-weed competition.
When damage is important	Low plant stands are important throughout growth. A good plant stand lays the foundation for good yields. The absence of a good stand automatically lowers yield potential.
Economic importance	As direct seeding increases establishing a satisfactory crop stand will become increasing important in direct seeded fields. Economic costs can be direct in terms of yield lost due to a poor crop stand with too few plants.
Management principles	For good establishment, direct seeded fields have to have good water management and well leveled. Ensure an appropriate seed rate with even distribution of seed. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are usually sufficient, if other factors (e.g., pest problems and seedbed preparation) are not problematic.
Contributors	J Rickman and M Bell

Seed - Too Deep


Poor crop establishment (IRRI)

Diagnostic summary

Effect on plants	• poor growth • poor emergence • low seedling vigor • low crop stand • poor crop establishment • more weeds than crop
Signs	• pattern of damage may be in lines, general across the field, or patchy depending on the seeding method
Importance/Occurrence	• a problem in crop establishment • occurs in wet and or direct seeded fields where seed is planted too deep

Full fact sheet

Symptoms	• Poor crop establishment • Low plant vigor • Pattern of damage varies with the method of seeding • May be in lines if machine seeded • More general across the field if seed has been broadcast • May be patchy if seed falls in areas with softer soil
Confirmation	Check or ask farmer about seed depth.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests

	such as ants, birds and rats that remove seed at planting.
Why and where it occurs	The problem occurs in wet and or direct seeded fields where seed is planted too deep.
Mechanism of damage	When seed is planted too deep (e.g., > 0.5 cm), or sinks too deep in wet soil, the seed can have great problems of emerging. If seeding depth is too great, yield can be lost due to a variety of reasons including: low seedling vigor and poor growth, or a low crop stand resulting in direct losses or loses due to weeds.
When damage is important	The damage is important at the time of crop establishment. Good crop establishment lays the foundation for good yield.
Economic importance	The extent of the problem depends on the method of crop establishment.
Management principles	Ensure seed is planted within 0.5 cm of the soil surface. In dry direct seeded fields, ensure that soil clod size is not too great or that soil is directly planted too deep. In wet direct seeded fields, ensure that soil is sufficiently hard to hold seed within 0.5 cm of the surface.
Contributors	J Rickman and M Bell

Seeder Clogged

There are no seeds dropped when a blocked seeder is used (IRRI).

Diagnostic summary

Effect on plants	• no plants or growth
Signs	• plants missing in rows • no seed or no plants emerge in the entire area
Importance/Occurrence	• often a problem in poorly designed seeder • may be a problem if the soil is sticky

Full fact sheet

Symptoms	• Plants missing in rows • For mechanically planted fields, a blocked (or clogged) seeder results in no seeds dropped and thus no plants • The pattern is no seed and plants emerge in the entire or portion of the rows affected while plants in adjacent seeded rows do emerge
Confirmation	Check or ask farmer whether field was mechanically direct seeded in rows.
Problems with similar symptoms	Sometimes seed may be eaten in rows by birds or rats.
Why and where it occurs	Crops can be drill seeded (using machines) on dry or wet fields. Pre-germinated seed is typically used when wet direct seeding. Clogging is often a problem in poorly designed seeder "shoes" and may be a problem if the soil is "sticky".
Mechanism of damage	Seed cannot fall to the ground through the seeding machine. The "shoe" or the outlet may be blocked.
When damage is important	The problem occurs at the time of seeding, but the resulting low plant stands are important throughout growth. A good plant stand lays the foundation for good yields. The absence of

	a good stand automatically lowers yield potential.
Economic importance	As direct seeding increases, establishing a satisfactory crop stand will become increasingly important in direct seeded fields. Economic costs can be direct in terms of yield lost due to a poor crop stand with too few plants.
Management principles	For good crop establishment, ensure the flow of seeds is proper and check seed drop during planting. After planting, direct seeded fields need good water management and well leveled. Ensure an appropriate seed rate with even distribution of seed. In direct seeded fields, the target number of spikes varies with season and variety but typically ranges from 350 to over 500 spikes per m^2. A direct seeded plant will typically give of the order of 2-3 spikes per plants. Thus, crop stand should be of the order of 100 to 200 plants per m^2. Seed rates between 40 to 100 kg per ha are usually sufficient, if other factors (e.g., pest problems and seedbed preparation) are not problematic.
Contributors	J Rickman and M Bell

Soil - Too Soft

Plants fail to emerge in field with soft soil (IRRI)

Diagnostic summary

Effect on plants	• poor crop emergence • poor stand establishment
Signs	• plants fail to emerge • general pattern of damage across the field
Importance/Occurrence	• important at the time of crop establishment • occurs in wet direct seeded environment where insufficient time is given for the soil to settle between final wet land preparation and sowing

Full fact sheet

Symptoms	• Poor crop emergence in direct seeded fields • Plants fail to emerge, as seeds sink too deep and have problems of reaching the soil surface • Pattern of damage across the field can be general, but often occurs in low spots of the field with standing water
Confirmation	Check or ask farmer about soil conditions at the time of direct seeding. Check if seed has sunk to more than 0.5 cm depth. Check soil consistency - the problem is likely to be greater the looser the consistency of the soil-water mix.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, poor emergence in low spots in fields, heavy rainfall at seeding, soil crusting, poor seed quality, poor seed distribution, low seed rate, water stress,

	muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.)
Why and where it occurs	The problem of soil being too soft occurs in wet direct seeded systems where insufficient time is given for the soil to settle between final wet land preparation (e.g., puddling) and sowing.
Mechanism of damage	In wet direct seeded fields, the seed should remain within 0.5 cm of the surface to adequately germinate and emerge. If the soil consistency is too soft, then the seed will sink into an anaerobic zone of the soil and the seed will have problems emerging resulting in poor stand establishment. Soil with high clay levels are often more prone to taking longer to settle.
When damage is important	The damage is important at the time of crop establishment. Good crop establishment lays the foundation for good yield.
Economic importance	If soils are too soft the crop stand in direct seeded fields can be greatly reduced. Its economic effect is direct due to a reduced plant stand and subsequent yield reduction.
Management principles	Soil consistency is primarily important just at the time of crop emergence. A general rule of thumb is that the field is ready to be sown when a small "V" channel made in the soil with a stick holds it's shape. If the small "V" collapses quickly, it is likely that the soil is still too soft for sowing.
Contributors	J Rickman and M Bell

Soil Crusting

Poor crop emergence (IRRI)

Diagnostic summary

Effect on plants	• germinating seed unable to break the crust • limit oxygen flow into and out of the soil • reduce crop growth
Signs	• poor crop emergence • pattern of damage depends on the levelness of the field and the pattern of soil drying across the field
Importance/Occurrence	• a problem in dry direct seeded fields where seed is covered by soil • important at the time of crop establishment

Full fact sheet

Symptoms	• Poor crop emergence in direct seeded fields • Plants fail to emerge, as they can not break through the drying soil surface • Pattern of damage depends on the levelness of the field and the pattern of soil drying across the field
Confirmation	Check or ask farmer if soil has sealed (become hard) at the time of crop emergence in direct-seeded field. Check for plants that have germinated but have not been able to penetrate the soil surface.
Problems with similar symptoms	Various problems causing problems of crop establishment (e.g., cloddy soil, seed too deep, soil too soft at seeding, poor emergence in low spots in fields, heavy rainfall at seeding,

	poor seed quality, poor seed distribution, low seed rate, water stress, muddy water at seeding, clogged seeder and/or pests such as ants, birds and rats that remove seed at planting.
Why and where it occurs	Crusting occurs as the soil dries. The problem is primarily in dry direct seeded fields where seed is covered by soil, but may also occur in wet direct seeded fields if the soil dries during crop emergence.
Mechanism of damage	When soil dries it becomes harder. When this happens, the germinating seed may not have the strength to break the "crust" that forms as the soil dries. Soil with high silt levels are often more prone to crusting. In upland soils crusting can also limit oxygen flow into and out of the soil and thus reduce crop growth.
When damage is important	The damage is important at the time of crop establishment. Good crop establishment lays the foundation for good yield.
Economic importance	Crusting greatly reduce crop stand in direct seeded fields. Its economic effect is direct due to a reduced plant stand and subsequent yield reduction.
Management principles	Crusting is primarily important just at the time of crop emergence. If the soil surface can be kept moist then crusting is unlikely to be a problem.
Contributors	J Rickman and M Bell

Pests

Ants


Ants feeding on rice grains

Diagnostic summary

Damage to plants	• missing rice seeds • no plants or missing plants • loss of plant stand • patchy distribution of damage
Signs	• presence of honeydew producing homoptera • presence of ants feeding on sown seeds • ant nests below the soil surface
Factors favoring insect/pest development	• upland and rainfed wetland fields • seedling stage of the crop

Full fact sheet

Common name	Ants
Latin names	*Solenopsis geminata (Fabricius)*
Symptoms	• Mainly occur in upland rice • Missing rice seeds • No plants or missing plants • Loss of plant stand • Patchy distribution of damage in the field • Increase the incidence of diseases vectored by homoptera

	 Field damage caused by ants (IRRI)
Confirmation	Ants have pedicel between the thorax and abdomen that distinguished them from other insects. They are often found in the damage area and seeds may also be seen in their underground nests.
Problems with similar symptoms	Missing rice seeds, no plants or missing plants and loss of plant stand are also feeding symptoms of the mole cricket.
Why and where it occurs	In upland fields, ant nests are below the soil surface. In rainfed wetland fields, they are confined to rice levees.
Causal agent or factor	Adult ants have reddish brown body with brown head. They have robust mandibles and mandibular teeth. Their pupae are whitish in color and they develop in the nests. The queen ant usually lays 75 to 125 eggs in a cluster.
Host range	Aside from the rice plant, ants prefer food with high protein content, but will feed on almost anything.
Life cycle	Ants undergo a complete metamorphosis from egg, larva, pupa to adult.
Mechanism of damage	Ants feed on seeds using their sclerotized mandibles.
When damage is important	Feeding damage caused by ants occur during the seedling stage of the rice crop.
Economic importance	Ants are minor pests of rice. If damage is light, the rice crop can often recover from the loss in plant stand due to seed removal by the ants.
Management principles	A cultural management, which is available against ants, is to increase seeding rate. Ants are hosts to nematodes, fungi, phorid flies, strepsipterans, and eucharitine wasps. They are also preys to birds, snakes, bull frog, and ground lizards.
Selected references	1. Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p.

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Contributors JLA Catindig and KL Heong

Armyworm

Larvae and pupae of armyworm (IRRI).

Diagnostic summary

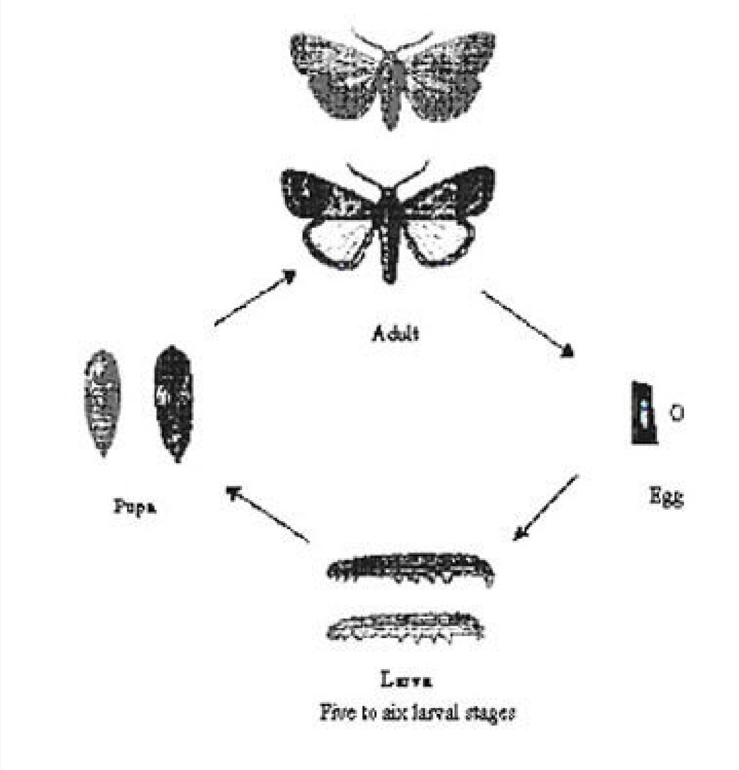
Damage to plants	• cutting off leaf tips, leaf margins, leaves and even the plants at the base • cutting off rice panicles from the base
Signs	• subspherical and greenish white to white rounded eggs either bare or covered with a thin layer of blackish felt • grass green young larvae with dorsal stripes feeding on leaves
Factors favoring insect/pest development	• presence of many alternate hosts • periods of drought followed by heavy rains • dryland and wetland fields • all stages of the rice crop

Full fact sheet

Common name	Rice armyworm, paddy armyworm, rice ear-cutting caterpillar
Latin names	*Mythimna separata* (Walker), *Spodoptera mauritia acronyctoides* (Guenee), *Spodoptera exempta* (Walker)
Symptoms	• Fed-upon leaf tips or along leaf margins • Fed-upon whole leaves leaving only midribs • Removal of whole leaves and plants

	• Cut on stem or plant base • Cutting off rice panicles from base  Fed upon leaf blades (IRRI).  Panicles are cut off from the base (IRRI).
Confirmation	The plant can be checked for the feeding damage by visually locating the presence of the insect pest. The characteristic form of leaf removal can confirm its symptom damage.
Problems with similar symptoms	The symptom damage can be confused with feeding damage caused by cutworms.
Why and where it occurs	A maximum temperature of 15 °C favors adult longevity, oviposition period and egg output and hatching of armyworms. Periods of drought followed by heavy rains sustain the

	development of the insect pest. Naturally fertilized plants can produce more offsprings. Likewise, the presence of many alternate hosts can fully support the continuous development of the insect pest. The insect is nocturnal. The adult feeds, mates, and migrates at night and rests in daytime at the base of the plant. The insect is highly attracted to light traps. The larvae feed in the upper parts of the plant on cloudy days and at nighttime. Pupation occurs in the soil or at the base of the rice plants in dryland fields. In wetlands, they pupate on the plants or grassy areas along the field borders.
Causal agent or factor	The adult is either grayish black with black markings on its forewings or pale red-brown with fewer markings on the front wings or it has pale red-brown forewings with two pale round spots. Its hindwings have two colors, dark red-brown on top and white underneath or the hindwings are lighter than the forewings. The insect has a body length of more than 15.0 mm. The pupa is 13.0 to 20.0 mm long. It is dark brown. Young larvae have two pairs of prolegs. They have brown to orange head with an A-marking on the frons. They are grass green with gray dorsal stripes. The body of mature larva has shades of green, gray, brown, pink, or black with dorsal or subdorsal longitudinal light gray to black stripes or clear yellow stripes running along the entire length of the body. Two rows of C-shaped black spots are either present or absent along the back. They are 31.0 to 45.0 mm long. The rounded eggs are either bare or covered with a thin layer of blackish felt and are laid in oblong clusters. They are subspherical and greenish white or pearly white. They turn yellow or dark brown with age.
Host range	The rice insect pest is polyphagous. Aside from the rice plant, it also feeds on bamboo, barley, cabbage, castor, cotton, cruciferous vegetables, flax, jute, maize, mungbean, oats, sorghum, sugarcane, sweet potato, tobacco, wheat, *Cynodon dactylon* (L.) Pers., *Cyperus* sp., *Echinochloa* sp., and *Imperata* sp., *Poa* sp., In a greenhouse study, the pest was found to feed on rice, *Brachiaria distachya* (L.) Stapf., *Echinochloa glabrescens* Munro ex Hook f., *E. colona* (L.) Link, *E. crus-galli* (L.) Beauv. subsp. *hispidula* (Retz.) Honda, *Paspalum conjugatum* Berg., and *Leptochloa chinensis* (L.) Nees. These hosts can support development of the armyworm from egg to egg.

Life cycle	
Mechanism of damage	The larvae feed on the crop by removing large portions of leaf epidermis using its mandibulate mouthparts.
When damage is important	The rice armyworm is present in all stages of the rice crop. It becomes very destructive when the population is high that it can totally devour the host plant. Mature panicles are cut off from the base of the plants.
Economic importance	This sporadic pest occasionally causes losses especially when an outbreak occurs. They become highly abundant and can move in large groups from field to field just so to feed and attack the crop.
Management principles	Parasitoids such as tachinids, ichneumonids, eulophids, chalcids, and braconid wasps parasitize this pest. Meadow grasshoppers, ants, birds and toads feed on the pest. Fungal diseases and a nuclear polyhedrosis virus also infect the larvae. Chemical control may be needed when populations are extremely high. Pyrethroids can often kill the larvae but can also cause development of secondary pests, such as the brown planthopper.
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Contributors JLA Catindig and KL Heong

Birds

Birds

Diagnostic summary

Damage to plants	• chewed grains • empty grains • whiteheads
Signs	• milky substance covering the grains • missing grains at maturity • nests near crops
Factors favoring insect/pest development	• ripening stage of the crop • staggered planting

Full fact sheet

Common name	Scaly breasted munia, White-rumped munia, White-headed munia, Chestnut munia, Baya weaver
Latin names	*Lonchura* spp., *Ploceus* sp.
Symptoms	• Chewed grains • Milky substance covering the grains • Empty grains • Missing grains at maturity • Whiteheads
Confirmation	The presence of milky substance on chewed grains confirms the feeding damage of birds. Likewise, whiteheads with grains removed also suggest bird damage.

Chewed grains and missing grains (IRRI)

Birds in rice plot at IRRI (IRRI)

Problems with similar symptoms

Whiteheads are also damaged symptom caused by stemborers. In bird’s damage, not all grains are chaffy. In stemborers, all grains in a panicle are chaffy and the panicle can be pulled out easily.

Why and where it occurs

The reproductive period of birds coincides with the ripening stage of the rice crop. Staggered planting also emphasizes bird damage. Their nests are built in low vegetation or in trees near the rice crop.

Causal agent or factor

The adult bird is small, brownish raw umber above with light-colored shafts. The chin is brown, each feather has lighter shaft lines. The upper tail is yellowish olive. The breast, abdomen, and other underparts are white in color, each feather with an exposed broad brown band surrounding the white median streak. The brown band is partly surrounded by a somewhat U-shaped white band, with a portion of its free arms

	covered by the overlapping feathers. The white band is continuous into a whitish buff fringe. The male and female sexes are similar.
Host range	Apart from rice, birds also feed on seeds of *Echinochloa crus-galli* (L.) P. Beauv. and green algae.
Life cycle	The female bird lays its eggs in the nest. Generally, there are three or four young that develop from the eggs.
Mechanism of damage	Birds squeeze the milky grains and feed on the grains. The damage shows milky white substance covering the grains. At grain maturation, birds often remove entire grains.
When damage is important	The ripened grains are the most susceptible stage for the rice-feeding birds.
Economic importance	Birds chew seeds in the milky stage of the crop. The damage due to perching of birds on the panicles result to crop loss. For example, in Malaysia, the crop loss may run up to 40%.
Management principles	One of the management options against birds is to destroy their nesting habitats. Scaring devices and chemical repellents can also be used in the field. To further avoid bird damage, simultaneous planting over large areas should be applied.
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Contributors	JLA Catindig and KL Heong

Black Bug

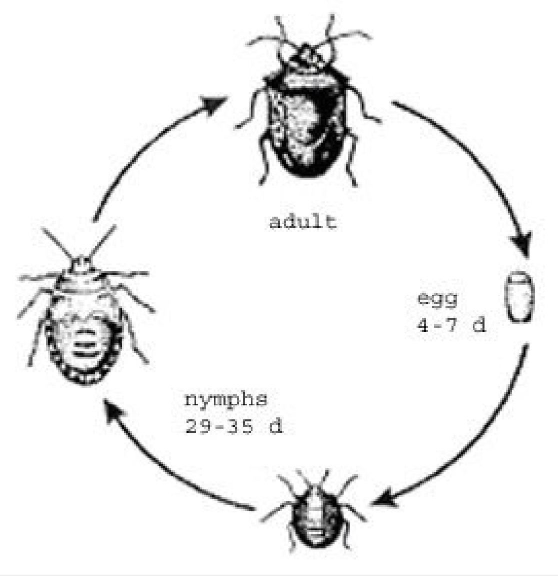
Adult black bug

Diagnostic summary

Damage to plants	• sap removal by adults and nymphs • browning of leaves or deadheart or bugburn • plant stunting • reduced tiller number • weakening of plants and preventing them from producing seeds • formation of whiteheads
Signs	• greenish or pinkish rounded eggs • brown or yellow nymphs • brownish black to black adults
Factors favoring insect/pest development	• rainfed and irrigated wetland environments • vegetative stages of the rice plant • continuously cropped irrigated rice areas • poorly drained fields • densely planted fields • staggered planting of the rice crop • excessive use of nitrogen • presence of alternate hosts/plants • lunar phase

Full fact sheet

Common names	Black bug, Malayan black bug, Japanese rice black bug
Latin names	*Scotinophara coarctata* (Fabricius), *S. lurida* (Burmeister), *S. latiuscula* Breddin
Symptoms	• Deadheart • Reddish brown or yellowing of plants • Chlorotic lesions on leaves • Decreased tillering • Bugburn • Stunting of plant • Stunted panicles, no panicles, or incompletely exerted panicles, and unfilled spikelets or whiteheads at booting • Incomplete and unfilled spikelets at crop maturation  Bugburn (PhilRice) 

	Nymphs of black bug (IRRI)
Confirmation	The deadheart damage caused by black bug may be confirmed if the infected plants cannot be pulled at the bases. The symptom "bugburn" occurs, the wilting of tillers with no visible honeydew deposits or sooty molds.
Problems with similar symptoms	Bugburn is comparable to hopperburn caused by the brown planthopper, whitebacked planthopper, or damages caused by rice hispa, and sheath rot disease. Deadhearts caused by stem borers.
Why and where it occurs	The insect is common in rainfed and irrigated wetland environments during the vegetative stages of the rice crop. It prefers continuously cropped irrigated rice areas and poorly drained fields. Damages are observed more frequently in dry season rice crops and densely planted fields are preferred. Black bug flight patterns are affected by the lunar cycle and on full moon nights, large numbers of adults swam to light sources. Staggered planting of the rice crop and excessive nitrogen favors the buildup of the pest. Presence of alternate breeding site favors population increase during non-rice periods.
Causal agent or factor	The newly emerged adult is white and tinged with green and pink. Mature adults are shiny dark brown or black. Different nymphal instars vary in size. They are brown or yellow with black spots on the body. They have rounded eggs, which are greenish or pinkish.
Host range	Its primary hosts include maize and rice. Its alternate hosts are *Hymenachae pseudointerrupta* (Steud.) Gilliland, Salix sp. (willow), and *Scirpus grossus* L. f. (greater club grass).
Life cycle	

Mechanism of damage	Both the adults and nymphs remove the plant sap by using its sucking mouthparts. They prefer the stem nodes because of the large sap reservoirs.
When damage is important	Black bugs feed on the rice plant from seedling to maturity growth stages. Heavy infestation and "bugburn" is usually visible after heading or maturing.
Economic importance	Feeding damage of black bugs causes half-filled and empty grains. Ten adults per hill can cause losses of up to 35% in some rice.
Management principles	One of the cultural control practices to reduce the population of the black bug is to maintain a clean field by removing the weeds and drying the rice field during plowing. Rice varieties of the same maturity date may be planted to break the insect's cycle. Direct-seeded rice crops tend to have less tillers in one planting point and thus discourage population growth. During early infestation, the water level in the field may be raised for 2-3 days to force the insects to move upwards. Flooding the fields can also cause higher egg mortality. After harvest, fields might be plowed to remove remaining insects. Mechanical control measures include the use of mercury bulbs as light traps for egg-laying adults. Light trapping of insects should start 5 days before and after the full moon. In the field, there are biological control agents such as small wasps that parasitize the eggs. Ground beetles, spiders, crickets, and red ants attack the eggs, nymphs, and adults. Both the eggs and the nymphs are fed-upon by coccinellid beetles. Ducks and toads also eat the nymphs and adults. There are 3 species of fungi attacking the nymphs and adults. Two IRRI varieties resistant to black bugs are available. For chemical control, foliar spraying of insecticides directed at the base of the rice plant is the most effective.
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Cricket

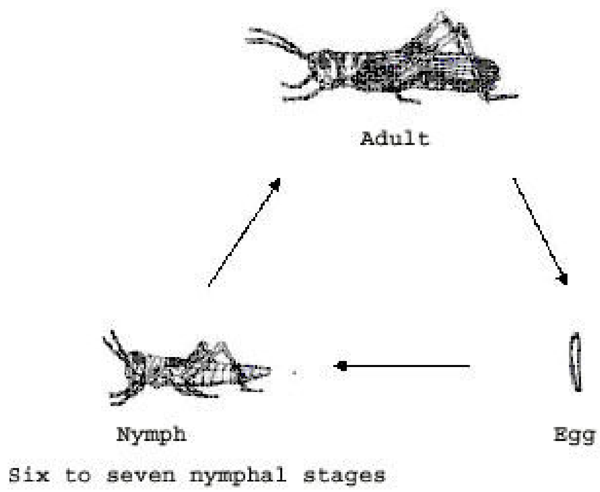
Crickets and their feeding damage (IRRI)

Diagnostic summary

Damage to plants	• feeds on leaves by making irregular to longitudinal exit holes • excessive feeding causes deadheart
Signs	• white to orange, elongate-ovoid eggs • pale brown nymphs and adults feeding on the rice plants
Factors favoring insect/pest development	• irrigated rice environment • presence of weed piles

Full fact sheet

Common name	Crickets or gryllid
Latin names	*Euscyrtus concinnus* (de Haan)
Symptoms	• Irregular to longitudinal exit holes • Cutting of central portions of the leaf blades leaving only the midrib • Deadheart
Confirmation	Its characteristic damage pattern of irregular to longitudinal exit holes confirms its feeding damage.
Problems	The symptoms can be confused with the damage caused by

with similar symptoms	grasshoppers and other defoliating insects.
Why and where it occurs	Crickets or gryllids are both leaf- and stem-feeding insects. They are active at night. Their nymphs are more destructive than the adults. They are common in the irrigated rice environment. In upland environment, the insects are found underneath heaps of weed piles. Presence of piles of weeds attracts the insect pest. Alternate hosts support continuous presence of the insect pest in rice environment.
Causal agent or factor	The adult gryllid is pale brown. It measures 1.0 to 1.8 cm long. It has long antennae and legs. The female has a long and spear-shaped ovipositor. The female is longer in size than the male gryllid. The nymph has the same color as the adult. It is a smaller version of the adult except for its wing pads. It has a pair of brown to black spots along its abdomen. Individual eggs are elongate-ovoid. Newly laid eggs are whitish and turn orange with age.
Host range	Aside from the rice plant, crickets also feed on *Cyperus rotundus* L., *Dactyloctenium aegyptium* (L.) Willd., *Digitaria sanguinalis* (L.) Scop., *Echinochloa spp.*, *Eleusine indica* (L.) Gaertn., *Paspalidium flavidum* (Retz.) A. Camus, and *Rottboellia cochinchinensis* (Lour.) W.D. Clayton.
Life cycle	
Mechanism of damage	Crickets feed on leaves and stems of the rice plants.

When damage is important	Crickets normally feed on seeds, roots, or leaves of young seedlings. They also feed on young panicles and mostly all stages of the rice crop.
Economic importance	Crickets are defoliators. They can be numerous at times and can totally infest the crop, especially the young rice panicles.
Management principles	There are no known control practices for this insect.
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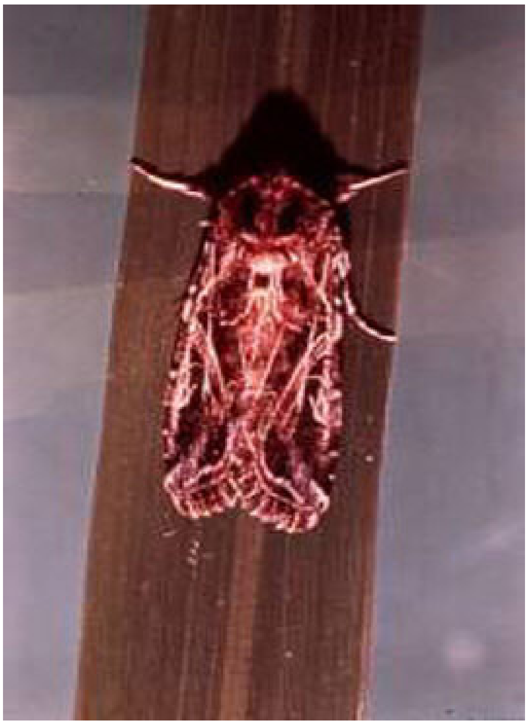
Cutworm

Cutworm larva (IRRI)



Adult moth (IRRI)

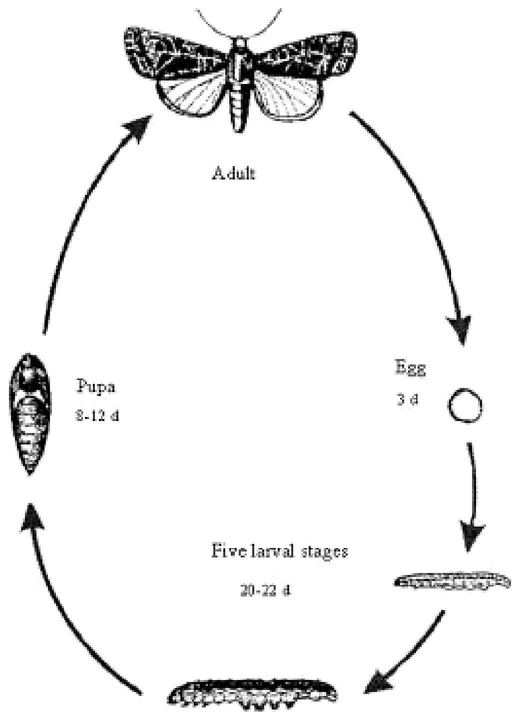
Diagnostic summary

Damage to plants	• young caterpillars eat the soft leaves of the rice plant • full-grown caterpillars devour the entire plant
Signs	• pearly white and round eggs • brown or brownish black larvae feeding on rice • fecal matters
Factors favoring insect/pest development	• presence of alternate hosts • all types of rice environments • vegetative stages of the crop

Full fact sheet

Common name	Common cutworm
Latin names	*Spodoptera litura* (Fabricius)
Symptoms	• Seedlings cut at bases • Leaf surfaces skeletonized • Entire plants devoured

Confirmation	The rice plant can be checked for the presence of eggs and feeding larvae. Likewise, the symptoms can be visually inspected like the presence of cut seedlings and leaves eaten.
Problems with similar symptoms	The defoliation or feeding damage caused by cutworms can be confused with other defoliators or leaf-feeding insects.
Why and where it occurs	The monsoonal rains favor the development of this insect pest. Likewise, the presence of alternate hosts contributes to the insect's abundance. Outbreaks of the pest often occur after periods of prolonged drought followed by heavy rains. The insect occurs in all types of rice environments during the vegetative stages. The adult moths are nocturnal and highly attracted to light traps. During the day, they hide at the bases of rice plants and grassy weeds. The eggs usually hatch in the early hours of the morning. Neonate larvae feed on the leaf tips or from the base of the leaf toward the apical area. At daytime, the larvae are found under leaf litter in the ground in dryland fields. In wetland environments, the larvae usually stay on plants above the water surface.
Causal agent or factor	The adult insect is a moth with dark brown forewings having distinctive black spots and white and yellow wavy stripes. Its hindwings are whitish with gray margins and somewhat irridescent. The moth has a black or brown pupa, which measures 22.5 mm long and 9.2 mm wide. The larva is the destructive stage. The newly hatched larvae are tiny and about 1 mm long, and are greenish. The full-grown larva has a cylindrical body, brown or brownish black tinged with orange. One to two dark spots are visible on the thoracic segments near the base of the legs. The abdominal segments have two light brownish lateral lines on each side, one above and one below the spiracles. Above the top lines is a broken line composed of velvety semicrescent patches that vary in color among individuals. Individual eggs are pearly white and round and have a ridged surface.
Host range	The insect pest is polyphagous and has about 150 host species. These include cotton, cruciferous vegetables, cucurbits, groundnut, maize, potatoes, rice, soybean, tea, tobacco, *Capsicum annum* (hot pepper), *Colocasia esculenta* (L.) Schott, and Phaseolus sp.

Life cycle	
Mechanism of damage	The larva feeds on leaves and sometimes cut off the stems.
When damage is important	The larva attacks rice during the vegetative stages of the crop.
Economic importance	The cutworm is polyphagous and may become serious during the seedling stage, especially in upland rice.
Management principles	Keeping fields flooded may keep population of this pest at low levels. Biological control agents of cutworm are very abundant. For example, scelionid and braconid wasps are egg parasitods and grasshoppers are predators of the pest. Fungal and polyhedrosis viruses are pathogens that attack this insect pest. Insecticides like pyrethroids, may be needed when larval populations are extremely high. As pyrethroids can also cause secondary pests, spot spraying only at high population densities may be advisable.
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Green Leafhopper


Green Leafhopper - adults (IRRI)

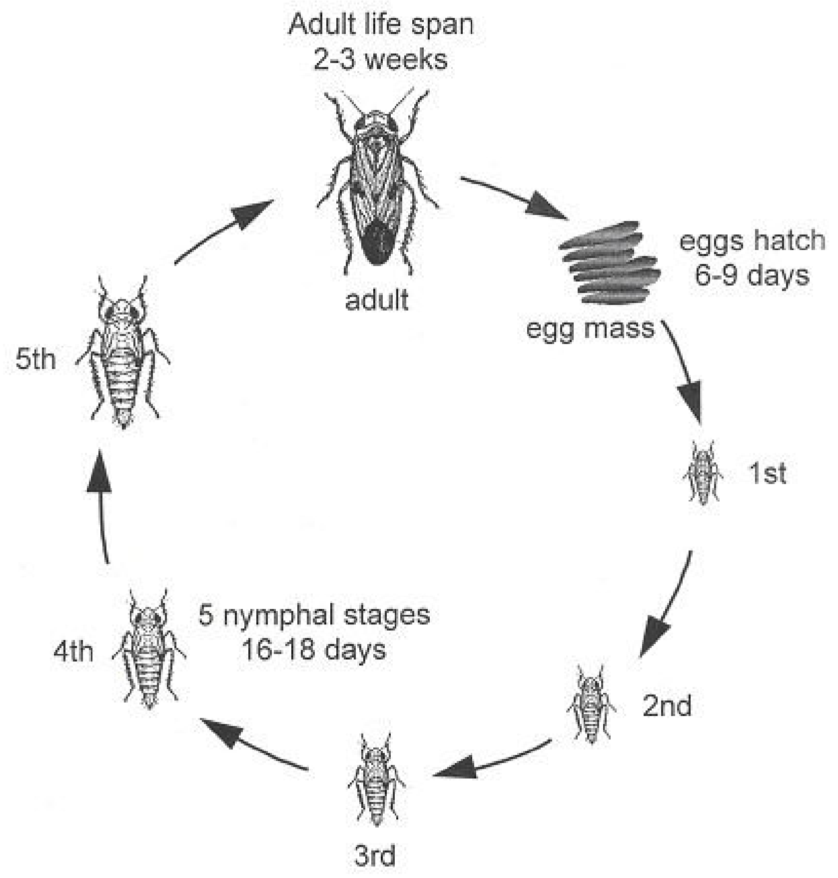
Diagnostic summary

Damage to plants	• cause direct damage to the rice plant • feed on rice by sucking the plant sap • plugging the vascular bundles with stylet sheaths • symptoms of various viral diseases
Signs	• white or pale yellow eggs inside leaf sheaths or midribs • yellow or pale green nymphs with or without black markings • pale green adults with or without black markings feeding on upper parts of the crop
Factors favoring insect/pest development	• grasses near irrigation canals and levees • rice ratoons • lot of sunshine, low rainfall, and high temperature • rainfed and irrigated wetland environments • excessive use of nitrogen

Full fact sheet

Common name	Green leafhopper (GLH)
Latin names	*Nephotettix virescens* (Distant) *Nephotettix nigropictus* (Stal) *Nephotettix malayanus* Ishihara et Kawase *Nephotettix cincticeps* (Uhler)
Symptoms	• Transmits virus diseases such as tungro, yellow dwarf, yellow-orange leaf, and transitory yellowing • Plant stunted and reduced vigor

	• Number of productive tillers reduced • Withering or complete plant drying
Confirmation	The presence of the insect and virus infected plants in the fields.
Problems with similar symptoms	Tungro infected crops may sometimes be confused with nitrogen deficiency or iron toxicity or acid soils.
Why and where it occurs	Staggered planting encourages population growth of GLH.
	Green leafhoppers are common in rainfed and irrigated wetland environments. They are not prevalent in upland rice. Both the nymphs and adults feed on the dorsal surface of the leaf blades rather than the ventral surface. They prefer to feed on the lateral leaves rather than the leaf sheaths and the middle leaves. They also prefer rice plants that have been fertilized with large amount of nitrogen.
Causal agent or factor	The adult leafhopper is slender and green. Its head is rounded or pointed with or without black bands. Its vertex is with or without an anterior black band and a submarginal black band extending beyond the ocelli to the inner margins of the eyes. The face is green. Its pronotum is smooth with or without a black anterior margin. A pair of black spots is either present or absent on the forewings. The insect is 4.2-4.3 mm. Neonate nymph measures 0.9 mm long. It is transparent, white, and shiny. As it matures, it turns yellowish to green with or without black markings on the head, thorax, and abdomen. A mature nymph is 3.1 mm long. The shape of the nymph is similar to that of the adult except that the nymph is smaller and is wingless. As the insect matures, blackish markings on the abdomen become more prominent as well as the blackish band on the last abdominal segment. Eggs are white and elongate or cigar-shaped. Individual eggs are arranged neatly and lie parallel to each other in each egg batch. A single egg measures 0.9 - 0.8 mm. Upon maturation, the egg turns brownish and develops red eyes.
Host range	The major host of the green leafhopper is the rice plant. It also feeds on a number of grasses.

Life cycle	
Mechanism of damage	Both nymphs and adults of the green leafhopper feed on rice by sucking the plant sap and plugging the vascular bundles with stylet sheaths.
When damage is important	The green leafhoppers are most numerous during the tillering and panicle initiation stages of the crop. Seedling and booting stages are also susceptible. They migrate to the field soon after seedlings have emerged. They can cause indirect damage to the crop because of the virus diseases that they transmit.
Economic importance	Green leafhoppers are important pests. They are vectors of viruses such as tungro, yellow dwarf, yellow-orange leaf, transitory yellowing, and dwarf.
Management principles	There are biological control agents, which are available for the insect. For example, small wasps parasitize the eggs. Mirid bugs also feed on them. Strepsipterans, small wasps, pipunculid flies, and nematodes parasitize both the nymphs and adults. They are also attacked by aquatic veliid bugs, nabid bugs, empid flies, damselflies, dragonflies, and spiders. A fungal pathogen infects both the nymphs and adults of the green leafhopper.

In India, there are some commercially available rice plants that show resistance to the green leafhoppers.

In areas without tungro source, insecticides are not needed. Spraying of insecticide should be avoided because it is often unable to prevent or reduce tungro infections.

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Contributors

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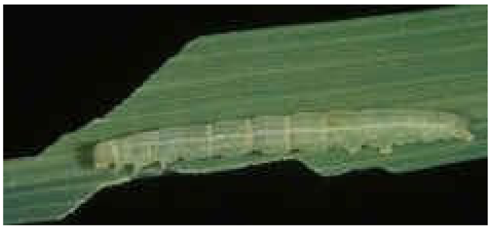
Green Semilooper

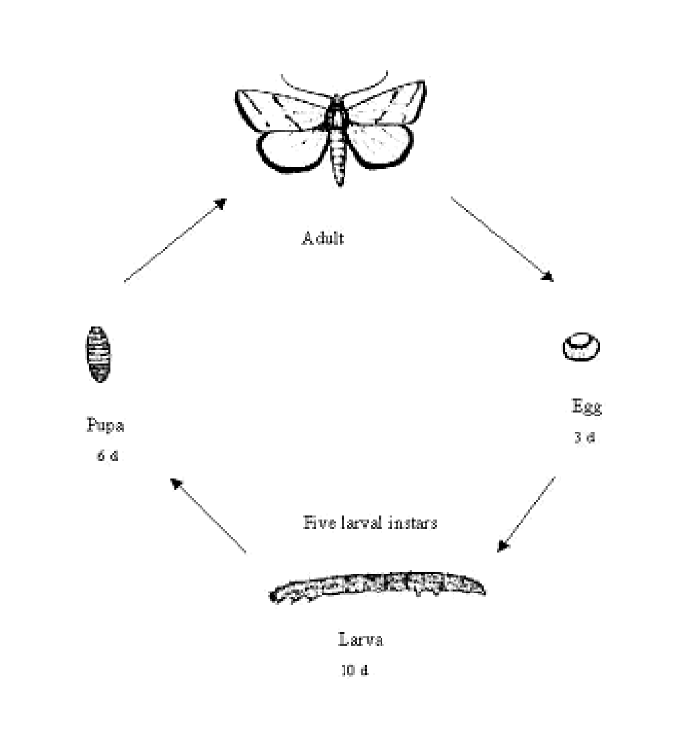

Larva creating notches (IRRI)

Diagnostic summary

Damage to plants	• young larvae scrape the tissues from leaf blades • mature larvae feed on leaf edges to create notches
Signs	• spherical eggs • light green larvae feeding on rice leaves
Factors favoring insect/pest development	• heavily fertilized crops • wetland environments • grassy areas

Full fact sheet

Common name	Green semilooper
Latin names	*Naranga aenescens* (Moore)
Symptoms	• Leaves scraped exposing the lower epidermis • Leaf edges damaged  Larval scrapings (IRRI)
Confirmation	The presence of the insect pest feeding on the plant will confirm its feeding damage. Likewise, its characteristic form of damage on the leaf can also identify what insect caused such symptoms.
Problems with similar symptoms	The feeding damage of the green semilooper is similar to that of the rice green hairy caterpillar.
Why and where it occurs	Heavily fertilized crops favor the development of green semiloopers. Green semiloopers are found in wetland environments. They

	are abundant during the rainy season. The adult moths hide at the base of the plants in rice fields or in grassy areas during daytime and are active at night. Prior to pupation, the older larvae fold a rice leaf and secure it with silk to form a pupal chamber.
Causal agent or factor	Both the male and female moths are yellow-orange. Their forewings have two diagonal dark red bands. The young pupa is light green and turns brown as it matures. The larval head and body are yellow-green. White lines run along the entire length of the body. The yellow eggs are spherical. Mature eggs have purple to violet markings.
Host range	The green semilooper feeds primarily on the rice plant. Its secondary hosts are *Echinochloa spp*. and *Eleusine sp*.
Life cycle	
Mechanism of damage	Both the young and mature larvae feed on leaves. Young larvae scrape the leaf tissues of the epidermis of the leaf blade leaving only the lower white surface. Matured larvae often cut out sections of leaf blades especially in the margins.
When damage is important	The insect pest is found during the seedling and tillering stages of the rice crop. Its damage is not important because green semilooper is only a minor pest of rice.
Economic importance	The larvae of green semiloopers defoliate the rice plants. However, this pest rarely causes economic loss to crops because of compensation. Natural enemies often suppress its

	populations.
Management principles	Highly fertilized crops may favor larval development. The insect pest is generally managed by natural biological control agents, like small trichogrammatid wasps that parasitize eggs. Ichneumonid, braconid, elasmid, eulophid and chalcid wasps parasitize both the larvae and pupae, and spiders feed on the adult moths.
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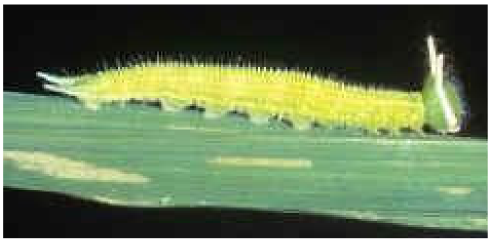
Greenhorned Caterpillar

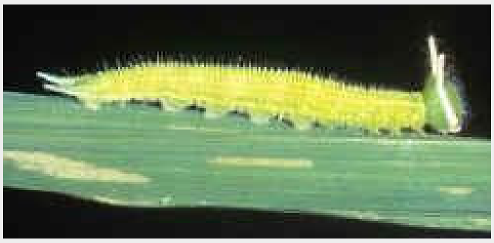


Larva of greenhormed caterpillar (IRRI)

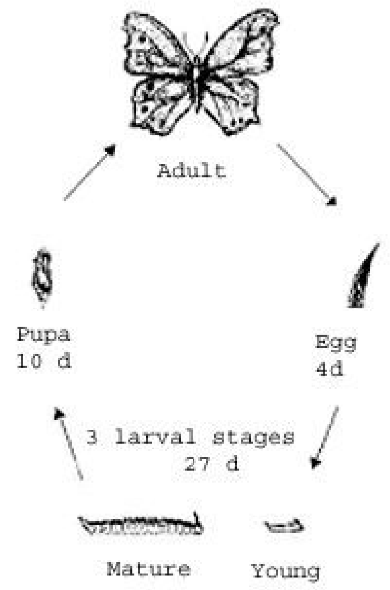
Diagnostic summary

Damage to plants	• larvae feed on the margins and tips of leaf blades • feeding damage causes removal of leaf tissues and veins
Signs	• shiny and spherical pearl-like eggs • yellow-green larva with body covered by small and yellow bead-like hairs
Factors favoring insect/pest development	• presence of alternate hosts • presence of natural enemies

Full fact sheet

Common name	Greenhorned caterpillar
Latin names	*Melanitis leda ismene* Cramer, *Mycalesis sp.*
Symptoms	• Leaf margins and leaf tips devoured • Leaf tissues and veins removed  Damaged leaf (IRRI)
Confirmation	The presence of the insect pest feeding on the rice foliage confirms its damage. It also causes a characteristic feeding damage on the margins and edges.
Problems with similar symptoms	The rice skipper and green semilooper cause the same damage symptoms.
Why and where it occurs	The larvae feed on alternate hosts that may also support their continuous development in the field. The two species are found in all rice environments. They are most common in rainfed areas.

	The adults are not attracted to a light trap. The larvae because of their color blend easily with the rice foliage. Pupation occurs on the leaves and the pupa is a chrysalis suspended from leaves.
Causal agent or factor	The adults are large butterflies and are easily recognized because of the pattern of eye spots on their wings. Two species of greenhorned caterpillars are common. They can be distinguished by the pattern of eye spots on their wings. *Melanitis* has two white eye spots on the topside of the forewing and seven eyespots on the hind wing. The underside of the forewing has three violet and yellow circles and six on the hind wing. *Mycalesis* has one eyespot on both the topside of the front wing and hind wing. There are two eyespots on the underside of the front wing and five on the hindwing. Their eyes are either hairy or smooth. The pupa is green and smooth. *Mycalesis* is more elongated and lacks constriction toward the head region, unlike *Melanitis*, which is robust. The larvae are identified by the two pairs of horns on the flat and square head and posterior end of the body. They are yellow-green. The body is covered with small and yellow bead-like hairs. A pair of distinct horns is visible on the larval head and another pair at the posterior end of the body. *Melanitis* has white or black horns and *Mycalesis* has red horns. The eggs are pearl-like in appearance, shiny and spherical.
Host range	Rice is their major host but they also feed on grasses, sugarcane, sorghum, *Anastrophus sp.*, *Imperata sp.*, and *Panicum spp*.

Life cycle	
Mechanism of damage	The larvae feed on the leaves causing the removal of leaf tissues and veins.
When damage is important	The greenhorned caterpillars feed on rice from tillering to panicle initiation stages of the crop.
Economic importance	The greenhorned caterpillars are minor pests of rice. Their potential severity is generally too low to cause yield loss. Natural enemies usually control their populations and rice compensate from the feeding damage of greenhorned caterpillars.
Management principles	Natural biological control agents often keep the larval population under control. For example, the eggs are parasitized by trichogrammatid wasps. Chalcid wasp and two species of tachinid flies parasitize the larvae and a vespid wasp preys on the larvae.
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Contributors	JLA Catindig and KL Heong

Mealybugs


Field damage caused by mealybugs (IRRI)

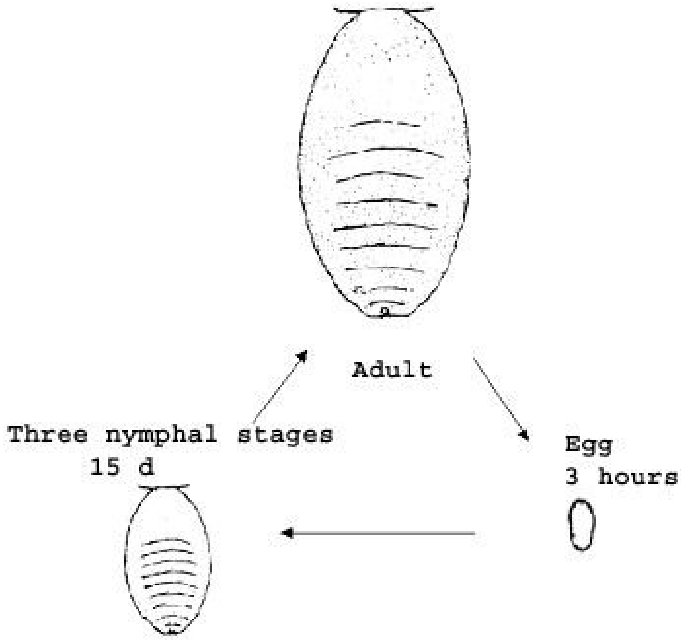
Diagnostic summary

Damage to plants	• both the adults and nymphs remove plant sap using their sucking mouthparts • yellowish curled leaves • wilting of plant
Signs	• hyaline to yellowish to pinkish eggs • crawlers or nymphs, unwinged pink female adults and winged pale yellow males removing plant sap • appearance of wax covering the eggs, nymphs and adults that stick on the stem or leaf
Factors favoring insect/pest development	• dry period • presence of grassy weeds • well-drained soils • upland and rainfed environments

Full fact sheet

Common name	Rice mealybug
Latin names	*Brevennia rehi* (Lindinger)
Symptoms	• Wilting • Plant stunting • Yellowish curled leaves • Damaged spots or chakdhora or soorai disease • Not uniform pattern of damage

	 Mealybugs (IRRI)
Confirmation	The symptom caused by rice mealybug can easily be detected by visually locating the insect on the plant. The insect is found sticking on the stem or leaf.
Problems with similar symptoms	Stunting is also a damage symptom caused by other insect pests like root grubs and rice root aphids. However, presence of rice mealybug confirms its damage on the rice plant.
Why and where it occurs	Dry spells and the presence of grassy weeds that harbor this insect pest favor the population buildup of the rice mealybug. Likewise, well-drained soils are also suitable for the insect pest. The rice mealybug is found in upland and rainfed environments. It is not common in irrigated rice. It occurs in great number during the rainy season. The nymphs are active until they molt. They first stay under the body of the adult female and later crawl from plant to plant. They are also dispersed by wind. After dispersal, they stay between the leaf sheath and stem to feed and complete their entire larval development. After molting, the female attaches itself to the plant for life and grows in size. The adult females remain stationary and feed while the winged adult male flies off. The insect is abundant in April to early July where two generations are completed during this period.
Causal agent or factor	The pale yellowish male adults have a single pair of wings and a waxy style-like process at the end of the abdomen. The first and middle legs of the male are approximately equal, whereas the last or third legs are longer. The body is 0.7-0.9 mm long. Adult females are oblong and wingless. They are reddish white and soft-

	bodied. Their body is covered with a distinct waxy or powdery coating. They measure about 1.2-3.0 mm long and 0.5-1.5 mm wide. They resemble woodlice in shape. The first instar nymphs or crawlers measure 0.1-0.2 mm wide and 0.3-0.5 mm long. Mature crawlers are 3-4 mm long. The elongated or oval eggs are hyaline to yellowish to pinkish. They are 0.3 by 0.5 mm. They are covered with wax. The eggs turn grayish red when about to hatch.
Host range	The rice plant is the primary host of the rice mealybug. It also feeds on some grasses such as *Echinochloa sp.* and *Cyperus sp*.
Life cycle	
Mechanism of damage	Both the adults and nymphs remove plant sap using their sucking mouthparts.
When damage is important	The rice mealybug feeds on rice during the tillering and stem elongation stages of the rice crop. Favorable conditions that cause high populations of the pest may cause yellowing and stunting of the crop.
Economic importance	The rice mealybug causes heavy losses to crops in Bangladesh, India, and Thailand. High density (> 100 mealybugs/hill) caused plants to wilt and die.
Management principles	Biological control can suppress the rice mealybugs. Small encyrtid wasps parasitize mealybugs. Spiders, chloropid fly, drosophilid, and lady beetles are predators of the mealybugs.
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Contributors JLA Catindig and KL Heong

Mole Cricket


Mole cricket adult (IRRI)

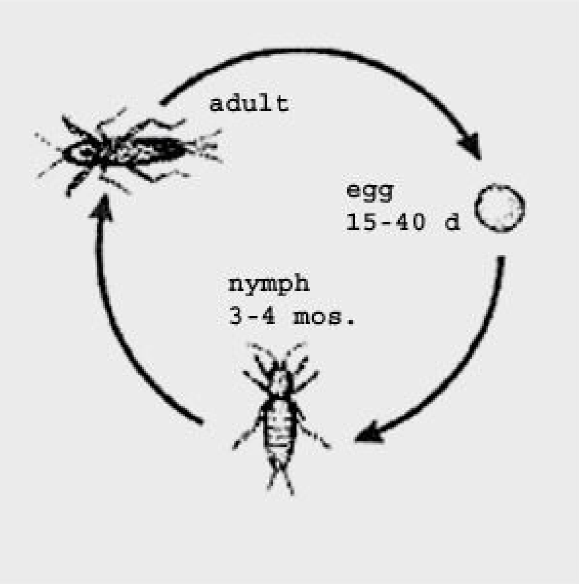
Diagnostic summary

Damage to plants	• feeding on seeds • fed-upon tillers in mature plants • visible feeding damage on roots • plants cut at the base • loss of plant stand
Signs	• presence of tan nymphs in tunnels on soil areas near the roots • brown adults
Factors favoring insect/pest development	• non-flooded upland fields • presence of alternate hosts • burrows or foraging-galleries in levees or field borders

Full fact sheet

Common name	Mole cricket
Latin names	*Gryllotalpa orientalis* Burmeister
Symptoms	• Loss of plant stand • Seedlings cut at the base • Poor seedling growth • Seedling death • Missing plants • Root damages

	 Affected root system (IRRI)
Confirmation	The insect tunnels made by mole crickets appear as disturbed soil areas. The plants are cut at the base and the roots have visible feeding damage.
Problems with similar symptoms	Loss of plant stand and the missing plants are symptoms also caused by ants.
Why and where it occurs	Mole crickets occur in all rice environments. They are more common in non-flooded upland fields with moist soil. In flooded rice fields, mole crickets are usually seen swimming in the water. They are also found in permanent burrows or foraging-galleries in levees or field borders. The entrances to burrows in the soil are marked by heaps of soil. The nymphs feed on roots and damage the crops in patches.
Causal agent or factor	The adult mole cricket is brownish and very plump. It measures 25-40 mm long. It has short antennae and its folded wings do not cover the entire length of the abdomen. The enlarged front legs, which are modified for digging, have strong teeth-like structures. Neonate nymph has a white and bluish prothorax and legs. With age, it turns gray to black with white markings. The last nymphal stage is similar to the adult except for its short wing pads. Eggs are oblong to oval and gray with a shiny surface. They are 2.6 mm long. The eggs are deposited in a hole constructed by the adult female.
Host range	Besides rice, the insect pest feeds on *Allium cepa* L. (onion), *Brassica oleraceae* L. (cabbage), *Camellia sinensis* (L.) *O. Ktze.* (tea), *Helianthus annuus* L. (sunflower), *Hordeum sp.* (barley), *Nicotiana tabacum* L. (tobacco), *Solanum tuberosum* L. (white potato), and *Triticum aestivum* L. em. Thell. (wheat).

Life cycle	
Mechanism of damage	The mole cricket tunnels into the soil using its enlarged fore legs. It feeds on seeds and resulting in loss of plant stand or poor crop stands.
When damage is important	Mole cricket is an important insect when flooded rice is drained or when water level varies exposing the soil. It feeds on rice during the seed to seedling stages of the crop.
Economic importance	Mole crickets are polyphagous. They feed on the underground parts of almost all-upland crops. They occasionally become sufficiently abundant to cause heavy damage to roots and basal parts of rice plants growing in raised nursery beds or upland conditions. In wetland rice, infestation occurs when there is no standing water.
Management principles	There are cultural control, biological control, and resistant varieties that can be used for mole crickets. For example, cultural control includes maintaining standing water, which can help remove the eggs on the soil. The eggs can also be eliminated using bund shaving and plastering of fresh wet soil. The rice field can be flooded for 3-4 days. Levelling the field provides better water control. Construction of a raised nursery should be avoided to reduce feeding damage on seedlings. During land preparation, the nymphs and adults can be collected. Modern varieties with long and dense fibrous can tolerate damage better. For natural biological control, a sphecid wasp, carabid beetle, nematodes, and a fungus are recorded as important natural enemies of the mole cricket. Mole crickets eat each other when they are together because of their cannibalistic behavior. There are poisoned baits made by mixing moistened rice bran and insecticide that can be placed along rice bunds or drier areas of the field, which can kill night-foraging mole crickets. Granular insecticides are effective unlike foliar insecticides.

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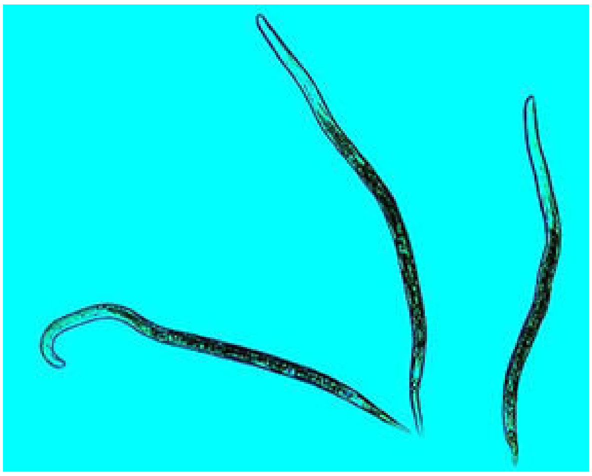
Nematodes (Root Knot)



Second stage juveniles of root -knot nematode
(LC Fernandez, IRRI)

Diagnostic summary

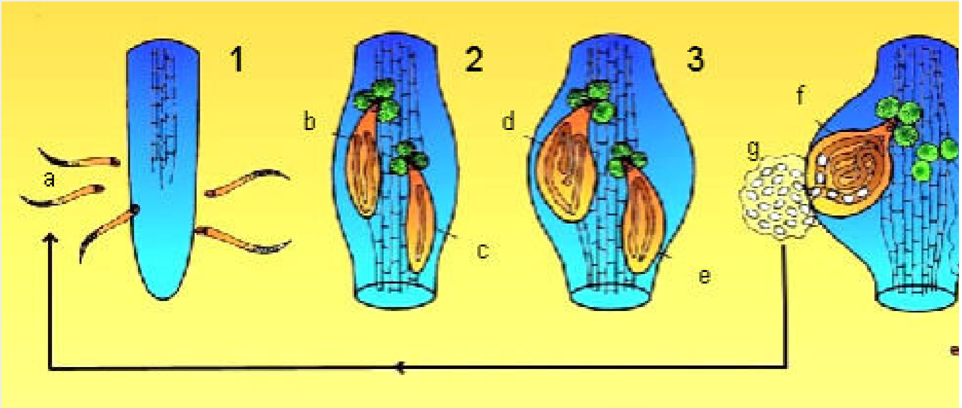
Damage to plants	• juveniles or immatures remain in the maternal gall or migrate within the root to feed • formation of galls
Signs	• presence of the nematodes • roots with galls • distorted and crinkled margins of newly emerged leaves • stunting • chlorosis • early flowering and maturation
Factors favoring insect/pest development	• soil moisture of 32% • soil dryness • flooded conditions • waterlogged soil • presence of alternate vegetable crops during dry season • lowland and deepwater rice field • tillering and panicle initiation stages of the crop

Full fact sheet

Common name	Rice root-knot nematode
Latin names	*Meloidogyne graminicola* (Golden & Birchfield)

Symptoms	• Characteristic hooked-like galls on roots • Newly emerged leaves appear distorted and crinkled along the margins • Stunting • Chlorosis • Heavily infected plants flower and mature early  Female adult and egg mass of root knot-nematode (LC Fernandez, IRRI)  Root galls on rice (RG Reversat, IRRI)
Confirmation	The roots of the host plants can be examined for hooked-like galling. They can be stained to determine the presence and populations of *M. graminicola*. The juveniles of *M. graminicola* can be extracted from the roots of the host plants.
Problems with similar symptoms	Other nematodes cause similar damage symptoms.
Why and where it occurs	*M. graminicola* is a damaging parasite on upland, lowland and deepwater rice. It is well adapted to flooded conditions and can survive in waterlogged soil as eggs in eggmasses or as juveniles for long periods. Numbers of *M. graminicola* decline rapidly after 4 months but

	some egg masses can remain viable for at least 14 months in waterlogged soil. *M. graminicola* can also survive in soil flooded to a depth of 1 m for at least 5 months. It cannot invade rice in flooded conditions but quickly invades when infested soils are drained. It can survive in roots of infected plants. It prefers soil moisture of 32%. It develops best in moisture of 20% to 30% and soil dryness at rice tillering and panicle initiation. Its population increases with the growth of susceptible rice plants. The presence of relatively broad host range and many of the alternative vegetable crops that are grown during dry season are favorable for this nematode.
Causal agent or factor	Adult females appear to be pear-shaped to spheroid with elongated neck, which is usually embedded in root tissue. Their body does not transform into a cystlike structure. Females have six large unicellular rectal glands in the posterior part of the body, which excrete a gelatinous matrix to form an egg sac, in which many eggs are deposited. The stylet is mostly 9-18 µm long with tree small, prominent, dorsally curved basal knobs. The esophageal glands overlap the anterior end of the intestine. The females have two ovaries that fill most of the swollen body cavity. The vulva is typically terminal with the anus, flush with or slightly raised from the body contour and surrounded by cuticular striae, which form a pattern of fine lines resembling human fingerprints called the perennial pattern. Infective second stage juveniles are short (0.3-0.5 mm) and have a weak cephalic framework. The esophageal gland lobe overlaps the intestine ventrally. The tail tip tapers to a long, fine point with a long hyaline region.
Host range	Aside from the rice plant, it also prefers *Alopecurus* sp., *Avena sativa* L., *Beta vulgaris* L., *Brachiaria mutica* (Forsk.) Stapf, *Brassica juncea* (L.) Czem. & Coss, *B. oleraceae* L., *Colocasia esculenta* (D.) Schott, *Cyperus procerus* Rottb., *C. pulcherrimus* Willd. ex Kunth, *C. rotundus* L., *Echinochloa colona* (L.) Link, *Eleusine indica* (L.) Gaertn., *Fimbristylis miliacea* (L.) Vahl, *Fuirena* sp., *Glycine max* (L.) Merr., *Lactuca sativa* L., *Lycopersicon esculentum* Mill., *Monochoria vaginalis* (Burm. f.) Presl, *Panicum miliaceum* L., *P. repens* L., *Paspalum scrobiculatum* L., *Pennisetum typhoides* (Burm. f.) Stapf & Hubbard, *Phaseolus vulgaris* L., *Poa annua* L., *Ranunculus* sp., *Saccharum officinarum* L., *Sorghum bicolor* (L.) Moench, *Sphaeranthus* sp., *Sphenoclea zeylanica* Gaertn., *Spinacia oleracea* L., *Triticum aestivum* L., and *Vicia faba* L.

Life cycle	 1. The larvae of the second stage (a) are attracted to the roots. They usually penetrate the roots closely behind the root tip. The larvae then migrate first towards the root tip, where the absence of differentiated endodermis allows them to enter the vascular cylinder. This migration happens intercellularly by mechanical and possibly enzymatic softening of the middle lamella. The parasites finally start feeding on three to ten cells, which are rapidly turned into multinucleated giant cells, by endomitosis and cell hypertrophy. 2. At the same time as the giant cells are formed, the cells of the neighboring pericycle start to divide, giving rise to a typical gall or root-knot. Inside the gall, a female (b) and a male (c) of the J3 larval stage are shown. 3. The gall continues to swell, while females (d) and males (e) are in their J4 stage. 4. During the last moult, the male (h) dramatically changes its shape, then leaves the root, and fertilizes the female (f) in the case of amphimictic species. However, parthenogenesis is often encountered in root-knot nematodes. The female lays its eggs in a gelatinous matrix (g) outside the root. From there, the larvae of the second stage (a) hatch and are attracted to roots. Depending on environmental conditions, this cycle is completed in one to two months.
Mechanism of damage	Infective second stage juvenile of *M. graminicola* penetrates through the root tips and takes about a minimum of 41 hours. Females develop within the root and eggs are laid in the cortex. Galls are formed in 72 hours. The juveniles or immatures remain in the maternal gall or migrate intercellularly through the aerenchymatous tissues of the cortex to new feeding sites within the same root.
When damage is important	The rice root-knot nematode attacks the rice plant in all growth stages.
Economic importance	The rice root-knot nematode is considered one of the limiting factors in rice production in all rice ecosystems. In upland rice, there is an estimated reduction of 2.6% in grain yield for every 1000 nematodes

	present around young seedlings. In irrigated rice, damage is caused in nurseries before transplanting or before flooding in the case of direct seeding. Experiments have shown that 4000 juveniles per plant of *M. graminicola* can cause destruction of up to 72% of deepwater rice plants by drowning out.
Management principles	There are cultural, biological, physical, mechanical, use of resistant varieties and chemical control that are available for the rice root-knot nematode. For example, cultural control includes continuous flooding, raising the rice seedlings in flooded soils, and crop rotation. These practices will help prevent root invasion by the nematodes. Soil solarization, bare fallow period and planting cover crops such as sesame and cowpea has been reported to decrease nematodes. Rotation crop like marigold (*Tagetes sp.*) is also effective in lowering root knot nematode populations because of its nematicidal properties. There is some IR cultivars, which are resistant against the nematode. Likewise, some related rice species such as some accessions of *Oryza longistaminata* Chev. et Roehr. and *O. glaberrima* Steud are also resistant. Several nematicidal compounds can be used as chemical control. They are volatile (fumigants) and nonvolatile nematicides applied as soil drenches and seedling root dips or seed soaks to reduce nematode populations. Seeds can be treated with EPN and carbofuran. The roots can be dipped in systemic chemicals such as oxamyl or fensulfothion, phorate, carbofuran, and DBCP. Telone (1,3- dichloropropene) can be injected into the soil before the crop is planted.
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Planthopper


WBPH adults (IRRI)

Diagnostic summary

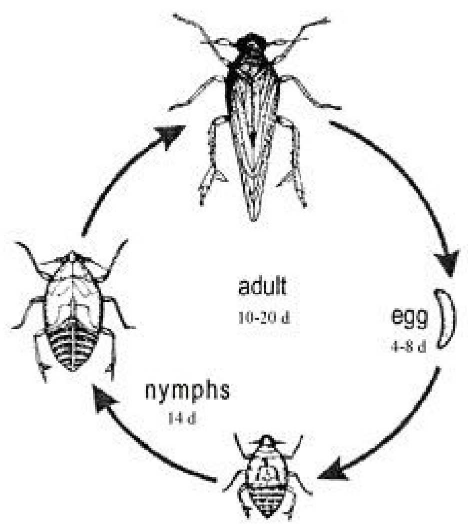
Damage to plants	• hopperburn • ovipositional marks exposing the plant to fungal and bacterial infections • ragged stunt or grassy stunt virus disease plant may be observed
Signs	• crescent-shaped white eggs inserted into the midrib or leaf sheath • white to brown nymphs and brown or white adults feeding near the base of tillers • presence of honeydew and sooty molds in the bases of areas infected
Factors favoring insect/pest development	• rainfed and irrigated wetland environments • continuous submerged conditions in the field • reproductive phase of the rice plant • high shady and humidity • closed canopy of the rice plants • densely seeded crops

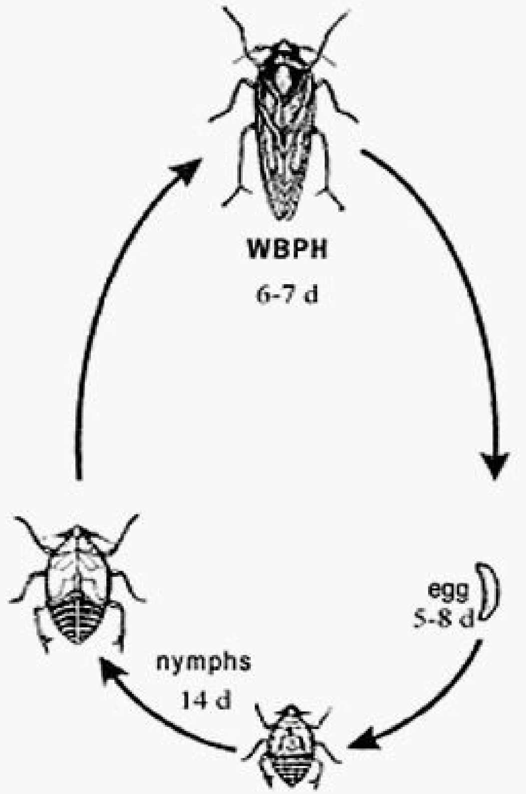
	• excessive use of nitrogen • early season insecticide spraying

Full fact sheet

Common name	Brown planthopper (BPH), Whitebacked planthopper (WBPH)
Latin names	*Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath)
Symptoms	• Hopperburn or yellowing, browning and drying of plant • Ovipositional marks exposing the plant to fungal and bacterial infections • Presence of honeydew and sooty molds in the bases of areas infected • Ragged stunt or grassy stunt virus disease plant may be observed  Hopperburn caused by BPH (IRRI)  BPH adult (IRRI)

Confirmation	Hopperburn caused by the planthoppers is distinguished from other hopperburn symptom by the presence of visible sooty molds at the bases of the rice plant. Virus infected plants may also be found.
Problems with similar symptoms	Hopperburn is similar to the feeding damage or "bugburn" caused by the rice black bug.
Why and where it occurs	The planthoppers are common in rainfed and irrigated wetland environments during the reproductive stage of the rice plant. The nymphs and adults of the insect are usually found at the bases of the canopy, where it is shady and humidity is high. The adult females are active at temperatures ranging from 10 °C to 32 °C. Macropterous females can survive more than males at varying temperatures. The adults usually live for 10-20 days in the summer and 30-50 days during autumn. The macropterous forms or the long-winged are more attracted to light trap. The most number of catch occurs during the full moon. High nitrogen levels and close plant spacing tends to favor both the BPH and WBPH increase. Outbreaks of the insect pests are closely associated with insecticide misuse, especially during the early crop stages. These insecticide sprays usually directed at leaf feeding insects disrupt the natural biological control, which favor the BPH development as secondary pest.
Causal agent or factor	BPH adult is brownish black with yellowish brown body. It has a distinct white band on its mesonotum and dark brown outer sides. The adults exist in two forms, macropterous and brachypterous. Macropterous adults or long-winged have normal front and hind wings, whereas brachypterous forms or the short-winged have reduced hind wings. A prominent tibial spur is present on the third leg. The nymph has triangular head with a narrow vertex. Its body is creamy white with a pale brown tinge. Mature nymph is 2.99 mm long. It has a prominent median line from the base of the vertex to the end of its metathorax where it is the widest. This line crosses at a right angle to the partition line between the prothorax and mesothorax. The eggs are crescent-shaped and 0.99 mm long. Newly laid eggs are whitish. They turn darker when about to hatch. Before egg hatching, two distinct spots appear, representing the eyes of the developing nymph. Some of the eggs are united near the base of the flat egg cap and others remain free. WBPH adult is brownish black with a yellowish brown body. It has very distinct white band on its mesonotum with dark brown outer sides. It has pale yellow to light brown cheeks. The adult exhibits two body forms. The males are all macropterous or long-winged and the females are both macropterous and brachypterous or short-winged. The adult is

	2.6-2.9 mm long. The apex of its front wing has an unbranched band. The hind tibia is noticeable because of its distinct movable spur. Neonate nymph is white to light yellow and 0.8 mm long. It has pink to red eyes. With age, the nymph becomes grayish with white markings on the thorax and abdomen of the creamy body. The mature nymph is 2.1 mm long. A distinct white band on its thorax starts to appear. Newly laid eggs are creamy white. They are elongate and very curved. A single egg measures 0.9 mm long and 0.2 mm wide. With age, the eggs become darker and develop two distinct spots that represent the eyes of the developing hopper.
Host range	Although there are many plants listed as alternate hosts to BPH and WBPH, none of them were able to support a population.
Life cycle	



Mechanism of damage	Both the nymphs and adults of the brown planthopper insert their sucking mouthparts into the plant tissue to remove plant sap from phloem cells. During feeding, BPH secretes feeding sheaths into the plant tissue to form feeding tube or feeding sheaths. The removal of plant sap and the blockage of vessels by the feeding tube sheaths cause the tillers to dry and turn brown or a condition called hopperburn.
When damage is important	The planthoppers attack all plant growth stages but the most susceptible stages are from early tillering to flowering or during the first 30 days after seeding until the reproductive stage.
Economic importance	Planthoppers suck the sap of the leaf blades and leaf sheaths. Feeding damage results in the yellowing of the plants. At high population density of the insect pests, hopperburn or complete drying of the plants is observed. At this level, the crop loss may be 100%. In field conditions, plants nearing maturity developed hopperburns if infested with about 400-500 BPH nymphs. In the 1970s and 1980s, BPH was considered a threat to rice production in Asia. Brown planthoppers also transmit ragged stunt and grassy stunt viruses. It was recorded that at a population density of more than 400-500 nymphs or 200 adults per plant, WBPH can cause

	complete loss of rice plants. Outbreaks of WBPH were reported in Pakistan in 1978, Malaysia in 1979, and India in 1982, 1984, and 1985. No record shows that WBPH is a vector of any rice virus disease.
Management principles	There are cultural controls and resistant varieties, which are recommended against BPH. For example, draining the rice field for 3-4 days is recommended during the early stage of infestation. Nitrogen application can be split to reduce BPH buildup. Synchronous planting within 3 weeks of staggering and maintaining a free-rice period could also decrease the build-up of BPH. The common parasites of the eggs are the hymenopteran wasps. Eggs are preyed upon by mirid bugs and phytoseiid mites. Both eggs and nymphs are preyed upon by mirid bugs. Nymphs and adults are eaten by general predators, particularly spiders and coccinellid beetles. Hydrophilid and dytiscid beetles, dragonflies, damselflies, and bugs such as nepid, microveliid, and mesoveliid eat adults and nymphs that fall onto the water surface. Fungal pathogens also infect brown planthoppers. There are varieties released by IRRI, which contain genes for BPH resistance, like IR26, IR64, IR36, IR56, and IR72. BPH is a secondary problem due to insecticide spraying for leaf-feeding insects in the early crop stages. To reduce the risk of hopperburn, application of early season insecticide should be avoided. WBPH population can be regulated by natural biological control agents. For example, small wasps parasitize the eggs. Predatory mites and mirid feed upon both the eggs and nymphs. Predators for the nymphs and adults are aquatic dytiscid and hydrophilid beetles, immature forms of damselflies and dragonflies, and water-dwelling veliid and mesoveliid bugs. Spiders, stapphylinid and carabid beetles, and lygaeid bugs search the plant for WBPH nymphs and adults.
Selected references	1. Nasu S. 1967. Taxonomy, distribution, host range, life cycle and control of rice leafhoppers. In: Major insect pests of rice. Proceeding of a Symposium in the International Rice Research Institute, Philippines, Sept. 1964. Baltimore, Md. (USA): Johns Hopkins Press. p 493-523. 2. Pathak MD, Khan ZR. 1994. Insect pests of rice. Manila (Philippines): International Rice Research Institute. 89 p.

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Rice Bug

Rice bug adult (IRRI)

Diagnostic summary

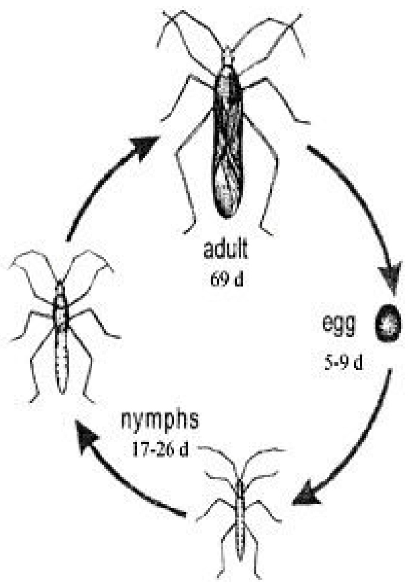
Damage to plants	• feeding causes empty or small grains during the milking stage • feeding causes deformed or spotty grains at the soft or hard dough stage • grains become dark
Signs	• oval, shiny, and reddish brown eggs along midrib of leaf • slender and brown-green nymphs and adults feeding on endosperm of rice grains
Factors favoring insect/pest development	• staggered rice planting • woodlands and extensive weedy areas near rice fields • wild grasses near canals • warm weather, overcast skies, and frequent drizzles • rainfed and wetland or upland rice • flowering to milky stages of the rice plant

Full fact sheet

Common name	Rice bug
Latin names	*Leptocorisa oratorius* (Fabricius), *L. chinensis* (Dallas), *L. acuta*

	(Thunberg)
Symptoms	• Small or shrivelled grains • Deformed or spotty grains • Empty grains • Erect panicles  Damaged grains caused by rice bug (IRRI)  Damaged grains are smaller (IRRI)
Confirmation	The presence of the insect can be easily determined by an offensive smell. The grains are small, shrivelled, spotty, or deformed. Some grains are also empty.
Problems with similar symptoms	The symptoms can be confused with the damage caused by nutrient deficiency or flower thrips.
Why and where it occurs	High rice bug populations are brought about by factors such as nearby woodlands, extensive weedy areas near rice fields, wild grasses near canals, and staggered rice planting. The insect also becomes active when the moonsoonal rains begin. Warm weather, overcast skies, and frequent drizzles favor its population buildup. The population of the rice bug increases at the end of the rainy

	season. Rice bugs are found in all rice environments. They are more common in rainfed and upland rice and prefer the flowering to milky stages of the rice crop. Adults are active during the late afternoon and early morning. Under bright sunlight, they hide in grassy areas. They are less active during the dry season. In cooler areas, the adults undergo aestivation or diapause in grasses. They feed on wild hosts for one to two generations before migrating into the rice fields at the flowering stages. The nymphs are found on the rice plant where they blend with the foliage. There, they are often left unnoticed. When disturbed, the nymphs drop to the lower part of the plants and the adults fly within a short distance.
Causal agent or factor	The adults of the three species of rice bugs are slender and brown-green. They measure 19-16 mm long. They have long legs and antennae. Distinct ventrolateral spots on the abdomen are either present or absent. The younger instars are pale in color. The nymphs have long antennae. The older instars measure 1.8-6.2 mm long. They are yellowish green. The eggs are oval, shiny, and reddish brown. They are laid in batches of 10-20 in one to three rows along the midrib on the upper surface of the leaf.
Host range	Its main hosts are rice and *Echinochloa* sp. It also feeds on *Alloteropsis cimicina* (L.) Stapf, *Artocarpus* sp. (breadfruit), *Bothriochloa pertusa* (L.) A. Camus, *Brachiaria miliiformis* (Presl) A. Chase, *B. mutica* (Forssk.) Stapf, *Camellia sinensis* (L.) O. Ktze. (tea), *Chloris barbata* Sw., *Dactyloctenium aegyptium* (L.) Willd., *Dicanthelium clandestinum* L., *Eleusine indica* (L.) Gaertn., *Mangifera indica* L. (mango), *Myristica* sp. (nutmeg), *Panicum miliaceum* L. (millet), *P. repens* L., *Paspalidium punctatum* (Burm.) A. Camus, *Phaseolus* sp. (beans), *P. maximum* Jacq., *Psidium guajava* L. (guava), and *Setaria glauca* (L.) R. Br.

Life cycle	
Mechanism of damage	Both adults and nymphs insert their needlelike mouthparts between the lemma and palea of the rice hull to suck the endosperm of rice grain. In order to feed, they secrete a liquid to form a stylet sheath that hardened around the point of feeding and holds the mouthparts in place.
When damage is important	The rice bug is an important insect pest during the milky stage of the rice plant. Both the nymphs and adults prefer the endosperm of the rice grain resulting to production of smaller grains. They also feed during the soft or dough stages and can cause grain discoloration.
Economic importance	Both the adults and nymphs feed on grains at the milking stage. They can be serious pests of rice and sometimes reduce yield by as much as 30%.
Management principles	The rice bug population can be managed using different cultural control measures and biological control agents. Cultural control measures include the removal of alternate hosts such as grasses on bunds, early planting, and the use of late-maturing cultivars. Netting and handpicking the bugs reduce their numbers. Likewise, putting attractants such as arasan or anything with an odor like dead snails or rats can easily capture rice bugs in the field. Among the biological control agents, small wasps parasitize the eggs and the meadow grasshoppers prey on them. Both the adults and nymphs are preys to spiders, coccinellid beetles and dragonflies. A fungus infects both nymphs and adults. Coarse-grain and bearded cultivars may be resistant to the rice

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Rice Caseworm


Floating leaf cases (IRRI)

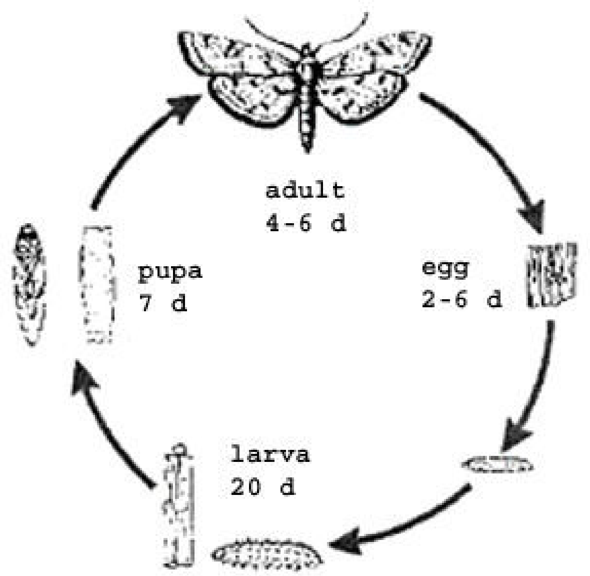
Diagnostic summary

Damage to plants	• cutting off leaf tips to make leaf cases • ladder-like appearance of skeletonized leaf tissues • leaves cut at right angle as with a pair of scissors
Signs	• pale yellow, disc-like eggs on underside of leaves • young pale green larvae feeding on the surface of tender leaves • older larvae are enclosed within the case and feed by scraping leaf tissues or biting through leaf sheaths
Factors favoring insect/pest development	• rice field with standing water • transplanting young seedlings • wetland and irrigated environments

Full fact sheet

Common name	Rice caseworm, case bearer
Latin names	*Nymphula depunctalis* (Guenee)
Symptoms	• Leaf cases floating on water • Leaves cut at right angles as with a pair of scissors • Leaves with papery upper epidermis that were fed on • Skeletonized leaf tissues usually appear ladder-like

	 Damaged leaves (IRRI).
Confirmation	The symptom can be visually inspected by the appearance of the ladder-like leaf tissues. The leaves are cut at right angles as with a pair of scissors. The presence of leaf cases attached onto leaf sheaths and floating in the water with the larvae enclosed can also confirm the damage caused by this defoliator.
Problems with similar symptoms	The damage symptoms can easily be confused with symptoms of other defoliating insect pests.
Why and where it occurs	A rice field with standing water increases the pest's abundance. Transplanting young seedlings favors the development of the insect. The insect is commonly found in rice fields in low populations. They inhabit wetland and irrigated environments with standing water. The adults are nocturnal and are attracted to light traps. The larva hides in its case then float on the water surface during the day and crawls to the rice plant with its case to feed. Severe infestation may be observed occasionally on dwarf, compact, heavy tillering, high yielding varieties during the rainy season.
Causal agent or factor	The adult moth is about 5 mm long. It is bright white with light brown and black spots. First instar larva is pale cream with light yellow head. It is 1.2 mm long. With age, the larva turns greenish. It has branched

	and thread-like gills along the sides of the body. The pupa is cream in color and about 5.5 mm long. Mature pupa is silvery white. Individual egg is circular, flattened, and measures 0.5 mm in diameter. It is light yellow and has a smooth surface. Mature eggs are darker and develop two purplish dots.
Host range	Its main host is *Oryza sativa* L. The larva also feeds on *Brachiaria mutica* (Forssk.) Stapf, *B. ramosa* (L.) Stapf, *B. reptans* (L.) Gard & C.E. Hubb, *Cleistochloa patens* (L.) A. Camus, *Cyperus brevifolius* (Rottb.) Hassk., *C. difformis* L., *C. iria* L., *C. rotundus* L., *Cynodon dactylon* (L.) Pers., *Echinochloa colona* (L.) Link, *Eragrotis interrupta* (Lam.) Doell., *Isachne dispar* Trin., *Leersia hexandra* Swartz, *Leptochloa chinensis* (L.) Nees, *Ottelia alismoides* (L.) Vahl, *Panicum colona* L., *P. distachyum* L., *P. repens* L., *P. stagninum* Retz., and *Paspalum scrobiculatum* L.
Life cycle	
Mechanism of damage	The larva scrapes the green tissue of the leaf with only the white epidermis remaining. The white epidermis appears ladder-like because of the back and forth motions of the larval head during feeding.
When damage is important	The rice caseworm feeds on rice during the seedling and tillering stages of the crop. Its damage usually starts in a flooded seedbed but does not occur after the maximum tillering stage.
Economic importance	The rice caseworm is commonly found in rice fields in low populations. It can build up and cause patches of severe

defoliation that results in stunted growth and death of plants because of pesticide use, control practices, and ecological disruptions by weather.

The rice plants can recover from the damage if there are no other defoliators present. However, maturity may be delayed for 7-10 days.

Management principles

There are cultural control practices, which are available for the pest. For example, the use of correct fertilizer application, wider spacing (30 × 20 mm), and early planting. Furthermore, draining the field, transplanting older seedlings, or growing a ratoon can also help control this insect. Sparse planting also reduces damage.

Among the biological agents, snails are useful predators of eggs of the rice caseworm. The larvae are fed upon by the hydrophilid and dytiscid water beetles. Spiders, dragonflies, and birds eat the adults. There is a nuclear polyhedrosis virus, which is a potential control agent against the rice caseworm.

Rice caseworm larvae are highly sensitive to insecticides. The use of foliar treatments of carbamate insecticides can control the insect pest. Pyrethroids should be avoided as they can cause secondary problems, such as brown planthoppers.

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Rice Field Rats

Rattus argentiventer (GR Singleton)

Diagnostic summary

Damage to plants	• missing germinating seeds • missing hills or plants • cut or pull up transplanted plants • chopped young seedlings • irregular cuttings of stem • tillers cut near base at 45° angle • retillering of stems • chewed developing buds or ripening grains • missing grains and panicles
Signs	• their runways, active burrows and footprints are visible in the muddy areas near the damage they created • characteristic damage on rice crops • cut tillers and active holes on the bunds that surround the fields
Factors favoring insect/pest development	• lowland irrigated rice crops both the wet and dry seasons • availability of food, water, and shelter • presence of breeding sites • presence of major channels and village gardens

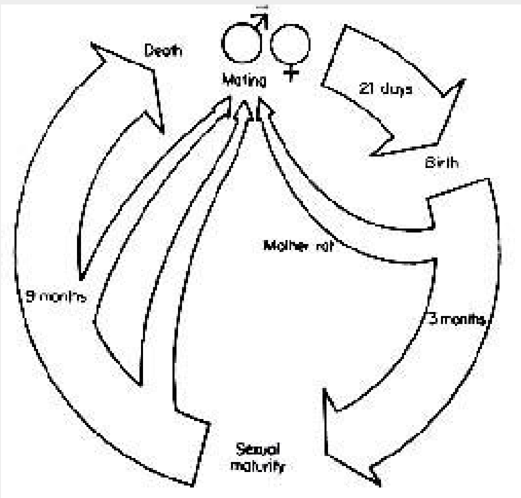
Full fact sheet

Common name	Rice field rats
Latin names	*Rattus argentiventer* Robinson and Kloss, *R. exulans* Peale, *R. rattus* spp., *R. tanezumi*
Symptoms	• Missing germinating seeds • Missing hills • Chopped young seedlings • Missing plants • Irregular cuttings of stem • Chewed developing buds or ripening grains • Tillers cut near base at 45° angle • Retillering of stems • Delayed grain maturity • Missing grains • Missing panicles  Tillers are cut and bent (GR Singleton)

Tillers are cut at 45° and retillering is observed (Van Vreden and Ahmadzabidi)

Confirmation	Often the runways, active burrows and footprints of the rice field rats are visible in the muddy areas, which are near the damage they have created. Cut tillers and active holes on the bunds that surround the fields can be closely examined for the presence of the rice field rats. To catch rats to identify the species, traps are best placed along runways, or the rats can be dug from their burrows.
Problems with similar symptoms	The feeding damage on the stem caused by the rice field rats may resemble insect damage although rat damage is usually distinguished by the clean cut at 45° of the tiller. The damage on the grains is similar to bird damage.
Why and where it occurs	In lowland irrigated rice crops both the wet and dry seasons are favourable for rat reproduction and crop damage. In rainfed rice crops rodents have their greatest impact in the wet season. The availability of food, water, and shelter are factors, which provide optimum breeding conditions. The presence of grassy weeds also triggers their development. Rice field rats feed at night with high activity at dusk and dawn. At daytime, they are found among vegetation, weeds, or maturing fields. During fallow period, they utilize major channels and village gardens as prime habitats. At tillering, 75% of time they are in burrows along the banks and after maximum tillering, 65% of time they are in rice paddies.
Causal agent or factor	Rice field rats are black to brown in color. They have scaly, thinly furred tails and distinctive chisel-like incisors. The rice field rat, *R. argentiventer*, is the major rodent pest in SE Asia and is distinguished by a tuft of red hair at the base of its ears, fur on back orange-brown flecked with black, and a silvery white ventrum. In some countries, such as Indonesia, the rice field rats are the most important pre-harvest pests that reduce crop production. Rodents are also noted to consume and contaminate significant amounts of stored grain. Although the rodents that cause post-

	harvest losses are often a different suite of species (e.g. *Rattus norvegicus*, *Bandicota indica*).
Host range	Aside from the rice plant, rice field rats also feed on grasses and invertebrates living in and around the rice field.
Life cycle	Breeding in ricefield rats appears to be triggered by the maturation of the rice plant itself, with females first entering estrous 1-2 weeks prior to maximum tillering. Breeding extends through until harvest. After a short pregnancy lasting 3 weeks, female rats produce litters of up to 18 pups (average of 11-12 pups). The pups grow rapidly and are ready to breed at 6 weeks in age. Adult females are able to fall pregnant again within a few days of giving birth, and can therefore produce three litters during the generative phase of growth of a rice crop – a total of 30-40 extra rats per female by harvest time.



Rice field rat life cycle

Mechanism of damage	Rice field rats feed on seeds directly. They pull up germinating seeds. They either cut or pull up transplanted plants. Tillers are usually cut and then chewed.
When damage is important	The breeding season of the rice field rats and their relative amount of damage are closely linked to the crop growth and development. If there is one crop per year then there is one breeding season. If there are two rice crops per year then there are two breeding seasons. Where harvest is staggered by more than one or two weeks within a single cropping area, the rat population will move from field to field, causing increasingly severe damage in the later-harvested crops. Even more critically, rats born during the early part of the cropping season will themselves be old enough to start breeding. This can produce a sudden explosion in the rat population, with densities peaking at many thousands of animals per hectare.
Economic importance	In Asia, an estimated rodent damage from 5% to 10% prior to harvest was recorded in 1999.
Management principles	Effective management of rodents will involve strategic actions that limit population growth so that damage is kept below the threshold of economic concern of farmers. Unfortunately, most of

the rodent management in Asian countries is reactive – only occurring once a problem has been noticed. Generally this is too late to provide effective management. Many of these reactive actions, such as organising a bounty or application of an acute rodenticide provide farmers with a feeling that they have achieved some measure of success in their fight against rats because they can see dead bodies. However, in reality, once rodent numbers are high the management actions would have to remove at least 70% of the population to have a marked effect on reduction in yield loss to rice crops.

Strategic actions for management are most effective if they are developed on the basis of a sound knowledge of the ecology of the species to be controlled.

There are a range of physical methods available to farmers, ranging from simple woven or plastic barriers designed to deflect rats from growing crops, through to complete enclosures, most often erected around stored grain. These 'barrier systems' sometimes incorporate traps or snares set across gaps or 'doorways' – hence the term Trap Barrier System or TBS.

In recent years the TBS system has been modified as follows:

- Incorporation of a 'trap' or 'lure' crop to draw rats to the TBS;
- Development of minimum specifications for construction and maintenance of a TBS;
- Use of the TBS technology to develop both a community and an integrated approach to rodent pest management.

The result is what we now call the Community Trap Barrier System (http://www.cse.csiro.au/research/VFP/rodents/) or CTBS method. The word 'community' in the name gives emphasis to the fact that the method works best, and is most cost effective, when it is adopted by an entire farming community.

Other methods of physical control includes hunting, rat drives, digging, and exclusion.

Cultural management actions such as hygiene around villages, keeping the cover low along the banks of main irrigation canals, maintaining smaller bunds or banks with height and width of less than 300 mm to prevent rats from utilizing these as nesting sites, synchrony of cropping, and rat campaigns at key times are recommended at the community level. Other actions include shortening the harvest period and having a 1 to 2 month fallow over the dry season.

In Vietnam and Lao PDR, the use of bounty systems failed because they considered bounties as a source of income rather than as a control measure.

Lethal control can be implemented through the use of rodenticides like acute poisons (e.g. Zinc phosphide), chronic poisons or anti-coagulants.

Among the biological control, fertility control or the use of immunocontraception is being studied in Australia. In Malaysia, the use of the barn owl was reported to reduce rat damage. Wildcats, snakes, and birds are also predators of rice field rats.

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Rice Gall Midge


Feeding site of immature (IRRI)

Diagnostic summary

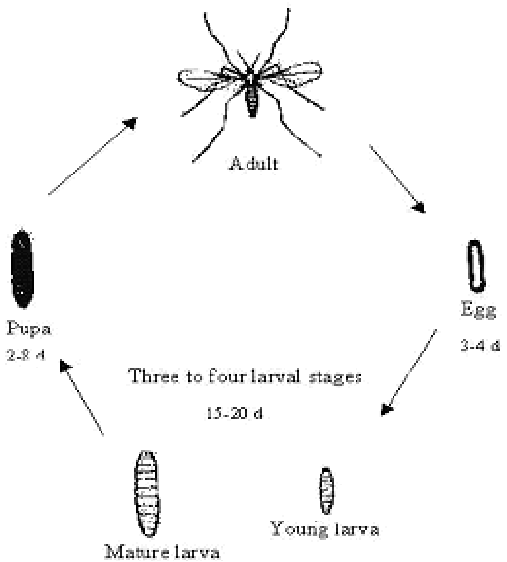
Damage to plants	• tubular gall is formed at the base of a tiller • elongation of leaf sheaths called onion leaf or silvershoot
Signs	• elongate-tubular eggs • maggot-like larva feeding inside developing buds
Factors favoring insect/pest development	• tillering stage of the rice plant • irrigated or rainfed wetland environments • presence of alternate hosts • cloudy or rainy weather • cultivation of high-tillering varieties • intensive management practices • low parasitization

Full fact sheet

Common name	Asian rice gall midge
Latin names	*Orseolia oryzae* (Wood-Mason)
Symptoms	• Formation of a hollow cavity or tubular gall at the base of the infested tiller • Gall is a silvery white hollow tube, 1 cm wide and 10-30 cm long • Affected tiller inhibits growth of leaves and fails to produce panicles • Deformed, wilted, and rolled leaf • Elongation of leaf sheaths called onion leaf or silvershoot • Plant stunting

	 Tubular gall IRRI)  Affected tillars (IRRI)  Onion shoots
Confirmation	The rice field can be checked for the presence of onion leaves or silvershoots. Larvae and pupae may be dissected from infected tillers.
Problems with similar symptoms	The plant stunting and leaf deformity, wilting and rolling are also symptoms observed on plants caused by drought, potassium deficiency, salinity, and ragged stunt virus, orange leaf virus and tungro virus diseases. The rolled leaves can also be associated with the symptom caused by rice thrips.
Why and where	The Asian rice gall midge is found in irrigated or rainfed wetland

it occurs	environments during the tillering stage of the rice crop. It is also common in upland and deepwater rice. The adults are nocturnal and they are easily collected using light traps. During the dry season, the insect remains dormant in the pupal stage. They become active again when the buds start growing after the rains. The population density of the Asian rice gall midge is favored mainly by cloudy or rainy weather, cultivation of high-tillering varieties, intensive management practices, and low parasitization.
Causal agent or factor	The Asian rice gall midge is found in irrigated or rainfed wetland environments during the tillering stage of the rice crop. It is also common in upland and deepwater rice. The adults are nocturnal and they are easily collected using light traps. During the dry season, the insect remains dormant in the pupal stage. They become active again when the buds start growing after the rains. The population density of the Asian rice gall midge is favored mainly by cloudy or rainy weather, cultivation of high-tillering varieties, intensive management practices, and low parasitization.
Host range	Wild rices, such as Oryza rufipogon are common alternate hosts.
Life cycle	



Mechanism of damage	The larva of the Asian gall midge moves between the sheath and the stem to reach the growing point. It feeds inside the developing buds of a new tiller and release chemicals in its saliva causing the plant to grow abnormally to produce a hollow cavity or gall at the base of the tiller. The developing and feeding larva causes the gall to enlarge and elongate at the base. Gall appears within a week after larval entry. The infected tiller becomes abnormal and silvery in color.

	Examination of the tubular gall shows that it is capped by a solid plug of plant tissue at the base of the point where the leaf forms.
When damage is important	The Asian gall midge is an important pest from the seedbed to maximum tillering stages of the rice crop.
Economic importance	The Asian gall midge is an important pest and can cause significant yield losses of 30-40% in some areas like Sri Lanka and parts of India.
Management principles	There are cultural control practices, which are recommended against the Asian gall midge. Plowing ratoon of the previous crop and removing all off-season plant hosts can reduce infestation. Natural biological control agents such as platygasterid, eupelmid, and pteromalid wasps, which parasitize the larvae, is effective. The pupa is host to two species of eupelmid wasps. Phytoseiid mites feed upon the eggs, whereas spiders eat the adults. There are rice cultivars from India, Thailand, and Sri Lanka, which are resistant to the Asian gall midge. It is difficult to control the gall midge with insecticides.
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Contributors JLA Catindig and KL Heong

Rice Hispa

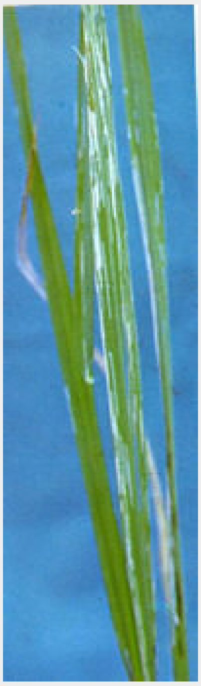

Field damage (IRRI)

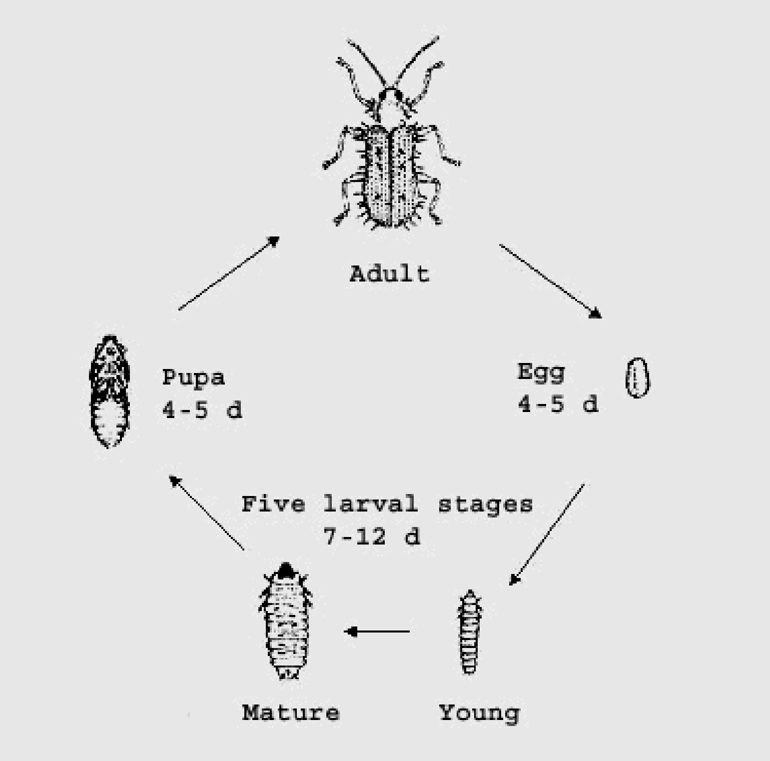
Diagnostic summary

Damage to plants	• scraping of upper surface of the leaf blade leaving the lower epidermis • tunneling through leaf tissue causing irregular translucent white patches that -are parallel to the leaf veins • damaged areas have white streaks that are parallel to the midrib
Signs	• shiny blue-black adults scraping the upper surface of the leaf blade • flat white larvae tunneling through leaf tissues as leafminers
Factors favoring insect/pest development	• close spacing of rice plants • presence of grassy weeds as alternate hosts • heavily fertilized fields • rainfed and irrigated wetland environments

Full fact sheet

Common name	Rice hispa
Latin names	*Dicladispa armigera* (Olivier)
Symptoms	• Scraping of the upper surface of the leaf blade leaving only the lower epidermis as white streaks parallel to the midrib • Tunneling of larvae through leaf tissue causes irregular translucent white patches that are parallel to the leaf veins

	• Damaged leaves wither off • Damaged leaves turn whitish and membranous • Rice field appears burnt when severely infested  Damage on leaf (IRRI)
Confirmation	The damage symptoms are seen as elongated, clear, feeding marks as white streaks of uneaten lower epidermis between the parallel leaf veins. Likewise, the presence of the insect confirms its damage.
Problems with similar symptoms	The feeding damage is similar to the feeding marks caused by flea beetles.
Why and where it occurs	Close spacing causes greater leaf densities that favor the buildup of the rice hispa. The presence of grassy weeds in and near rice fields as alternate hosts harbor and encourage the pest to develop. Heavily fertilized field also encourages the damage. Heavy rains, especially in premonsoon or earliest monsoon periods, followed by abnormally low precipitation, minimum day-night temperature differential for a number of days, and high RH are favorable for the insect's abundance. The rice hispa is common in rainfed and irrigated wetland environments and is more abundant during the rainy season.
Causal agent or factor	The adult is blue-black and very shiny. Its wings have many spines. It is 5.5 mm long. The pupa is brown and round. It is about 4.6 mm long. The larva or grub is white to pale yellow. A younger grub

	measures 2.5 mm long and a mature larva is about 5.5 mm long. Fresh egg is white. It is small and oval. It measures 1-1.5 mm long. With age, it turns yellow. A small dark substance secreted by the female covers each egg.
Host range	Rice hispa feeds primarily on rice. It also feeds on grasses such as *Brachiaria mutica* (Forssk.) Stapf and *Cynodon dactylon* (L.) Pers, none supported complete development of the insect.
Life cycle	
Mechanism of damage	The larvae or grubs mine or tunnel inside the leaves as leaf miners. Then the larvae feed on the green tissues using their mandibulate mouthparts. During emergence, the adult beetle cuts its way out from the leaf. The adult insects are external feeders.
When damage is important	The rice hispa is a defoliator during the vegetative stage of the rice plant. Extensively damaged plants may be less vigorous.
Economic importance	The insect is a problem pest particularly in Bangladesh. Records show that it can infest large areas and causes yield losses of up to 20%.
Management principles	A cultural control method that is recommended for the rice hispa is to avoid over fertilizing the field. Close plant spacing results in greater leaf densities that can tolerate higher hispa numbers. To prevent egg laying of the pests, the shoot tips can be cut. Clipping and burying shoots in the mud can reduce grub populations by 75-92%. Among the biological control agents, there are small wasps

	that attack the eggs and larvae. A reduviid bug eats upon the adults. There are three fungal pathogens that attack the adults.
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Contributors	JLA Catindig and KL Heong

Rice Leaffolder


Field damage (IRRI)

Diagnostic summary

Damage to plants	• larva removes the leaf tissues • folds a leaf blade together and glues it with silk strands • feeds inside the folded leaf creating longitudinal white and transparent streaks on the blade
Signs	• disc-shaped ovoid eggs laid singly • young larvae feeding on the base of the youngest unopened leaves • folded leaves enclosing the feeding larvae • fecal matter present
Factors favoring insect/pest development	• heavily fertilized fields • high humidity and shady areas • presence of grassy weeds from rice fields and surrounding borders • expanded rice areas with irrigation systems and multiple rice cropping • all rice environments

Full fact sheet

Common name	Rice leaffolder, rice leaf roller, grass leaf roller
Latin names	*Cnaphalocrocis medinalis* (Guenee), *Marasmia patnalis* (Bradley), *M. exigua* (Butler)
Symptoms	• Longitudinal and transparent whitish streaks on

damaged leaves

- Tubular folded leaves
- Leaf tips sometimes fastened to the basal part of leaf
- Heavily infested fields appear scorched with many folded leaves

Folded leaf with silk (IRRI)

Confirmation

The folded leaves enclosing the larvae are typical and can be observed easily. Likewise, the linear white feeding areas on the leaves are also visually seen.

Problems with similar symptoms

The folded leaves are also symptoms similar to the ones caused by rice skippers and green semilooper. The whitish streaks are comparable to leaves damaged by rice whorl maggot and thrips.

Why and where it occurs

The heavy use of fertilizer encourages rapid multiplication of the insect. High humidity and shady areas of the field also favor their development. The presence of grassy weeds from rice fields and surrounding borders support continuous development of the pest.

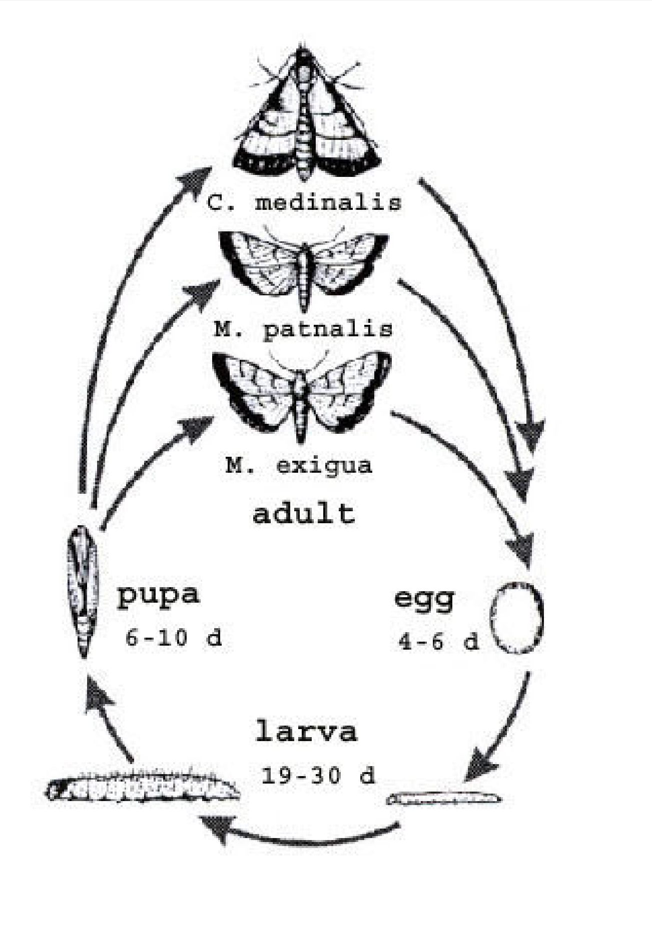
Expanded rice areas with irrigation systems, multiple rice cropping and insecticide induced resurgences are important factors in the insect's abundance.

The rice leaffolders occur in all rice environments and are more abundant during the rainy seasons. They are commonly found in shady areas and areas where rice is heavily fertilized. In tropical rice areas, they are active year-round, whereas in temperate countries they are active from May to October. The adults are nocturnal and during the day, they stay under shade to escape predation. Moths fly short distances when disturbed.

Causal agent or factor

There are three species of leaffolder and the adult moths can be distinguished by the markings on the wings. The adult is whitish yellow or golden yellow. It has three black bands on the forewings, either complete or incomplete. It has a wing span of 13 to 18 mm.

The pupa is light brown or bright brown. With age, it turns

	reddish brown. It is 6 to 12 mm long. Neonate larvae are yellow. With age, they turn yellowish green with brown or black heads. They have distinct pinnaculae or one to two pairs of subdorsal spots on the mesonotum or metanotum. A third species lack spots on the notum. The apex of their pronotum is angulated, convex or always straight. They are from 8.5 to 25 mm long. The newly laid egg is jelly-like and transparent. It is oblong with an irregular upper surface. The mature egg is ovoid and whitish yellow. It is ventrally flattened.
Host range	Aside from the rice plant, the rice leaffolder also feeds on *Avena* sp. (oats), *Cocos nucifera* L. (coconut), *Echinochloa colona* (L.) Link (jungle rice), *Eleusine coracana* (L.) Gaertn. (koracan), *Hordeum* sp. (barley), *Musa* sp. (banana), *Nicotiana tabacum* L. (tobacco), *Panicum milliaceum* L. (millet), *Saccharum officinarum* L. (sugarcane), *Saccharum spontaneum* L. (wild sugarcane), and *Setaria italica* (L.) P. Beauv. (German millet).
Life cycle	
Mechanism of damage	The larva forms a protective feeding chamber by folding a leaf blade together and glues it with silk strands and feed on leaf

	tissues. Longitudinal white and transparent streaks on leaf blades are created.
When damage is important	The rice leaffolder is very common and can be found in all rice growth stages. The damage may be important when it affects more than half of the flag leaf and the next two youngest leaves in each tiller.
Economic importance	Feeding damage of the rice leaffolders during the vegetative stage may not cause significant yield losses. Crops generally recover from these damages. Leaffolder damage at the reproductive stage may be important. Feeding damage, if it is very high, on the flag leaves may cause yield loss. The highly visible symptoms are often the cause of farmers' early season insecticide use. Most of these sprays have little or no economic returns. Instead, they can cause ecological disruptions in natural biological control processes, thus enhancing the development of secondary pests, such as planthoppers. In some countries, about 40% of farmers' sprays target leaffolders. Through participatory experiments, farmers who stopped early season sprays had no yield loss and saved up to 15-30% in pesticide costs. The spray reduction also decreases farmers' exposure to health risk posed by pesticides.
Management principles	The rice leaffolders may be managed by cultural practices, the use of biological agents and resistant varieties. In most cases, chemical control is not advisable. In cultural control, it is advised not to use too much fertilizer. It was observed in a field experiment that highly fertilized plots attract females. Surrounding grass habitats should be maintained because these serve as temporary reservoirs of natural enemies like crickets, which are egg predators of leaffolders. Herbicide spraying and burning of these non-rice habitats might not be useful. Among the biological control agents, there are small wasps and crickets that attack the eggs. The larval and pupal stages are parasitized by many species of wasps. Damselflies, ants, beetles, wasps, mermithids, granulosis virus, and nucleopolyhedrosis virus prefer the larval stages. Spiders and mermithids attack the adults. There are many varieties from the Philippines, Korea, United States, Honduras, Taiwan, Vietnam, and the former USSR that show resistance to the rice leaffolders. Control of the rice leaffolders using chemicals during the early crop stages is not advisable. A general rule-of-thumb is "spraying insecticides for leaffolder control in the first 30 days after transplanting (or 40 days after sowing) is not needed." The rice crop can compensate from the damage when water and fertilizer are well managed. Pyrethroids and other broad-spectrum insecticides can kill the larvae but can put the crop at

risk because of the development of secondary pests, such as the brown planthopper.

If infestations of the flag leaves are extremely high (>50%) during maximum tillering and maturity stage, insecticide sprays may be useful. Such applications may stop further defoliation and may avoid losses.

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Contributors JLA Catindig and KL Heong

Rice Skipper


Folded leaf created by Rice Skipper (IRRI)

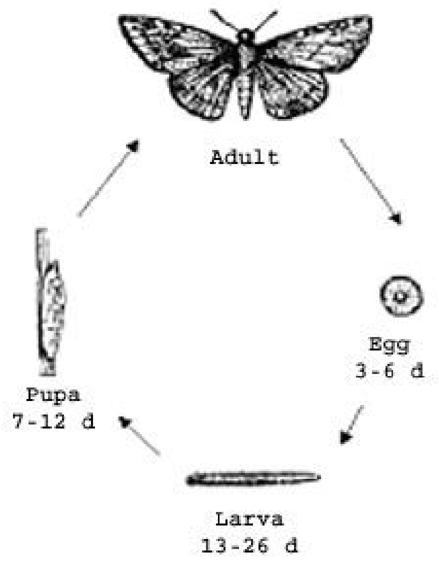
Diagnostic summary

Damage to plants	• feeding causes removal of leaf tissues • leaf rolling to make a protected chamber
Signs	• white spherical eggs laid singly on leaf blades • larvae feeding on rice foliage
Factors favoring insect/pest development	• diverse microhabitats in upland environment • droughts, downpours, or floods • misuse of pesticides • presence of natural enemies • young transplanted rice seedlings

Full fact sheet

Common name	Rice skippers
Latin names	*Pelopidas mathias* (Fabricius), *Parnara guttata* Bremer and Grey
Symptoms	• Removal of leaf tissues and veins and sometimes leaving only the midrib • Rolling down of leaf tip or folding two edges of the same leaf or two adjacent leaves and tying them with silken threads to make a protective chamber
Confirmation	The presence of the larva feeding on the leaf blade will confirm the damage created by this insect pest on the rice crop.
Problems with similar symptoms	The symptoms are similar to the damage caused by the greenhorned caterpillar and the green hairy caterpillar.

Why and where it occurs	The diverse microhabitats in upland environment are conducive to the rice skipper's development. Droughts, downpours, floods, or misuse of pesticides are favorable for the insect because beneficial organisms, which held them in check, die. Rice skippers are found in all rice environments. They are most abundant in rainfed rice fields. The adults are diurnal. At nighttime, they rest. They have very fast and erratic flight movement as they skip from plant to plant. The larvae are nocturnal. They feed on the leaf blades at night and rest during daytime. They also create a leaf chamber where they rest during the day. The insect favors young transplanted rice seedlings. Feeding damage continues until plant maturation.
Causal agent or factor	The adults of the two species are light brown with orange markings and white spots on the wings. They can be distinguished by the pattern of white spots on the wings. One adult has seven C-shaped white spots on the front wing and four white spots on the hind wing. The other one has four small spherical white spots and two elongated spots on the front wing and the hind wing lacks spots. The larval bodies of both species are green. They differ in the coloration on the head. One larva has reddish vertical bands at each lateral side of the head and the other one has brown bands that are closer together and W-shaped. The mature caterpillar measures 50 mm long. The pupae of both species are light brown or light green. They have pointed ends. The eggs are white or pale yellow and spherical. They are pearl-like in appearance.
Host range	Rice skippers prefer rice. It also feeds on grasses such as *Cynodon sp.*, *Eleusine sp.*, *Paspalum sp.*, maize, sorghum, and sugarcane.

Life cycle	
Mechanism of damage	The larva uses its mandibulate mouthparts to feed on rice foliage.
When damage is important	Rice skippers feed on rice foliage from tillering, stem elongation to panicle initiation stages of the rice crop. Feeding damage is not that important as the insect is considered a minor pest.
Economic importance	Rice skippers are easily controlled because of the low potential severity and their low population density. They are minor pests of rice and occasions of yield loss are very rare.
Management principles	Parasites and predators usually control the population density of rice skippers in the field. The eggs of rice skippers are parasitized by small wasps. Big wasps and tachinid flies parasitize the larvae. They are preyed upon by reduviid bugs and earwigs. The orb-web spiders feed on the adults during flight. A nuclear polyhedrosis virus also infects skipper larvae.
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Contributors JLA Catindig and KL Heong

Rice Thrips

Leaf curling caused by Rice Thrips (IRRI)

Diagnostic summary

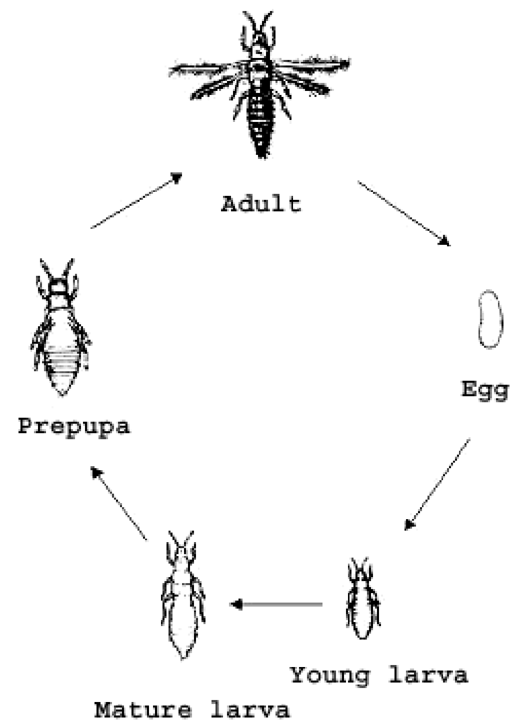
Damage to plants	• leaf shows discoloration and rolling • damaged leaves visible as silvery streaks
Signs	• cream-colored eggs on leaf tissue with upper half of eggs exposed on leaf surface • yellow larvae and dark brown adults lacerate the plant tissues
Factors favoring insect/pest development	• dry weather • no standing water • all rice environments • presence of graminaceous weeds

Full fact sheet

Common name	Rice thrips
Latin names	*Stenchaetothrips biformis* (Bagnall)
Symptoms	• Leaves damaged have silvery streaks or yellowish patches • Translucent epidermis becomes visible on damaged area • Leaves curled from the margin to the middle • Leaf tips wither off when severely infested • Unfilled grains at panicle stage

Damaged leaves (IRRI)

Confirmation	The presence of thrips inside the curled leaves confirms the feeding damage caused by this insect. The leaf shows discoloration, rolling, and the extensive removal of leaf tissues causing a translucent epidermis to remain.
Problems with similar symptoms	Rolled leaves are also symptoms of drought.
Why and where it occurs	Periods of dry weather favor the development of the rice thrips. No standing water in the rice fields encourages damage. These insects are present in all rice environments. In the tropics, the rice thrips becomes abundant in dry periods from July to September and January to March. In temperate areas, the insects migrate and hibernate on graminaceous weeds during the winter season. The adult thrips are day-flying. They migrate during the day and look for newly planted rice fields and other hosts. Eggs are laid in the slits of leaf blade tissue. The upper half of the egg is exposed. Neonate larvae feed on the soft tissues of unopened young leaves.
Causal agent or factor	The adult has a slender body. It is dark brown and 1-2 mm long. It exists in two forms, winged or wingless. The winged form has two pairs of elongated narrow wings that are fringed with long hairs. The pupa has long wing pads that reach two-thirds the length of the abdomen. It also has four pointed processes on the ninth abdominal tergite. The prepupa is brown. Four pointed processes are present on

	the hind margin of the ninth abdominal tergite. Neonate larvae are transparent and towards the second molting, they turn to pale yellow. The legs, head, and antennae of the second instar larvae are slightly darker than those of the first instar larvae. Freshly laid egg is hyaline and turns pale yellow when about to mature. The egg is very tiny and measures 0.25 mm long.
Host range	Rice thrips prefers rice and maize. It also feeds on *Phalaris sp.* and *Imperata sp.*
Life cycle	
Mechanism of damage	Both the larvae and the adults of rice thrips use their rasping mouthparts or their single mandible to lacerate the plant tissues. They utilize their maxillae and mouth cone to suck the plant sap.
When damage is important	Rice thrips are more serious pests during the dry season. It infests the rice plant during the seedling stage or 2 weeks after early sowing.
Economic importance	In direct-seeded rice fields in Malaysia, losses can reach 100% when infestation is severe in the first 20 days, after sowing.
Management principles	Flooding to submerge the infested field for 2 days as a cultural control practice is very effective against the rice thrips. There are identified cultivars with known resistance to the rice thrips. Predatory thrips, coccinellid beetles, anthocorid bugs, and staphylinid

	beetles are biological control agents that feed on both the larvae and adults.
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Contributors	JLA Catindig and KL Heong

Rice Whorl Maggot

Rice whorl maggot (IRRI)

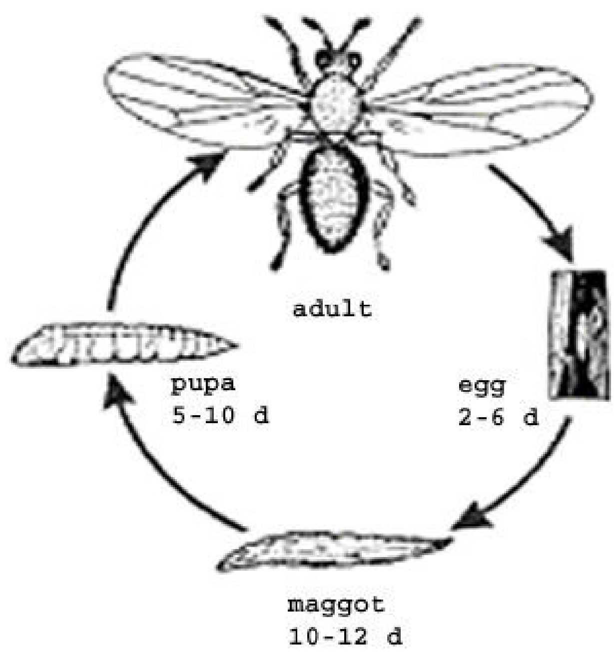
Diagnostic summary

Damage to plants	• feeding damage causes yellow spots, white or transparent patches and pinholes
Signs	• elongate, white eggs glued on leaves • transparent to light cream legless young larvae rasping the tissues of unopened leaves • yellow mature larva feeding on developing leaves of the new developing tillers at the base of the rice plant
Factors favoring insect/pest development	• standing water in paddies during the vegetative stage • host plants • transplanted young seedlings • standing water and thick vegetation near fields

Full fact sheet

Common name	Rice whorl maggot
Latin names	*Hydrellia philippina* Ferino
Symptoms	• White or transparent patches • Pinholes • Damaged leaves easily break from the wind • Somewhat distorted leaves • Clear or yellow spots on inner margins of emerging

	leaves • Stunting • Few tillers  Pinholes and patches (IRRI)
Confirmation	The rice plant can be visually examined for the distorted leaves, small clear or yellow spots, transparent streaks, pinholes, and other damage symptoms caused by the rice whorl maggot.
Problems with similar symptoms	There are no other symptoms similar to those caused by the rice whorl maggot.
Why and where it occurs	The following factors favor the development of the rice whorl maggot: standing water in paddies during the vegetative stage, the presence of host plants year-rounds, and transplanting of young seedlings. The rice whorl maggot is semi-aquatic. It is common in irrigated fields and feeds on the central whorl leaf of the vegetative stage of the rice plant. It does not occur in upland rice. It also prefers ponds, streams and lakes or places with abundant calm water and lush vegetation. The insect does not prefer direct-seeded fields and seedbeds. The adult is active during the day and rests on rice leaves near the water. It floats on the water or perches on floating vegetation. At midday, it is sedentary or it clings on upright vegetation. It prefers thick vegetation and is attracted to open standing water around seedbeds. Neonate maggots feed on the unopened central leaves where larval development is completed in 10-12 days. The full-grown maggots pupate outside the feeding stalk.
Causal agent or factor	The adult fly is grey with transparent wings. It has a silvery white frons and cheeks. Its antennae are dark gray with 7-10 aristal hairs. The inner portion of the second antennal segment has silvery tinge. The fly has a greyish mesonotum with silvery white and brown tinges. Its scutellum is silvery white to grey. Its abdomen is silvery white to grey with blackish brown in the middle of the three basal segments. The adult fly has yellow

	legs except for the femora. The females are usually bigger than the males and are 1.5-3.0 mm long. The pupa is dark brown and subcylindrical. It measures 4.8 mm long. Its posterior end is tapering and has two terminal respiratory spines. The larva is legless. Neonate larva is transparent to light cream, whereas mature larva is yellowish. A mature larva is cylindrical with a pair of pointed spiracles found posteriorly. It is 4.4-6.4 mm long. The egg is whitish, elongate, and measures 0.65-0.85 mm long and 0.15-0.20 mm wide. It is banana-shaped with a hard shell covering.
Host range	Its primary host is the rice plant. Its alternate hosts include grasses such as *Brachiaria sp., Cynodon sp., Echinochloa sp., Leersia sp., Leptochloa sp., Panicum sp.*, and wild rice.
Life cycle	
Mechanism of damage	The larva uses its hardened mouth hooks to rasp the tissues of unopened leaves or the growing points of the developing leaves. The damage becomes visible when the leaves grow old. Mature larva prefers to feed on the developing leaves of the new developing tillers at the base of the rice plant.
When damage is important	The rice whorl maggot begins to infest the rice plant at transplanting. It locates rice fields by reflected sunlight from the water surface.

<table>
<tr><td>Economic importance</td><td>The use of insecticide is not recommended for the rice whorl maggot control because the rice plant can compensate for the damage caused.</td></tr>
<tr><td>Management principles</td><td>There is no cultural control for rice whorl maggot.

Small wasps parasitized the eggs and the maggots. Dolicopodid flies prey on the eggs and ephydrid flies and spiders feed on the adults.

The rice plant can compensate for the damage caused by the rice whorl maggot. Usually, the symptoms disappear during the maximum tillering stage of the crop.</td></tr>
<tr><td>Selected references</td><td>1. Bandong JP, Litsinger JA. 1986. Oviposition of rice whorl maggot (RWM) in wet seedbeds. Int. Rice Res. Newsl. 11(1):16-17.
2. Barrion AT, Litsinger JA. 1986. Ephydrid flies (Diptera: Ephydridae) of rice in the Philippines. Int. Rice Res. Newsl. 11(4):29-30.
3. Barrion AT, Litsinger JA. 1994. Taxonomy of rice insect pests and their arthropod parasites and predators. In: Biology and management of rice insects. Manila (Philippines): International Rice Research Institute. p 13-362.
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6. Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p.
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9. Viajante VD, Heinrichs EA. 1986. Rice growth and yield as affected by the whorl maggot Hydrellia philippina Ferino (Diptera: Ephydridae). Crop Protect. 5(3):176-181.</td></tr>
<tr><td>Contributors</td><td>JLA Catindig and KL Heong</td></tr>
</table>

Root Aphids

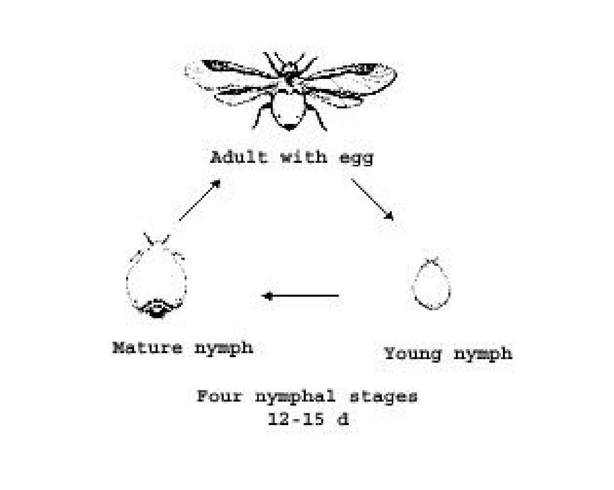
Adults and immatures of rice root aphids (IRRI)

Diagnostic summary

Damage to plants	• adults and nymphs suck the plant to remove plant fluids • feeding causes yellowing of the leaves and stunting
Signs	• globular and tan or brown nymphs and greenish, to brownish white, to yellow, to dark orange adults feeding on plants
Factors favoring insect/pest development	• drought • well-drained soils in upland and rainfed wetlands • presence of ants that transport the insect from plant to plant

Full fact sheet

<table>
<tr><td>Common name</td><td>Rice Root Aphid</td></tr>
<tr><td>Latin names</td><td>Tetraneura nigriabdominalis (Sasaki)</td></tr>
<tr><td>Symptoms</td><td>Leaf yellowing
Stunting if infestation is very severe
</td></tr>
</table>

	Plants are stunted and leaves are yellow (IRRI)
Confirmation	Checking for aphids feeding in the roots may confirm the symptom damage.
Problems with similar symptoms	Except for the yellowing of the plant, stunting can be compared with the damage caused by root grubs.
Why and where it occurs	Rice root aphids are favored by drought. During this period, aphid populations occur unevenly. Rice root aphids are dominant in well-drained soils in upland and rainfed rice. They are not present in irrigated rice. The adults are found on roots below ground level. They can also be located in cavities made by ants around the root system. The nymphs produce honeydew, which attracts ants. In return, ants transport the nymphs from plant to plant, protecting the growing aphids from predators and parasites.
Causal agent or factor	The adult is small and oval. Its color ranges from greenish, to brownish white, to yellow, and to dark orange. There are two adult forms: the winged and nonwinged forms. The winged adults are 1.5-2.3 mm long. The nonwinged forms are 1.5-2.5 mm long. All adults are females. The nymph is globular and tan or brown.
Host range	Aside from rice, the primary hosts of the rice root aphid are *Allium cepa* L. (onion), *Glycine max* (L.) Merr. (soybean), *Solanum tuberosum* L. (potato), and *Triticum aestivum* L. (wheat). Its secondary hosts include *Digitaria corymbosa* (Roth ex Roem. & Schult.) Veldk., *Echinochloa colona* (L.) Link (jungle grass), *Eleusine indica* (L.) Gaertn. (fowlfoot grass), *Eragrostis interrupta* (Thunb.) Trin, *Fimbrystilis miliacea* (L.) Vahl (fimbristylis), and *Panicum reptans* (L.) Gard. & C.E. Hubb. (millets).
Life cycle	
Mechanism of damage	Both adults and nymphs of rice root aphid use their sucking mouthparts to remove plant fluids.
When damage is important	Rice root aphid is an important insect pest during the tillering stage of the rice crop. A high number of aphids can cause

	yellowing and stunting once plant saps are removed.
Economic importance	Rice root aphids are minor pests of rice. They are seldom widespread within a field.
Management principles	There are natural enemies that can manage the population of rice root aphids. Both the nymphs and adults are parasitized by a small braconid wasp and a mermithid nematode and are preyed upon by lady beetles.
Selected references	1. Pathak MD, Khan ZR. 1994. Insect pests of rice. Manila (Philippines): International Rice Research Institute. 89 p. 2. Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, Barrion AT. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Manila (Philippines): International Rice Research Institute. 411 p. 3. Shepard BM, Barrion AT, Litsinger JA. 1995. Rice-feeding insects of tropical Asia. Manila (Philippines): International Rice Research Institute. 228 p.
Contributors	JLA Catindig and Dr. KL Heong

Root Grubs


Root grub (IRRI)

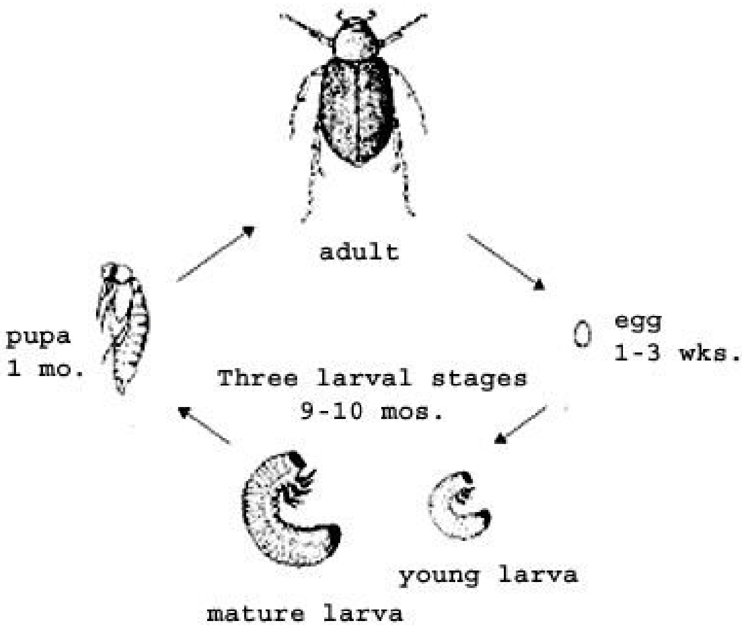
Diagnostic summary

Damage to plants	• fed-upon roots or root loss • abnormal plant height • color of the plant • orange-yellow leaves • wilting
Signs	• ovoid and creamy white eggs • adults feeding on the leaves • grubs or larvae feeding on the roots
Factors favoring insect/pest development	• plants with fibrous root system • soil moisture requirements • upland and rainfed wetland rice environments

Full fact sheet

Common name	Root Grubs
Latin names	*Leucopholis irrorata* (Chevrolat)
Symptoms	• Orange-yellow leaves • Wilting plants • Stunted plants • Root loss

	 Root grub adult (IRRI)  Damaged plant (IRRI)
Confirmation	The presence of the insect pest can confirm the symptom damage on the crop. The rice crop can be visually inspected for the damages such as damaged roots, abnormal height, and yellowish color of plants.
Problems with similar symptoms	Other insect pests such as mealybugs and root aphids also cause plant stunting. The orange-yellow leaf symptom is similar in appearance to nutrient deficiency.
Why and where it occurs	Root grubs generally prefer plants with fibrous root system. Root grubs are widespread in upland and rainfed rice environments. The adults are nocturnal and are attracted to light traps. Eggs are laid and developed in moist soil made by the burrowing females. In the soil, they usually remain close to where moisture is available.
Causal agent or factor	The adult beetle is black or dark brown in color. Its pronotum is not margined except for its lateral edges. The male has a longer antennal club than the female adult. While the female has a broader tibial spur with a rounded end, the male has a slender and pointed tibial spur. The pupa is dark brown. The grub is creamy white and has a pair of sclerotized mandibles. Three pairs of prominent legs are visible on the thoracic area and its

	body is curled in a C-shaped position. The eggs are pearly white and elongated or ovoid in shape.
Host range	Aside from the rice plant, root grubs prefer plants with a fibrous root system such as maize, millet, sorghum, sugarcane and various grasses.
Life cycle	
Mechanism of damage	The adults feed on the leaves while the grubs feed on the roots of rice plants by digging through the soil.
When damage is important	Root grubs feed on rice during the seedling stage of the crop. During drought, damage caused by the insect pest is higher.
Economic importance	White grubs are minor insect pests of rice and usually in upland rice. Both the adults and larvae feed on the leaves and roots, respectively.
Management principles	The population of root grubs is generally controlled by natural biological control agents. Scoliid wasps parasitize the larvae. Carabid beetles, birds, toads, bats, and storks also eat the larvae and adults. The larvae are also infected by fungal pathogens.
Selected references	1. Barrion AT, Litsinger JA. 1994. Taxonomy of rice insects and their arthropod parasites and predators. In: Heinrichs EA, editor. Biology and management of rice insects. Manila (Philippines): International Rice Research Institute. p 13-362. 2. Braza RD. 1990. Laboratory evaluation of *Metarhizium anisopliae* (Metch.) Sorokin against *Leucopholis irrorata* Chevrolat (Coleoptera: Scarabaeidae). Philipp. Entomol.

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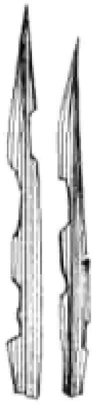
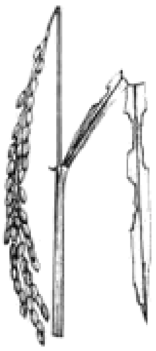
Contributors	JLA Catindig and Dr. KL Heong

Short-horned Grasshopper - Locust



Cut-out areas on leaves (IRRI).



Panicles are cut-off (IRRI).

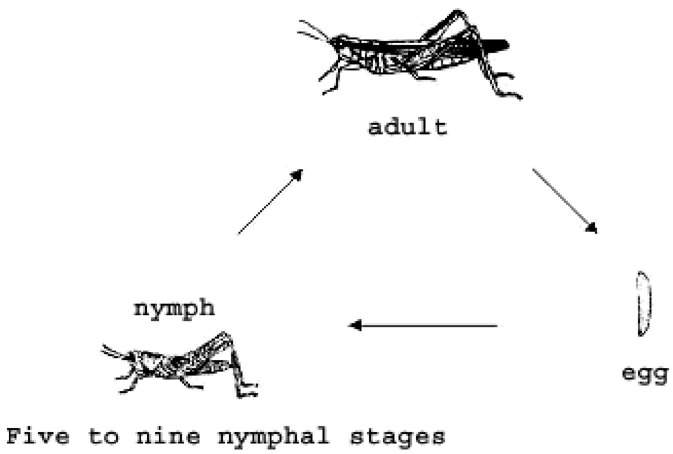
Diagnostic summary

Damage to plants	• feeding causes cut-out areas on leaves
Signs	• eggs in pods • presence of yellow and brown nymphs and adults feeding on rice foliage
Factors favoring insect/pest development	• aquatic environments, drier environments and drought • presence of alternate hosts • irrigated rice environment surrounded by grassland breeding grounds

Full fact sheet

Common name	Short-horned grasshoppers, Oriental migratory locust
Latin names	*Oxya hyla intricata* (Stal), *Locusta migratoria manilensis* Meyen

Symptoms	• Feeding marks on leaves and shoots • Large portions of leaf edges consumed • Panicles cut-off
Confirmation	The presence of the insect on the crop and the characteristic form of leaf damage can easily confirm the symptom damage caused by short-horned grasshoppers and locusts.
Problems with similar symptoms	The symptoms can be confused with the damage caused by other insect defoliators on the rice crop.
Why and where it occurs	Aquatic environments are suitable for the development of short-horned grasshoppers, while locusts may prefer dry environments. Both are favored by the presence of alternate hosts. The short-horned grasshoppers are common in moist and swampy areas. They are abundant during September and October. The insect pests are nocturnal. Oriental migratory locusts are commonly found in all rice environments but they are more concentrated in rainfed areas. They predominate the irrigated rice environment surrounded by grassland breeding grounds. Both the adults and the nymphs are nocturnal. They feed on the rice foliage at night. At daytime, they hide at the base of the plant. Under favorable conditions, the adults swarm and migrate.
Causal agent or factor	Short-horned grasshoppers are small to medium and moderately slender insects. They measure from 20-30 mm in length. They are yellow and brown with shiny bodies and with a finely pitted integument. Their eyes are large and close to each other. A broad and brown stripe runs laterally through the eyes and extends posteriorly along the wings. They have short filiform antennae. The antennae of the male are slightly longer than the head and pronotum combined. The female has shorter antennae. Both sexes have fully developed wings. Their wings are green with brownish to bluish bands. They have green and slender hind femora with rounded upper knee lobes and lower knee lobes extended into acute spine-like projections. They have greenish tibiae. The locust is a large insect with a smooth or finely dotted integument. Its filiform antenna is about as long as the head and pronotum combined. The adults have two forms. The darker adults are those that are bred at high population densities. They have wider heads with almost concave or straight in profile low pronotal crest. They have shorter femur than its wings. The other form of adults came from low population densities. They have a narrow head, high pronotal crest, and long hind femur. The nymph of short-horned grasshopper is a smaller version of the adult except for the small wing pads. Neonate nymphs of oriental migratory locust are gray-brown and measure 6 to 10 mm long. Mature nymphs exhibit two colors. At low densities, they are either green or brown. The nymphs are reddish or

	brownish orange at high densities. Two thin horizontal black stripes are prominent behind the compound eyes. A broader horizontal black band is also located on the lateral sides of the pronotum, on the developing wing pads, and on the dorsal and lateral surfaces of the abdomen. The eggs of both short-horned grasshopper and oriental migratory locust are in pods. They are capsule-like and yellow to dull reddish brown. With age, they turn darker.
Host range	Rice is the primary host of both species. Short-horned grasshoppers also feeds on maize, sorghum, sugarcane, millet, and *Echinochloa* spp. Oriental migratory locust also prefers bamboo, banana, beans, betel, cassava, citrus, coconut, cotton, fibers, groundnut, kenaf, kumquat, lablab, legumes, lop buri, maize, market garden produce, millets, nipa palm, phrae, pigeonpea, pineapple, sago palm, soybean, sugarcane, sweet potato, tobacco, wheat, *Artemisia* sp., *Cymbopogon citratus* (DC.) Stapf, *Dendrocalamus* sp., *Eragrostis* sp., *Gigantochloa* sp., *Imperata* spp., *Miscanthus* sp., *Pandanus* spp., *Panicum* spp., *Phragmites* sp., *Polygonum* sp., *Psophocarpus* sp., *Saccharum spontaneum* L., *Themeda gigantea*, and *Vigna* spp. In a laboratory experiment in China, the insect developed on *Sorghum* sp., *Cynodon dactylon* (L.) Pers., and *Miscanthus* sp.
Life cycle	
Mechanism of damage	Short-horned grasshoppers and oriental migratory locusts feed on the leaf margins of leaves.
When damage is important	Both the nymphs and adults feed on the leaves and shoots at all growth stages of the rice crop.

Economic importance	Both species are sometimes important pests of the rice crop. The nymphs and adults feed on the leaf by consuming large amounts of leaves. Serious damage caused by short-horned grasshoppers has been reported in Vietnam and China. Oriental migratory locust migrates in swarms and can be highly abundant. Outbreaks of the insect pest usually occur during drought. Records showed outbreaks in China, Philippines, Sabah, and Malaysia.
Management principles	Among the cultural control options, the following are recommended for short-horned grasshoppers: flooding the stubbles, shaving of bunds, sweeping along the bunds and adults can be picked directly from the foliage at night because they are sluggish. Short-horned grasshoppers and oriental migratory locusts are generally controlled under by natural biological control agents. Scelionid wasps parasitize the eggs of short-horned grasshopper. Nymphs and adults are hosts of parasitic flies, nematodes, and fungal pathogens. They are also infected by a certain species of an entomophthoralean fungus. Among the predators, birds, frogs, and web-spinning spiders are known. A platystomatid fly and mite prey on the eggs of oriental migratory locust. Different species of ants feed on the nymphs and adults. They are also prey to birds, bats, field rats, mice, wild pigs, dogs, millipedes, fish, amphibia, reptiles, and monkeys. A fungus also infects the insect pest. Chemical management includes the use of poison baits from salt water and rice bran. Foliar sprays can also control grashoppers in rice fields. Granules are not effective.
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Contributors JLA Catindig and KL Heong

Snails

Egg mass of golden apple snail (IRRI)

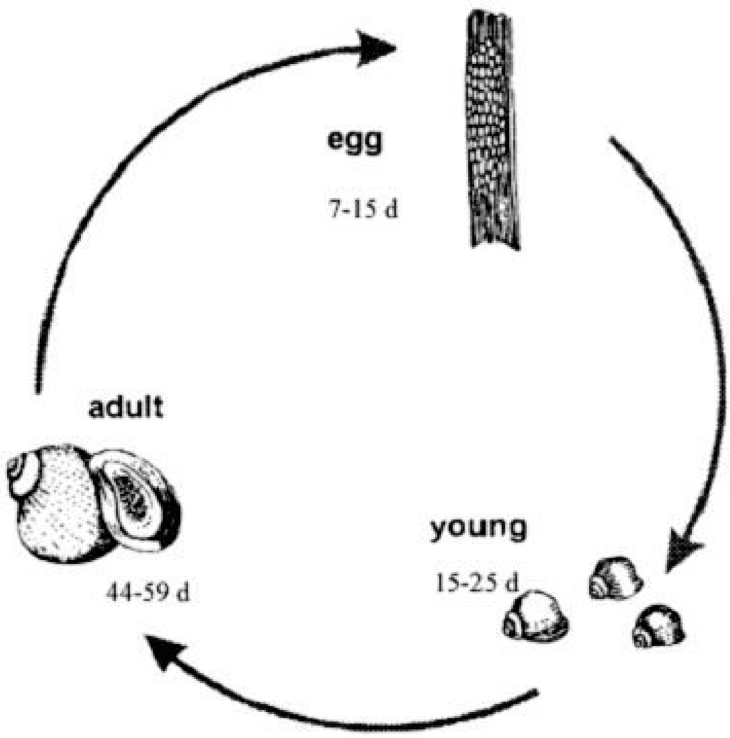
Diagnostic summary

Damage to plants	• rasp plant tissue • feeding damage causes missing seedlings and floating cut leaves
Signs	• bright pink eggs • the different color and size of the snail
Factors favoring insect/pest development	• wetland and dryland habitats • irrigation canals and rivers • presence of alternate hosts • presence of young seedlings • continuous flooding of the rice fields • presence of both gills and lung-breathing organs • ability to survive in any environmental condition

Full fact sheet

Common name	Golden apple snail, golden miracle snail, Argentine apple snail, channelled apple snail, apple snail, golden "kuhol", Miami golden snail
Latin names	*Pomacea canaliculata* (Lamarck)
Symptoms	• Missing seedlings • Floating cut leaves • Cut stems • Decreased plant stand

	• Sparse or uneven stand  Snail adult (AT Barrion, IRRI).  Missing seedlings (IRRI)
Confirmation	The presence of the egg mass and the organism, and the symptoms such as the missing seedlings confirm the damage caused by the snail.
Problems with similar symptoms	The damage symptoms are comparable to the symptoms caused by the rice caseworm. Although the latter have the leaves rolled into tubes or cases.
Why and where it occurs	The golden apple snail is prevalent in wetland such as seasonal swamps or rice fields. It can also be found in irrigation canals and rivers. It has both gills and a lung-breathing organ. It digs deep into the mud and surfaces again after renewed flooding. During drought, it closes its operculum. Mating occurs any time of the day in all seasons of the year in places where there is a continuous supply of water. The wide host range of the golden apple snail supports its continuous development. The presence of young seedlings and continuous flooding of the rice fields also encourage its population buildup. Water currents in rivers, irrigation systems and floods also contribute to its spread. Its ability to aestivate during the dry season enhances its survival under adverse conditions.
Causal agent or factor	The golden apple snail has a muddy brown shell. The shell is lighter than the darker and smaller native snails. Its succulent flesh is creamy white to golden pinkish or orange-yellow. The

	male has a convex operculum that curves out or away from the shell, whereas the female lid curves into the shell. Neonates or the newly hatched snails have soft shell. The juveniles or young snails are <1.5 to 1.6 cm. Medium-sized snails have a shell height of 2 to 3 cm. The eggs are bright pink or strawberry pink. With age, they lighten in color or turn light pink when about to hatch. Further information about this species can be obtained at http://www.applesnail.net.
Host range	Aside from the rice plant, the golden apple snail also feeds and develops on azolla, duckweed, lotus, maize, parsley, pearl barley, ramie, rice, rush, taro, water chestnuts, water hyacinth, water oats, most lowland weeds, and other succulent leafy plants.
Life cycle	
Mechanism of damage	The golden apple snails rasp plant tissue and cut of stems with their file-like radula or horny tongue.
When damage is important	It is a serious pest of young rice seedlings because it often cuts and kills growing seedlings. It also leaves large patches without rice, is particularly a more serious problem in direct-seeded crops.
Economic	The golden apple snail is considered a major problem in direct-

importance	seeded rice. During dry periods or drought, the golden apple snails remain inactive in rice fields. They become active when fields are flooded. In the Philippines, 400,000 ha of rice were reported to be infested in 1988. In 1989, more than 16,000 ha suffered from golden apple snail damage in Japan. The golden apple snail is now considered of quarantine importance in many countries, eg., Australia, Malaysia, and United States.
Management principles	There are physical, mechanical, cultural, biological, and chemical control measures recommended against the golden apple snail. The physical control practice is to install screens with 5 mm mesh at water inlets. This can minimize the entry of snails into the rice fields and will also facilitate hand-collection. Increase mortality by mechanical action prior to crop establishment is advisable. Other mechanical control measures include handpicking and crushing, staking with bamboo or other wooden stakes before and after transplanting can be practiced to facilitate egg mass collection. Likewise, the use of a hand-operated device to smash egg clusters between two snail egg clappers can also reduce the snail population. Among the recommended cultural control measures, planting older seedlings, planting at higher densities, or planting on ridges above the water line are advised against the golden apple snail. The field can be leveled-off or hydrotiller or rototiller to prepare the land. An off-season tillage to crush snails can also be employed. Snails can also be exposed to sun. Draining the field is also advised. Crop rotation with a dryland crop and fallow periods is also recommended as control. For easier drainage and collection of the golden apple snail, canalets can be constructed along bunds and inside paddies. Atractants like newspaper can be used. Depressed strips can be constructed to retain a small amount of water drainage. This method also confines the snail to limited areas, hence handpicking can be facilitated. It can be done during the final harrowing period. Good water management obtained by good levelling for the first two weeks is recommended. The use of common carp, Japanese crucian, heron, and weasels as biological control agents against the golden apple snail were effective in Japan. A firefly nymph is also an effective natural enemy of the snail. Herding ducks and raising fish in the paddy are also recommended as biological control. Birds prey on both eggs and neonates. Rats and snakes also feed on them.

	Molluscicides such as metaldehyde is recommended.
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Stem Borers


Whitehead or dead panicles at reproductive stage (IRRI)

Diagnostic summary

Damage to plants	• fed-upon tillers • causes deadheart or drying of the central tiller during the vegetative stage • causes whiteheads at reproductive stage
Signs	• eggs bare or covered with hairs, laid in masses • neonate larvae suspend themselves from leaves by silken threads and blown to other plants to feed • mature larvae bore into the sheath and tiller of the plant • presence of frass or fecal matter
Factors favoring insect/pest development	• fields planted late • stubbles that remain in the field

Full fact sheet

Common name	Yellow stem borer (YSB), White stem borer (WSB), Striped stem borer (SSB), Gold-fringed stem borer, Dark-headed stem borer, Pink stem borer
Latin names	*Scirpophaga incertulas* (Walker), *S. innotata* (Walker), *Chilo suppressalis* (Walker), *C. auricilius* Dudgeon, *C. polychrysus* (Meyrick), *Sesamia inferens* (Walker)
Symptoms	• Deadhearts or dead tiller that can be easily pulled from the base during the vegetative stages • Whiteheads during reproductive stage where the emerging panicles are

	whitish and unfilled or empty • Tiny holes on the stems and tillers • Frass or fecal matters inside the damaged stems  Drying of the center tiller or deadheart (IRRI)
Confirmation	The young rice crop can be visually inspected for deadhearts in the vegetative stages and whiteheads in reproductive stages. Stems can be pulled and dissected for larvae and pupae for confirmation of stem borer damage.
Problems with similar symptoms	Deadhearts and whiteheads symptoms may sometimes be confused with damages caused by rats, neck blast, and black bug diseases.
Why and where it occurs	The yellow stem borer is a pest of deepwater rice. It is found in aquatic environments where there is continuous flooding. Second instar larvae enclose themselves in body leaf wrappings to make tubes and detach themselves from the leaf and falls onto the water surface. They attach themselves to the tiller and bore into the stem. Striped stem borer is most abundant in temperate countries and in non-flooded areas. Their final instars remain dormant in temperate areas during winter. The pink stem borer is found in upland rice, which is grown near sugarcane or related grasses. The presence of alternate hosts encourages the pink stem borer to develop, multiply and survive during winter or dry season. Unlike other species of stemborers, the pink Stem borer have bare eggs laid between the leaf sheath and the stem. High nitrogenous field favors population buildup of the stem borers. Fields planted later favors more damage by the insect pest that have built up in fields that have been planted earlier. Stubble that remains in the field can harbor stem borer larvae and or pupae.
Causal	The female YSB moth has a pair of black spots at the middle of each whitish, light brown to yellowish forewing. It has a wingspan of 24-36 mm. Its

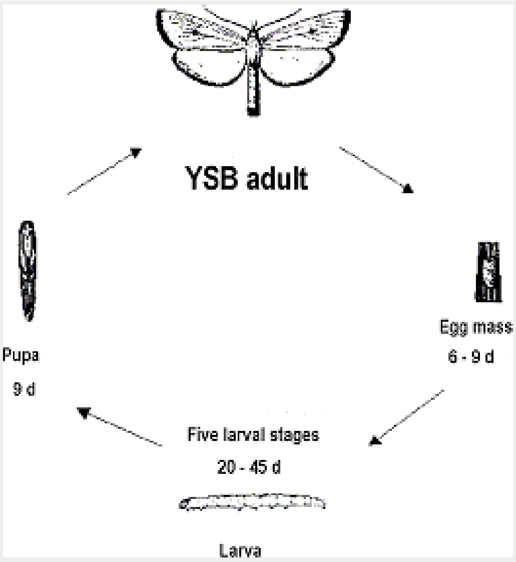
agent or factor	abdomen is wide with tufts of yellowish hairs all over. The male, gray or light brown in color, is smaller and has two rows of black spots at the tip of the forewings. It has a wingspan of about 20-30 mm. Its abdomen is slender toward its anal end and is covered with thin hairs dorsally. The YSB pupa is pale green and measures about 12 mm long. It is enclosed in a white silk cocoon. Fresh cocoon is pale brown and turns dark brown with age. The first instar YSB larva is about 1.5 mm long with yellowish green body. A full-grown larva has brown head and prothoracic shield and measures 20 mm. The egg mass of YSB is covered with brownish hairs from the anal tufts of the female. Individual eggs of are white, oval, and flattened. The male and female WSB moths are immaculately white. The male moth is smaller than the female. Both adults have a tuft of long hairs on the thorax. Its fresh pupa is whitish and soft-bodied and turns brown with age. The larva is whitish to light yellow and without body markings. A mature larva is 25 mm long. The egg mass of WSB is disc-shaped and is covered with hair. It measures 3.5 mm to 6 mm long. The SSB adults are brownish yellow with silvery scales. It has a row of 7 or 8 small black dots on the terminal margin of each forewing. The pupa is reddish brown and it measures about 11 to 13.5 mm long. It has two ribbed crests on the pronotal margins. The head has two short horns. The last segment of the pupa has visible spines. Neonate larvae have large shiny brown or orange head. Their prothoracic shields have the same color as their head. Their body is light brown or pink. Five rows of brown or pale purple longitudinal stripes run the entire length of the body. The stripes are found dorsally and laterally. Mature larvae measure 20 to 25 mm long. Newly laid eggs are glistening white. They are disc-shaped. Mature eggs turn yellow. They are black when about to hatch. The adult moth of the gold-fringed stem borer is straw to light brown with silvery specks on the discal cell of the forewings or near the apical one-fifth. Several black dots are also found at the tip of the forewings. The male is generally smaller than the female moth. The pupa is yellow-brown. It has two distinct bumps at the front of the head. The larva has a black head. Five pinkish longitudinal stripes run along the entire length of the body. Newly laid eggs are white and are scale-like in appearance. They turn pale yellow to brown with age. Mature eggs that are about to hatch turn blackish. Dark-headed stem borer adult is brownish yellow. It has dark markings of silvery scales or 6-7 tiny black dots on the center of the forewings. The hindwing has a lighter color. The female adult is larger than the male. The pupa is yellowish brown or light brown with remnants of abdominal stripes. It has sharp spines on the cremaster at the end of the abdomen. Neonate larvae are grayish white with a large head. The head and prothoracic shield are both black. It has a dirty white body with five longitudinal stripes of grayish violet or purplish brown passing through the entire larval body. The freshly deposited egg mass is glistening white. Individual egg is flat and scale-like. It measures 0.6 mm long and 0.4 mm wide. It turns yellowish and becomes black when about to hatch. Pink stem borer adult is bright pale brown with some scattered dark brown markings. A purplish red band radiates from the central point in the forewing to the wing tip. Light stripes border the wing apex. The hindwings are whitish

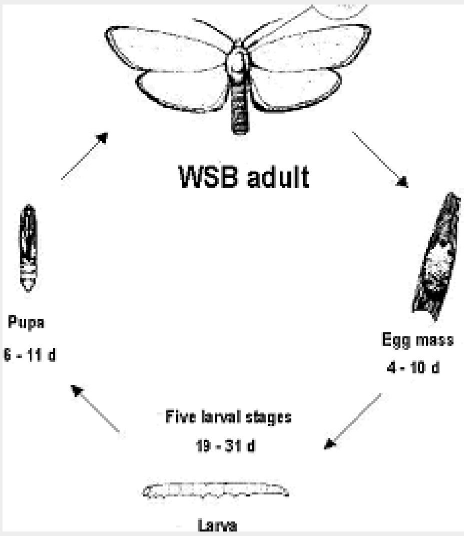
	with light yellow scales along the major veins. The male moth is slightly smaller than the female and has a pectinate antenna. The female has a filiform type of antenna. The pupa is brown to dark brown with a tinge of bluish powdery substance. The male pupa is 12.0 mm long and the female measures 18.0 mm long. Neonate larva is white with a yellowish tinge and a black head capsule and prothoracic plate. With age, it turns pinkish purple with a brown or orange-red head capsule. Its body has no longitudinal stripes. The larva is 25.0 to 35.0 mm long. Freshly laid eggs are creamy white. They are nearly spherical or bead-like and measures 0.5 × 0.4 mm long. A one-day old egg is light yellow while a mature egg turns pink and black.
Host range	The yellow stem borer is monophagous to rice. The white stem borer feeds primarily on rice. Its secondary host includes grasses like *Cynodon dactylon* (L.C. Rich) Pers., and *Oryza australiensis* Domin. and sedges *Cyperus rotundus* L., and *Cyperus sp*. Rice is the main host of the striped stem borer. It also feeds on *Brassica campestris* L., *Coix lachryma-jobi* L., *C. l.* var. *aquatica* Roxb., *Coix* sp., L., *Colocasia antiquorum* Schott, *Cyperus digitatus* Roxb., *Echinochloa colona* (L.) Link, *E. crus-galli* (L.) P. Beauv. var. *cruspavanis*, *E. crus-galli* (L.) P. Beauv., *Echinochloa* sp., *Eleusine indica* (L.) Gaertn., *Eriochloa procera* (Retz.) C.E. Hubb., *Ischaemum rugosum* Salisb., *I. timorense* Kunth, *Lycopersicon lycopersicum* (L.) Karsten, *Miscanthus sinensis* Anderss., *Oryza latifolia* Desv., *O. minuta* J.C. Presl ex C.B. Presl, *O. ridleyi* Hook. f., *Panicum auritum* Presl ex Nees, *P. miliaceum* L., *P. repens* L., *Paspalum punctatum* Burm., *P. scrobiculatum* L., *Pennisetum glaucum* (L.) R. Br., *Phragmites australis* (Cav.) Trin., *P. karka* (Retz.) Trin., *Pleiblastus simoni* (Carr.) Nakai, *Polygonum reynoutria* Makino, *Raphanus sativus* L. var. *acanthiformis*, *Saccharum arundinaceum* Retz., *S. fuscum* Roxb., *S. officinarum* L., *Sacciolepis myosuroides* Ridl., *Scirpus grossus* L. f., *Setaria gracilis* H.B.K., *S. pumila* (Poir.) Roem. & Schult., *Solanum melongena* L., *Sorghum bicolor* (L.) Moench, *Triticum vulgare* Villars, *Typha latifolia* L, *Vetiveria odorata* Virey, *Zea mays* L., *Zizania aquatica* L., and *Z. latifolia* Turcz. The rice plant is the primary host of the gold-fringed stem borer. It also feeds on *Hemarthria compressa* (L.f.) R. Br., *Oryza latifolia* Desv., *Saccharum arundinaceum* Retz., *S. fuscum* Roxb., *S. officinarum* L., *S. spontaneum*, *Sacciolepis myosuroides* (R. Br.) A. Camus, *S. myurus* (Lam.) A. Chase, *Setaria pumila* (Poir.), *Sorghum bicolor* (L.) Moench, *S. halepense* (L.) Pers., and *Zea mays* L. The host plant range of the dark-headed stem borer in Malaysia are: *Brachiaria distachya* (L.) Stapf, *Coelorachis glandulosa* (Trin.), *Cyperus ditatus* Roxb., *Echinochloa colona* (L.) Link, *Eleusine coracana* (L.) Gaertn., *E. indica* (L.) Gaertn., *Eriochloa procera* (Retz.) C.E. Hubb., *Hymenachne acutigluma* (Steud.) Gilliland, *Ischaemum timorense* Kunth, *Oryza sativa latifolia* Desv., *O. minuta* J.C. Presl, *Panicum auritum* Presl ex Nees, *P. repens* L., *Paspalum punctatum* Burm., *P. scrobiculatum* L., *Pennisetum purpureum* K. Schum, *Saccharum officinarum* L., *Saccharum* sp., *Sacciollepis myosuroides* (R. Br.) A. Camus, *S. myurus* (Lam.) A. Chase, *Sacciolepis* sp., *Setaria gracilis* H.B.K., *S. pumila* (Poir.) Roem, and Schult., and *Vetiveria odorata* Virey. In India, *Echinochloa crus-galli* (L.) P. Beauv. is its alternate host. *Oxya rufipogon* Griff.

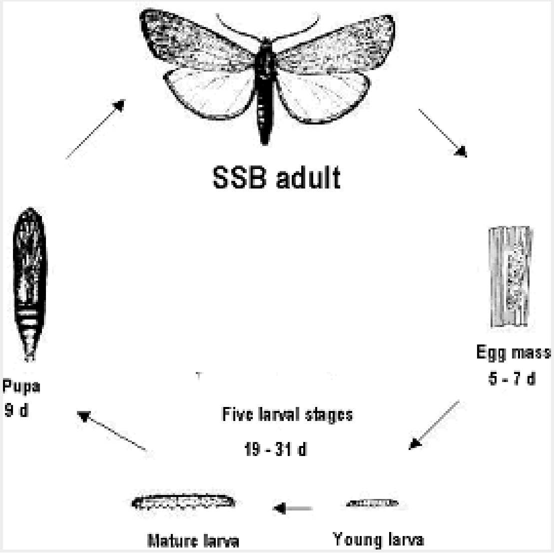
and *Saccharum officinarum* L. are alternate hosts in Bangladesh. *Setaria italica* (L.) P. Beauv. is a recorded host in Bangladesh, India, and Malaysia.

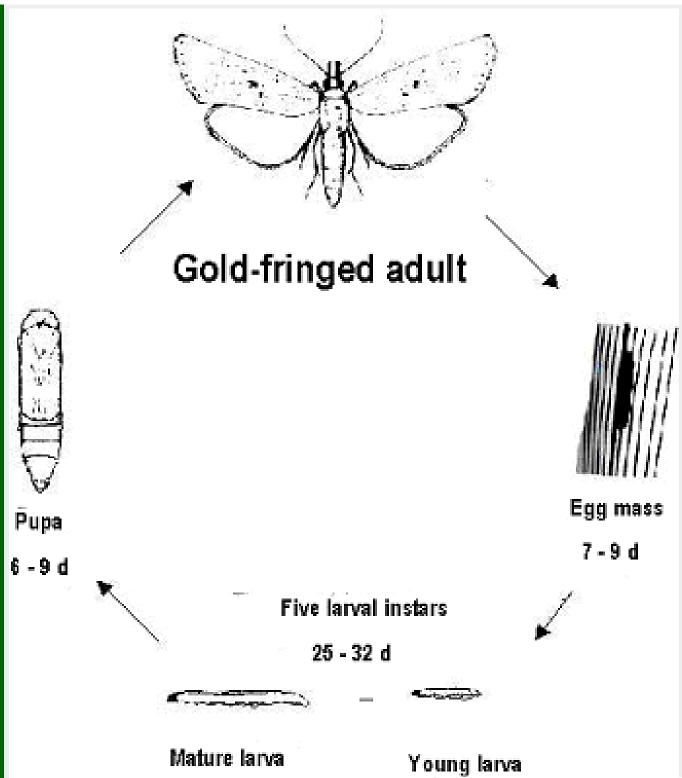
Aside from the rice plant, other hosts of the pink stem borer include *Andropogon schoenanthus* L. (lemon grass), *Avena sativa* L. (oat), *Beckmannia erucaeformis* (L.) Hochst. (minogome), *Calamagrotis epigejos* Roth, *Coelorachis glandulosa* (Trin.) Stapf ex Ridl., *Coelorachis sp*., *Coix lachryma-jobi* L. (Job's tears), *Cymbopogon nardus* (L.) Rendle, *Cyperus digitatus* Roxb., *C. japonicus* Makino (sedge), *C. rotundus* L. (coco grass, nutgrass), *Cyperus sp., Echinochloa colona* (L.) Link (jungle grass, jungle rice), *E. crus-galli* (L.) *P. Beauv.* (barnyard grass), *E. frumentacea* Link (sema), *Echinochloa sp*., *E. stagnina* (Retz.) P. Beauv., *Eleusine stagnina* (Retz.) *P. Beauv*., E. coracana (L.) Gaertn. (finger millet, ragi), E. indica (L.) Gaertn. (goose grass), *Eleusine sp., Eragrostis cilianensis* (All.), *Eragrostis sp., Erianthus arundinaceus* (Retz.) Jesw., *Erianthus sp., Eriochloa procera* (Retz.), *E. villosa* (Thum.) Kunth, *Hemarthria compressa* (L.f.) R.Br. (jove grass), *Hordeum sativum* Jess. (barley), *Hymenachne myurus* (Lam.) Beauv., *Hymenachne sp*., *Ischaemum rugosum* Salisb., *Ischaemum sp., I. timorense* Kunth, *Miscanthus sinensis* Anderss., *Miscanthus sp.*, *O. latifolia* Desv., *Oryza minuta* J.C. Presl ex C.B. Presl, *Panicum auritum Presl, P. maximum* Jacq. (guinea grass), *P. miliaceum* L. (porso or brown corn millet), *P. repens* L. (torpedo grass, panic rampant), *Panicum sp., Paspalum punctatum* Burm., *P. scrobiculatum* L. (kodo millet, kodra millet), Paspalum sp., P. thunbergii Kunth ex Steud., Pennisetum glaucum (L.) R. Br. (pearl millet, bulrush millet), *Pennisetum sp., Phragmites karka* (Retz.) Trin. Ex Steud. (millet), *Phragmites sp*., *Polypogon fugax monospeliensis* (L.), *Polypogon sp*., *Rumex crispus* L., *Rumex sp.* (giant lobelias), *Saccharum arundinaceum* Retz. (kanra), *Saccharum arundinaceum var. ciliaris* (sar), *S. fuscum* Roxb. (ikri), *S. officinarum* L. (sugarcane), *Saccharum sp.*, *S. spontaneum* L. (wild sugarcane), *Sacciolepis myosuroides* (R. Br.) A. Camus, *S. myurus* (Lam.) A. Chase, *Sacciolepis sp., Scirpus grossus* L.f., *S. lacustris* L., *S. maritimus* L., *Scirpus sp.*, *Setaria italica* (L.) *P. Beauv.* (Italian millet, foxtail millet, Indian millet), *S. pumila* (Poir.) Roem. and Schult., *Setaria sp.*, *Sorghum bicolor* (L.) Moench (sorghum), *S. halepense* (L.) Pers. (Johnson grass), *S. sudanense* (Piper) Stapf, *Teosinte sp.*, *Triticum aestivum* L. (wheat), *Triticum sp*. (wheat), *Vetiveria odorata Virey, Zea mays* L. (maize), *Zea sp.*, and *Zizania latifolia* (Griseb.).

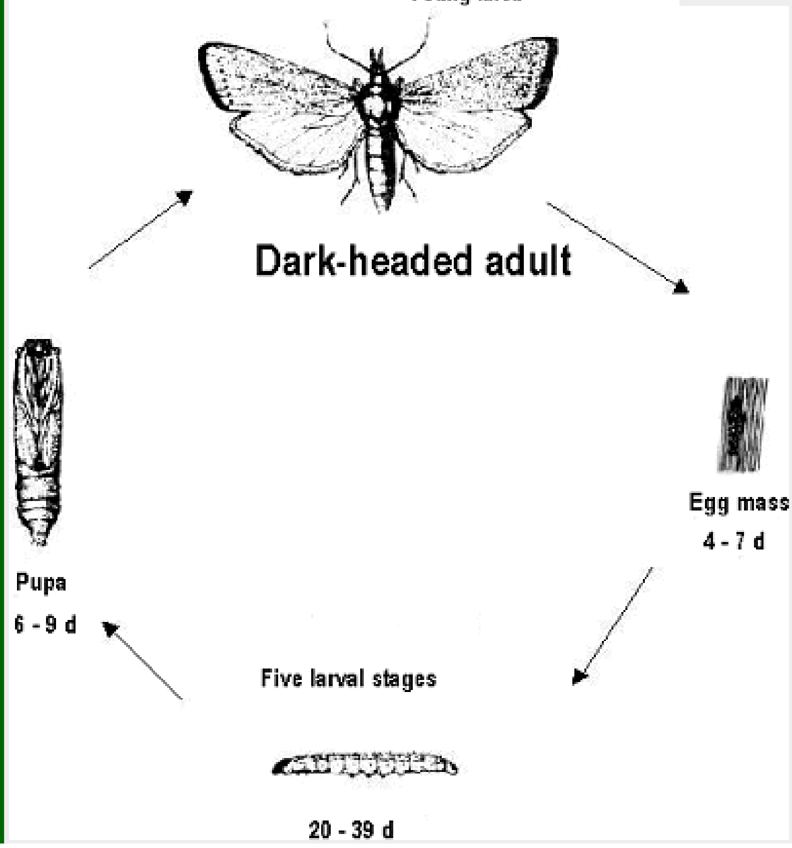
Life cycle	

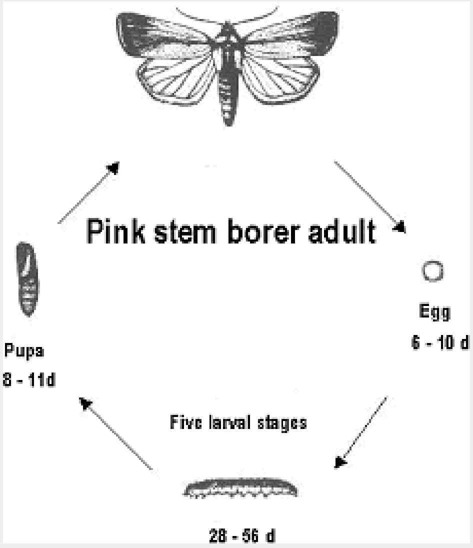

YSB adult
Egg mass
6 - 9 d
Five larval stages
20 - 45 d
Larva
Pupa
9 d


WSB adult
Egg mass
4 - 10 d
Five larval stages
19 - 31 d
Larva
Pupa
6 - 11 d


SSB adult
Egg mass
5 - 7 d
Five larval stages
19 - 31 d
Young larva
Mature larva
Pupa
9 d


Gold-fringed adult
Egg mass
7 - 9 d
Five larval instars
25 - 32 d
Mature larva
Young larva
Pupa
6 - 9 d


Dark-headed adult
Egg mass
4 - 7 d
Five larval stages
20 - 39 d
Pupa
6 - 9 d



Mechanism of damage	Stemborers feed on the crop during the vegetative and reproductive stages of the rice plant. Excessive boring through the sheath can destroy the crop. Its damage caused reduction in the number of reproductive tillers.
When damage is important	The stem borer larvae bore at the base of the plants during the vegetative stage. On older plants, they bore through the upper nodes and feed toward the base. Late infestation causes whiteheads.
Economic importance	The yellow stem borer is an important pest of irrigated rice in South and Southeast Asia. In the Philippines, it caused about 5% to 10% yield loss. About 1% to 19% yield loss in early planted rice crops and 38% to 80% yield in late-planted rice were reported in India. The white stem borer (WSB) is an important pest in rainfed wetland rice. In West Java, Indonesia, this pest has been observed in irrigated rice fields. WSB causes occasional outbreaks, especially in the Indramayu and Cirebon areas. Along the northern portion of West Java, an outbreak occurred and destroyed 15,000 ha of rice fields during the wet season of 1989-90. The striped stem borer is one of the most important insect pests in temperate Asia. During the vegetative stage, larval feeding causes deadheart. The rice plant can compensate by growing new tillers. At the reproductive stage, feeding causes whitehead. The damage could reach 100%. The gold-fringed stem borer is a major pest of sugarcane in India and Taiwan. It is a pest of maize and upland rice. Yield losses of 30% and 20% due to this insect were reported in India and Bangladesh, respectively Among the stem borers, the dark-headed and the pink stem borer are less important. The pink stem borer is polyphagous and prefers sugarcane to rice.

Management principles

Stem borers can be managed using cultural control measures, biological control agents, the use of resistant varieties, and chemical control.

Cultural control measures include proper timing of planting and synchronous planting. The crops should be harvested at ground level to remove the larvae in stubble. Likewise, stubble and volunteer rice should be removed and destroyed. Plowing and flooding the field can kill larvae and pupae in the stubbles. At seedbed and transplanting, egg masses should be handpicked and destroyed. The level of irrigation water can be raised periodically to submerge the eggs deposited on the lower parts of the plant. Before transplanting, the leaf-top can be cut to reduce carry-over of eggs from the seedbed to the field. Application of nitrogen fertilizer should be split following the recommended rate and time of application.

Biological control agents include braconid, eulophid, mymarid, scelionid, chalcid, pteromalid and trichogrammatid wasps that parasitize the eggs of yellow stem borer. Ants, lady beetles, staphylinid beetles, gryllid, green meadow grasshopper, and mirid bug also eat eggs. The larvae are parasitized by phorid and platystomatid flies, bethylid, braconid, elasmid, eulophid, eurytomid and ichneumonid wasps. They are attacked by carabid and lady bird beetles, chloropid fly, gerrid and pentatomid bugs, ants, and mites. Bacteria and fungi also infect the larvae. A mermithid nematode also attacks the larvae. Chalcid, elasmid and eulophid wasps parasitize the pupae. Ants and earwigs also eat the pupa. Bird, asilid fly, vespid wasp, dragonflies, damselflies, and spiders prey upon the adults.

There are varieties from IRRI with resistance to the stem borers.

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Zigzag Leafhopper


Zigzag leafhopper nymph (IRRI)

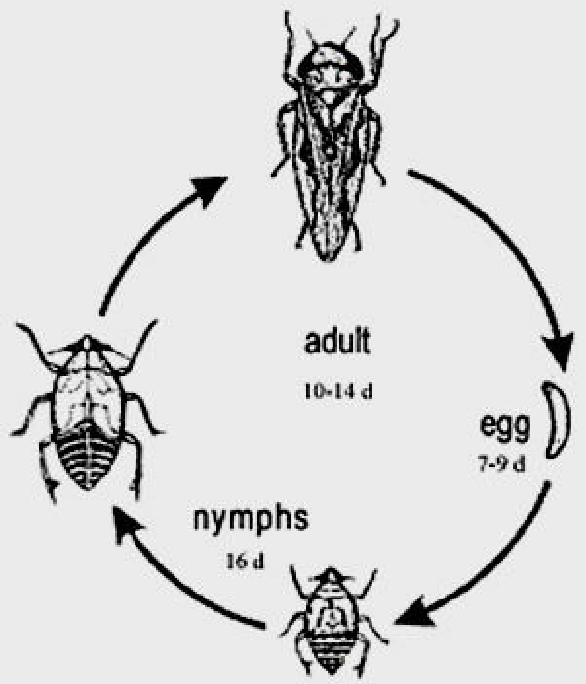
Diagnostic summary

Damage to plants	• feeding damage causes the leaf tips to dry up, whole leaves become orange and curled • symptoms of viral diseases
Signs	• white eggs laid singly in the sheaths • yellowish brown nymphs and adults sucking sap from the leaves in the upper parts and tillers near the base of the plant
Factors favoring insect/pest development	• presence of grassy weeds • volunteer rice in fallow fields • all rice environments • early growth stages of crop • seedbeds and weeds between planting seasons

Full fact sheet

Common name	Zigzag leafhopper
Latin names	*Recilia dorsalis* (Motschulsky)
Symptoms	• Drying of leaf tips • Whole leaves become orange • Leaf margins become orange and curl  Zigzag leafhopper adult (IRRI)

Confirmation	The presence of the insect pest feeding on the rice plant confirms its symptom damage.
Problems with similar symptoms	There are no other symptoms that exhibit the feeding damage caused by the zigzag leafhopper.
Why and where it occurs	Grassy weeds and volunteer rice in fallow fields attract the zigzag leafhopper and the viruses it transmit to exist between rice crops. The rice zigzag leafhopper is found in all rice environments. It is abundant during the early rainy season in the early growth stages of the rice plant. It rarely occurs in large numbers. The adults usually stay in the upper parts of the rice plants. A high population density of the zigzag leafhopper occurs in seedbeds and weeds between planting seasons.
Causal agent or factor	Adult hoppers have characteristic zigzag white and brown pattern on the front wings. The female adult is 3.5-3.8 mm long. The male is 3.1-3.4 mm long. Neonate nymphs are yellowish brown with a white abdomen, dull pink eyes, a deep brown thorax, and brown patches on the vertex. Mature nymphs are brown with darker brown markings. Individual eggs are cylindrical and white. They measure 0.9 mm long and 0.2 wide. With age, they turn to straw color. Two distinct red spots appear as eyes of the developing nymph prior to hatching.
Host range	Its main host is rice. It also feeds on grasses such as *Echinochloa sp.*, sugarcane, wheat, and barley.

Life cycle	
Mechanism of damage	Both the adults and nymphs of the zigzag leafhopper suck sap from the leaves and leaf sheaths using their slender and segmented beak.
When damage is important	In large numbers, these insects become important because they transmit viral diseases such as rice tungro, dwarf, and orange leaf viruses. They feed on the rice plant during all most all the stages of the crop particularly the vegetative stage.
Economic importance	Zigzag leafhopper may transmit virus diseases but its low population makes the insect a minor pest of rice.
Management principles	There are parasites and predators that help regulate the population of this insect. Mymarid wasp and the mirid bug prey on the eggs. Dryinid wasp and pipunculid flies parasitize both the adults and the nymphs and spiders eat the adults.
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