Rice

Scientific Name: *Oryza sativa*
Order / Family: Cyperales: Poaceae
Local Names: Swahili: Mchele(husked rice) / Mpunga (upland rice)
Pests & Diseases: African armyworm, African gall midge, Bacterial leaf blight, Blast, Brown leaf spot, Case worm, Damping-off diseases, Flea beetles, Hispid beetles, Rice root-knot nematode, Rice sucking bugs, Rice whorl maggots and leafminers, Rice yellow mottle virus, Spotted stemborer, Stalk-eyed shoot flies, Storage pests, Termites, White tip nematode
Other pests: Purple witchweed, Sedges

Green stink bug (Nezara viridula) (nymphs and adults). Adults are about 1.2cm long. (Host: Pearl Millet)
(c) Russ Ottens, University of Georgia, Bugwood.org

1. General Information and Agronomic Aspects

The cultivated rice is an annual grass. Depending on the degree of sensitivity to light its growth duration may range from 60 to more than 200 days. Cultivated rice belongs to two species, O*ryza sativa* -Asian rice, (which is more widely used) and *Oryza glaberrima* - African rice. Rice is grown in four ecosystems, which are broadly defined on the basis water regimes. The ecosystems are irrigated, rain-fed lowland and upland, and flood prone.

Uses
Rice is cultivated primarily for the grain, which is a main staple food in many countries, especially in Asia. In Kenya it is becoming increasingly popular, especially in urban centres. From 2010 to 2014, Kenya had a yearly production of about 119,000 metric tons (FAOSTAT, 2014). Consumption of wheat has been on a steady increase from 410,000 metric tons in 2010 to 564,000 metric tons in 2014 (Economic Review of Agriculture, 2015). This increase in demand and the development of new upland varieties have created an opportunity for farmers to venture into rice growing.

Rice will give the same or better yield as maize and fetch the double price on the market at harvest time. Grains are quite nutritious when not polished. Common or starchy types are used in various dishes, cakes, soups, pastries, breakfast foods, and starch pastes; glutinous types, containing a

sugary material instead of starch, are used in the Orient for special purposes as sweetmeats. Grain is also used to make rice wine, "Saki", much consumed in Japan. Rice hulls are sometimes used in the production of purified alpha cellulose and furfural (an industrial chemical derived from a variety of agricultural by-products, and commonly used as a solvent). Rice straw is used as roofing and packing material, feed, fertiliser, and fuel.

Nutritive Value per 100 g of edible Portion

Raw or Cooked Rice	Food Energy (Calories / %Daily Value*)	Carbohydrates (g /%DV)	Fat (g / %DV)	Protein (g / %DV)	Calcium (g / %DV)	Phosphorus (mg / %DV)	Iron (mg / %DV)	Potassium (mg / %DV)	Vitamin A (I.U)	Vitamin C (I.U)	Vitamin B 6 (I.U)	Vitamin B 12 (I.U)	Thiamine (mg / %DV)	Riboflavin (mg / %DV)	Ash (g / %DV)
Brown Rice, long-grain, cooked	111 / 6%	23.0 / 8%	0.9 / 1%	2.6 / 5%	10.0 / 1%	83.0 / 8%	0.4 / 2%	43.0 / 1%	0.0 IU / 0%	0.0 / 0%	0.1 / 7%	0.0 / 0%	0.1 / 6%	0.0 / 1%	0.5
Brown Rice, medium-grain, cooked	112.0 / 6%	23.5 / 8%	0.8 / 1%	2.3 / 5%	10.0 / 1%	77.0 / 8%	0.5 / 3%	79.0 / 2%	0.0 IU / 0%	0.0 / 0%	0.1 / 7%	0.0 / 0%	0.1 / 7%	0.0 / 1%	0.4
White Rice, glutinous, cooked	97.0 / 5%	21.1 / 7%	0.2 / 0%	2.0 / 4%	2.0 / 0%	8.0 / 1%	0.1 / 1%	10.0 / 1%	0.0 IU / 0%	0.0 / 0%	0.0 / 1%	0.0 / 0%	0.0 / 1%	0.0 / 1%	0.1
White Rice, long-grain, regular, cooked	130 / 7%	28.2 / 9%	0.3 / 0%	2.7 / 5%	10.0 / 1%	43.0 / 4%	1.2 / 7%	35.0 / 1%	0.0 IU / 0%	0.0 / 0%	0.1 / 5%	0.0 / 0%	0.2 / 11%	0.0 / 1%	0.4
White Rice, medium-grain, cooked	130 / 7%	28.6 / 10%	0.2 / 0%	2.4 / 5%	3.0 / 0%	37.0 / 4%	1.5 / 8%	29.0 / 1%	0.0 IU / 0%	0.0 / 0%	0.1 / 3%	0.0 / 0%	0.2 / 11%	0.0 / 0%	0.2
White Rice, short-grain, cooked	130 / 7%	28.7 / 10%	0.2 / 0%	2.4 / 5%	1.0 / 0%	33.0 / 3%	26.0 / 1%	1.5 / 8%	0.0 IU / 0%	0.0 / 0%	0.1 / 3%	0.0 / 0%	0.2 / 11%	0.0 / 1%	0.2
Rice Bran crude	316.0 / 16%	49.7 / 17%	20.8 / 32%	13.3 / 27%	57.0 / 6%	1677 / 168%	18.5 / 103%	1485 / 42%	0.0 IU / 0%	0.0 / 0%	4.1 / 203%	0.0 / 0%	2.8 / 184%	0.3 / 17%	10.0
Brown Rice Flour	363 / 18%	76.5 / 25%	2.8 / 4%	7.2 / 14%	11.0 / 1%	337 / 34%	2.0 / 11%	289.0 / 8%	0 IU / 0%	0.0 / 0%	0.7 / 37%	0.0 / 0%	0.4 / 30%	0.1 / 5%	1.5
White Rice Flour	366.0 / 18%	80.1 / 27%	1.4 / 2%	5.9 / 12%	10.0 / 1%	98.0 / 10%	0.4 / 2%	76.0 / 2%	0.0 IU / 0%	0.0 / 0%	0.4 / 22%	0.0 / 0%	0.1 / 9%	0.0 / 1%	0.6
Wild Rice cooked	101 / 5%	21.3 / 7%	0.3 / 1%	4.0 / 8%	3.0 / 0%	82.0 / 8%	0.6 / 3%	101 / 3%	3.0 IU / 0%	0.0 / 0%	0.1 / 7%	0.0 / 0%	0.1 / 3%	0.1 / 5%	0.4

*Percent Daily Values (DV) are based on a 2000 calorie diet. Your daily values may be higher or lower, depending on your calorie needs.

Climate conditions, soil and water management

Rice thrives on land that is water saturated or even submerged during part or all of its growth. Optimal temperatures for rice growing are 20 to 37.7degC, and no growth occurs below 10oC. Optimal pH is between 5 and 7, though rice has been grown in fields with pH between 3 and 10. Rice will grow in altitudes ranging from 0 to 2500 m above sea level, but world wide is mostly grown on the humid coastal lowlands and deltas. Aquatic rice may require a dependable supply of fresh, slowly moving water, at temperature of 21 to 29degC. Rain fed rice requires an average of 800 to 2000 mm of rainfall well distributed over the growing season. If rainfall is less than 1250 mm annually, irrigation is used to make up deficit. The crop is salt tolerant at some stages of growth; during germination but not seedling stages and has even been grown to reclaim salty soils. Terrain should be level enough to permit flooding, yet sloped enough to drain readily. The soils on which rice can grow are as varied as the climatic regime it tolerates, but ideally it prefers a friable loam overlying heavy clay, as in many coastal and delta areas.

Propagation and planting

Seedling production. Steps for producing healthy seedlings:

1. Seed selection. Select plump and healthy seeds.

2. Seed pre treatment: This is practised in order to secure better germination of seeds and better growth of seedlings. It involves:

- **Seed disinfection.** Hot water treatment is effective in destroying the nematode *Aphelenchoides besseyi,* which causes the white tip disease. For more information on hot-water treatment click here
- **Seed soaking**. To supply the required moisture for germination, to shorten germination period and reduce seed rotting. During the soaking period change water to remove poisonous substances and allow entry of fresh air.
- **Pre-sprouting**. The seeds are drained and covered with grass for 24 to 48 hours. This ensures uniform seed germination, avoids over sprouting and allows air circulation for germination.

3. Sowing:

- Sowing 80 to 100 g/m2 is normal practice.
- Broadcast seed uniformly.
- Do not submerge the nursery bed after sowing.
- Use a seed rate of about 20 kg/acre (50 kg/ha).

4. Seed bed preparation (nursery):

- Plough at least 2 weeks before sowing and flooding.
- Puddle 1 week before sowing and prepare raised nursery bed
- Drain the nursery bed the day before sowing to stabilise the surface of the soil
- If the soil covering the nursery bed is too soft, sown grains are buried into the soil resulting in poor establishment.
- For 1 ha of transplanted rice, a nursery of about 350 m2 is required
- Irrigate a few days after sowing so that the surface is kept moist, and as the seedlings emerge keep submerged conditions with water controlled at 1 to 3 cm according to growth of seedling.
- Raise the water level to 10 cm one day before uprooting to ease washing off of soil that sticks to roots. This will make transplanting easy.

Main land preparation

a) Under irrigation: Land preparation is carried out by flooding the fields to a depth of 10 cm and then cultivating by use of tractor (40 to 75 hp) equipped with rotavators. Good timing and quality of land preparation will influence the growth of rice. Poor and untimely land preparation will cause serious weed problems and expose plants to harmful substances such as carbon dioxide and butyric acid, released by decaying organic matter in the soil.
It is recommended that land should be tilled and immediately flooded at least 15 days before transplanting or direct sowing. The purposes of this are:

- To save the seedling from the effect of high concentration of harmful substances generated by decomposing organic matter rotated into flooded soils.
- To prevent loss of nitrogen released by decomposing organic matter through denitrification. The ammonia released during decomposing of organic matter is conserved because ammonia is not converted to nitrate due to the absence of oxygen in the soil. This ammonia is later utilised by the rice plant.

b) Under rainfed situation: Land should be ploughed twice and harrowed once.

Transplanting

It is important to transplant from the nursery as soon as the seedlings are big enough. Seedlings are said to be ready for transplanting after a period of between 3 to 4 weeks depending on daylight, temperatures and the variety. "Basmati 217" will be ready for transplanting 25 days after sowing (4.5 to 5 leaf stage); "BW 196" and others at 28 to 30 days after sowing (5 to 5.5 leaf number).

Spacing:

Seedlings are spaced according to the tillering ability of a variety. "Basmati 217" should be planted at 20 cm x 10 cm, "BW 196" and others at 20 x 20 cm.
Seedling number per hill: Two to three for "Basmati" and other low tillering varieties. For "BW 196" one to two seedlings per hill are more suitable for good rooting and tillering. Higher seedling rates increase competition for the available nutrients, hence should be discouraged.

Planting depth:

Practise shallow planting of about three cm depth for vigorous initial growth and will result in good rooting and tillering. Deep transplanting delays and reduces tillering resulting in a non-uniform crop growth and ripening, consequently resulting in yield losses.

Seedlings should be transplanted in an upright position to allow correct tillering and rooting.

Direct sowing method: Trials have been done on direct sowing and have showed that the same level of yields performance as those of transplanting system can be obtained. This method saves substantially on labour input. However it has some disadvantages such as uneven germination rate and more weeding work in the paddy field.

Planting under rainfed conditions:

Planting should be done before the onset of the long rains. Farmers are advised to use certified seed and appropriate variety for the region. Drill seed in rows at the rate of 50 kg/ha with a spacing of 25 cm for short varieties and 35 cm for tall varieties. In case of broadcasting, 75 kg/ha is often used.

Main field water management

Water is applied to the rice field for the use of the rice plant and also for suppressing weed growth. For this reason, it is important to practise appropriate water management throughout the growing period of a rice crop.
In lowland rice fields, water comes from rainfall and irrigation. Water is lost by transpiration, evaporation, seepage and percolation. Prevent water loss by:

- Repairing levees to minimise seepage.
- Removal of weeds to avoid competition with rice plants for water.
- Increasing the height of levees to prevent surface run-off water.

Critical stages when water is required in large quantities are:

- For a period of 3 to 7 days after transplanting cover the crop up to 80% of its height. This reduces transpiration and gives the plants a chance to re-establish their roots to be able to take up enough water from the soil
- From the stage of booting to 14 days after heading, more water is required because the shedding of pollen and the process of fertilsation requires very high moisture content in the air. Low moisture content in the air leads to sterile spikelets.

Seven to 10 days before harvesting, drain the field to harden the soil for good harvesting and also to hasten the drying and ripening of the rice grains.

Varieties in Kenya

"Sindano", highly susceptible to Rice Yellow Mottle Virus (RYMV) and "Basmati 217" highly susceptible to blast have been grown since the 1960s. Since then alternative varieties of both irrigated rice and rain fed rice have been identified.

Varieties of irrigated rice and their characteristics:

Variety	Height in cm	Maturity days	Yield t/ha	Cooking quality	RYMW	Blast
"Basmati 217"	118	122	4.6	Very good	Resistant	Susceptible
"Basmati 370"	118	122	5.3	Very good	Resistant	Susceptible
"IR 2035-25-2"	86.2	128	5.5	Good	Moderately susceptible	Moderately resistant
"IR 2793-80-1"	89	142	6.4	Good	Susceptible	
"BW 96"	68	135	9.0	Fair	Susceptible	Moderately resistant
"UP 254"	84.2	124	6.4	Good	Moderately susceptible	Moderately resistant
"AD 9246"	78.2	128	5.1	Good	Moderately resistant	Moderately susceptible
"IR 19090"	96.6	122	5.8	Good	Moderately susceptible	Moderately resistant

Varieties for lowland (swampy) zones	Varieties for upland (dry land) zones
"Ci cong Ai"	"Dourado Precose"
"TGR 78"	"2051 A 233/79"
"IR 2793-80-1"	"TGR 94"
"BW 196"	"WAB 181-18"
"WaBis 675"	"Nam ROO"
	"NERICA 1", "NERICA 4", "NERICA 10", "NERICA 11"

The upland "NERICA" rice varieties were developed at the Africa Rice Center (AfricaRice) ex-WARDA. They are resistant to blast, RYMV stemborers and leafminers and are high yielding and doing well from West Africa to Uganda. They are now also being promoted by NIB (National Irrigation Board), Kenya, KALRO and JICA. In Kenya they have great potential for medium altitudes with high rainfall or possibility for irrigation. "NERICA" can be planted as other small grains, but do need irrigation especially during flowering, and fertilisation.

Some characteristics of the NERICA varieties (KEPHIS)

Variety	**Optimal production altitude (masl)**	**Maturity in days**	**Gain yield (t/ha)**	**Special attributes**
"NERICA 1"	1500-1700	90-100	2.5-55	Aromatic, blast tolerant, long grains
"NERICA 4"	1500-1700	90-112	3.2-6.5	Blast tolerant, long grains
"NERICA 10"	1500-1700	86-93	3.5-6.7	Blast tolerant, long grains
"NERICA 11"	1500-1700	90-105	3.5	High rationing, tolerant to blast and drought, long grains
NIBAM 110	1500-1700	110-120	3.0-5.0	Blast tolerant, RYMV tolerant, long grains, no anthocyanin
IR_05N221	Irrigated and rain-fed lowland	75-90	4.0-6.7	Tolerant to some blast and RYMV strains, good cooking qualities, good milling quality

Varieties in Tanzania

- "Supa". Optimal production altitutde: 0-400 m; grain yield: 1.5-3.5 t/ha; moderately resistant to RYMV and sheath rot.
- "IR 54". Optimal production altitude: 400-600 m; grain yield: 4.0-7.0 t/ha; moderately resistant to bacterial blight and sheath rot
- "IR 22". Optimal production altitude: 400-1000 m; grain yield: 6.6-8.0 t/ha; days to maturity: 120-13"5; resistant to bacterial blight.
- "Katrin". Optimal production altitude: 400-1000 m; grain yield: 6.6-8.0 t/ha; very low panicle shattering.
- "Dakawa". Optimal production altitude: 400-1000 m; grain yield: 3.5-5.2 t/ha; none-photoperiod sensitive; resistant to lodging except under high N levels; easy to thresh.
- "TXD 85". Optimal production altitude: 0-400 m; grain yield: 4.8-7.0 t/ha; moderately resistant to sheath rot, blast and RYMV.
- "TXD 88". Optimal production altitude: 0-400 m; grain yield: 2.8-6.5 t/ha; moderately resistant to sheath rot, blast and RYMV.

- "SARO 5". Optimal production altitude: 0-600 m; grain yield: 4.0-6.5 t/ha; susceptible to RYMV and sheath rot. Adapted to rain-fed lowlands and irrigated ecosystems.
- "Kalalu". Grain yield: 2-3 t/ha; resistant to RYMV and blast.
- "Mwangaza". Grain yield: 2-3 t/ha; resistant to RYMV and blast.

Husbandry

Crop rotation:

Continuous rice monoculture systems result in decline in soil fertility due to over dependence on chemical fertiliser, and deterioration in physical properties of the soil like texture and microbial existence.
To improve the situation, trials have been carried out on many potential rotation systems. Soybeans and green grams have shown a lot of potential in alleviating the problem. Such legumes can be cultivated during off-season at the time the land used to lie fallow. Crop rotation with bananas or sugarcane is another possibility.

Natural fertilisers commonly used in rice production are rice straw, rice ash, stable manure, buffalo dung, green manure, natural manure, rock phosphate, gypsum etc. The need of nitrogen varies with varieties. In Kenya, commonly about 80kg N/ha is recommended, along with 58 kg P_2O_5 (Mwea irrigation scheme). However, the National Irrigation Board (NIB) has found that planting soybean or green gram in the fallow season can halve the need for nitrogen. They further recommend composting of rice straw and manure to further cut down on chemical fertilisers. In organic growing, phosphorous can be applied as rock phosphate, and nitrogen through green manure legumes, which fix the nitrogen from the atmosphere.
See also Mwea Rice Production Manual available from NIB.

Harvesting

Time from planting to harvesting varies between 4 to 6 months. Rice is cut, swathed and threshed from windrow. In the tropics it is essential to harvest the crop on time, otherwise grain losses may result from feeding by rats, birds, insects and from shattering and lodging. The crop should be ready to harvest when 80% of the panicles are straw dust coloured and the grain in the lower portion are in the hard dough stage. In a well-grown crop the grain matures evenly and can be harvested in one operation. Cutting can be done with a sickle. The cut stems are bundled for transport to the threshing place, where final drying to around 12% moisture takes place before threshing and storage.

2. Information on Pests

African gall midge (*Orseolia oryzivora*)

It is a small reddish-brown midge (similar to a mosquito) 4 to 5 mm long. Females lay up to 300 eggs on rice leaf sheaths. Upon hatching, the small maggots wiggle down to the leaf blade and

move between the leaf sheath and the stem until the growing points where they feed for 2 to 3 weeks. Larval feeding induces development of light swellings or galls, which are inconspicuous until larvae are ready to pupate. The galls are long cylindrical, about 3 mm in diameter and from a few cm up to 1 to 1.5 m long. They are often silvery white and resemble an onion leaf, hence they are generally known as 'silver shoots' or 'onion leaf galls'.

Galls generally appear about 20 to 40 days after the crop has been transplanted. Gall midges can cause serious damage from the seedling stage to panicle initiation. Attacked tillers do not produce panicles. Galled plants may tiller profusely to compensate for loss of growing points. A serious attack results in stunted plant growth and poor yields. Gall midges do not attack rice plants that have matured beyond tillering stage. These midges spent some generations on wild grasses and then move to attack young rice plants. They are pests during the rainy season, and are most serious on rain-fed lowland and irrigated rice.

What to do:

- Destroy alternative host plants such as rice ratoon crop, volunteers and wild red rice or longstamen rice (*Oryza longistaminata*).
- Destroy stubble after harvest.
- Plant resistant and early maturing varieties. Varieties tolerant to the rice gall midge released in West Africa include "Cisadane", "BW 348-1" and "Leizhung". "NERICA L-25" was found to be moderately resistant to this pest in Nigeria. The *Oryza sativa japonica* sub-species "TOS 14519" has shown moderately resistant to the gall midge across West Africa (WARDA). Embark on early and synchronised planting. Rice fields planted early are less likely to suffer serious damage than those planted late.
- Avoid close spacing since it provides a suitable micro-environment for the survival of this pest.
- Conserve natural enemies. Parasitic wasps (*Aprostocetus procerae* and *Platygaster diplosisae*) are very important in the natural control of the African rice gall midge. These wasps provided an important check to pest populations, especially late in the season. However, the wasp populations usually build up too late to prevent heavy gall midge infestation.
- Habitat manipulation such as dry-season cultivation to encourage *Paspalum* grass (*Paspalum scrobiculatum*) abundance early in the wet season is suggested as a way of improving the natural biological control of the rice gall midge. *Paspalum* grass is attacked by a different gall midge, which does not attack rice but is an alternative host for the parasitic wasps. The carry-over of parasitic wasps from gall midges attacking *Paspalum* grass to the rice field early in the season, could improve the natural control of the rice gall midge. The combination of growing gall midge tolerant varieties with *Paspalum* grass management at the edge of rice fields had significantly increased farmers' yields (WARDA).

African gall midge *(Orseolia oryzivora)*, onion shoot galls on rice.

Rice-sucking bugs, stink bugs (*Aspavia* spp, *Nezera viridula*), and Alydid bugs (*Mirperus* spp.and *Riptortus* spp.)

Stink bugs produce a strong odour when disturbed. Adult *Aspavia* bugs are brown bugs with a large triangular shield on the back having three yellow spots and a spine at each side of the thorax. *Nezera viridula* is green and about 1.2 cm long. Alydid bugs have a long slender body and lack a triangular shield on the back. *Riptortus* is stout and varies from light to dark brown; the hind legs are enlarged.

Both nymphs and adult bugs feed sucking rice grains in the milky stage. When grains have ripened the bugs feed on panicle stalks and pedicels. *Riptortus* bugs also feed on hard dough rice grains. Bug feeding causes pecky rice that is partially or wholly stained due to infections with bacteria and fungi. The glumes change colour first to light brown, then darker and may turn grey in severe cases. Damage grains are shrivelled and unfilled. Severity of the damage depends on the stage of grain development and on the number of punctures in the grain.

What to do:

- If necessary spray plant extracts. A number of plants (lantana, garlic, oleander, African marigold, blackjack, goat weed, wormseed, among others) are reported as effective against various species of bugs (Elwell and Maas, 1995).

Pyrethrins are recommended for control of sucking bugs in organic production in USA (Layton, 2004).

Green stink bug *(nymphs and adults).* Adults are about 1.2cm long. (Host: Pearl Millet)

(c) Russ Ottens, University of Georgia, Bugwood.org

Storage pests (*Sitophilus oryzae, Rhyzopertha dominica*)

The most serious pests of stored rice are the rice weevils (*Sitophilus oryzae*) and the lesser grain-borer (*Rhyzopertha dominica*). Good store hygiene plays an important role in limiting infestation by rice weevil.

What to do:

- Remove infested residues from last season's harvest

Rice weevil *(Sitophilus oryzae).* The adults are small (2.5 to 4.0 mm long)

(c) Courtesy EcoPort (http://www.ecoport.org): Food Agency and Ministry of agriculture, forestry

More information on Storage pests

Rice root-knot nematode (*Meloidogyne graminicola*)

Symptoms consist of characteristic hooked-like galls on roots, newly emerged leaves appear distorted and crinkled along the margins, and infested plants are stunted and yellow. Heavily infested plants flower and mature early. The rice root-knot nematode 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 egg-masses or as juveniles for long periods.

Numbers of nematodes decline rapidly after 4 months but some egg masses can remain viable for at least 14 months in waterlogged soil. This root-knot nematode can also survive in soil flooded to a depth of one 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.

What to do:

- Practise crop rotation with crops that are resistant or poor hosts of the rice root-knot nematode (e.g. castor, cauliflowers, cowpea, common beans, groundnut, maize, onion, sesame, soybeans, sunflower and sweet potatoes). Long rotations, greater than 12 months, will be needed to reduce nematode soil populations to low levels. Rotation crops like marigold (*Tagetes* sp.) are also effective in lowering root knot nematode populations because of its nematicidal properties.
- Amend soil. Experiments with organic soil amendments such as leaves of chrysanthemum, neem and marigold, and oil cakes of sesame, neem and coconut oil cakes, incorporated at the rate of 0.12%, 0.50% and 1.00% (w/w), showed that these amendments decreased root-knot nematode severity, caused reduction in nematode populations and increased seedling growth (Hossain et al.1999).
- Introducing a fallow into the rotation will also give control of the nematodes but, to be effective, it needs to be a bare fallow free of weed hosts and is therefore impractical. However, the weed, false daisy (*Eclipta alba*), is toxic to the rice root-knot nematodes and could be grown and incorporated into the field soil to kill the nematodes (CABI, 2000).
- Water management. Continuous flooding and raising rice seedlings in flooded soils will help prevent root invasion by the nematodes.
- Soil solarisation and planting cover crops such as sesame and cowpea has been reported to decrease nematodes. For more information on Solarisation click here

Rice root knot nematode *(Meloidogyne graminicola).* Left: Female nematodes and eggs inside rice root gall. Right: Characteristic hooked, root tip galls on rice.

 Root-knot ... Root-knot ...

White tip nematode (*Aphelenchoides besseyi*)

Rice is the most important host worldwide. Other host plants include; strawberry, onion, garlic, sweet corn, sweet potato, soybean, sugar cane, horseradish, lettuce, millet, many grasses, orchids, chrysanthemum, marigold, Mexican sunflower, African violets, and rubber plant (*Hibiscus brachenridgii*). Feeding of the nematodes at leaf tips in rice results in whitening of the top 3 to 5 cm of the leaf leading to necrosis (described as "White Tip" of rice). There is also distortion of the flag leaf that encloses the panicle. Diseased plants are stunted, lack vigour and produce small panicles. Affected panicles show high sterility, distorted glumes and small and distorted kernels.

What to do:

- Plant nematode-free seeds.
- Plant in nematode-free areas.
- Plant resistant rice varieties if available.
- Treat seed with hot water. Hot water treatment of seed can be used to destroy this nematode infecting the seeds. Thermal wet treatment was the most effective at 55-60degC for 15 minutes. For more information on Hot-water treatment click here.

White tip nematode *(Aphelenchoides besseyi).* Left: Characteristic 'white tip' symptom on rice leaf. Right: Necrotic patches and crinkled rice leaves.

African armyworm (*Spodoptera exempta*)

Armyworms may cause severe defoliation in upland rice plants leaving only the stem. Armyworms are regarded as occasional pests, but during an outbreak they devastate rice crops.

What to do:

- Monitor regularly the crop to detect small caterpillars before they cause serious damage. Look in field margins, low areas where plants have lodged, beneath plant debris around the base of plants, on the ground, and underneath the plant leaves.
- Spray Bt or botanicals such as neem and pyrethrum extracts. Spray when caterpillars are small. Once caterpillars are mature (about 3 to 3.5 cm long) they may have cause serious damage and it may no longer be economical to treat the crop. For more information on Neem click here, for Pyrethrum click here and for Bt click here
- Conserve and encourage natural enemies. For more information on Natural enemies click here
- Practise field sanitation. For more information on Field sanitation click here

African armyworm (*Spodotera exempta*). Mature caterpillars measure up to 4 cm.

(c) University of Arkansas

More information on African armyworm

Stemborers

Several species of **stemborers** attack rice. The more important are the **striped borer** (*Chilo partellus*), *Chilo zacconius, Chilo orichalcocilielus,* the **white rice borer** (*Maliarpha separatella*), the **yellow borer** (*Scirpophaga* sp.) and the **pink stemborer** (*Sesamia calamistis*).

The caterpillars bore into the stem of rice plants. Caterpillars of the yellow borer bore into the stem below the growing point, destroying tillers. The white borer and the pink stemborer attack rice at full tillering stage preventing grains from filling up and ripening. This damage results in empty panicles known as "whiteheads". The striped borer feed on rice plants at all stages. Young caterpillars cause "dead hearts".

What to do:

- Practise field sanitation. Burn or feed debris to livestock after harvest.
- Plough and flood after harvest. These practices destroy diapausing stemborer caterpillars.

- Practise early and synchronised planting. Synchronised planting over a large area allows the most susceptible stage of rice to escape from stemborer damage.
- Practise proper water management.
- Conserve natural enemies. Wasps that parasitise eggs and caterpillars, and predators such as ants, dragonflies, assassin bugs, carabid beetles and spiders are important natural enemies of stemborers.
- The following cultivars are reported to be resistant to stemborers: *Oryza sativa japonica* sub-species: "LAC 23", "ITA 121", "TOS 4153", and upland "NERICA"s ("NERICA 1", "NERICA 2", "NERICA 4", "NERICA 5", and "NERICA 7") (WARDA).

Spotted stemborer *(Chilo partellus)*

More information on Spotted stemborer

Stalk-eyed shoot flies (*Diopsis* spp.)

The dark brown flies are about 8 mm in length, and have the eyes situated on 2 long stalks projecting from both sides of the head. Flies lay eggs singly on the upper surface of young leaves, or on the leaf sheath of older plants. The whitish maggots that hatch from the eggs penetrate into the growing zone (heart) of the plant. As a result of maggot feeding the central whorl does not open, but dries-up and dies, producing what is commonly known as "dead heart".

Maggots move readily from one tiller to another. One maggot can destroy up to 10 neighbouring tillers. Later generations feed on the developing flower head. Pupation normally occurs in the first 3 leaf sheath of healthy tillers, generally one pupa per tiller. A severe attack is likely to occur when water levels are low. Such attacks reduce yields of rice plants. Shoot fly attack rice plants early in the crop growth stage, shortly after emergence in direct-seeded fields or shortly after transplanting. They are present throughout the crop growth period, although infestation is low in the flowering-ripening stages.

What to do:

- Practise early and synchronised planting.

- Proper plant spacing. There are indications that damage increase with an increases in plant density (Heinrich and Barrion, 2004).
- Apply calcium silicate to strengthen stem tissues.
- Avoid panicle harvesting (leaving tall stems) and destroy stubbles after harvest.
- Water management: keep basis of stems always under water.
- Conserve natural enemies. Spiders are the main natural enemies of these flies.
- The cultivars "WAB 1159-2-12-11-6-9-1-2" has been reported in Uganda to trap *Diopsis thoracica* larvae with their highly hairy leaves (WARDA).

Stalk-eyed shoot fly *(Diopsis spp.)*. It is about 8mm long.

(c) A.M. Varela, icipe

Case worm (*Nymphula depunctalis - Parapoynx stagnalis*)

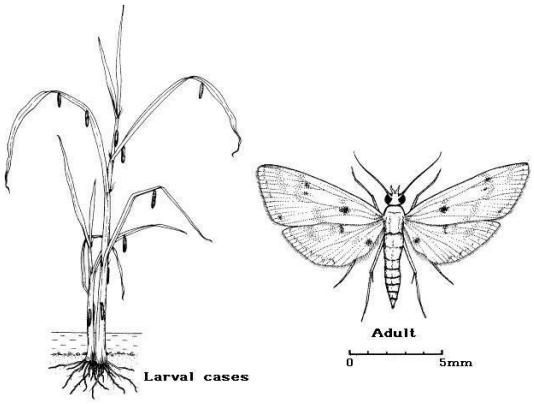
The case worm is a common pest on wetland rice. Moths are small (1 to 1.2 cm in wingspan) with white markings and black specks on the wings. Females lay eggs in small batches (about 20) on the lower side of leaves that are floating on the water surface. Upon hatching caterpillars are yellow to green with light brown heads. They climb onto a leaf and begin feeding by scrapping the leaf surface causing linear grazing of leaves giving the leaf tissue a ladder-like appearance. Later caterpillars cut a piece of rice leaf, roll it up into a case and seal the edges with silk material leaving the interior end open. The cut near the tip of a leaf is characteristic.

At all times the caterpillar is likely to be partly or wholly enclosed in its portable leaf case. The caterpillar attacks the food plant only in the vegetative stage, during the first 4 weeks after transplanting. Caterpillars of the case worm are semi-aquatic, ascending the plants at night to feed. Heavy infestation on small seedlings may completely destroy a rice crop. Damaged plants may recover but crop maturation may be delayed about a week. Yield loss may occur when the caseworm occurs in combination with other non-defoliating insects such as whorl maggots and stemborers. Damaged plants are stunted and produce fewer tillers.

What to do:

- Practise field sanitation (burning debris or feeding of debris to livestock after harvest).
- Practise early and synchronised planting.

- Proper plant density. A study in West Africa showed that defoliation due to the caseworm ranged from 16% in seedlings transplanted at a wide spacing (40 X40 cm) to 68% at a spacing of 10 X 10 cm (WARDA).
- Practise proper water management. Ensure good drainage for 3 days, since larvae cannot survive without water.
- Hand pick and destroy rolled leaves in the nursery.



Rice Case Worm

Termites (*Microtermes* spp., *Ancistrotermes* spp., *Trinervitermes* spp., *Macrotermes* spp., and *Odontotermes* spp.).

Termites, also known as white ants are common pests of upland rice in West Africa where they may cause serious damage during dry periods. They may also occur in lowland areas in light texture soils. They generally attack plants in their later growth stage by hollowing out their root system and filling it with soil resulting in the lodging of the rice plants. The attacked plants are then predisposed to further damage by ground-dwelling pests such as rodents, ants, and secondary infection by fungi and bacteria. Damaged plants can easily be pulled up by hand because the roots are severed.

What to do:

- Plant resistant varieties whenever available. "LAC 23", "NERICA 1", "NERICA 5" and "NERICA 14" are resistant to termites. In experiments in Nigeria "NERICA 5" and "NERICA 1" had lower levels of termite attack than other rice varieties tested ("NERICA 2", "NERICA 3", "NERICA 4", "NERICA 6" and "NERICA 7", "LAC 23" and "OS 6"). "NERICA 2" and "NERICA 3" showed some levels of tolerance (WARDA; Nwilene et al., 2008)
- Use neem products. They provide effective control of termites on rice fields. In experiments in Nigeria 2 litres of neem seed oil (Cobeneem) mixed with 1 litre of water and 10 g of detergent soap (OMO) applied in an area of 900 m^2 gave the best protection against termite attack, followed by neem powder (800 kg per ha). Applications were done close to the rice hills along the rows (Nwilene et al., 2008). For more information on Neem click here

- The application of red palm oil mixed with pawpaw is an indigenous control practice. The mixture attracts soldier ants that attack and drive away the termites.

Termites *(Coptotermes formosanus)*

(c) A. M. Varela, icipe

More information on Termites

Hispid beetles (*Trichispa* spp., *Dicladispa viridicyanea, Dactylispa bayoni*)

Hispid beetles are serious pests of rice in some countries in Africa, causing severe defoliation and as vectors of the Rice Yellow Mottle Virus. Adult beetles have numerous spines on thorax and abdomen. *Trichispa sericea* is the most common of the hispid beetles. The adult is a dark grey beetle covered with spines, and about 3 to 4 mm long. Females lay eggs singly in slits made under the epidermis of the upper portion of the leaf. Eggs are white, boat-shaped and about 1 mm long. Upon hatching, the grubs (larvae) mine within the leaf. Grubs are slender, yellow and about six mm long. They pupate in the mine. When infested leaves are held against the light, the grub or pupa may be seen as a dark spot in the mine. Hispid beetles attack the crop in the early growth stages. Larval feeding occurs during the tillering stage. The first attack in a field is highly localised, but the infested area spreads rapidly.

Feeding by adults on the leaves causes characteristic narrow white streaks or feeding scars that run along the long axis of the leaf. Mining by grubs within the leaf shows as irregular pale brown blister-like patches. Feeding results in loss of chlorophyll and the plants wither and die. The most serious damage occurs in nurseries, which may be completely destroyed. Severe infestations sporadically occur on transplanted rice and can kill the plant. When the plants survive, they usually recuperate and produce some grain. However, damaged plants often mature late. Hispid beetles are prevalent in wetland environments, especially irrigated lowland fields. They are generally most abundant during the rainy season.

What to do:

- Use close proper spacing. Populations of adult hispid (*T. sericea*) are affected by the spacing of transplanted seedlings. Studies in West Africa have shown that population of

this hispid beetle was higher in close spacing of 10 x 10 cm) than in wider spacing of 20 x 20cm (WARDA).

- Keep bunds and surroundings free of grass weeds.
- Destroy stubbles and avoid ratooning.
- Ensure balanced nutrition. Avoid excessive nitrogen application.

Rice hispa (*Dicladispa armigera*). It usually mines and scrapes the leaves of rice

(c) Guido Bohne, 2011

Flea beetles (*Chaetocnema* spp.)

Flea beetles make small holes in the leaf when feeding, however, this damage is considered minor. Most important, these beetles are potential vectors of the Rice Yellow Mottle Virus. Flea beetles are small, and have enlarged hind legs and jump when disturbed.

What to do:

- Use proper spacing. Populations of flea beetles are affected by the spacing of transplanted seedlings. Studies in West Africa have shown that population of this hispid beetle was higher in close spacing of 10 x 10 cm) than in wider spacing of 20 x 20cm (WARDA).
- Keep bunds and surroundings free of grass weeds.
- Destroy stubbles and avoid ratooning.
- Ensure balanced nutrition. Avoid excessive nitrogen application.

Flea beetle *Phyllotreta mashonana* feeding on young okra pod.

(c) A.M. Varela, icipe

Rice whorl maggots (rice leafminers) (*Hydrellia* spp.)

The rice whorl maggot (*Hydrellia prosternalis*) has been reported from West Africa. Another species *Hydrellia* sp. has been reported in Kenya (NIB, 1995). Adults of the rice whorl maggot and rice leafminers are small flies (1.5 to 3 mm long), grey to black in colour with silvery white or golden brown markings on the lower part of the head. They lay white cigar-shaped eggs on the leaves. Upon hatching the maggots of the leafminers penetrate the leaf tissue and feed in between the 2 layers of the leaf causing mines parallel to the veins. Maggots may pupate in an existing mine or migrate to a different leaf to form a new mine. High humidity (80-100% relative humidity) is required for leafminer development, therefore, mines are typically observed in leaves close or lying on the water surface. Whorl maggots start feeding on the leaf margins causing large scarred areas giving the leaf a ragged appearance and causing eventual leaf collapse. Eventually the maggots enter the whorl and tunnel the plant's developing stem.

Feeding damage by leafminers retards plant development, reduces plant vigour and renders infested plants less competitive with weeds. Plant vigour and weather conditions affect the extent and seriousness of the damage caused by the rice leafminer. Damage extent is closely related to the speed the plant growths erect and out of the water. Any factor affecting plant growth, which increases the number of leaves remaining lying on the water, or the length of time they are fully in contact with water will increase damage. The plant is usually able to produce additional leaves, but continued mining can result in reduced tillering, greater susceptibility to later pest attack, delayed maturity, or death of the plant. Once leaves start growing upright above the water, the rice leafminer does not cause economic damage. Attack by the whorl maggot may kill young plants (2 to 6 weeks after emergence) depending on the severity of the damage. Plants that survived damage are eventually drowned by the flood, or plant stands get so thinned that are easily overwhelmed by weeds.

Other leaf-mining fly (*Creodont orbiting*) has been reported as a minor pest in West Africa. This leaf-mining fly is widely spread in the rice-growing region in Ghana, but it is of no apparent economic importance. The adult is a small fly (about 1.6 mm long). Females lay eggs into the leaf

tissue, and the maggots feed forming mines towards the leaf tip. Maggots pupate within the mines. Symptoms of damage are the transparent, light brown mines that are elongated along one side of the midrib reaching up to 6 cm in length.

What to do:

- The rice leafminer can be controlled by managing the water level.
- Avoid leaf contact with water. However, this practice seems to intensify the whorl maggot problem. Field observations in Louisiana, USA showed that by draining fields, the maggot enters the plant whorl and stems without being drowned (LSU AgCenter).
- Drain the water at intervals of 3 to 4 days during the first 30 days after transplanting to reduce egg laying as the adult flies are more attracted to standing water.
- To reduce the potential for damage by the rice leafminer encourage the rice to emerge quickly and grow erect.
- Level the field as accurately as possible and start the crop in 7-10 cm of water. Increase the water depth slowly after the leaves begin to grow upright.
- Monitor for rice leafminers to determine the need to lower the water level. Begin monitoring two to four weeks after planting, just after most of the rice plants have emerged from beneath the water and the leaves are lying on the water surface (UC Pest Management Guidelines).
- Crop establishment methods that enable the plants to cover the water surface most rapidly usually result in insignificant damage.Thus, close planting has been shown to decrease egg laying and subsequent damage by leafminers in several countries in Asia and South America.

Hydrella rice miner damage to rice

(c) Boris Castro, Texas A&M University - Dept. Entomology, Bugwood.org

3. Information on Diseases

The most serious diseases of rice are: Rice blast disease (*Magnaporthe grisea*) and Bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*).

Other diseases of economic importance include Brown Leaf Spot (*Bipolaris oryzae*), Rice Yellow Mottle Virus (Sobemovirus) and White Tip Disease (nematode - *Aphelenchoides besseyi*).

Examples of Rice Diseases and Organic Control Methods

Damping-off diseases

Failure of seedlings to emerge is the most obvious symptom of seed rot and pre-emergence damping off. Examination may reveal a cottony growth of mycelium (mould) in and around seed coats and the emerging seedlings, indicating attack by water mould(s). The growing point or root of germinated seedlings has a dark brown discolouration or rot. The base of the leaf sheath and the roots of emerged seedlings have a similar dark brown or reddish-brown rot. Affected seedlings appear stunted and yellow and may soon wither and die (seedling blight). Water moulds are particularly severe in water-seeded rice culture. In areas where fields are frequently water-seeded, it has become difficult to obtain adequately dense and uniform stands. Seed rots caused by the water moulds *Pythium* and *Achlya*, and to a lesser extent by the fungus *Fusarium*, have been identified as the causes of the problem. These fungi often act as a complex within affected fields.

Symptoms of water mould can be observed through the flood water as balls of fungal strands radiating from seeds on the soil surface. When the water is removed using the critical point method of water-seeding, affected seeds are surrounded by a mass of fungal strands. This results in circular, copper brown or dark green spots on the soil surface, about the size of a penny, with the rotted seed at the centre. The colours of the spots are the result of bacterial and algal growth. Seed rot by water moulds is favoured when the water temperature is unusually high or low. If seedlings are attacked after germination at pegging, seedlings become yellow and stunted and grow poorly.

What to do:

- Use certified disease-free seeds for planting.

Damping-off on rice

(c) Courtesy EcoPort (http://www.ecoport.org): Jurgen Kranz

More information on Damping-off diseases

Bacterial leaf blight (*Xanthomonas oryza* pv. *oryza*)

The first symptom of the disease is a water soaked lesion on the edges of the leaf blades near the leaf tip. The lesions expand and turn yellowish and eventually greyish-white and the leaf dries up. High rainfall with strong winds provides conditions for the bacteria to multiply and enter the leaf through injured tissue.

What to do:

- Plant resistant varieties if available.
- Use certified disease-free seeds.
- Practise rotation with legumes.
- Practise good field sanitation. Plough or roll the stubble to hasten decay of the rice debris; this helps to manage the disease by destroying the tissue in which the bacterium is maintained.

Rice seedlings infected with **Bacterial leaf blight** *(Xanthomonas oryzae pv. oryzae)*. Infected leaves wilt and roll up, turning grayish-green to yellow, until the whole seedling dies. Plants which have survived the disease are stunted and yellowish.

(c) T.W. Mew, International Rice Research Institute, Bugwood.org

Blast (*Pyricularia oryzae* (*Magnaporthe grisea*)

This disease can cause serious losses to susceptible varieties during periods of blast favourable weather. Depending on the part of the plant affected, the disease is often called leaf blast, rotten neck, or panicle blast. The fungus produces spots or lesions on leaves, nodes, panicles, and collar of the flag leaves. Leaf lesions range from somewhat diamond-shaped to elongated with tapered, pointed ends. The centre of the spot is usually grey and the margin brown or reddish-brown. Both the shape and colour of the spots may vary and resemble those of the brown leaf spot disease. Blast differs from brown leaf spot in that it causes longer lesions and develops more rapidly.

The blast fungus frequently attacks nodes at the base of the panicle and the branches of the panicle. If the panicle is attacked early in its development, the grain on the lower portion of the panicle may be blank giving the head a bleached whitish colour, giving the name "blasted" head or rice "blast". If the node at the base of the panicle is infected, the panicle breaks causing the "rotten neck" condition. In addition, the fungus may also attack the nodes or joints of the stem. When a node is infected, the sheath tissue rots and the part of the stem above the point of infection often is killed. In some cases, the node is weakened to the extent that the stem will break causing

extensive lodging. Blast generally occurs scattered throughout a field rather than in a localised area of the field. Late planting, frequent showers, overcast skies, and warm weather favour development of blast. Spores of the fungus are produced in great abundance on blast lesions and can become airborne, disseminating the fungus a considerable distance. High nitrogen fertilisation should be avoided in areas that have a history of blast.

What to do:

- Plant early.
- Avoid excessive or high levels of nitrogen.
- Proper flood (water) management.
- Plant resistant varieties (e.g. "NERICA". This is the most effective method of controlling rice blast.

Dried rice tassels caused by **rice blast disease** *(Magnaporthe grisea)*

Brown leaf spot (*Bipolaris oryzae*)

This disease was previously called *Helminthosporium* leaf spot. Most conspicuous symptoms of the disease occur on leaves and glumes of maturing plants. Symptoms also appear on young seedlings and the panicle branches in older plants. Brown leaf spot is a seed-borne disease. Leaf spots may be evident shortly after seedling emergence and continue to develop until maturity.

Leaf spots vary in size and are circular to oval in shape. The smaller spots are dark brown to reddish brown, and the larger spots have a dark-brown margin and reddish brown to grey centres. Damage from brown spot is particularly noticeable when the crop is produced in nutritionally deficient or otherwise unfavourable soil conditions. Significant development of brown spot is often indicative of a soil fertility problem.

What to do:

- Plant resistant varieties.
- Use certified high quality disease-free seeds.
- Ensure balanced fertilisation.
- Practise crop rotation.

Brown leaf spot on cassava *(Cercosporidium henningsii)*

(c) Courtesy EcoPort (http://www.ecoport.org): LandCare Ltd., New Zealand

Rice Yellow Mottle Virus (RYMV) (Sobemovirus)

Rice yellow mottle virus is endemic in Africa, was first reported in Kenya in 1966, but is now known to occur in almost all irrigated rice growing areas in Africa. This disease can cause up to 92% yield loss on "Super", the most popular rice variety in Tanzania.

RYMV causes severe infections mainly in irrigated rice and is transmitted by beetles (*Sesselia pusilla*, *Chaetocnema pulla*, *Trichispa sericea* and *Dicladispa viridicyanea*) and mechanically. It is not seed transmitted.

Major symptoms of the disease are yellowing of leaves, stunting of affected plants, reduced tillering of the affected plants and sterility of the seed/grain.

What to do:

- Plant resistant varieties. The following cultivars are reported as resistant to RYMV: *Oryza sativa japonica* sub-species: 'LAC 23', 'Moroberekan', 'IR 47686-1-1' for direct seeded rainfed lowlands, and *Oryza sativa indica* sub-species: "WITA 9", "WITA 11" and "Gigante" Ttete) for irrigated lowlands (WARDA)
- Avoid and/or minimise mechanical injuries.
- Avoid exposing healthy seedlings and plants to virus contaminated and infected material (water, soil, cattle faeces and plants).
- Control insect vectors (see above under pests Hispid beetles and flea beetle)
- Transplant early before the outbreak of Hispid beetles and *Trichispa sericea*, with reduction in spacing of plants.
- Destroy crop residues after harvest and ratoons that harbour the virus and insect vectors.
- Synchronise planting. Wide range and non-synchronous planting dates increase the risks of RYMV outbreaks.
- Plant diverse varieties on a single plot.
- Change of site for nurseries.

- Remove infected plants in nurseries and fields.
- Reduce fertiliser application on attacked plots.
- Weed timely. Early and double weeding helps reduce the weed reservoir of the virus and insect vectors.
- Withhold irrigation water between plantings to provide a rice free period and so restrict the build-up of the virus and insect population.

Symptoms of Rice_yellow_mottle. Pic 102, y ellow green spots on youngest leaves enlarge causing **streaking**. Pic 103 & 104 yellowing and necrosis of leaves

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