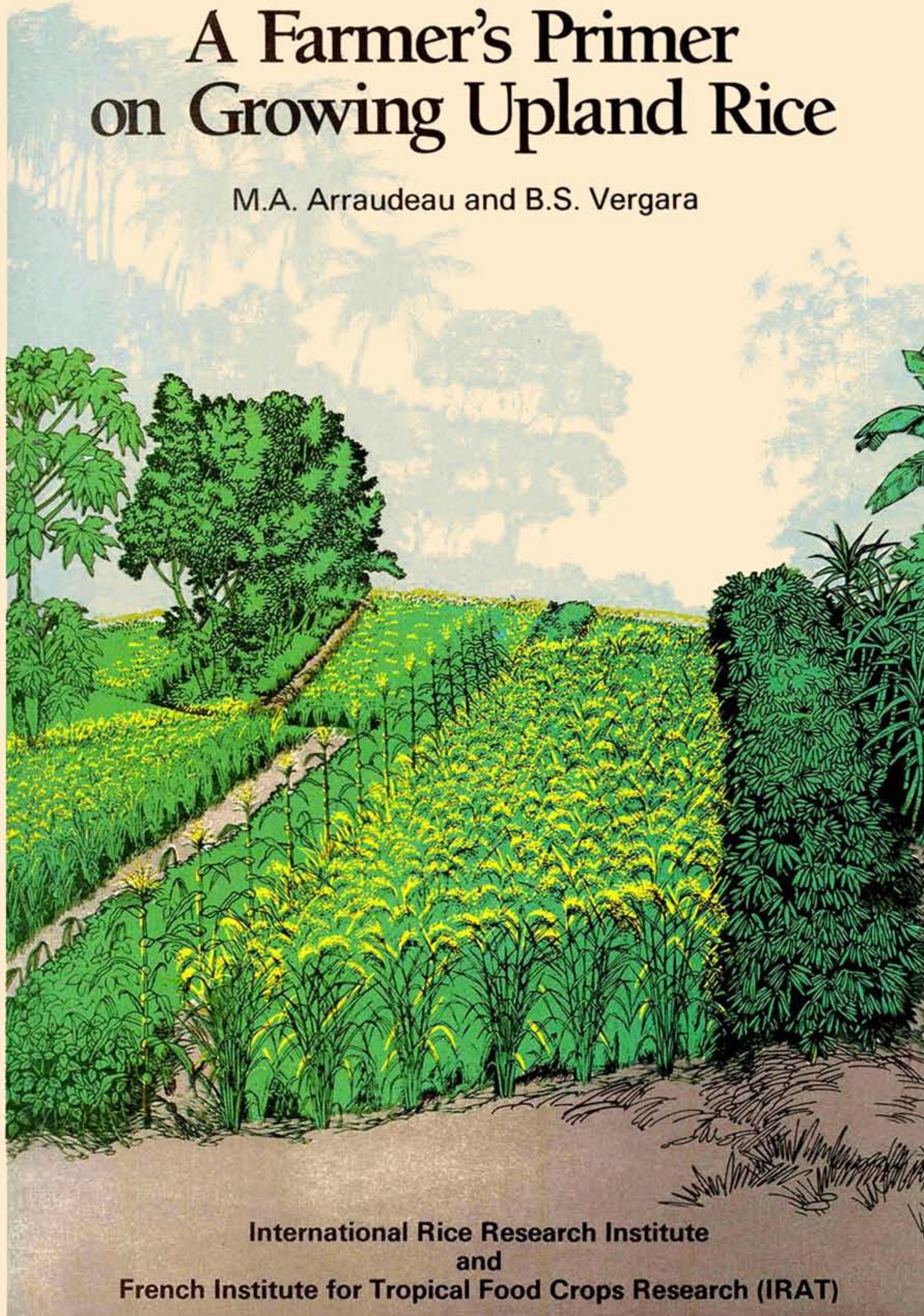
A Farmer's Primer on Growing Upland Rice

M.A. Arraudeau and B.S. Vergara



International Rice Research Institute
and
French Institute for Tropical Food Crops Research (IRAT)

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1988
International Rice Research Institute
Los Baños, Laguna, Philippines
P.O. Box 933, 1099 Manila, Philippines

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of the 13 nonprofit International research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations. the International Bank for Reconstruction and Development (World Bank). and the United Nations Development Programme (UNDP). The CGIAR consists of 50 donor countries, international and regional organizations, and private foundations.

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The responsibility for this publication rests with the International Rice Research Institute.

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Foreword

Upland or dryland rice covers nearly 20 million hectares worldwide. It is usually grown by the most underprivileged rice farmers under adverse and risky conditions. Yields are low, averaging about 1 ton per hectare. Scientists and extension workers have demonstrated in many countries, however, that improved cropping systems and practices can be combined with higher-yielding varieties to achieve a stable 2 tons per hectare under various ecosystems.

But the dearth of literature on upland rice farming means that extension workers lack the background to guide farmers, who in turn lack the technical knowledge to use existing cultural practices efficiently to minimize cash inputs and maximize returns.

A Farmer's Primer on Growing Upland Rice is part of a global upland rice strategy to train extension workers and help farmers. Students and scientists will also find advice and guidelines for their own programs and projects in the book.

The book is patterned after the widely known *A Farmer's Primer on Growing Rice,* which the International Rice Research Institute (IRRI) released in 1979. Modifications have been made to meet the needs of upland rice growers, and additional information on diseases, pests, and cropping systems of upland rice has been added.

This new primer was written by M.A. Arraudeau, a visiting IRRI plant breeder from the Institut de Recherches Agronomiques Tropicales, Centre International de Recherche Agronomique pour le Developpement, France, in collaboration with B.S. Vergara of IRRI, who wrote the original *Farmer's Primer.*

Like the original primer, which had been published in 35 languages by mid-1988, this book is designed for inexpensive copublication in developing countries. The English text has been blocked off from the line drawings. IRRI makes complimentary sets of the illustrations available to cooperators, who may translate, strip text onto the drawings, and print translated editions on local presses.

The volume was edited by Stephen J. Banta with the assistance of Gloria Argosino. The art was prepared by John Figarola, Gladys Balacuit, Oscar Figuracion, Arturo Ortega, and Ed Delfino.

Klaus Lampe
Director General

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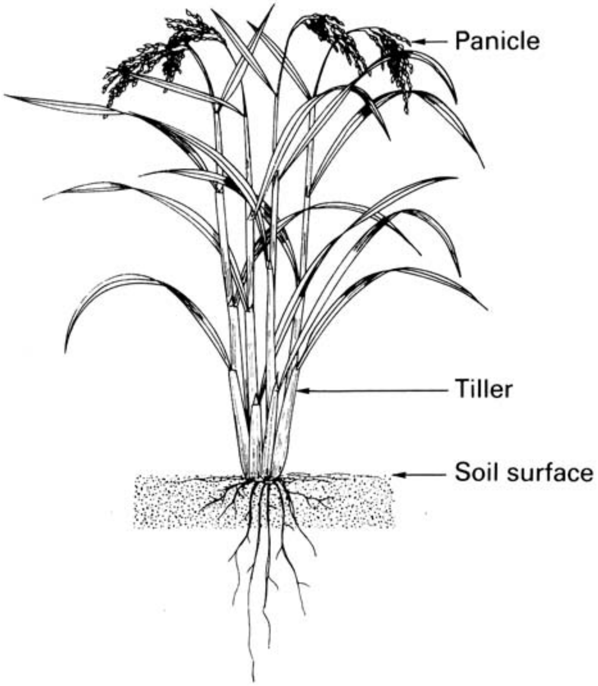
Upland rice plant types

Tall, traditional upland variety

Rice plant with four tillers



- Height: 120 to 180 cm.
- Usually 2 to 4 productive tillers.
- Large panicles with many (150 to 300) grains per panicle.
- Widely cultivated in West Africa, Latin America, and Southeast Asia (especially Indonesia, Thailand, Laos).
- Well adapted to poor environments.
- Low to medium grain yield.
- Major problem: may lodge under good management.

Intermediate-statured plant type

- Height: 80 to 120 cm.
- Usually 4 to 8 productive tillers.
- Cultivated mainly in Latin America, West Africa, and a few areas in Asia.
- The area planted to intermediate types is increasing.
- Well adapted to both poor and favorable environments.
- Medium to good grain yield.

Aus type from the Indian subcontinent

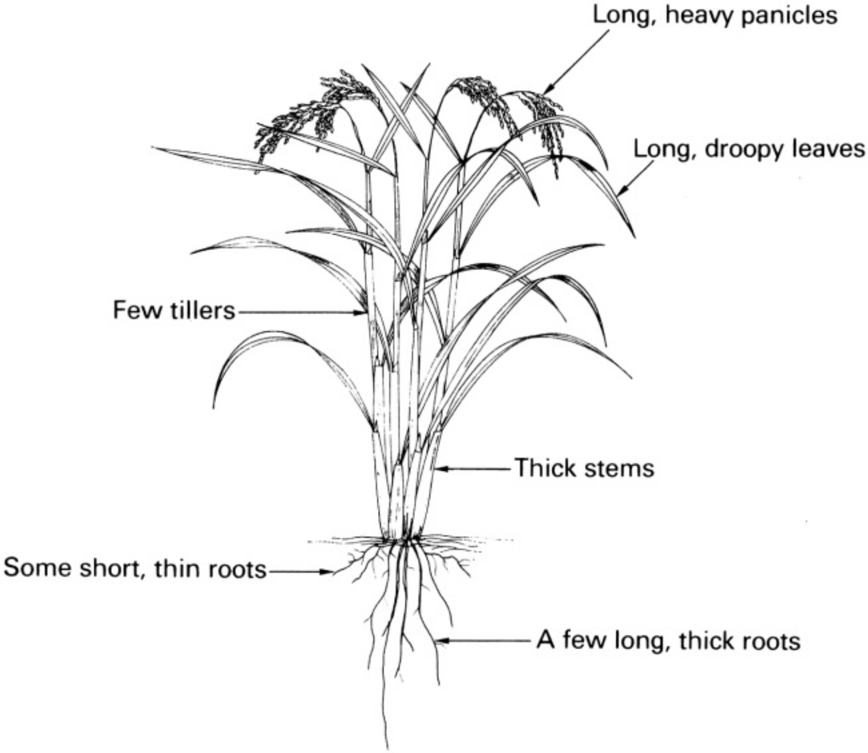
- Height: 50 to 100 cm.
- Usually 6 to 12 productive tillers.
- Low to medium number of grains per panicle.
- Cultivated only in eastern India and Bangladesh during the aus season (early rainy season).
- Short growth duration: 100 days or less.
- Well adapted to the specific conditions where cultivated.
- Low to good grain yield.

Modern plant type

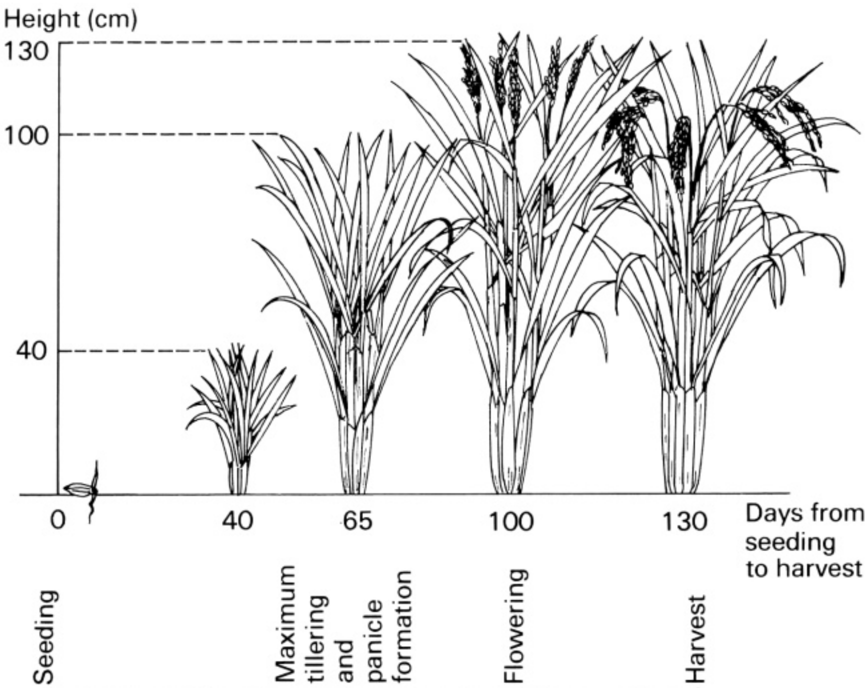
- Height: 80 to 100 cm.
- Usually 10 to 15 productive tillers.
- Medium number of grains per panicle.
- Short to medium growth duration: 100 to 130 days.
- Well adapted to favorable environments.
- Requires good cultivation practices.
- Good to high grain yield under favorable conditions.

Life cycle of the rice plant

A traditional upland variety



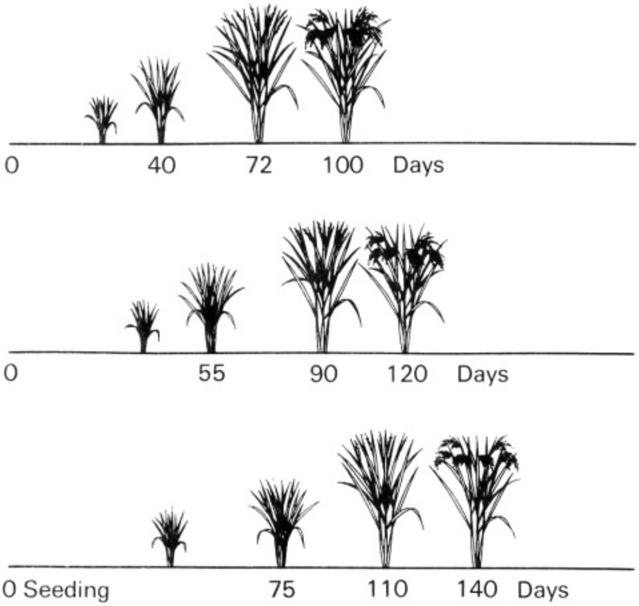
Growth phases of an upland rice plant



65 days	35 days	30 days
Vegetative phase	Reproductive phase	Ripening phase

- The duration of the vegetative phase differs with variety.
- The reproductive and ripening phases are fairly constant for most varieties. The reproductive phase last about 35 days; the ripening phase lasts about 30 days.
- The time from sowing to harvest ranges from 80 to 180 days or longer.

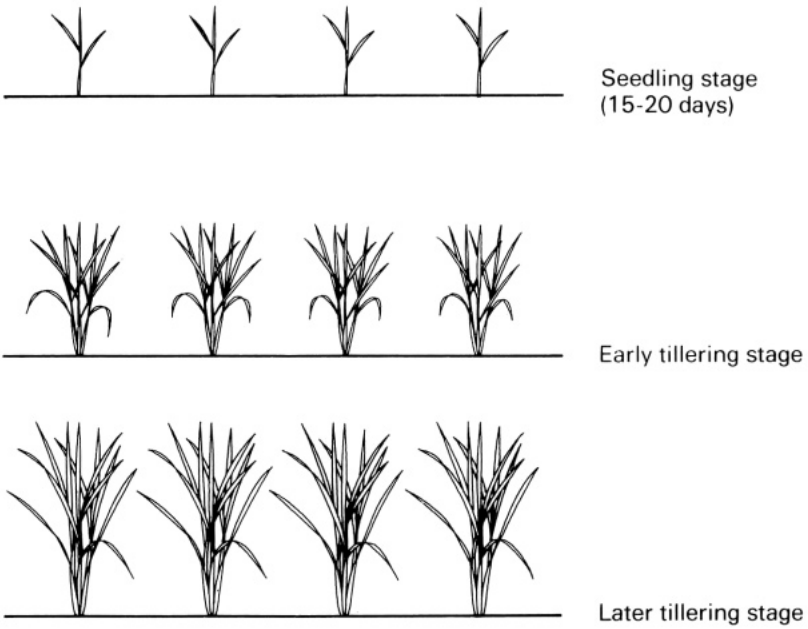
Growth phases and growth duration



- Differences in growth duration are determined mainly by the duration of the vegetative phase:

Vegetative phase	*Reproductive and ripening phases*	*Growth duration*
40 days	60 days	100 days
55 days	65 days	120 days
75 days	65 days	140 days

Vegetative phase



- Number of tillers, leaf number, and leaf area increase during the vegetative phase.
- Low temperature, long daylength, and drought can increase the duration of the vegetative phase.

Reproductive phase

Flowering

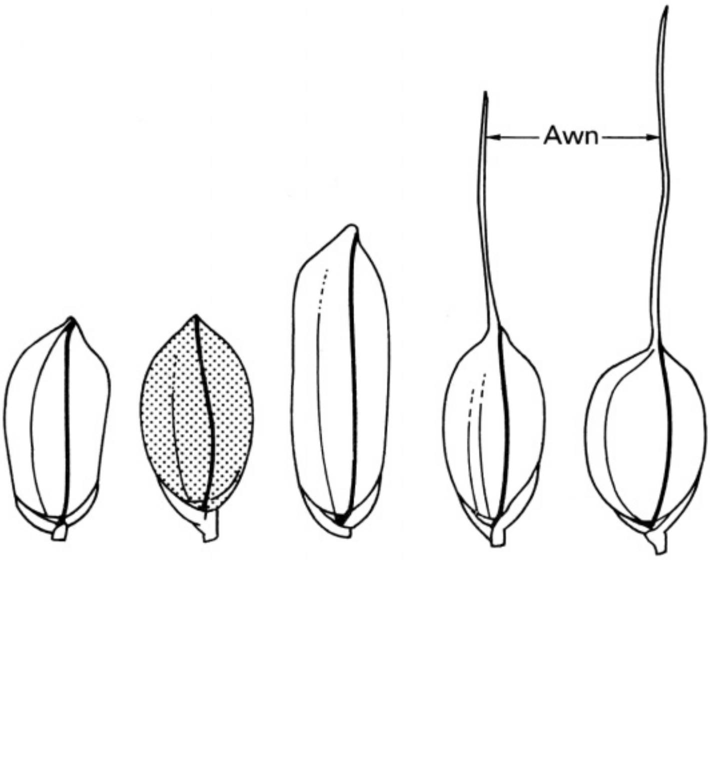
- The reproductive phase begins at the start of panicle formation and ends at flowering. This usually takes about 35 days.
- The plant is most sensitive to stresses such as drought and low temperature during the reproductive phase.

Ripening phase

- The ripening phase starts at flowering and lasts for about 30 days.
- Rainy days or low temperature may prolong the ripening phase.
- Sunny and warm days shorten the ripening phase.
- To produce high yields, follow good farming practices at each growth stage.

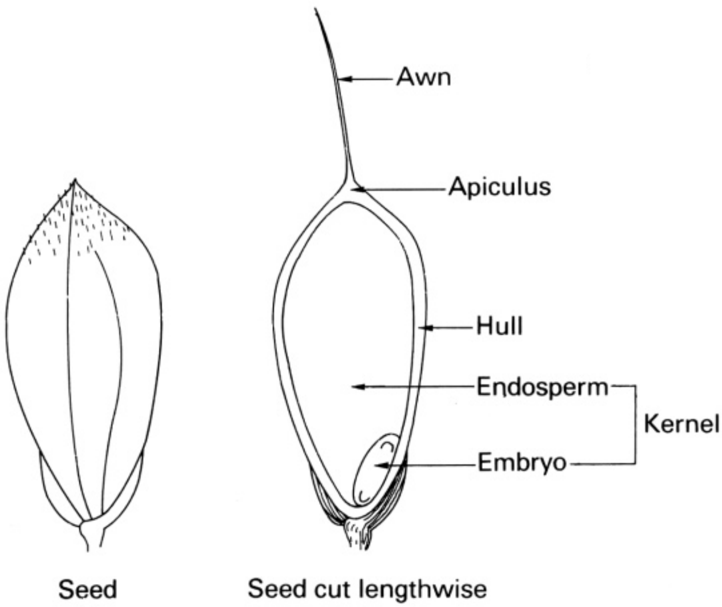
Seeds

Seed types



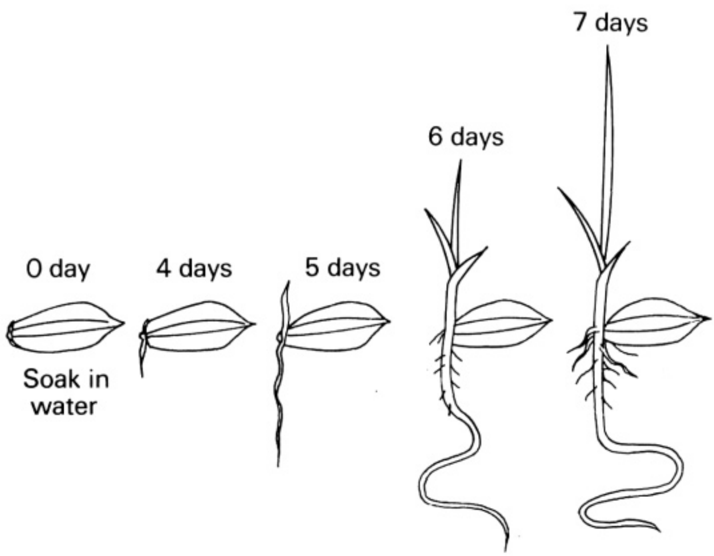
- Seeds vary in size, shape, color, and length of awn.

Parts of the seed



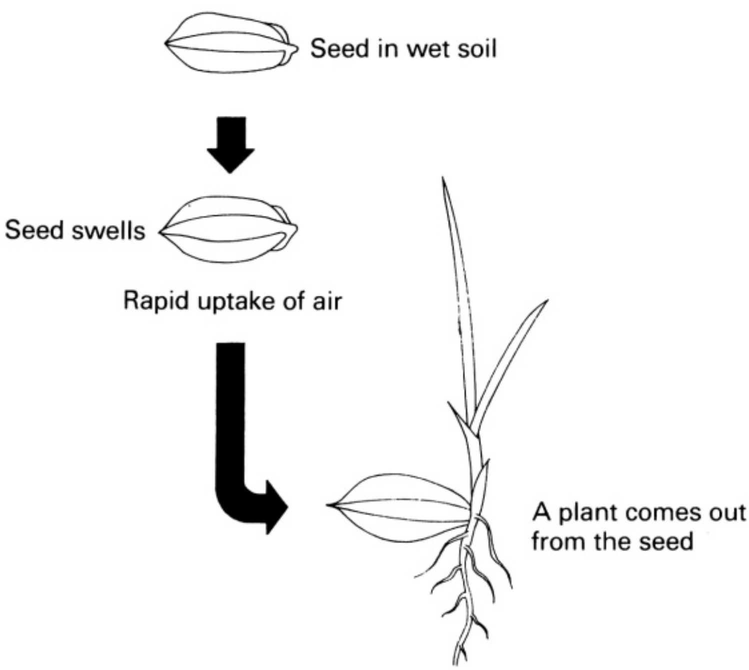
- The hull is the hard cover of the seed.
- The food needed for seed germination – starch, sugar, protein, and fats – is in the endosperm.
- Almost 80% of the endosperm is starch.
- The endosperm of some varieties lets light through; others have chalky endosperm.
- Glutinous rices have chalky endosperm.

Stages of germination



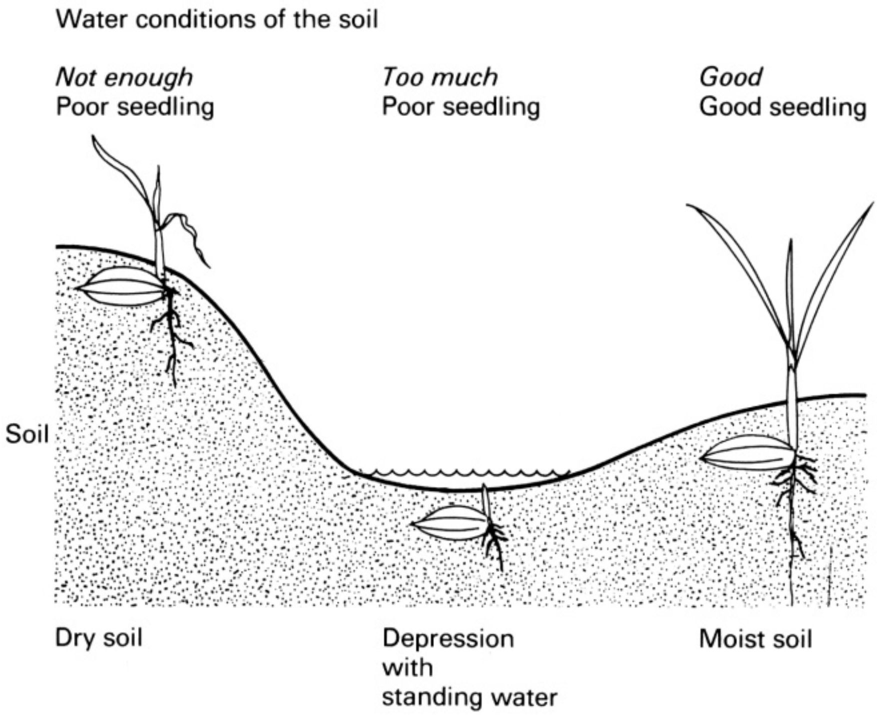
- Seed germination is the development of the embryo into the shoot and roots.
- Growth of the embryo varies with variety.
- Growth of the embryo depends on temperature and availability of water and air.
- High topsoil temperature and drought will delay or prevent seed germination.

Water is needed for seed germination



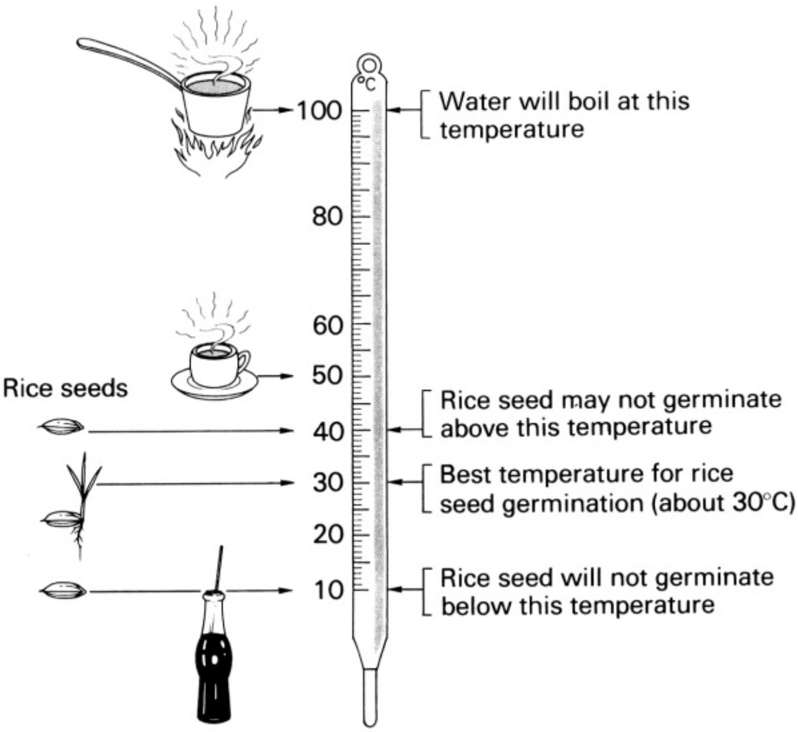
- Uptake of water is the first need for germination.
- There are many activities going on inside the germinating seed. Starch, protein, and fats are being changed into food for the embryo.
- Upland rice is always direct seeded. Seeds are not soaked before sowing.

Water and air are needed for seed germination



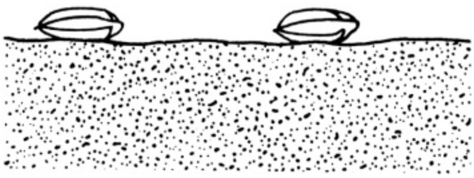
- Germinating upland rice seeds need water to live.
- Air is sufficient in most upland soils except in areas with standing water.
- Standing water inhibits the growth of the embryo and may prevent the seed from germinating.

Temperature conditions for seed germination

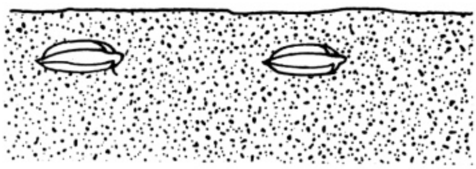


- Warm temperature is needed to increase the growth activities inside the seed.
- High (40°C or higher) or low (10°C or lower) temperature decreases activities inside the seed and may kill sprouting seeds.

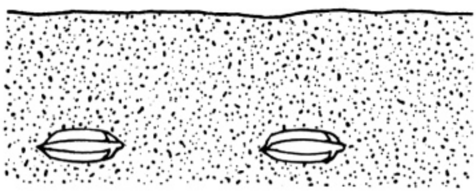
Depth of sowing influences germination



Top seeded rice seeds are often eaten by rodents or birds, or damaged by drought or high temperature.

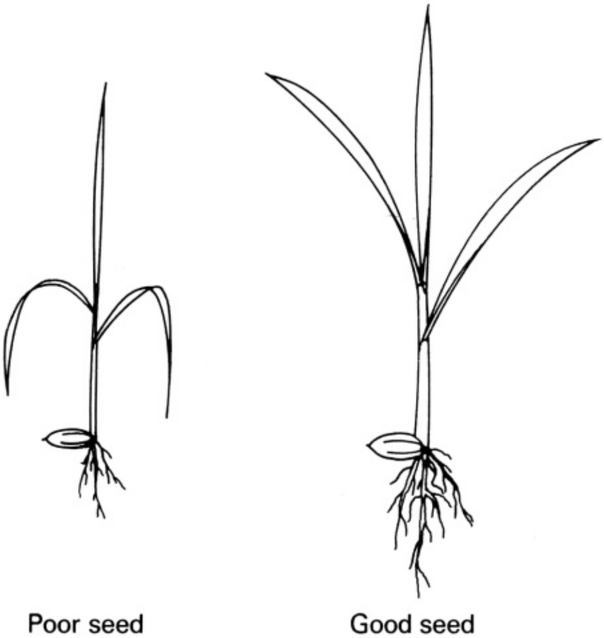


A good depth (1 to 3 cm depending on soil type) ensures good germination.



Seeds sown too deep germinate late or fail to germinate.

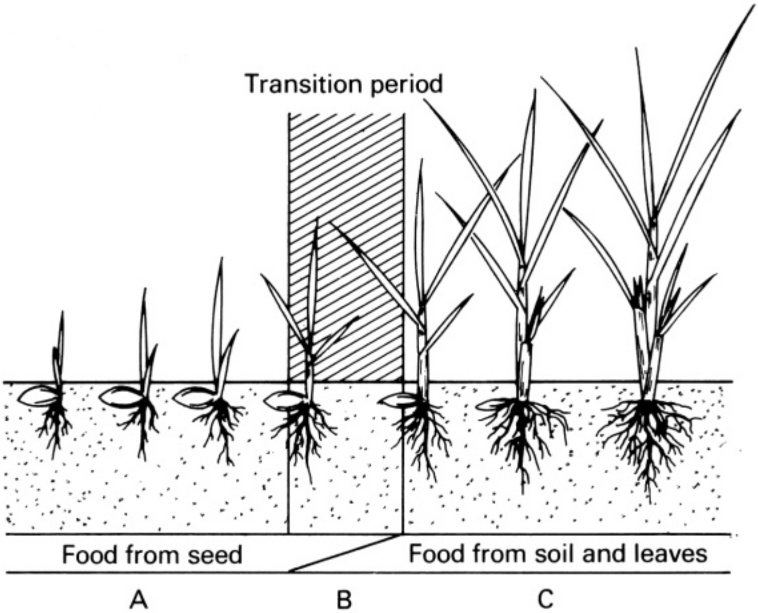
Why select good seeds?



- Good seeds have more food and produce healthier, heavier seedlings with more roots.
- Healthy seedlings grow faster and more uniformly.

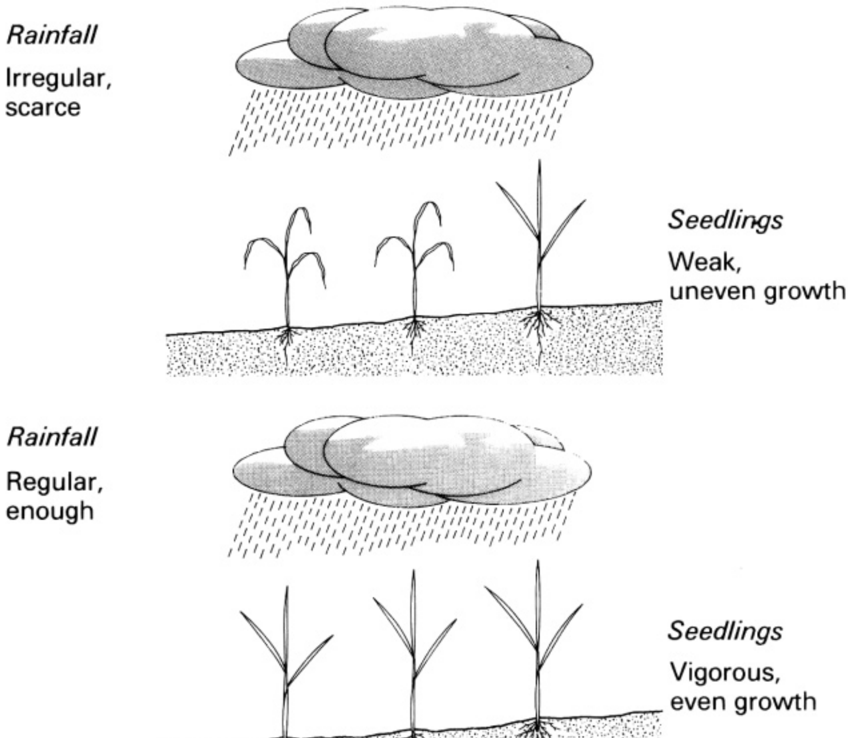
Factors that affect seedling growth

Sources of food for growth



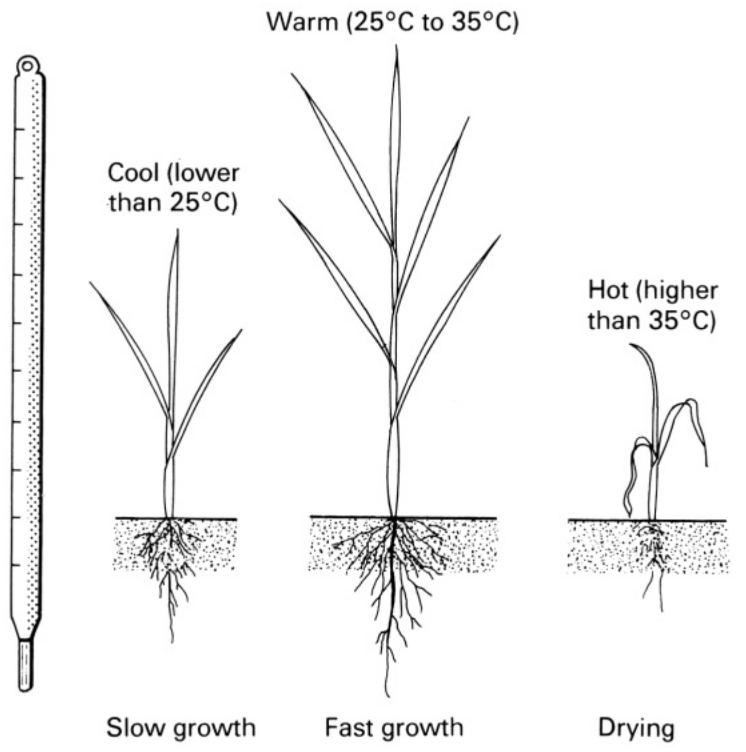
- A. The seedling grows first by using food from the endosperm of the seed.
- B. As the seedling gets older, it depends more on the environment for food.
- C. After producing 4 leaves at about 12 days old, the seedling grows from food taken through the roots and manufactured in the leaves.

Amount of rainfall



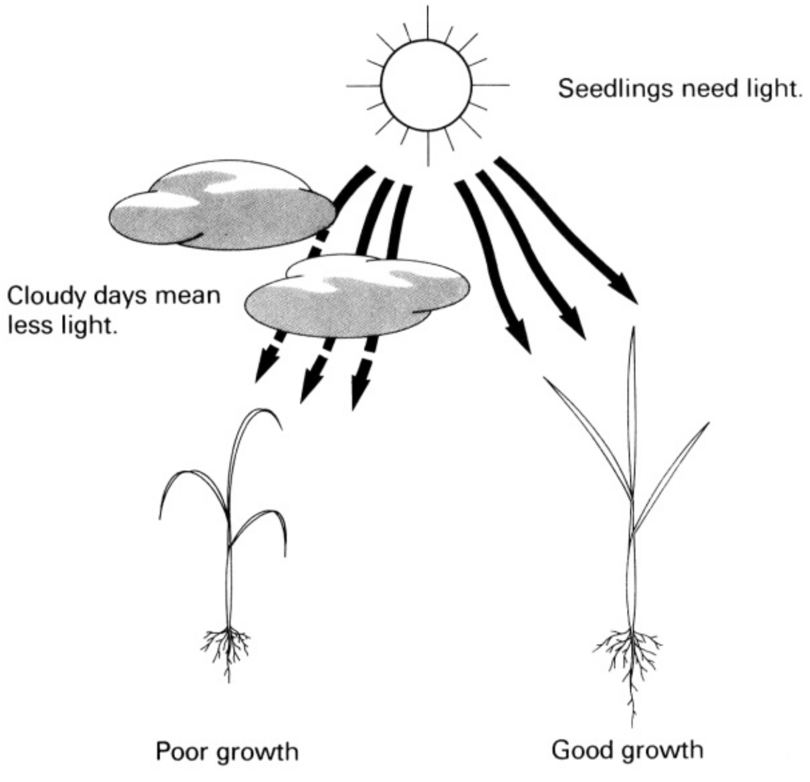
- Irregular rainfall means slow and uneven seedling growth.
- Severe drought will kill seedlings.
- Drought resistance during early growth, and good early vegetative vigor are important characters.

Temperature



- High temperature dries the seedlings, resulting in poor growth.
- Plants grow faster at warm temperature than at cool temperature.

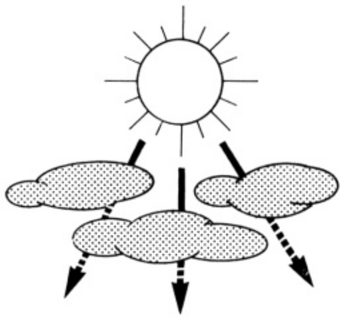
Light intensity



- Less light can cause the leaf blades and sheaths to elongate. The taller plants are weaker and will "lodge" or fall over if their panicles become heavy with grain.
- Plants produce food from light, water, and air. Less light means less food, which results in weak seedlings.
- Seedlings grow better when sunlight is bright.

Low light intensity

- Low light intensity results in



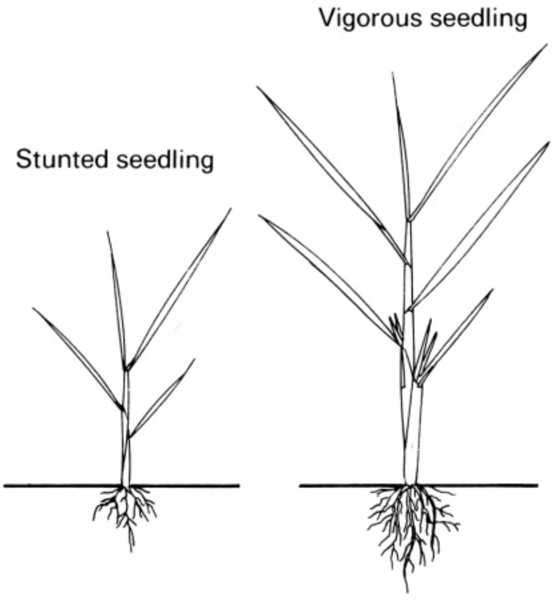
— tall and weak seedlings.

— seedlings with low dry matter.

— seedlings that are easily injured by stresses.

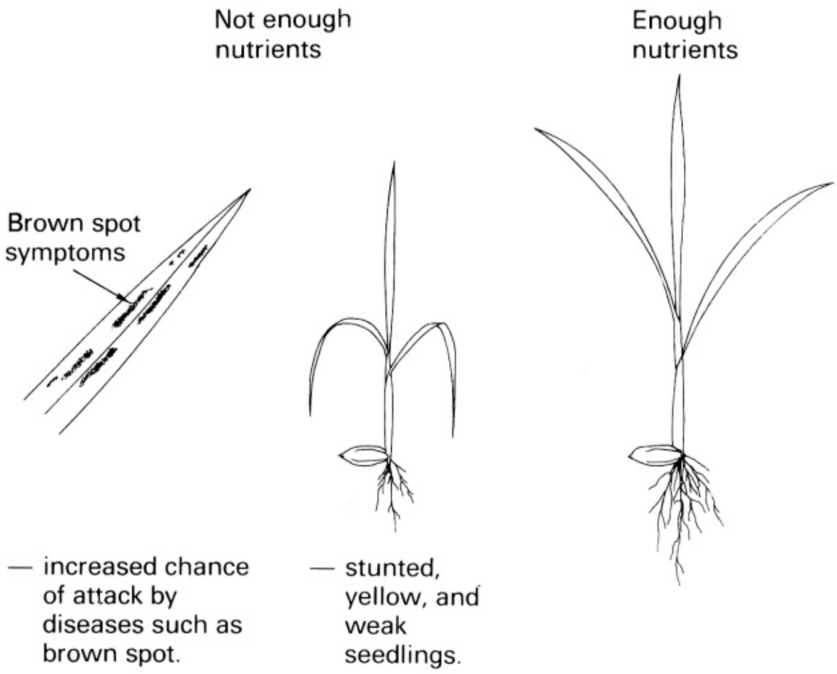
— increased chance of disease.

Available nutrients



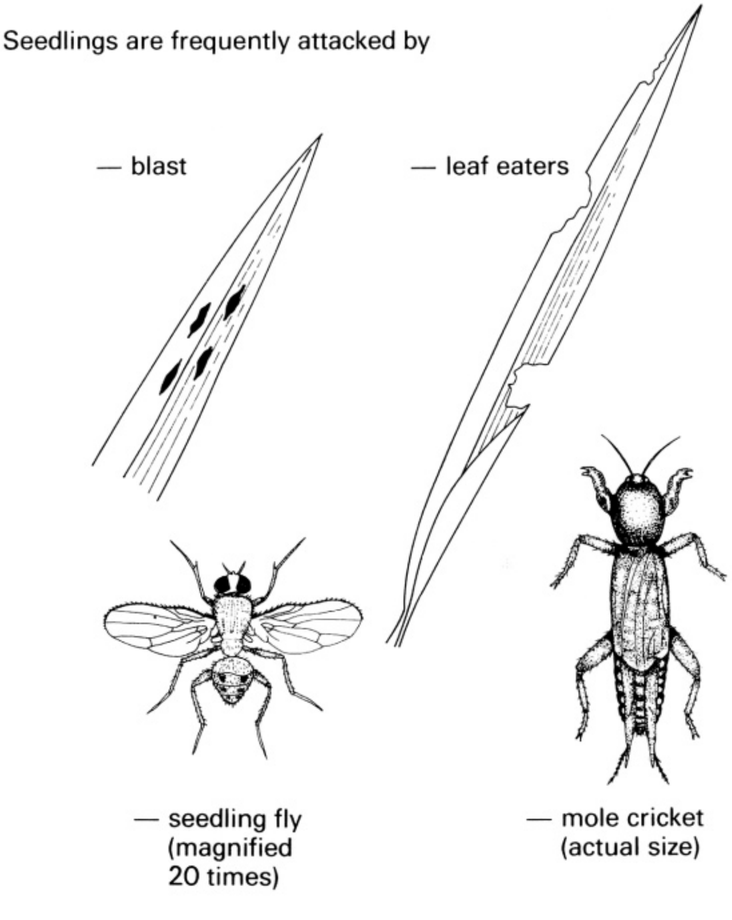
- Fertilizers supply nutrients (plant food) in addition to what is already available in the soil.
- Fertilizers are needed to produce high yields in areas with poor soil.

Insufficient nutrients



- The availability of sufficient nutrients ensures good vigor.

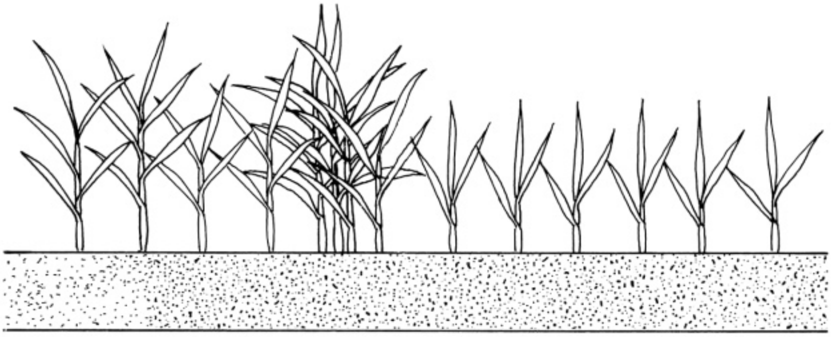
Pests and diseases



- Stem borers, termites, ants, and white grubs also attack seedlings.

What is a good seedling?

Good seedlings have uniform height



- Irregular seedling growth may indicate
  - uneven distribution of seeds during seeding.
  - uneven germination of seeds.
  - poor land preparation.
  - variable rainfall.
  - uneven soil particles.
  - different levels of nutrients (plant food) in the soil.

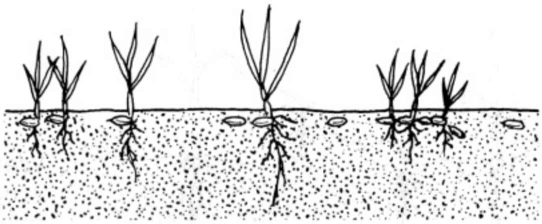
Good seedlings have more roots that are longer and heavier

- Heavy seedlings become stronger plants as they grow older.

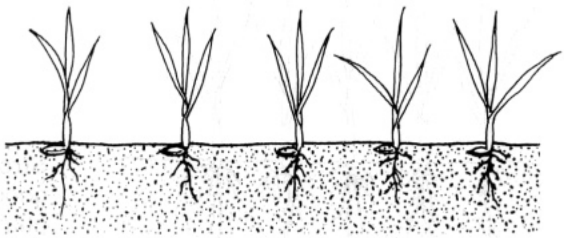
How to grow good seedlings

Good seed distribution and germination

Poor germination

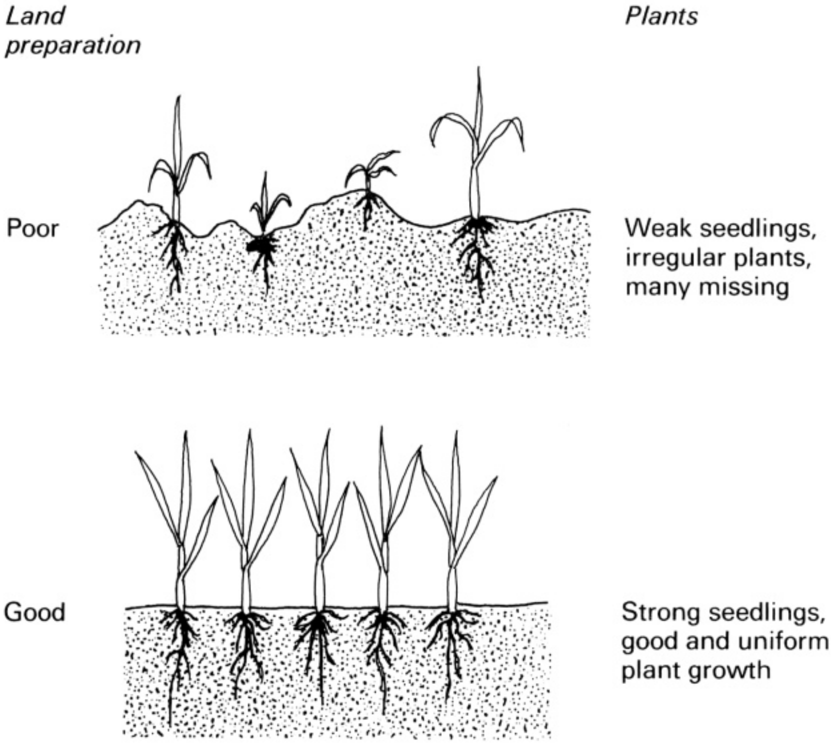


Good germination



- Irregular spacing between seedlings results from poor seed distribution and germination.
- Good seedlings result from uniform distribution of seeds in the field.

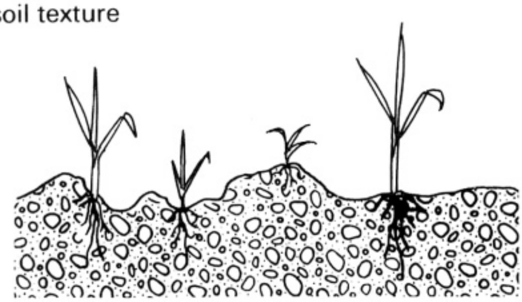
Good land preparation



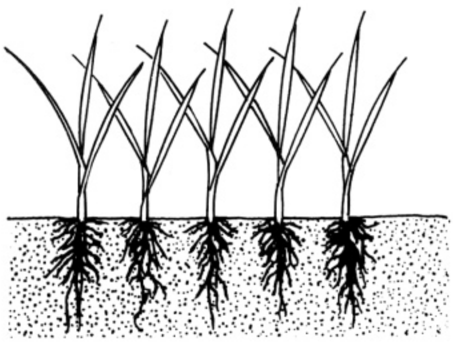
- Good land preparation is important for early growth of upland rice.
- Good land preparation ensures vigorous growth and correct number of plants per unit area.

Uniform size of soil particles

Coarse soil texture



Uniform soil particles

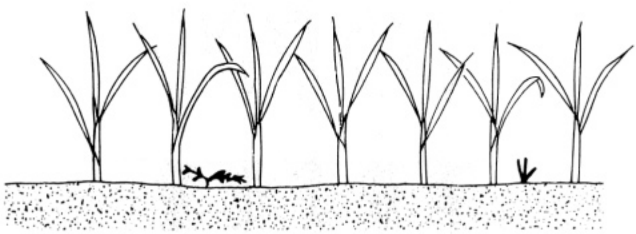


- The particles of upland soils are often irregular.
- Poor soil texture causes irregular growth.
- Soils with fine, uniform particles are better.

Early and good weeding

Many weeds: weak seedlings

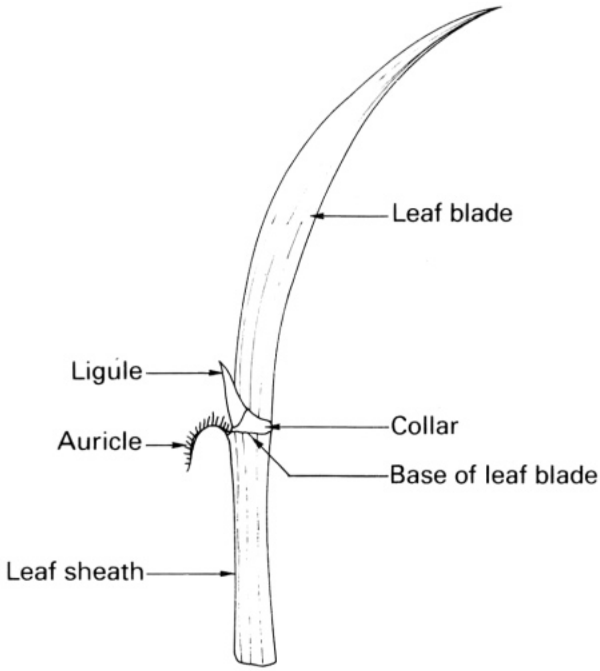
Few or no weeds: strong seedlings



- Early and good weeding is very important in upland rice. Weeds are the most important constraint to vigorous seedlings.
- Weak, pale, or missing seedlings result from weed competition.

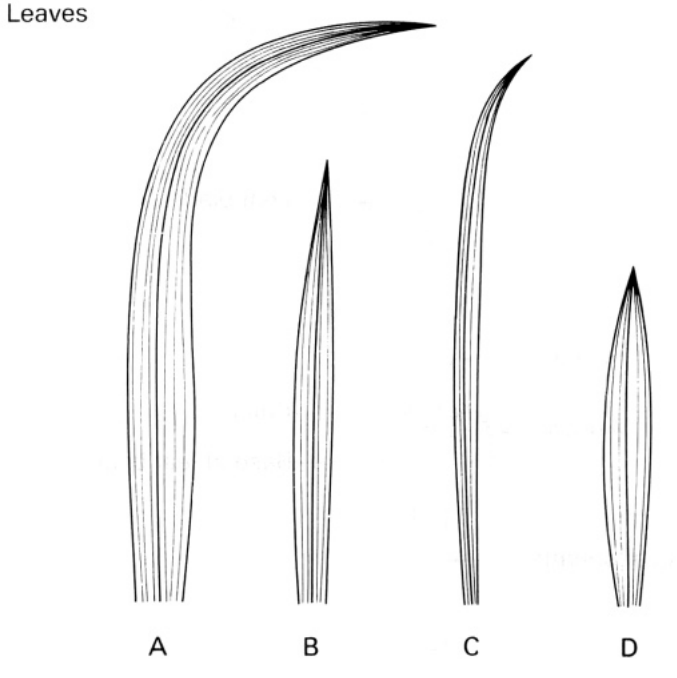
Leaves

The rice leaf



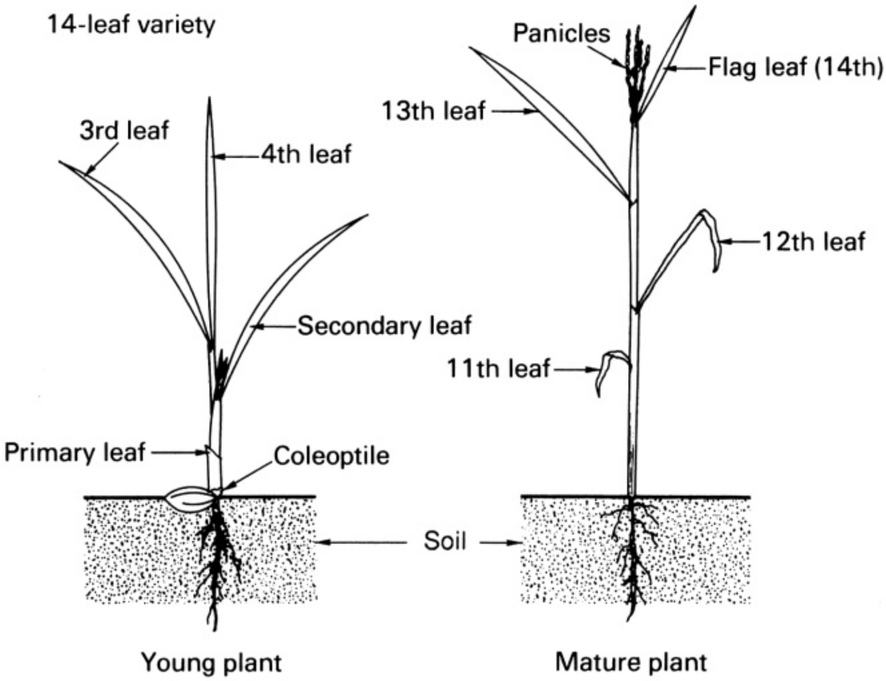
- The rice plant is a grass.
- A rice leaf, like all grasses, has parallel veins.
- Other grass leaves have a collar but may have only a ligule or an auricle or neither.
- A rice leaf has both a ligule and two auricles.

Leaf variations in upland rices



- A. Tall, traditional type. Leaves are long, broad, and droopy.
- B. Intermediate type, Leaves have medium length and are semi-erect.
- C. Aus type. Leaves are long, narrow, and semi-erect.
- D. Modern type. Leaves are relatively short and erect.

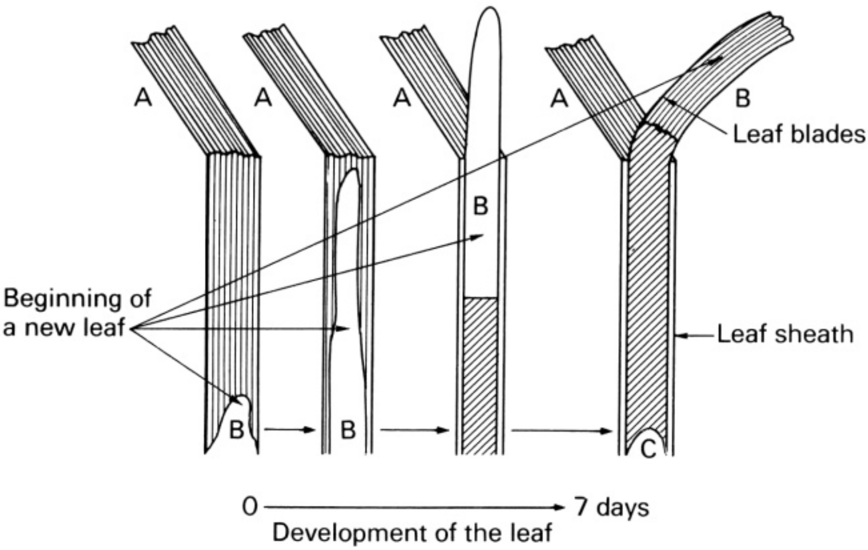
Leaves of the main stem



- The coleoptile comes out of the seed first. It is followed by the primary leaf, then the secondary leaf with the first expanded leaf blade, then the other leaves.
- The last leaf is called the *flag leaf.*
- Most upland traditional rices have long, broad, and droopy leaves.

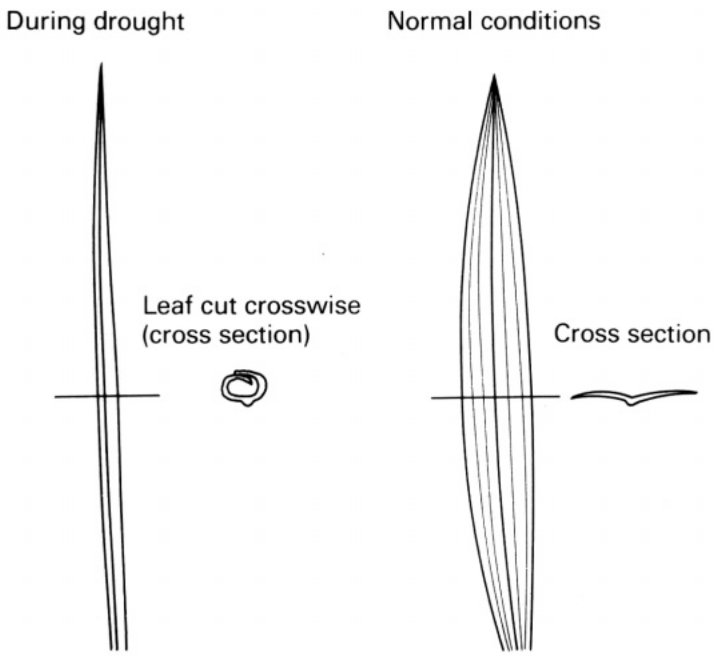
Leaf production

The tip of the rice stem, cut lengthwise, showing 3 leaves (A, B, and C) at different growth stages



- Rice leaves on the main stem are produced one at a time.
- A new leaf is produced about every 7 days.
- A new rice leaf grows on the opposite side of the leaf before it.

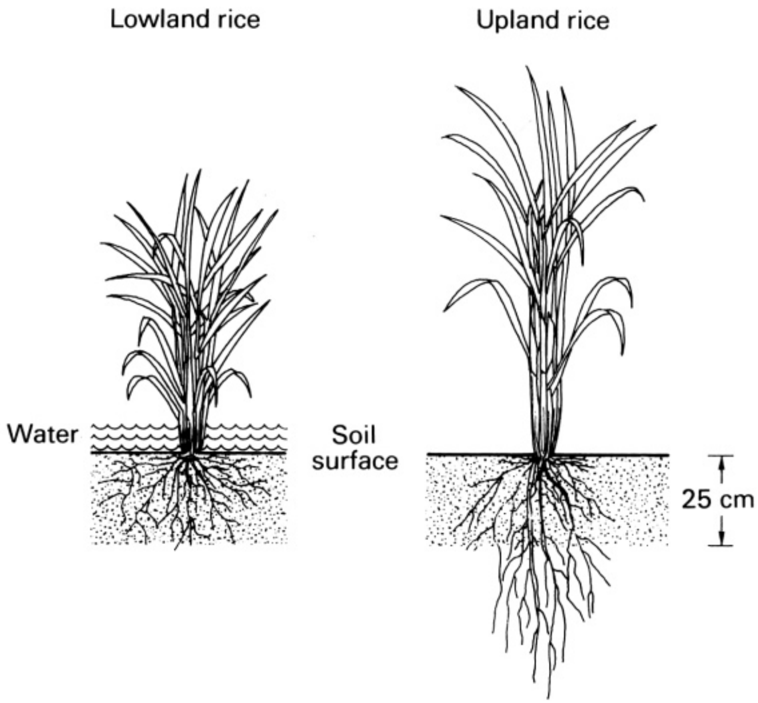
Effect of drought on leaves



- The leaves curl during drought. Their color turns light blue-green or whitish.
- The ability to recover after long drought stress is an important character of a good upland variety.

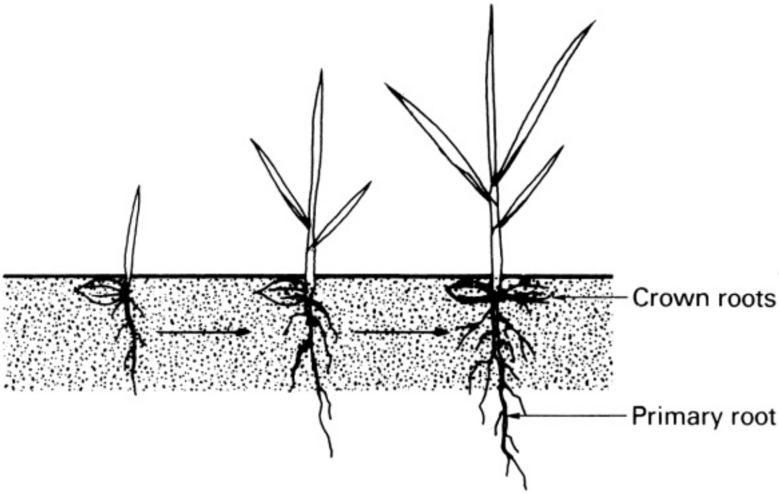
Roots

Upland versus lowland rice varieties



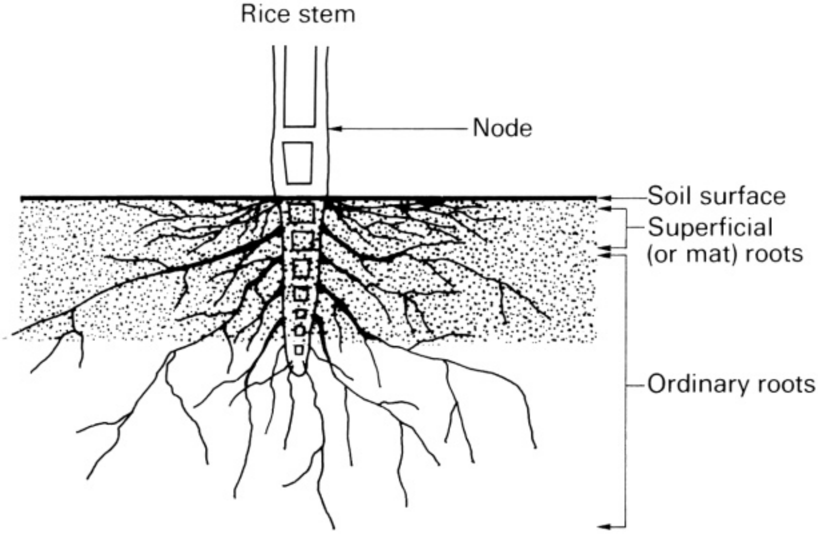
- Most tall, traditional upland rices have deeper, thicker, and fewer roots than lowland rices.
- A deep root system is important for reaching water and nutrients deep in the soil.

Origin of roots



- The radicle or primary root usually dies within a month.
- Crown roots develop from the lower nodes.
- Old roots and older parts of a root are brown.
- New roots and young parts of a root are white.

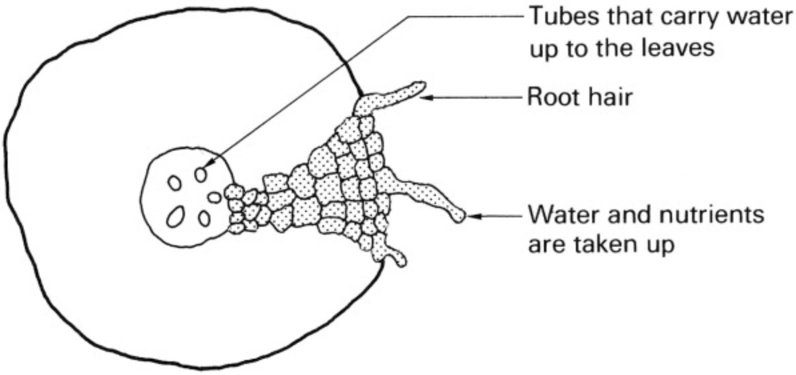
Crown roots



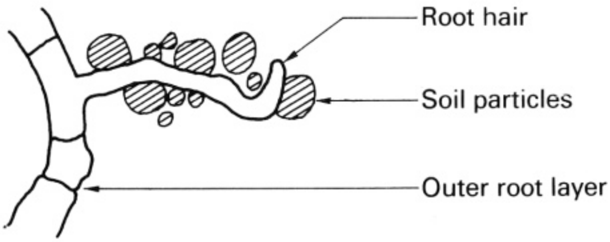
- There are two types of crown roots — superficial (mat) roots and ordinary roots.
- Traditional upland rices produce few superficial roots, even at later growth stages.

Root hairs

Cross section of a young root enlarged 120 times

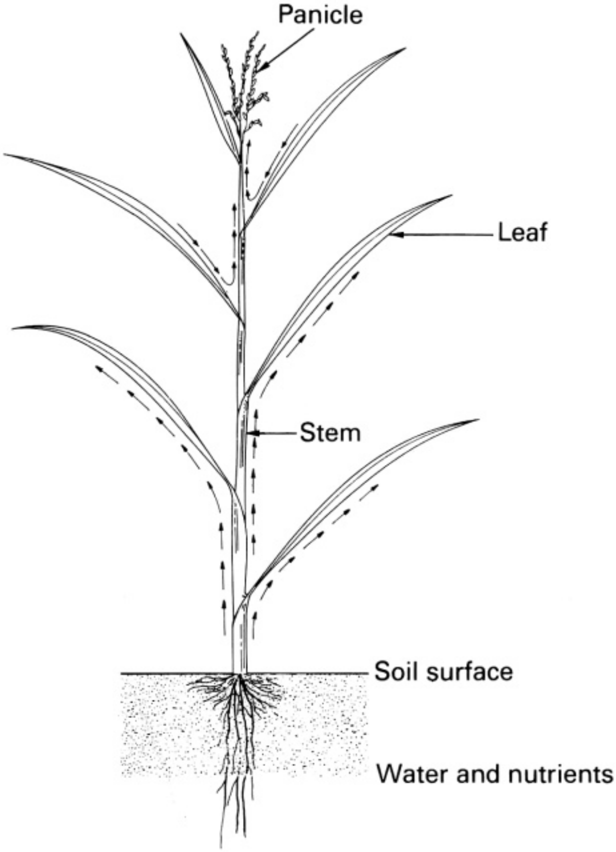


Enlarged 300 times



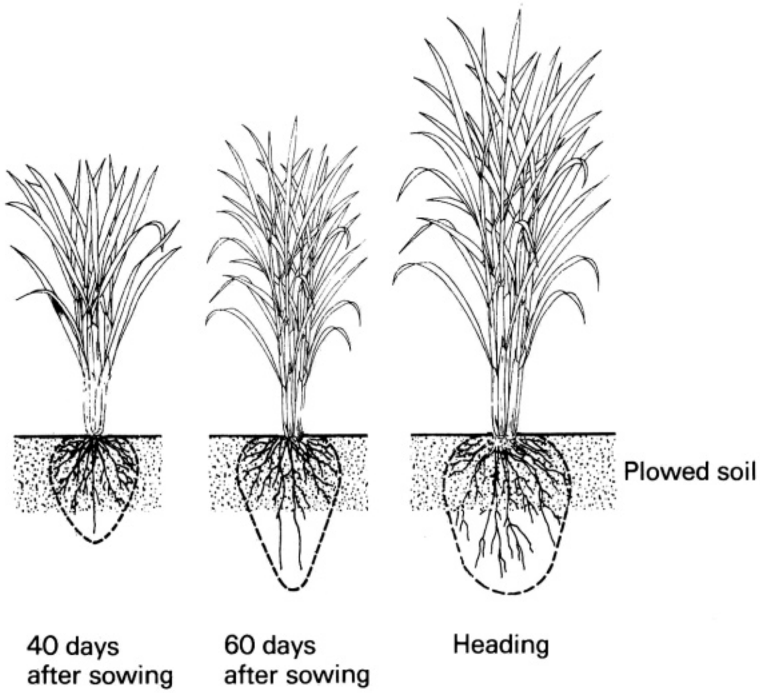
- Root hairs
  - are tubular extensions on the outermost layer of the roots.
  - are important in water uptake as well as in nutrient uptake.
  - are generally short-lived.

Root functions



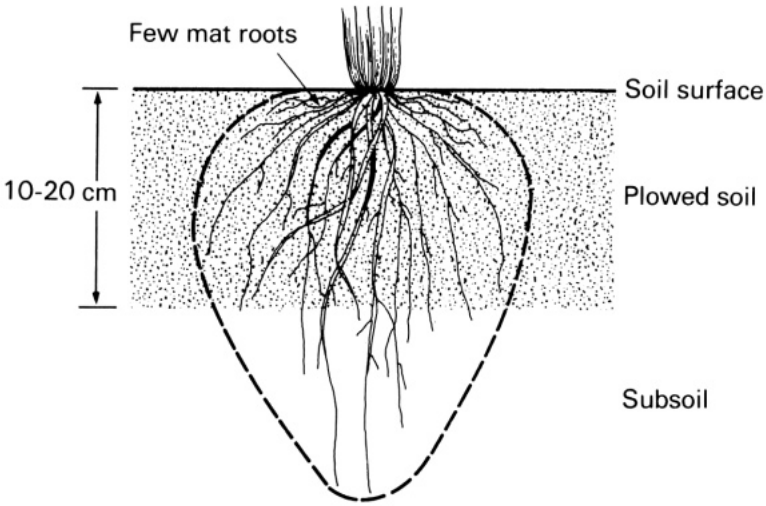
- Soil water contains nutrients such as nitrogen, phosphorus, and potassium.
- The roots take up soil water and nutrients.
- The roots also support the upper parts of the plant.
- The roots anchor the plant in the soil.

Root development



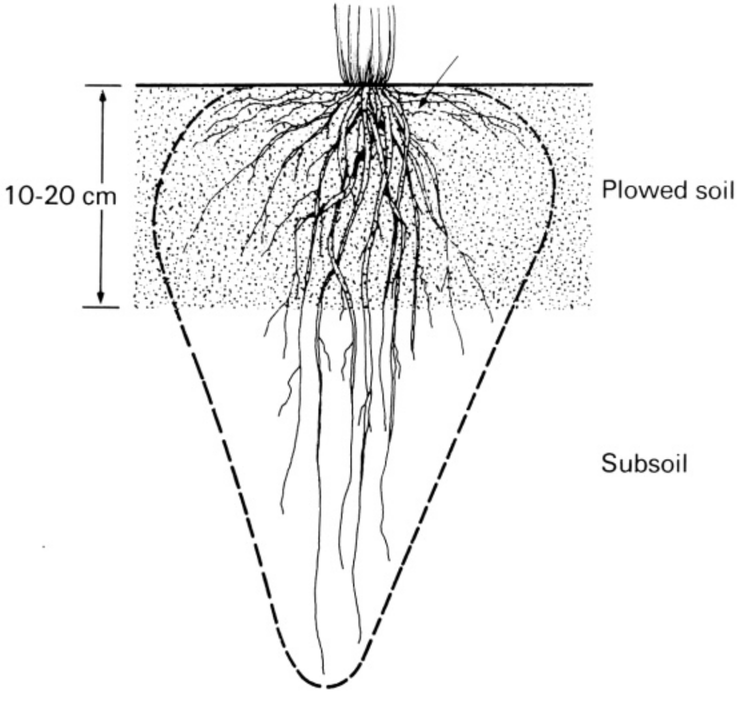
- As the plant grows older, the initial roots from the upper nodes below the soil surface develop into horizontal "super-ficial" roots.

Root development at 40 days after sowing



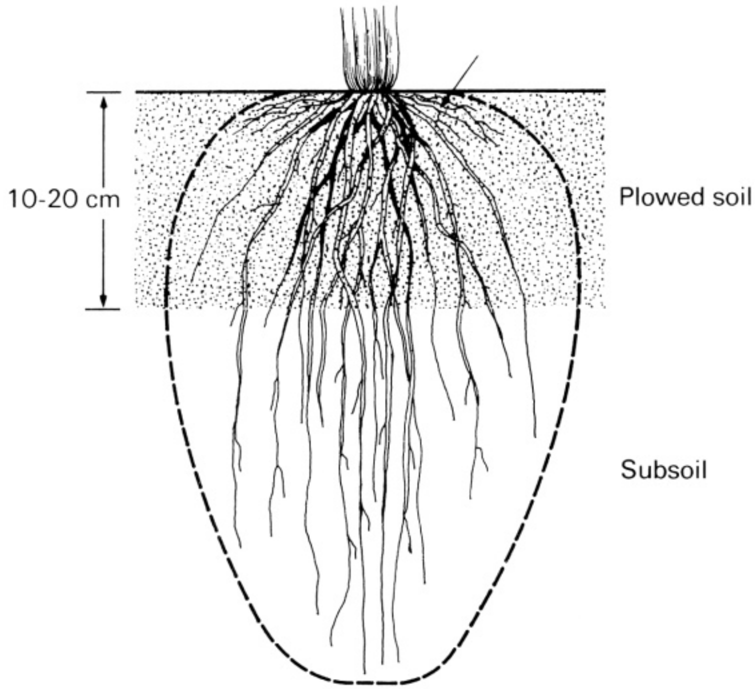
- Most roots are in the plowed layer of soil, but some go deeper into the subsoil.

Root development at 60 days after sowing



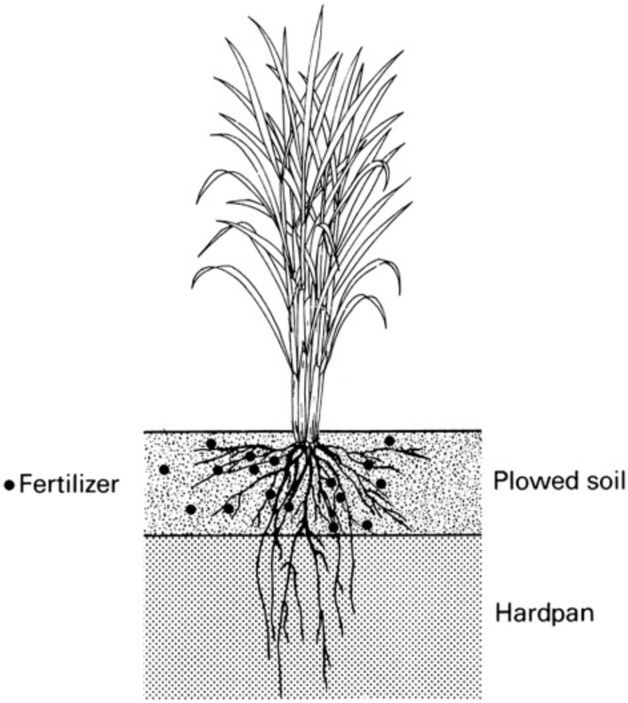
- More roots penetrate the subsoil.

Root development at heading



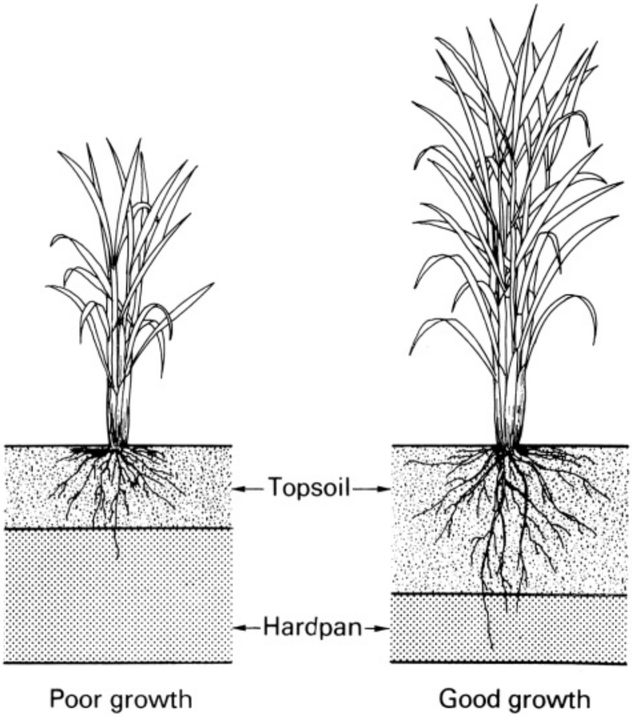
- More roots are big and strong, They have penetrated further into the subsoil.

Root distribution



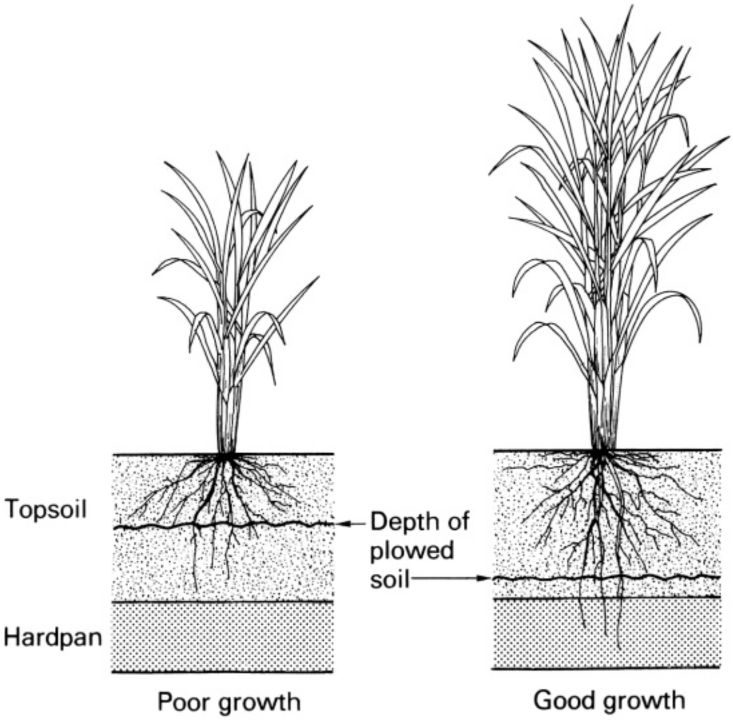
- Root distribution depends on
  - variety.
  - depth of the topsoil.
  - depth of the plowed layer.
  - soil composition.
  - placement of fertilizer.
- Roots must penetrate deeply and spread widely and evenly for good uptake of water and nutrients from the soil.

Root distribution depends on depth of topsoil



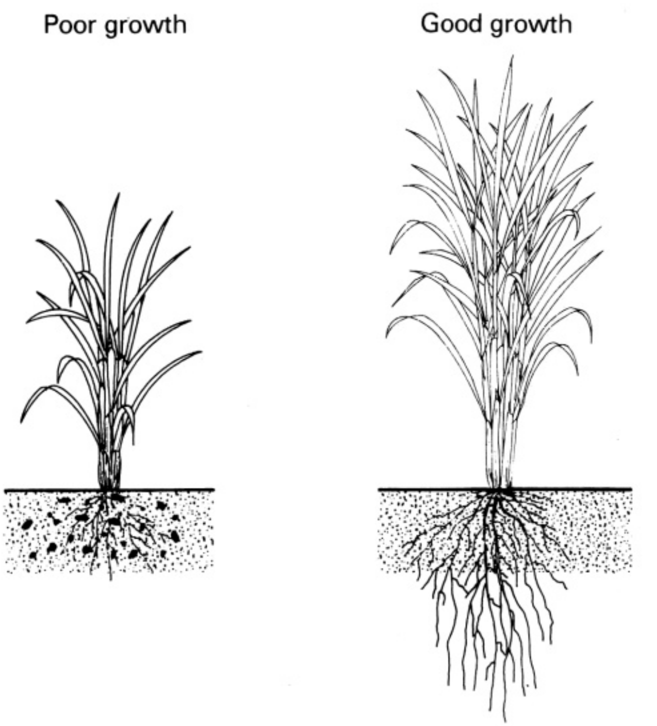
- The topsoil is the distance between the surface and the hardpan. Deeper topsoil means deeper root penetration.

Root distribution depends on depth of plowed layer



- Plow as deep as possible. Shallow plowing restricts root growth. Deeper plowing means deeper root penetration.

Root distribution depends on soil composition

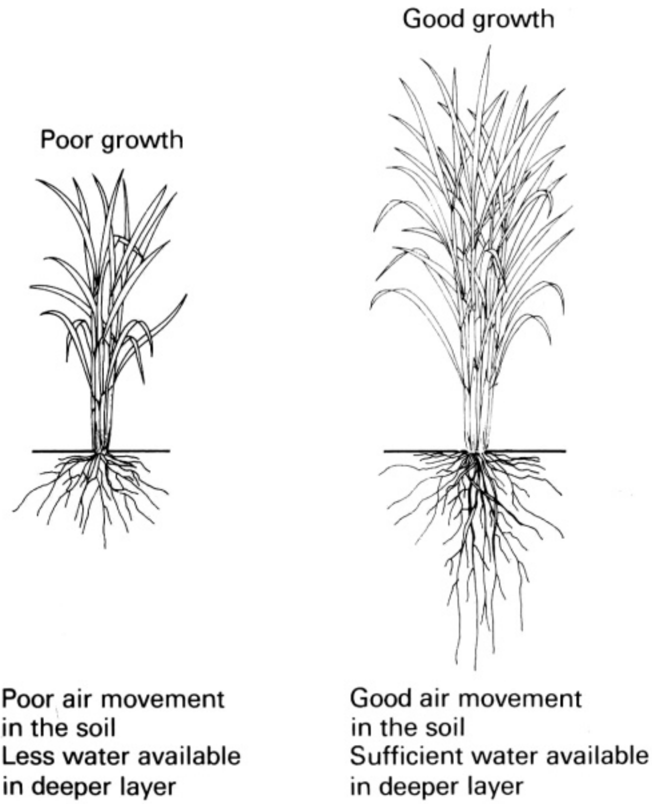


Poor soil is
— heavy clay,
— stony,
— coarse-textured, or
— sandy.

Good soil
— has uniform texture;
— is not stony, coarse, or sandy; and
— holds enough water, not too much.

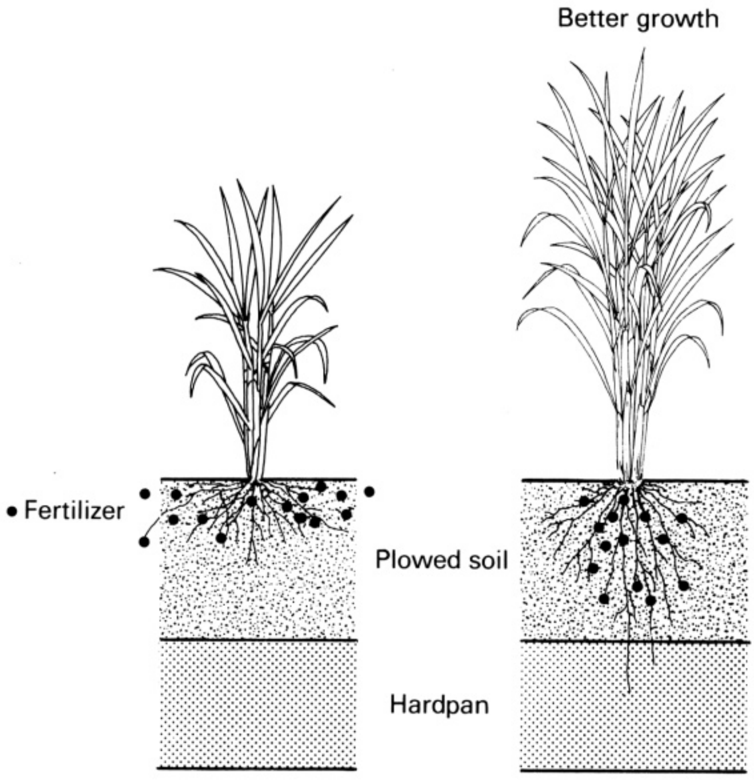
- Soil composition varies widely.

Root distribution depends on availability of air and water



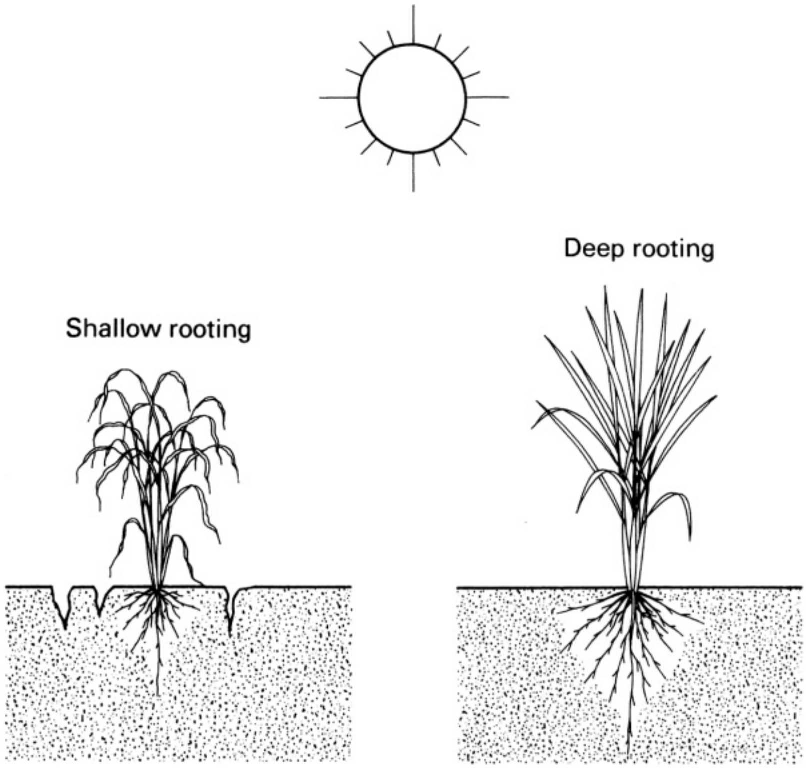
- Shallow root type develops if water and air are not sufficient.
- Good plowing increases the availability of water and air.
- Good roots develop if air and water in deeper layers are sufficient.

Root distribution depends on fertilizer placement



- Mixing the fertilizer thoroughly into the plowed soil results in deeper roots and better root distribution.
- Deep placement of fertilizer near the plant is more efficient than broadcasting it.

Thick and deep roots help plants withstand drought

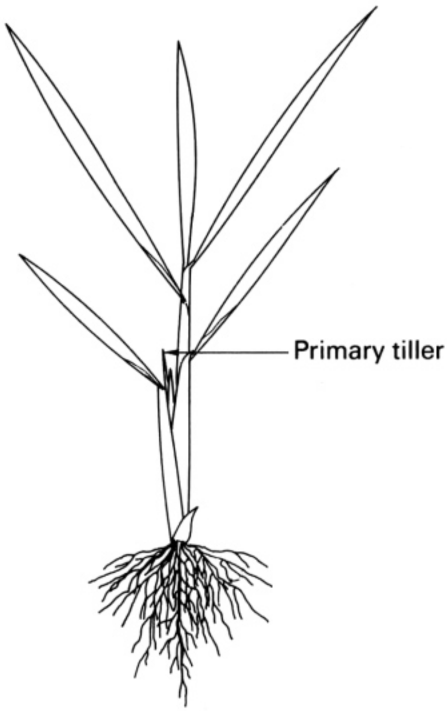


- Plant dries rapidly.

- Better ability to get water from the soil during drought.
- Plant remains strong and healthy.

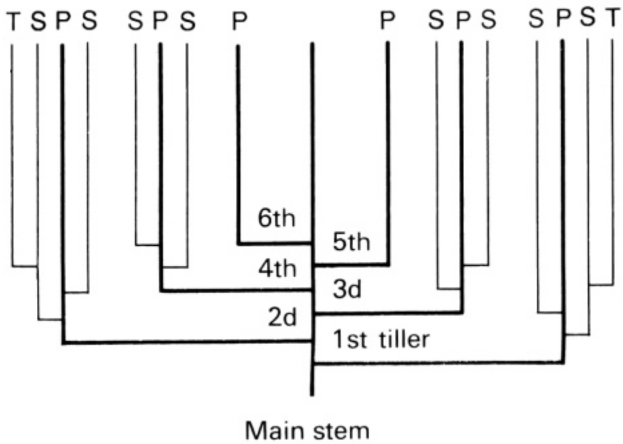
Tillers

Primary tiller



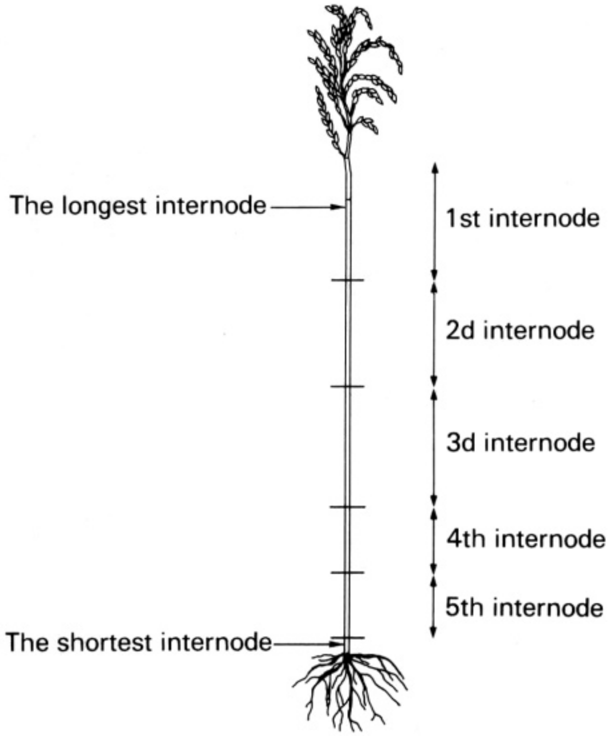
- The first primary tiller usually develops between the main stem and the second leaf from the base.
- The tiller remains attached to the mother plant at later growth stages but is independent because it produces its own roots.

Tillering pattern



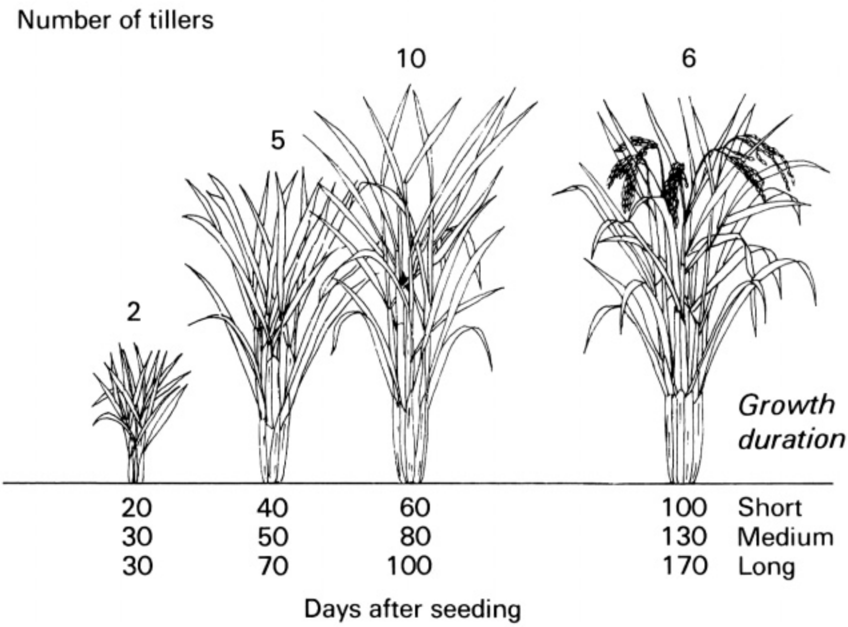
- Primary (P) tillers come from the main stem.
- Secondary (S) tillers develop from primary tillers.
- Tertiary (T) tillers develop from secondary tillers.
- The lower the point of origin on the main stem, the older the tiller is.

Internodes of a tiller



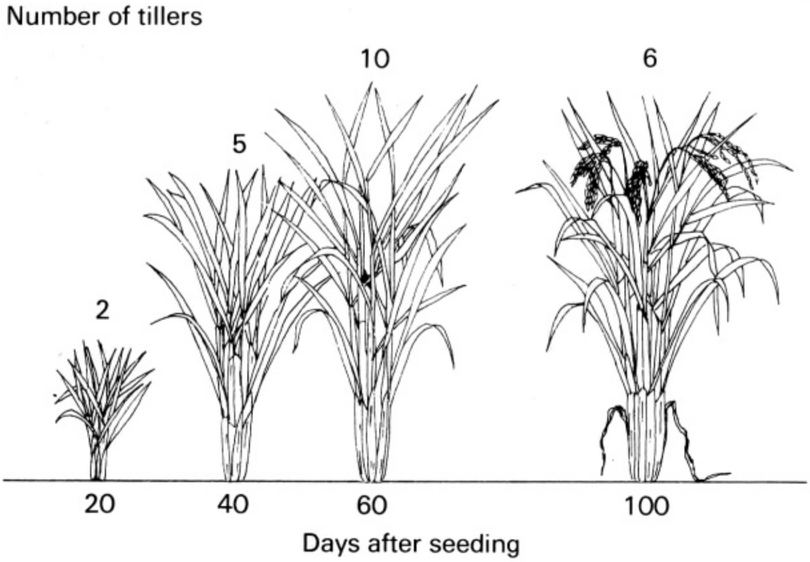
- Rice plants normally have 4 to 6 elongated internodes (more than 1 cm) at harvest.
- Longer basal internodes increase the tendency of the plant to fall flat on the ground — to lodge.
- Closer planting, cloudy weather, higher soil nitrogen level, and higher temperature cause longer internodes.

Production of tillers



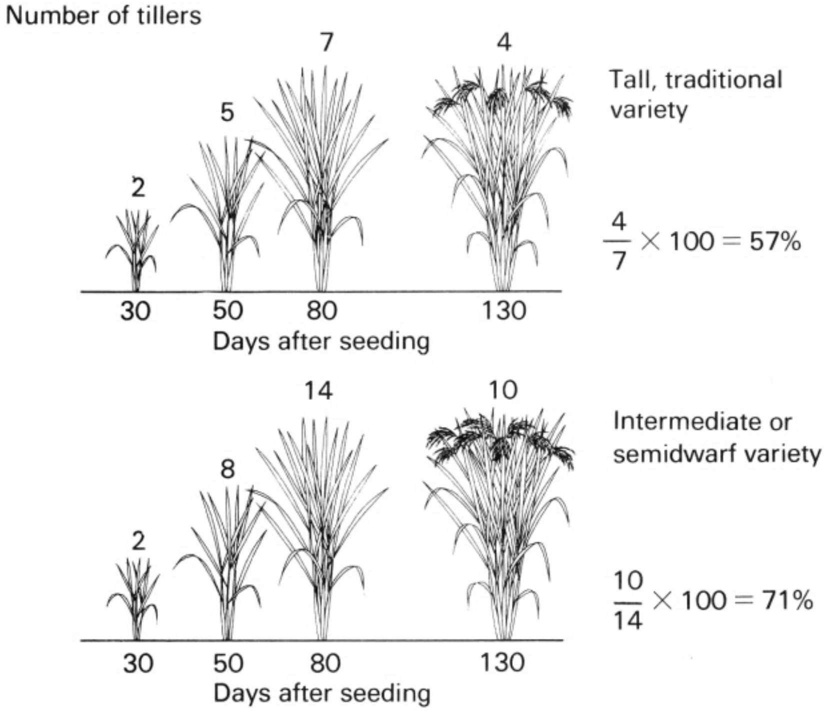
- Tillering starts 20 to 30 days after sowing and maximizes 60 to 100 days after sowing.
- After tiller number maximizes, weak tillers begin to die, particularly in high-tillering varieties.

Productive and nonproductive tillers



- Most traditional upland varieties have few primary tillers. Their early secondary tillers are generally large and productive.
- Most tillers formed during late growth are nonproductive. Many die. The panicles produced on late tillers are usually small and ripen too late. The spikelets are only half filled or empty at harvest.
- Tiller loss may be caused by shading, competition among tillers, drought, or lack of nitrogen or other nutrients.

How to calculate percentage of productive tillers



$$\text{Percentage of productive tillers} = \frac{\text{number of panicles produced}}{\text{highest number of tillers produced}} \times 100$$

- In the above drawings, the traditional variety has 57% productive tillers; the semidwarf variety has 71 %.

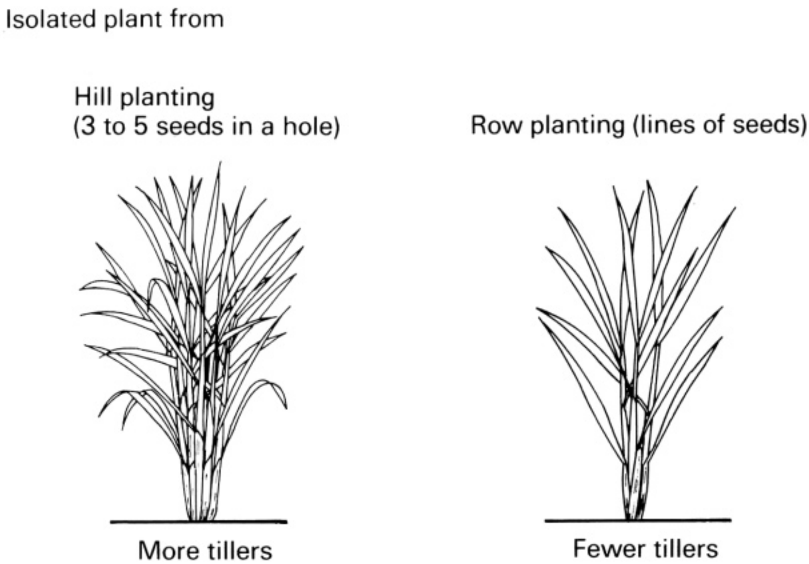
Variety affects tillering

A variety with 6 tillers

A variety with 12 tillers

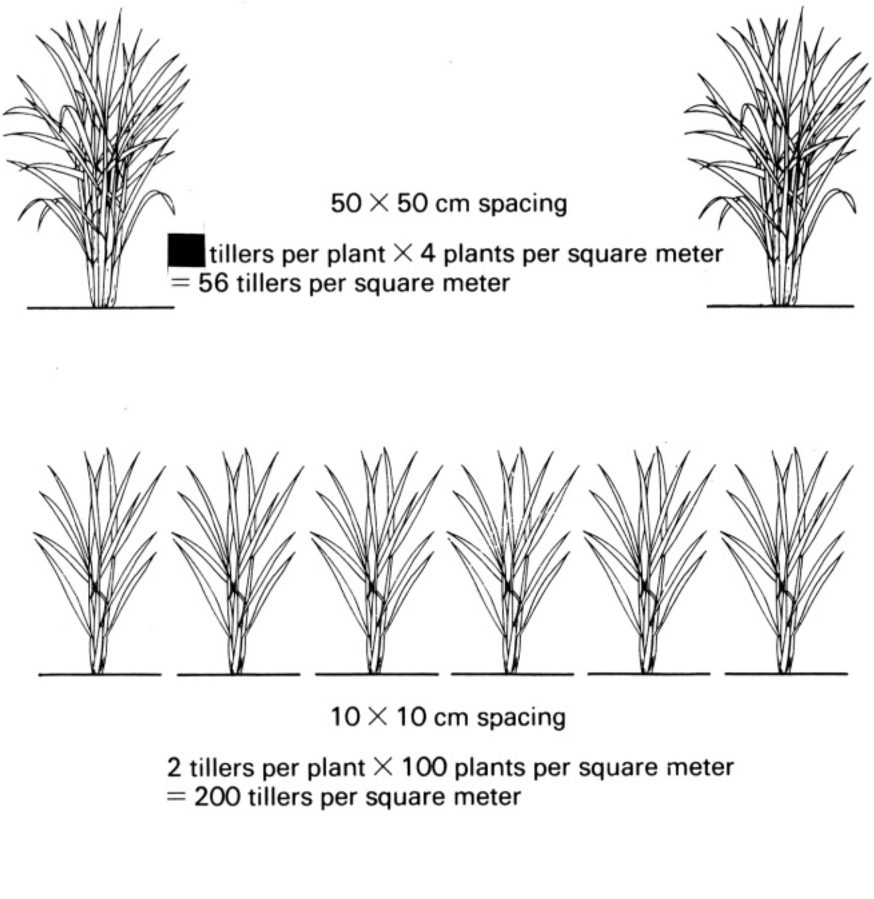
- Varieties differ in tillering ability.
- Spacing the plants widely in rich soil gives maximum tillering.
- Most plants do not reach full tillering ability, particularly if soils are poor.

Planting method affects tillering



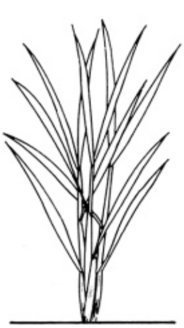
- More seeds used per unit area and less space between rows or hills reduce the number of tillers per plant.
- Too many seeds per hill or within a row reduces tillers per plant.

Spacing affects tillering



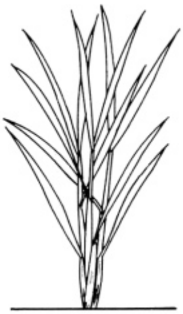
- The tiller number per plant increases as the distance between plants increases.
- Wide spacing of plants reduces the number of tillers per square meter.

Rainfall and soil affect tillering



Erratic and low rainfall
Low tillering

Stable and good rainfall
High tillering

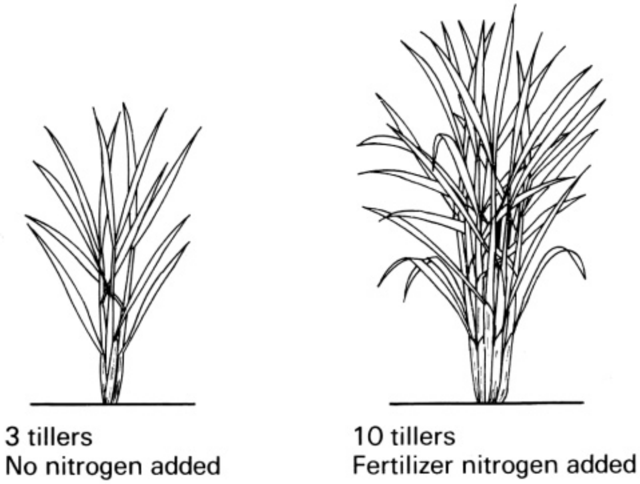


Poor soil
Low tillering

Good soil
High tillering

- Amount and distribution of rainfall, and soil composition strongly affect tillering.

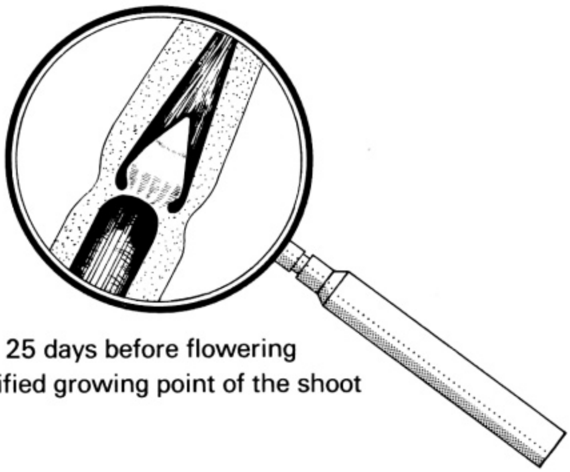
Nitrogen level affects tillering



- Nitrogen is important to increase tiller number.
- But too much nitrogen can increase diseases and lodging, except in very poor soils.

Panicles

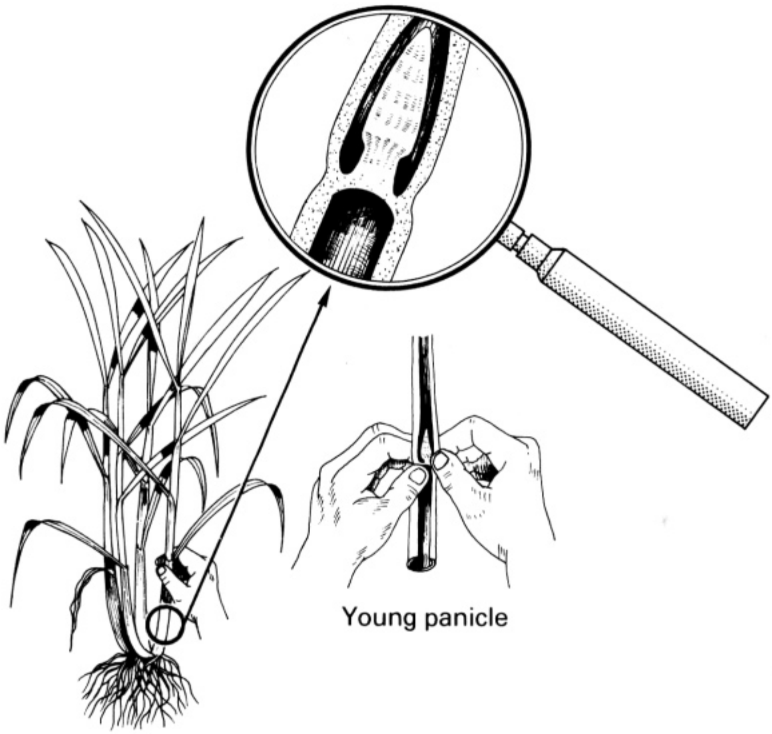
Panicle formation



25 days before flowering
Magnified growing point of the shoot

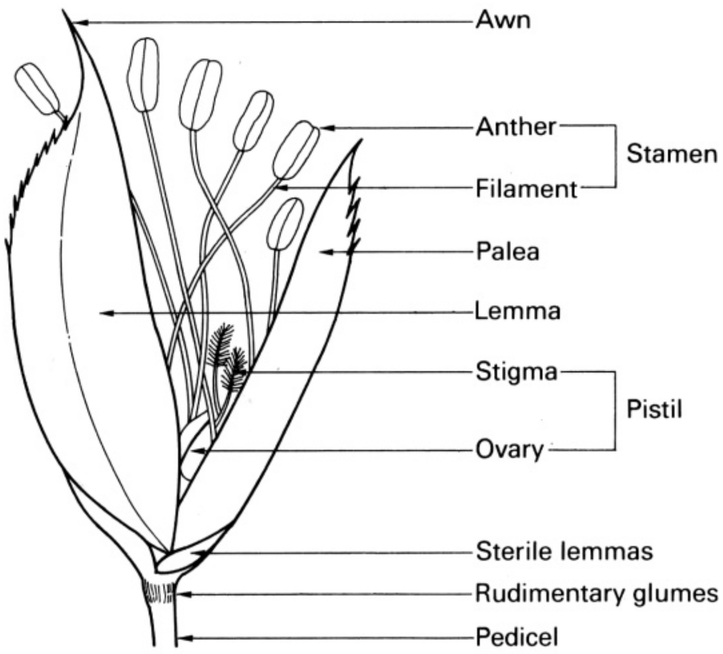
- A panicle forms at the tip of the growing point of the shoot.
- The panicle is visible to the naked eye when it is 1 mm long.
- At 1 mm, the young panicle has many fine, white, hairy structures at the tip.
- When the panicle inside the leaf sheath is about 1 mm long, three more leaves will be produced before the panicle comes out.

Booting



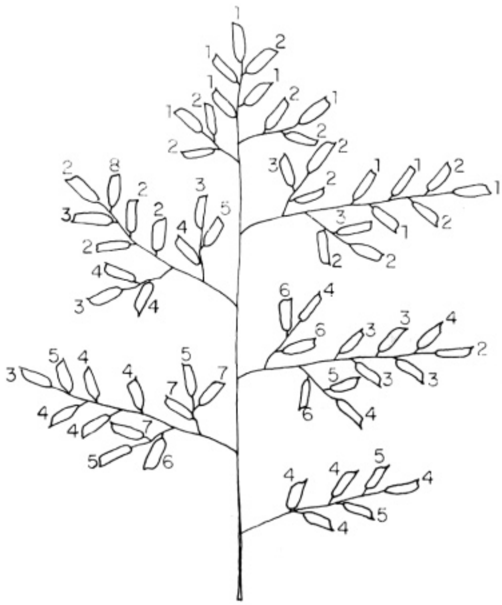
- Booting is 20 to 25 days before flowering. The panicle is 1 mm long.
- The base of the leaf sheath bulges at the booting stage.
- Flowering occurs 35 days after the start of panicle formation.

The spikelet



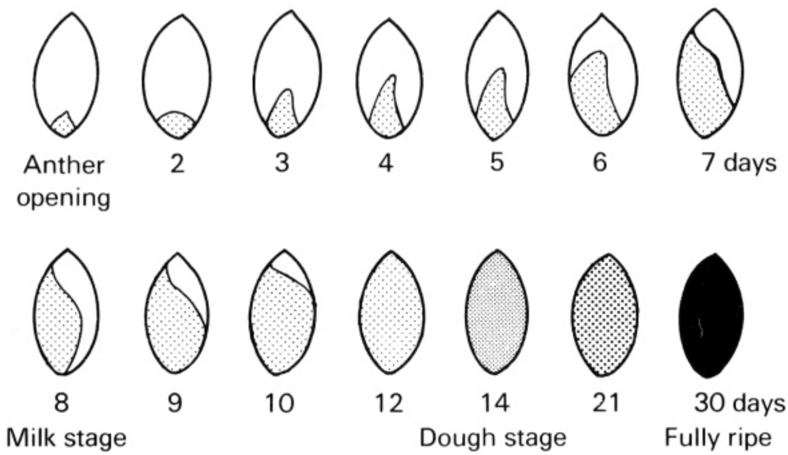
- The anthers open 1 day after the panicle comes out.
- Low temperature delays the opening of the anthers.
- Pollen (fine dust) from the anthers must reach the stigma and unite with the egg inside the ovary before a grain can develop.
- A grain is a ripened ovary together with the lemma and palea.
- A spikelet bears only one grain.

Flowering order of a panicle



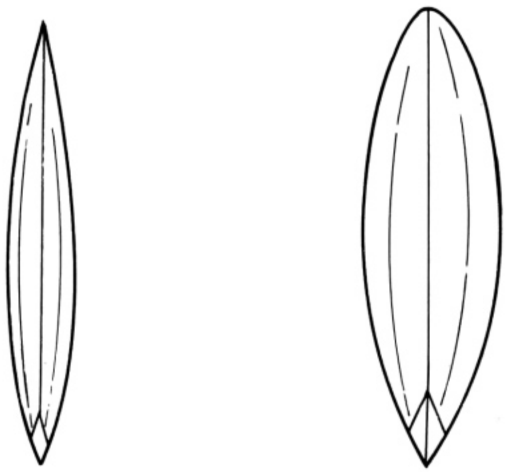
- It takes around 7 days for all the spikelets in a panicle to open.
- The uppermost spikelets open first.
- The lower spikelets open last and, in large panicles, usually do not completely fill.
- Tall, traditional varieties usually have more spikelets per panicle than other plant types.

Stages of grain formation



- Buildup of starch inside the spikelet begins after part of the male cell unites with the egg in the ovary (fertilization).
- The spikelet reaches maximum weight at 21 days after fertilization.
- Since it takes 7 days for all the spikelets in a panicle to open, full maturity for the whole panicle does not occur until 30 days after flowering.
- Extra days are needed to ripen all the grains because the panicles do not come out at the same time.

Causes of empty spikelets



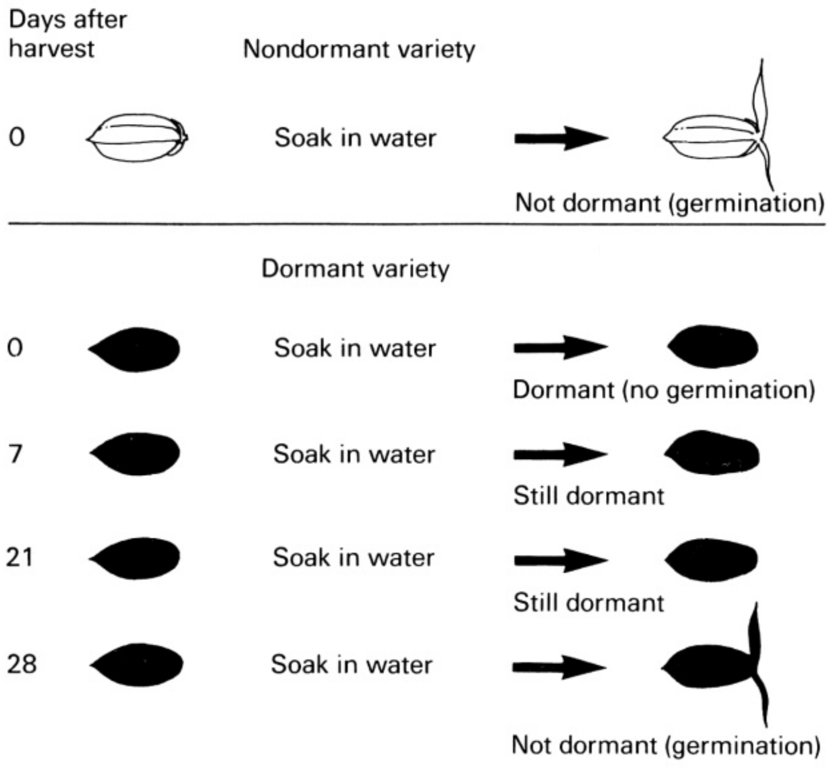
Side view of an empty spikelet

Side view of a fully filled spikelet

- Many factors can affect the filling of spikelets.
  - Drought between panicle initiation and postflowering may cause total yield loss.
  - A lack of starch may be caused by lodging, low light intensity, drying of the leaves, disease, or damage by insects.
  - Dry winds or high temperature may cause the stigma to dry.
  - Low temperature or high humidity at flowering may prevent spikelets from opening.
  - Low temperature at panicle formation can cause spikelets to degenerate.

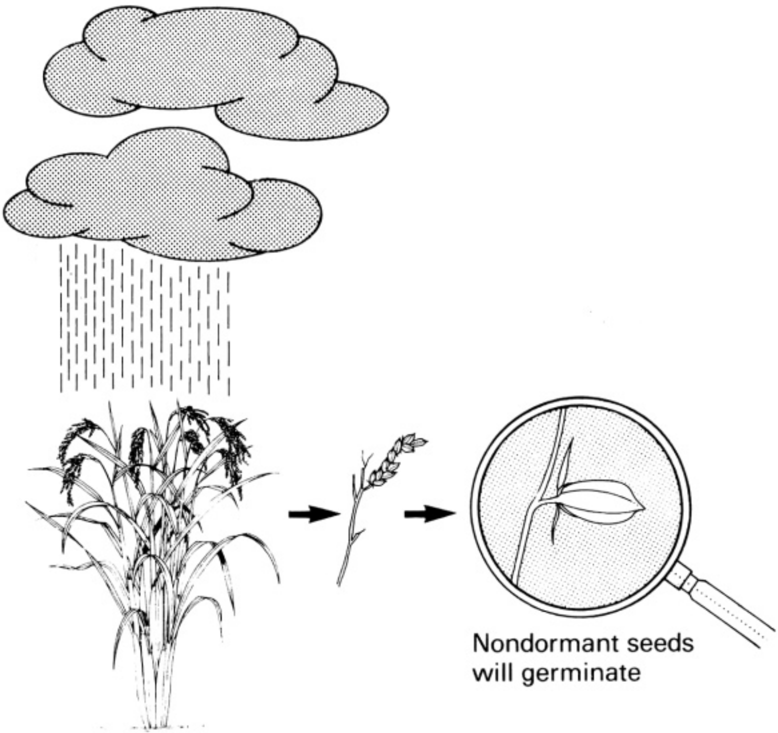
Dormancy

Grain dormancy



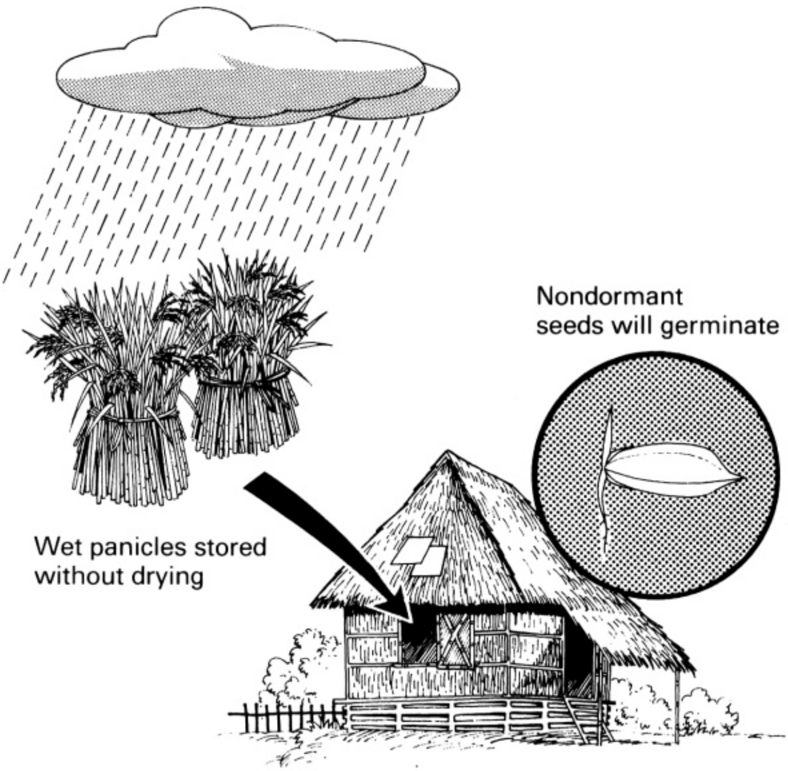
- Dormancy is the failure of a mature seed to germinate under favorable conditions.
- Not all varieties have dormancy.
- Seed dormancy may last from 0 to 80 days, depending on variety and harvest conditions.

Dormancy prevents seed germination on the panicle



- Dormancy is important during the rainy season harvest.
- Nondormant seeds may germinate if exposed to rain when mature.
- Harvest the crop as soon as possible after maturity and on dry days if possible.

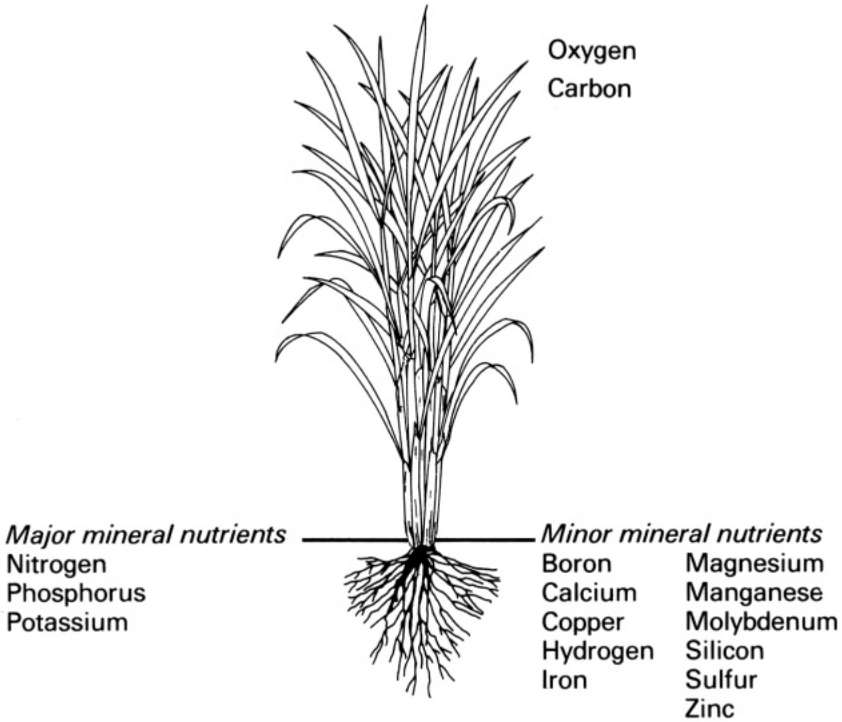
Dormancy prevents germination of seed stored in wet conditions after harvest



- The causes of dormancy are not clear.
- Dormancy can be a disadvantage. Freshly harvested seeds cannot be planted immediately.

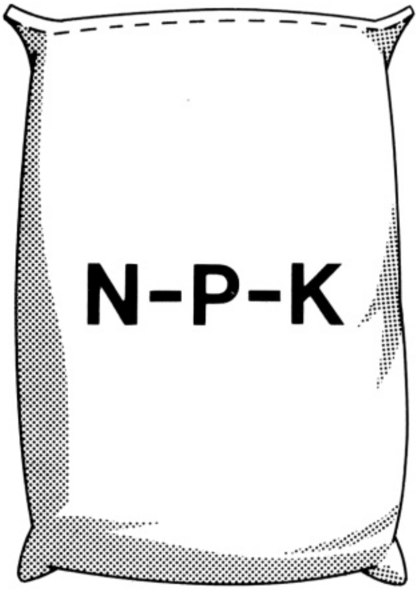
Fertilizers

Nutrients that the rice plant needs



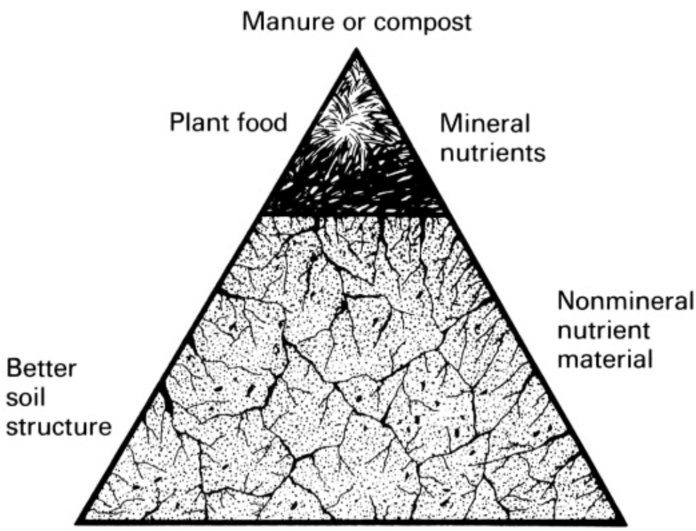
- Plants need oxygen and carbon from the air, and mineral nutrients from the soil.
- Plants need nitrogen, phosphorus, and potassium in large amounts. These are the major mineral nutrients.
- Minor nutrients are needed in smaller amounts. The soil often has sufficient minor nutrients. If not, they must be added.

What are fertilizers?



- Fertilizers are food for plants; they contain important mineral nutrients.
- The main nutrients in fertilizers are nitrogen (N), phosphorus (P), and potassium (K).
- Fertilizers should be applied when the soil does not supply enough nutrients.
- Fertilizers are *organic,* such as farm manure, or *inorganic,* such as urea.

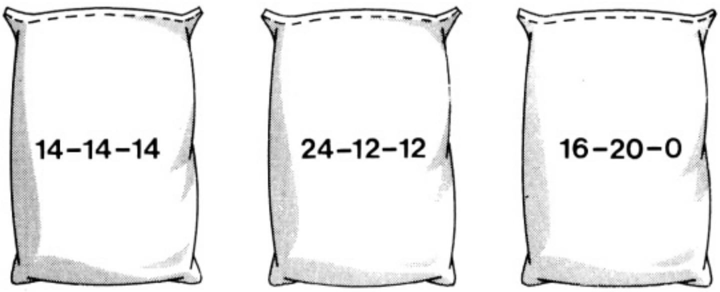
Organic fertilizers



- Organic fertilizers come from plant and animal matter such as rotten leaves or chicken manure.
- Large amounts of organic fertilizer contain small amounts of the mineral nutrients needed by plants.
- Organic fertilizers improve soil structure.

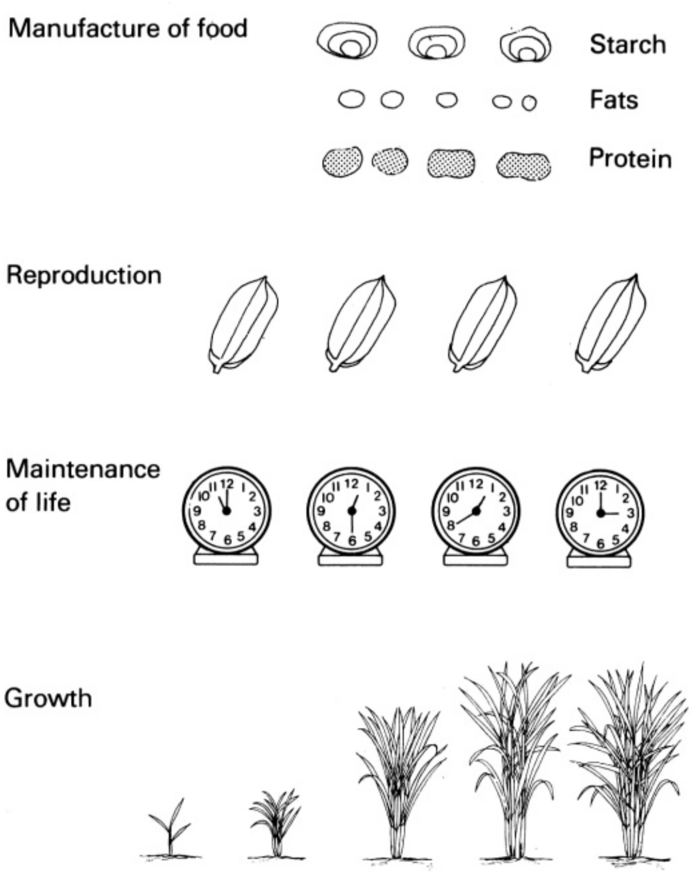
Inorganic fertilizers

Examples
Urea (45-0-0)
Superphosphate (0-25-0)
Muriate of potash (0-0-60)



- Inorganic fertilizers are commercially manufactured mineral nutrients.
- There are several combinations of nitrogen (N), phosphorus (P), and potassium (K) fertilizers.
- The numbers on the bag refer to the percentage by weight of mineral nutrients in the fertilizer. 24-12-12 means 24% nitrogen, 12% phosphorus (P_2O_5), and 12% potassium (K_2O).
- The rest of the material in the fertilizer bag is ”filler” and may contain calcium, sulfur, or small amounts of minor mineral nutrients such as zinc.

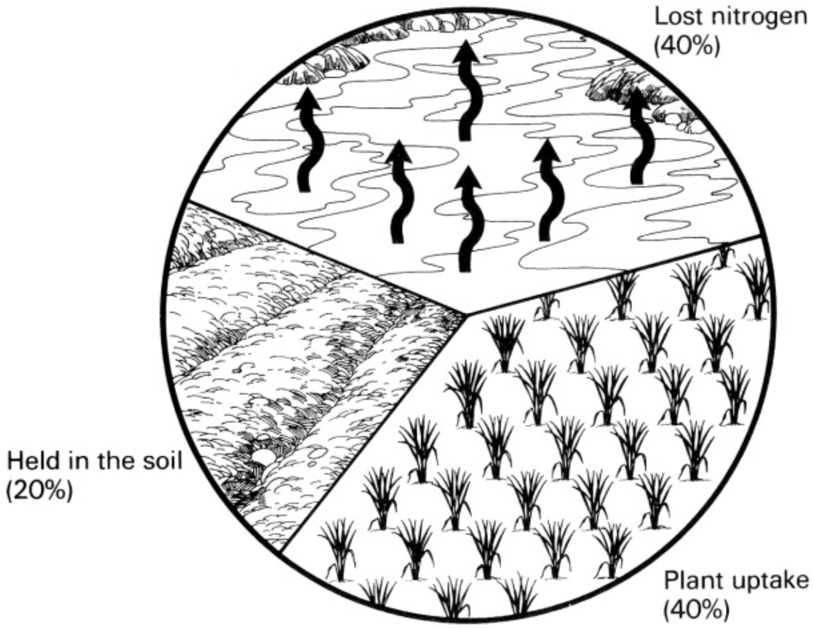
Role of fertilizers



- Nitrogen, phosphorus, and potassium are needed for the plant's life processes.

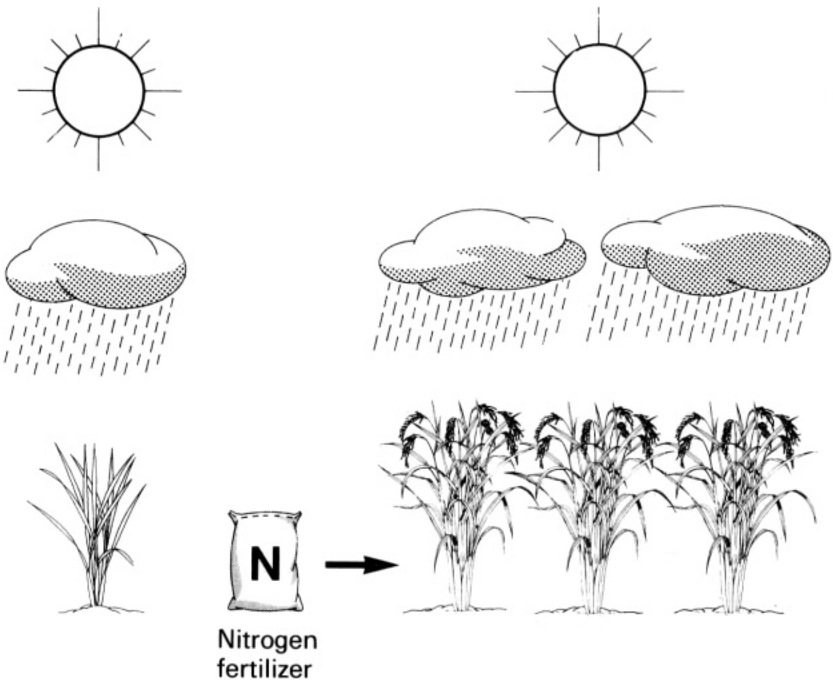
How much nitrogen to apply

What happens to nitrogen applied to soil?



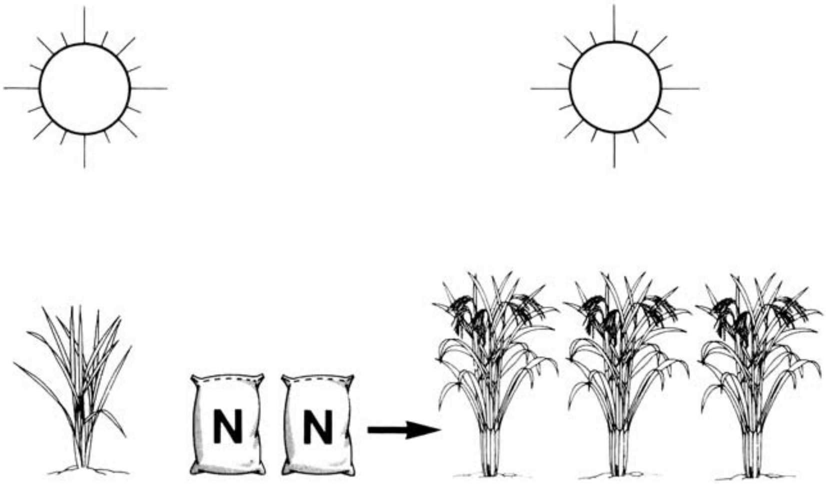
- A high percentage of the applied nitrogen is lost.
- Some of the nitrogen in the soil can be used by the next crop.
- Learning to minimize the loss of available nitrogen and to maximize its use is important.

The humid tropics



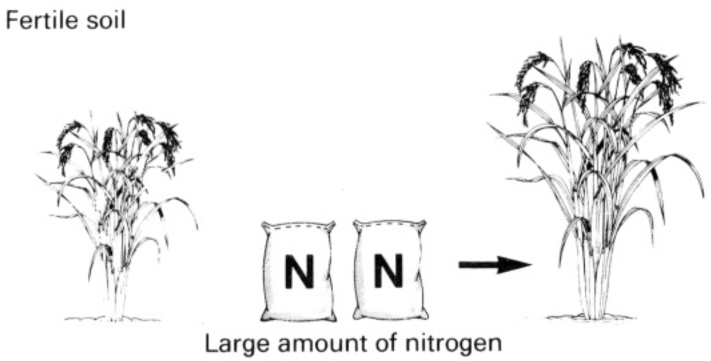
- In the humid tropics, where rainfall is 2,000 mm or more during crop growth, drought is not severe, although dry spells may occur.
- Light is low above and inside the crop.
- Plants grow tall and leafy with high rainfall and low light.
- Plants shade each other, which decreases food production in the leaves.
- Use lower nitrogen rates in these conditions

The semiarid tropics

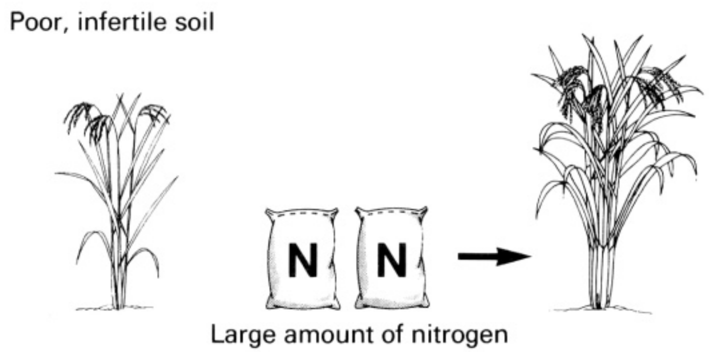


- In the semiarid tropics, rainfall is 1,500 mm or less during crop growth.
- More light is available.
- Plants grow shorter, with fewer tillers.
- Grain yield can be higher. More nitrogen can be applied profitably if drought is not severe.

Fertility of the soil

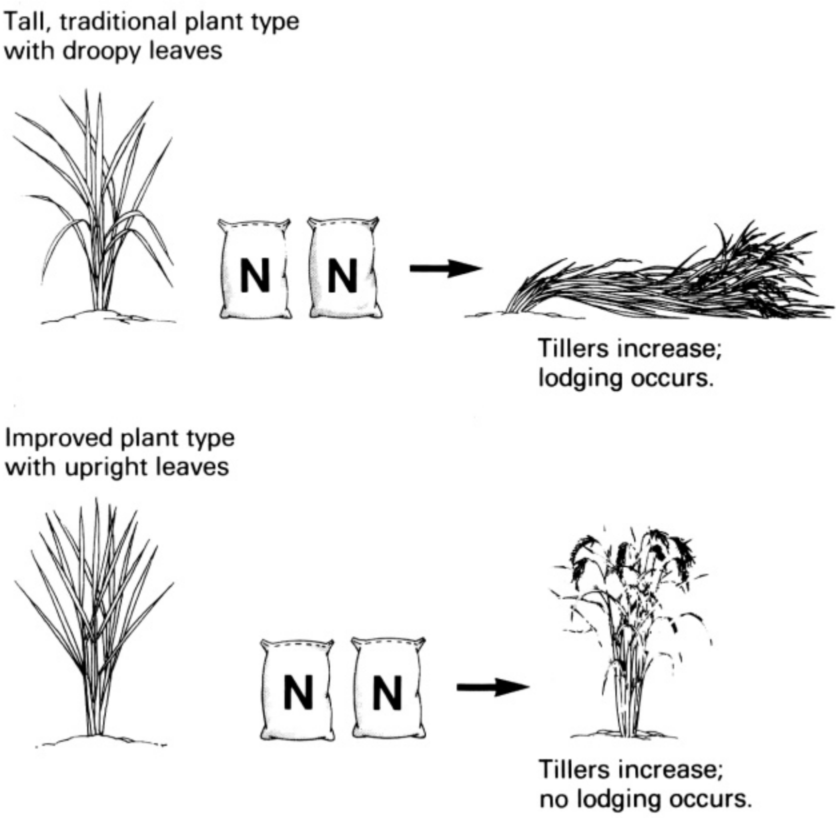


- A large amount of nitrogen fertilizer applied to a fertile soil results in too much vegetative growth, a high rate of non-productive tillers, lodging, and increased spikelet sterility.



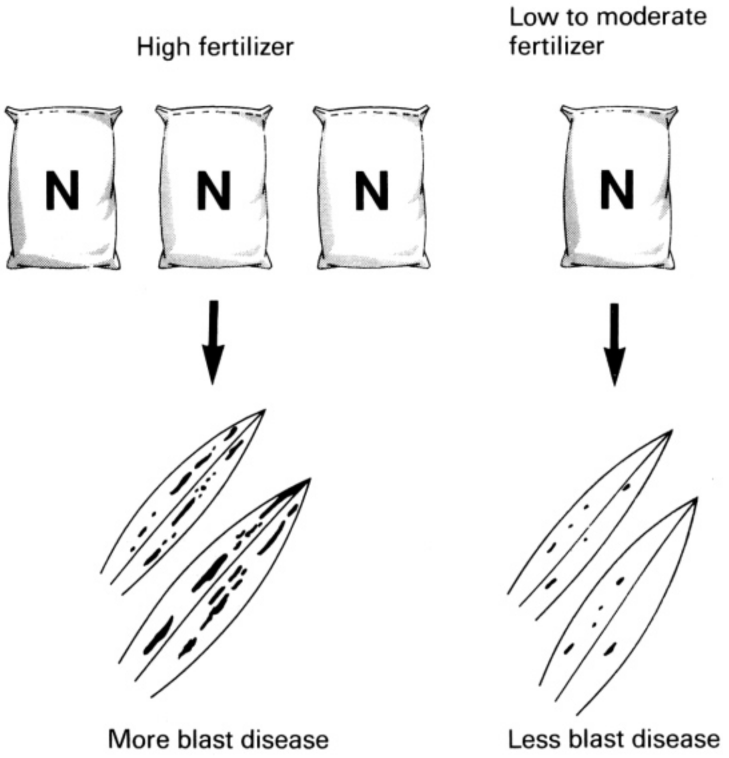
- Poor, infertile soils require higher amounts of nitrogen.
- The right nitrogen level in the soil results in a high number of productive tillers and high spikelet fertility.

Plant type



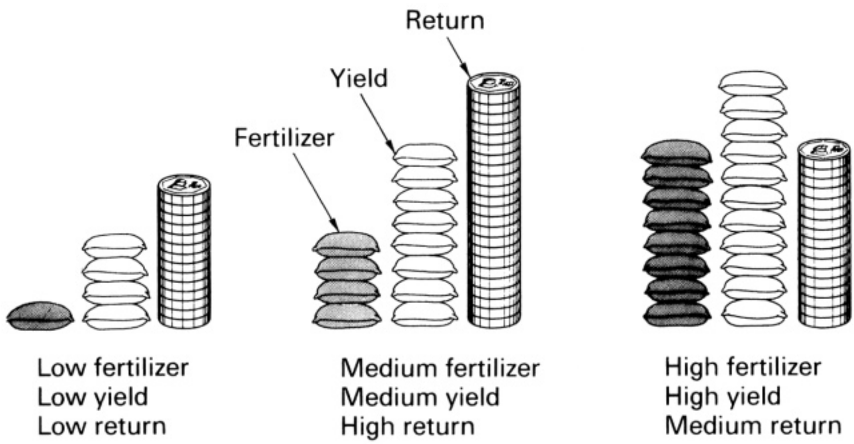
- The efficiency of nitrogen fertilizer use is higher in improved varieties than in traditional varieties.
- With tall varieties, too much nitrogen increases plant height and causes lodging.

Disease incidence



- Too much nitrogen usually increases blast disease, particularly in susceptible varieties.
- Do not use too much nitrogen in late sowings.

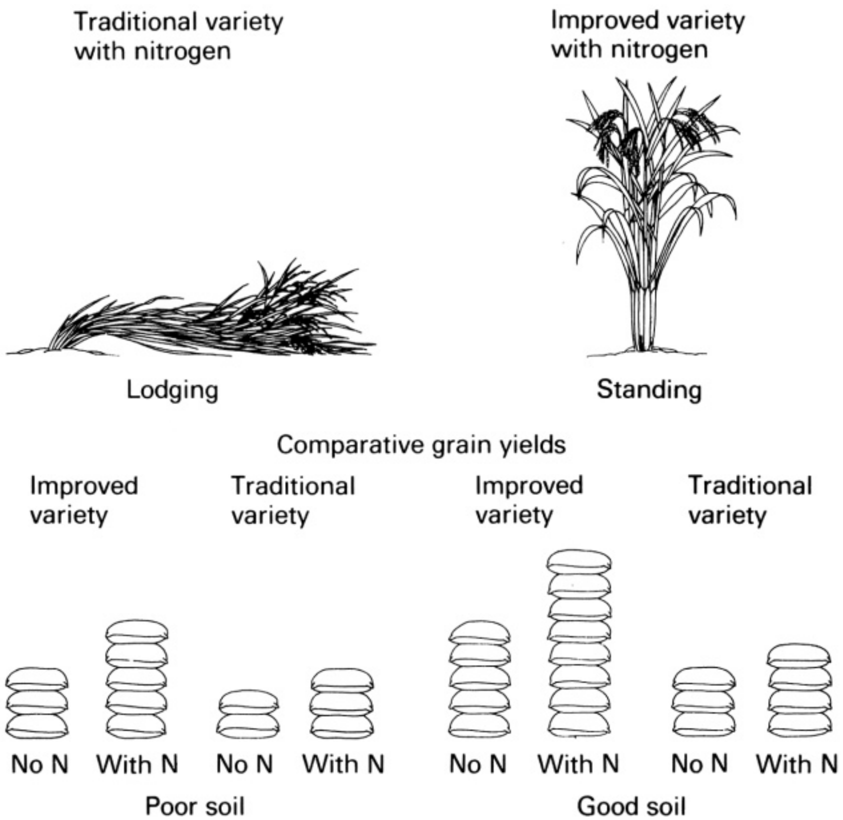
Profit from applied fertilizer



- Application of the right amount of fertilizer gives maximum return.
- The right amount of fertilizer depends on its price in relation to yield increase.
- The right amount of fertilizer varies with soil, rainfall, and sunlight.
- The return from nitrogen depends on the risks (drought, disease, etc.).

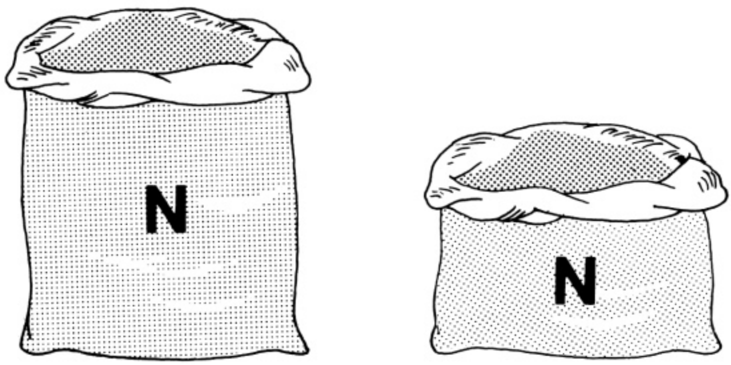
How to increase the efficiency of nitrogen fertilizer

Use improved varieties



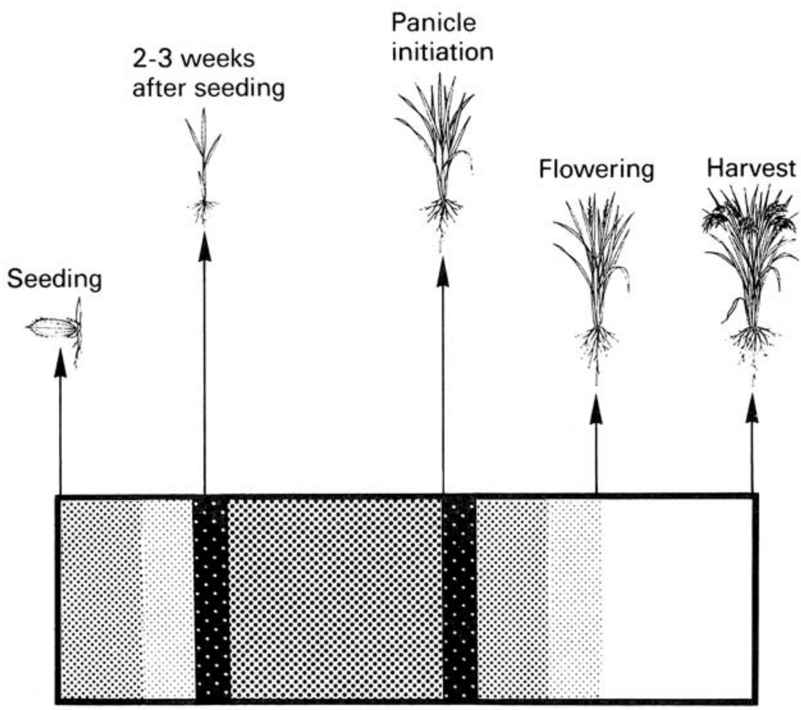
- Grain yield increase as a result of nitrogen application is higher in improved varieties than in traditional varieties regardless of soil.

Apply the right amount of fertilizer



- The right amount of fertilizer depends on
  - — soil fertility,
  - — yield potential of the variety,
  - — price of fertilizer, and
  - — time and method of application.
- Less drought risk means higher returns from fertilizer in poor or moderately rich soils.

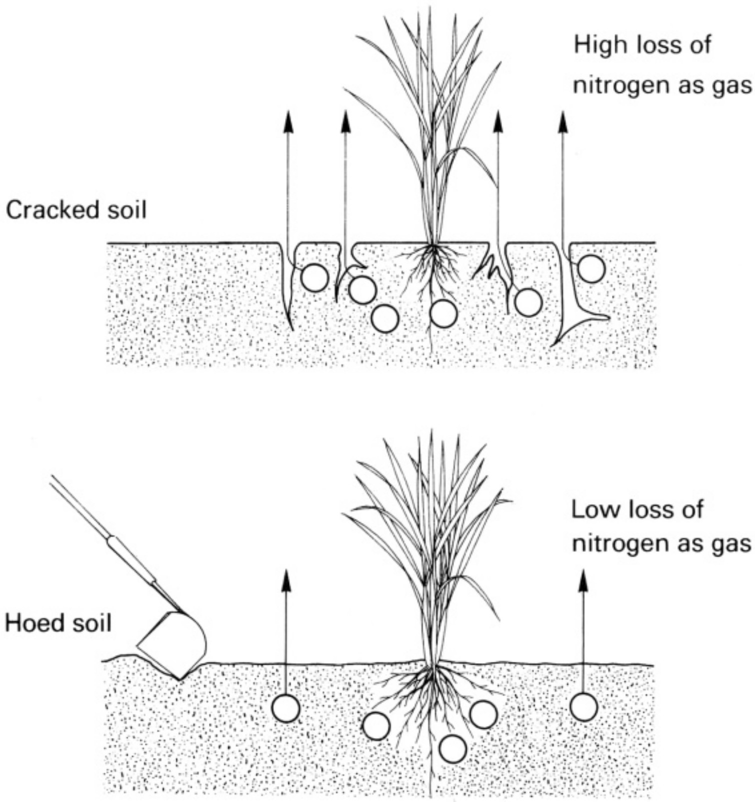
Apply fertilizer at correct growth stage



The darker the shade is, the better the time of fertilizer application.

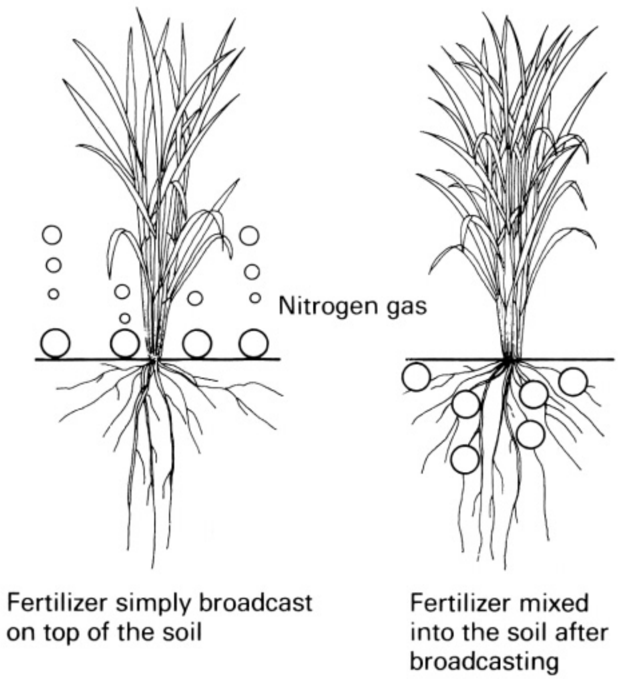
- The early tillering stage and the panicle initiation stage are the best times for applying nitrogen fertilizer.
- Fertilizer application after flowering may increase spikelet sterility and result in late and useless tillers.

Do not let the field dry out



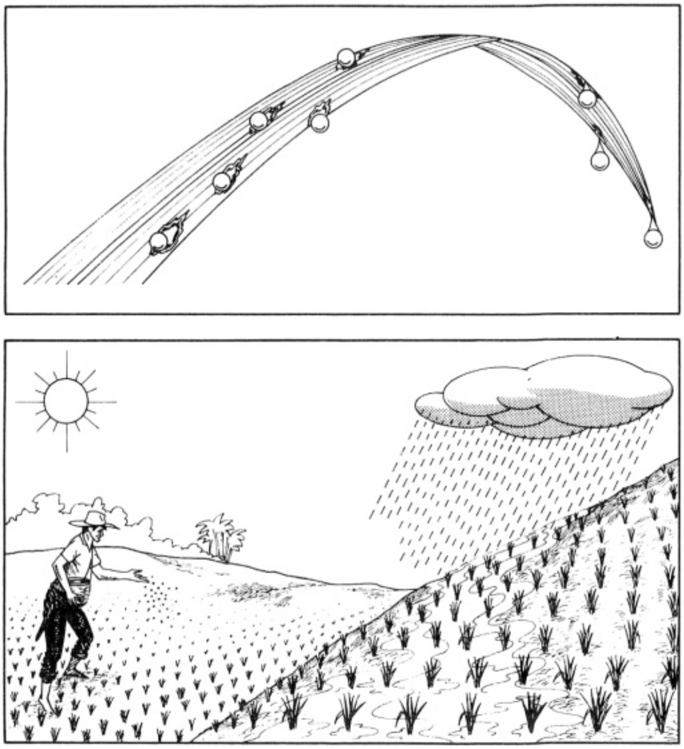
- Hoeing and plowing prevent loss of nitrogen as a gas.
- Hoeing also helps prevent evaporation of water from the soil.

Mix the fertilizer into the soil



- After broadcasting, mix fertilizer thoroughly into the soil
  – to prevent nitrogen loss into the atmosphere, and
  – to keep the fertilizer nearer to the roots.

Do not topdress when leaves are wet



- Fertilizer sticks on wet leaves, causing leaf burn.
- As the water evaporates, the dissolved fertilizer is lost to the air.
- Do not topdress when you expect heavy rain. The fertilizer may be washed from the field.

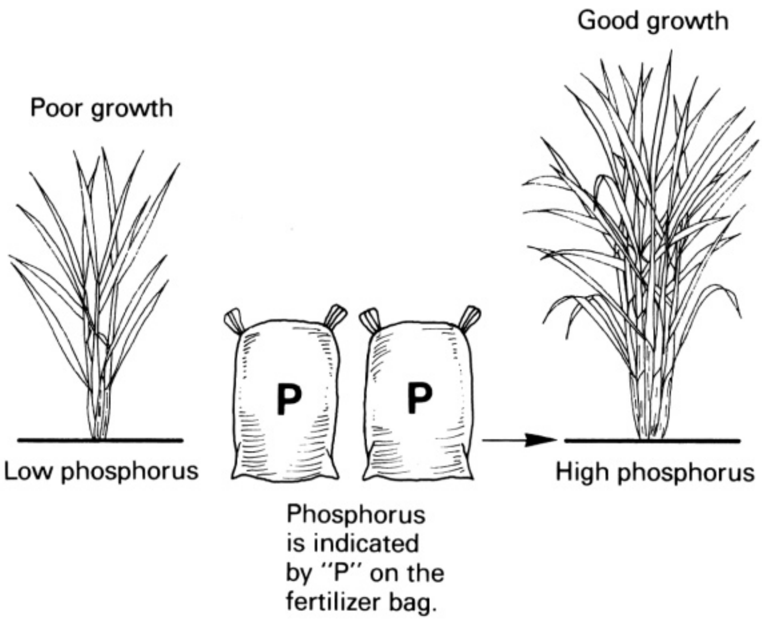
Keep the fields free from weeds

Nitrogen fertilizer

- Weeds compete with rice plants for nitrogen as well as water, light, and space.
- Like rice, weeds grow faster when fertilizer is applied.
- Remove weeds before applying nitrogen or immediately afterward. You can combine two operations — fertilizer incorporation and hoeing.

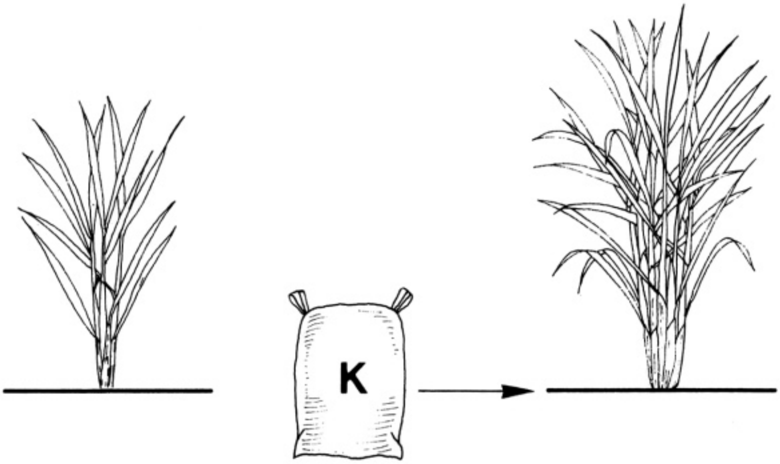
Other fertilizers and organic matter

Phosphorus



- Many upland soils in the humid tropics are acid and very deficient in phosphorus.
- Phosphorus fertilizers are very important in many upland soils.
- When the phosphorus level in acid soils is low, nitrogen efficiency can be low. Phosphorus must be applied to increase total soil fertility.
- Apply phosphorus as a basal fertilizer.

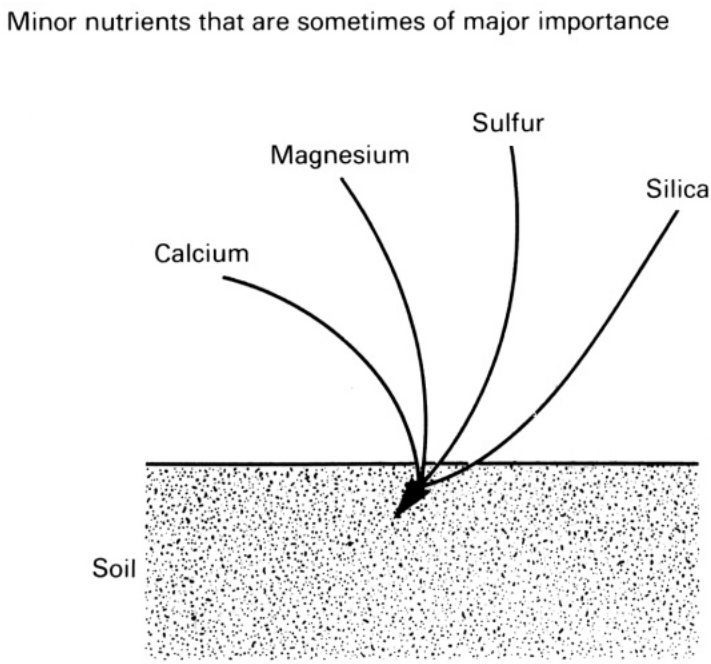
Potassium



Potassium is indicated by "K" on the fertilizer bag.

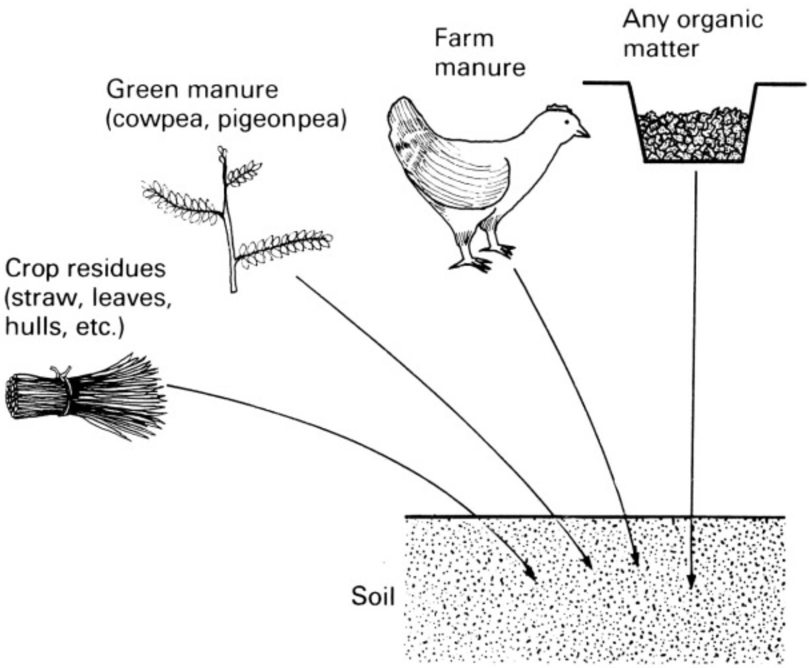
- Response of upland rice to potassium is generally low, except in highly deficient soils.
- Incorporation of straw into the soil raises its potassium content.
- Sufficient soil potassium minimizes lodging and diseases such as brown spot.
- Split application of potassium is best in some soils.

Minor fertilizers



- Calcium is the main nutrient missing in acid soils.
- Liming decreases soil acidity and provides calcium and magnesium.
- Small applications of minor nutrients sometimes give high yield increases.

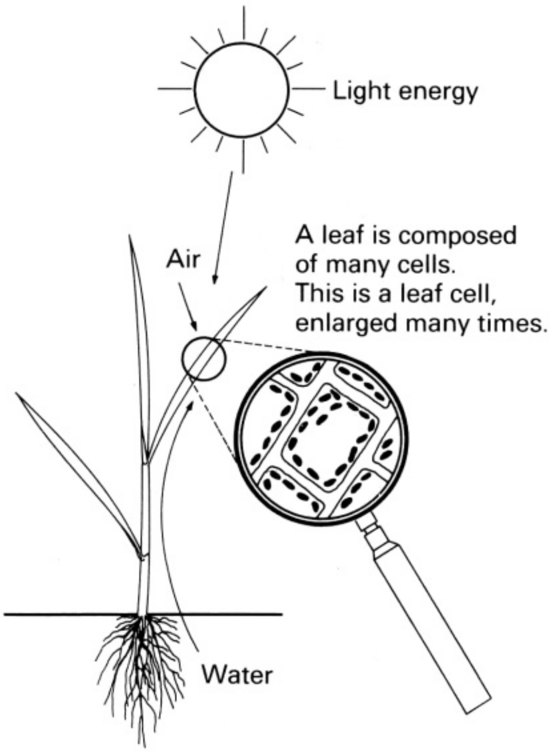
Organic matter



- Upland soils often lack organic matter.
- Incorporation of any type of organic matter into soils improves their physical and chemical properties.
- Avoid burning crop residues. Instead, plow the residues back into the soil.

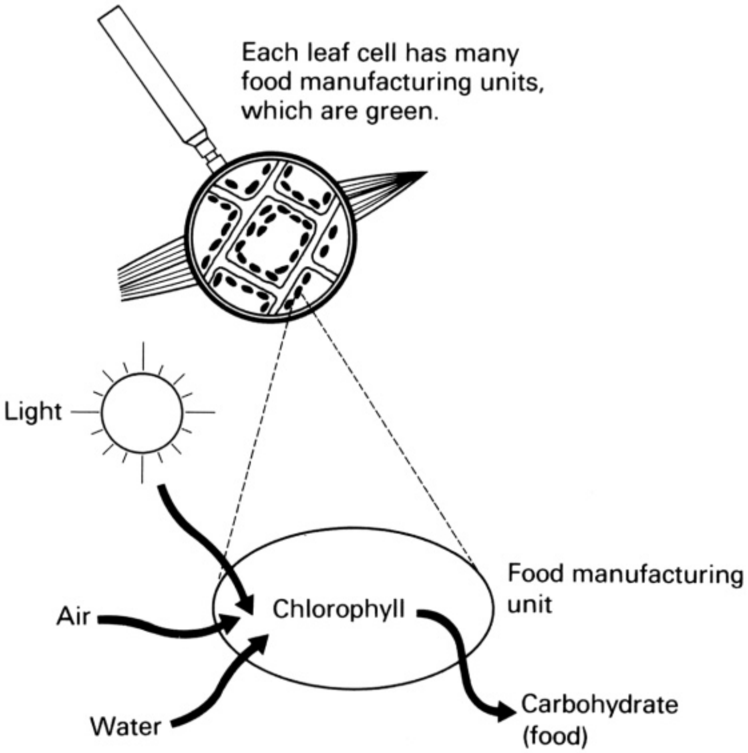
Carbohydrate production

Carbohydrate manufacture



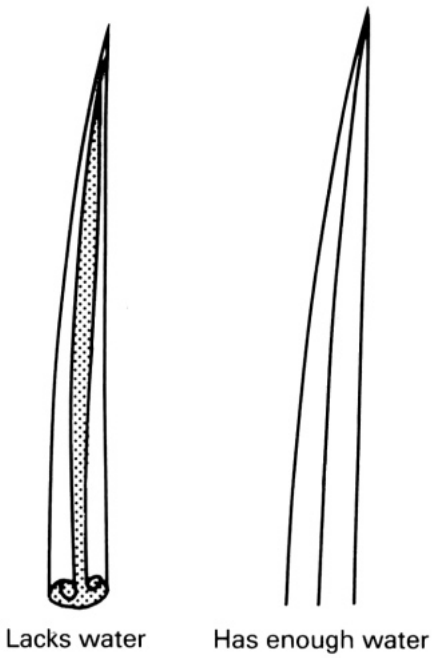
- Carbohydrates are food manufactured in the green leaves.
- Water from the soil and carbon dioxide from the air are the main materials in the manufacture of carbohydrates.
- The roots absorb water from the soil. Air enters the plant through pores on the leaf surface.

The food factory



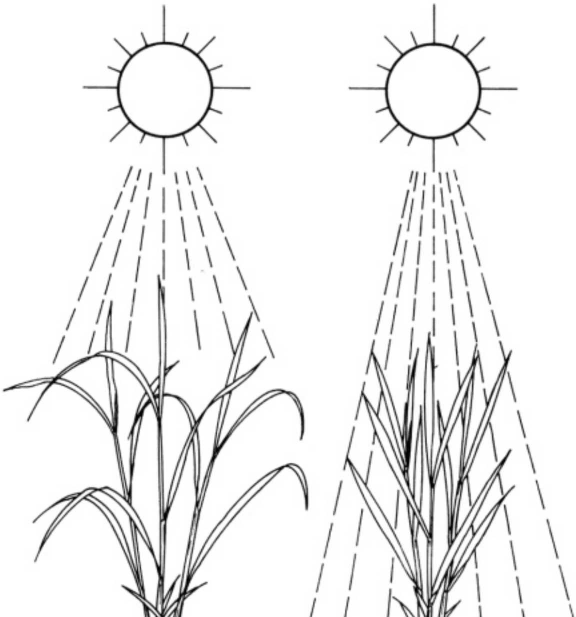
- Water and air combine in the food manufacturing unit to make food.
- Light provides the energy.
- The green color is chlorophyll. Chlorophyll collects the light energy.

Amount of water in the leaf affects carbohydrate production



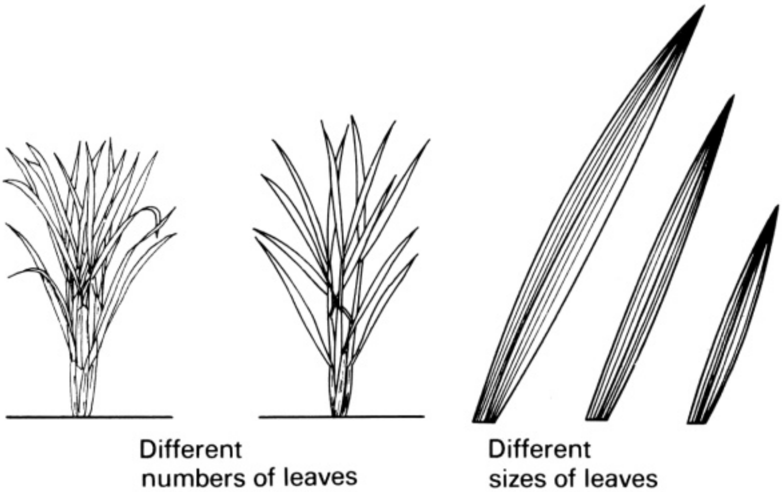
- When the leaves lose water, their pores close and air cannot enter. The leaves roll to protect the plant.
- This leads to decreased food manufacture.
- This occurs during drought.

Amount of light affects carbohydrate production



- Brighter light gives more light energy and thus higher carbohydrate production.
- Plants with erect leaves receive more light and thus manufacture more carbohydrate.

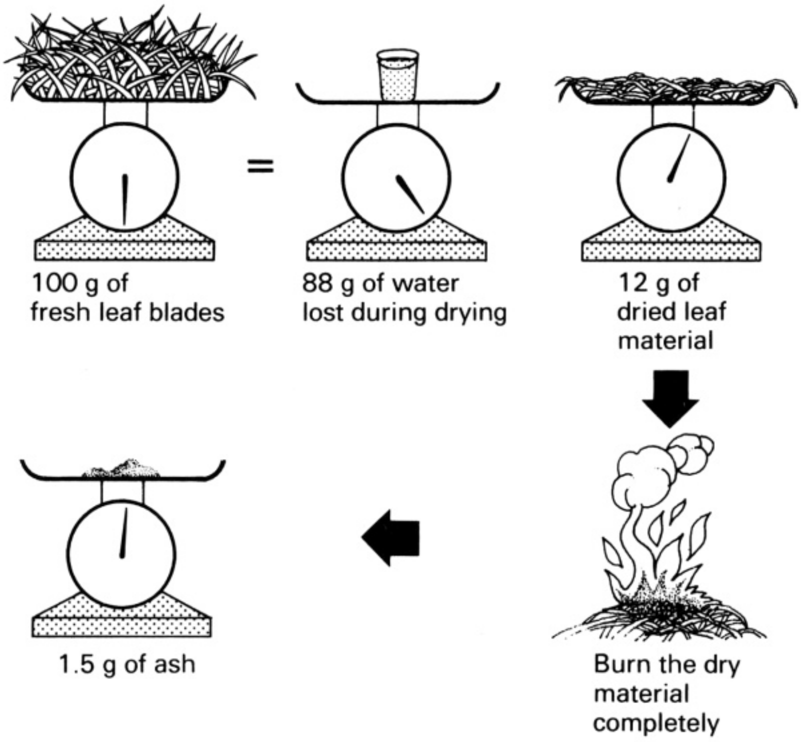
Amount of green color affects carbohydrate production



- The amount of green chlorophyll per plant increases as the number and size of the leaves increase. Thicker leaves usually have more chlorophyll.
- If any one of the four essential factors – water, air, light, or chlorophyll – is lacking, food manufacturing is slowed down, even if the others are abundant.

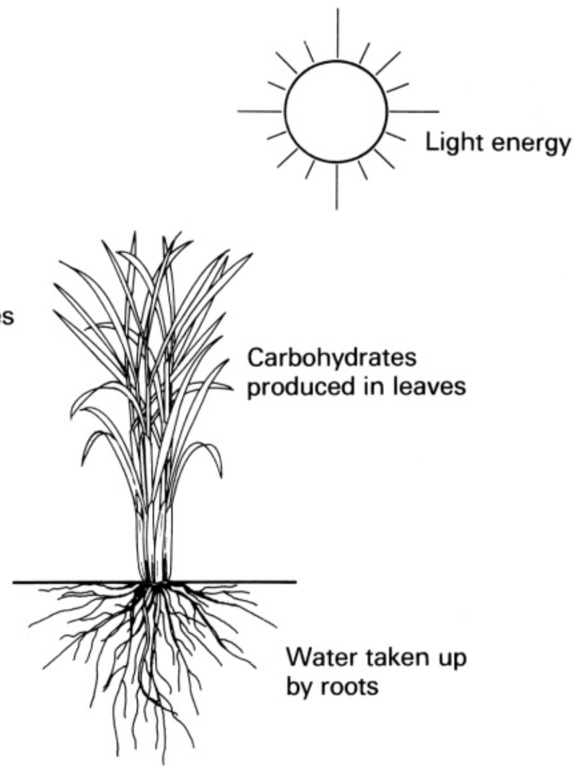
Water

Major components of the plant



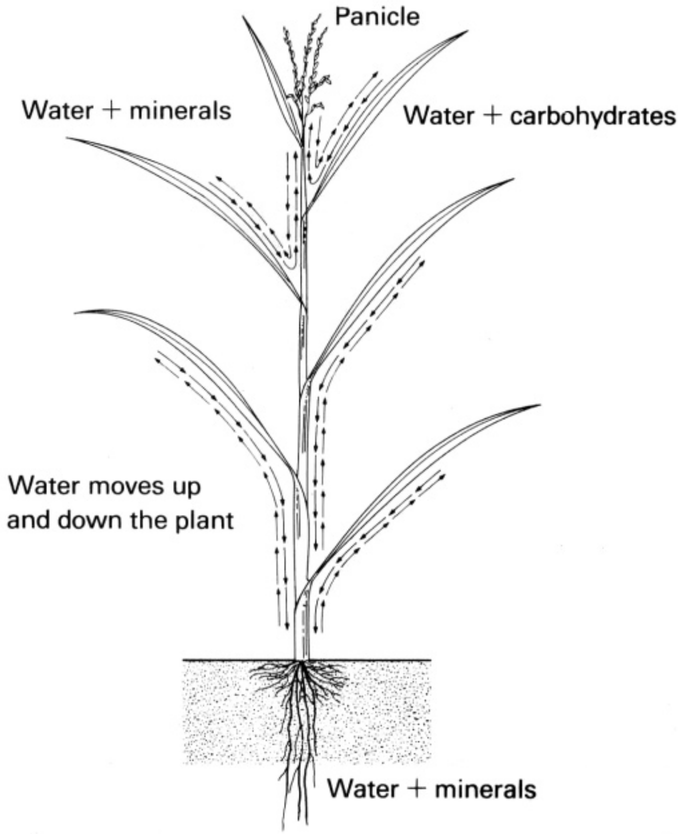
- The leaves, culms, and roots are made up mostly of water. The grains have less water.

Raw material for food manufacture



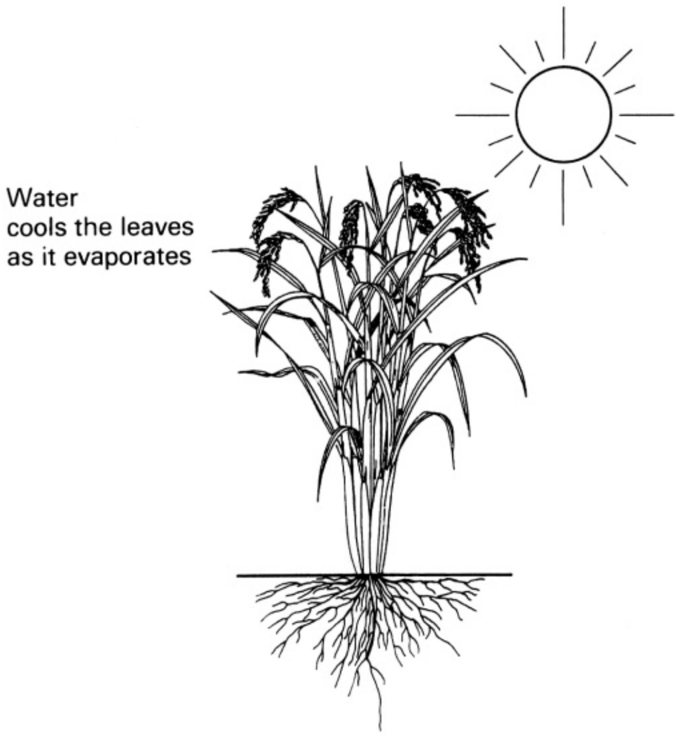
- Water is the first limiting factor in upland rice.
- Drought spells decrease the amount of food manufactured.

Water carries the food



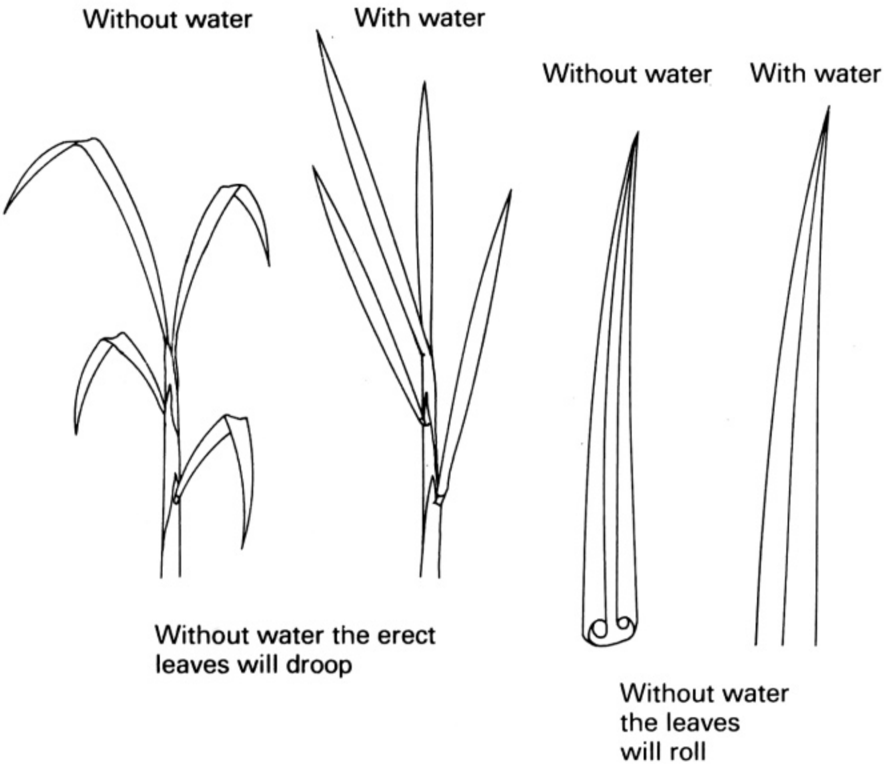
- Water carries the carbohydrates and mineral nutrients to the plant parts.
- One hectare of rice plants uses at least 8 million liters (400,000 big kerosene cans) of water for one crop.

Water cools the plant



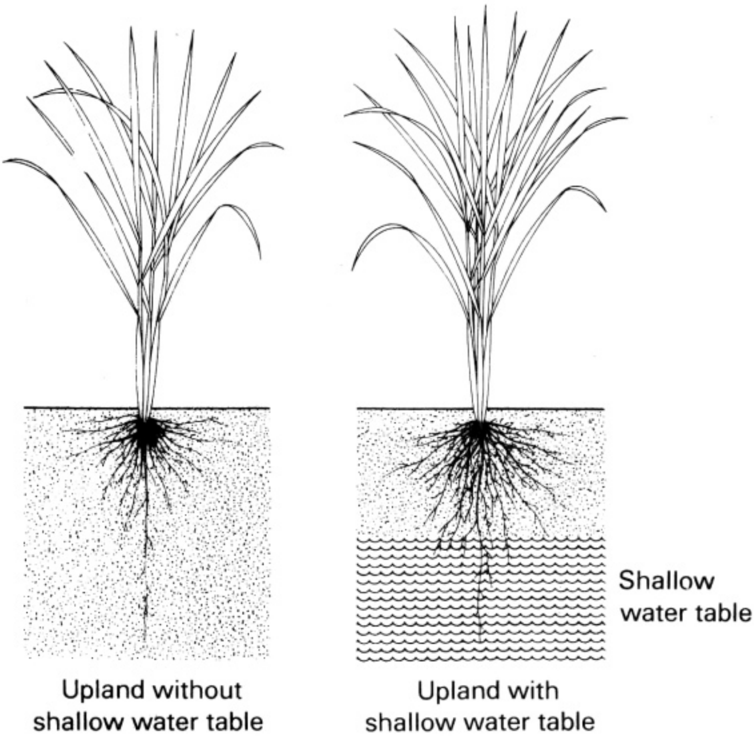
- As water evaporates, it cools the leaves the way perspiration cools our bodies.
- Without water in the leaves, the pores close. Water cannot pass out, and air cannot enter. Growth is greatly slowed down.
- If the temperature is too high and water does not evaporate, the leaves dry up.
- Most of the water taken up by the rice plant is lost through evaporation.

Water stiffens the plant



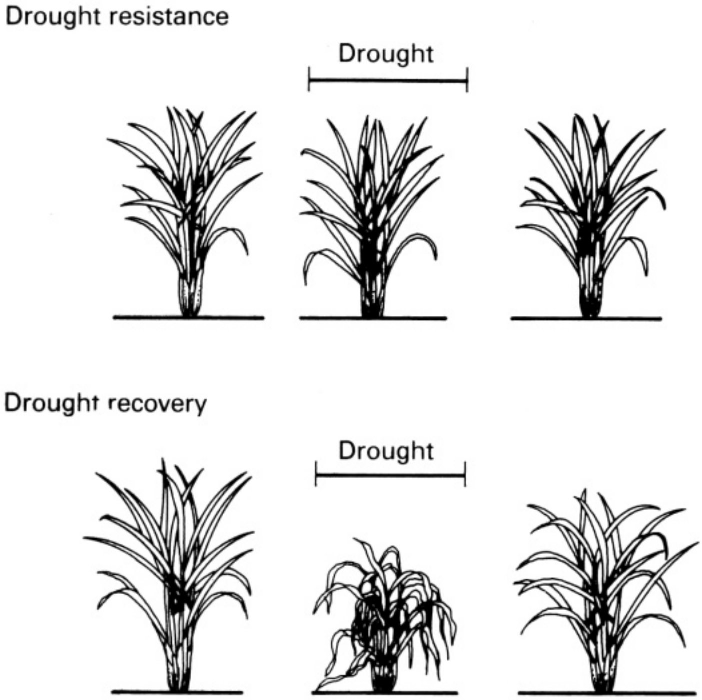
- Water helps in making the leaves erect and fully expanded.
- Water in the plant is like the air in the tires of a car.
- During drought spells, leaves dry and turn whitish or bluish green. They die if drought is severe.

Influence of shallow water table



- The presence or absence of a water table is very important to the growing plant.
- Some upland areas have a permanent or temporary shallow water table.
- Drought injury is much more severe if there is no shallow water table.

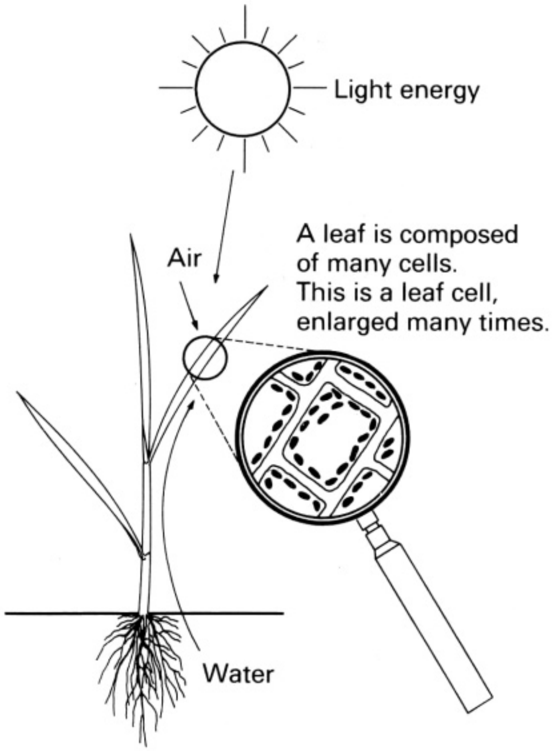
Drought resistance and recovery



- Drought resistance. Drought has no or little effect. Leaves are lightly dried or rolled. Growing is not delayed or is only slightly disturbed.
- Drought recovery. During a drought spell, leaves dry up and growth stops. After the rains, some leaves turn green and growth starts again.

Yield components

Growth stages when yield components are determined

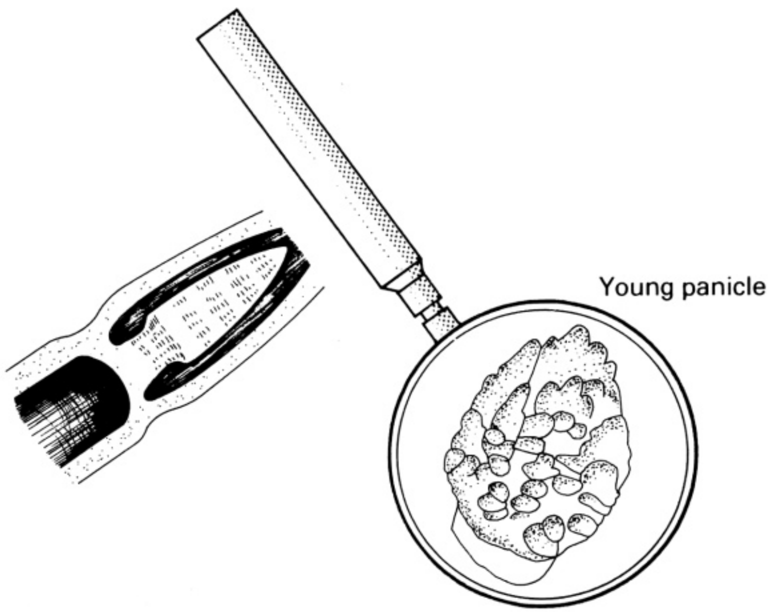


- Every stage of growth contributes to grain yield. Good management is necessary at all stages.
- Environmental factors affect every stage.

Leaf development and tillering affect yield

- The number of tillers determines the number of panicles and is a very important factor in grain yield.
- Enough leaves are necessary to ensure a large number of spikelets and to fill the spikelets.
- Enough water, the right amount of fertilizer, proper spacing, and good weed control produce the most tillers.

Panicle formation affects yield



- The number of spikelets per panicle is determined at the panicle formation stage.
- Drought during this stage can cause aborted spikelets. If drought is severe, spikelet abortion can be 100%.
- Other factors such as low available light energy can also cause spikelet abortion.
- Spikelet abortion means lower yield.

Flowering affects yield

- Transfer of the male cell to the female cell in the ovary occurs at flowering.
- Successful transfer will determine the development of the spikelet into a grain.
- The percentage of fertility of the spikelets is one important yield component.
- At any time between panicle formation and flowering, drought can cause irreversible yield loss.

Ripening affects yield

- The weight of a single grain is determined at ripening.
- Drought between flowering and ripening will cause lower grain weight.

Importance of yield components

- A detailed study of the different factors contributing to grain yield (yield components) can reveal why yields are high or low.

$$\text{Grain yield in grams per square meter} = \text{Number of panicles per square meter} \times \text{Number of spikelets per panicle} \times \text{Percentage of fertile spikelets} \times \text{Weight of a single grain in grams}$$

- Each yield component shows wide variation.
- Row or hill sowing can modify the number of panicles per square meter.
- The number of spikelets per panicle in a variety can vary from about 50 to more than 200.
- The percentage of fertile spikelets is greatly dependent on environmental conditions. Drought incidence is therefore very important.
- The weight of a single grain of a variety can vary from less than 0.01 g to more than 0.04 g.

- Two examples of yield calculation:

	Example 1	Example 2
Panicles per square meter		
Hill sowing	150	
Row sowing		210
Spikelets per panicle		
Traditional	120	
Improved		80
Percentages of fertile spikelets		
Drought	50	
No drought		75
Weight of a single grain		
Heavy	0.034	
Light		0.024
Yield in grams per square meter	300	300
Yield in t/ha	3	3

- Two conclusions:
  - With very different data for each yield component, the same yield is obtained.
  - Yield is affected by important changes in the environment. Poor soil fertility and percent sterility induced by drought are very important yield-limiting factors.

Variations in yield components

Few but large panicles
= panicle weight type

Many but small panicles
= panicle number type

- Increase in grain yield of *panicle number* types is usually the result of an increase in number of panicles.
- Increase in grain yield of *panicle weight* types is usually the result of an increase in weight per panicle.
- Most modern high-yielding varieties are *panicle number* types, while traditional varieties are *panicle weight* types.

How to use yield components

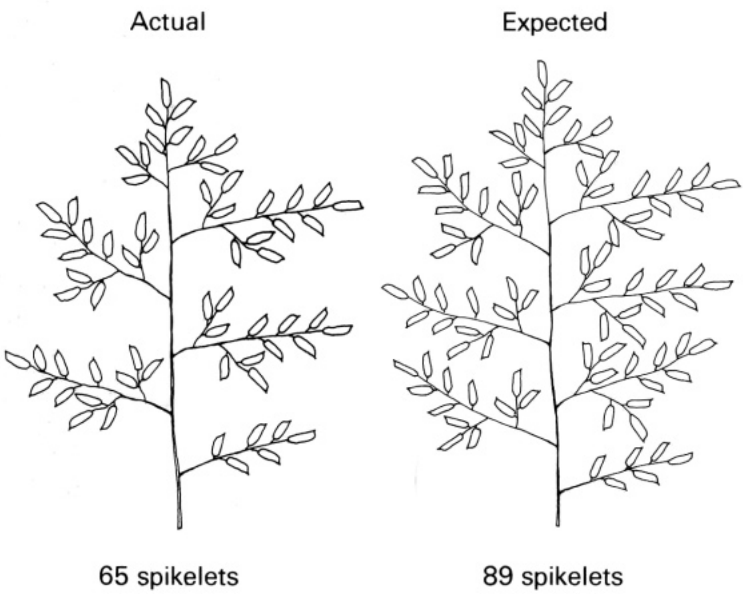
Problem: few panicles per plant

Actual | Expected

3 panicles | 8 panicles

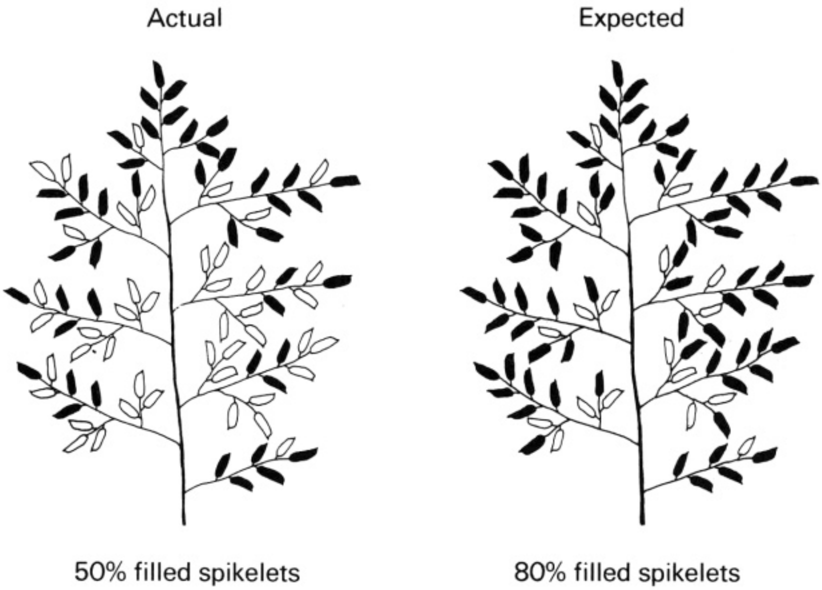
- What was wrong: a defect in the soil or in the application of fertilizer, lack of water during tillering, or damage by pests and diseases during early growth.

Problem: few spikelets per panicle



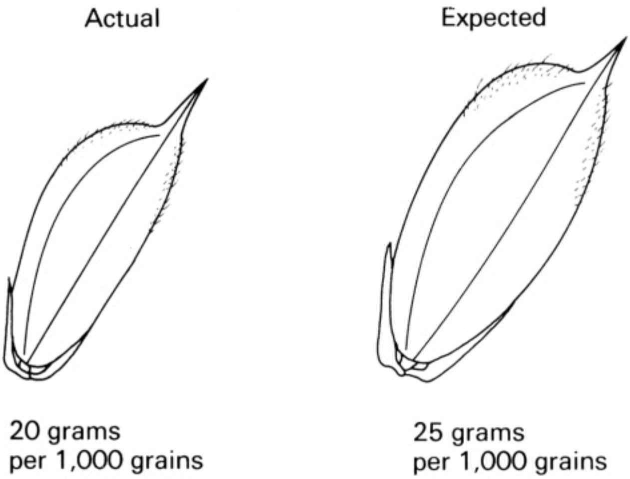
- What was wrong: The problem occurred during the growing of the crop, a little before or during the formation of the spikelets. It possibly resulted from lack of food in poor soils, drought stress during panicle initiation, or heavy disease or insect damage to the leaves.

Problem: low percentage of fertile spikelets



- What was wrong: lack of water before or at flowering time, too much applied nitrogen, very heavy rains at flowering, insect damage such as from stem borers or disease injury at booting, temperature above 35°C at flowering, or lodging.

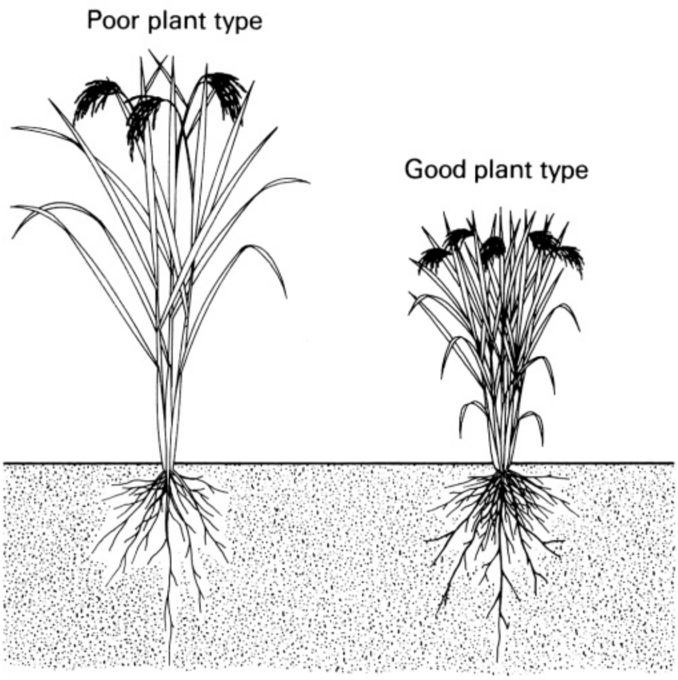
Problem: low weight of single grain



- What was wrong: unfavorable conditions after flowering, such as intense drought, not enough food in poor soils, not enough green leaves to manufacture the food, or very cloudy and rainy weather.

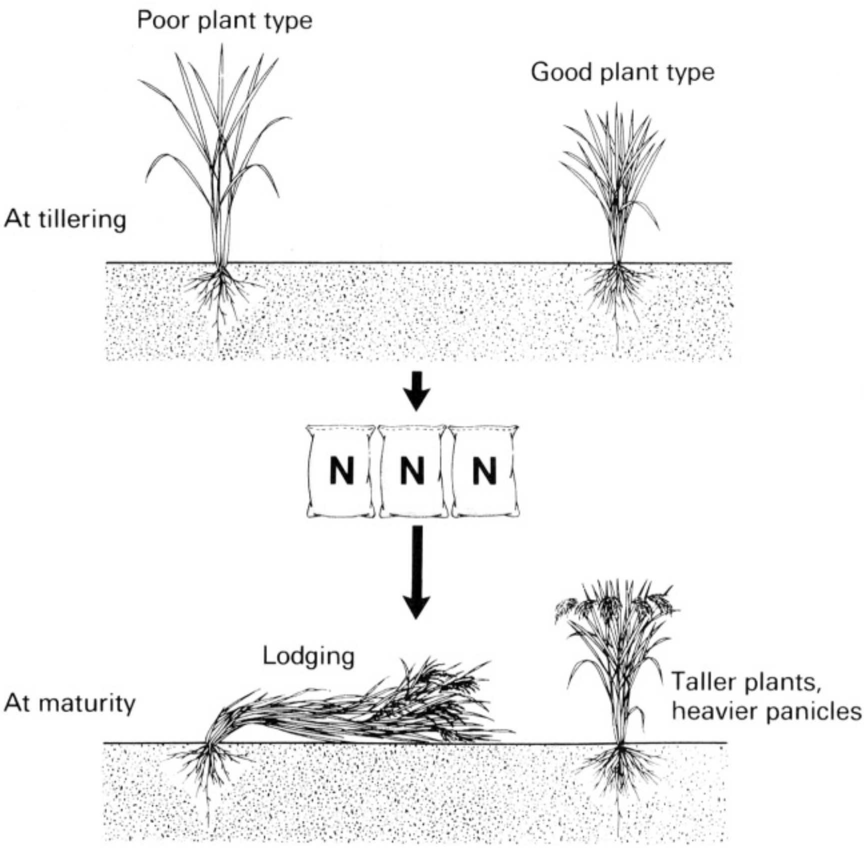
Plant type with good yield potential

Short to intermediate stature



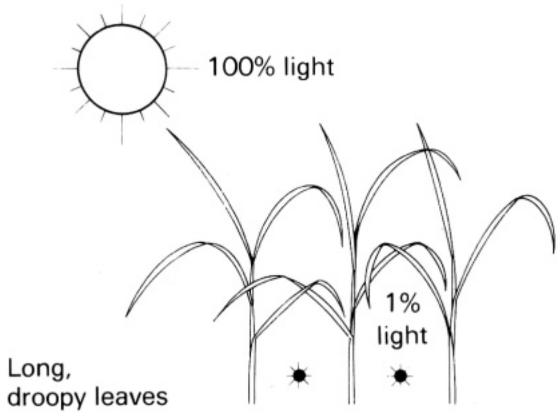
- Reduction in height is very important in increasing yield potential.
- Good plant types have deep roots and short to intermediate stature.

Nonlodging

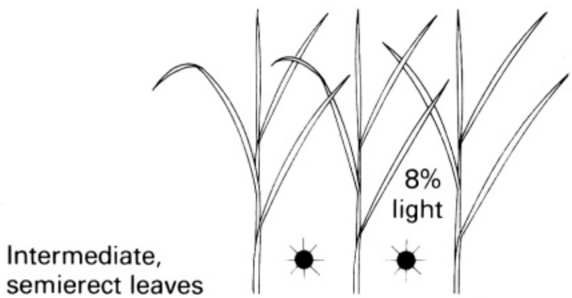


- Height increases with nitrogen application. Lodging becomes a problem with tall, traditional types.
- Early lodging causes lower grain weight because less food is provided to the panicles.

Semierect, semilong leaves

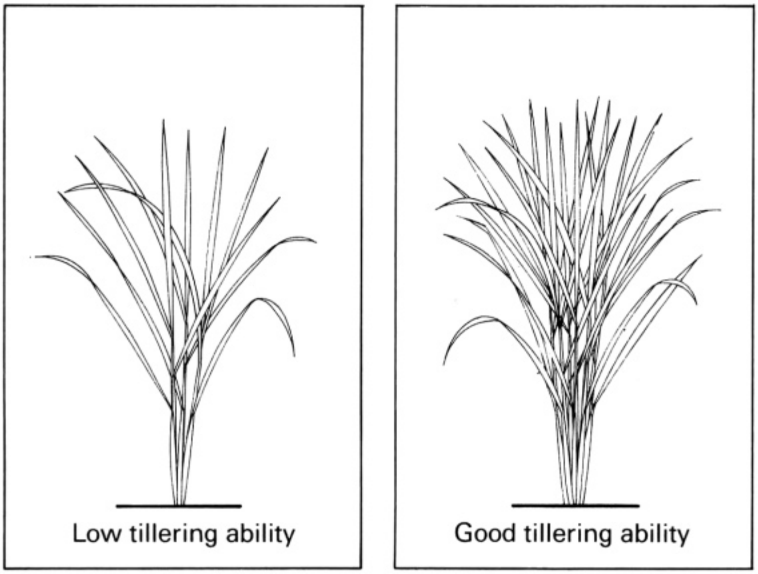


- Little light is received by lower leaves



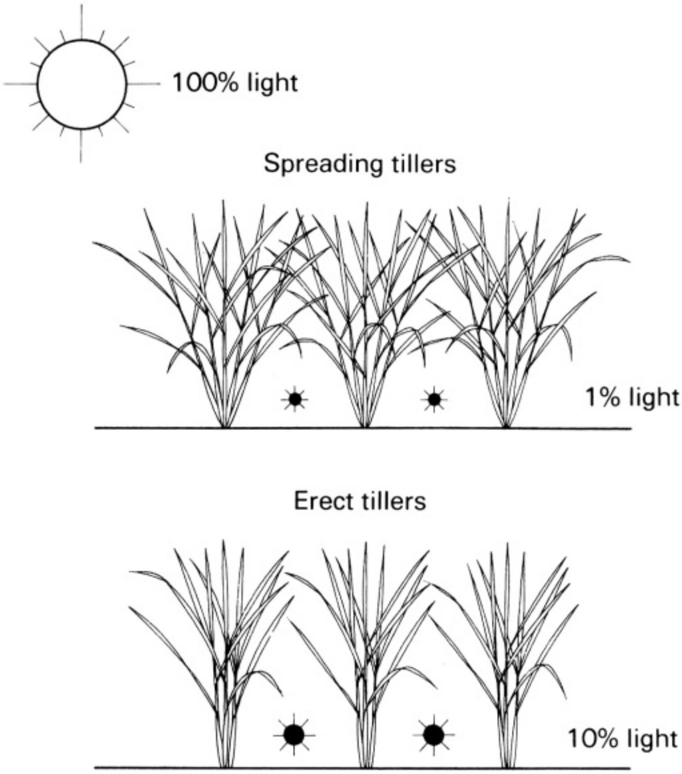
- Less shading of lower leaves

Good tillering



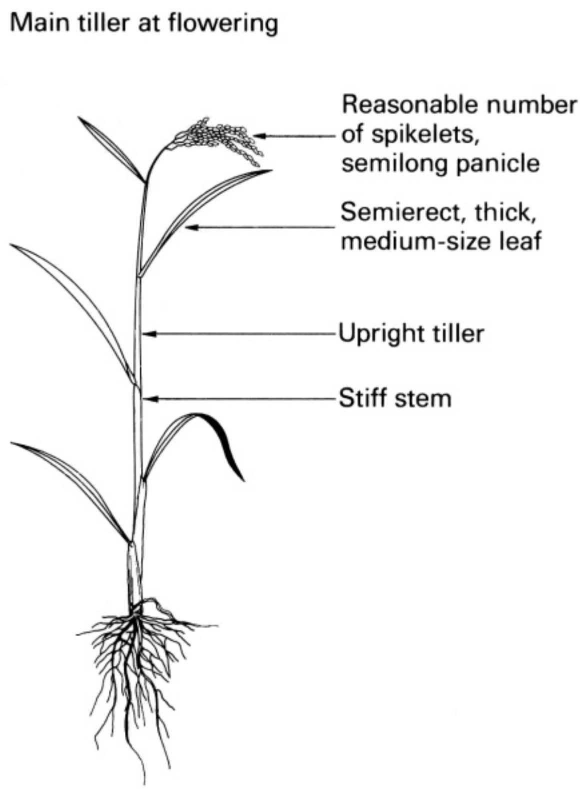
- A good number of productive tillers ensures adequate tillers per square meter.

Erect tillers



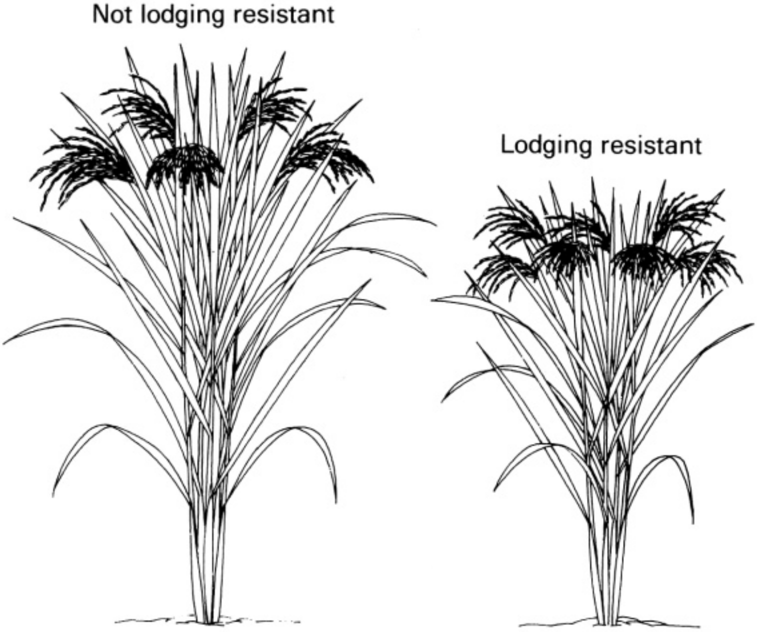
- Upright tillers give better light distribution.

A desirable tiller



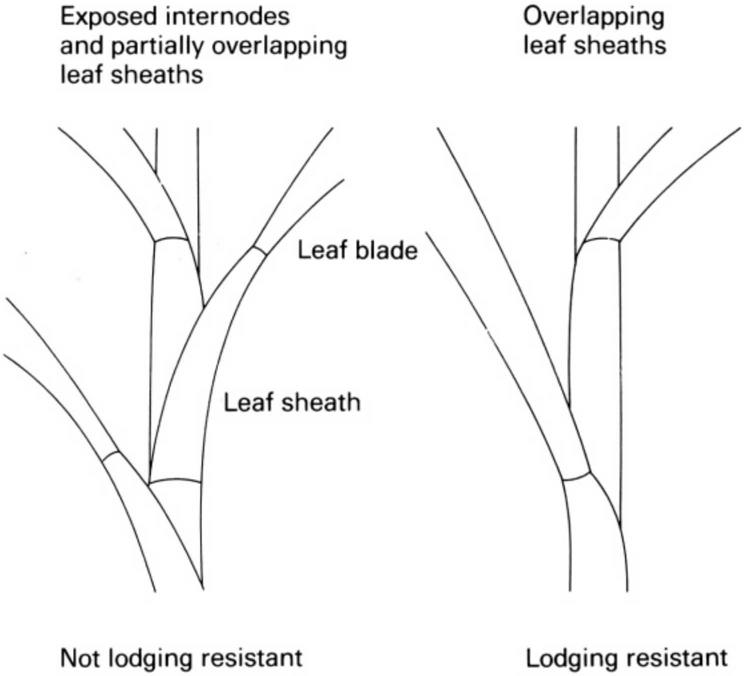
Factors that affect lodging

Plant height

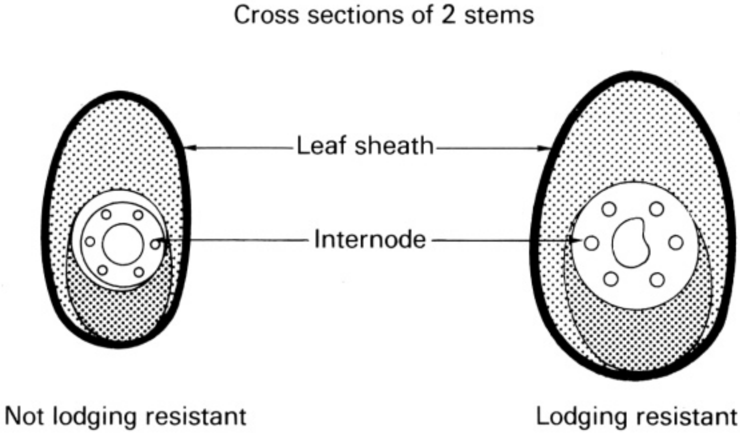


- The taller the plant, the greater is the tendency to lodge.
- Short, stiff stems prevent lodging.

Type of leaf sheath



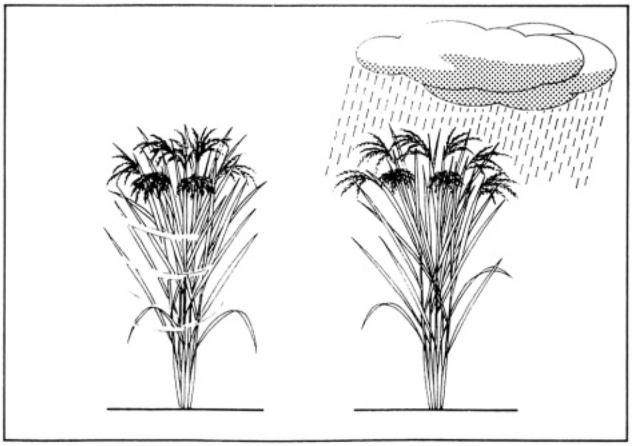
Stem thickness



- The thicker the stem and the thicker the internode, the higher is the resistance to lodging.

Wind and rain

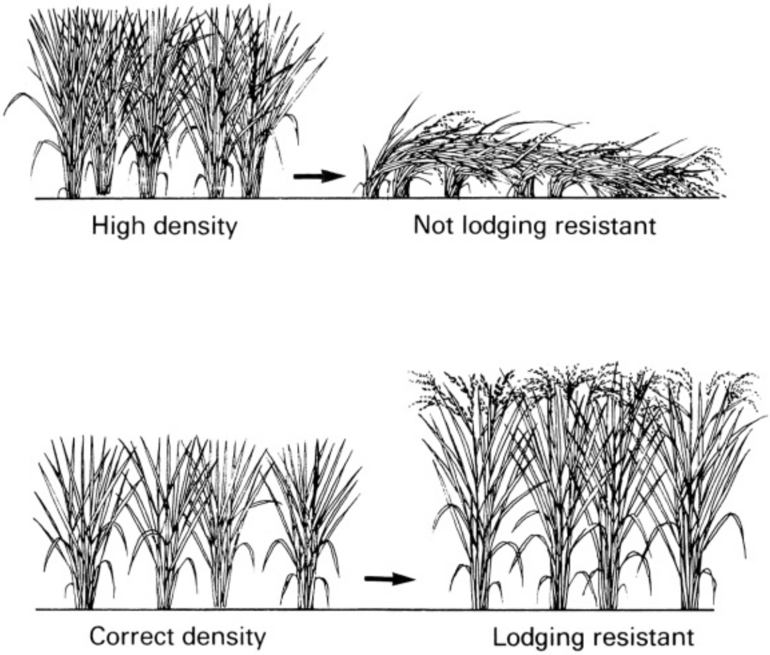
Not lodging resistant



Lodging resistant

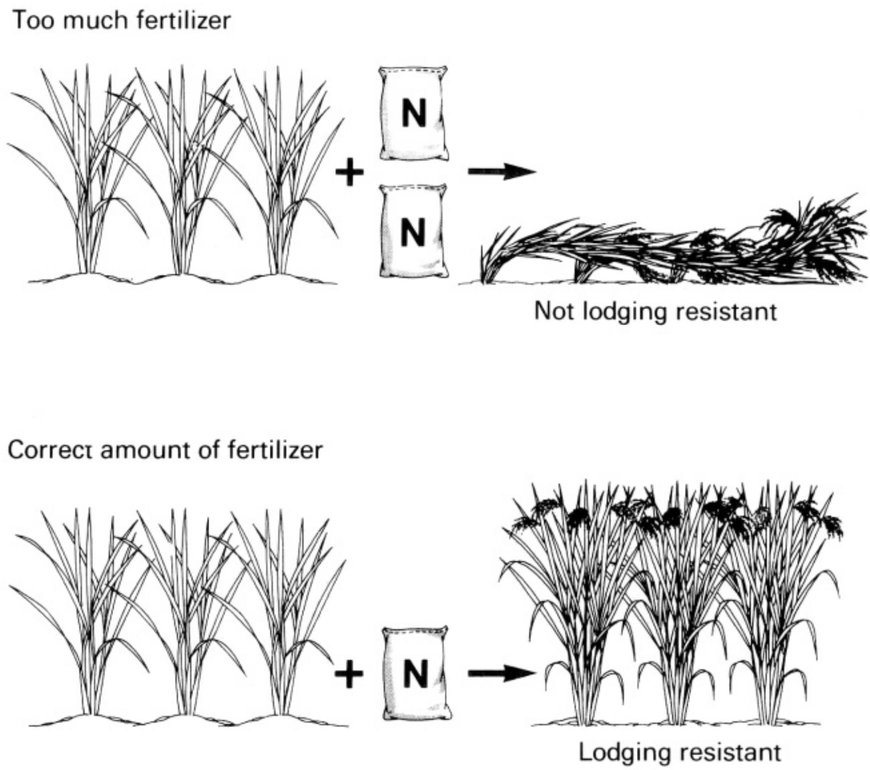
- Wind and rain can cause the plant to lodge. The stronger the wind, the more likely the plant will lodge.
- Avoid using tall varieties.

Seed density



- High density causes taller plants and weaker stems.

Amount of fertilizer

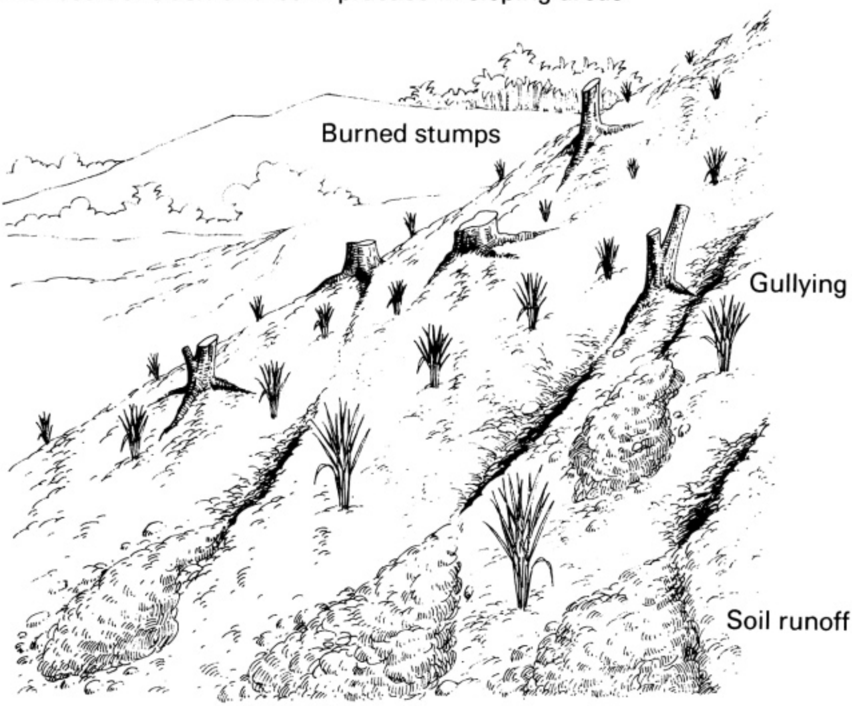


- Fertilizer, mostly nitrogen, increases plant height. Tall varieties cannot stand too much fertilizer.

Land conservation and crop management

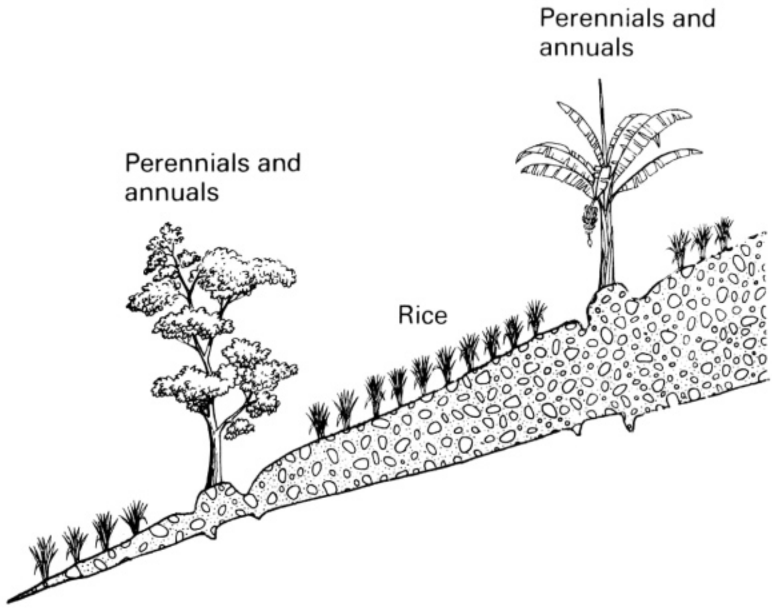
Damage caused by erosion

The result of slash-and-burn practice in sloping areas



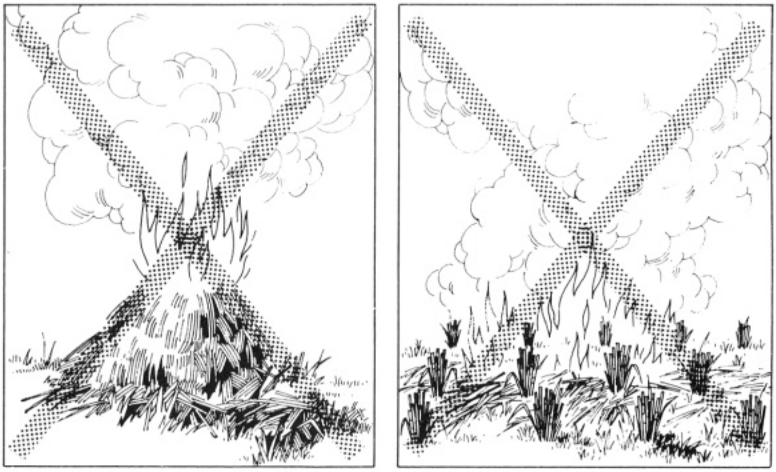
- Burning or clearing of natural vegetation from sloping lands exposes the soil to running water and causes erosion.
- When erosion is severe, the land becomes useless for cultivation. Even natural vegetation cannot grow again.

Protection against erosion



- On sloping areas, intercrop and plant perennials and annuals on levees following contour lines.
- The steeper the slope, the closer the levees should be.
- Sow rice in rows following contour lines.
- If the slope is too steep, do not plant rice.

Cleaning the land



Do not burn your forests.

Do not devastate your countryside.

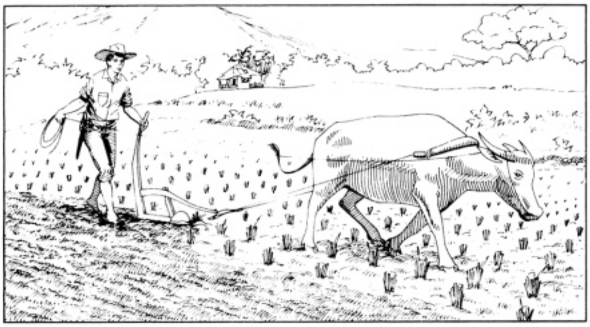
Protect your lands for your children's and your grandchildren's future.

Avoid burning. It is dangerous for the soil because organic matter is destroyed.

- Be careful in cleaning the land to avoid erosion.
- Avoid forest destruction.
- The slash-and-burn system destroys soil and is dangerous for the future of the land.
- Slashing the vegetation and incorporating the residue into the soil is better, even if more time is needed.

Plowing

Plowing the land



After plowing, keep the land weed free.

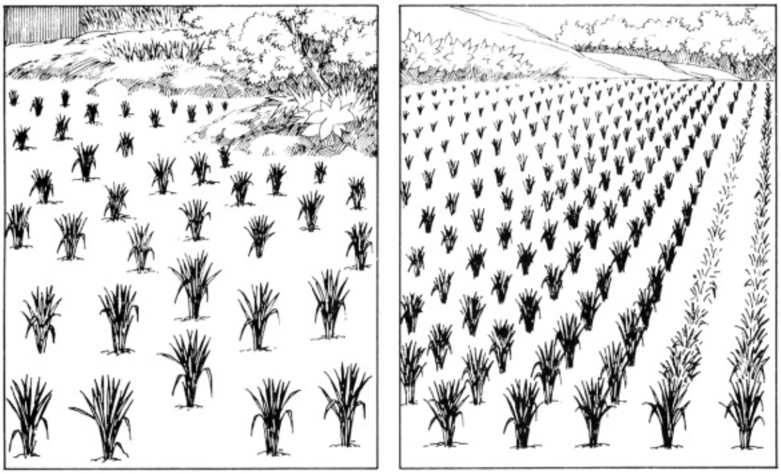
- Animals or tractors can be used for plowing.
- Plow as deep as possible.
- In sloping areas, plow according to contour lines and never with the slope.
- Plow at the end of rainy season, just after harvesting the crop.
- Correct plowing means better land preparation.
- Correct plowing makes harrowing easier.
- Keep fallow land weed-free by tillage during dry season.

Harrowing/hoeing and final tillage

Different methods of harrowing/hoeing

- Animals or tractors can be used for harrowing.
- After plowing, harrowing or other final land preparation ensures a proper seedbed for sowing.
- Harrowing just before sowing means better weed control.
- Good harrowing and tillage prevent weed infestation during early stages of rice growth.

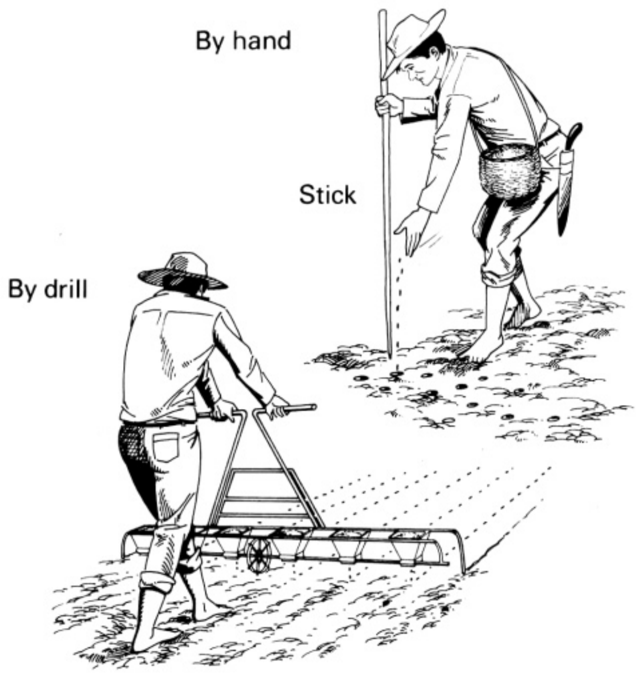
Sowing



Hills Rows

- Seeding rate varies with soil and variety, and ranges from about 25 to 100 kg/ha.
- Avoid random hill sowing because it requires more time for weeding. Also, weeding with random hill sowing is more difficult than with row sowing.
- The distance between rows varies with soil and rainfall. It ranges from 25 to 60 cm.

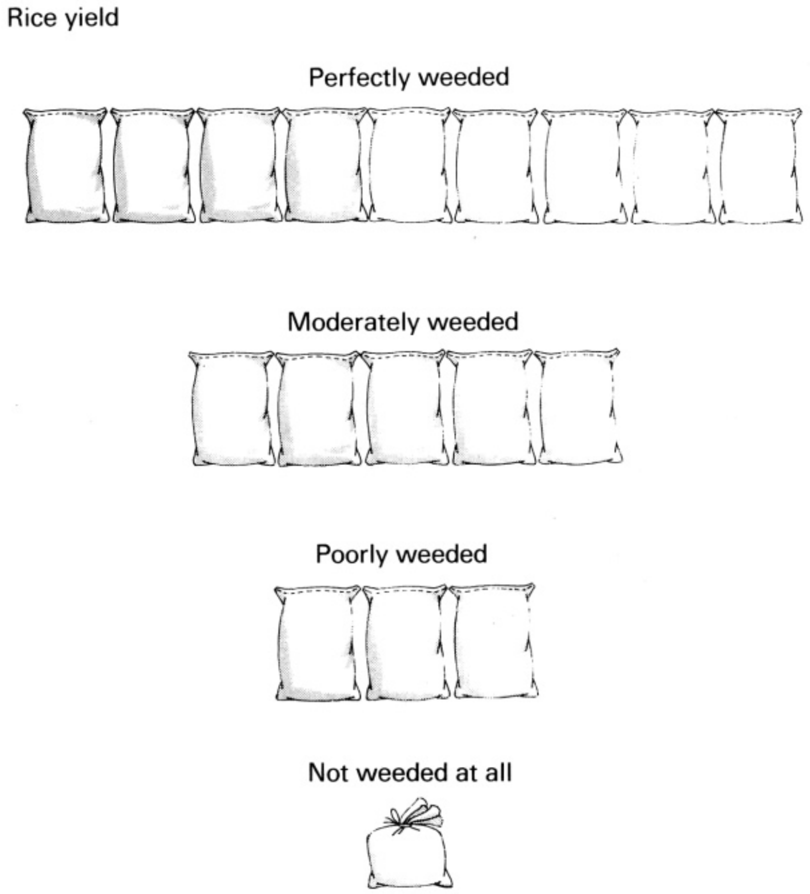
Methods of sowing



- Weeds are difficult to control if rice seed is broadcast.
- Hill sowing and row sowing by hand are time-consuming. They are used mainly on steep slopes or small areas.
- Drill sowing ensures better spacing, better germination because of controlled sowing depth, and easier weeding by mechanical tools.
- Hand or animal/tractor drills are available in many sizes.

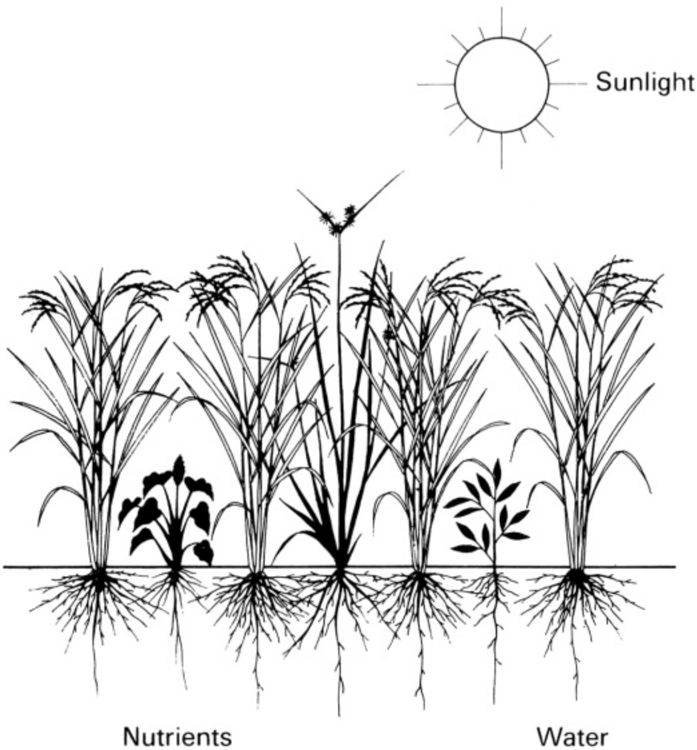
Weeds

Weeds reduce rice yield drastically



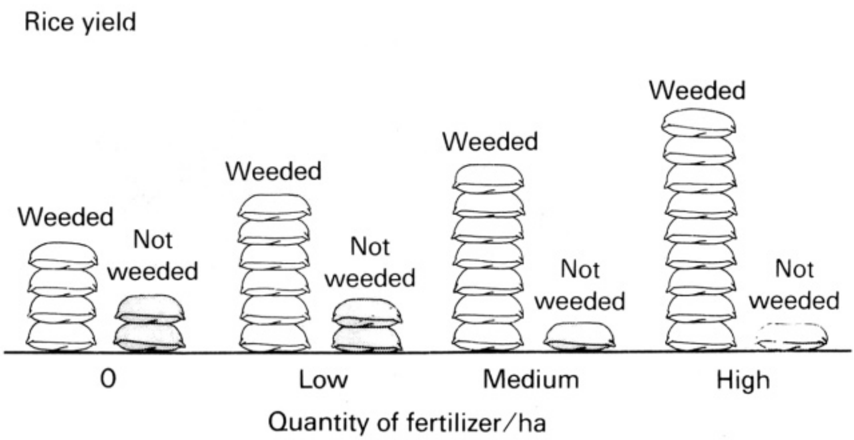
- Weeds are the major constraint in upland rice.
- Good weed control means large yield increases.

Weeds compete with rice



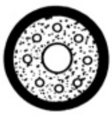
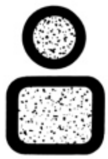
- Weeds compete with rice for water, nutrients, and sunlight.
- If any of these is lacking, the others cannot be used effectively, even if present in large amounts.
- Competition results in poor rice growth and less grain yield.

Weeds decrease the effect of fertilizer



- Weeds compete with rice for the applied fertilizer, mostly nitrogen.
- Applied nitrogen favors the growth of weeds more than the growth of rice.
- The higher the amount of fertilizer applied, the less is the grain yield if the crop is not weeded.
- Nitrogen fertilizer should not be used until weeds are controlled.

Differences among grasses, sedges, and broadleaves

Character	Grasses	Sedges	Broadleaves
Leaf shape			
Vein arrangement			
Stem cross section			
Plant shape			
Examples	*Rottboellia, Digitaria, Imperata, Echinochloa, Cynodon*	*Cyperus*	*Amaranthus, Commelina, Portulaca, Ipomoea*

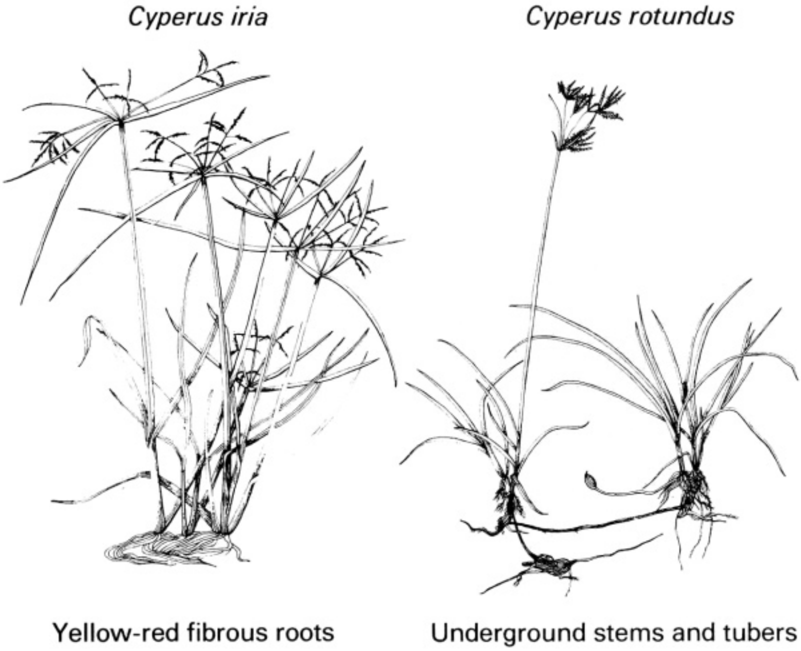
Common grasses in upland ricefields

Eleusine indica

Digitaria ciliaris

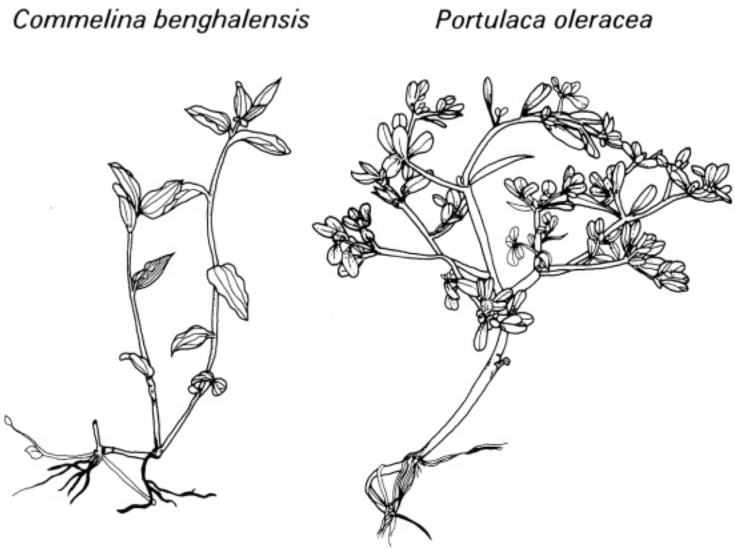
- Serious, difficult to control

Common sedges in upland ricefields



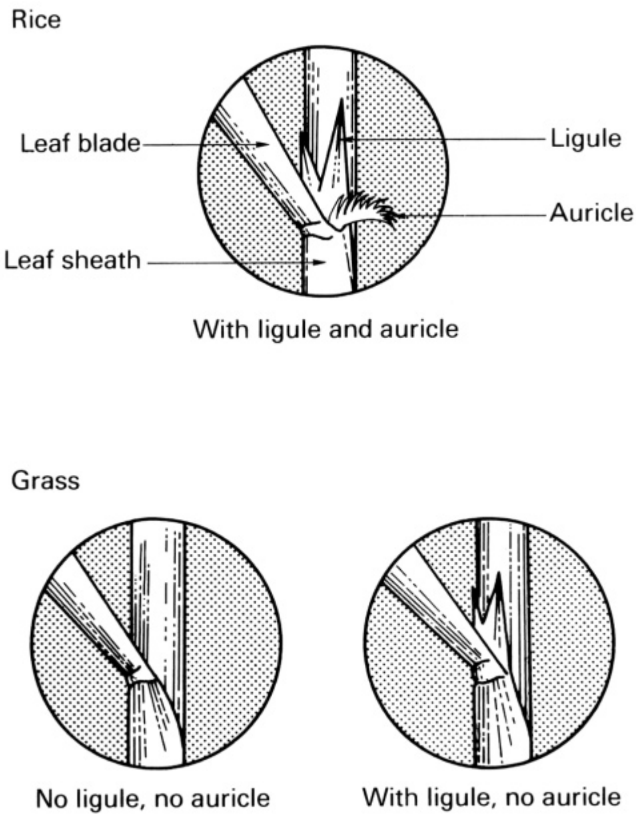
- Very serious, very difficult to control

Common broadleaved weeds in upland ricefields



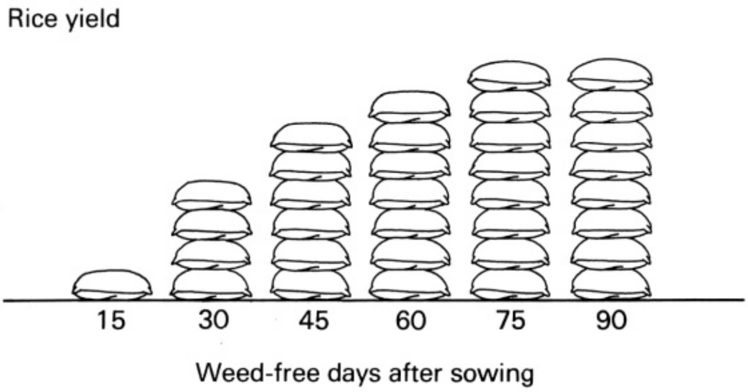
- Serious, but easier to control

Differences between grasses and rice



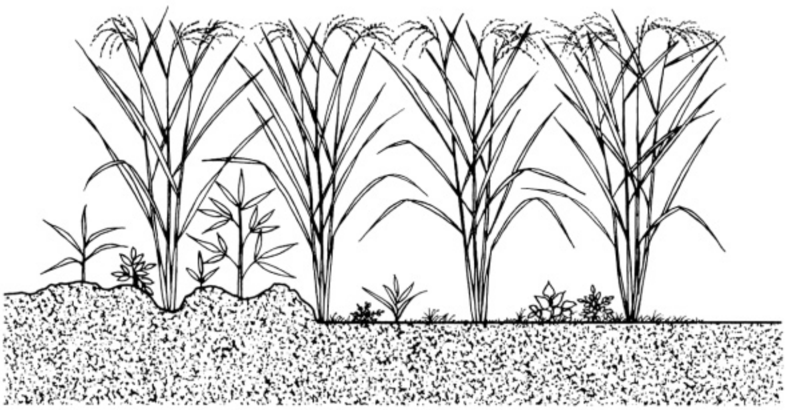
Control of weeds

When to weed the rice crop



- Weeding in the first 3 weeks after sowing rice is very important.
- Weeding during the first 3 weeks of rice growth means better growth and higher yield.
- Grain yield is drastically reduced if rice is not weeded during early growth stages.

Control by land preparation

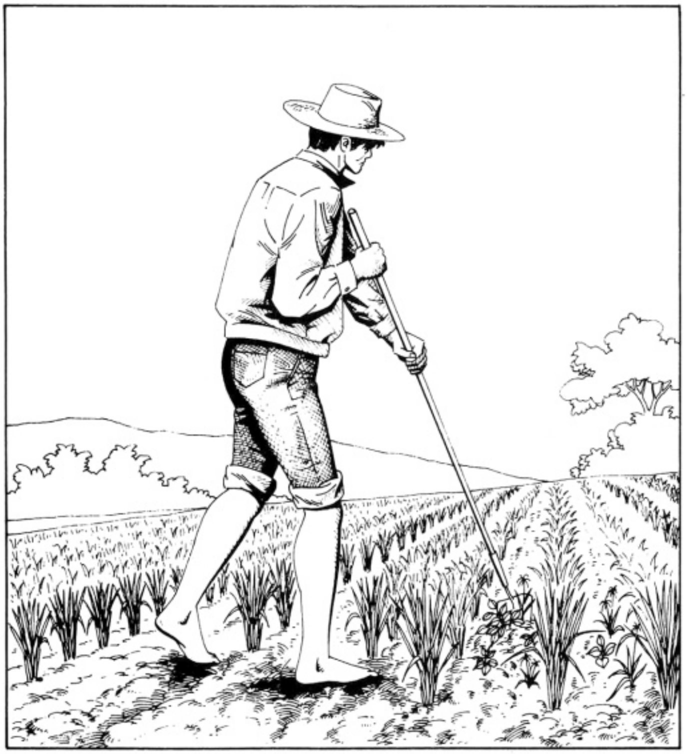


- Weeds can grow better than rice when land is poorly and unevenly prepared.
- Deep plowing ensures better land preparation because weed seeds and seedlings are buried.

Control by hand

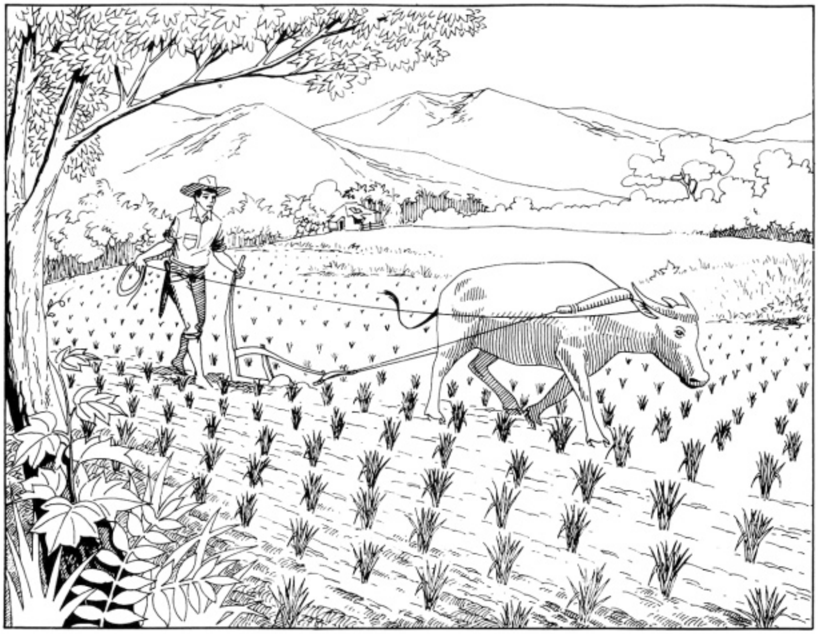
- Hand pulling is difficult and time-consuming.
- Cutting the weeds at the soil level with a blade is inefficient.

Control by hand tools



- Using a hand weeder, such as a hoe, is more efficient than hand weeding.
- Straight row sowing is better if a hoe is to be used.
- When possible, hoe after a light rain when the soil is soft.

Control by animals or tractors



- An animal or tractor can be used for weeding.
- With row sowing and wider spacing between rows, interrow cultivation can be done more easily.

Control by crop competition

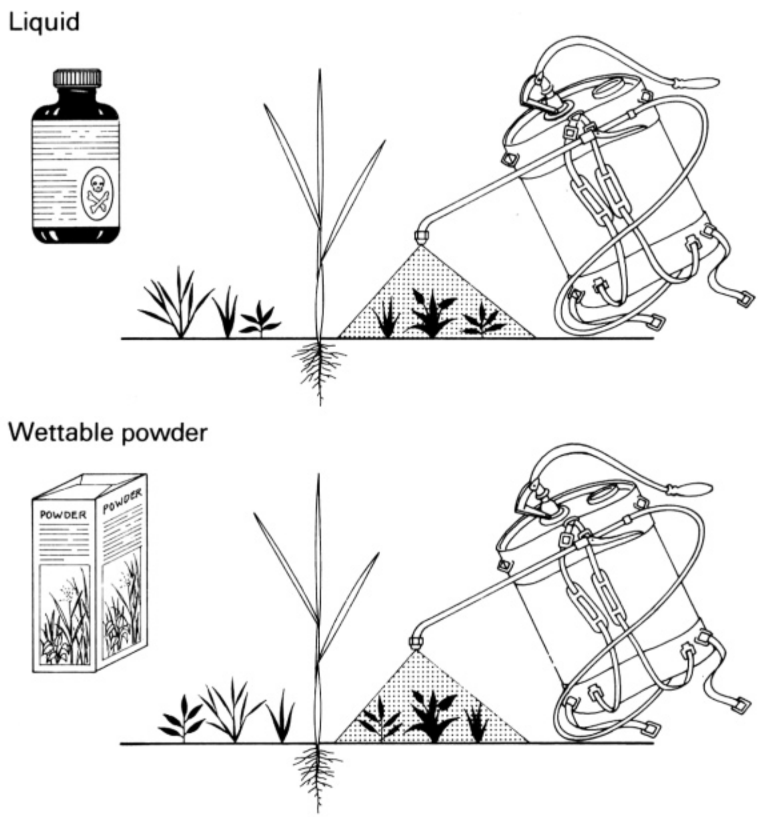
- The closer the rows the fewer the weeds — there is less light for the weeds to germinate and grow in.
- Tall, traditional rice cultivars are more competitive against weeds than many improved lines.
- Row sowing is better than hill sowing, because less space is available for weeds.

Control by herbicides

- Using herbicides requires less labor than any other weeding method.
- When well managed, herbicides are more efficient and less costly than any other weeding method.

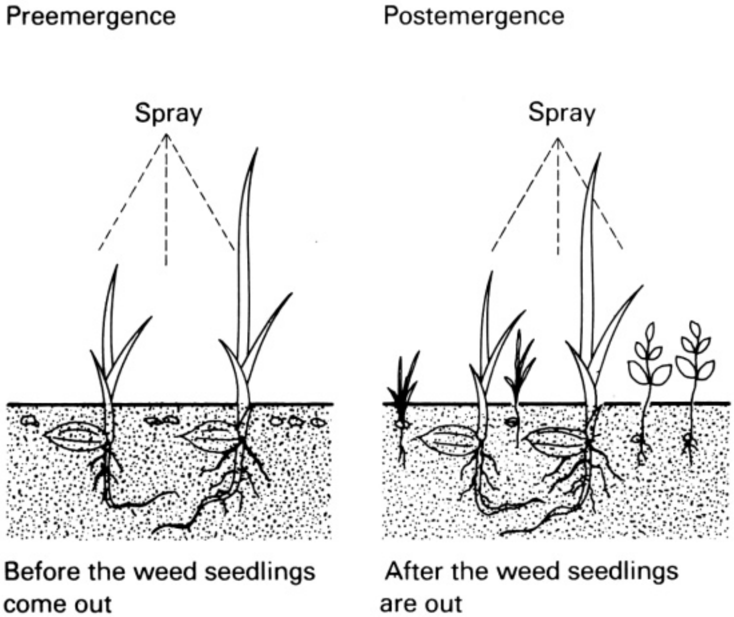
Herbicides

Types of herbicide based on formulation



- Most commercial herbicides are either liquid or powder.
- Both are mixed with water and sprayed.
- Low-volume sprayers, which use much less water than conventional sprayers, are preferable.

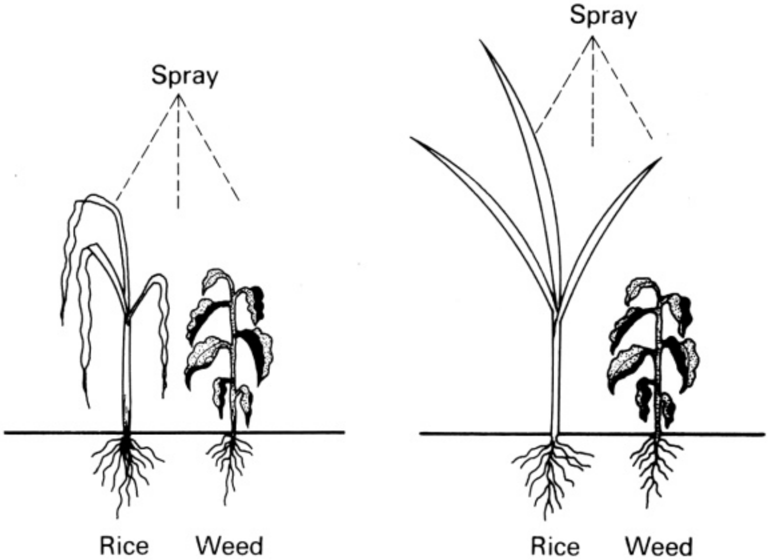
Types of herbicide based on time of application



- Time of application is very important in postemergence sprays. Application when weeds are tall is too late.

Types of herbicide based on selectivity

Nonselective | Selective

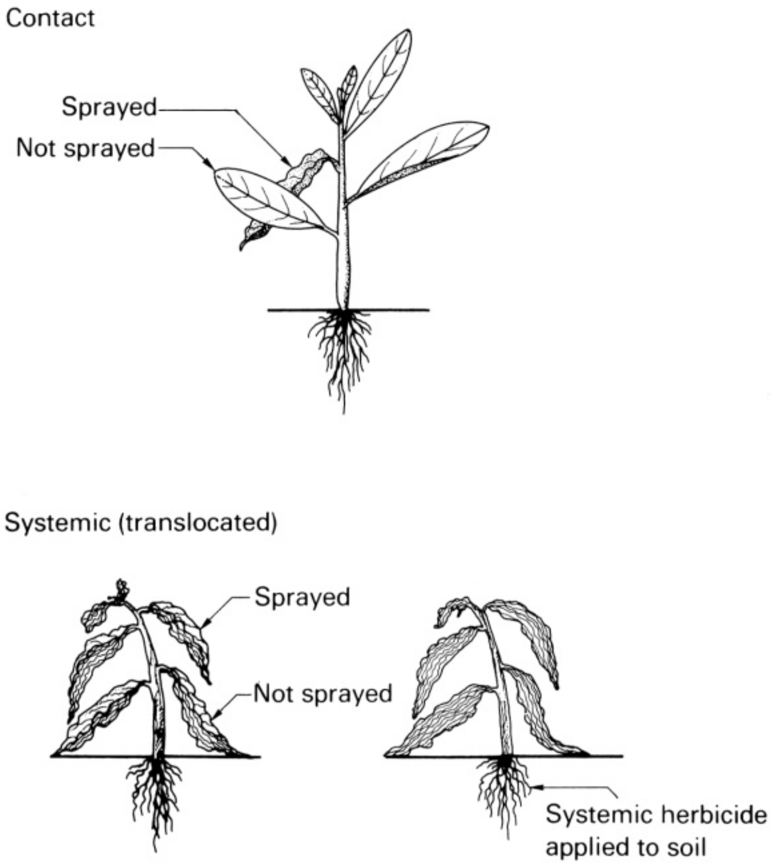


Nonselective herbicides kill all plants.

Selective herbicides kill certain plants only, but not rice.

- Even for selective herbicides, the rate of application should be carefully checked.

Types of herbicide based on type of action

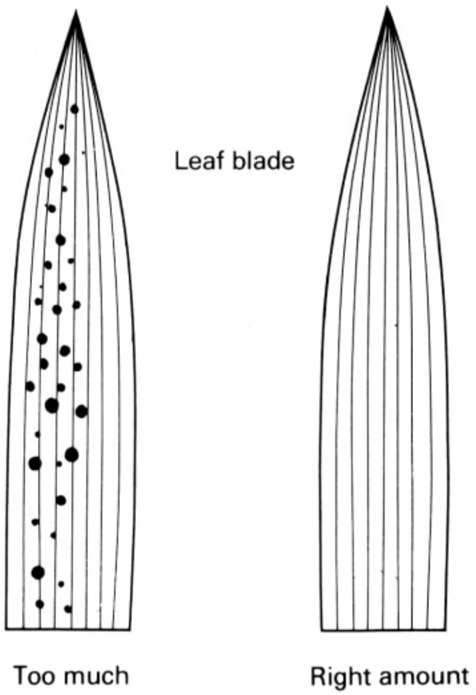


- Contact herbicides kill only the plant parts that were sprayed.
- Systemic (translocated) herbicides can travel inside the plant and kill the whole plant.

Rice injuries from too much herbicide — dwarfing and spreading out

- Sometimes the leaves are onion-like, tube-like, or cylindrical if too much herbicide was applied.
- Be sure to use the correct amount of herbicide. Strictly follow the recommended rate.

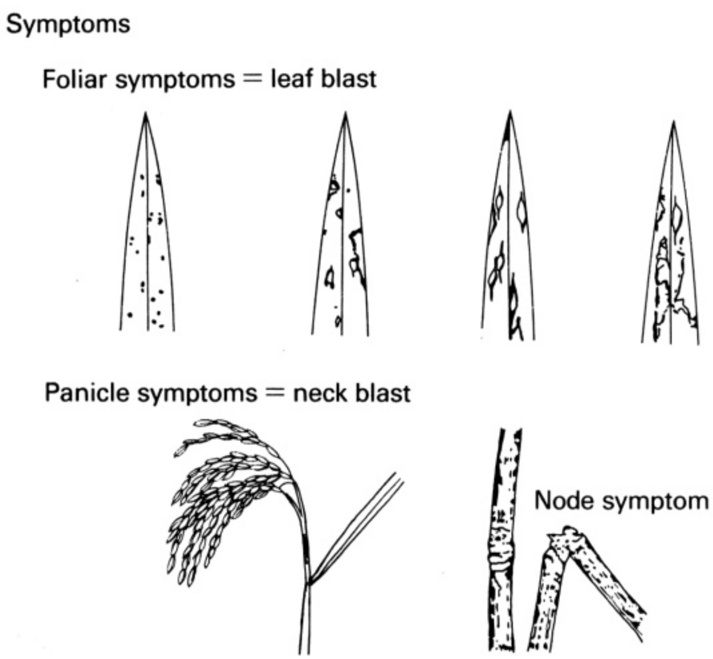
Rice injuries from too much herbicide — brown spots



- Herbicide injury may look like blast, brown spot, or narrow brown leaf spot, but a closer look shows that the spots are round.

Major diseases

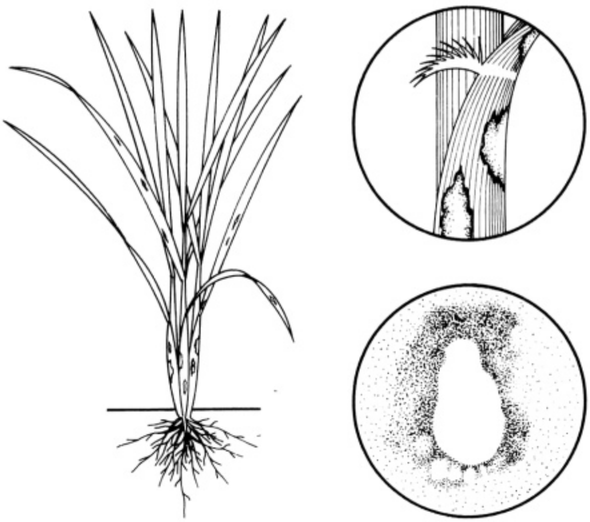
Blast



- Blast is the most severe disease in upland rice.
- On leaves, the fungus produces dark brown spots, elongated and pointed at each end, and lesions with greyish centers.
- An infected panicle base turns dark brown, and the stem usually breaks just below the panicle.
- Infected nodes turn blackish and break easily.
- A high amount of nitrogen, cloudy skies, and frequent rains favor the disease.
- Planting resistant varieties is the most economical and practical way of controlling blast.

Sheath blight

Symptoms



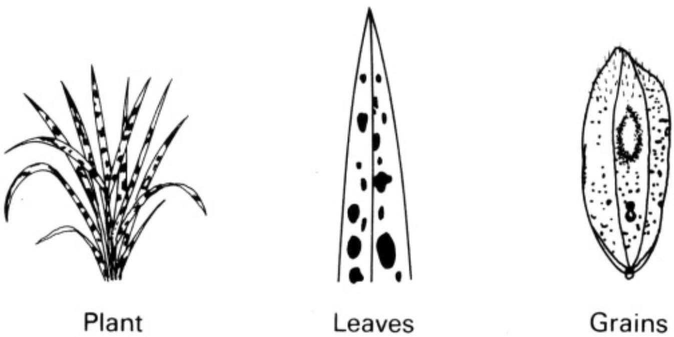
Sheath blight causes large, greyish spots, mostly on the leaf sheath, but spots may also occur on the leaf blades.

Infection bodies called sclerotia form on the spots.

- In very susceptible varieties, emerging panicles are contaminated, causing sterility.
- Many leaves die during severe infections.
- High amounts of nitrogen, high temperature, and high humidity increase the severity of the disease.
- No variety has high resistance.
- Growing moderately resistant varieties is useful.
- Chemical sprays can control the disease.

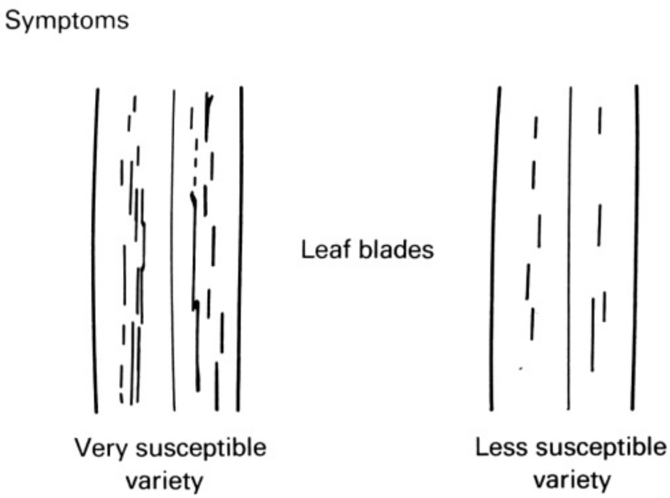
Brown spot

Symptoms



- Dark brown, more or less round spots are the most common symptoms on leaves. Grains can show the same symptoms.
- This disease is very frequent in poor, acidic soils lacking phosphorus, calcium, magnesium, silica, or nitrogen.
- Improving soil conditions reduces disease severity.
- Plant resistant varieties to control brown spot.
- Treating seeds with fungicides or hot water will also help control the disease.

Narrow brown leaf spot



- The disease produces linear dark brown spots, mostly on the leaf blades. Spots may also occur on the leaf sheaths and rice hulls.
- Symptoms appear mainly during later growth stages on the flag leaf.
- Plant varieties that are less susceptible to the disease.

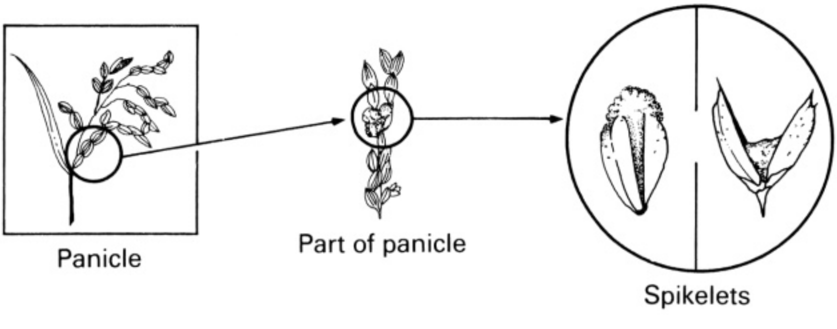
Sheath rot

Symptoms

- Large, greyish-brownish spots develop on the uppermost leaf sheaths enclosing the panicles.
- The young panicles remain in the leaf sheaths or emerge only partially. Grains remain unfilled or are discolored.
- Sheath rot can be confused with sheath blight. The symptoms are similar when the plants are young, and the damage is about the same.
- Hot, humid weather, as in forest areas, favors sheath rot.

False smut

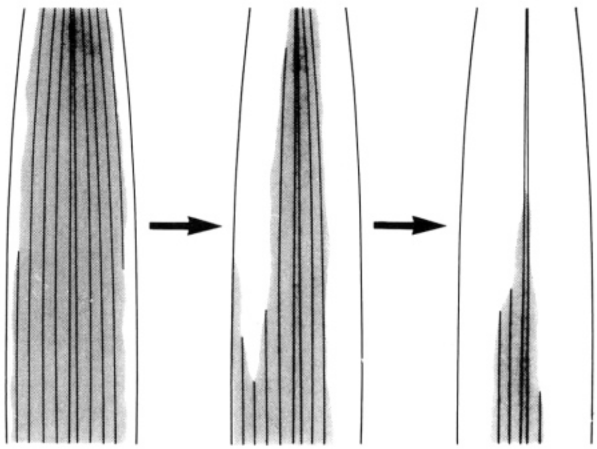
Symptoms



- The disease changes single grains of the panicle into orange-green, velvety smut balls, which may grow to a diameter of more than 1 cm.
- No special control is needed. The disease is very rarely severe. Only a few panicles in the same field are contaminated.

Bacterial blight

Symptoms



Phase 1

Lesions appear first, at about the heading stage, as water-soaked stripes on the leaf margin.

Phase 2

The lesions enlarge. The edges become wavy and turn yellow or light brown.

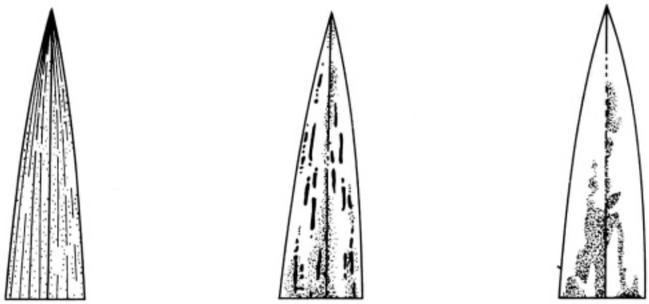
Phase 3

As the disease advances, the lesions cover the whole leaf blade and turn greyish and later white.

- Bacterial blight is not frequent in upland rice, except in areas close to lowland ricefields.
- Symptoms like those of stem borer can also occur in young seedlings.
- Planting resistant varieties is the only way of controlling the disease, but resistance varies from year to year and from place to place.

Bacterial leaf streak

Symptoms



Phase 1

Transparent, linear lesions form between the veins. Many tiny oozes can be observed on the lesions.

Phase 2

The lesions turn brown, become longer, and cover the larger veins.

Phase 3

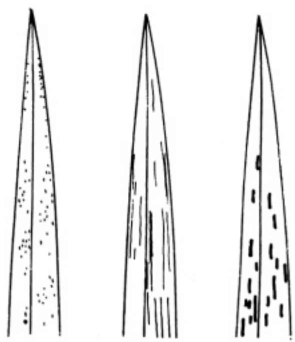
Whole leaves of susceptible varieties may turn grayish brown and die during the later phases of disease development. At this point, the disease symptoms look the same as those of bacterial blight.

- Bacterial leaf streak can decrease grain yields in upland rice.
- Plant resistant varieties.

Viruses

Symptoms

Plants are frequently stunted.



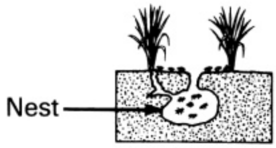
Infected leaves turn white or yellow-orange and can be mottled or striped.

- Several viruses can occur in upland rice, causing whitish or yellowish leaves, stunting, and sometimes serious yield losses.
- Viruses are transmitted by insects, mostly leafhoppers.
- Rice seeds do not transmit viruses.
- Control by using resistant varieties.
- In Asia, virus diseases seldom occur in upland rice. In Africa and South America, damage can sometimes be serious.

Major soil-borne insect pests

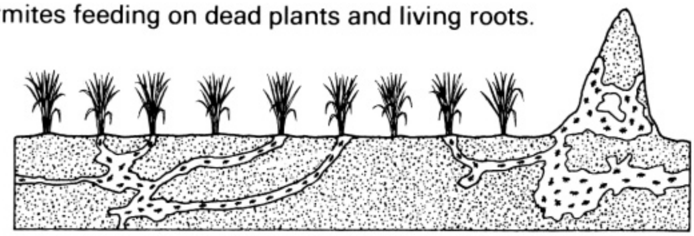
Ants and termites

Ants store rice seed from the fields in underground nests.



Potential damage	Abundance	Control
Moderate	Abundant some years over large areas	Easy

Termites feeding on dead plants and living roots.

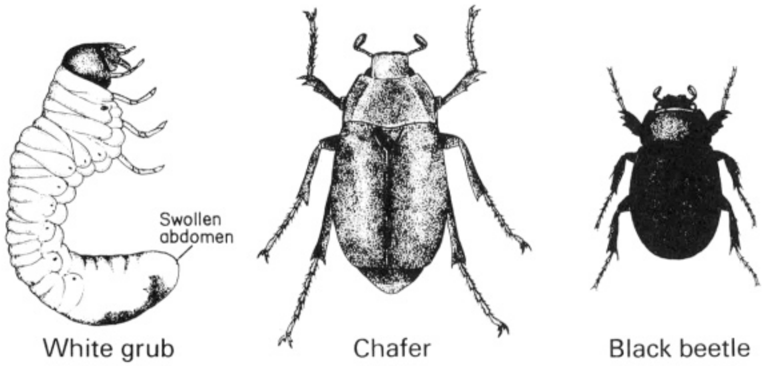


Potential damage	Abundance	Control
Moderate	Rarely abundant	Easy

- Ants and termites can occasionally cause serious problems in very dry areas and during severe drought spells.
- Treating soil and seeds with insecticides is an effective control.

White grubs

Actual sizes

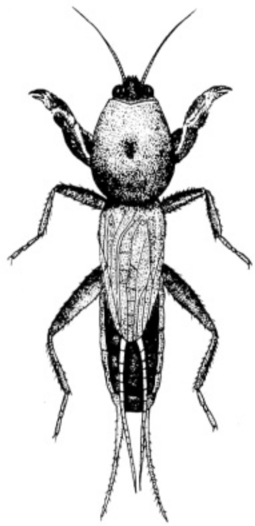


Potential damage	Abundance	Control
Moderate	Abundant most years in limited areas	Difficult

- There are many species of white grubs.
- Only the larvae of some species – chafers – feed on plant roots.
- Only the adults of other species – like the black beetle – are root feeders.
- Granular insecticide applied in crop furrows or hills at sowing is an effective control.

Mole cricket

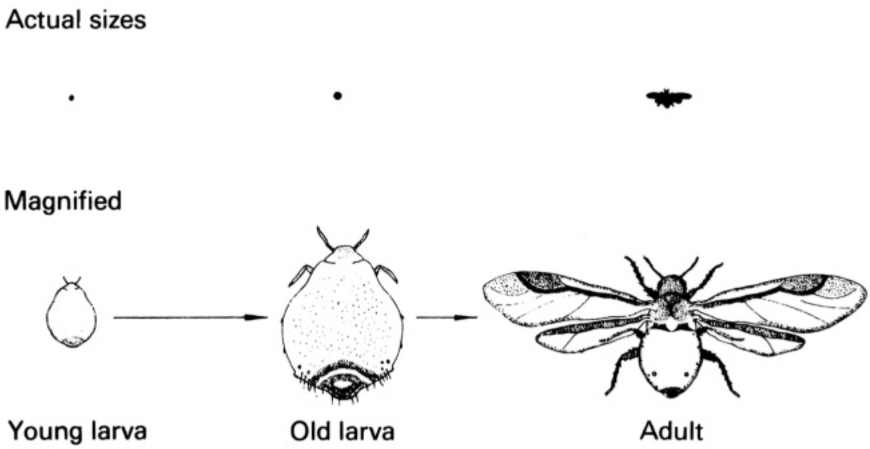
Actual size



Potential damage	Abundance	Control
Moderate	Abundant most years in limited areas	Easy

- When feeding, mole crickets can kill young plants by cutting the roots.
- Poisoned bait made from moistened rice bran and insecticide is a cheap and effective control.
- Granular insecticides applied to the soil are effective but costly.

Root aphids

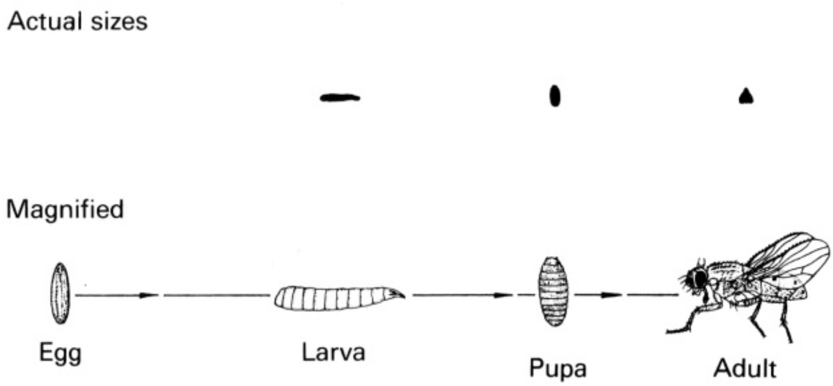


Potential damage	Abundance	Control
Moderate	Abundant in limited areas in some years	Difficult

- Adults and old larvae remove plant fluids from roots and cause yellowing and stunting of leaves.
- Sprayed and granular insecticides are effective if spraying is directed at the bases of the plants and if granules are covered by raking soil over them.

Major insect pests during vegetative phase

Seedling maggots

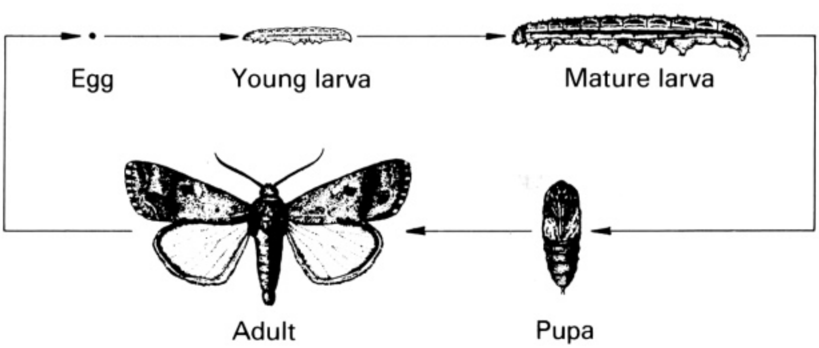


Potential damage	Abundance	Control
Moderate to high	Abundant in most years, but highly seasonal	Difficult

- Larvae feed on young tillers and can form deadhearts similar to those caused by stem borers.
- During severe infestation, the field may have to be replanted.
- Treating seeds with insecticide is most effective.
- After the crop is planted, foliar spray is the best control method. The first application must be within one week after crop emergence.

Armyworms and cutworms

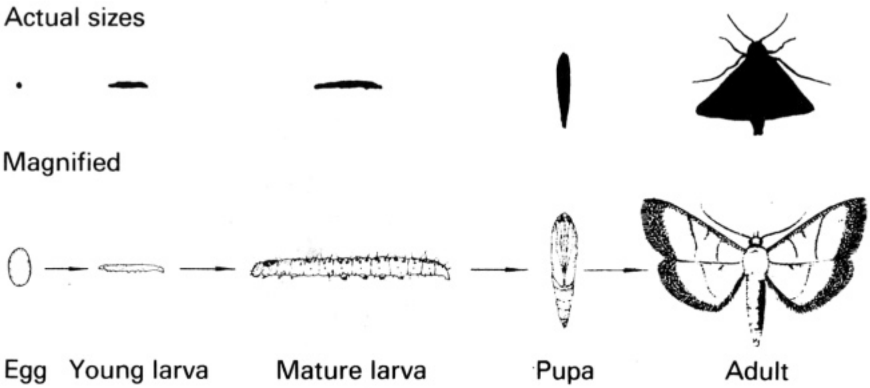
Actual sizes



Potential damage	Abundance	Control
Moderate	Abundant some years in limited areas	Easy

- Many different species can cause damage to rice.
- The larvae feed on the tips and margins of leaf blades and on young seedlings and panicles.
- Chemical sprays are more effective than granules.
- Spray only areas where larvae are found late in the afternoon.
- Grasshoppers and crickets cause the same damage and are also controlled with sprays or poison bait.

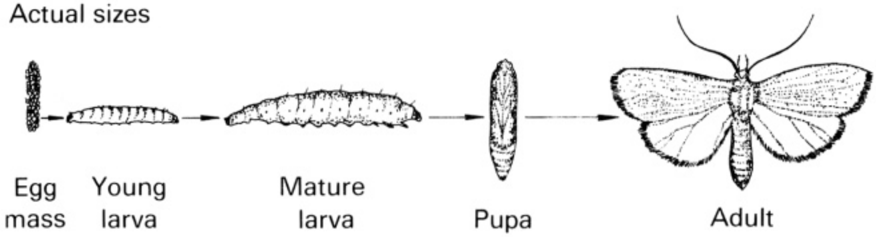
Leaffolders



Potential damage	Abundance	Control
High	Abundant most years over large areas	Variable

- Several species of leaffolder exist.
- Larvae damage the leaves, causing lengthwise white and transparent streaks on the leaf blades.
- A plant may contain many folded leaves; the leaves become dry, and yield losses are high when flag leaves are damaged.
- Control with chemicals sprayed on the leaves.

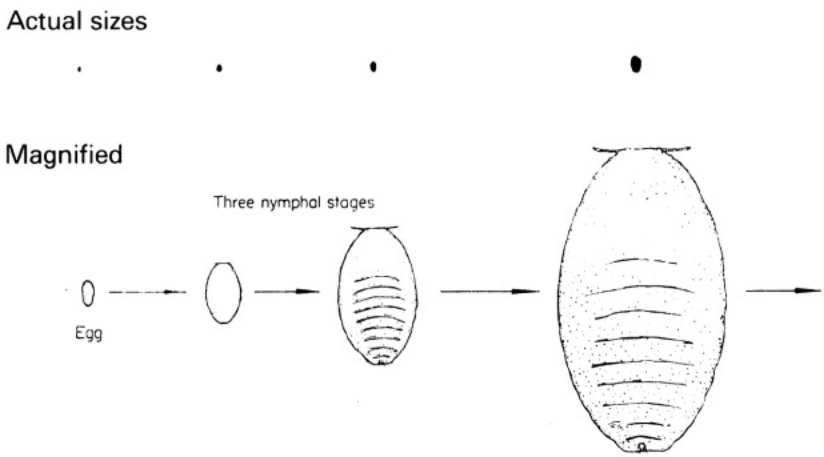
Stem borers



Potential damage	Abundance	Control
High	Abundant most years over large areas	Difficult

- Many species of stem borer occur.
- Young larvae penetrate the leaf sheath and feed between the sheath and tiller before entering the stem. Deadheart damage occurs at this stage.
- Older larvae feed inside the stem, causing whiteheads or empty grains.
- Pupae are located inside the stem, from where the adults emerge.
- Avoid excessive nitrogen to help prevent heavy infestation. Preferably use split N application.
- Plow stubble as soon as possible after harvest.
- Systemic insecticides can be effective because the larvae live inside the tillers.

Mealybugs

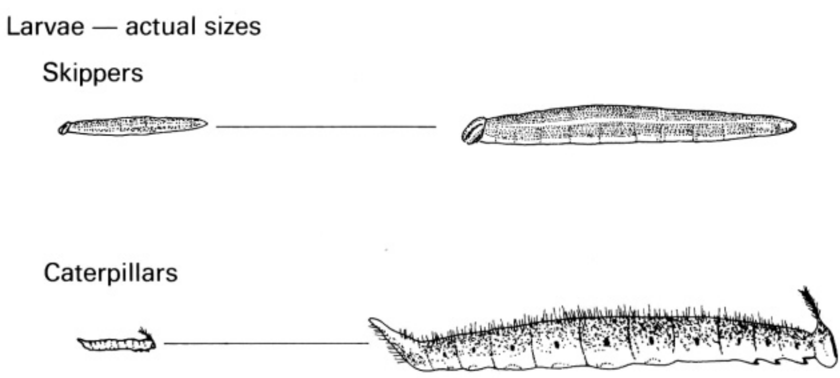


Potential damage	Abundance	Control
Moderate	Abundant some years in limited areas	Difficult

- The females are soft-bodied, pink, and covered with white, waxy threads. They suck the plant sap from the stems and the bases of leaves.
- The leaves turn yellow and the plant is stunted.
- A drought spell can cause a large population buildup. Damage to drought-stressed plants can be high.
- Chemical control isdifficult. Foliar sprays at the base of plants are most effective.

Major insect pests during reproductive phase

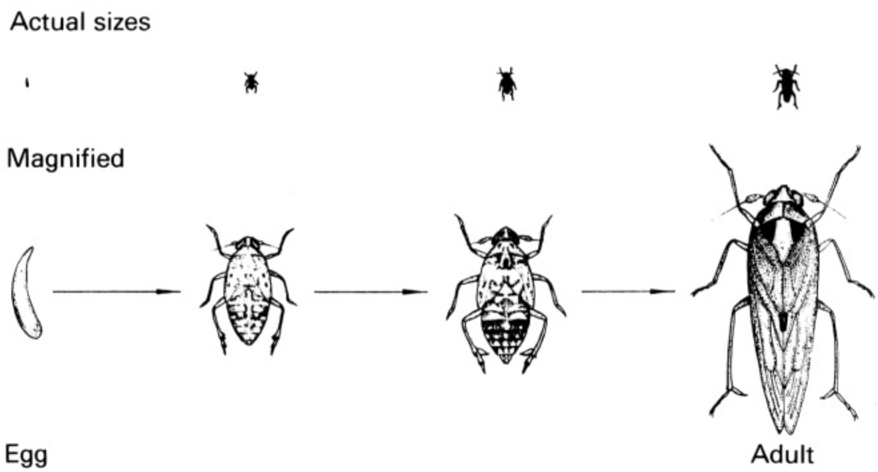
Caterpillars and skippers



Potential damage	Abundance	Control
Low	Rarely abundant	Easy

- The adults are different butterfly species.
- Only the larvae, which differ in size according to development and species, feed on the leaf margins and tips, removing leaf tissue and veins.
- Spraying insecticides can easily control all these larvae.

Planthoppers

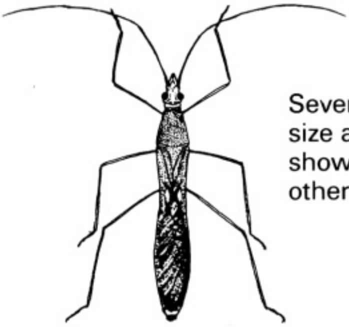


Potential damage	Abundance	Control
Moderate	Abundant some years in limited areas	Difficult

- Several species occur on rice.
- Larvae and adults suck sap from tillers and leaves.
- Damage is mostly from viruses carried by most species. The viruses cause pale yellow to orange leaves and stunting of the plant. The damage can be very severe.
- Insecticide sprays, preferably systemic insecticides, are effective.

Rice bugs

Actual size



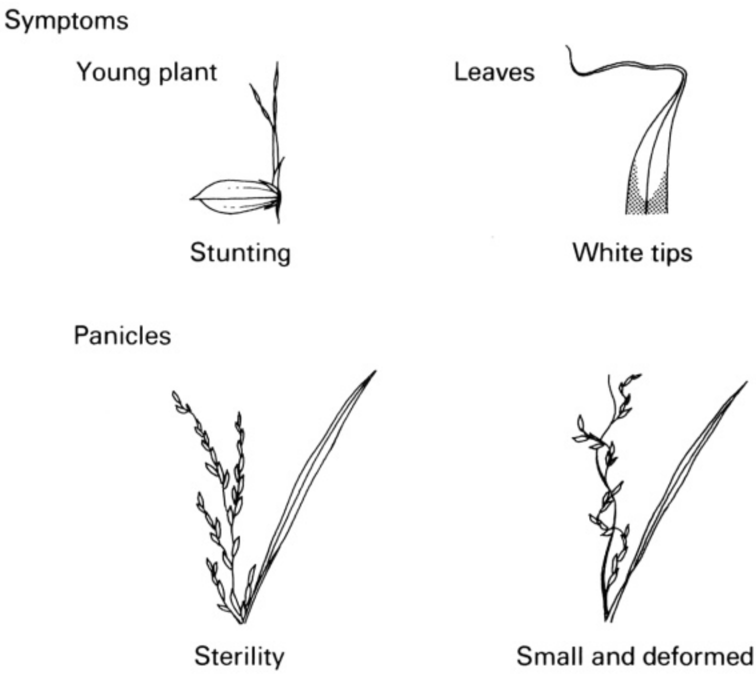
Several species differing in size and color occur. The one shown is very common; the others are wider and shorter.

Potential damage	Abundance	Control
Moderate	Abundant most years over large areas	Variable

- Larvae and adults feed on the endosperm of the rice grain and also suck plant sap.
- Removal of the liquid, milky-white endosperm causes smaller grains that are broken during milling.
- Insecticide sprays or dusts can control rice bugs.

Other pests

Nematodes



- Nematodes are microscopic worms living in soil or in the plant.
- On roots, they can cause knots, and stunting and yellowing of plants.
- On panicles, they cause sterility, deformed empty hulls, and reduction in seed number.
- Plowing the soil just after harvest and destroying the remaining stubble is the main cultural control method.
- Some varieties show some nematode resistance.

Rodents

Rat damage

- Rats sometimes cut young plants. More frequently they cut mature plants near the base or bend the tillers to eat the grains, sometimes causing severe loss.
- Weed-free fields, removing and destroying straw piles after harvest, and cleaning the land surrounding the field are effective cultural controls.
- Chemical baiting is useful and efficient if done during the whole season.

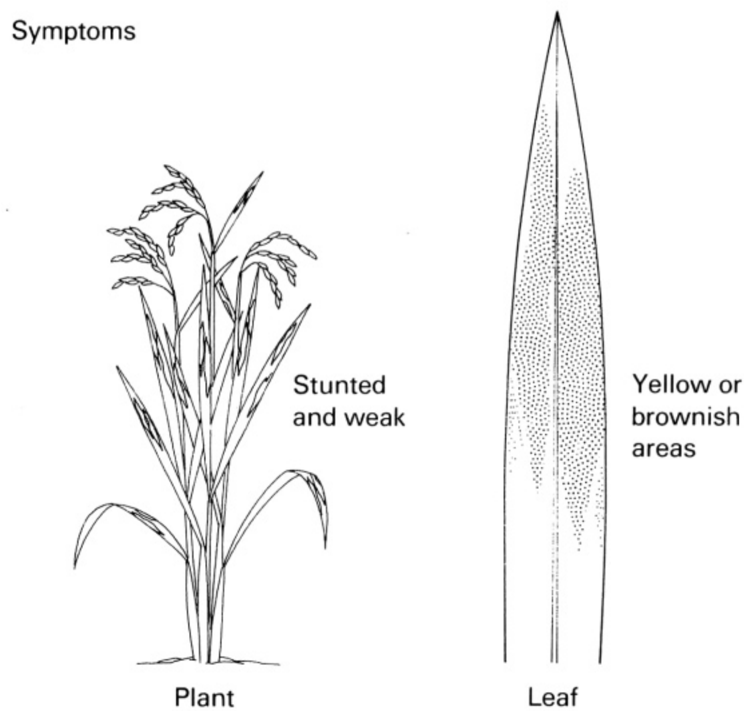
Birds

Symptoms — whitish empty grains

- Many species of birds can cause severe losses.
- At seeding, several bird species feed on grains.
- Most birds feed during the milk stage, causing partially or totally unfilled grains. The grainsappear greyish-whitish and flat.
- Diseases can occur on damaged grains and cause more severelosses.
- Varieties with awns sometimes resist bird attacks. Birds have difficulty reaching the grains.
- Bird control is difficult and not very efficient. Noise and scarecrows can reduce bird damage.

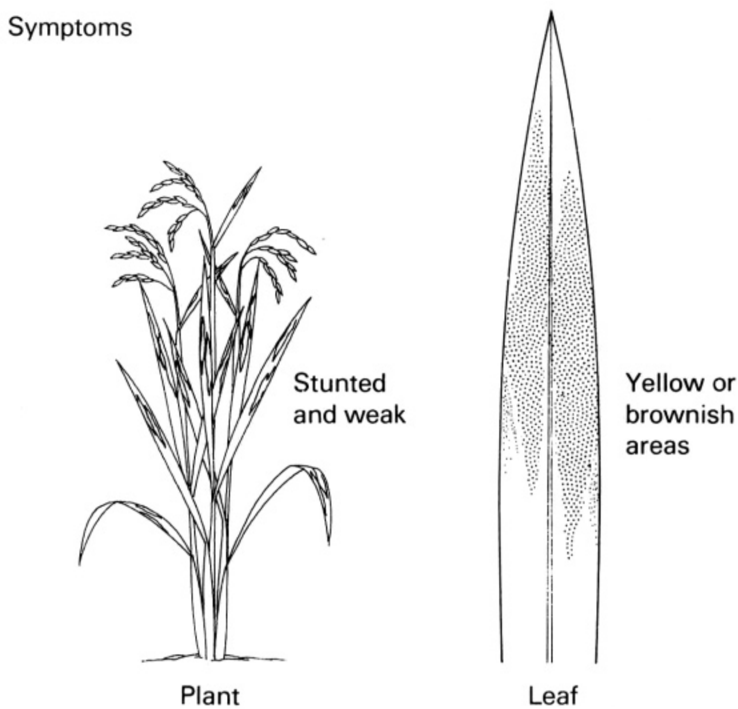
Soil problems

Soil deficiencies



- Nitrogen and phosphorus deficiencies are common.
- Among the minor elements, sulfur and iron deficiencies are common, but many others can occur.
- Plants are stunted and weak. Yellow or brownish leaves are the most frequent symptoms.
- Soil and plant chemical analyses show what fertilizer to use.

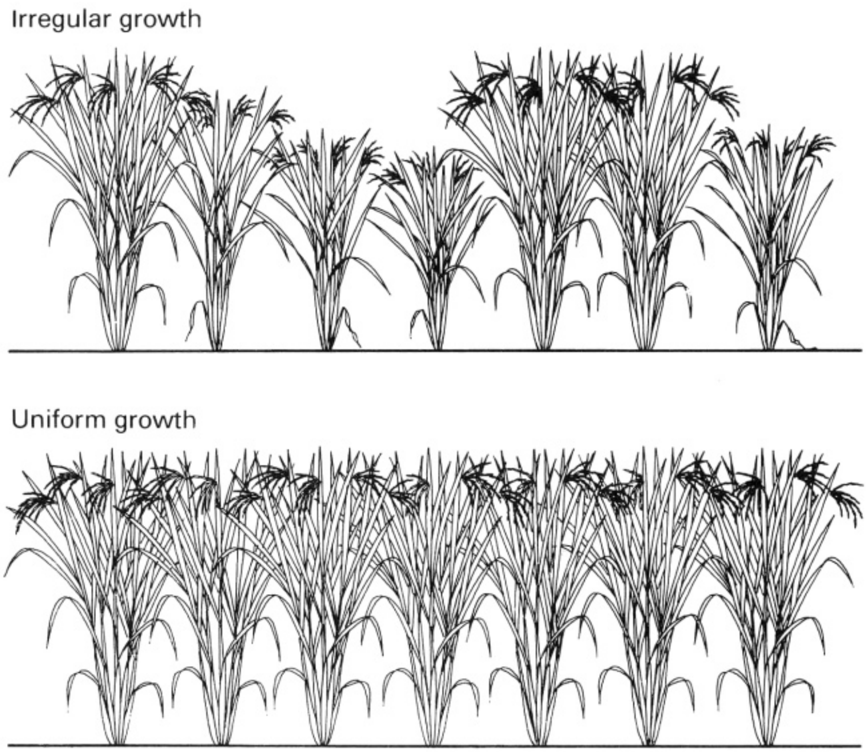
Soil toxicities



- Aluminum and manganese toxicities are very common in acid soils.
- The symptoms frequently look like soil deficiencies or virus diseases.
- Soil and plant chemical analyses provide information about the toxicity.

How to judge a rice crop at flowering

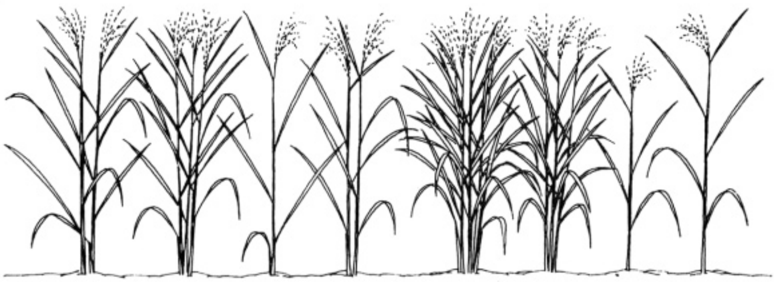
Uniform plant height



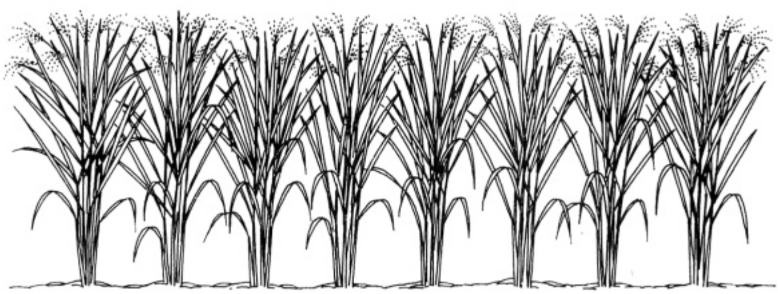
- Irregular plant height can mean
  - drought, insect, or disease incidence.
  - inadequate land preparation.
  - uneven soil texture.
  - uneven fertilization.
  - mixed seeds.

Uniform tiller number

Irregular tillering

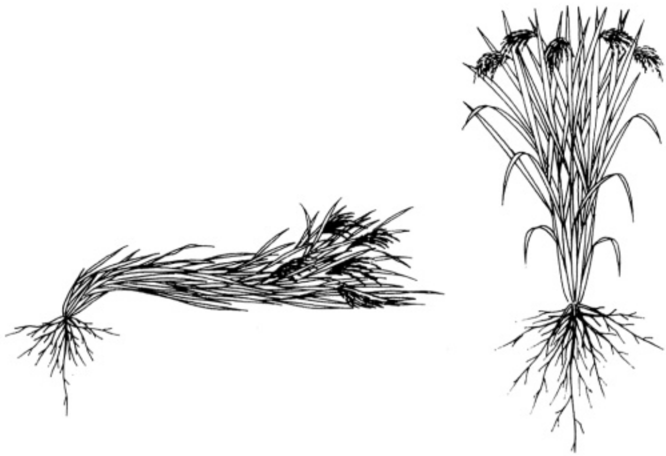


Uniform tillering



- Irregular tillering may indicate
  - drought, insect, or disease incidence.
  - inadequate land preparation.
  - uneven soil.
  - uneven fertilization.
  - mixed seeds.

No lodging

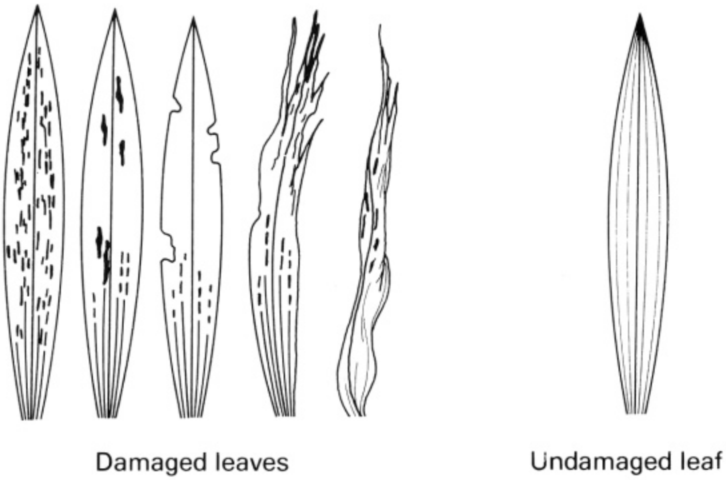


- Lodging may indicate
  - high planting density.
  - tall variety.
  - very heavy rains and storms.
  - soil problems.
  - too much fertilizer.

Long, thick, and healthy roots

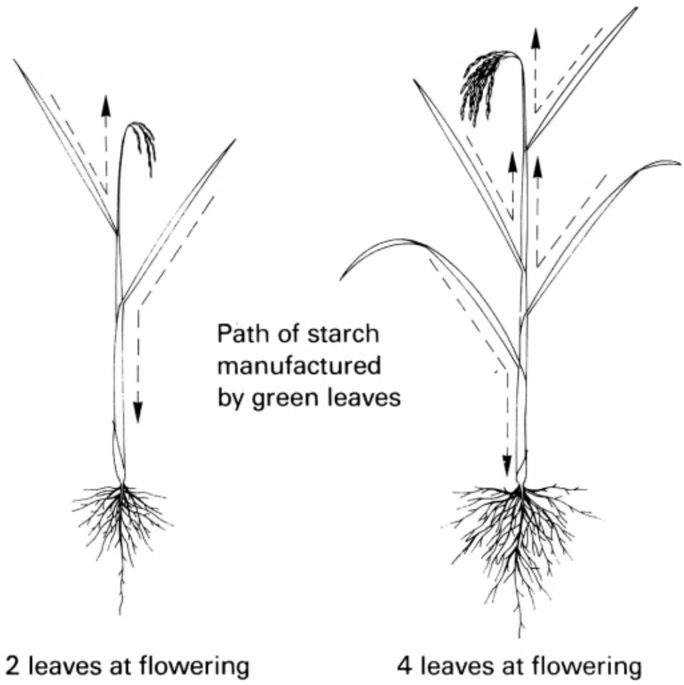
- Short, few roots indicate something is wrong with the soil, for example,
  - aluminum toxicity.
  - lack of nutrients.
  - rocky, stony soil.
  - very poor soil.
- Damaged roots indicate soil-borne insects such as mole crickets or white grubs.

Green, undamaged leaves



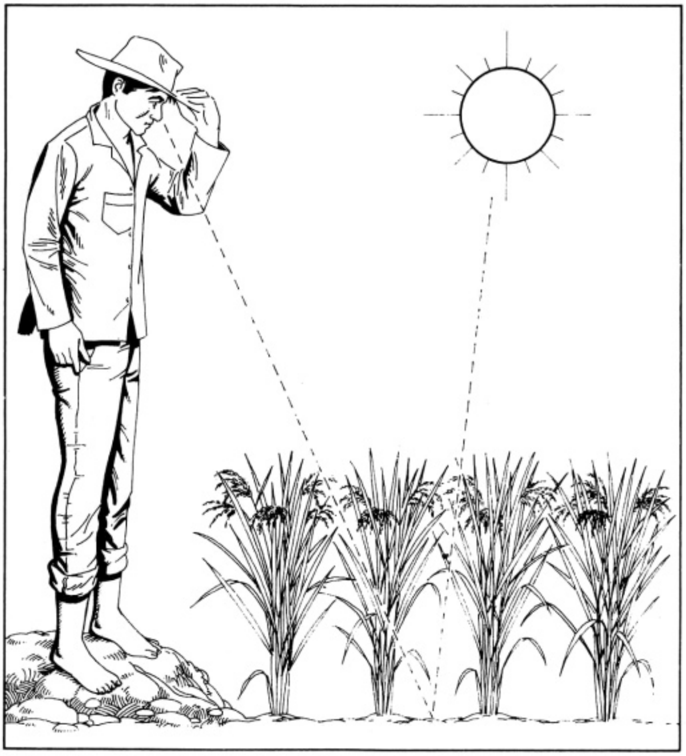
- Yellow leaves may indicate soil toxicity, deficiency, or virus disease.
- Brownish-whitish leaves may indicate drought.
- Jagged leaves may indicate wind effects, disease, or pests.
- Green, undamaged leaves indicate a good and healthy plant.

At least 3 to 4 leaves per tiller



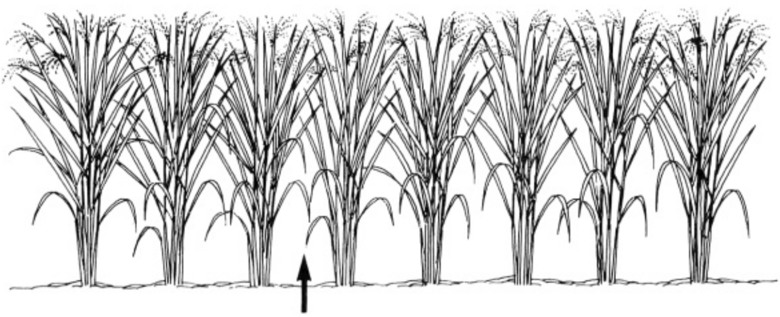
- A tiller, needs 3 to 4 leaves
  – to provide the roots and other parts with food.
  – to fill the spikelets with starch manufactured in the leaves.
- If a tiller has only 2 leaves, suspect some deficiency in the soil or water stress at an earlier growth stage.

Correct plant density

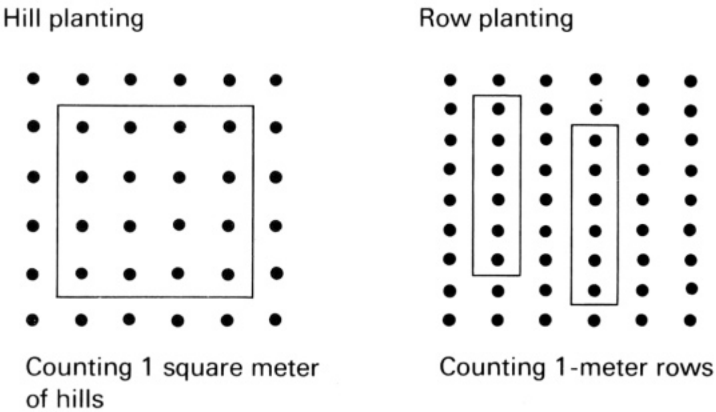


- The correct number of plants per unit area can be checked bv standing on a levee. If you can see only a little soil area or only some sun rays reaching the soil, the density is right.
- If you can easily see large areas of soil, the spacing is probably too wide, the soil is poor, or not enough fertilizer has been applied.

Good number of panicles



- There should be
  - 110 to 150 panicles per square meter in unfavorable environments.
  - 200 to 250 panicles per square meter in favorable environments.
- Depending on whether hill or row sowing was used:
  - Count the number of panicles per hill (clump) in at least 3 hills inside the field, or count the number of panicles in a one-meter row length, and repeat the countings inside the field several times.
  - Calculate as shown on the next page.



- *Hill planting*
  If the distance between hills is 25 X 25 cm, the area per hill is 25 X 25 = 625 square cm (= 0.0625 square meter). The number of hills per square meter is 1/0.0625 = 16.
  If the mean of the number of panicles on several hill countings is 9 per hill, the number of panicles per square meter is 9 X 16 = 144 panicles.
- *Row planting*
  If the distance between rows is 25 cm, the area per 1 -meter row is 100 X 25 = 2,500 square cm = 0.25 square meter. The number of counting areas per square meter is 1/0.25 = 4. If the mean number of panicles per counting is 32, the number of panicles per square meter is 32 X 4 = 128 panicles.

Harvest and postharvest

Harvest

- At maturity, the grains are full-sized and hard, and the panicles bend down.
- Avoid harvesting during rainy days. Preferably harvest during the afternoon, when the grains are dry.

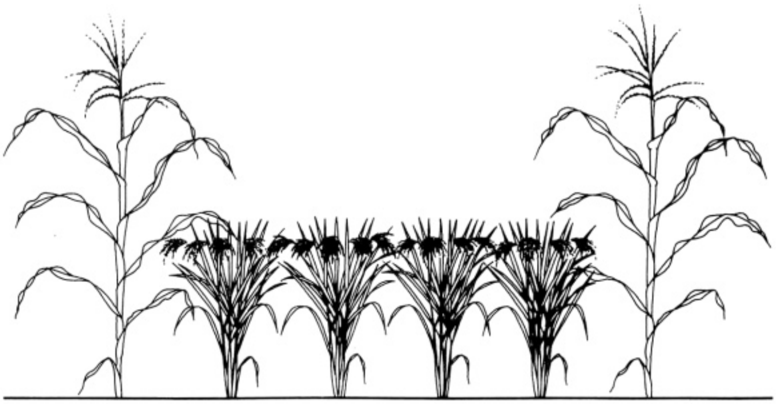
Postharvest

- After harvest, keep the panicles away from rain or moisture.
- Thresh as soon as possible to avoid pest and rain damage in the field.
- Dry the grain as well as possible.
- Store the grain in a dry location.
- Protect the stored grain from insects, rats, and moisture.

Cropping systems

Intercropping

One example of intercropping



- Mixing several crops in the same field is a frequent practice.
- Mixing a legume — beans or soybean — with rice in alternate rows is useful and efficient.
- Avoid random hill plantings of different crops; it is less efficient than alternate rows.
- In areas with a short rainy season, where only one crop a year is possible, rice intercropped with legume, maize, or cassava is a good practice.

Crop rotation

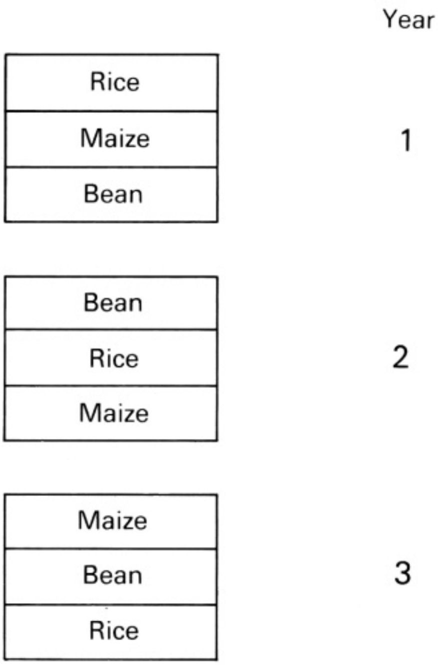
Years of cultivation of the same field

Bad		Good	
Year	Plant	Year	Plant
1	Rice	1	Rice
2	Rice	2	Maize
3	Rice	3	Bean
4	Rice	4	Rice
5	Rice	5	Maize
6	Rice	6	Bean
7	Rice	7	Rice

- Always planting the same crop in the same field causes nutritional disorders. Deficiencies in nutrients increase disease and insect incidence.
- Crop rotation — using different plants sown in the same field in successive years — is a good and efficient practice.

Cropping pattern

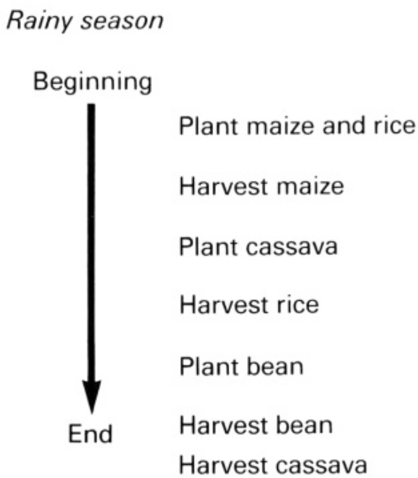
An example of a 3-year crop rotation, based on 3 crops:
- rice
- maize
- bean



The field is split into 3 areas, and every year, one given crop is located in one-third of the total field area.

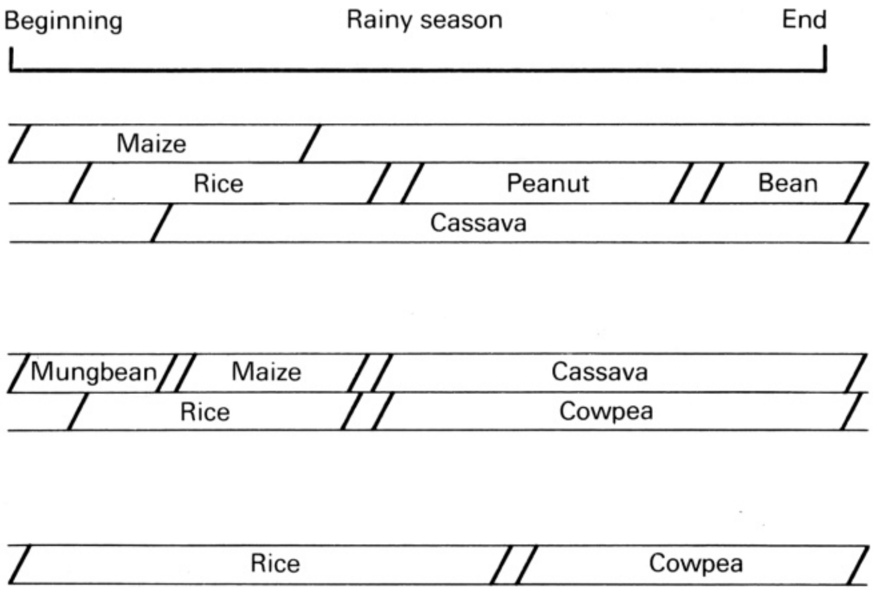
- Crop rotation is a good control against erosion when broad-leaved crops are used.
- Crop rotation has fewer risks; if one crop is damaged by disease or pests, others may still grow.
- Crop rotation ensures better and more stable food for the family.
- Crop rotation ensures steadier cash returns.

Successive cropping and cropping pattern for long rainy season



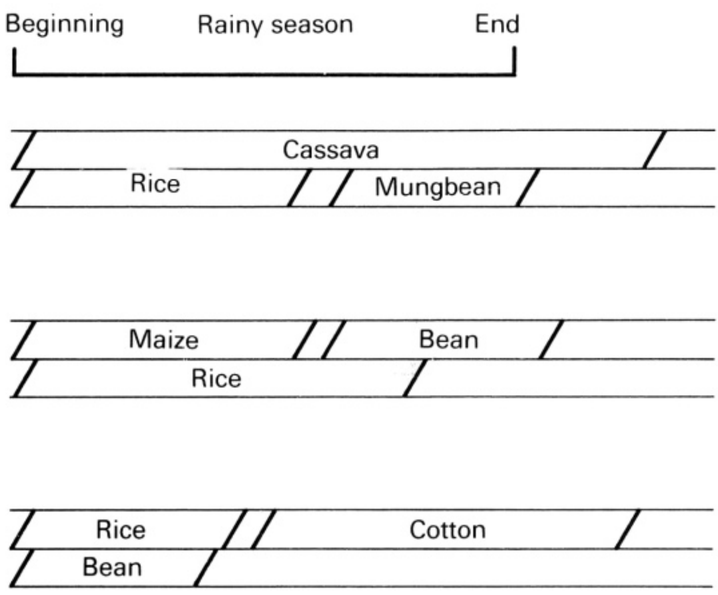
- In areas with a long rainy season, alternate cropping can be practiced with different crops according to the length of that season.
- In these areas, 3 to 4 crops can be harvested successively during the season.
- Other cropping patterns including yam, cotton, or any other crop can be used according to need.
- Fertilizers, and weed and pest controls must be well-managed.

Some other cropping patterns in long rainy season



- Many other combinations can be used, according to preference or to marketing possibilities.
- Such cropping patterns require low to moderate cash inputs and entail fewer risks.

Some cropping patterns in medium length rainy season



- Any other crop combination can be used, including short-duration vegetables, mustard, chickpea, finger millet, etc.
- A legume is very useful for nitrogen fixing in upland soils.