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A Farmer's Primer on Growing Rice

IRRI

REVISED EDITION

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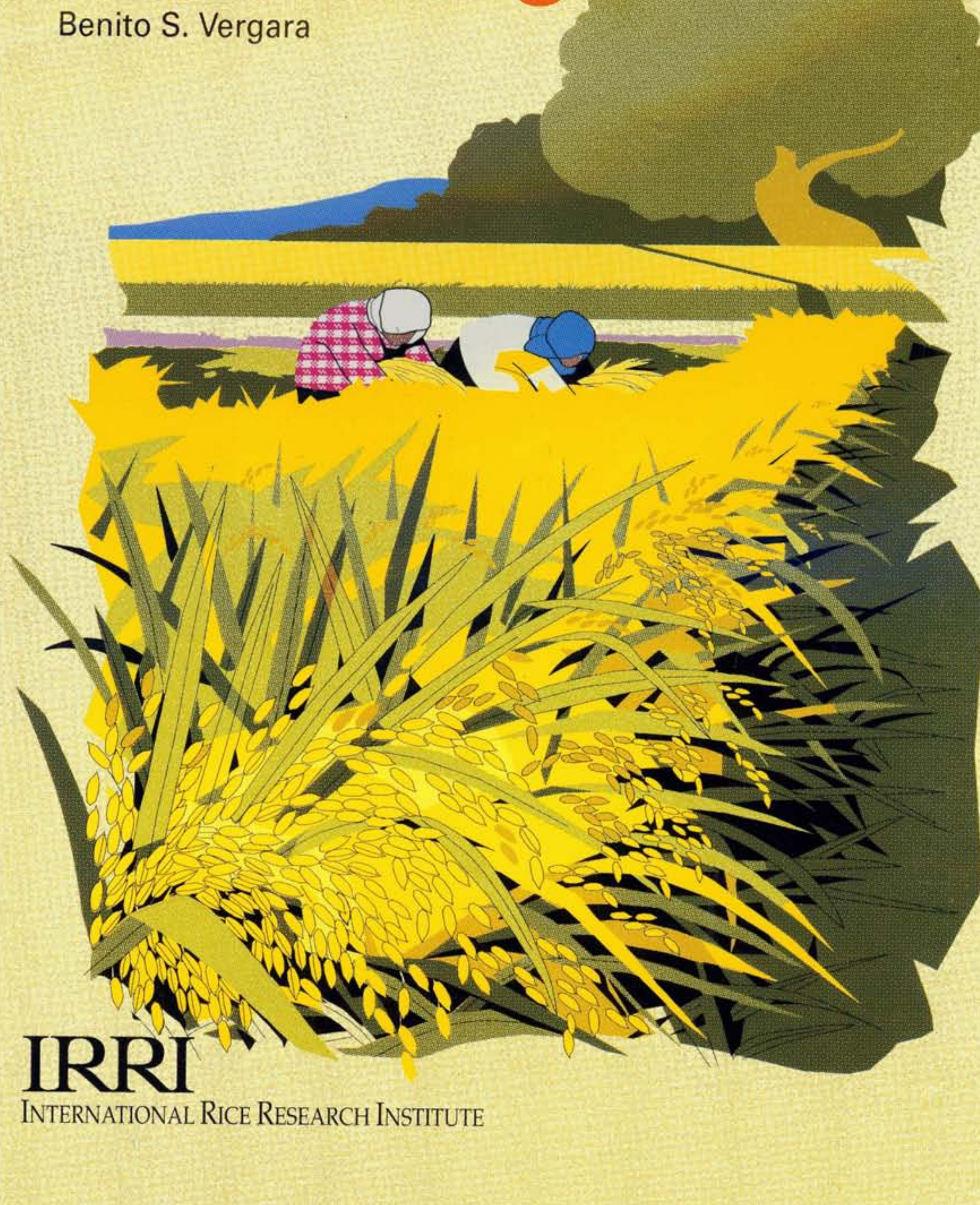
Benito S. Vergara



IRRI

INTERNATIONAL RICE RESEARCH INSTITUTE

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1992
IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE
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 16 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 Organiration 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

In less than 30 years, the earth will be home to8 billion people, more than half of whom will depend on rice as their staple food. To feed them will require a 50% increase in global rice production, from today's 518 million tons to 782 million tons.

More than ever, rice farmers, technicians, teachers, and scientists need to understand the whys and hows of modern rice production. But recommendations given to farmers often do not answer questions such as how to increase the efficiency of nitrogen fertilizer, how to lessen the chance of lodging, or why modern varieties are usually superior.

IRRI Plant Physiologist Benito S. Vergara conceived the idea for the original primer while teaching rice production courses at IRRI. He became aware of the lack of simple but precisely written information that clearly explained good rice-growing practices.

Forty-eight editions of A *farmer's primer an growing rice* have been published since 1979 in 40 languages in more than 20 countries in Asia, Africa, and Latin America. Vergara has revised the primer to update and improve the presentation of the information.

Carolyn Dedolph and Stephen Banta edited this handbook with the assistance of Teresita Rola. John Figarola drew the illustrations. Tine Brinkman was involved in the revision process.

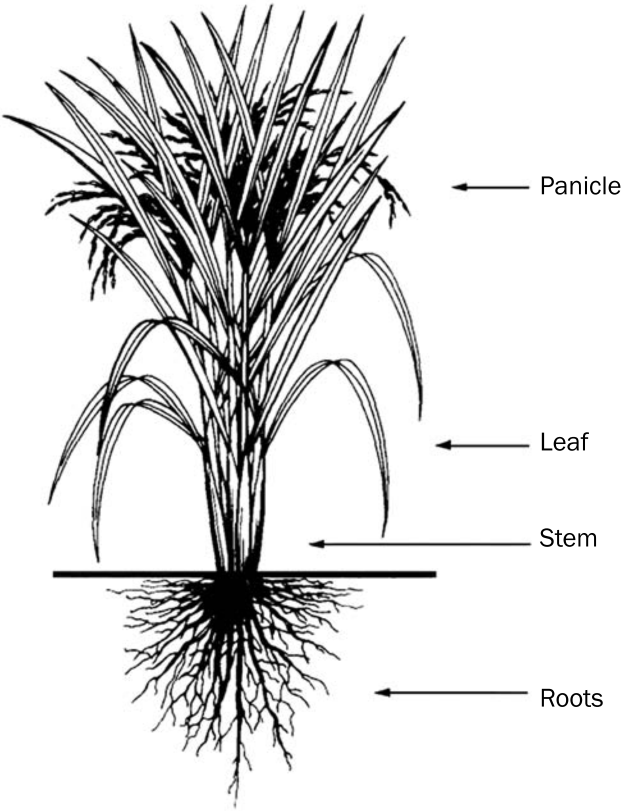
Klaus Lampe
Director General

Contents

THE PLANT

Growth phases of the rice plant

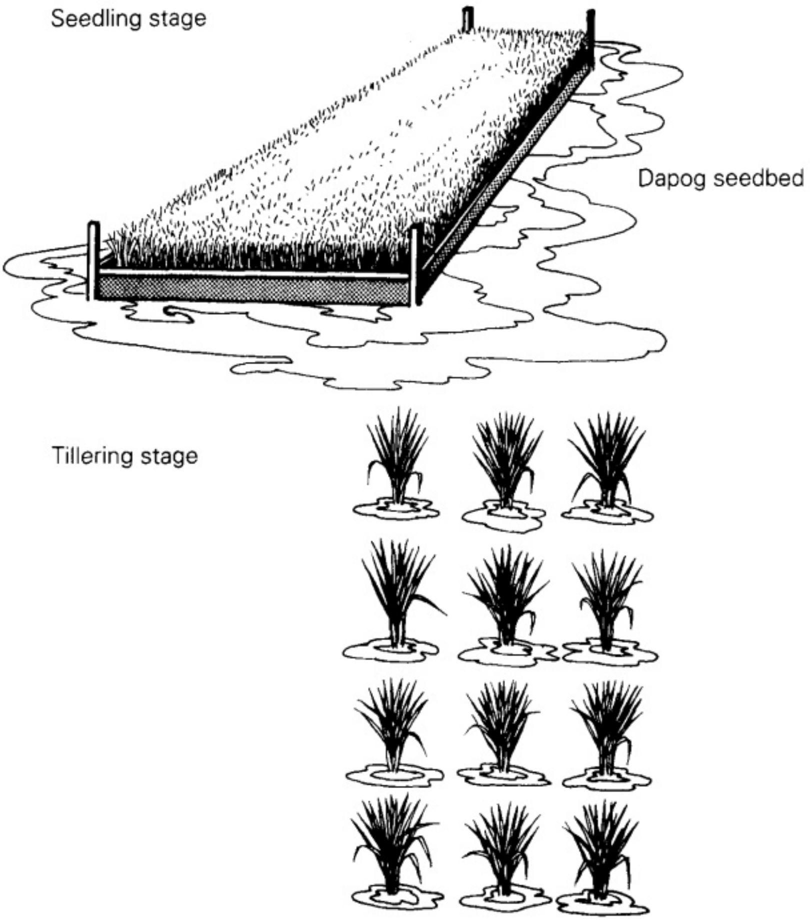
The rice plant



Plant with five tillers

¢ A tiller is a shoot that includes roots, stem, and leaves. It may or may not have a panicle.

Vegetative phase



¢ Seedling or nursery stage duration varies:
— dapog (9-11 days),
— wetbed (16-20 days), and
— direct seeding (none).

¢ Tiller number and leaf area increase during the vegetative phase.

¢ Low temperature or long daylength can increase the duration of the vegetative phase.

Reproductive phase

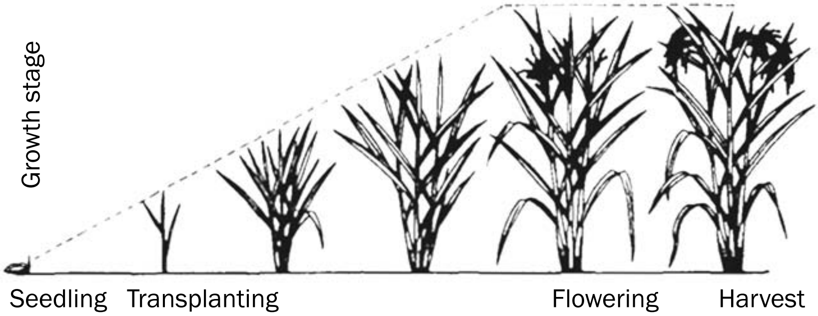
Panicle at flowering stage

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

Ripening phase

Panicle at ripening phase

- The ripening phase starts at flowering and lasts for about 30 days.
- Rainy days or low temperatures may lengthen the ripening phase.
- Sunny and warm days shorten the ripening phase.
- Follow good farming practices during each growth phase to produce high grain yields.



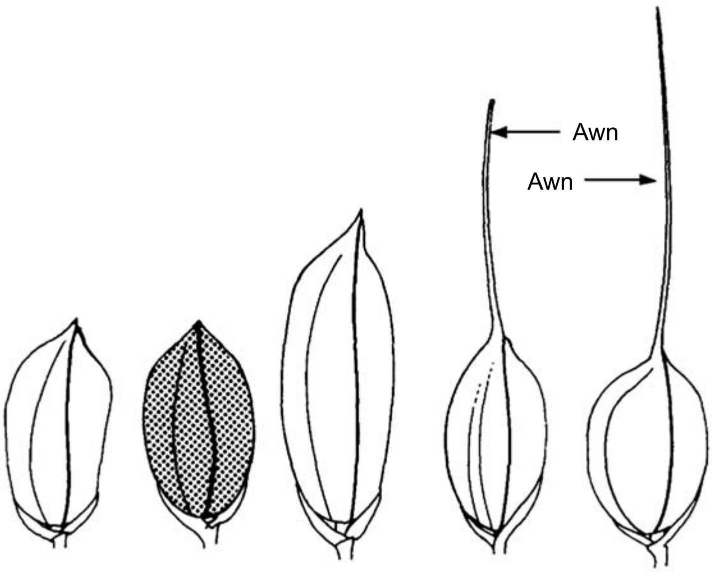
Maximum Tiller number

Panicle formation

Growth phase	Vegetable phsase	Reoroductive phase	Ripening phase
Duration	Variable	35 days	30 days

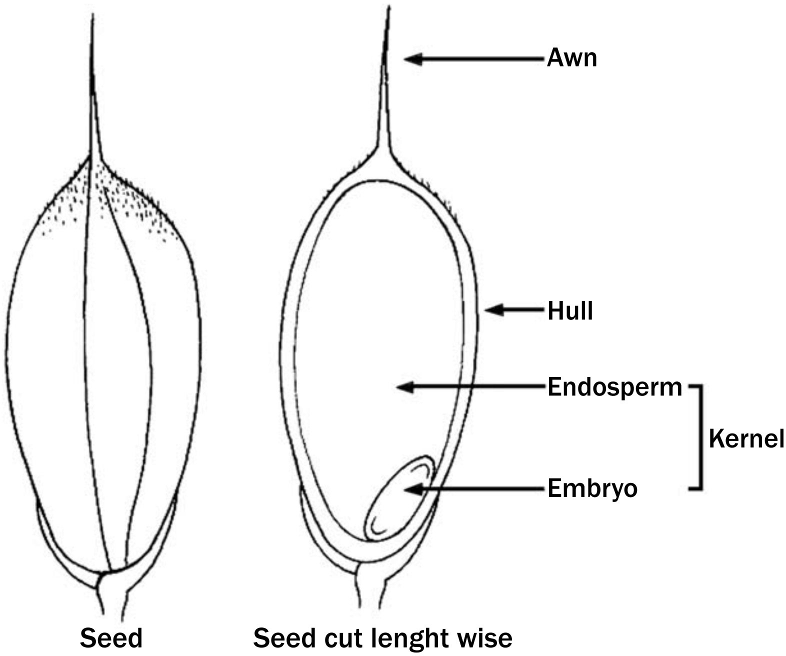
Seeds

Seed types



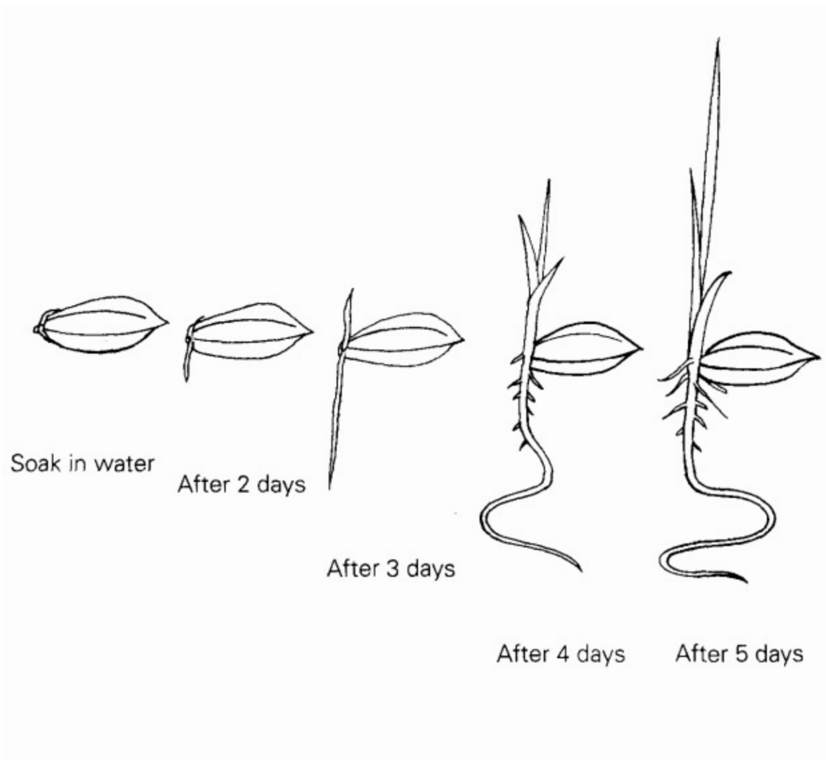
¢ Seeds vary in size, shape, color, and awn length.

Parts of the seed



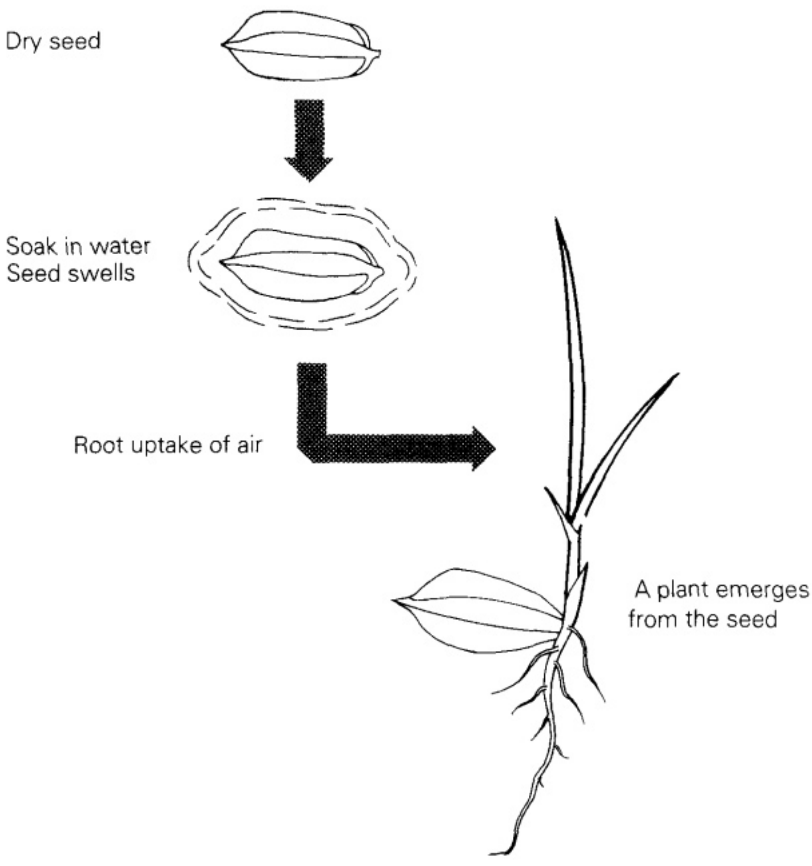
- ¢ The hull is the hard cover of the seed.
- ¢ The food needed for seed germination — starch, sugar, protein, and fat — is in the endosperm.
- ¢ Almost 80% of the endosperm is starch.
- ¢ The embryo develops into the shoot and the roots. The development is called seed germination.

Stages of germination



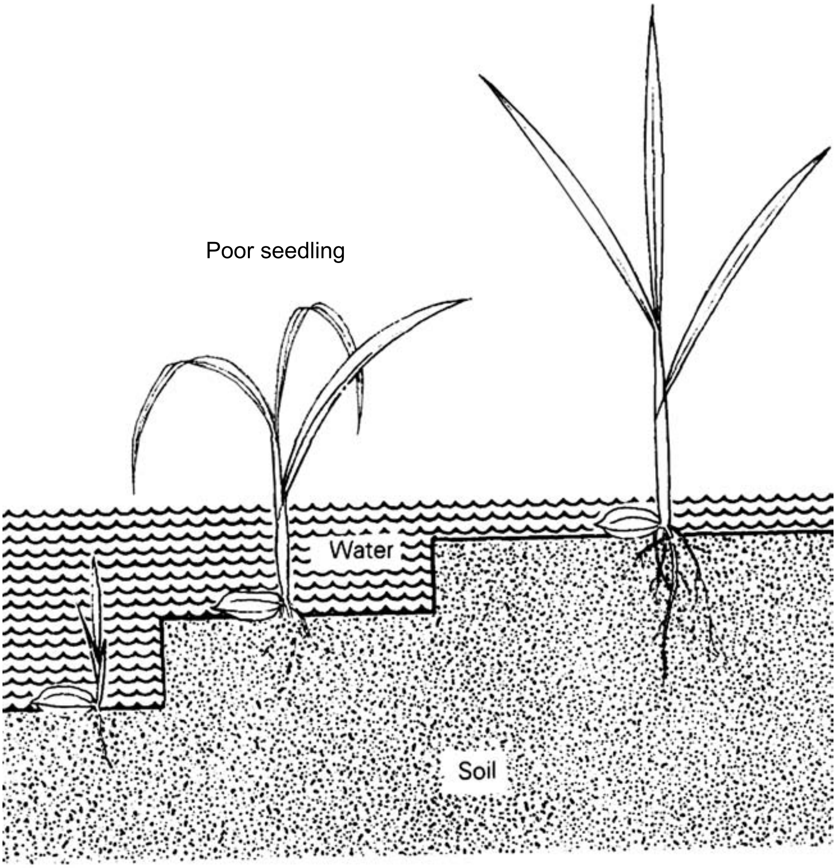
¢ Embryo growth dependson temperature and availability of water and air.

Water is needed for germination



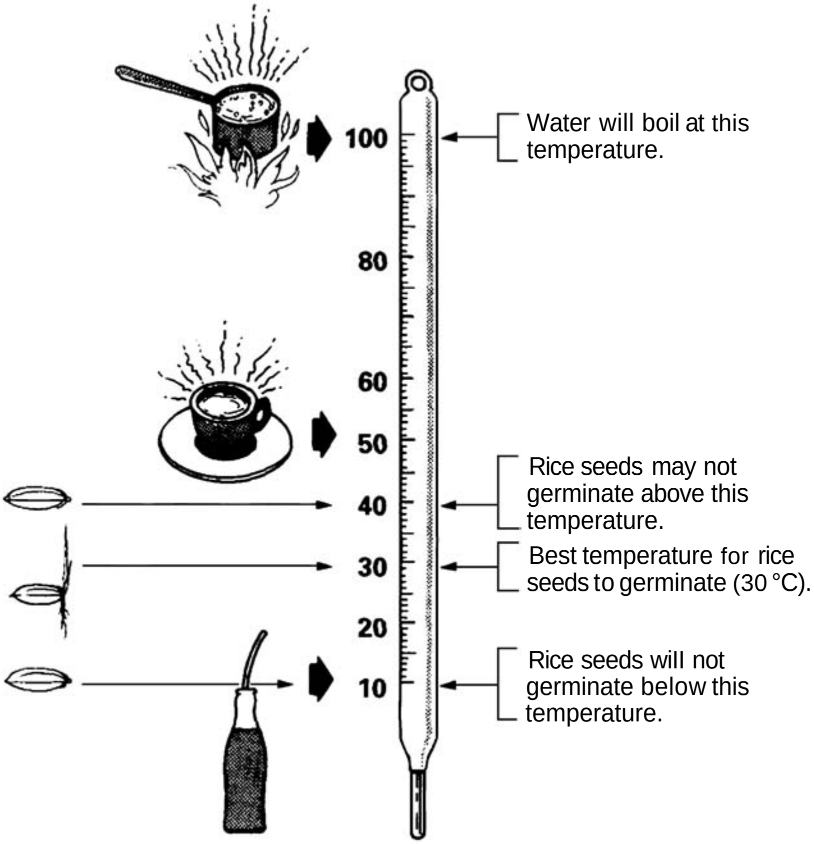
- Uptake of water is the first need for germination.
- Soak seeds for at least 24 hours for a more uniform germination.
- Many activities go on inside the germinating seed. Starch, protein, and fat are changed into simple foods for the embryo.

Air is needed for germination



- Germinating rice seeds need air to live.
- Water contains very little air.
- If the germinated seeds are covered too deeply with water, embryos will grow slowly, resulting in tall, weak shoots. Embryos will die in some cases if the water is too deep.

Temperature conditions for germination

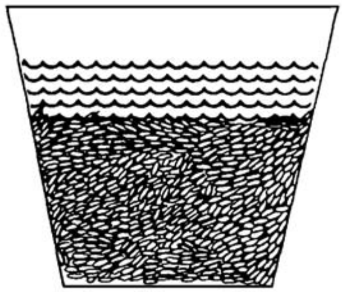


- Warm temperature is needed to increase the growth activities inside seeds.
- Low temperature (10 °C) decreases activities inside seeds.
- Very high temperature (40 °C or higher) decreases the germination percentage. Too much heat can kill sprouting seeds.

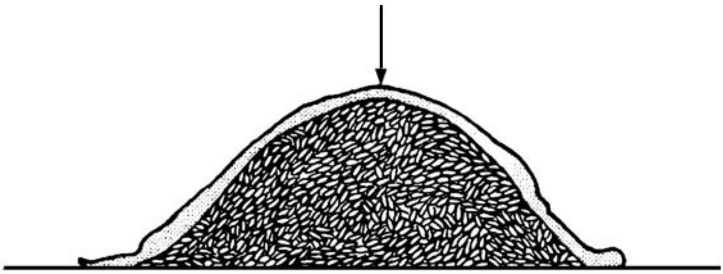
Why incubate seeds?

Preparation of seeds for sowing

Soak clean seeds in water.
Remove seeds that float.



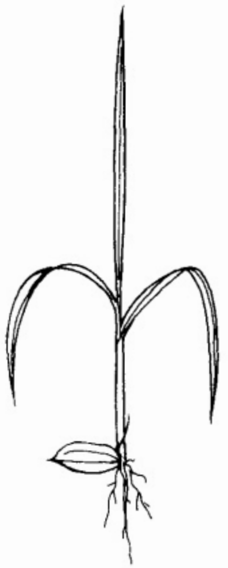
After 24 hours of soaking, remove water and wash seeds. Place on cement floor and cover with a wet sack. Incubate seeds for 24 hours or longer. Keep sack wet.



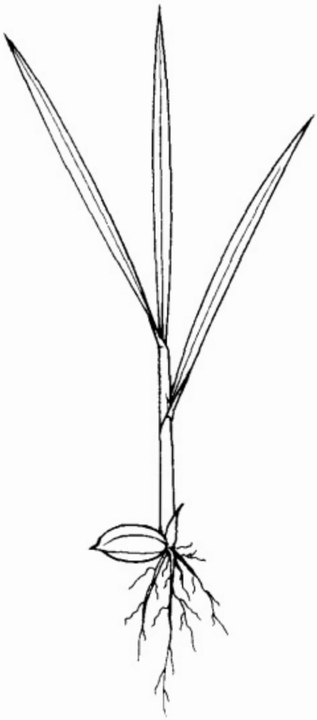
After 1 or 2 days, seeds have germinated and are ready for the seedbed.

■ incubation keeps the seeds warm. It increases embryo growth and results in uniform germination.

Why select good seeds?



Poor seed

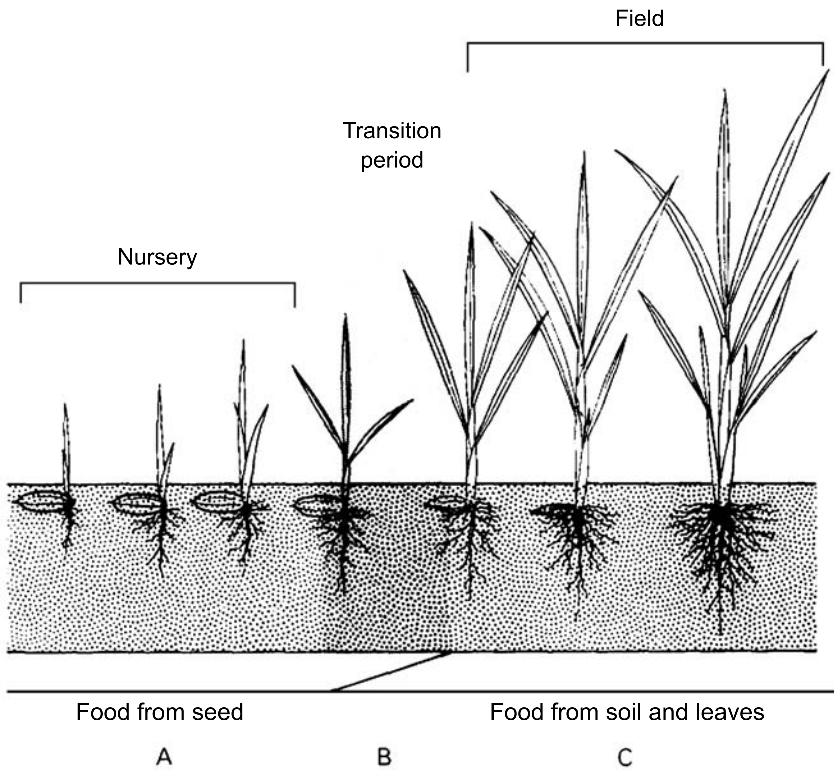


Good seed

- Good seeds contain more food and produce healthier, heavier seedlings with more roots.
- Healthy seedlings grow faster than poor seedlings when transplanted in the field.
- Good seeds result in uniform germination and growth.

Factors that affect seedling growth

Sources of food for growth



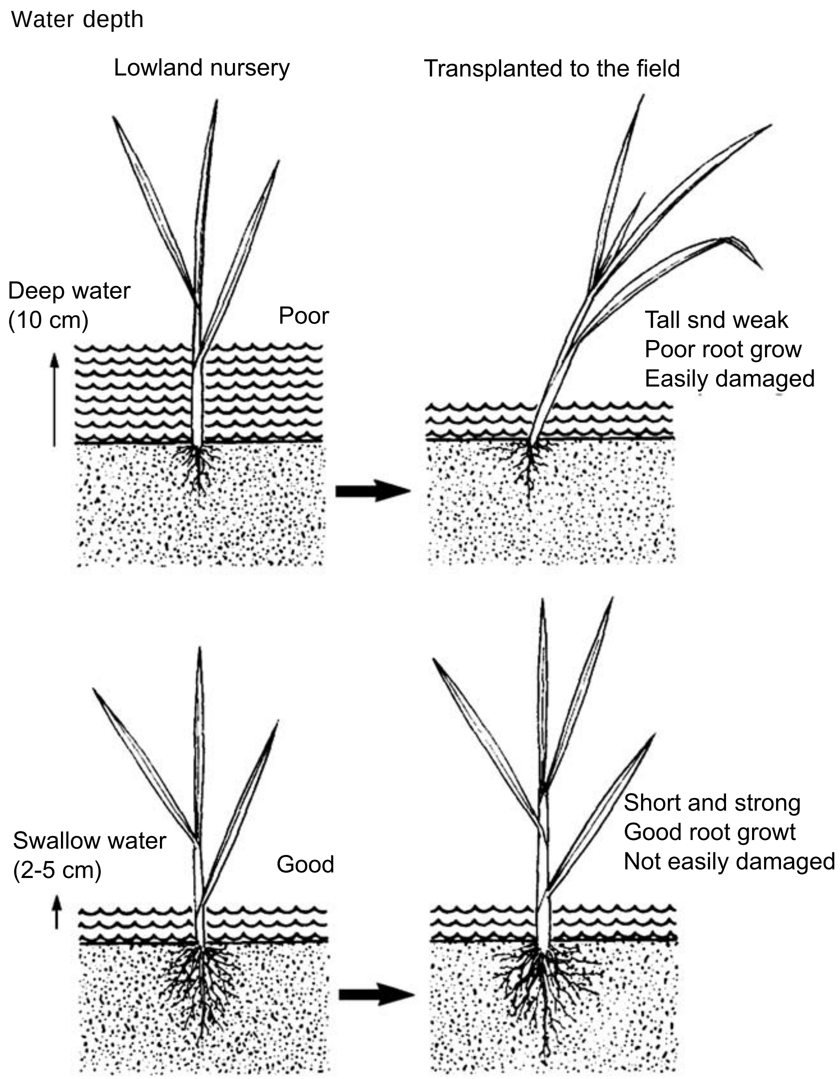
¢ The seedling grows first by using food from the endosperm (A).

¢ As the seedling gets older, it depends more on the environment for food (B).

¢ After producing four leaves, the seedling grows from food taken up through the roots and produced in the leaves (C).

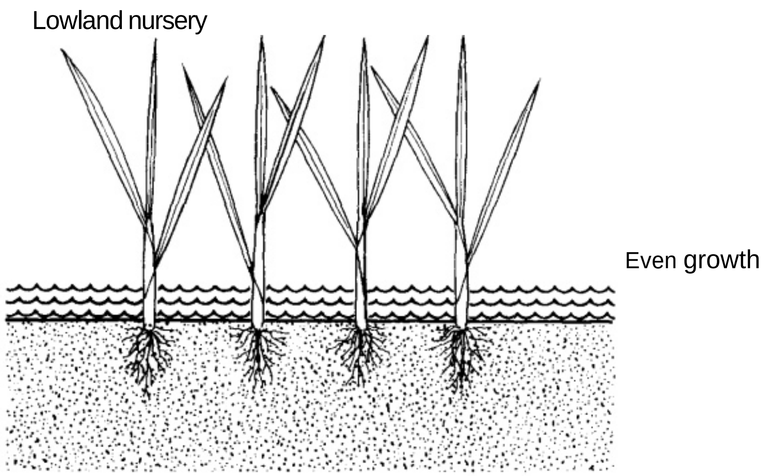
¢ The endosperm of a dapog seedling contains very little food at transplanting. The seedling is just beginning to produce its own food.

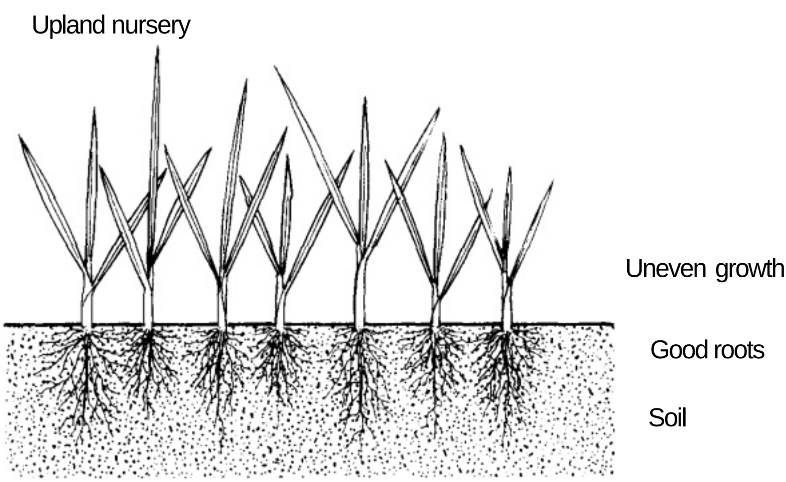
Water depth



- Deep flooding results in tall seedlings and poor root growth because of lack of air in the soil. Those tall seedlings are easily damaged when transplanted.

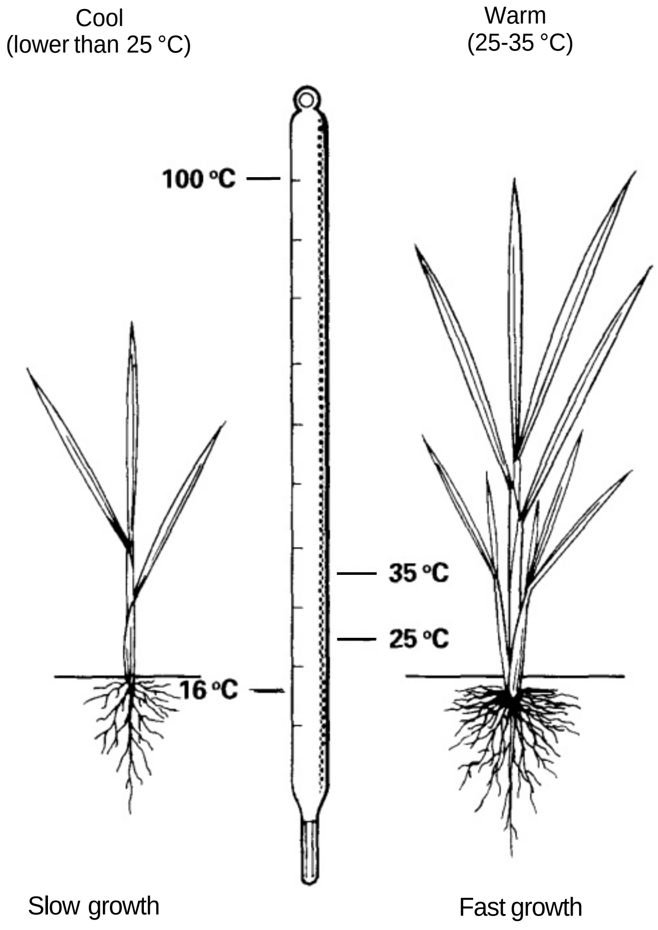
Amount of water





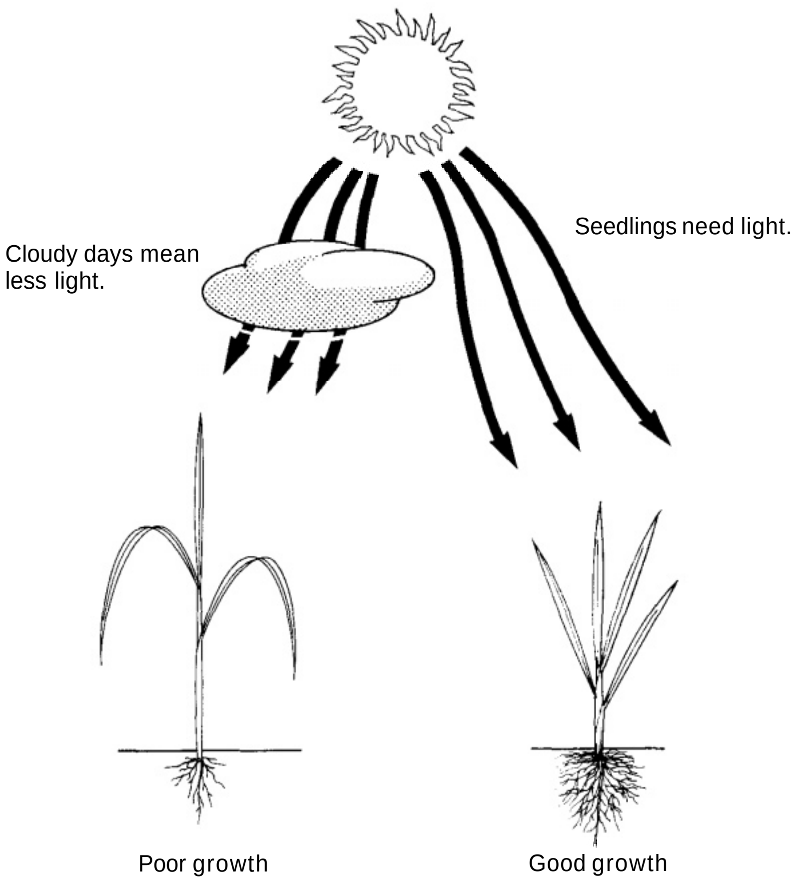
- The large amount of water available to the plants in a lowland nursery results in uniform shoot growth.
- The irregular distribution of water in an upland nursery results in uneven growth. Root growth, however, is usually excellent.
- Insufficient water results in slow seedling growth.

Temperature



- Plants grow faster at warm temperatures than at cool temperatures.
- Seedlings grow taller at warm temperatures than at cool temperatures.
- Cool temperatures can cause leaves to yellow. Some seedlings may eventually die.

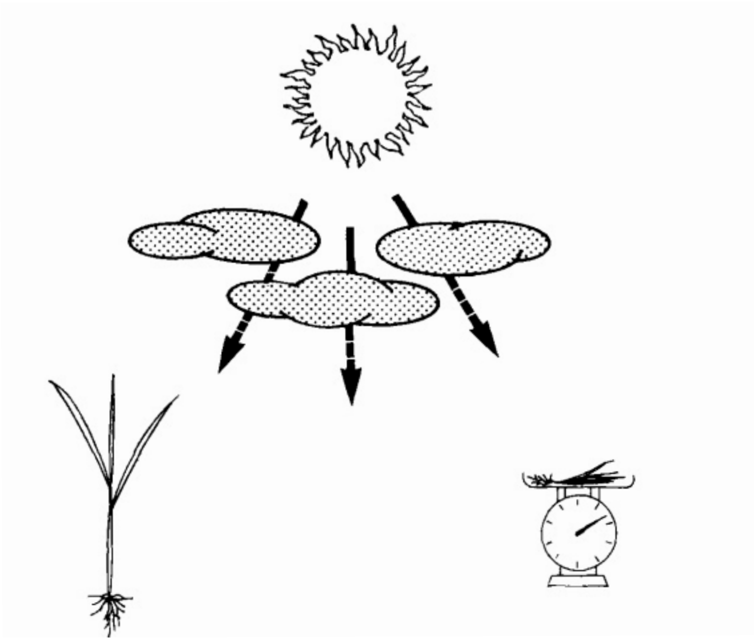
Light intensity



- ¢ Seedlings need bright light, Cloudy days have less light.
- ¢ Prepare the seedbed away from shadows of trees and buildings.
- ¢ Plants produce food from light, water, and air. Less light means less food and therefore weaker seedlings.
- ¢ Less light can cause the leaf blades and leaf sheaths to elongate, resulting in taller and weaker plants.

Low light intensity

Low light intensity results in



— tall and weak seedlings.

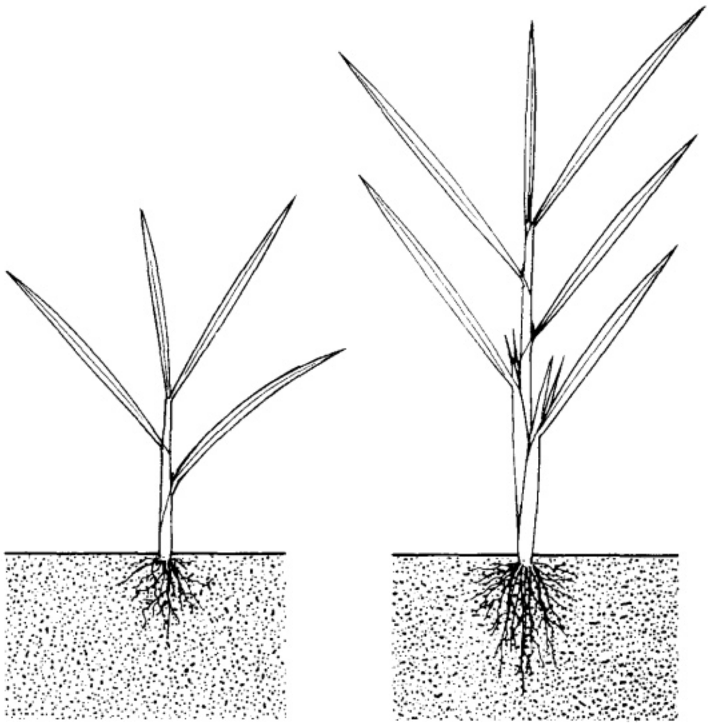
— seedlings with low dry matter.

— seedlings that are easily injured by stresses.

— Increased chance of disease.

Sufficient nutrients

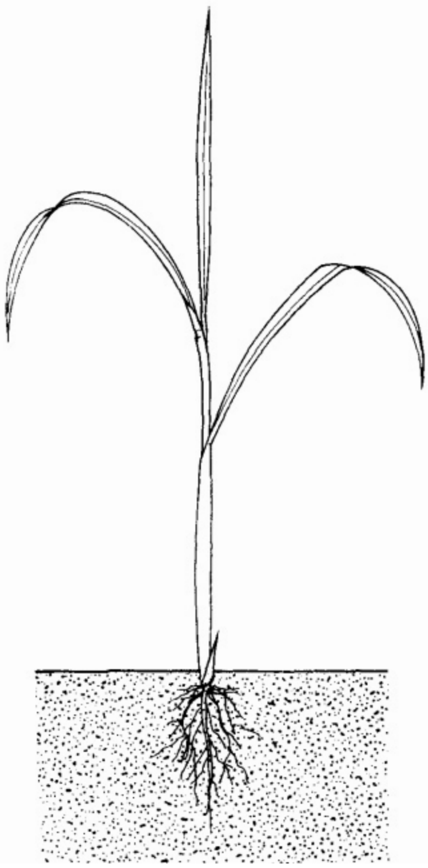
Stunted seedling growth | Vigorous seedling growth



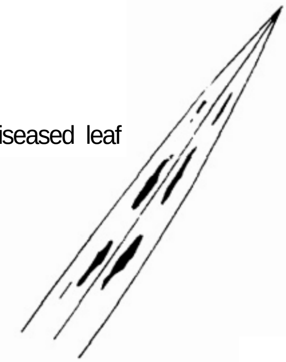
Poor nutrient supply | Sufficient nutrients available

- Fertilizer supplies nutrients (plant food) in addition to what is already available in the soil.
- Fertilizer may be needed in the seedbed if the nursery period is long, in areas with poor soil, in upland nurseries, and in cold areas.

Excess nutrients



Tall and weak seedling

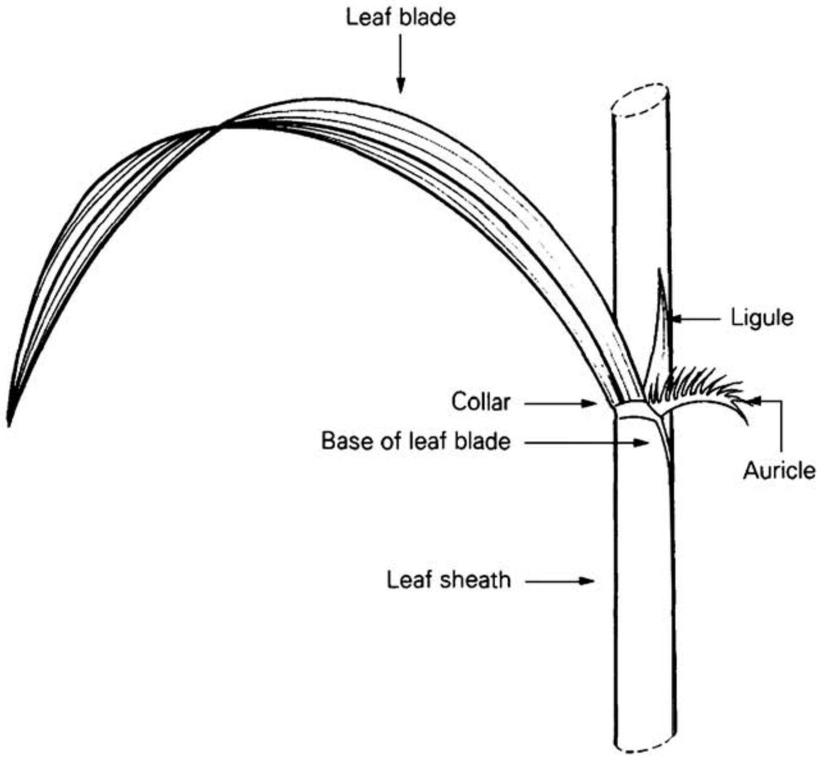


Diseased leaf

- Too much fertilizer in the seedbed may result in very tall, weak seedlings and increase chances of seedlings being attacked by diseases, such as blast.
- The nursery period in warm regions of the world is only 10 - 20 days; fertilizer is usually not used.

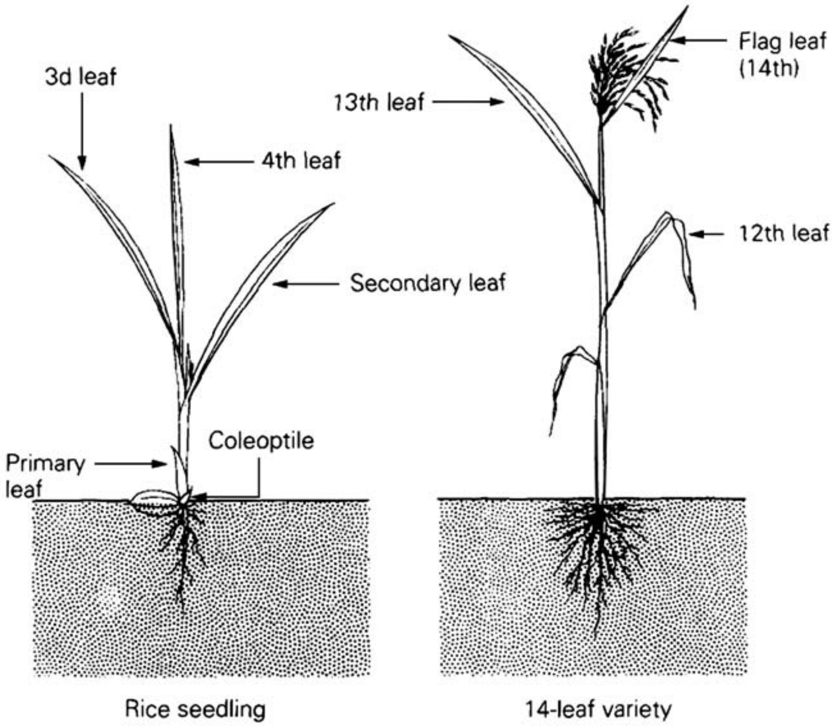
Leaves

The rice leaf



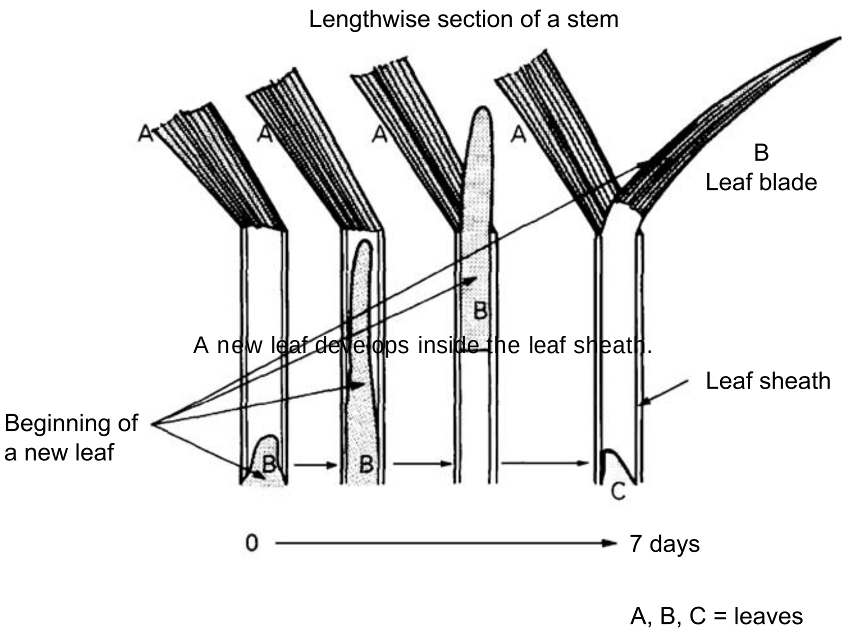
- The presence of both a ligule and an auricle distinguishes a rice leaf from other grasses.
- A grass leaf has a collar but may have only a ligule or an auricle or neither.
- A rice leaf, like all grasses, has parallel veins.

Leaves of the main stem



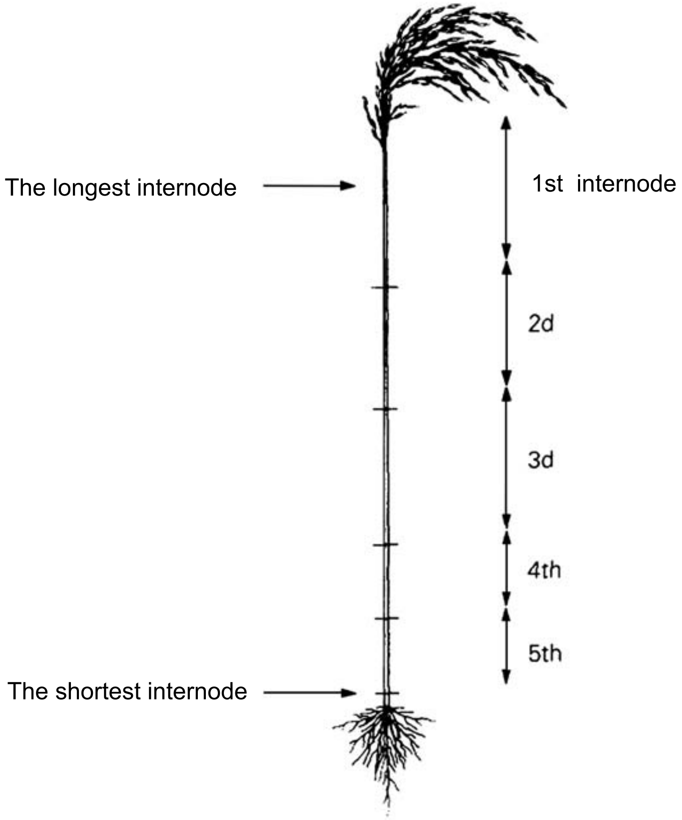
- The coleoptile comes out of the seed first. It is followed by the primary leaf, then the secondary leaf with the first expanded leaf blade, and then the other leaves.
- The last leaf is called the flag leaf.

Development of a leaf



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

Internodes



¢ The rice stem has distinct nodes and internodes. Leaves and tillers may arise from the nodes. Internodes are the elongated parts between two nodes.

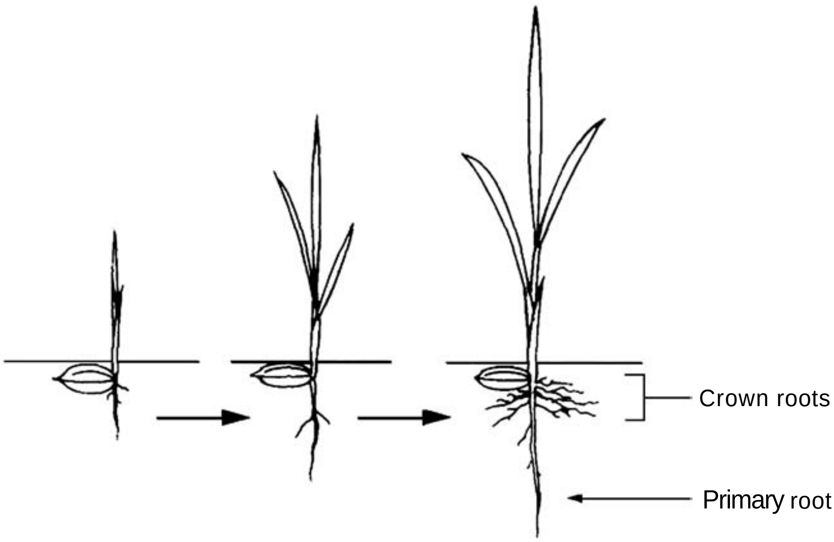
¢ There are normally 4-6 elongated (more than 1 cm) internodes at harvest.

¢ The longer the lower internodes, the greater the tendency for the plant to lodge.

¢ Closer planting, cloudy weather, higher nitrogen level in the soil, and higher temperatures will cause longer internodes.

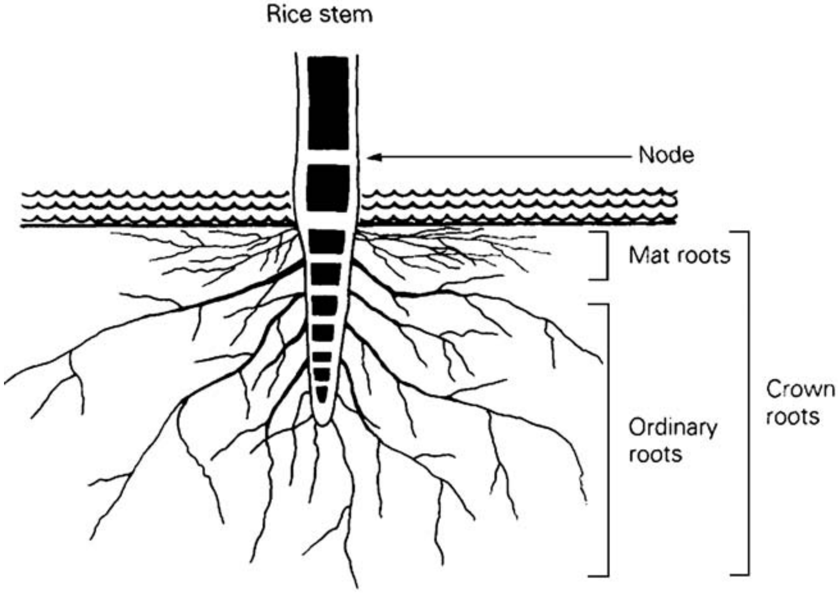
Roots

Origin of roots



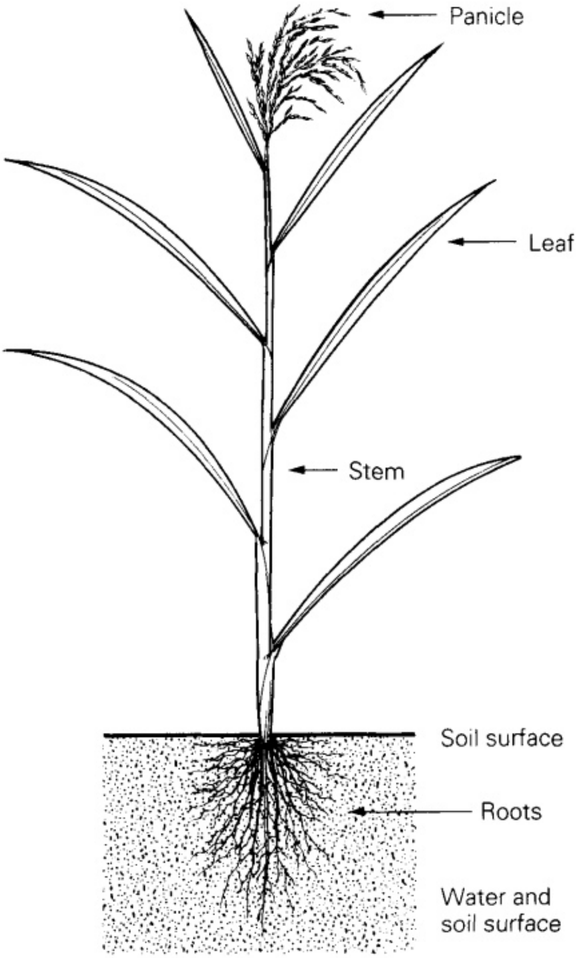
- The primary root usually dies within a month.
- Crown roots develop from the lower nodes.
- Old roots and older parts of a root are brown.
- New roots and young parts of a root are white.

Crown roots



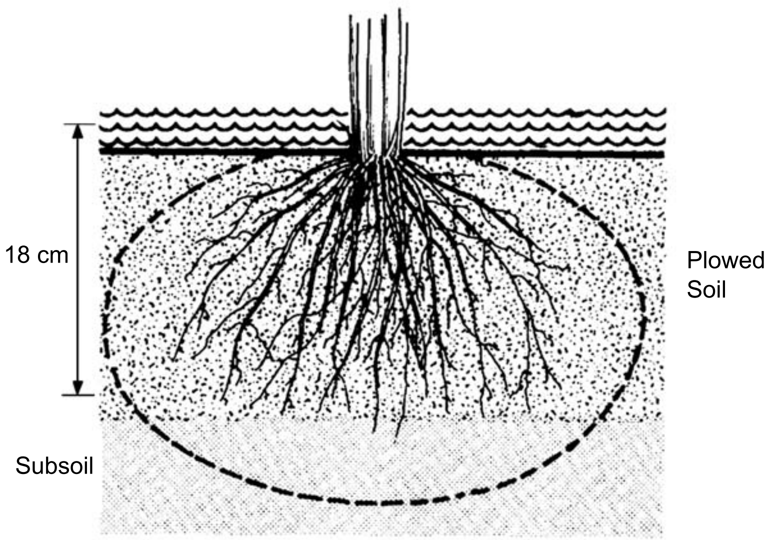
- ¢ There are two types of crown roots: mat roots, which are shallow, and ordinary roots.
- ¢ Mat roots develop when the air content of the soil is low, as in later growth stages.

Root functions



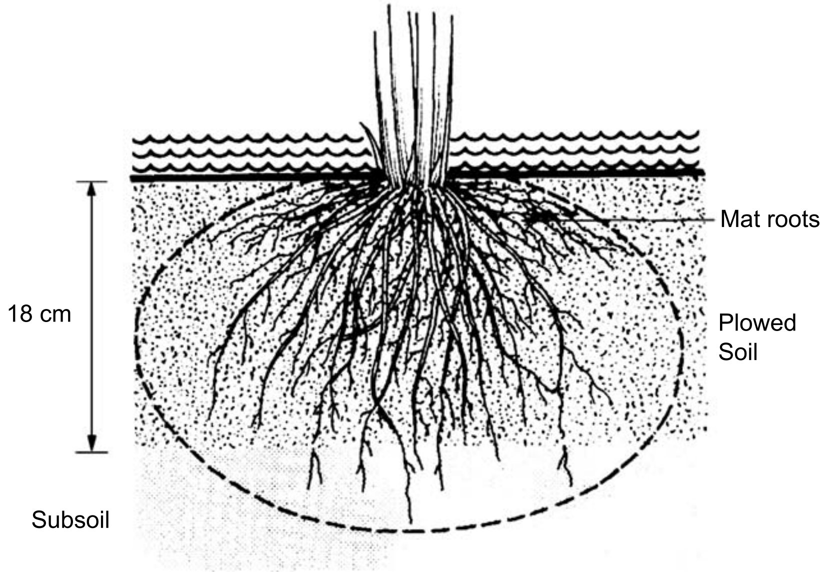
- Soil water contains nutrients such as nitrogen, phosphorus, and potassium.
- The roots take up soil water with nutrients in it.
- The roots support the upper parts of the plant.

Root development at 30 days after transplanting



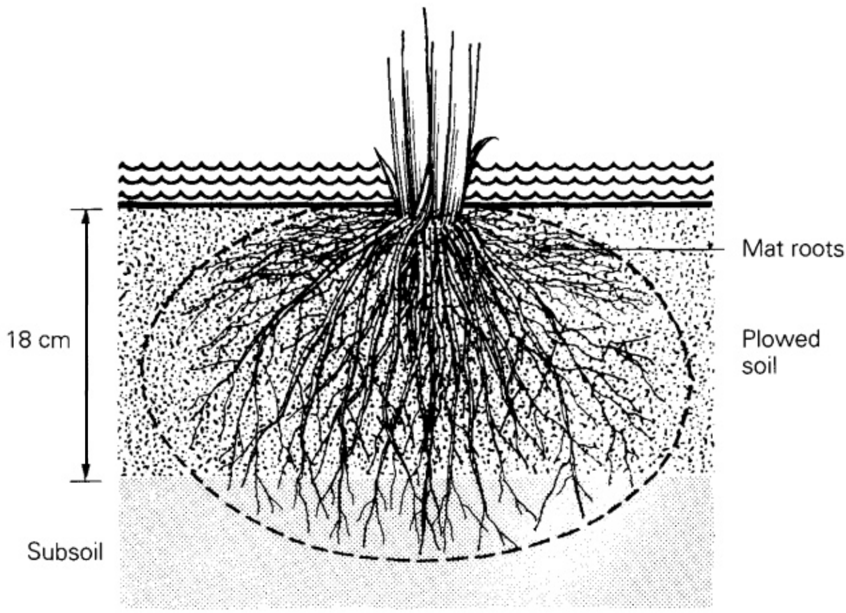
¢ Most roots are in the plowed layer of the soil (18 cm).
¢ Almost no roots are found in the subsoil.

Root development at 50 days after transplanting



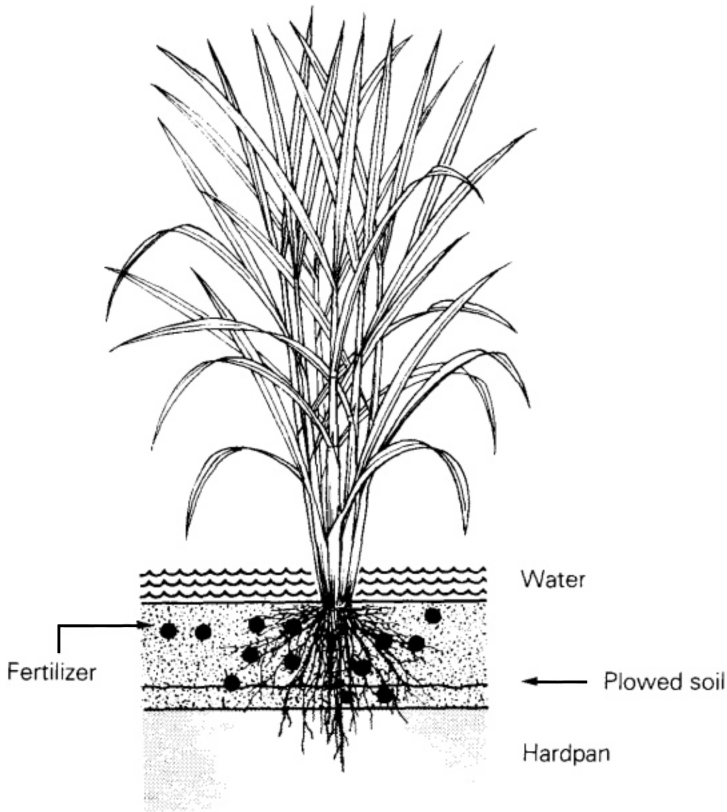
¢ Some roots have grown nto the soubsoil.

Root development at flowering



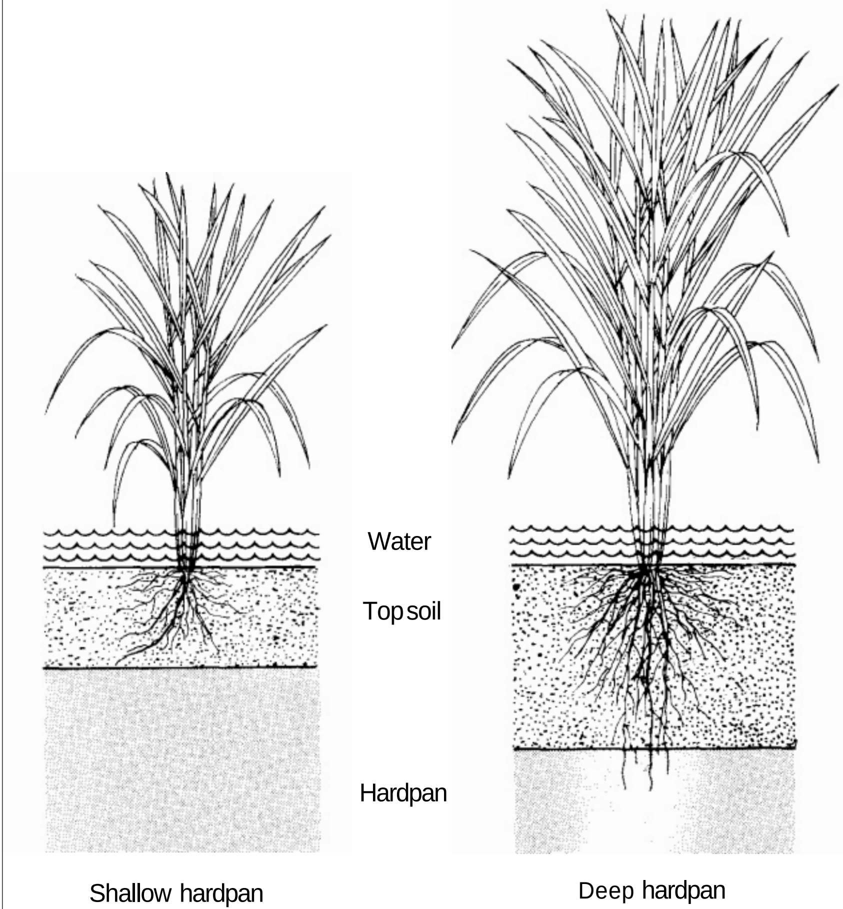
- More roots have penetrated the subsoil.
- There are many mat roots.

Root distribution



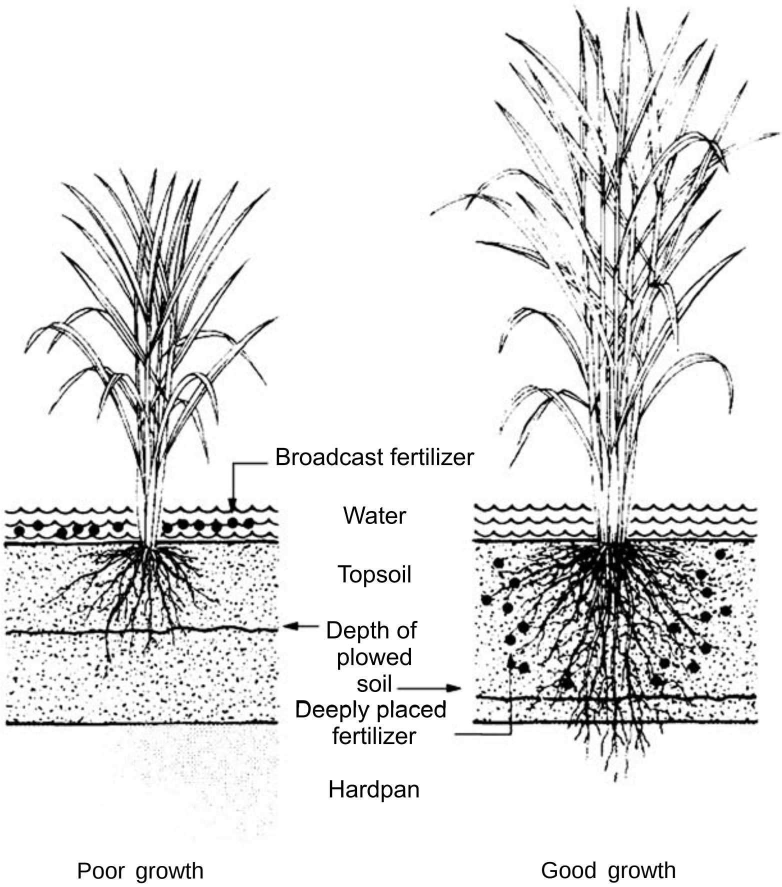
- ¢ Root distribution depends on
  - depth of the topsoil,
  - depth of the plowed layer,
  - downward movement of water,
  - amount of air available,
  - type of irrigation,
  - placement of fertilizer, and
  - variety.
- ¢ Roots must penetrate deeply and spread widely and evenly for good uptake of nutrients from the soil.

Root distribution depends on depth of topsoil



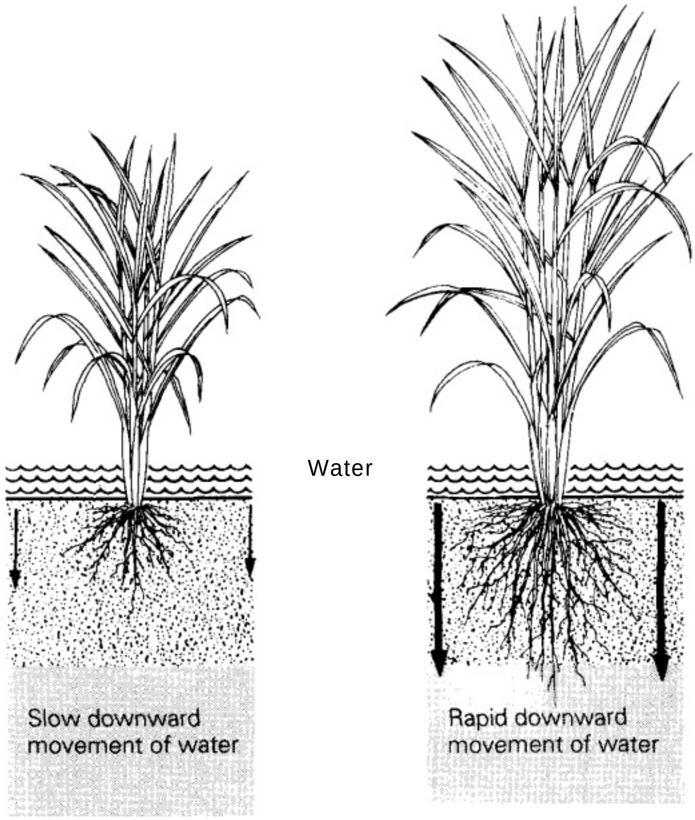
- The topsoil is the distance between the soil surface and the hardpan.
- Deeper topsoil means deeper root penetration.

Root distribution depends on depth of plowed layer



- Plow as deep as possible. Deeper plowing means deeper root penetration.
- Mix fertilizer thoroughly into the plowed soil to get deeper roots and better root distribution.
- Deep placement of fertilizer near the plant is more efficient than broadcasting fertilizer.

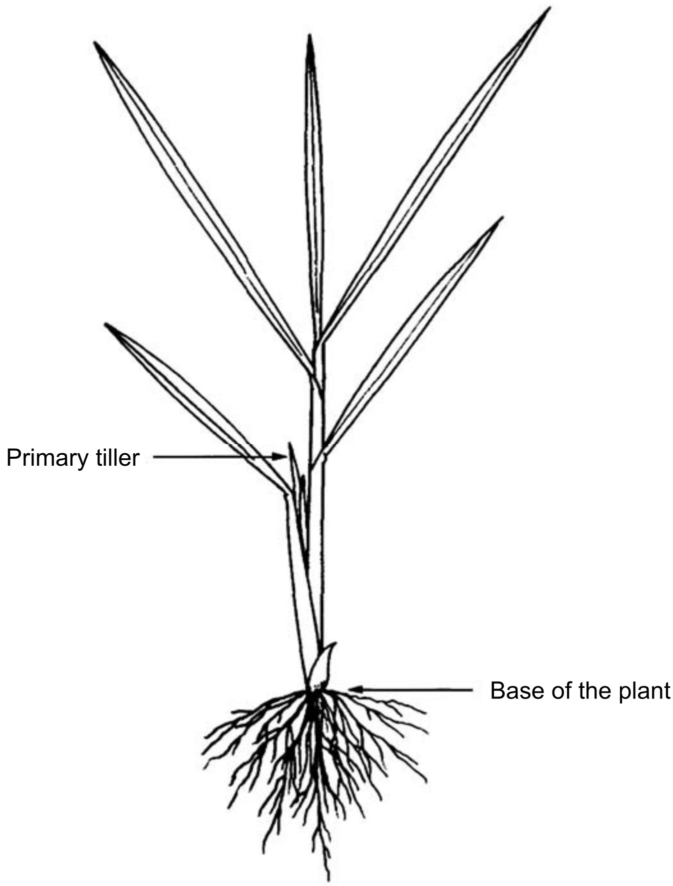
Root distribution depends on downward movement of water



- If water moves downward freely and quickly, the roots develop downward easily.
- The downward movement of water makes more air and fertilizer available in the lower soil layer.
- The deeper the roots, the better the plant can absorb water. This is a very important plant characteristic where the water supply is not dependable.

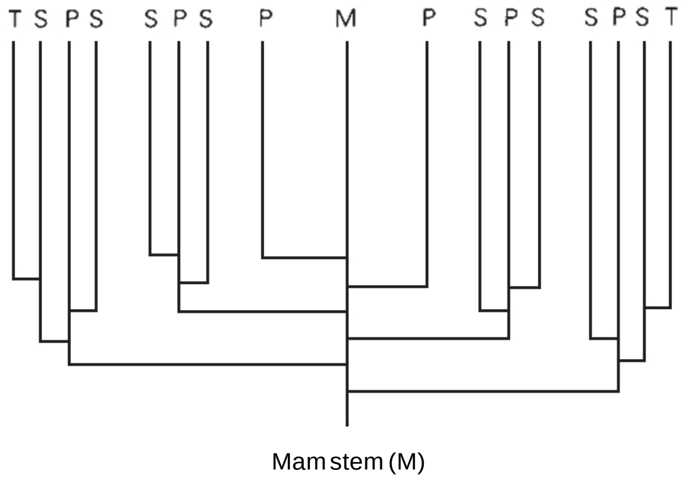
Tillers

Primary tiller



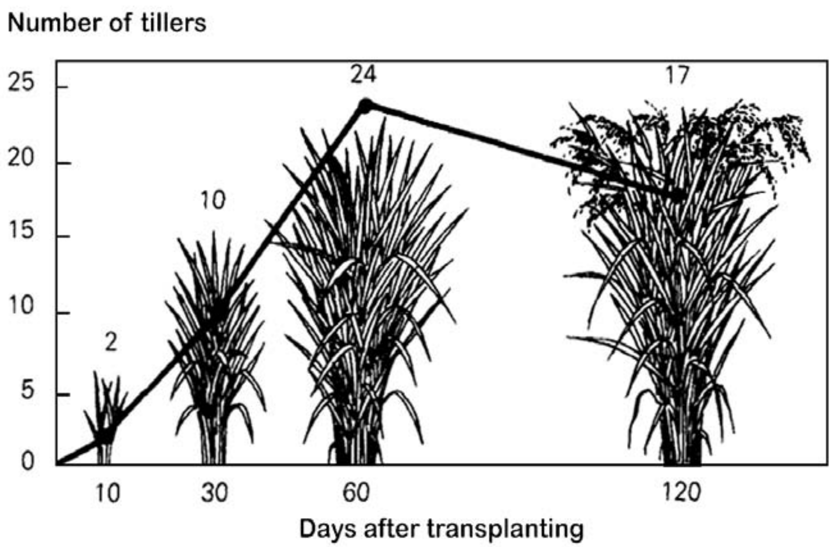
- The first primary tiller usually develops between the main stem and the second leaf from the base of the plant.
- The tiller remains attached to the mother plant at later growth stages but is Independent because it produces its own roots.

Tillering pattern



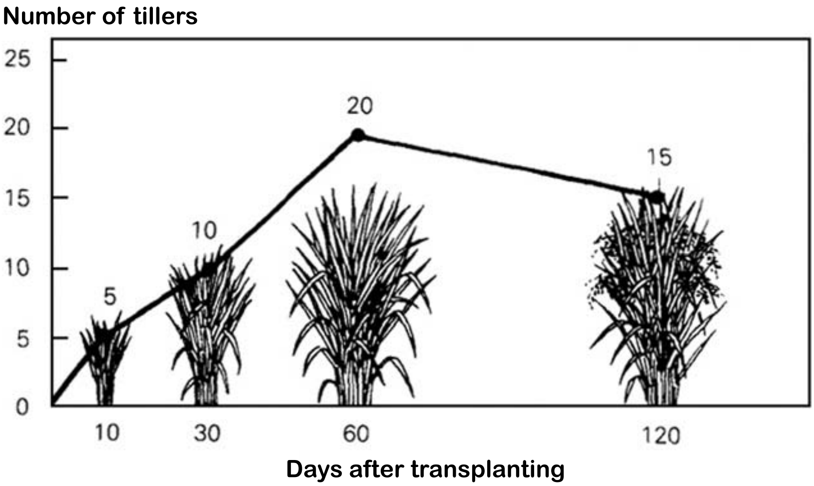
- Primary (P) tillers come from the main stem.
- Secondary (S) tillers develop from primary tillers.
- Tertiary (T) tillers develop from secondary tillers.
- The lower the point of origin on the main stem, the older the tiller.

Production of tillers



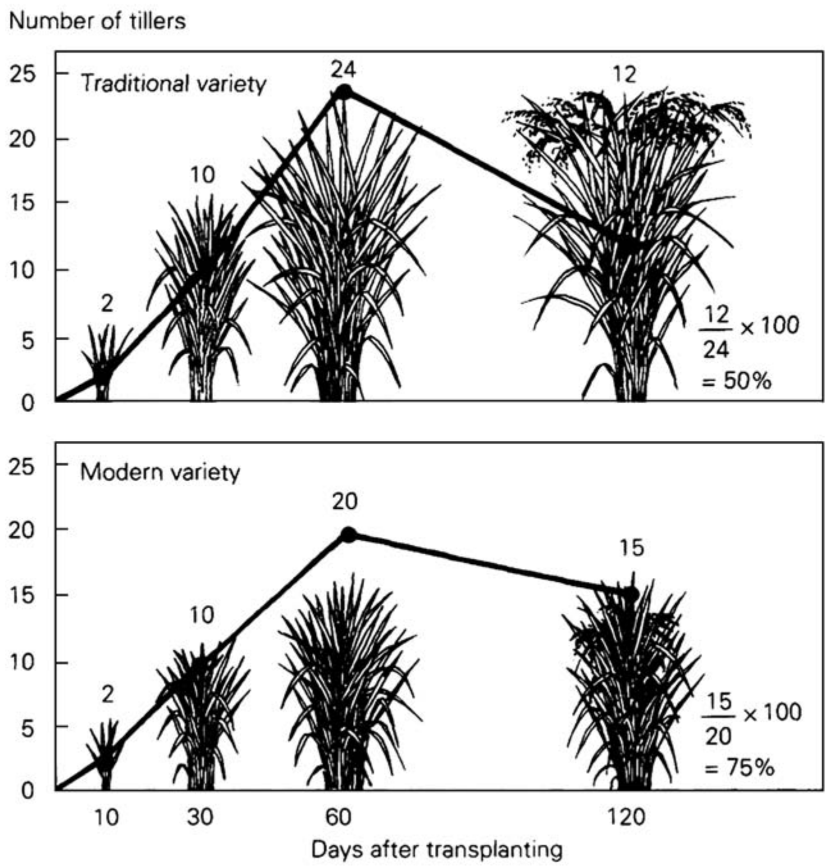
- ¢ Tillering starts 10 days after transplanting and reaches maximum 50-60 days after transplanting.
- ¢ After reaching the maximum, tiller number decreases as weak tillers die.

Productive and nonproductive tillers



- ¢ Tillers formed during late growth stages are usually nonproductive. Either the tillers die or the panicles produced are too small and ripen late. Spikelets are only half-filled at harvest.
- ¢ Modern varieties have more tillers at flowering and lose fewer tillers.
- ¢ Mutual shading, competition among tillers, or lack of nutrients (especially nitrogen) may cause tiller loss.

How to calculate percentage of productive tillers



$$\text{Percent productive tillers} = \frac{\text{Number of panicles produced}}{\text{Highest number of tillers produced}} \times 100$$

¢ In the drawings above, the traditional variety has 50% productive tillers; the modern variety has 75%.

Variety affects tillering

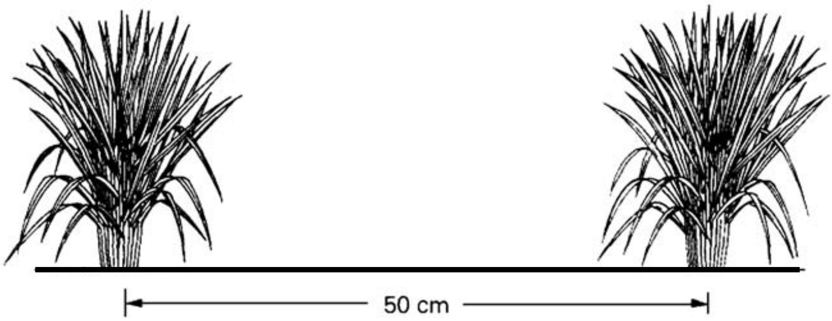
A variety with 6 tillers

A variety with 20 tillers

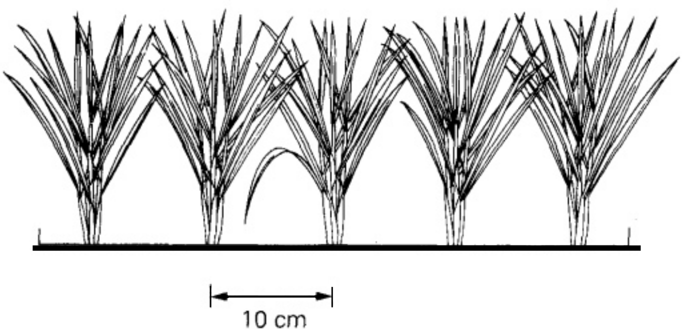
Planted at wide spacing

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

Spacing affects tillering



50- x 50-cm spacing
33 tillers per plant
4 plants per square meter
132 tillers per square meter



10- x 10-cm spacing
3 tillers per plant
100 plants per square meter
300 tillers per square meter

- The tiller number per plant increases as the distance between plants increases.
- If plants are spaced far apart, the number of tillers per square meter may be reduced.

Season of planting affects tillering

Wet season — 21 tillers

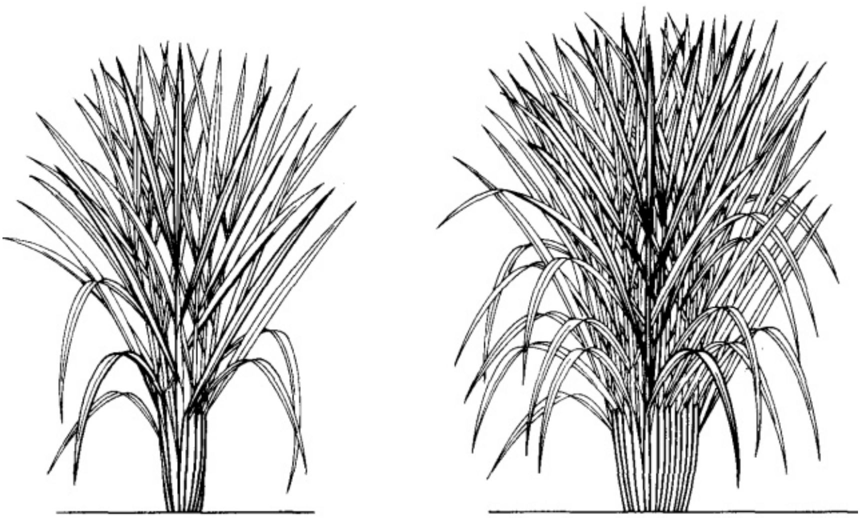
Dry season — 10 tillers

¢ Plants produce more tillers during wet season than during dry season.

¢ Plants need more nitrogen fertilizer during dry season to increase tiller number.

¢ Closer spacing in dry season helps to produce the same number of tillers per square meter as in wet season.

Nitrogen level affects tillering



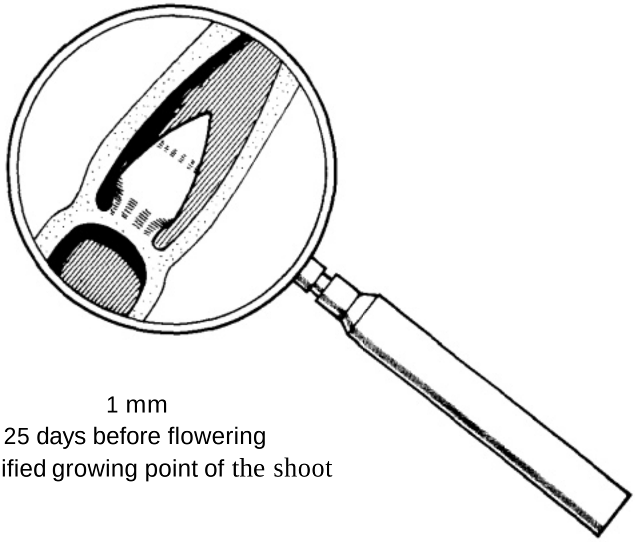
10 tillers
No nitrogen added

30 tillers
Nitrogen fertilizer added

- Nitrogen is important to increase tiller number.
- But too much nitrogen can increase the incidence of diseases and lodging.

Panicles

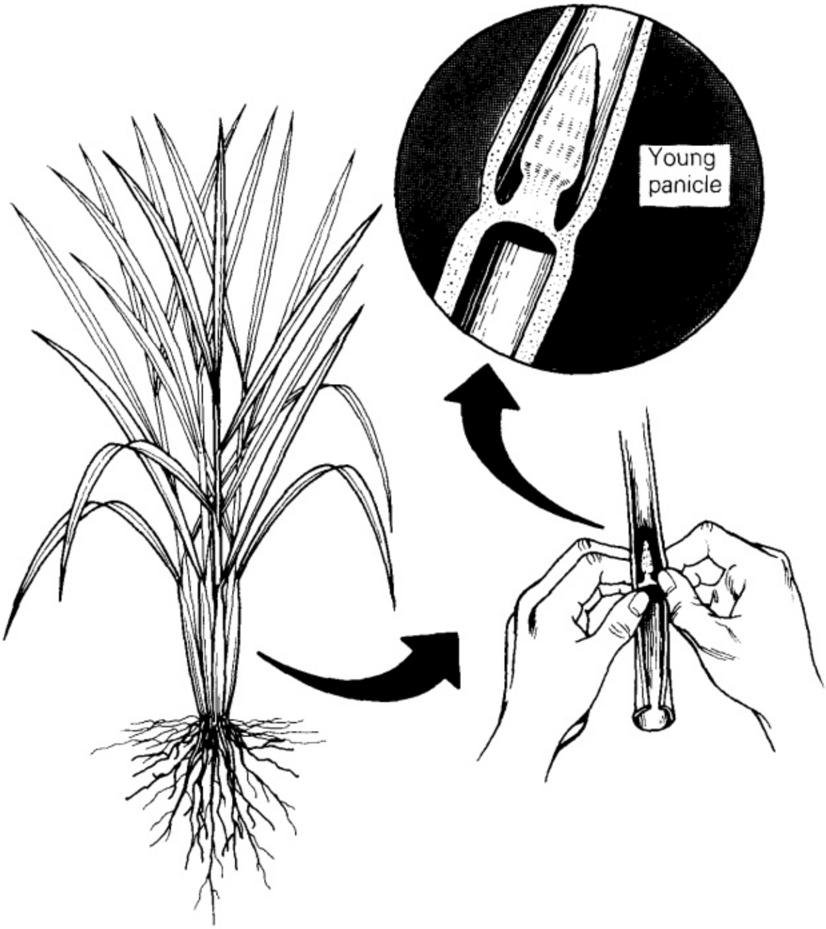
Panicle initiation



1 mm
25 days before flowering
Magnified growing point of the shoot

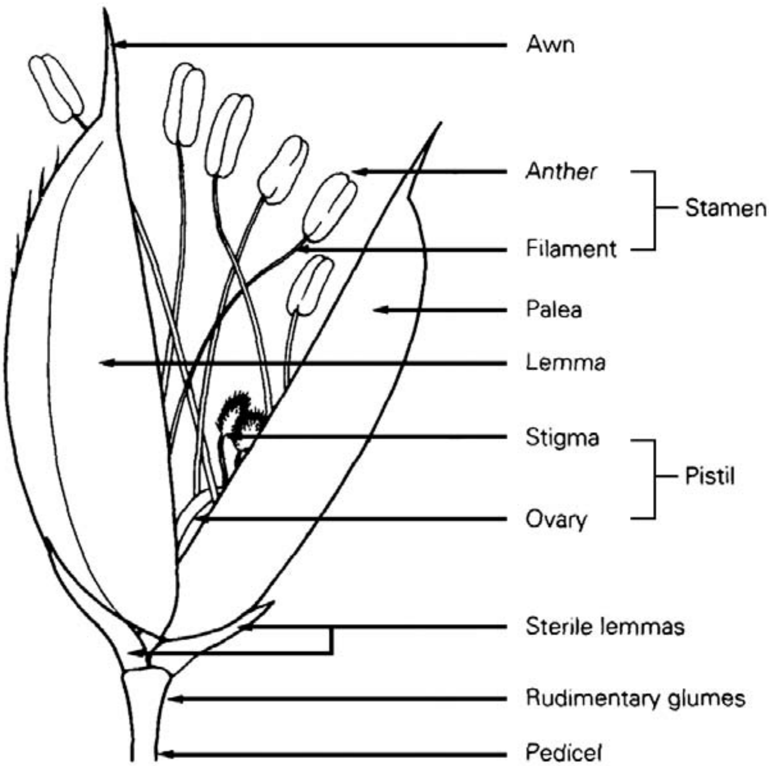
- ¢ A panicle forms at the tip of the growing point of the shoot.
- ¢ The panicle is visible to the naked eye when it is 1 mm long.
- ¢ At 1 mm, the young panicle has many fine, white, hairy structures at the tip.
- ¢ The plant will produce three more leaves before the panicle comes out of the leaf sheath.

Booting stage



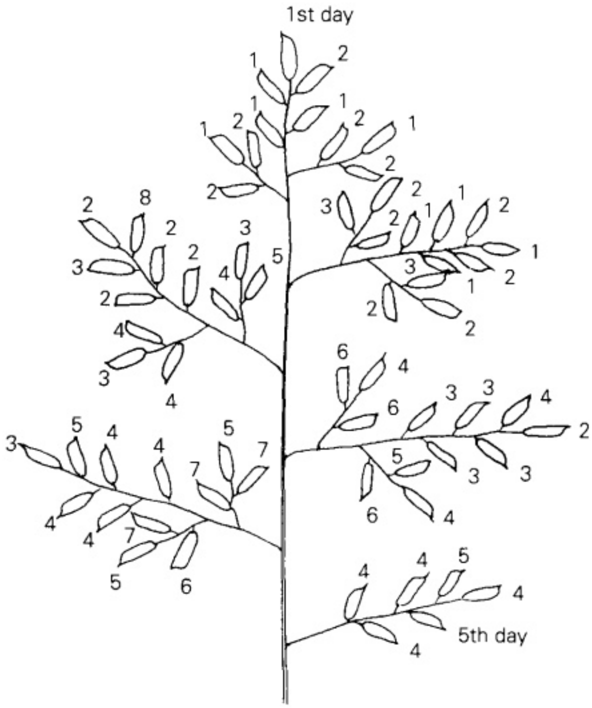
- ¢ Booting starts 20-25 days before flowering. The panicle is 1 mm long.
- ¢ The base of the leaf sheath bulges at booting.
- ¢ Flowering occurs 35 days after the start of panicle formation.

The spikelet



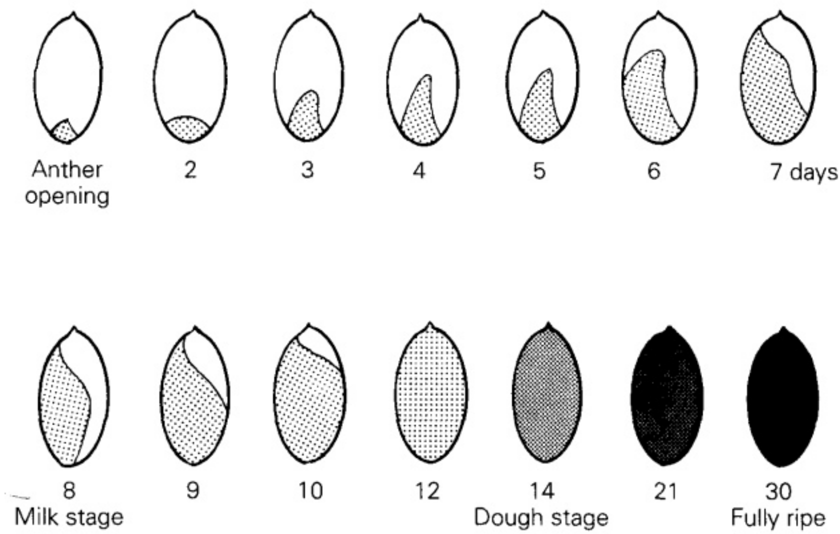
- Some anthers begin to open 1 day after the panicle comes out.
- When the spikelet opens, the anthers inside the spikelet will also open.
- Low temperature delays the opening of the anthers.
- The pollen (male cells), which is like a fine dust, comes from the anthers. It must reach the stigma and unite 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 about 7 days for all of the spikelets in a panicle to open.
- The upper spikelets (number 1) open first.
- The lower spikelets open last. They usually do not completely fill in large panicles.
- Modern varieties have 100-120 spikelets per panicle.

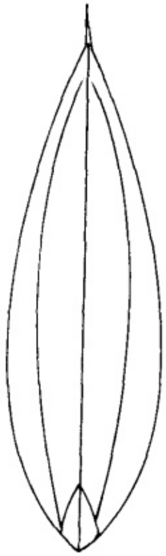
Stages of grain formation



- 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 21 days after fertilization.
- Extra days are needed to ripen all the grains because the spikelets on the panicles open at different times.

Causes of empty spikelets

Side view of an
empty spikelet

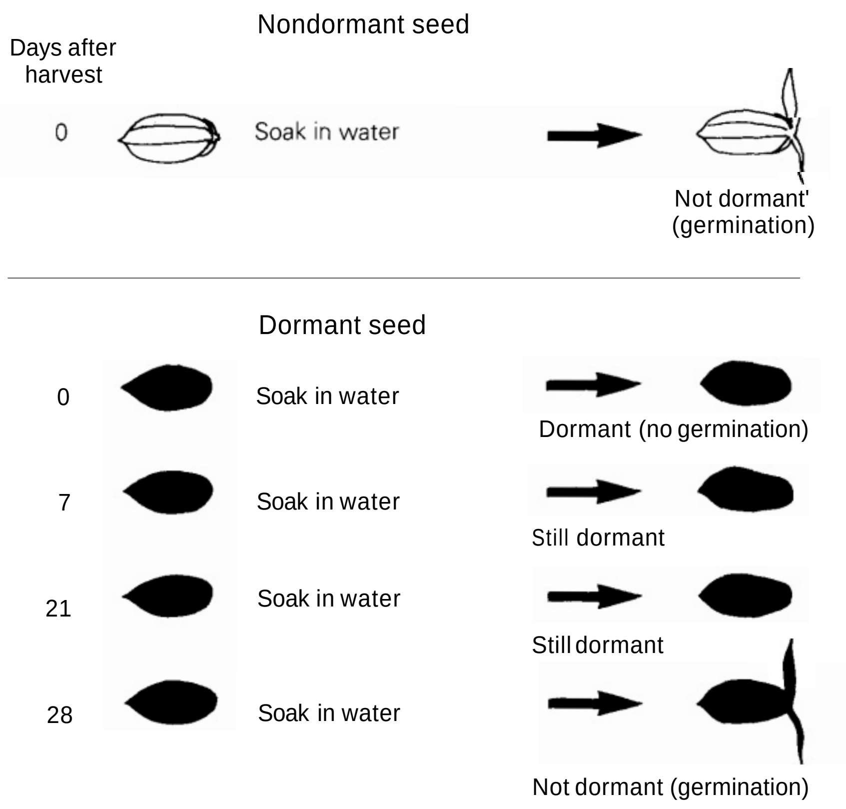


Side view of a
fully filled spikelet

- Many factors can affect the filling of spikelets.
  - Lodging, low light intensity, drying of the leaves, disease, or insect damage can cause a lack of starch.
  - High temperature or dry winds can cause the stigma to dry and no fertilization to occur.
  - Low temperature or high humidity at flowering can prevent spikelets from opening.
  - Too much nitrogen at panicle formation can prevent normal spikelet development.
  - Low temperature at panicle formation can cause damage to spikelets.
- Empty spikelets will float when placed in water.

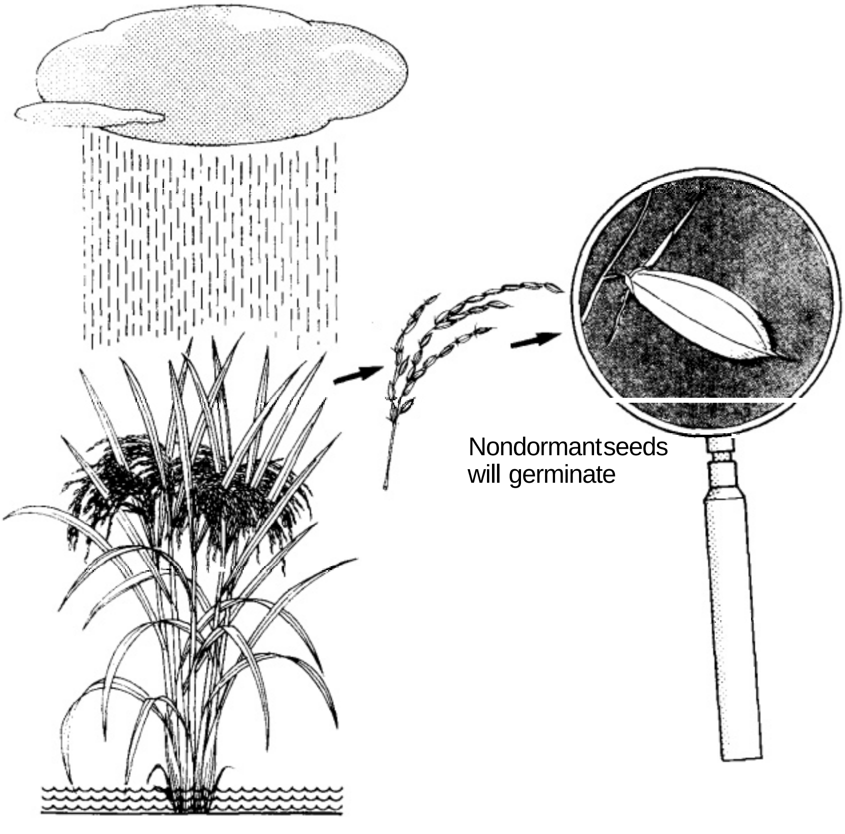
Dormancy

Seed dormancy



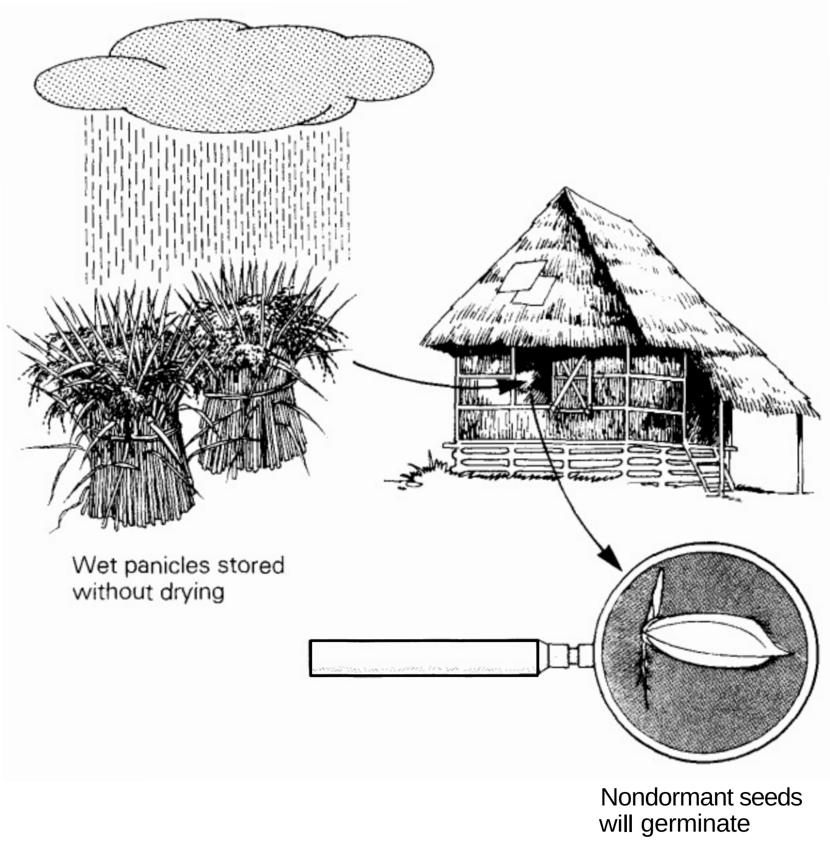
- A mature seed is dormant if it fails to germinate under favorable conditions.
- Not all varieties have dormancy.
- Seeds may be dormant from 0 to 80 days. Dormancy depends on the variety and conditions at harvest.

Dormancy prevents seeds from germinating on the panicle



- Dormancy is important during the rainy season harvest.
- Nondormant seeds may germinate if exposed to rain when mature.
- Seeds harvested during the dry season have a lower percentage of dormancy.

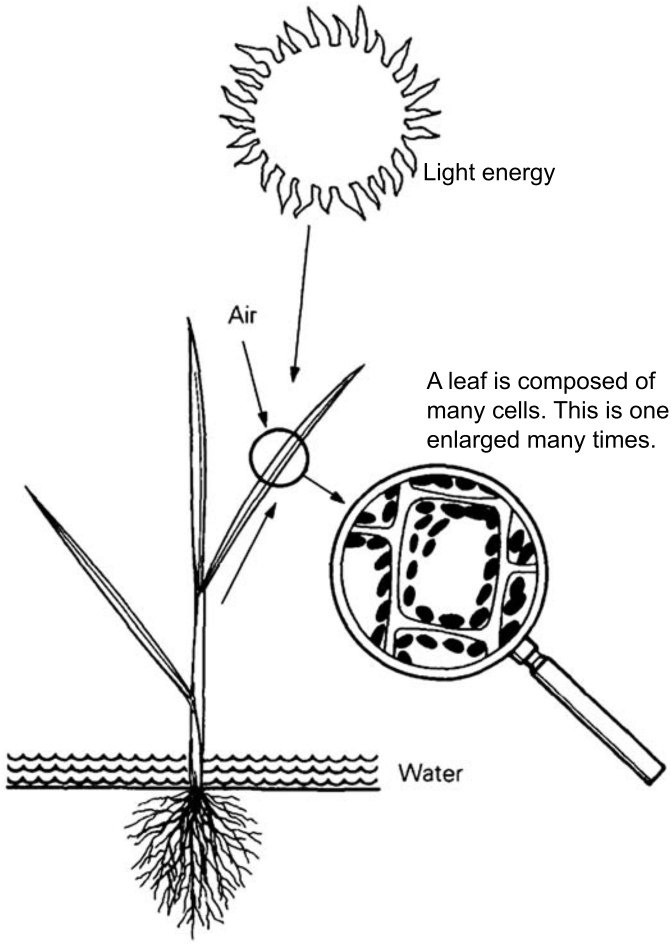
Dormancy prevents germination of seeds stored in wet conditions after harvest



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

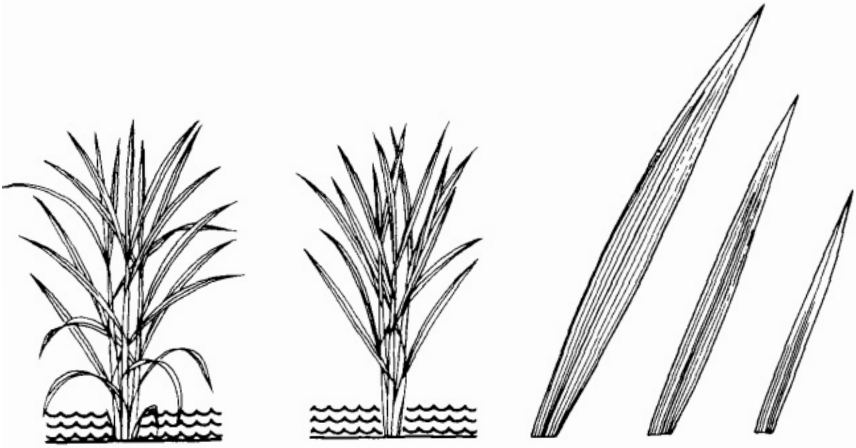
Carbohydrate production

The food factory



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

Amount of green color affects carbohydrate

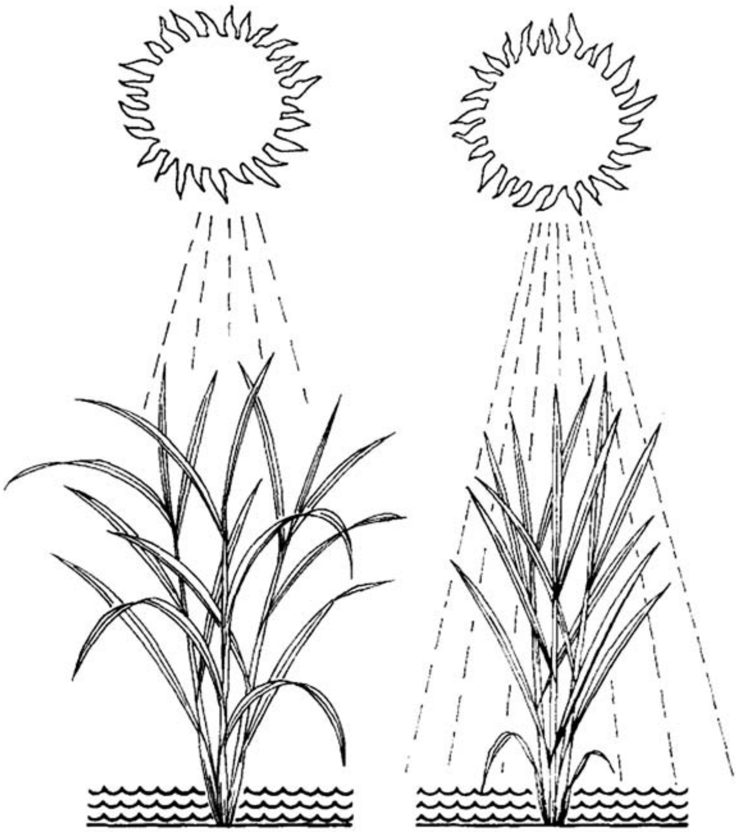


Different number of leaves

Different leaf size

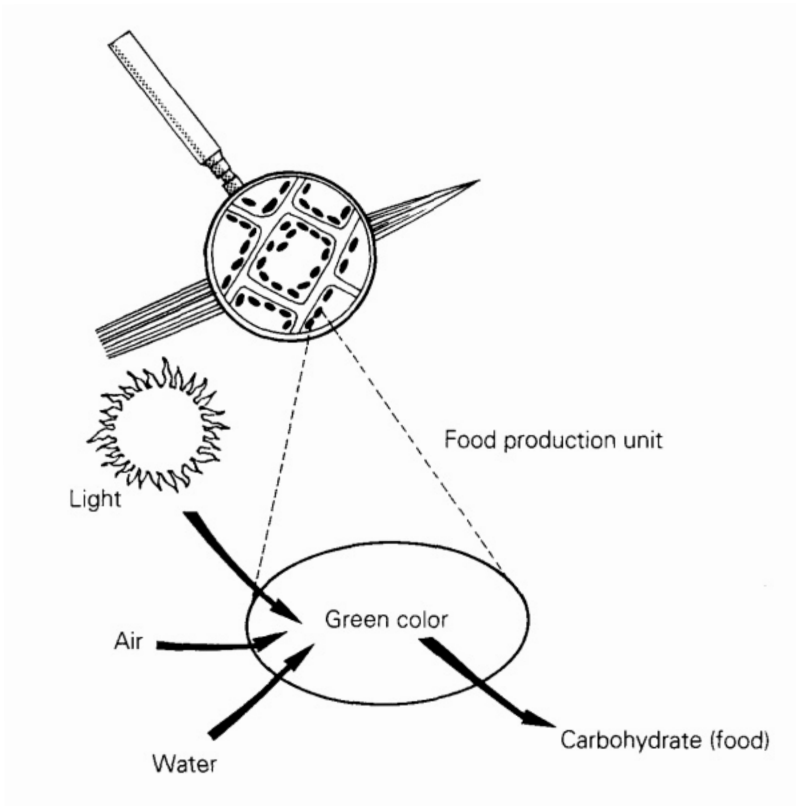
¢ The amount of green color per plant increases as the number of leaves and leaf size increases. Thicker leaves usually have more green color.
¢ Low nitrogen in the plant decreases the green color.
¢ The more green color per plant, the higher the carbohydrate production.

Amount of light affects carbohydrate production



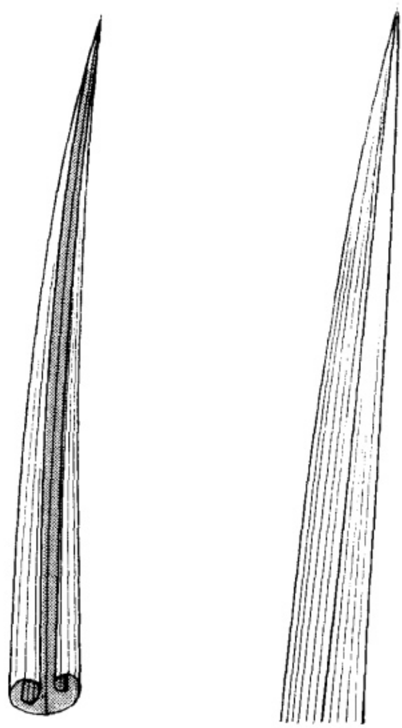
- ¢ Brighter light gives more light energy to the plant, which can then produce more carbohydrates.
- ¢ Plants with erect leaves receive more light and thus produce more carbohydrates.
- ¢ The amount of light is less during the wet season.

Amount of carbon dioxide in the air affects carbohydrate production



- The plant uses carbon dioxide from the air to produce food.
- Carbon dioxide is plentiful and is rarely the cause of a decrease in food production. The amount of carbon dioxide in the air has been increasing in recent years.

Amount of water in the leaf affects carbohydrate production



Lack of water
Enough water

Enough water

¢ Water is an important part of a carbohydrate unit.

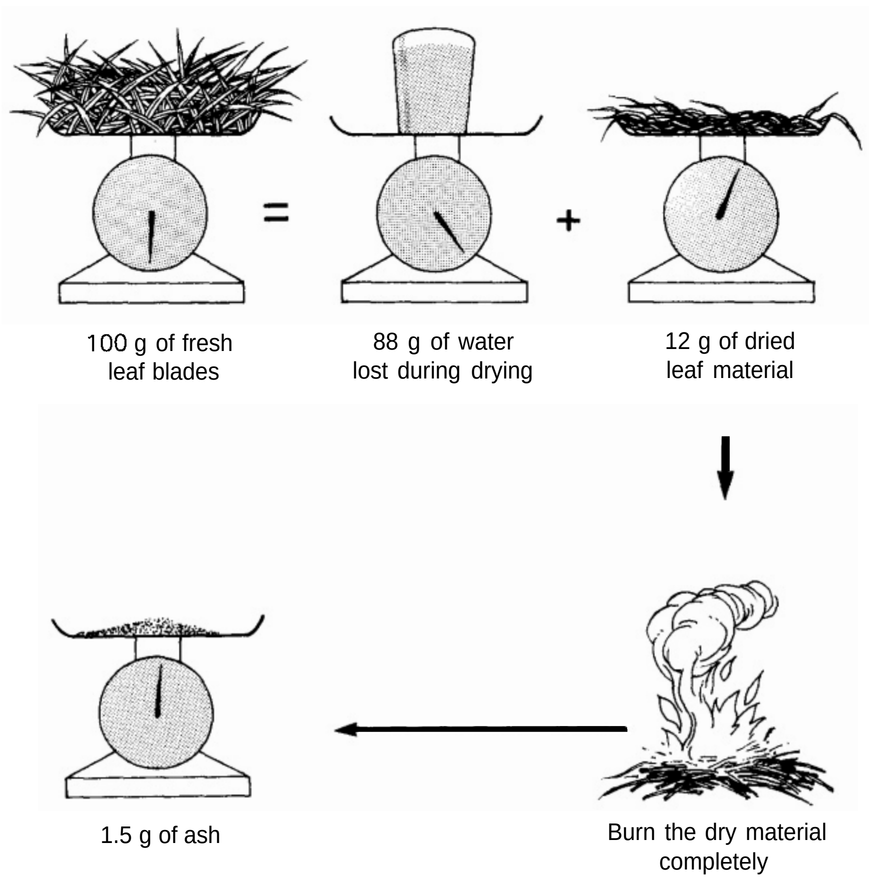
¢ Lack of water leads to decreased food production.

¢ When the leaves lose water, their pores close and air cannot enter. Carbon dioxide in the air is important in carbohydrate production.

¢ The leaves roll to protect the plant from further water loss. This reduces the amount of light the leaves can absorb to produce carbohydrates.

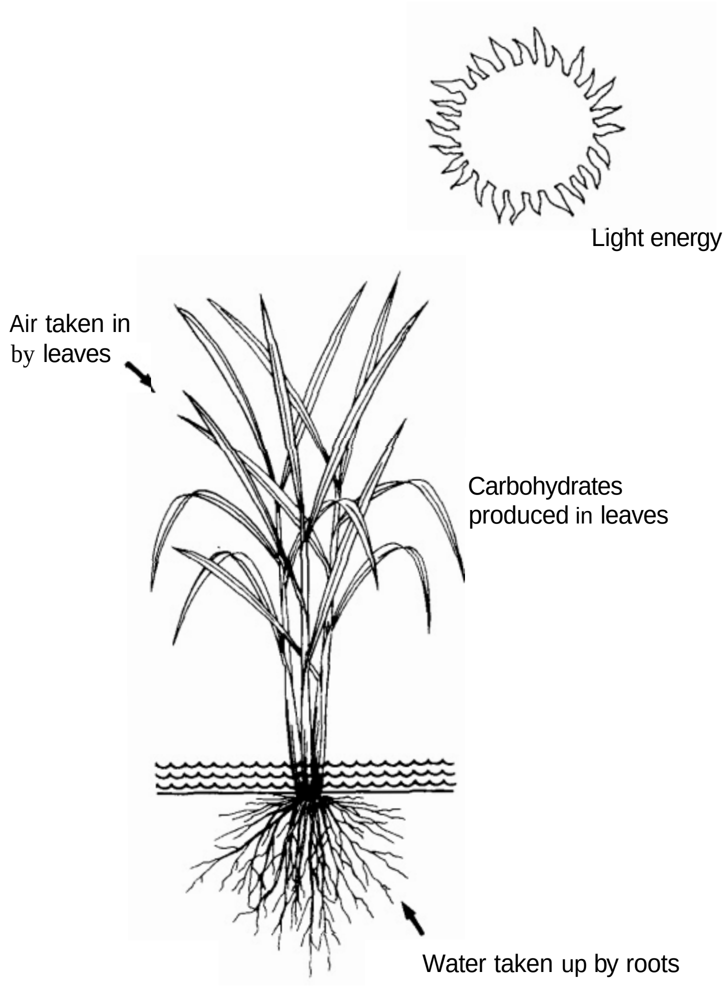
Water

Major components of the plant



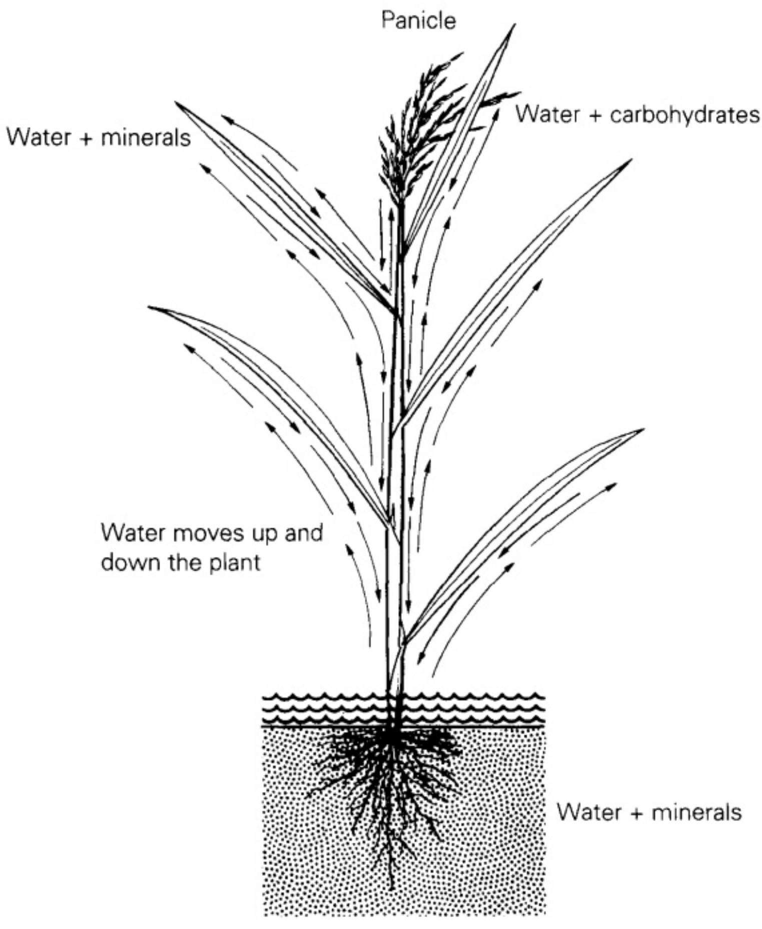
- Leaves, stems, and roots are mostly water. Grains have less water than the rest of the plant.

Raw material for food production



- Water, air, and light are needed to produce food. Water is usually the limiting factor.
- Lack of water decreases the amount of food produced.

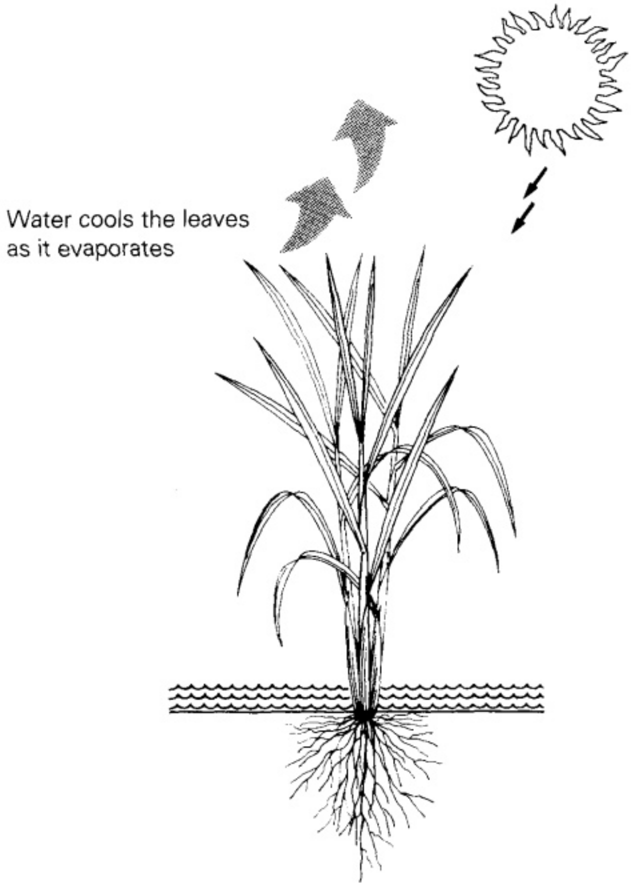
Water carries the food



¢ Water carries the carbohydrates and mineral nutrients to the plant parts.

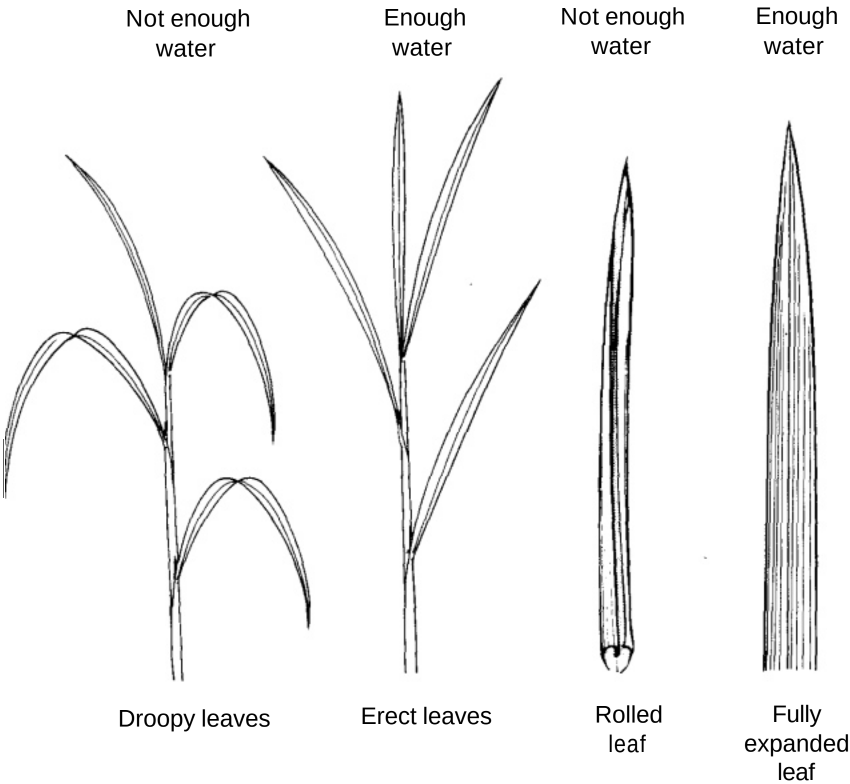
¢ One hectare of rice plants uses at least 8 million liters of water for one crop. That amount would cover the field waist-deep with water.

Water cools the plant



- As water evaporates, it cools the leaves the way perspiration cools our bodies.
- When there is not much 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 the rice plant takes up is lost through evaporation.

Water stiffens the plant



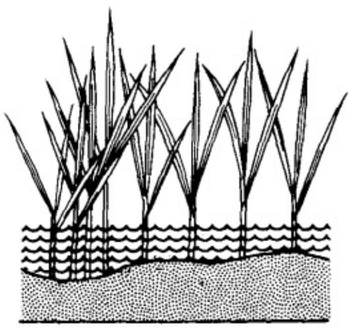
- Water helps make the leaves erect and fully expanded.
- Water in the plant is like air in the tires of a car.

FARM MANAGEMENT

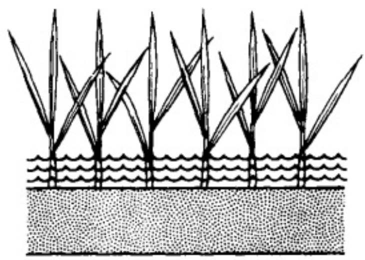
How to select good seedlings

84 Good seedlings have uniform height and growth
85 Good seedlings have short leaf sheaths
86 Proper water depth can cause short leaf sheaths
87 Good lighting can cause short leaf sheaths
88 Good seedlings have neither pests nor diseases
89 Good seedlings have more roots that are longer and heavier

Good seedlings have uniform height and growth



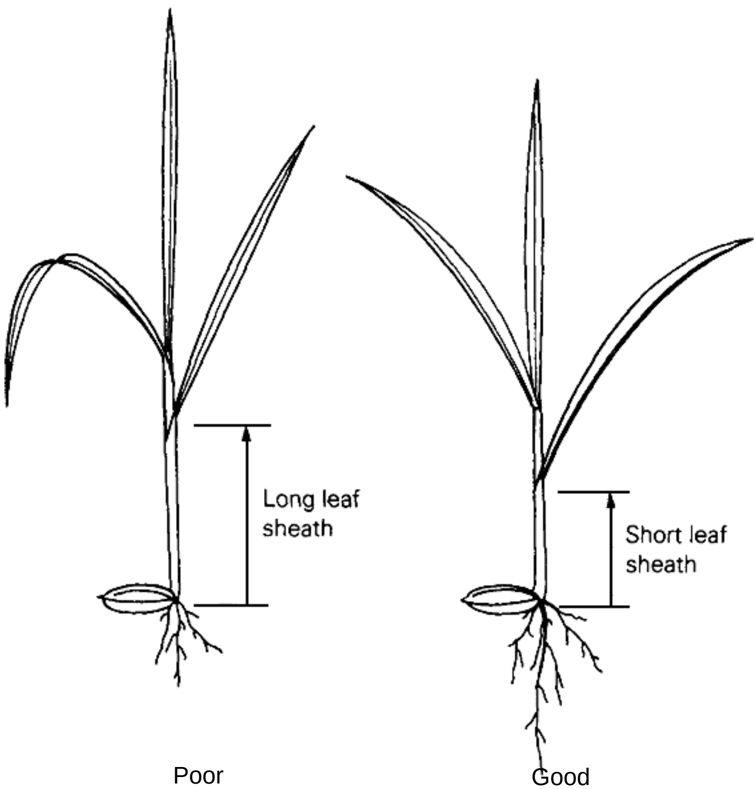
Irregular growth



Regular growth

- Irregular seedling growth may indicate unevenness in
  - seed distribution in the seedbed,
  - seed germination,
  - land preparation of the seedbed,
  - watering, or
  - availability of soil nutrients.

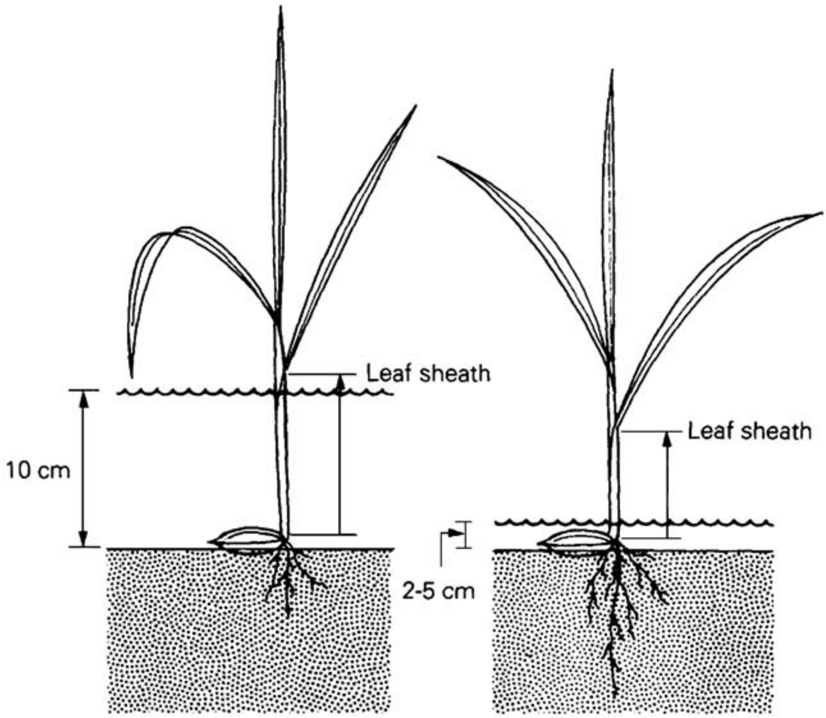
Good seedlings have short leaf sheaths



- The leaf sheath is the lower portion of the leaf that encloses the stem and young leaves.
- A long leaf sheath indicates very rapid initial elongation, making the seedling weak.

Proper water depth can cause short leaf sheaths

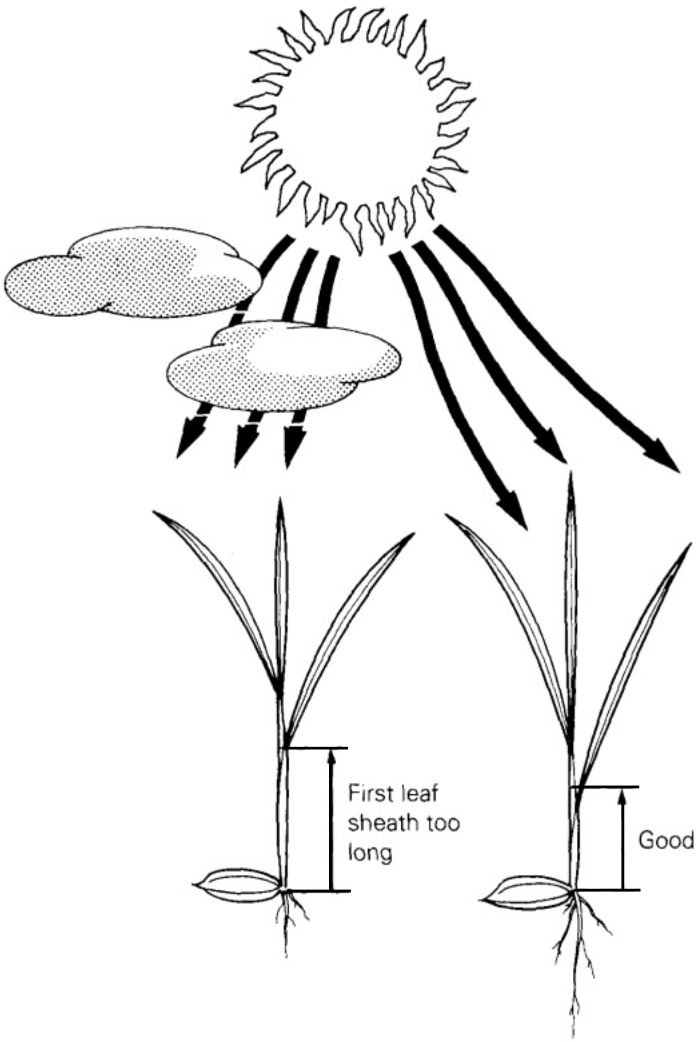
Seedbed water level



Poor **Good**

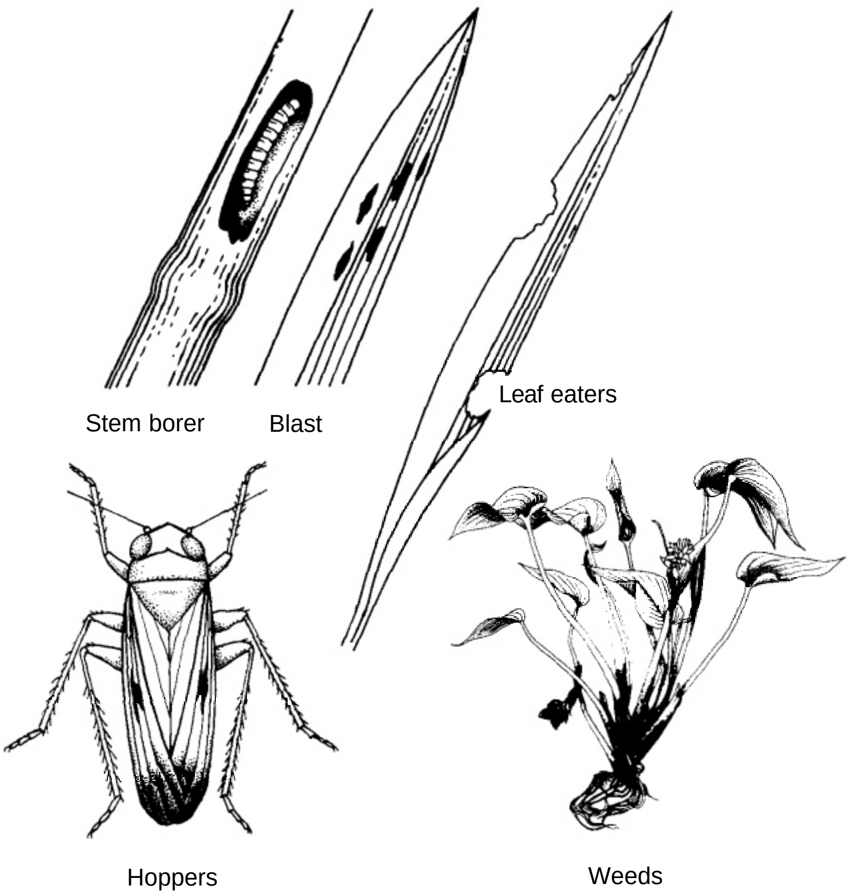
- Too much water can cause long leaf sheaths and weak seedlings.
- Weak seedlings grow poorly right after transplanting. They recover slowly.
- The long, droopy leaves of poor seedlings often stick to the mud when transplanted.

Good lighting can cause short leaf sheaths



■ Cloudy days, heavy seeding, or shadows from trees can result in long leaf sheaths because of low light.

Good seedlings have neither pests nor diseases



Good seedlings have more roots that are longer and heavier

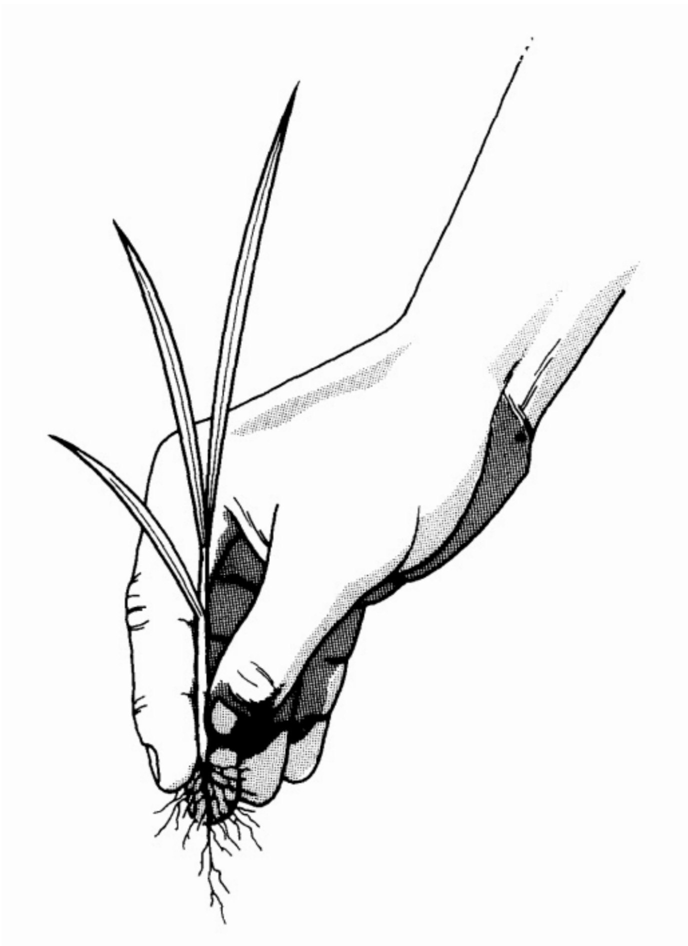
Poor seedling　　Good seedling

- Healthy seedlings—with more roots—recover from transplanting better than poor seedlings with fewer roots.

Transplanting

92 Why transplant?
93 How many seedlings per hill?
94 Why transplant at the proper depth?
95 Why cut leaves before transplanting?
96 Proper spacing

Why transplant?

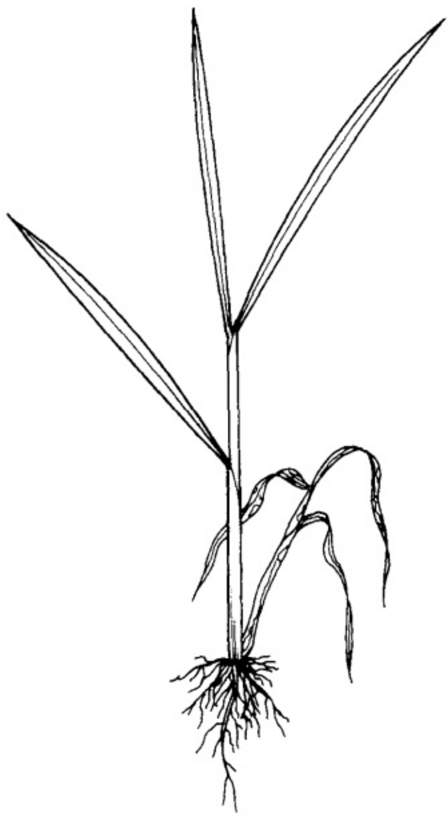


- ¢ Plant growth is set back at transplanting; it takes 2-4 days before new roots are formed.
- ¢ Weed control is simpler in straight row transplanting.
- ¢ Rats, snails, or birds may eat direct seeded rice just after seeding.

How many seedlings per hill?

Two seedlings per hill

One seedling per hill

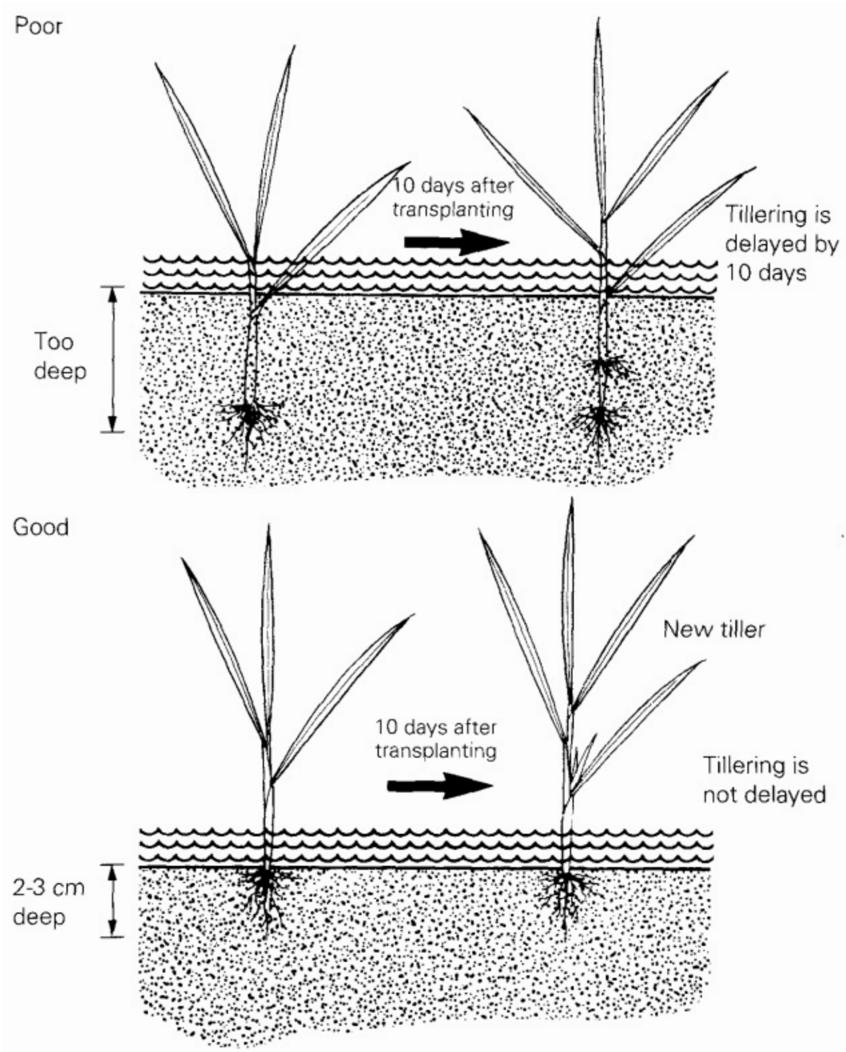


Replanting is needed if the seedling dies.

If one seedling dies, the remaining plant can produce sufficient tillers.

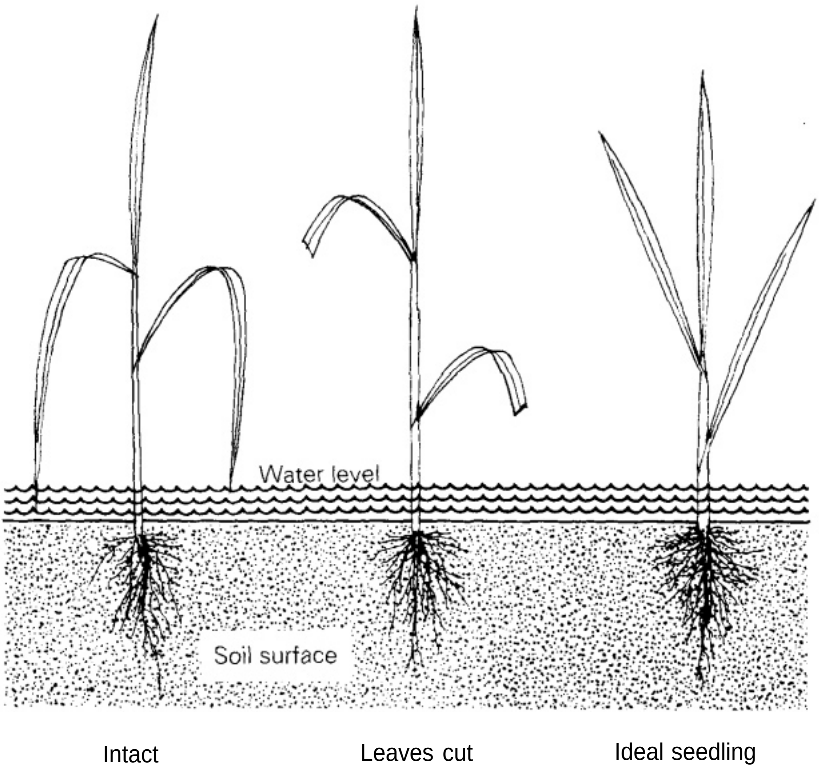
- If no seedlings die, there is no difference in grain yield between one and two seedlings per hill.

Why transplant at the proper depth?



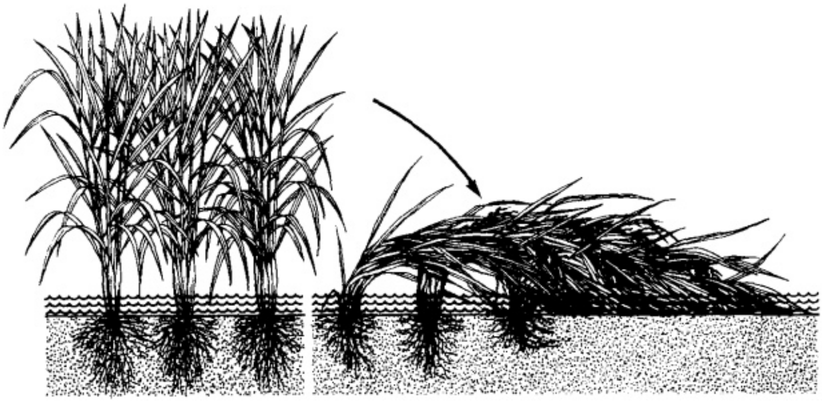
- Tillers normally develop 5-10 days after transplanting. Deep planting delays tillering.

Why cut leaves before transplanting?

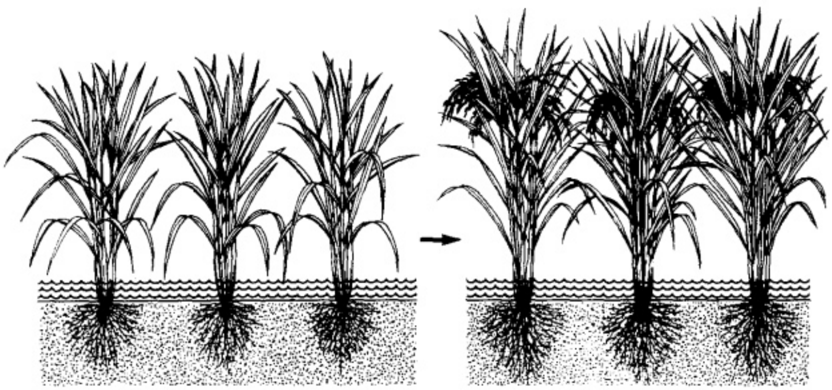


- Long, droopy leaves of tall seedlings touch the muddy water. This increases the chance of diseases infecting the leaves. Cutting the leaves prevents this.
- But wounds caused by cutting may allow bacteria to enter the leaves. To avoid cutting, plant healthy seedlings of the right age.

Proper spacing



Spacing too close

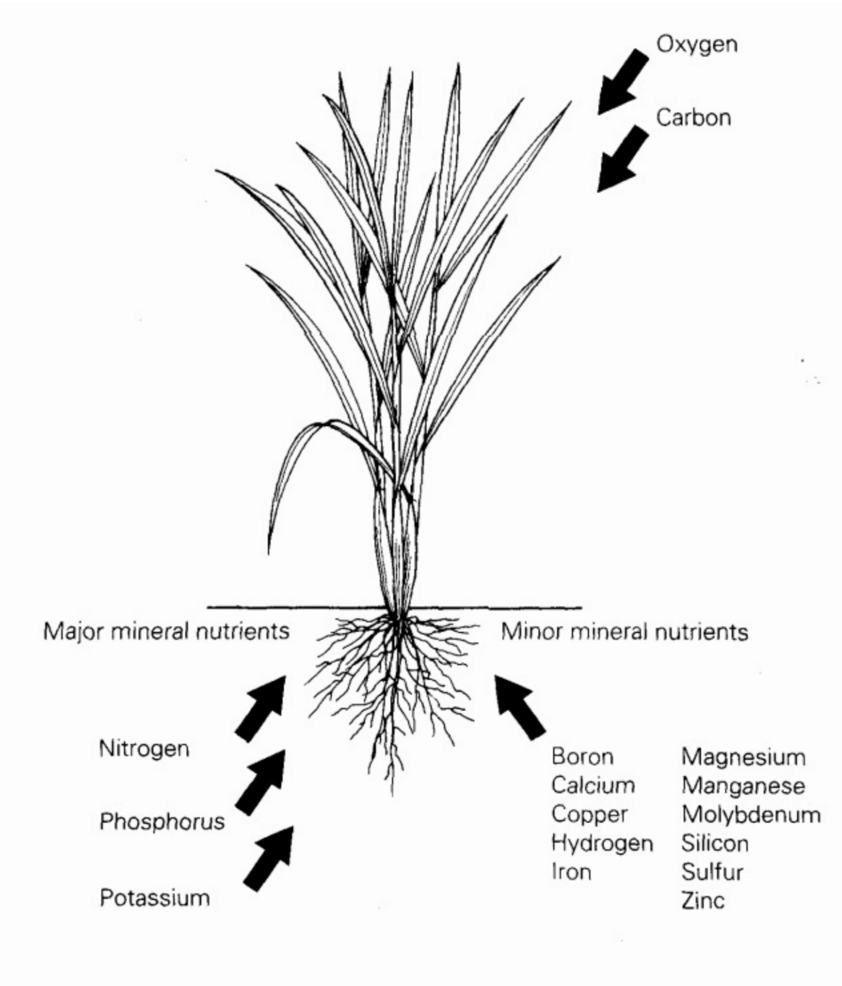


Proper spacing

- Close spacing increases the number of tillers per square meter.
- Close spacing produces tall and weak plants that lodge easily.
- Proper spacing helps control weeds.
- Proper spacing depends on the tillering capacity of the variety and the soil fertility.

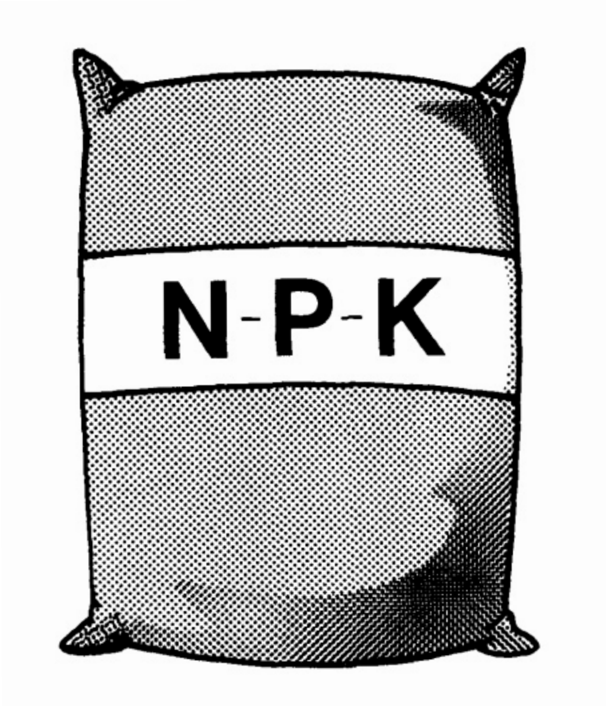
Fertilizers

Nutrients that the rice plant needs



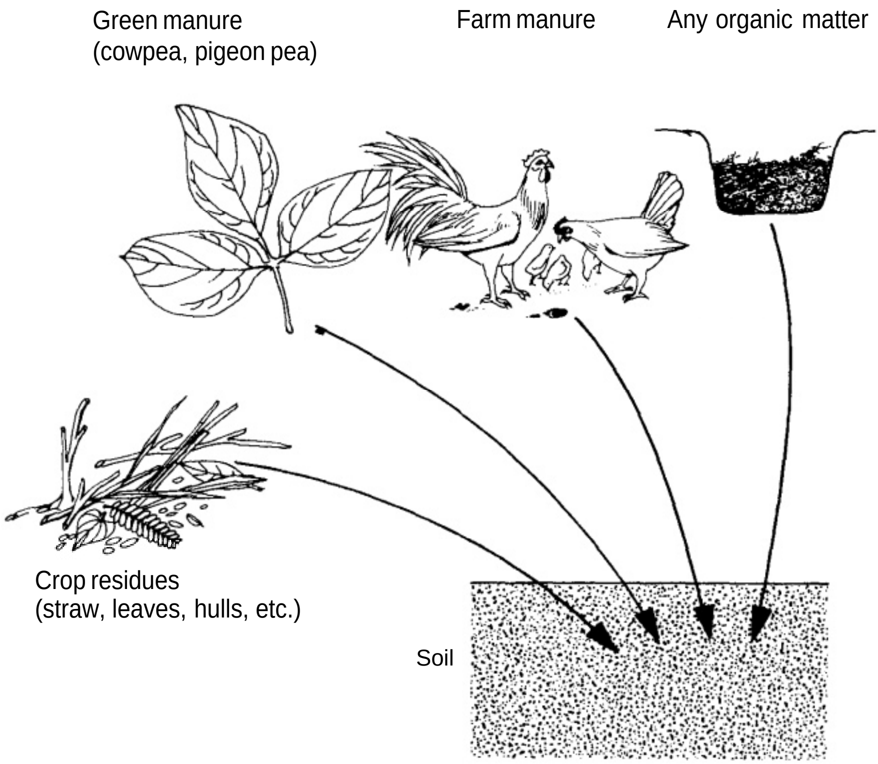
- Plants need oxygen and carbon from the air and mineral nutrients from the soil.
- Plants need nitrogen, potassium, and phosphorus in large amounts. These are the major mineral nutrients.
- Minor nutrients are needed in smaller amounts. The soil often has sufficient minor nutrients; if not, they must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

What are fertilizers?



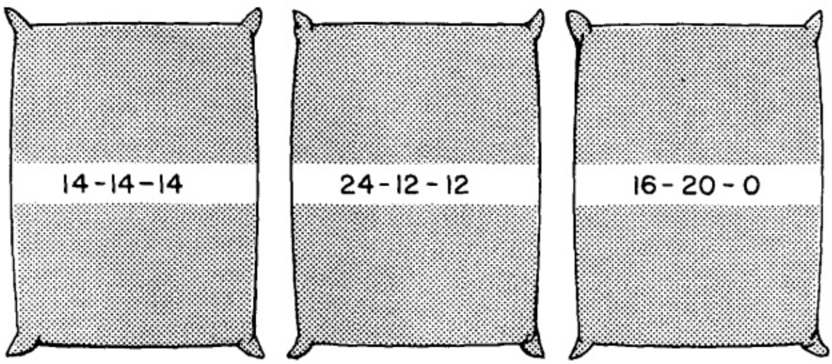
- Fertilizers are food for plants; they contain important mineral nutrients.
- The major nutrients in fertilizers are nitrogen (N), phosphorus (P), and potassium (K).
- Apply fertilizers when the soil does not supply enough nutrients.
- Fertilizers are organic, such as farm manure, or inorganic, such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

Organic fertilizers



- Organic fertilizers come from plant and animal matter, such as rotten leaves and chicken manure.
- Organic fertilizers contain small amounts of the mineral nutrients that the plant needs.
- Organic fertilizers improve soil structure.
- Avoid burning crop residues. Instead, plow the residues back into the soil.

Inorganic fertilizers



14% nitrogen (N)
14% phosphorus (P_2O_5)
14% potassium (K_2O)

24% N
12% P_2O_5
12% K_2O

16% N
20% P_2O_5
0% K_2O

Other examples

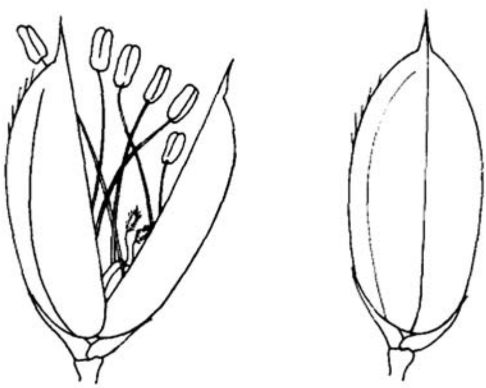
Urea (45-0-0)
Ammonium sulfate (21-0-0)
Muriate of potash (0-0-60)

- ¢ Inorganic fertilizers are commercially manufactured mineral nutrients.
- ¢ Several combinations of nitrogen, phosphorus, and potassium fertilizers are available.
- ¢ 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 other minor mineral nutrients.

Role of fertilizers

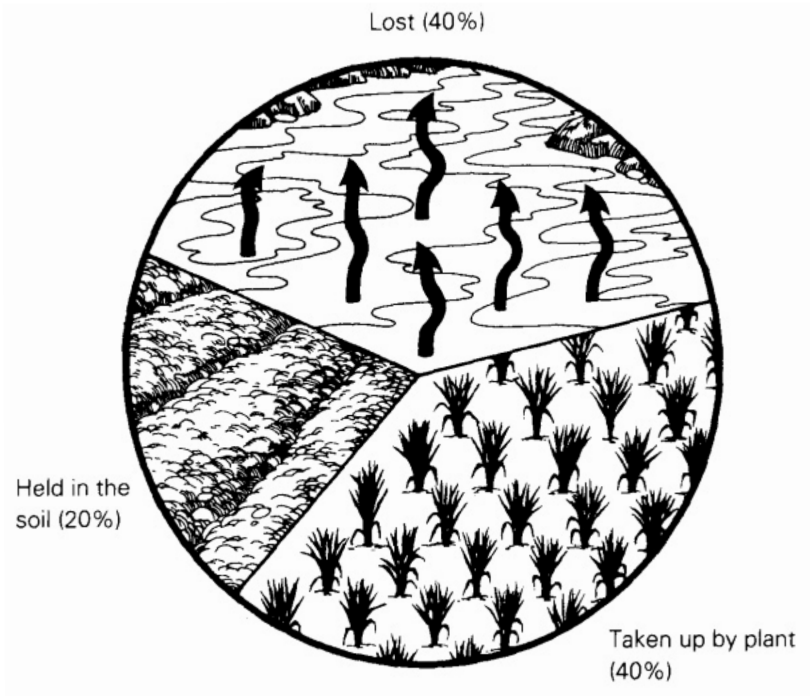
Food production for growth
and maintenance of life

Reproduction



- Nitrogen, phosphorus, and potassium are needed for the life processes going on in the plant.

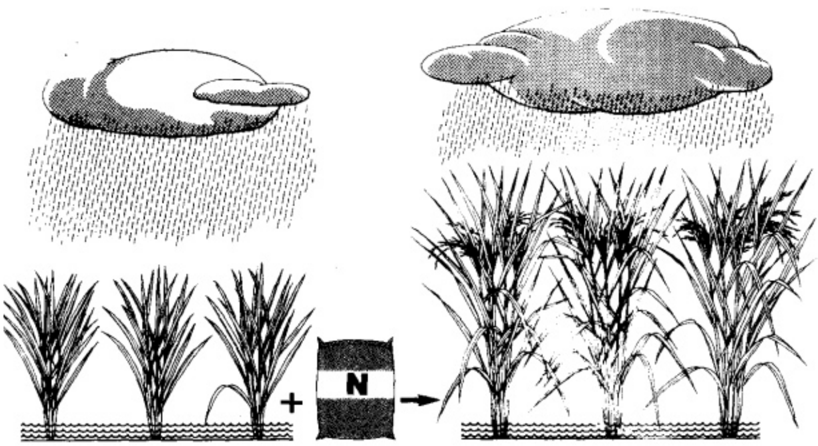
What happens to nitrogen fertilizer applied to the soil?



- A large percentage of the applied nitrogen is lost.
- Part of the nitrogen fertilizer applied to the rice crop may be used by the following crop.
- Minimizing the loss and maximizing the use of the available nitrogen are important.

How much nitrogen to apply

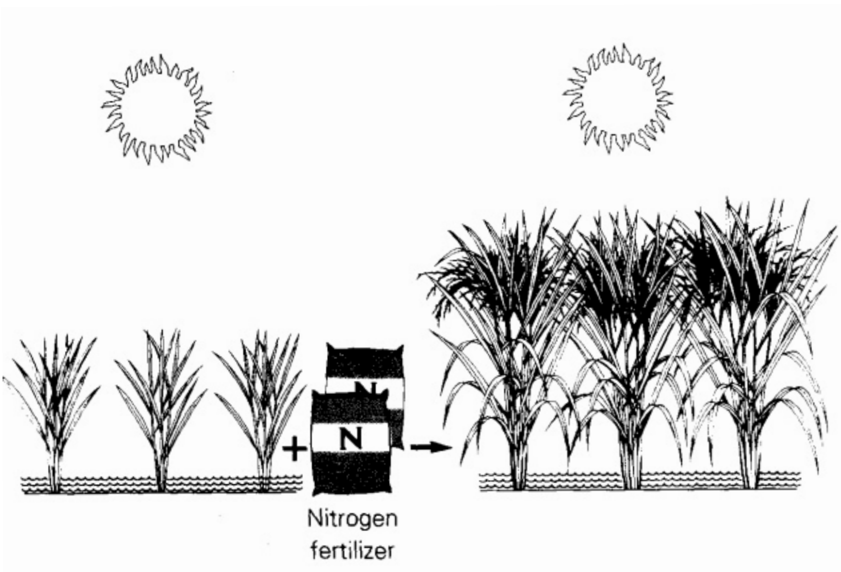
Wet season cropping



Nitrogen
fertilizer

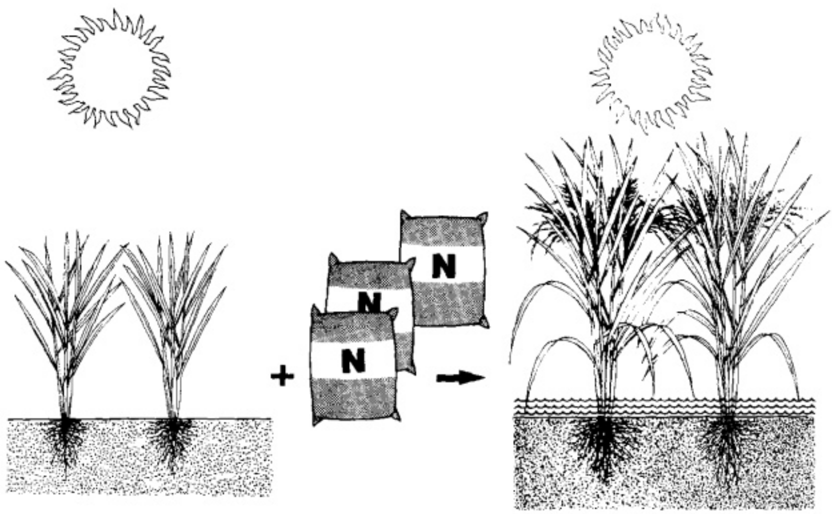
- Plants are tall and leafy during the wet season. They shade each other and this reduces food production in the leaves.
- Light energy is low above and inside the crop.
- The plant cannot fully use fertilizer applied during wet season for grain production.
- Use smaller amounts of fertilizer during wet season.

Dry season cropping



- ¢ In dry season, plants are shorter and have fewer tillers. More light energy is available.
- ¢ The applied fertilizer increases tiller number, leaf area, and rate of food production.
- ¢ More sunlight and more leaves increase food production. This results in higher profits for fertilizer applied.
- ¢ The possibility of increasing grain yield is greater by applying more nitrogen during dry season.

Soil fertility

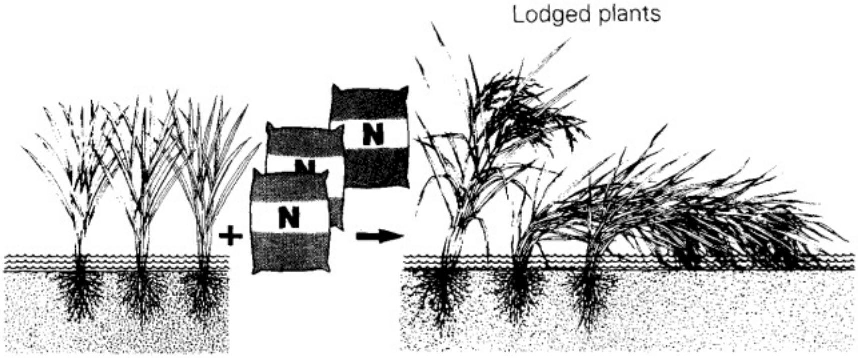


Nonfertile soil

Large amount of nitrogen needed

Optimum nitrogen
Optimum growth

- The right nitrogen level in the soil results in the optimum leaf area, tiller number, and light distribution — and therefore higher grain yield.
- Field trials can determine the right amount of nitrogen fertilizer needed.



Fertile soil

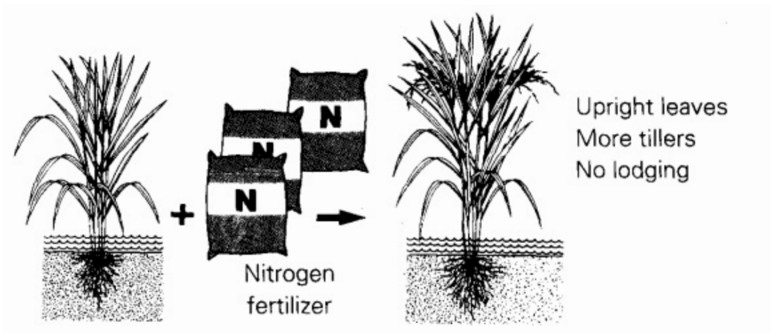
Large amount of nitrogen

Excess nitrogen

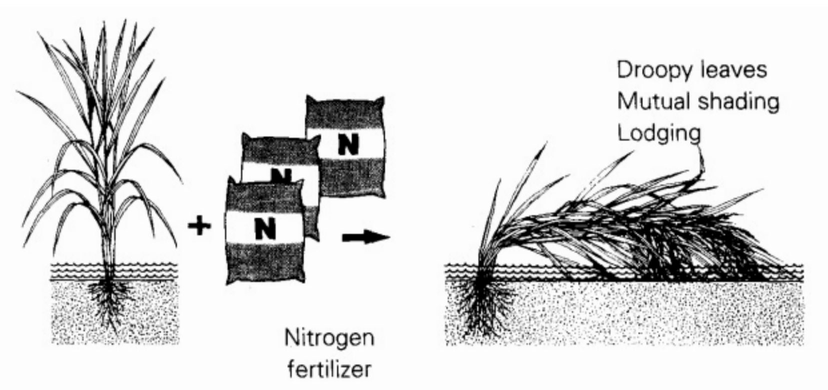
- Too much nitrogen fertilizer in the soil causes too much vegetative growth, resulting in poor light distribution and lodging.
- Too much nitrogen at later growth stages increases spikelet sterility and production of late tillers.

Yield potential of the variety

High yield potential—semidwarf

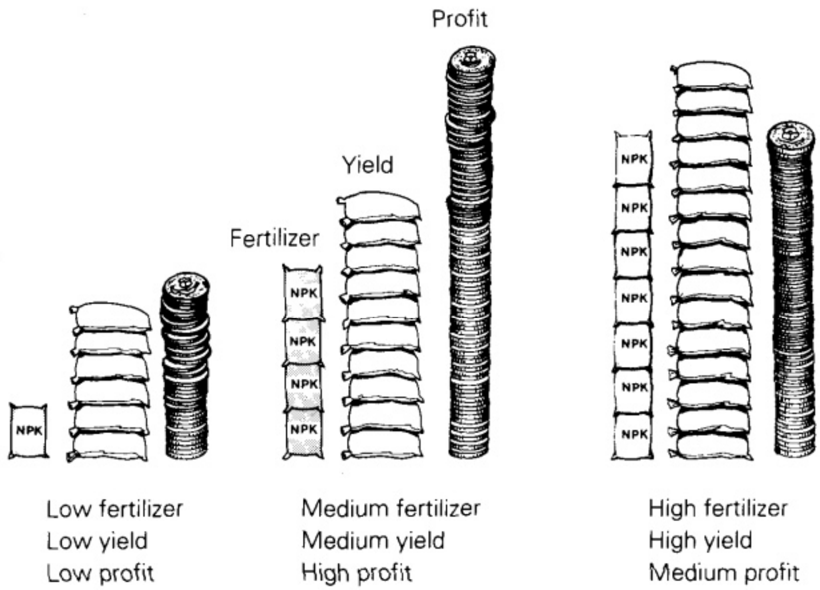


Low yield potential—tall



- Applying fertilizer to tall varieties will increase their height and tendency to lodge.
- Grain yields may actually decrease by applying fertilizer to tall varieties because of lodging and shading of leaves.

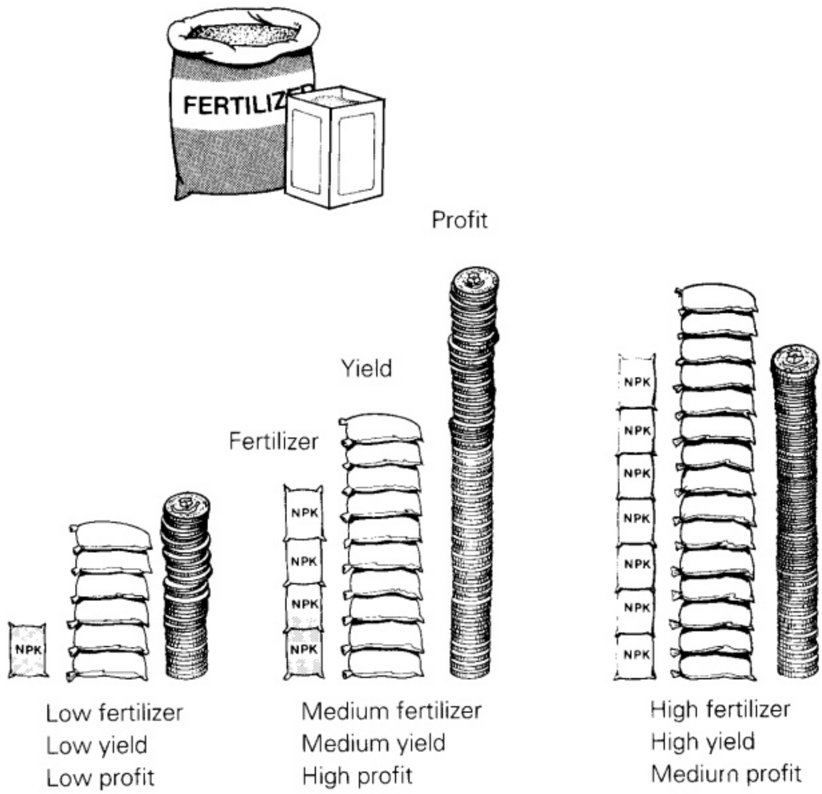
Profit from fertilizer applied



- Applying the right amount of fertilizer gives maximum profit.
- The right amount of fertilizer depends on its price in relation to yield increase.
- The profit from fertilizer applied is higher during dry season than during wet season.
- The right amount of fertilizer for high grain yield varies with the variety.

How to increase the efficiency of nitrogen fertilizer

Apply the right amount of fertilizer



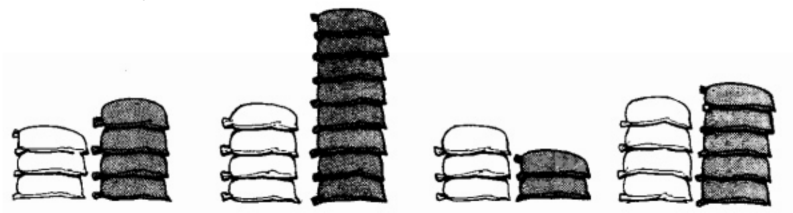
- The right amount of fertilizer will depend on
  - cropping season,
  - soil fertility,
  - yield potential of the variety,
  - fertilizer price, and
  - time and method of application.

Use modern varieties

Traditional variety Modern variety

Comparative grain yields

Dry season Wet season

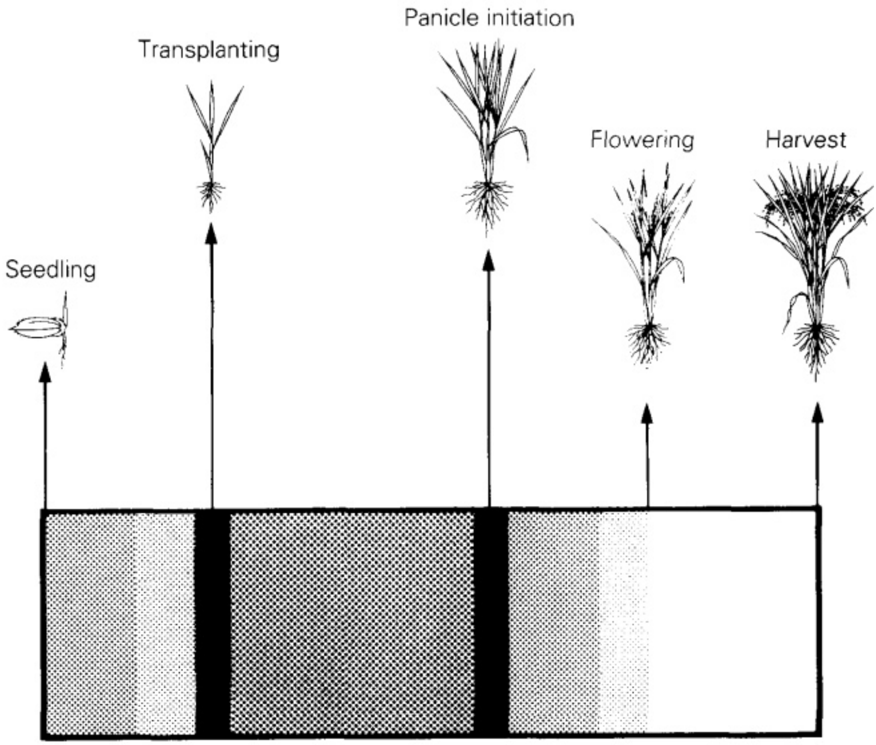


No N With N No N With N No N With N No N With N

Traditional variety Modern variety Traditional variety Modern variety

- Increased grain yield as a result of nitrogen application is higher in modern varieties than in traditional varieties, regardless of planting season or amount of nitrogen used.

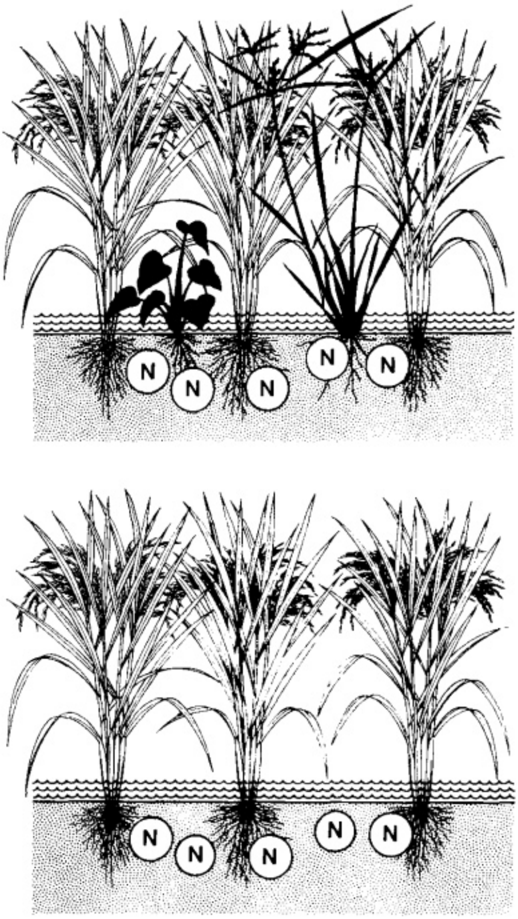
Apply fertilizer at correct growth stage



The darker the shade, the better the time to apply fertilizer.

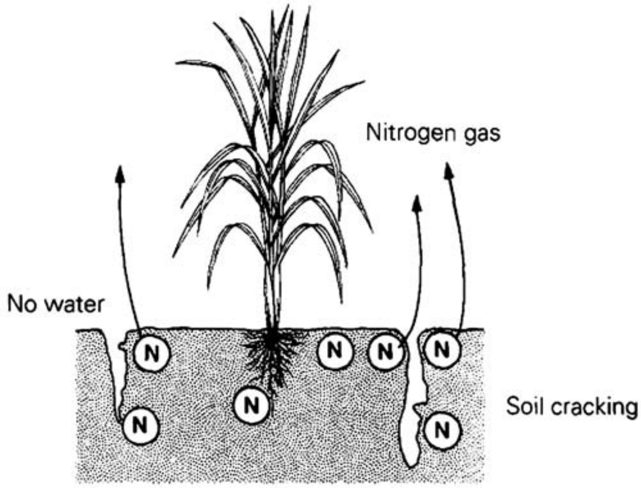
- The best times to apply nitrogen fertilizers are at transplanting and at panicle initiation.
- Fertilizer application after flowering may increase spikelet sterility and cause late tillers to be produced.

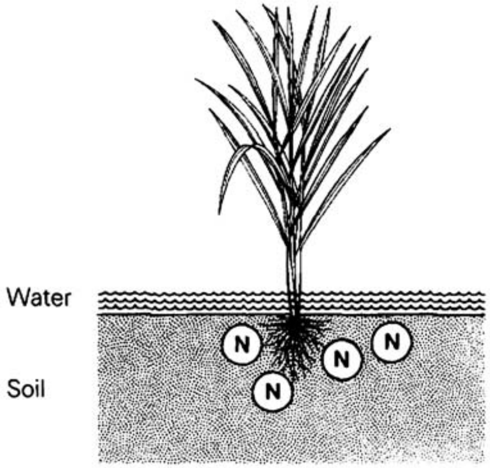
Keep the field free from weeds



- Weeds compete with the rice plants for nitrogen fertilizer.
- Remove the weeds before applying nitrogen.
- Like rice, weeds grow faster when fertilizer is applied.
- The more vigorous the weed growth, the greater the competition for fertilizer, water, light, and space.

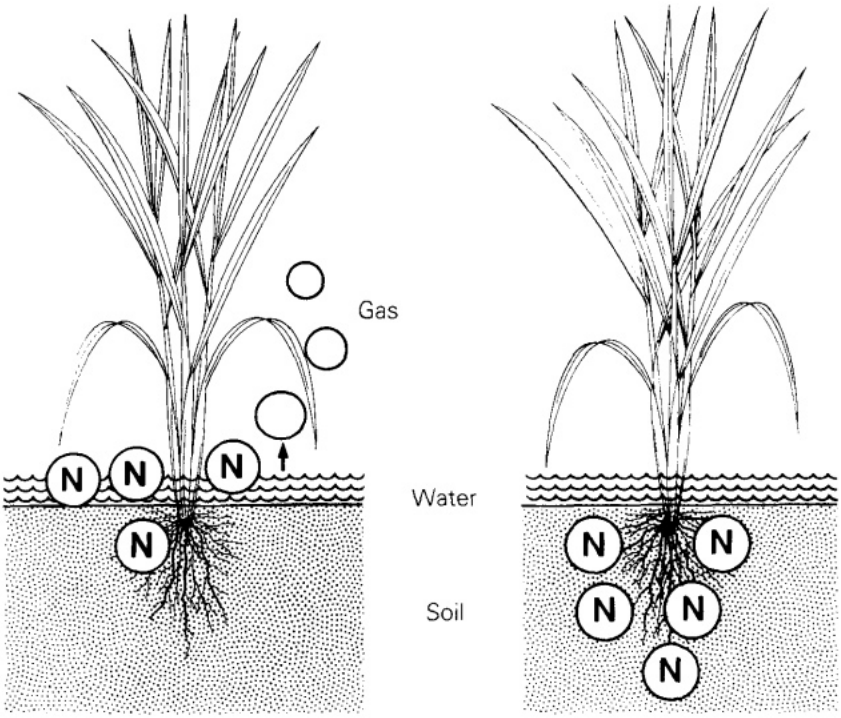
Prevent the field from drying out





- If fertilized flooded soils dry out and are then flooded again, part of the nitrogen fertilizer changes into a gas that escapes into the air.
- Water keeps the air from moving into the soil. The less air in the soil, the less nitrogen gas produced.
- Keep fields flooded to prevent nitrogen loss to the air.
- Prevent water loss by repairing levees.

Mix the fertilizer into the soil



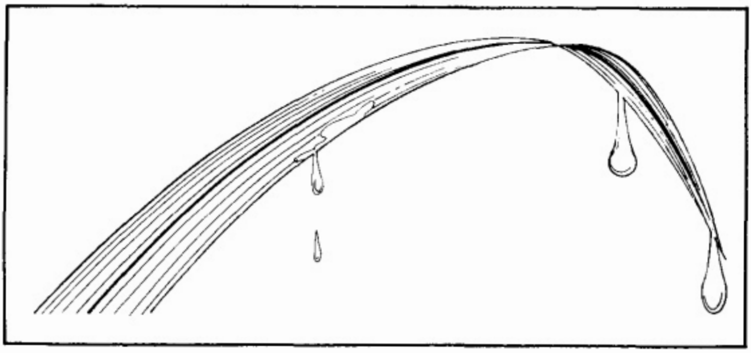
Fertilizer applied on top of the soil

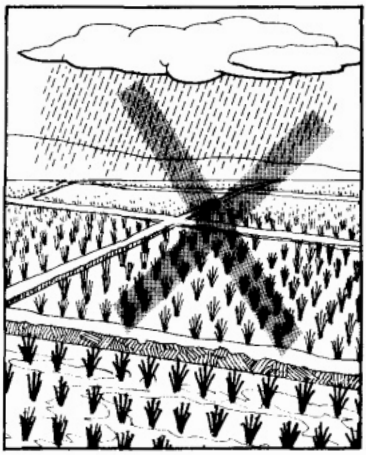
Fertilizer mixed into the soil

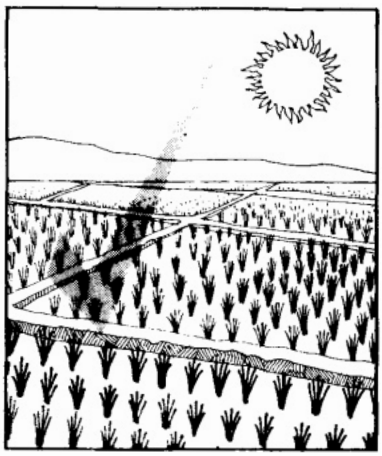
¢ Fertilizers applied before transplanting should be mixed thoroughly with the soil
  - to prevent nitrogen losses into the air, and
  - to keep the fertilizer nearer the roots.

¢ Do not topdress in water immediately after transplanting.

Do not topdress when leaves are wet







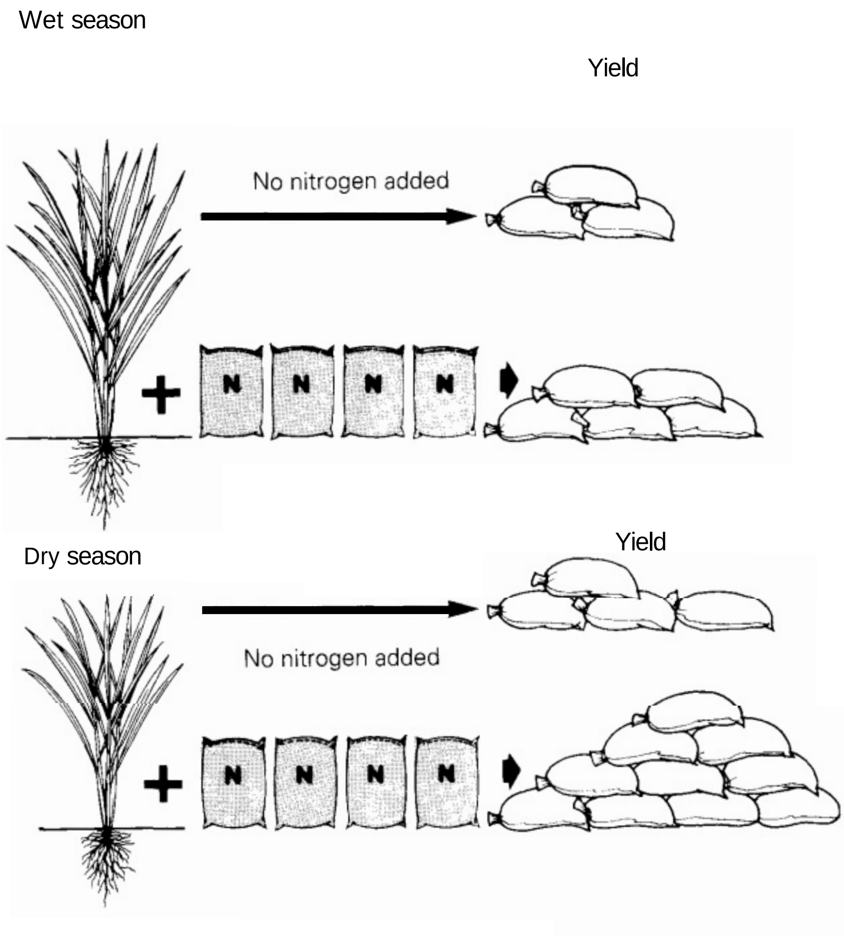
Do not topdress

Topdress

- Fertilizer sticks to wet leaves and may cause leaf burn.
- As the water evaporates, the dissolved fertilizer is lost to the air.
- Do not topdress if heavy rain is expected. The fertilizer may be washed away.

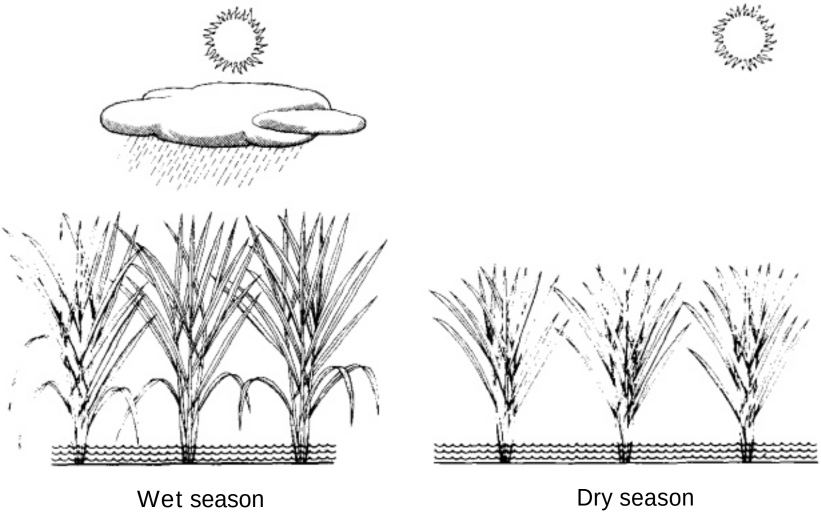
Why more nitrogen fertilizer is applied during dry season

Higher grain yields from nitrogen application



- Rice responds better to nitrogen fertilizer during dry season than during wet season.
- Sunlight, which is necessary for producing food, is more abundant during dry season.

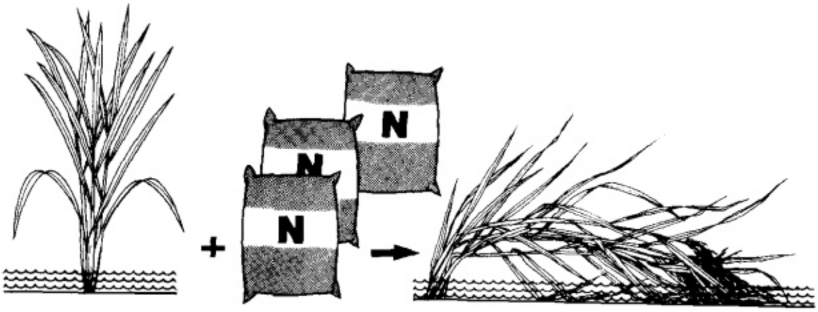
Less danger of shading



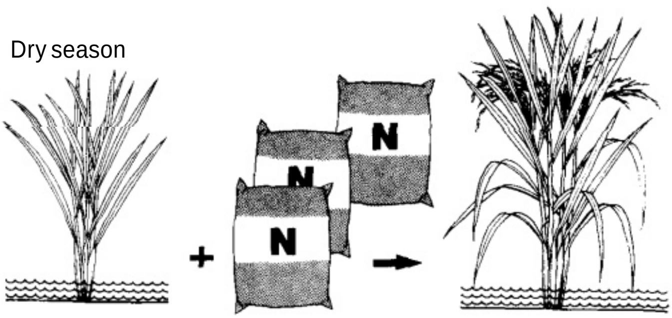
- ¢ Dry season rice crops produce shorter and more erect leaves than wet season rice crops.
- ¢ During dry season, there is more light and therefore less danger of shading. The leaf arrangement for catching the sunlight is also better during dry season.
- ¢ More light means more food produced.
- ¢ Yields are reduced if shading occurs.

Less danger of lodging

Wet season

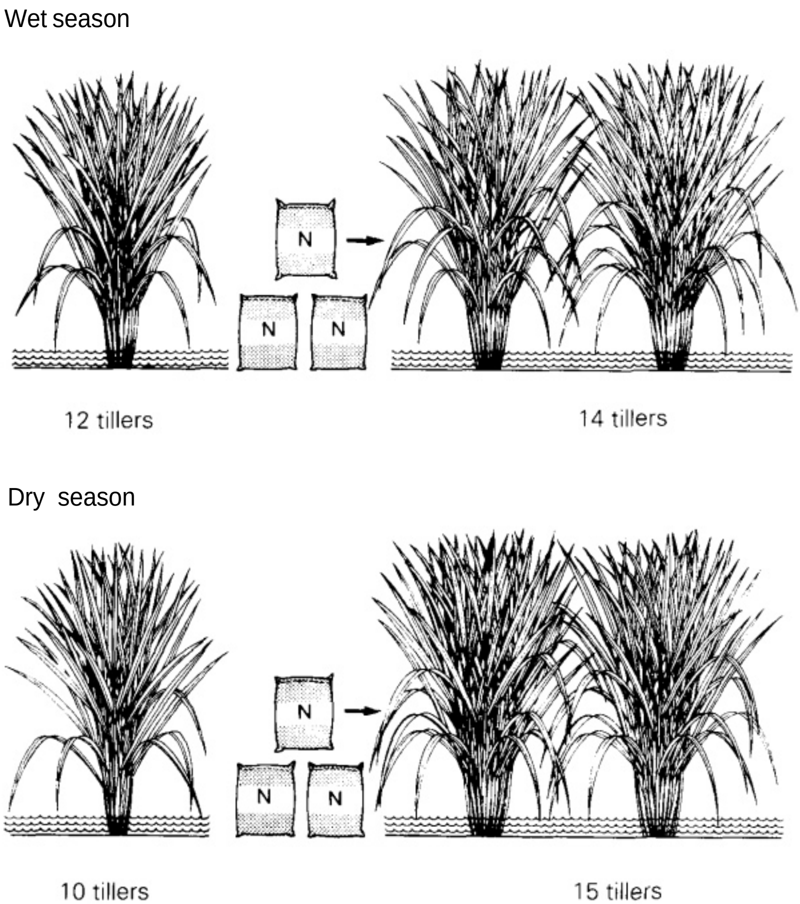


Dry season



- Plants are shorter during dry season than during wet season. Lodging is less likely during dry season, even with higher rates of nitrogen fertilizer.

Increases low tiller number



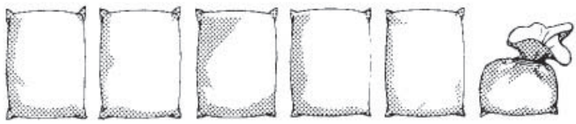
- Nitrogen increases tiller number.
- Rice generally produces fewer tillers during dry season than during wet season. Use closer spacing for dry season.
- Most of the tillers produced as a result of nitrogen fertilization are productive because there is less shading during dry season.

Weeds

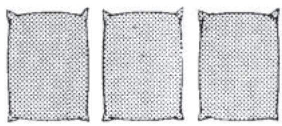
128 Weeds reduce rice yield
129 Weeds compete with rice
130 Weeds decrease the effect of nitrogen fertilizer
131 Differences among grasses, sedges, and broad-leaved weeds
132 A common grass
133 A common sedge
134 A common broad-leaved weed
135 Differences between rice and grasses
136 When to weed the rice crop

Weeds reduce rice yield

Grain yield during wet season

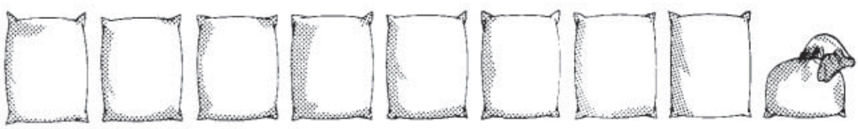


Weeded

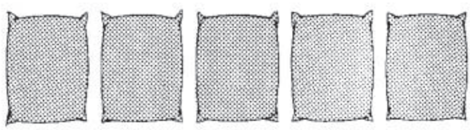


Not weeded

Grain yield during dry season



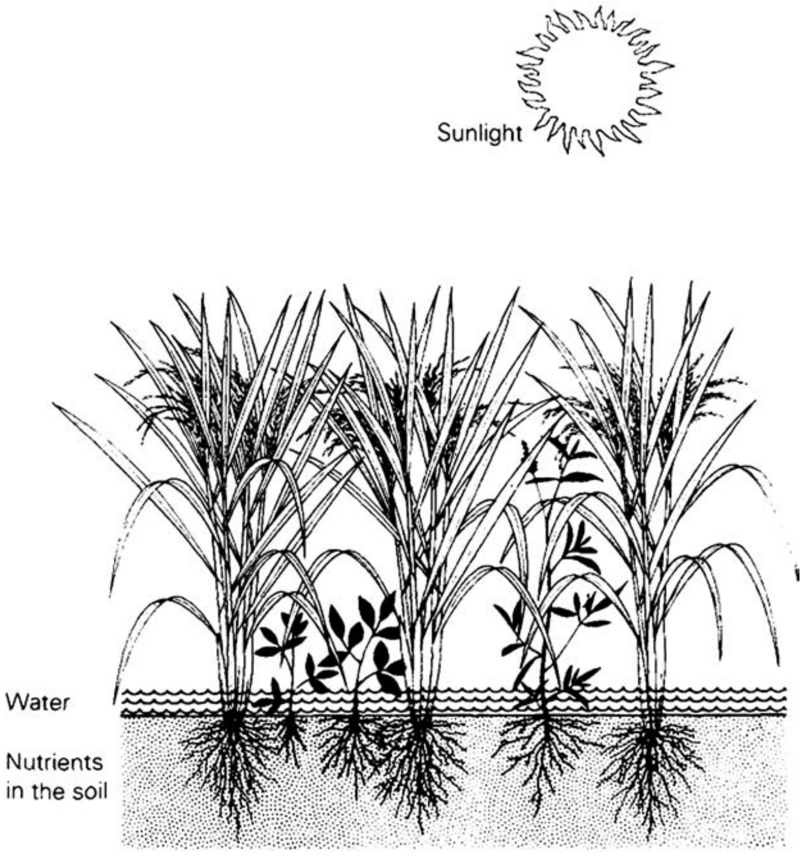
Weeded



Not weeded

¢ Weeds reduce grain yield regardless of planting seadon.

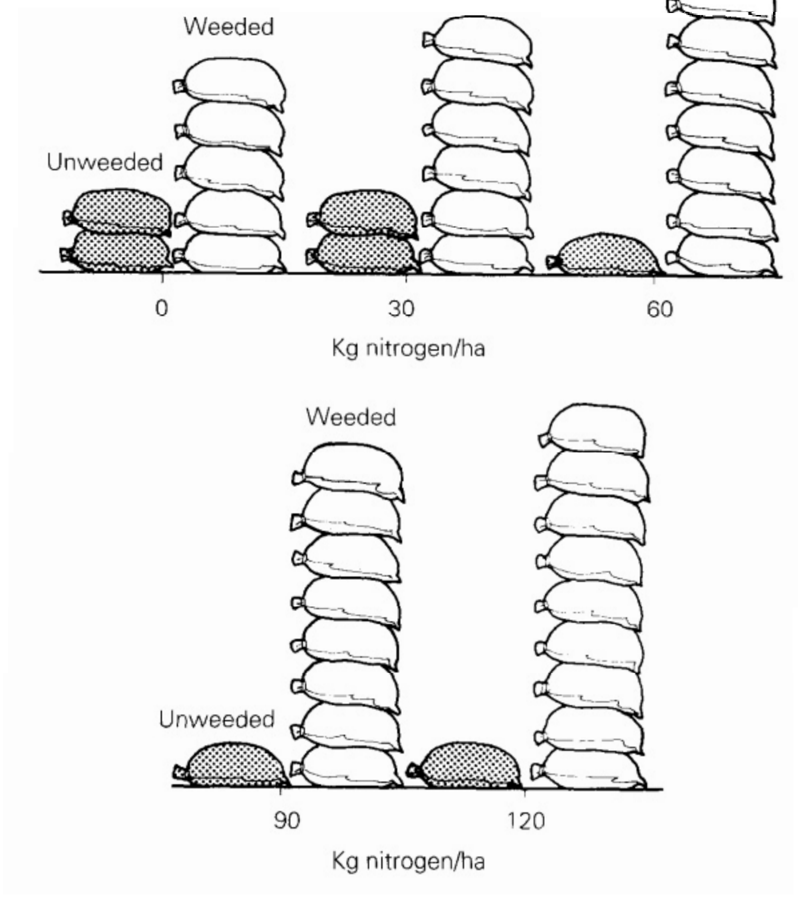
Weeds compete with rice



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

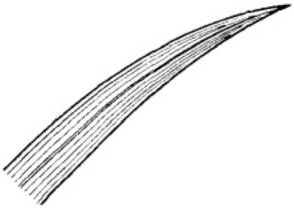
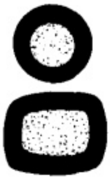
Weeds decrease the effect of nitrogen fertilizer

Grain yield



- ¢ Weeds compete with rice for the applied nitrogen fertilizer.
- ¢ Applied nitrogen favors the growth of weeds more than the growth of rice.
- ¢ The more nitrogen applied, the less the grain yield if the crop is not weeded.
- ¢ Control weeds before using nitrogen fertilizers.

Differences among grasses, sedges, and broad-leaved weeds

Character	Grasses	Sedges	Broad-leaved weeds
Leaf shape			
Vein arrangement			
Stem cross-section			
Plant shape			
Example	*Echinochloa*	*Cyperus*	*Monochoria*

A common grass

Scientific name: *Echinochloa glabrescens*
Common name: barnyard grass

A common sedge

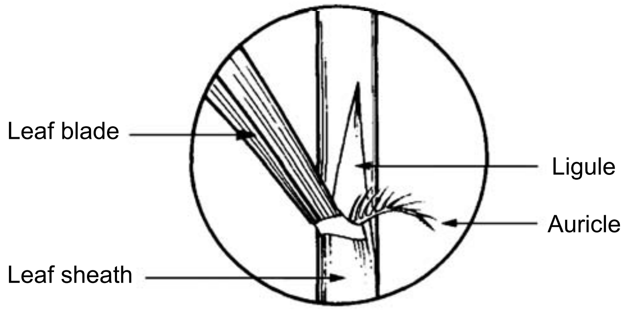
Scientific name: *Cyperus iria*
Common name: rice flatsedge

A common broad-leaved weed

Scientific name: *Monochoria vaginalis*
Common name: monochoria

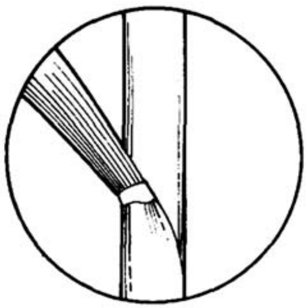
Differences between rice and grasses

Rice

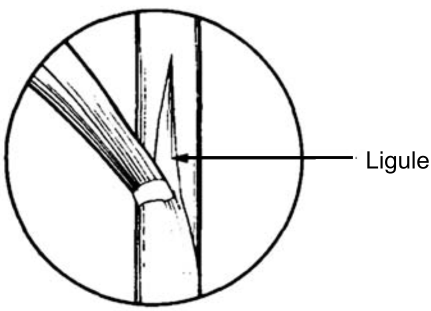


With ligule and auricle

Grasses



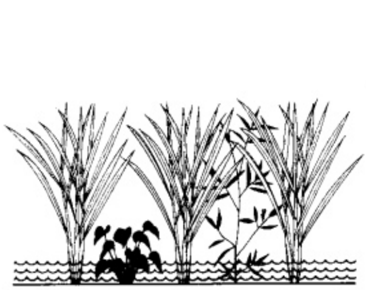
No ligule, no auricle



With ligule, no auricle

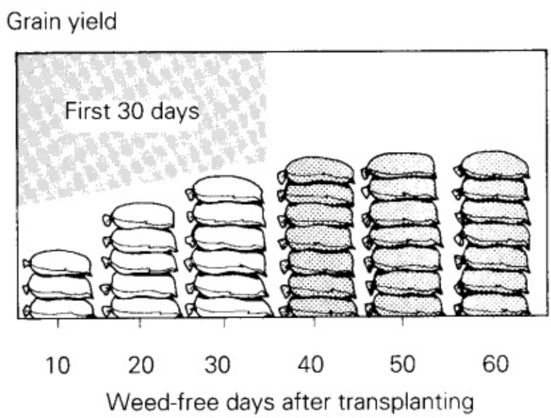
When to weed the rice crop

Rice at 30 days after transplanting



Weed-free up to 10 days after transplanting — poor growth

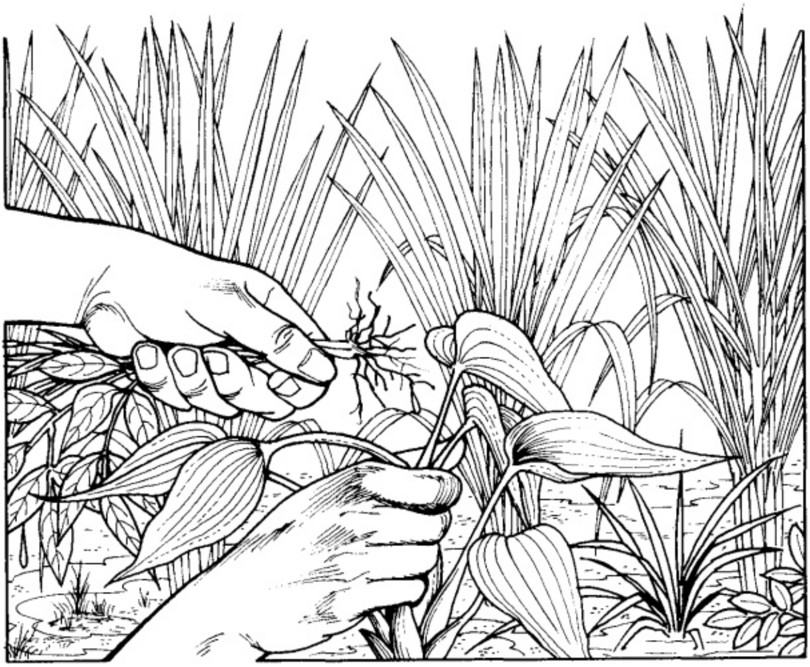
Weed-free up to 30 days after transplanting — good growth



- Weeding in the first 30 days following transplanting is important.
- Grain yield is drastically reduced if rice is not weeded during the early growth stages.

Control of weeds

Control by hand pulling

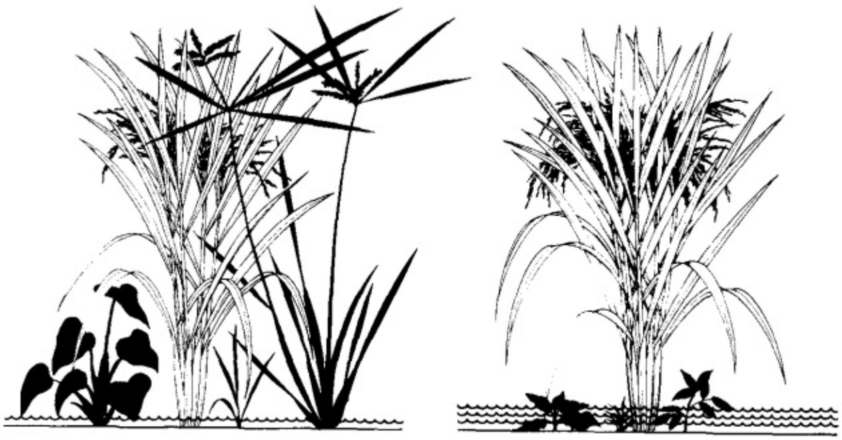


- Pulling weeds by hand is a manual method of control.
- Hand pulling takes a lot of time.

Control by mechanical means

¢ A rotary weeder is more efficient than hand weeding.
¢ Straight row planting is necessary when using a rotary weeder.
¢ Drain standing water from the field when using a rotary weeder.

Control by water management



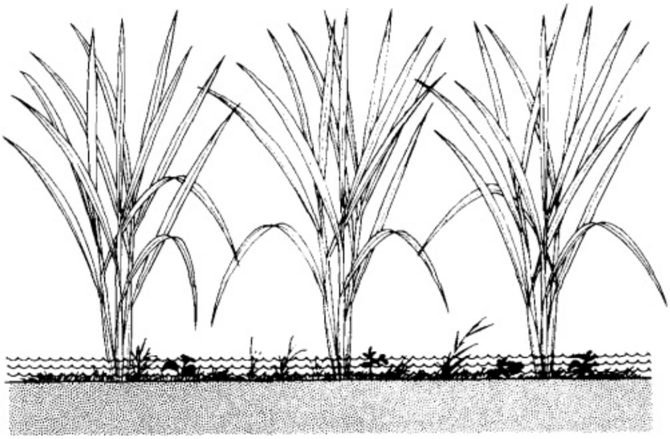
Water depth of 1-5 cm
Weed growth slightly reduced

Water depth of 5-1 0 cm
Weed growth greatly reduced

- Most grasses and sedges will not grow when covered with 5-10 cm of water.
- Flooding will not control some broad-leaved weeds.
- Many weed seeds do not germinate under water.

Control by land preparation

Unevenly prepared land has many and large weeds

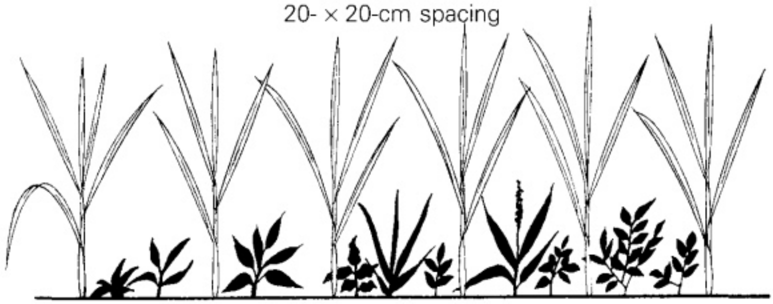


Evenly prepared land has fewer, smaller weeds

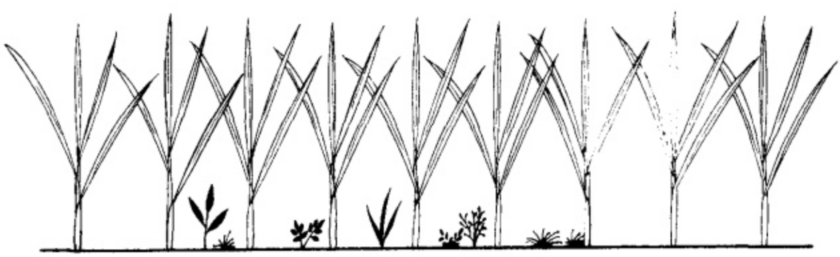
¢ Weeds can grow better than rice when land is poorly and unevenly prepared and some areas are not covered by water.

Control by crop competition

20- × 20-cm spacing



15- × 15-cm spacing

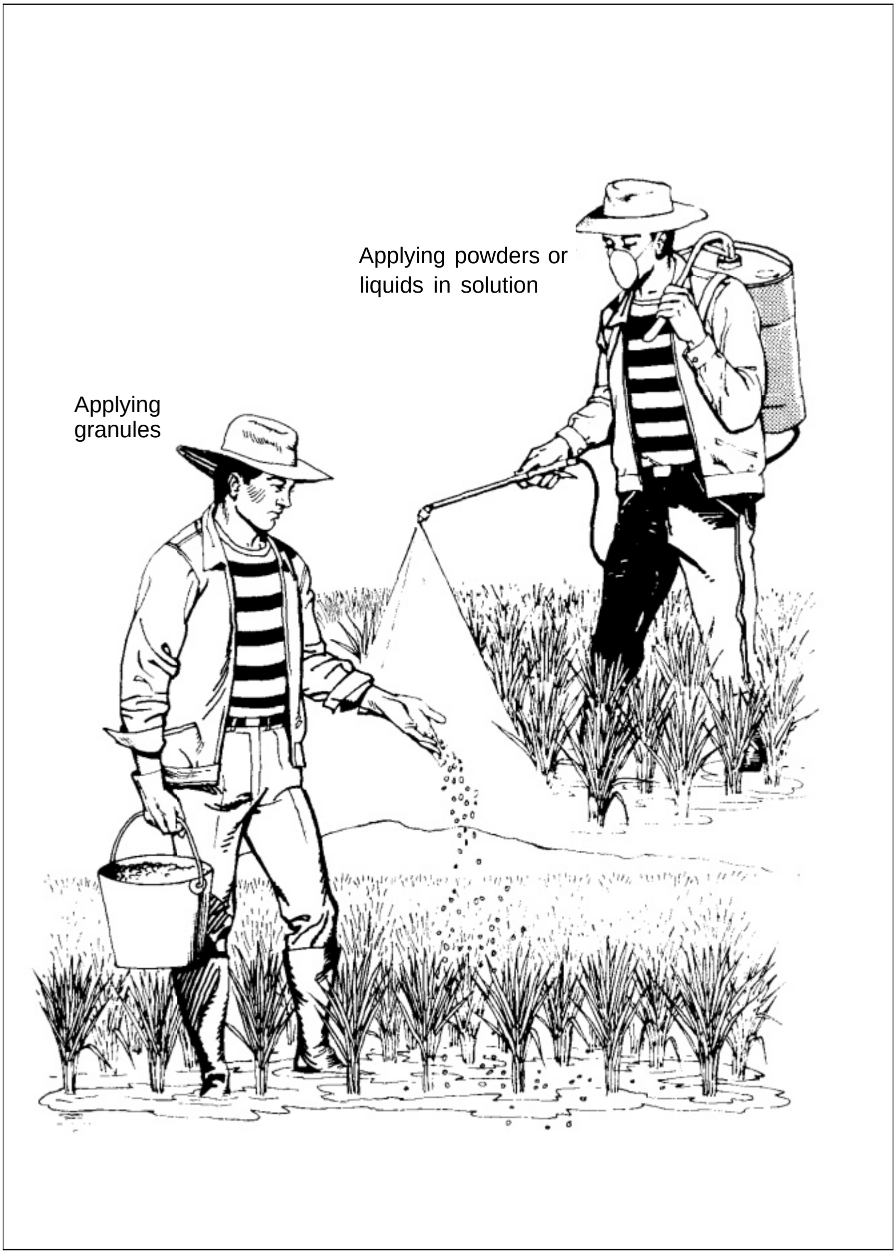


10- × 10-cm spacing

¢ The closer the plant spacing, the fewer the weeds because there is less light for the weeds to germinate and grow in.

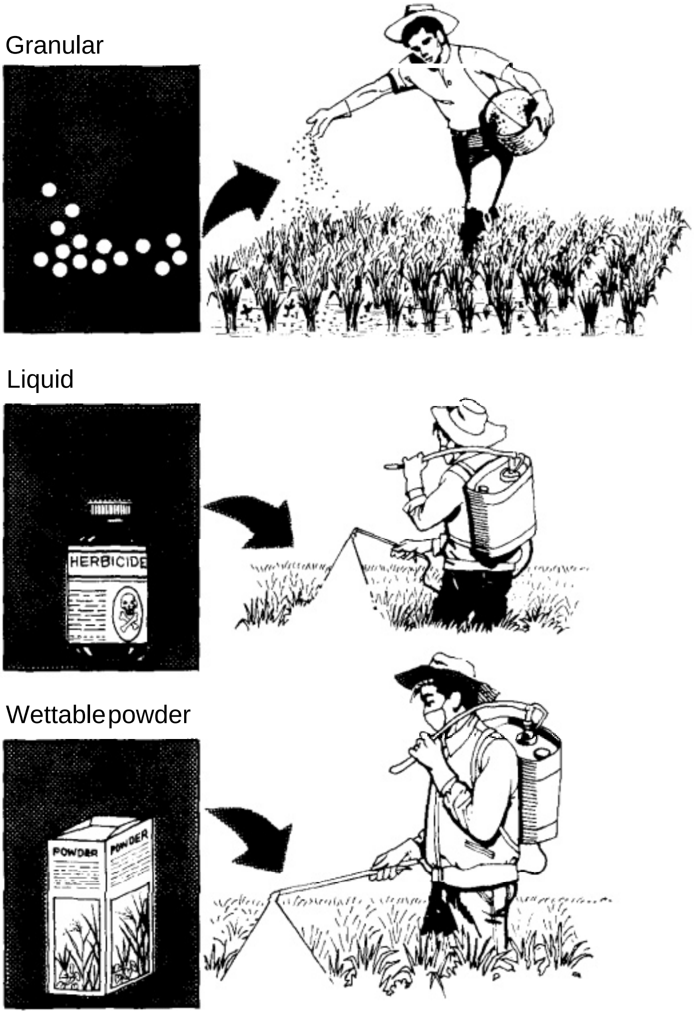
¢ The shorter the weeds, the less weed damage.

Control by herbicides



Herbicides

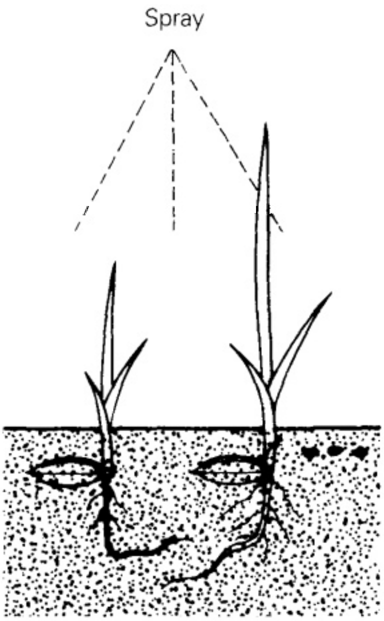
Types of herbicide based on formulation



- Commercial herbicides are available in granular, liquid, or powder forms.
- Granular forms are broadcast; no special equipment is needed for application.

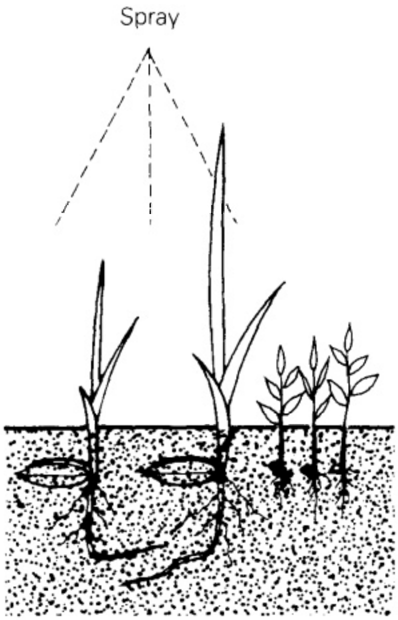
Types of herbicide based on time of application

Preemergence



Before the weed seedlings come out

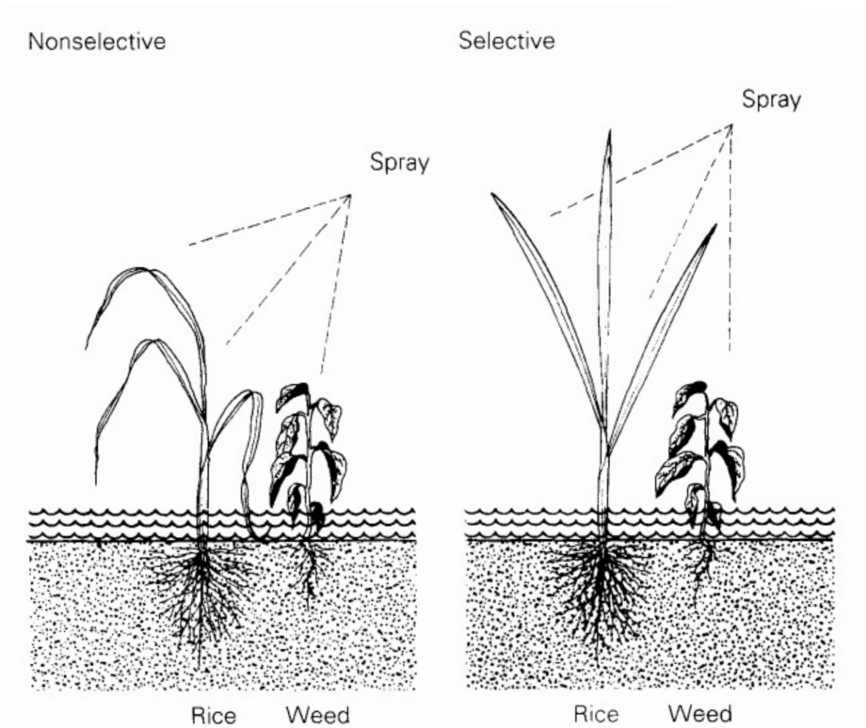
Postemergence



After the weed seedlings come out

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

Types of herbicide based on selectivity



Paraquat

2,4-D

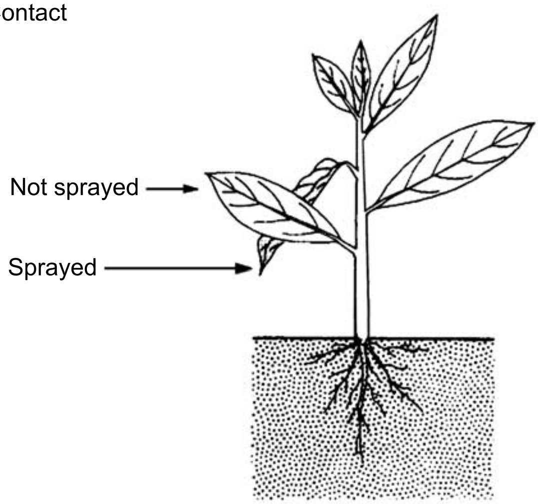
Nonselective herbicides will kill all plants.

Selective herbicides (at low concentration) kill only certain plants.

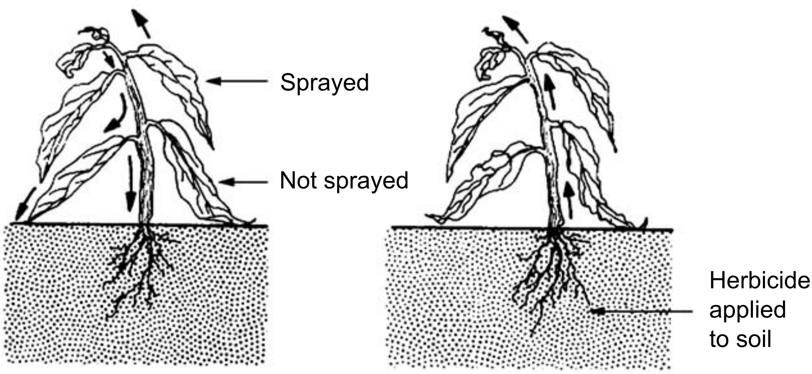
¢ Carefully check the application rate — even for selective herbicides.

Types of herbicide based on type of action

Contact

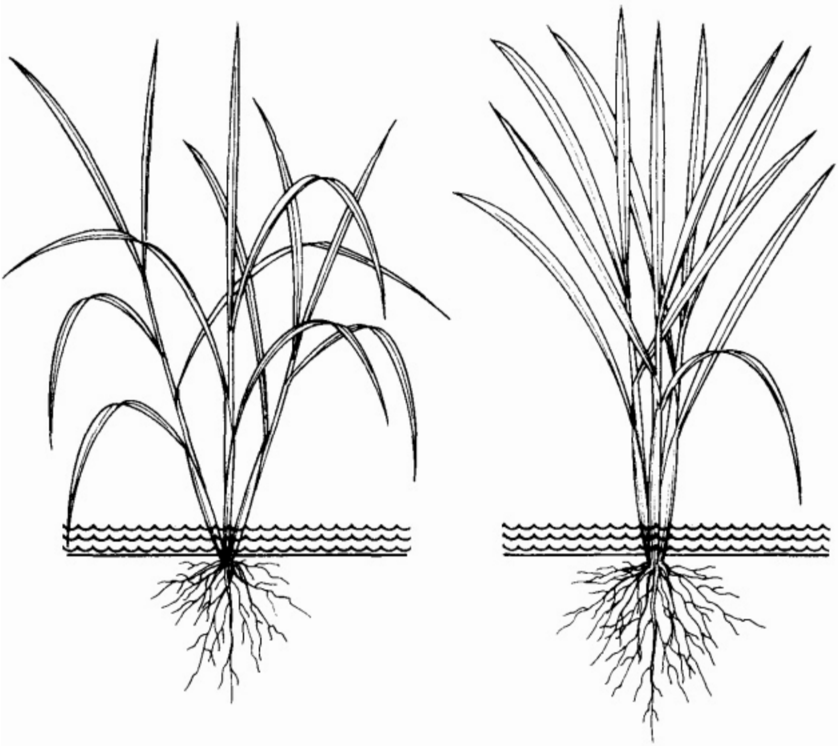


Systemic (translocated)



- Contact herbicides kill the parts of the plant sprayed.
- Systemic (translocated) herbicides travel inside the plant and kill the whole plant.

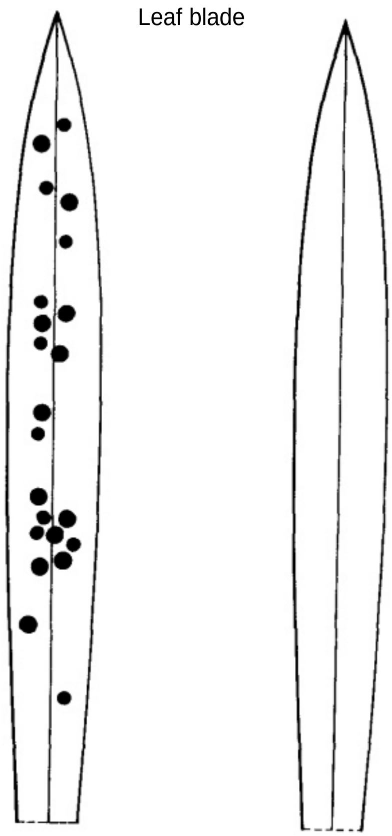
Rice injuries from too much herbicide — tillers spread out



Sprayed with too much herbicide

Sprayed with the correct amount of herbicide

Rice injuries from too much herbicide — brown spots

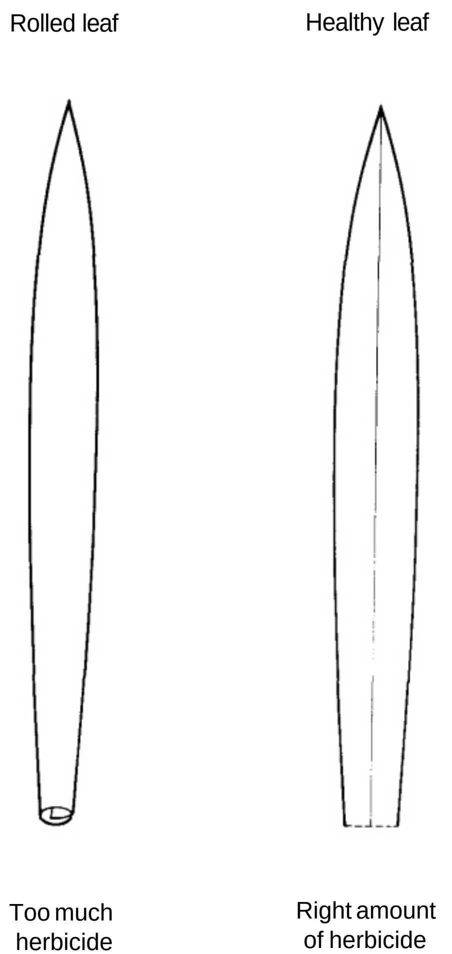


Too much herbicide
Brown spots

Right amount of herbicide
No injury

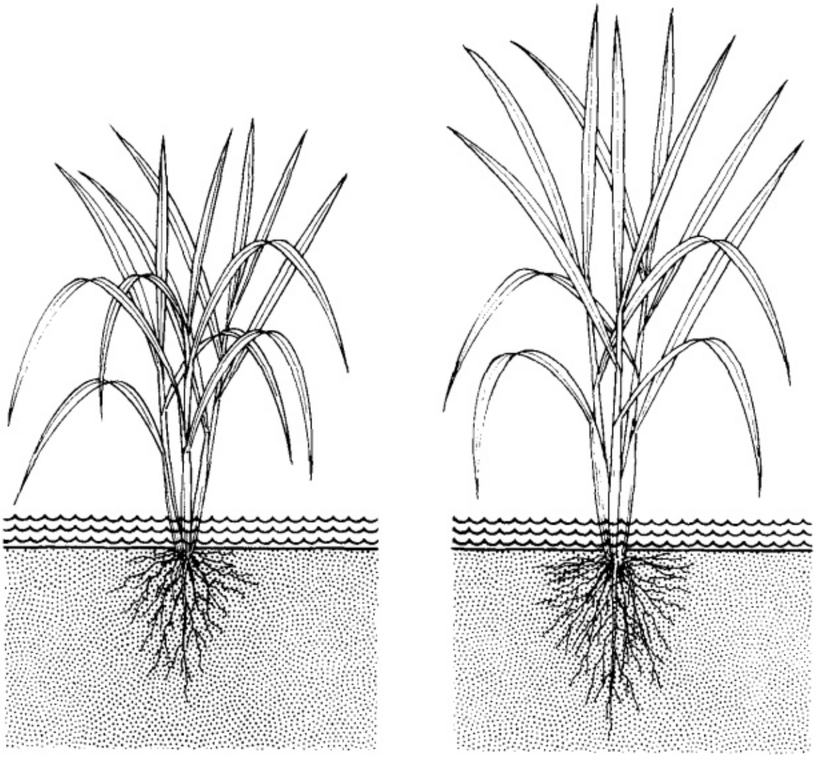
¢ Herbicide injury may look like blast or cercospora leaf spot, but a closer look shows that the spots are round.

Rice injuries from too much herbicide — onion-like leaves



¢ The new leaves coming out are tubelike or cylindrical if too much herbicide was applied.

Rice injuries from too much herbicide—dwarfing

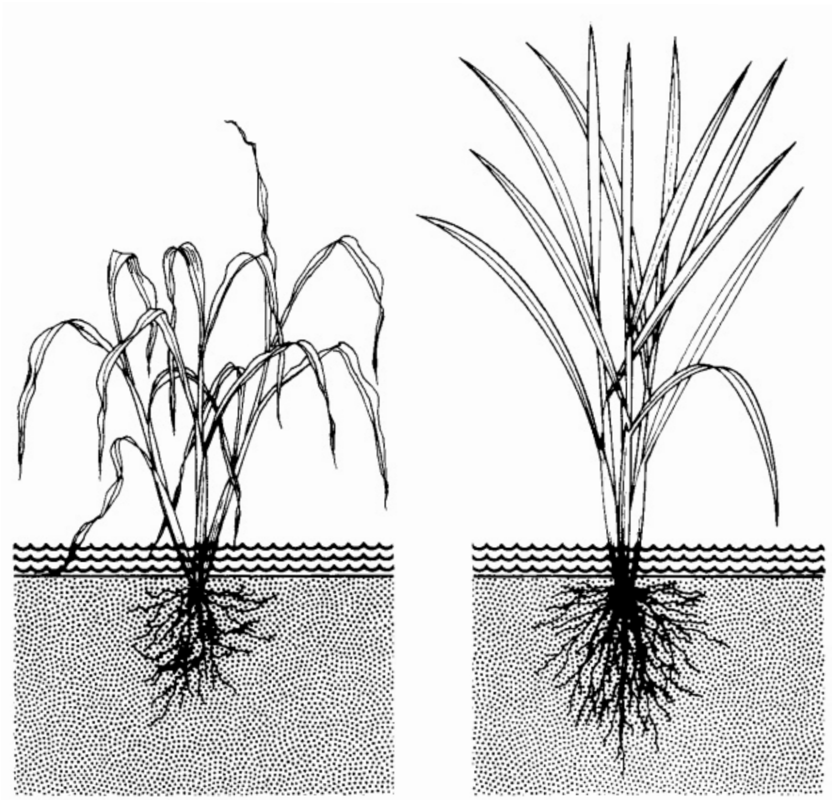


Too much herbicide

Right amount of herbicide

- Be sure to use the correct amount of herbicide. Follow the recommended rate

Herbicides can kill rice



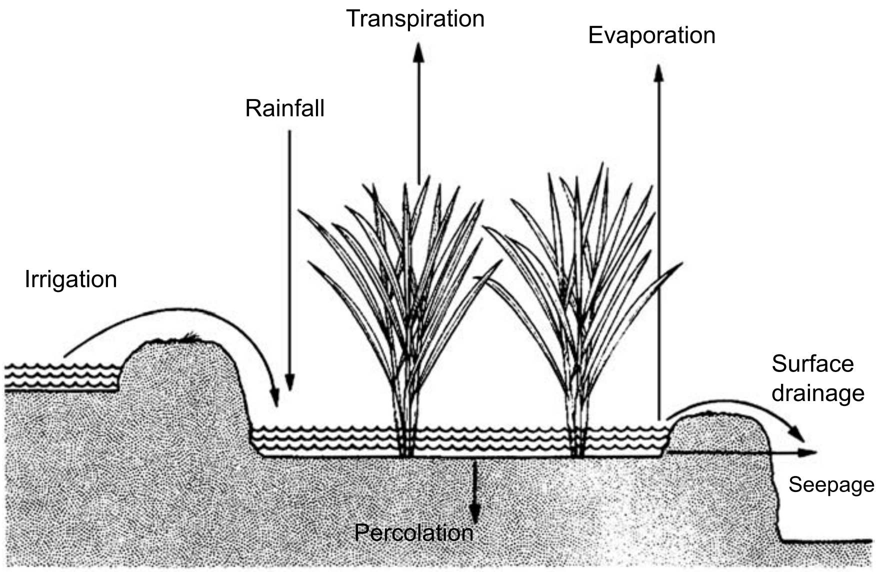
Wrong kind
of herbicide

Right kind
of herbicide

¢ Herbicides may kill rice plants by preventing food production or by interfering with energy manufacture.

Water management

Water source and loss

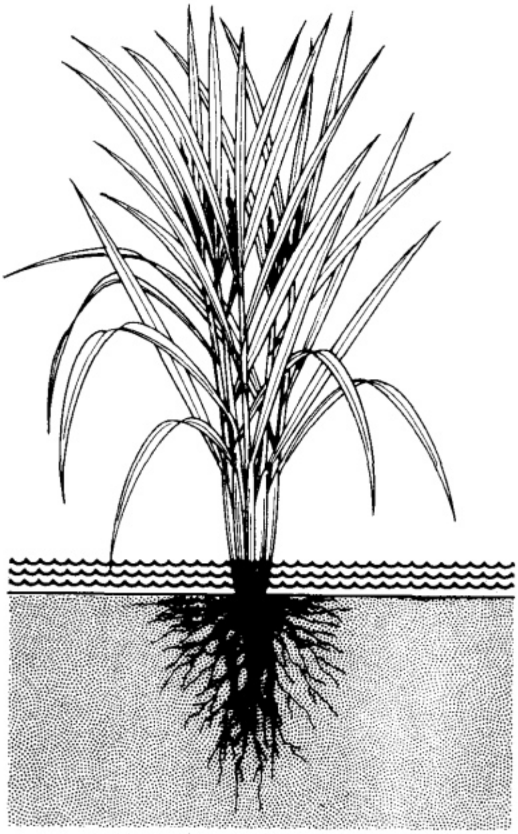


- ¢ In lowland ricefields, water comes from rainfall, irrigation, surface drainage, and seepage from other fields.
- ¢ Water is lost by transpiration, evaporation, seepage, and percolation.
- ¢ Transpiration is the evaporation of water through plant surfaces.
- ¢ Seepage is the horizontal loss of water through a levee.

Prevent water loss

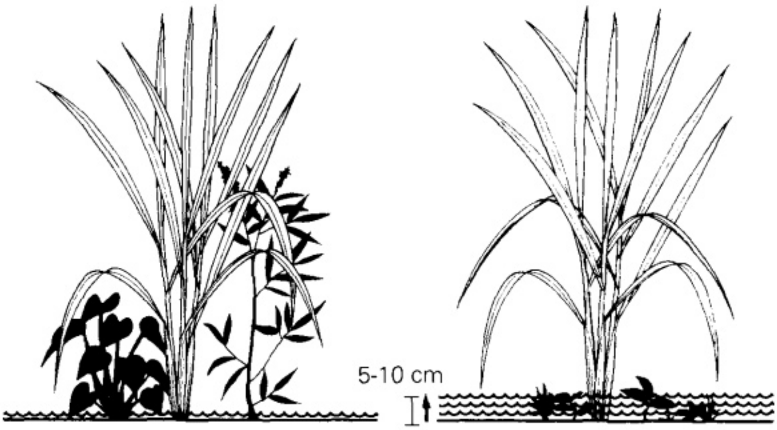
¢ Repair levees to minimize seepage.
¢ Remove weeds to prevent competition with rice plants for water.
¢ Increase the height of the levee to prevent surface runoff of water.

Critical stage in water management



- ¢ Lack of water at any growth stage may reduce grain yield.
- ¢ Leaf-rolling, leaf-scorching, stunting, delayed flowering, high sterility, and poor grain filling are common symptoms of water deficit.
- ¢ The rice plant is most sensitive to water deficit from booting to flowering. Make sure there is sufficient water at these stages.
- ¢ Once sterility occurs because of water deficit, the plant cannot compensate for it.

Water and weeds



Water level too shallow

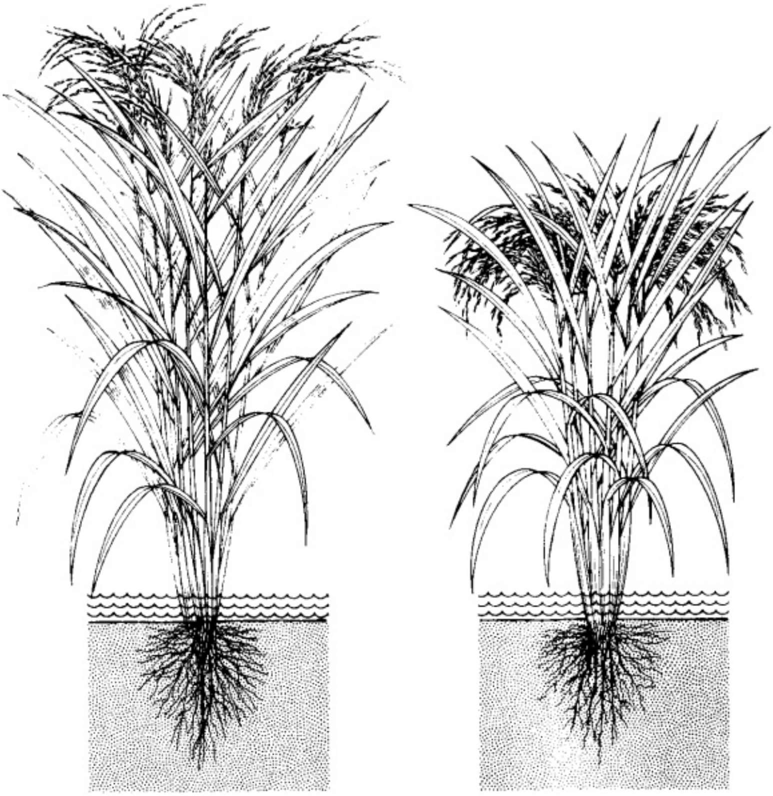
Proper water level

- Maintain a 5-1 0 cm water level, especially during the early vegetative phase.
- This level will prevent the germination and growth of many weeds.
- Do not allow the field to dry during the early growth stages.

FARM ANALYSIS AND IMPROVEMENT

How to select the variety to plant

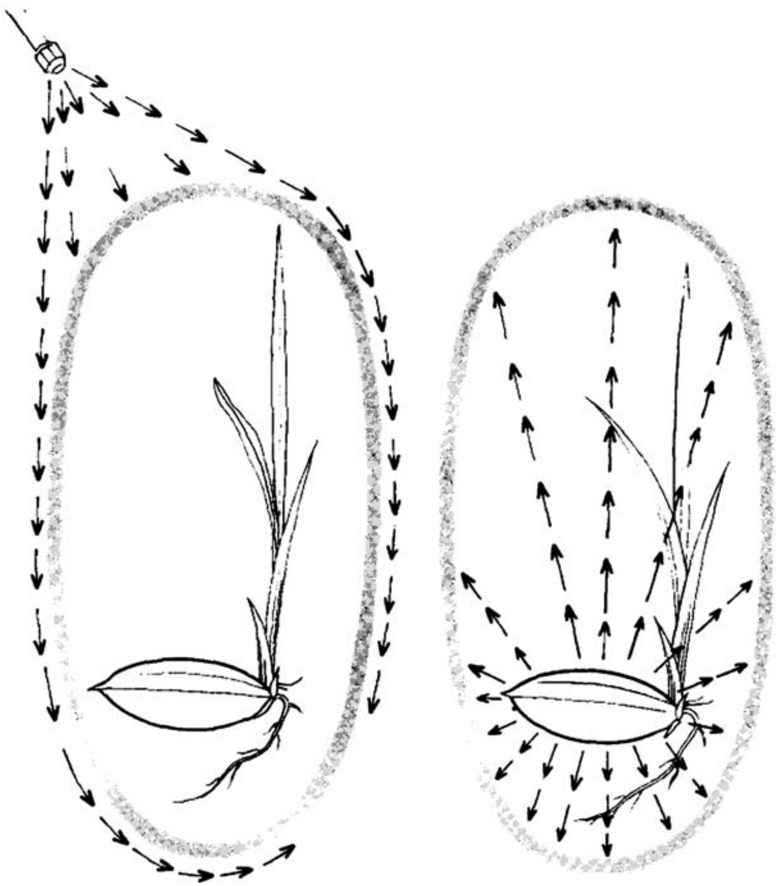
High grain yield potential



Traditional variety Modern variety

- Modern varieties have greater yield potential than traditional varieties.
- Even under the best conditions, traditional varietles cannot yield more than modern varieties.
- Use of fertilizers and improved farming practices will increase grain yield more in modern varieties than in traditional ones.
- Choose only from recommended varleties to minimize insect and disease infestation.
- Secure certified or good class seed for the selected variety.

Resistance to insects and diseases



Variety is not resistant to Insects and diseases. Insecticide and fungicide protection needed.

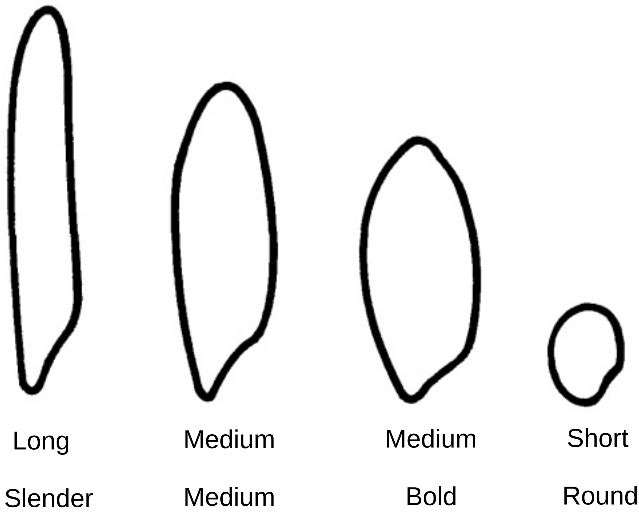
Variety is resistant to insects and diseases.

¢ Varieties differ in reactions to different pests. Select a variety resistant to pests and diseases in the area.

¢ Select the right variety to minimize pesticide cost.

Grain quality desired by consumers

Rice quality based on grain size and shape



¢ People have different preferences for size and shape of grain.

Rice quality based on amylose content.

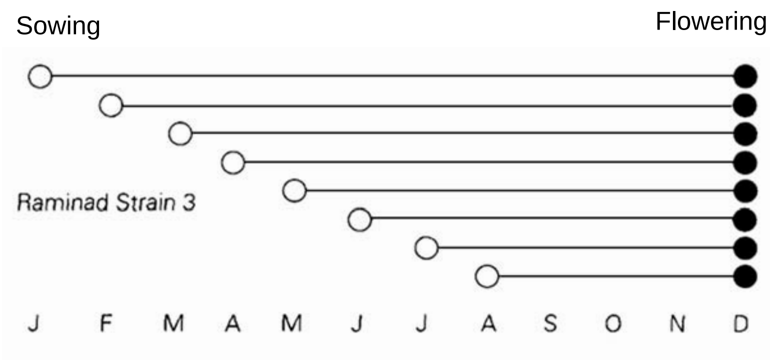
Cooked rice	Amylose content	Examples
Hard texture, dull appearance, fluffy, big volume expansion	High amylose, hardens quickly after cooking	IR8, IR42, IR52
	High amylose, hardens slowly after cooking	IR5, IR32, IR36, IR50
Intermediate In texture	Intermediate amylose	IR48, C12, C168, UPLRi-2, C4-63, BPI-121-407, Milagrosa, Azucena, Daggee
Soft texture, glossy, moist, sticky, tends to readily split and break up when overcooked	Low amylose	IR24, IR43
Tender, sticky, moist, glossy, takes up very little water; mostly for making desserts	Waxy	IR29, Malagkit Sungsong, UPLRi-1

■ Amylose is the relatively soluble portion of starch.

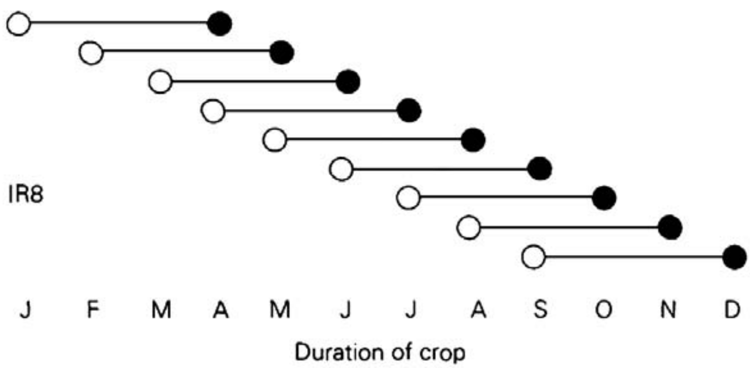
High grain yield at the specific location

¢ Farmers' evaluations of new rice selections show which varieties produce high grain yields.
¢ Observe performance of rice varieties at the specific location.

Wide climatic adaptability



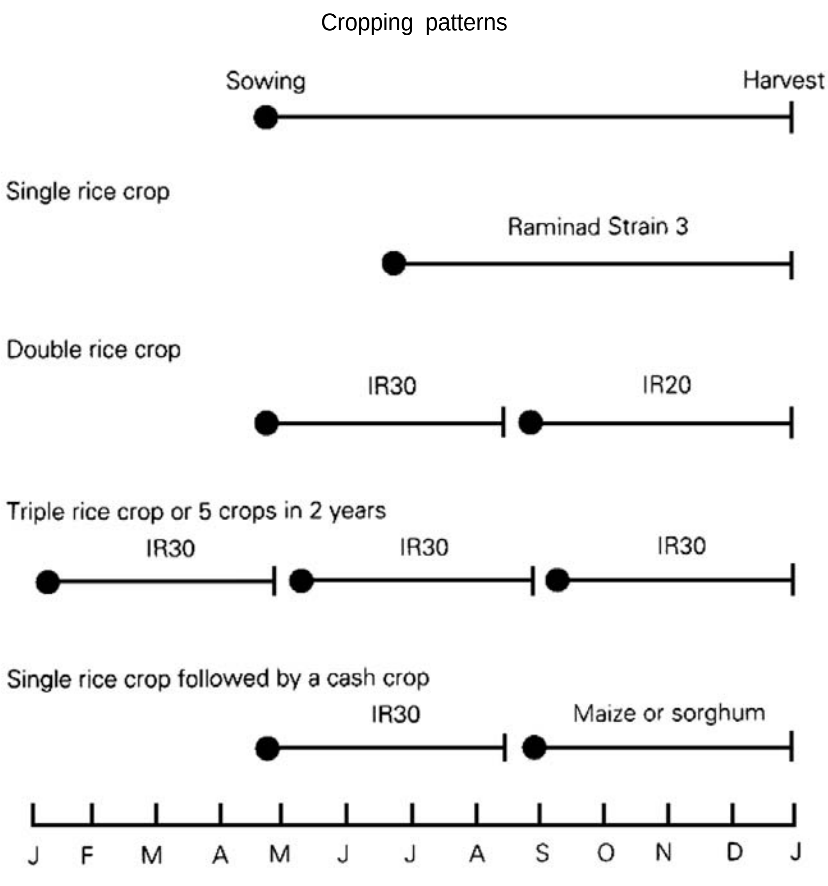
¢ Most traditional varieties, such as Raminad Strain 3, flower only when the days are short.



¢ Modern varieties, such as IR8, do not require short days to flower. They can be planted any time of the year and harvested after a definite number of days.

¢ This important characteristic of modern varieties makes more than one crop per year possible.

Desired growth duration



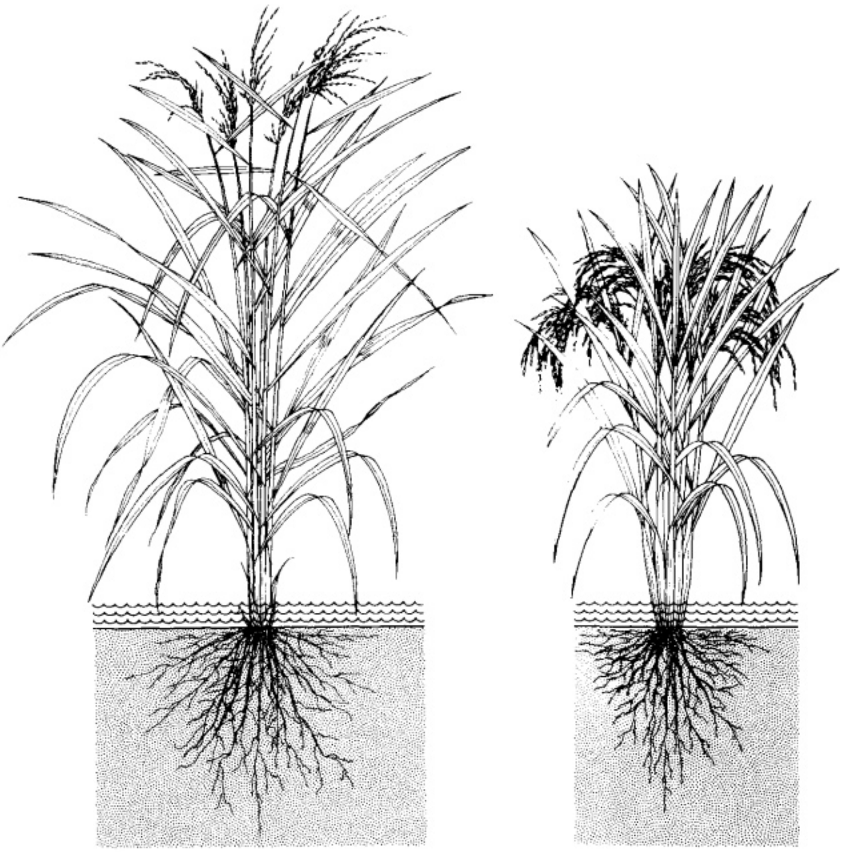
¢ Desired growth duration depends on the cropping pattern.
¢ The length of time the rice crop is in the field is more flexible if only one crop is planted per year.
¢ Shorter growth durations are needed if two crops are to be grown.
¢ Rice crops with a shorter growth duration need intensive care. Damage at any growth stage will greatly decrease grain yield.

Tolerance for specific local soil problems

- Saline soils: low-lying coastal areas often flooded by sea water.
  Tolerant varieties: IR4-11, IR2071-88-8-10.
- Zinc-deficient soils: soil or seedling treatment can overcome zinc deficiency.
  Tolerant varieties: IR34, IR2307-14-2-2.
- Phosphorus- and iron-deficient soils:
  Varieties tolerant of phosphorus deficiency: RDI, Pelita/l, IR34.
  Varieties tolerant of Iron deficiency: MI-48, IR36.
- Iron, manganese, and aluminum toxic soils:
  Varieties tolerant of iron toxicity: IR34, IR46, IR9764-45-3.
  Varieties tolerant of aluminum and manganese toxicity: IR36, IR45, IR46.

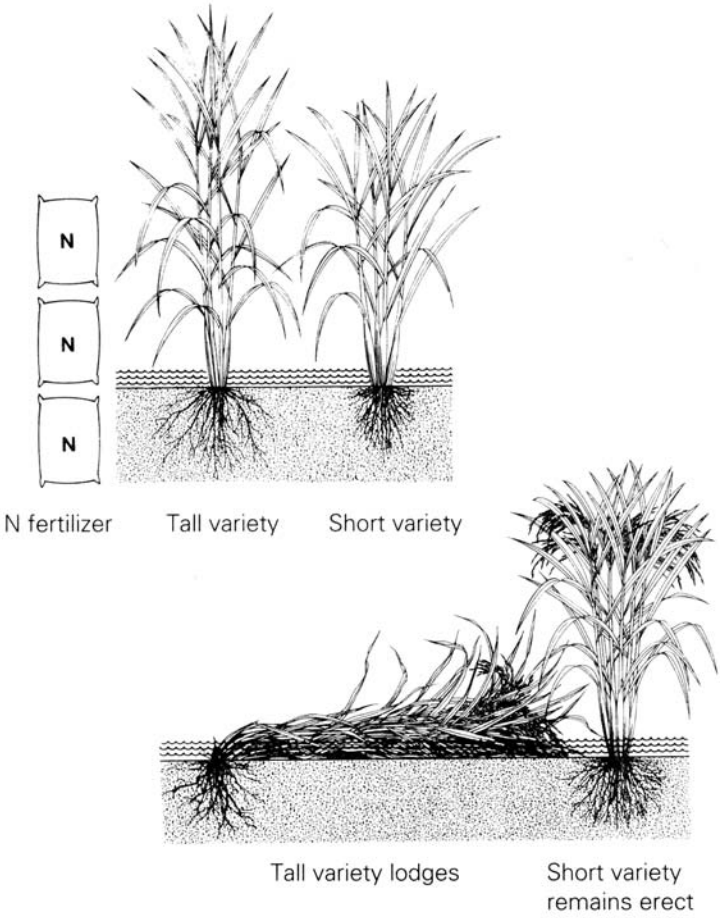
Lowland rice plant type with high yield potential

Short stature



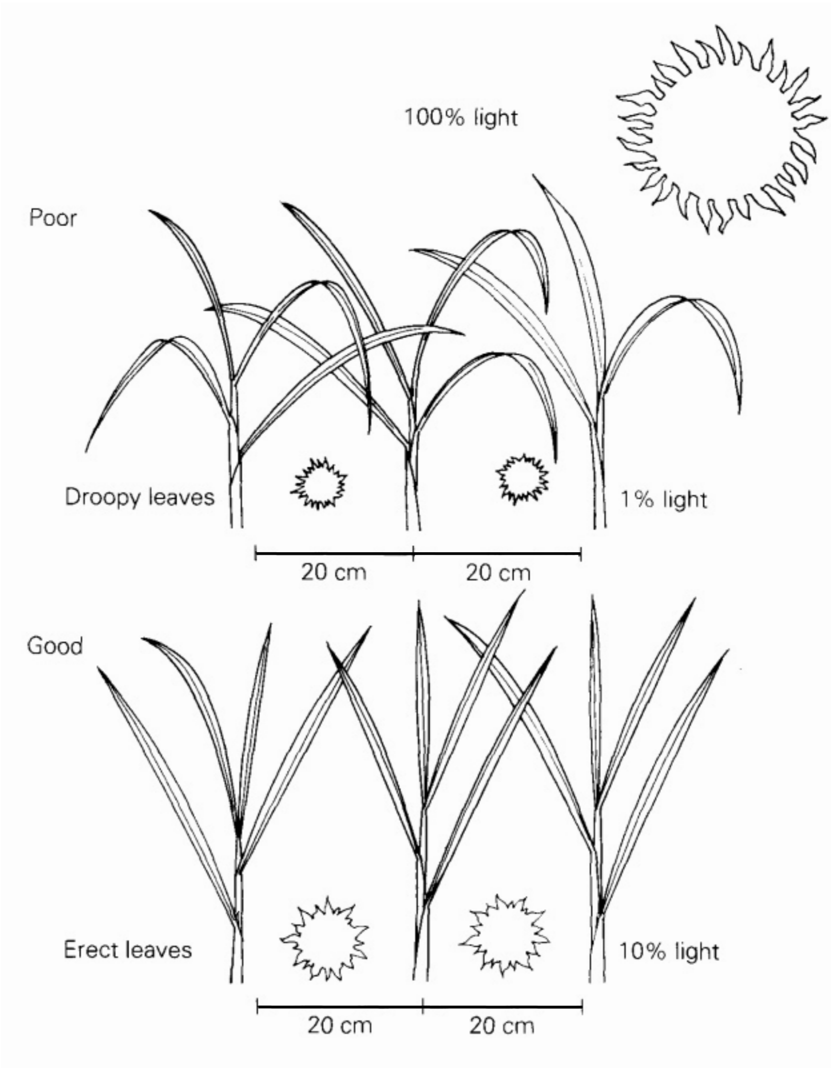
- Reduced plant height is the most important factor to increase the grain yield potential of rice.
- Shorter plants are more resistant to lodging.
- The lower leaves of tall, leafy plants receive very little light.
- Shorter plants can take up more nitrogen fertilizer without lodging, resulting in higher grain yields.

Nonlodging



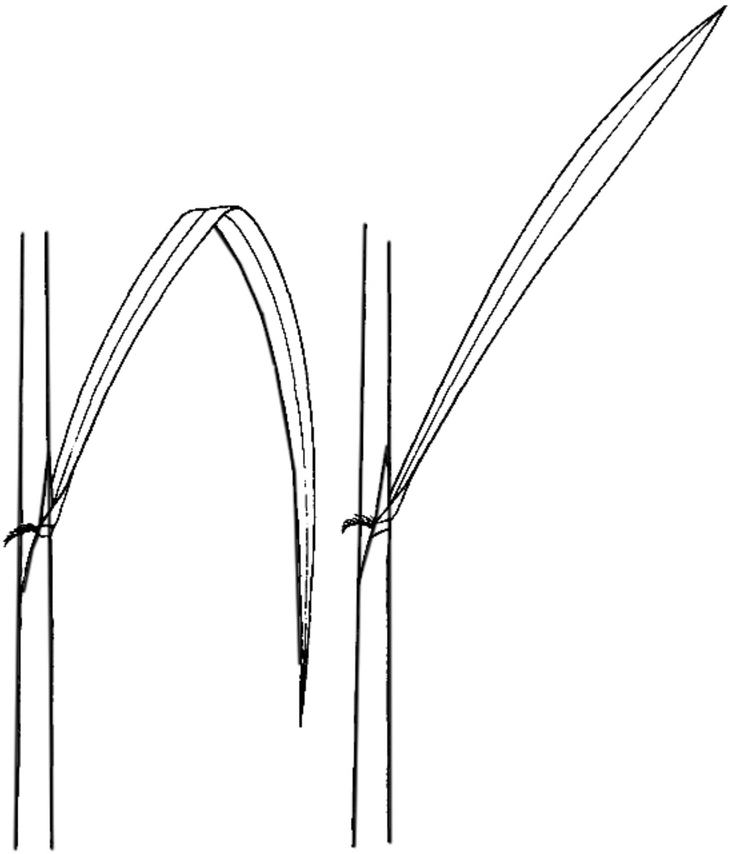
- ¢ Plant height increases with nitrogen application. Lodging can become a problem because added fertilizer results in taller plants, heavier panicles, and top-heavy plants.
- ¢ Many leaves decay on the lodged plants because they are soaked in water and do not receive enough light.
- ¢ Short, stiff stems prevent lodging.

Erect leaves



- Droopy leaves mean that the lower leaves receive very little light.
- At the same spacing and for leaves of the same length, erect leaves do not shade lower leaves very much.

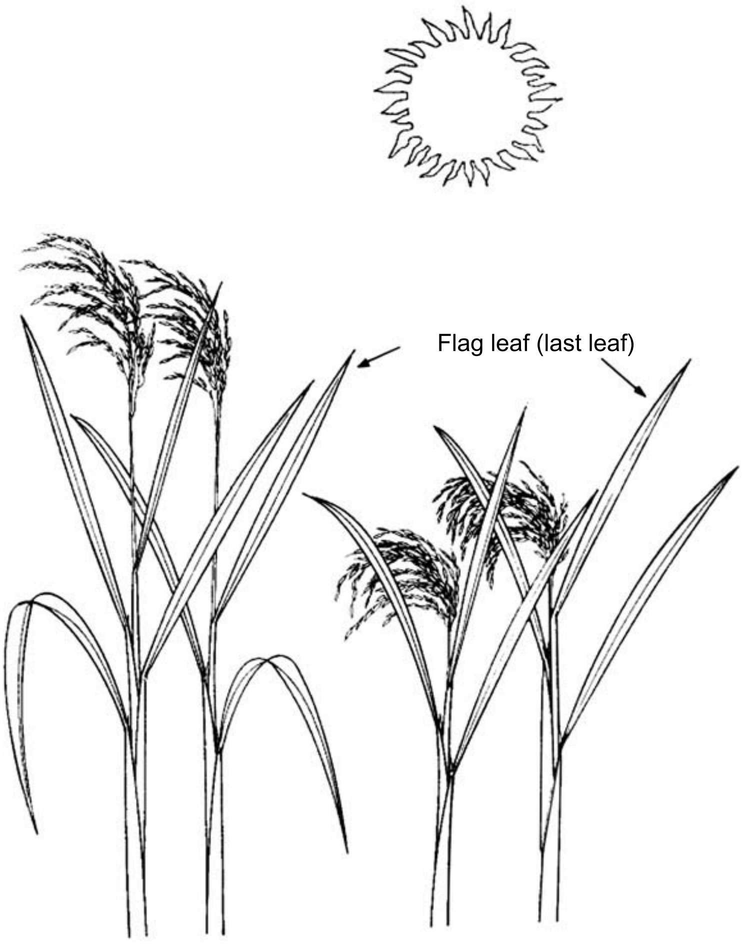
Short leaves



Poor leaf type Good leaf type

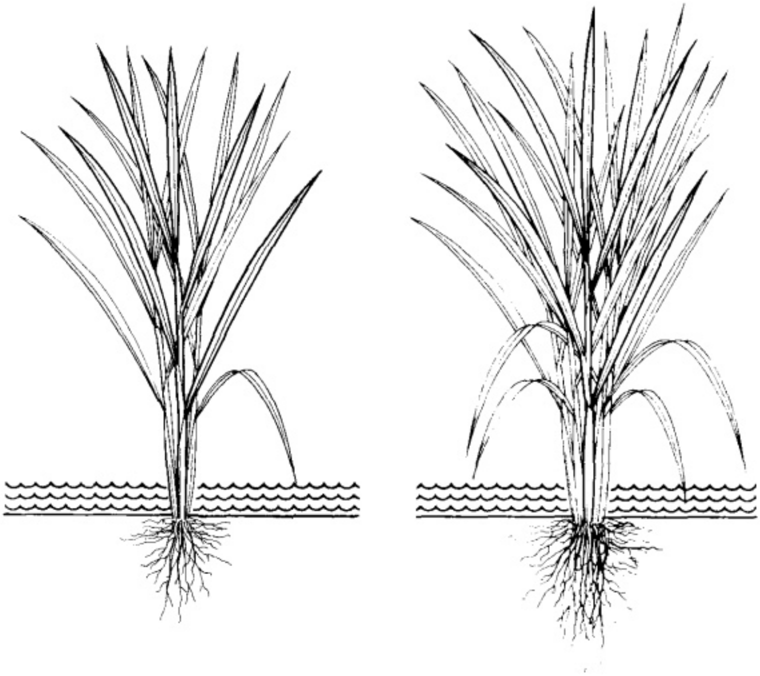
- Shorter leaves are more erect because they have less weight to carry.

Flag leaf higher than the panicle



¢ The leaves should get as much light as possible.
¢ The upper leaves are shaded less if the panicles do not extend far above the flag leaf.

Good tillering

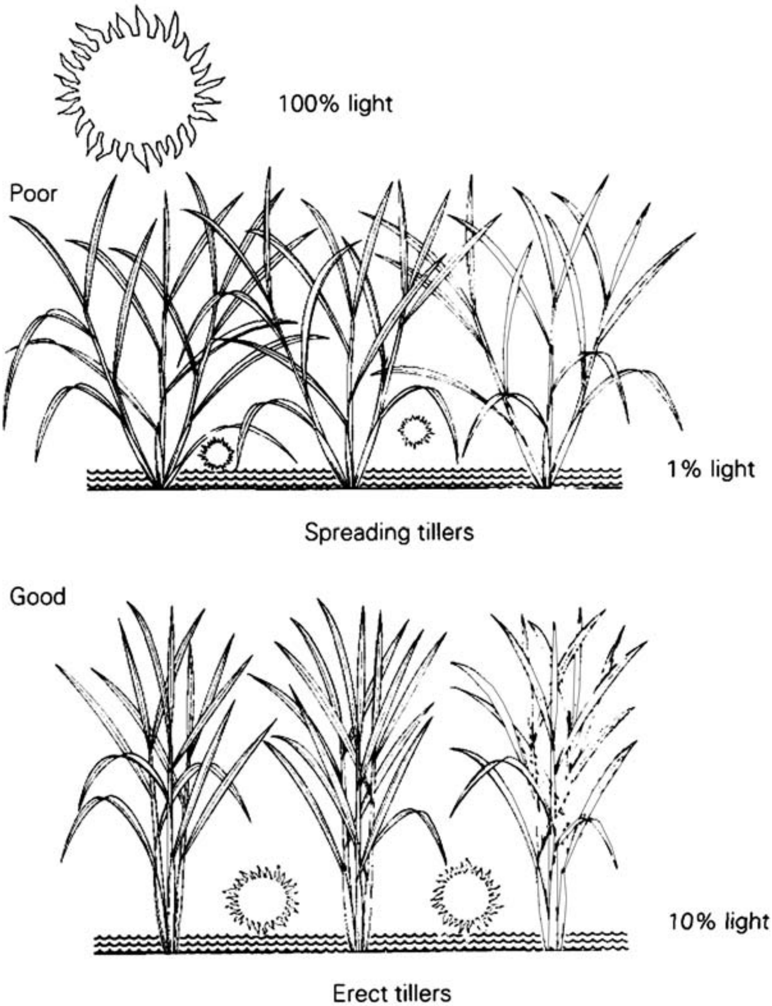


Poor tillering ability

Good tillering ability

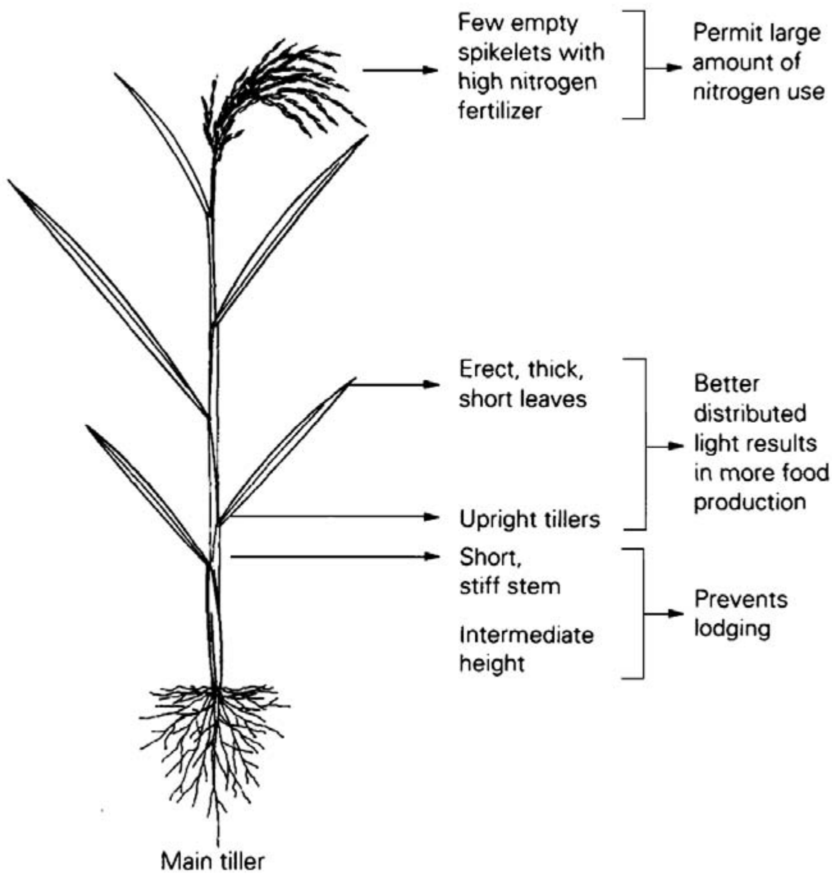
- Even if some plants die soon after transplanting, good tillering ability ensures adequate tillers per unit area.
- For direct seeding, a low-tillering plant may yield more.

Erect tillers

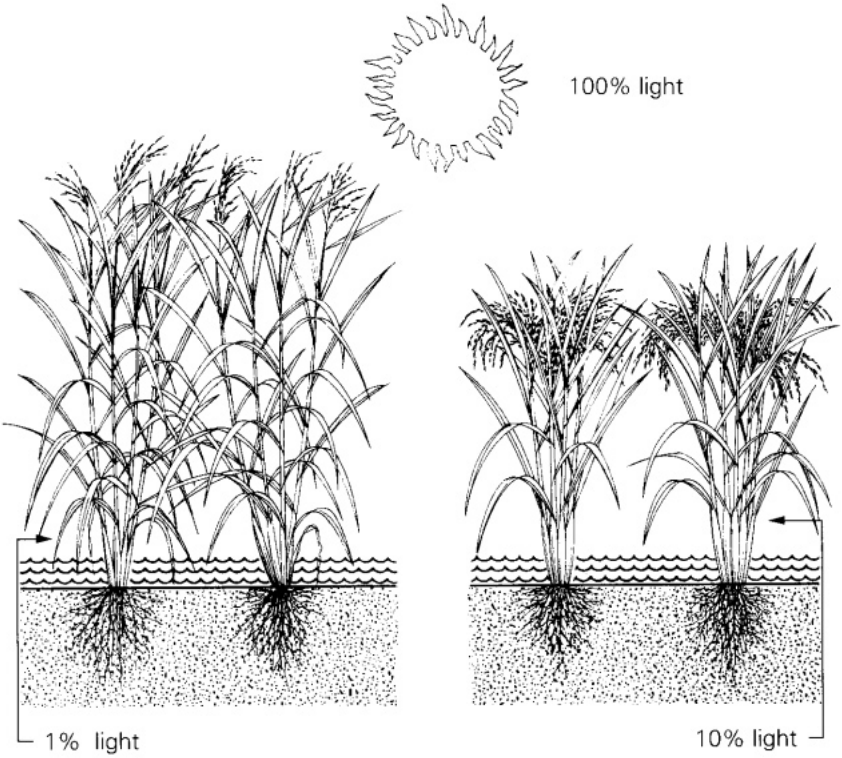


- Upright tillers contribute to better light distribution, resulting in more food production and higher grain yield.

The ideal tiller



Good plant type



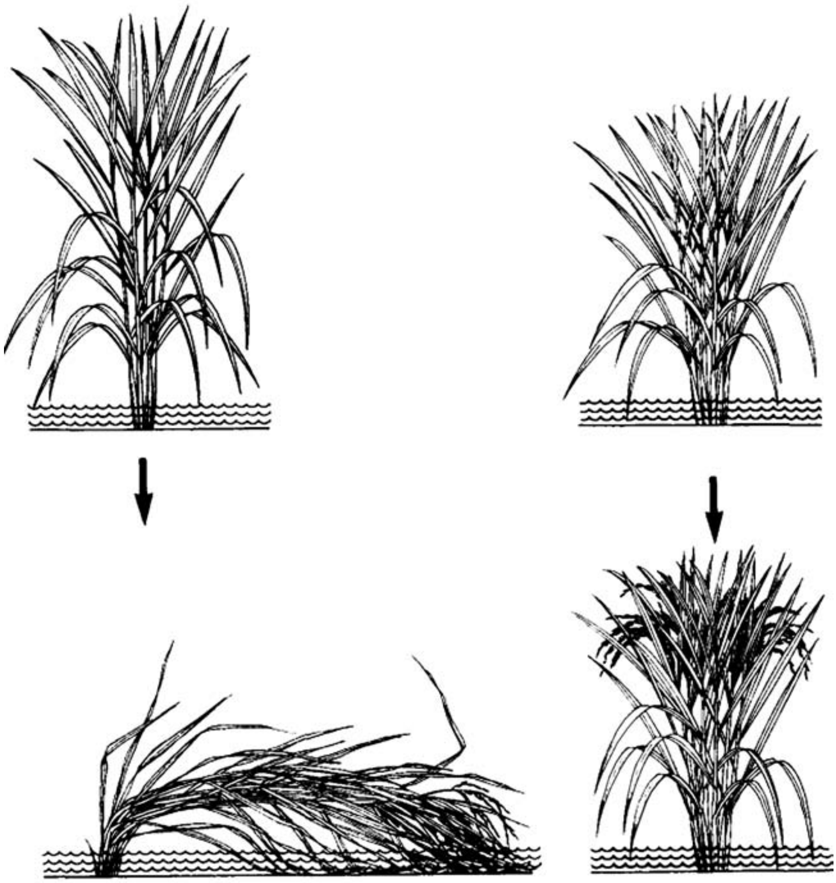
Poor plant type

Good plant type

¢ A good plant type has
- short stature (nonlodging),
- erect, short leaves,
- flag leaf higher than panicle, and
- erect tillers.

Factors that affect lodging

Plant height

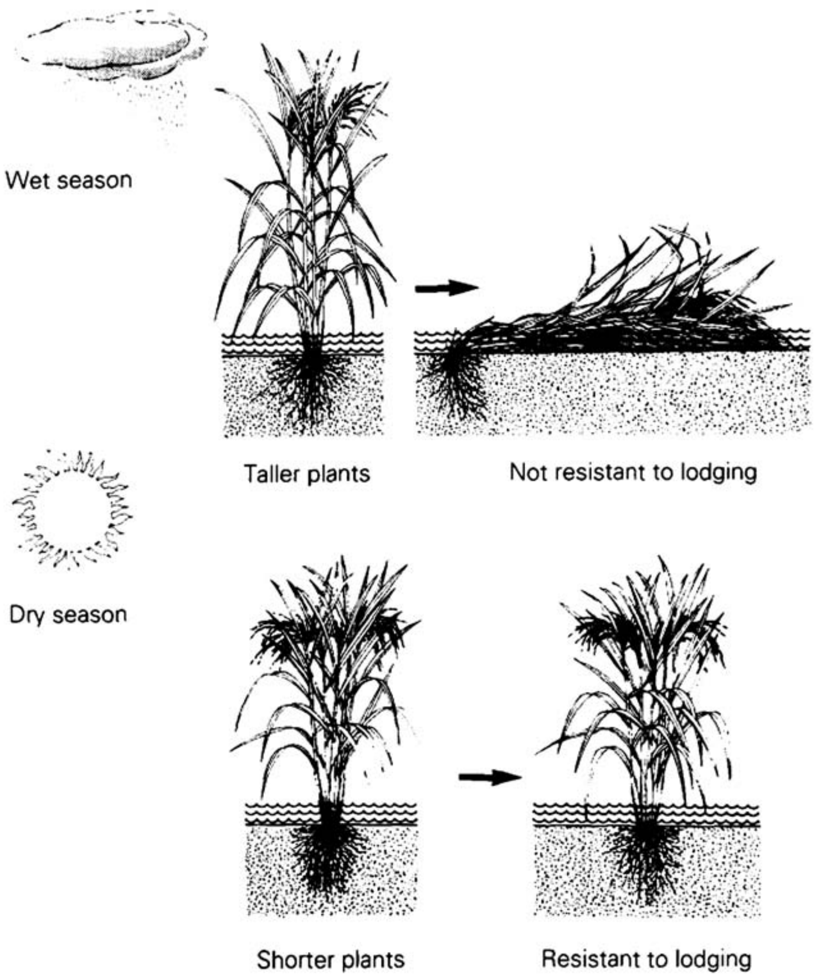


Not resistant to lodging

Resistant to lodging

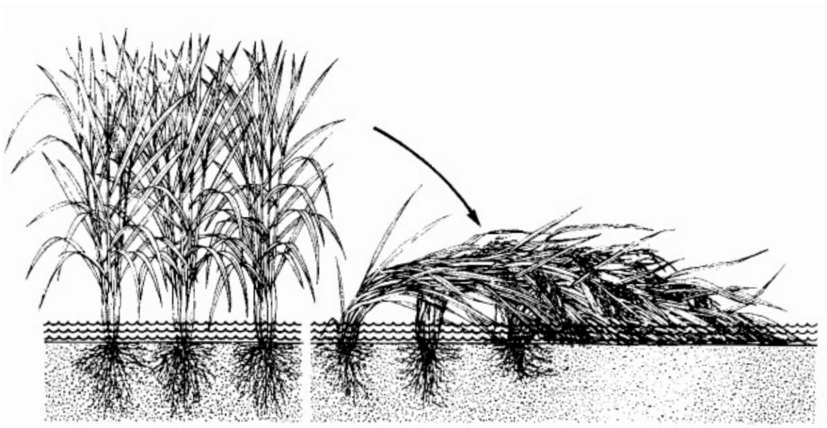
¢ The taller the plant, the greater the tendency to lodge.
¢ Short, stiff stems prevent lodging.
¢ Avoid using tall varieties during wet season.

Light intensity



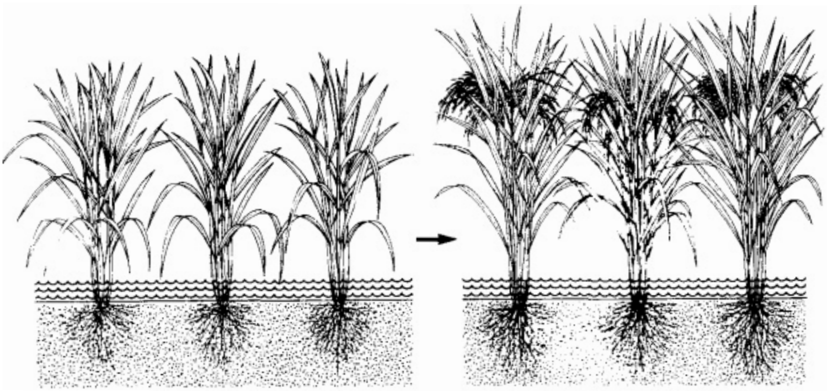
- Cloudy weather results in taller plants that have a greater tendency to lodge.
- Lodging is more common during wet season.

Spacing



Spacing is too close

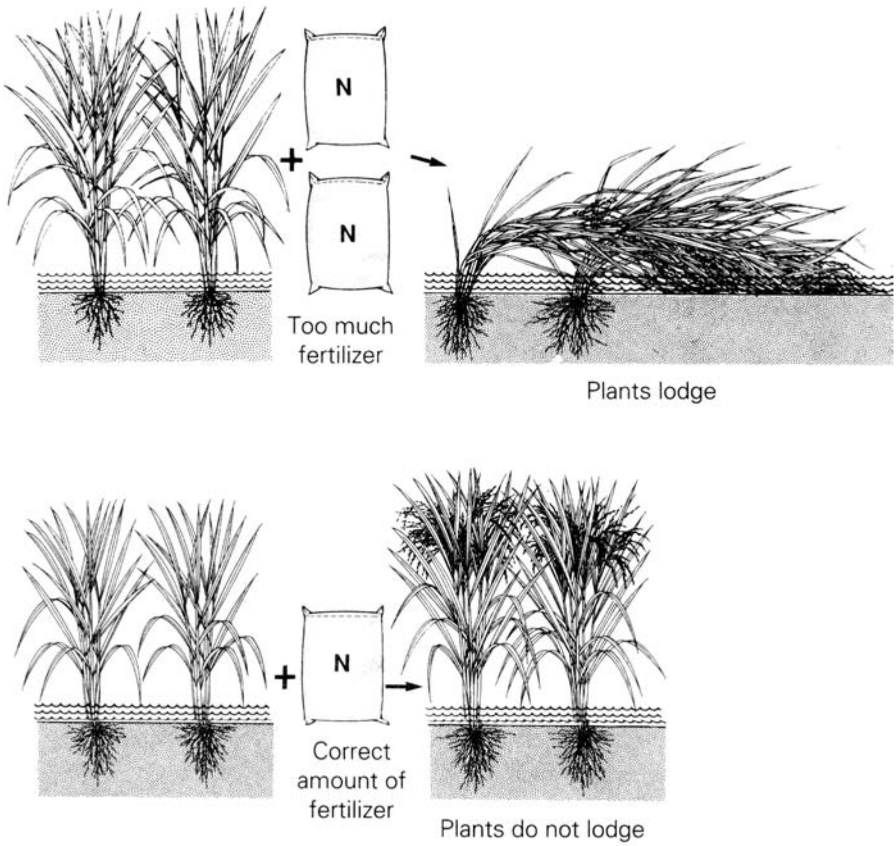
Not resistant to lodging



Correct spacing

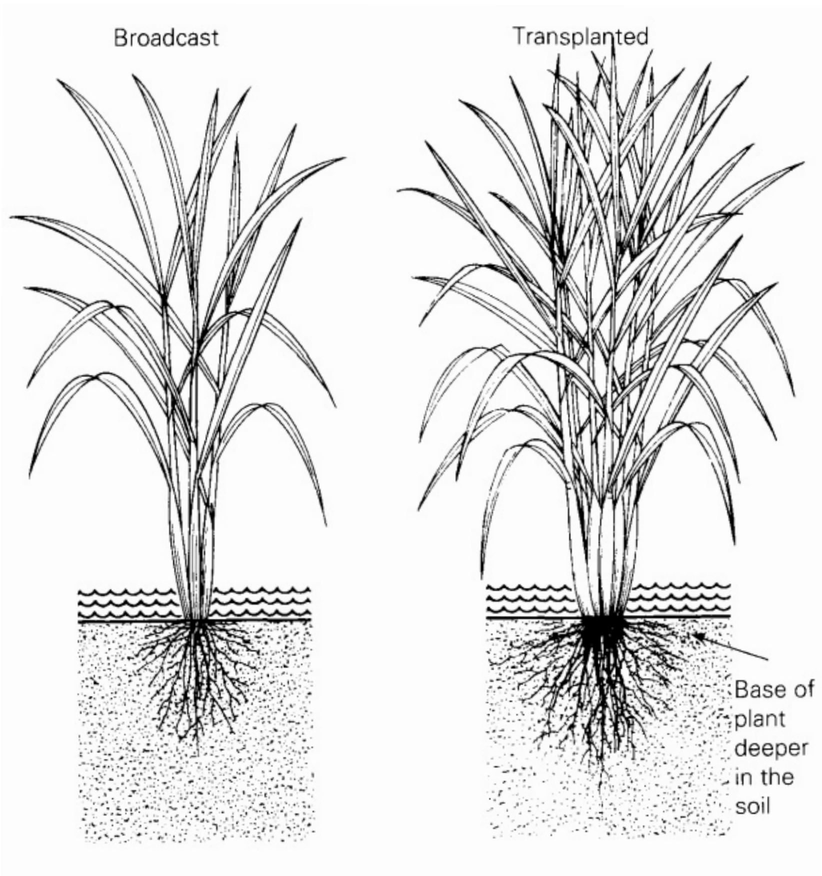
Resistant to lodging

The ideal tiller



¢ CFertilizer (mostly nitrogen) increases plant height. Tall varieties cannot stand too much fertilizer.

Method of sowing

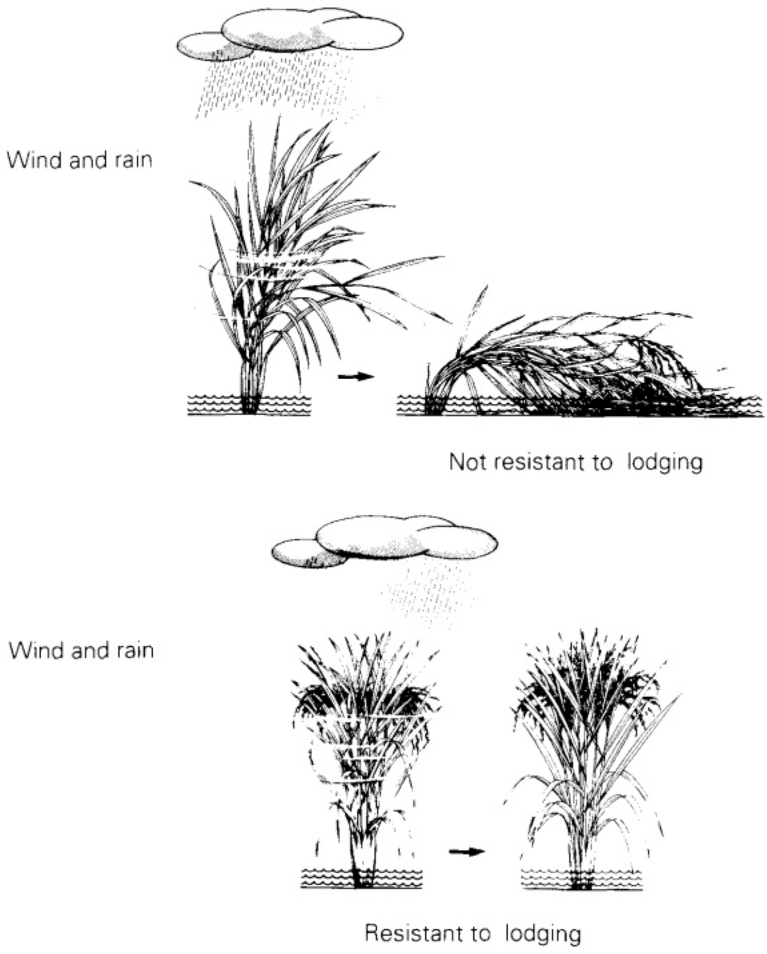


Less resistant to lodging

More resistant to lodging

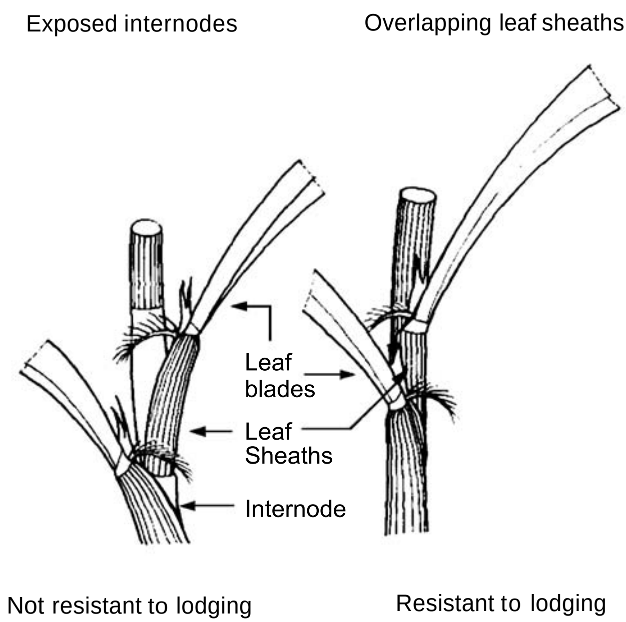
■ Transplanted rice is more resistant to lodging than broadcast rice because the base of the plant is better anchored.

Wind and rain



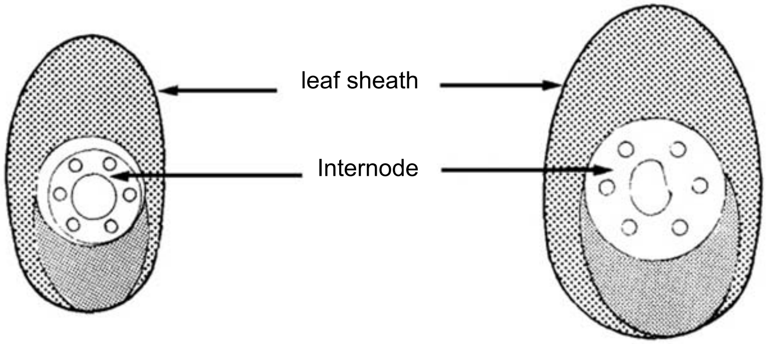
¢ Wind and rain can make a plant lodge. The stronger the wind, the more likely the plant will lodge.
¢ Many leaves on lodged plants decay and become unproductive because they are soaked in water or do not receive sufficient light.
¢ Avoid using tall varieties during wet season.

Type of leaf sheath



■ Overlapping leaf sheaths result in thicker and stronger stems.

Stem thickness



Not resistant to lodging

Resistant to lodging

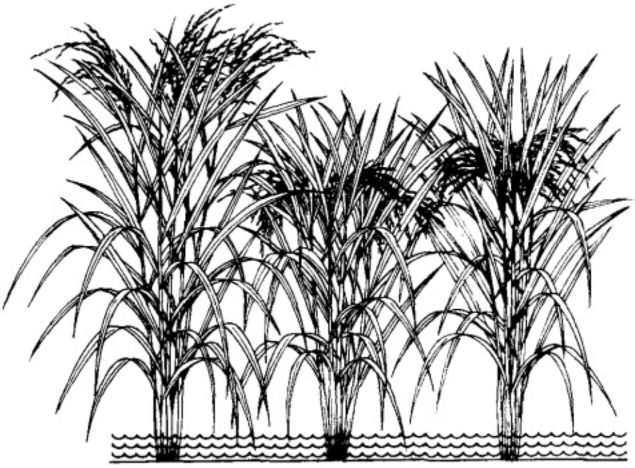
Cross-section of 2 stems or culms

¢ The thicker the leaf sheath and the internode, the greater the resistance to lodging.

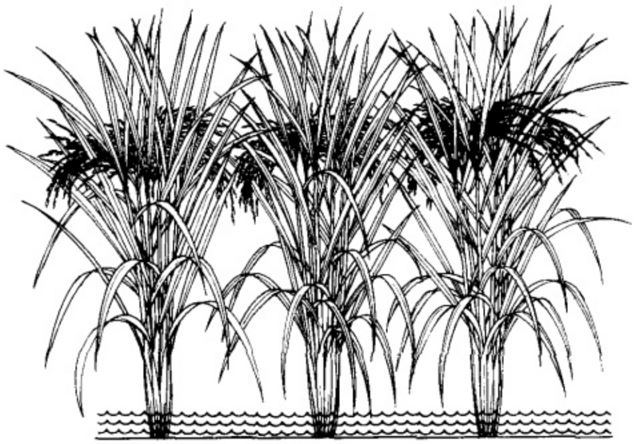
How to judge a rice crop at flowering

194 Uniform plant height
195 No lodging
196 Lodging may indicate spacing was too close
197 Lodging may indicate too much fertilizer was applied
198 Lodging may indicate variety used was too tall
199 White to brown roots
200 Green, undamaged leaves
201 At least 3-4 leaves per tiller
202 250-350 panicles per square meter
204 Correct plant density

Uniform plant height



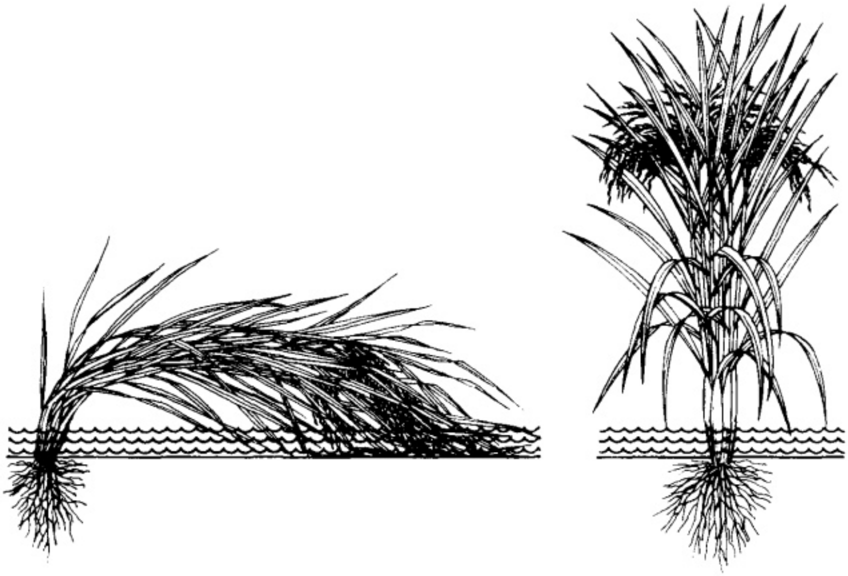
Irregular growth



Uniform growth

¢ Irregular plant height can mean
- drought, insect, or disease incidence;
- uneven land preparation;
- uneven fertilization; or
- mixed seeds.

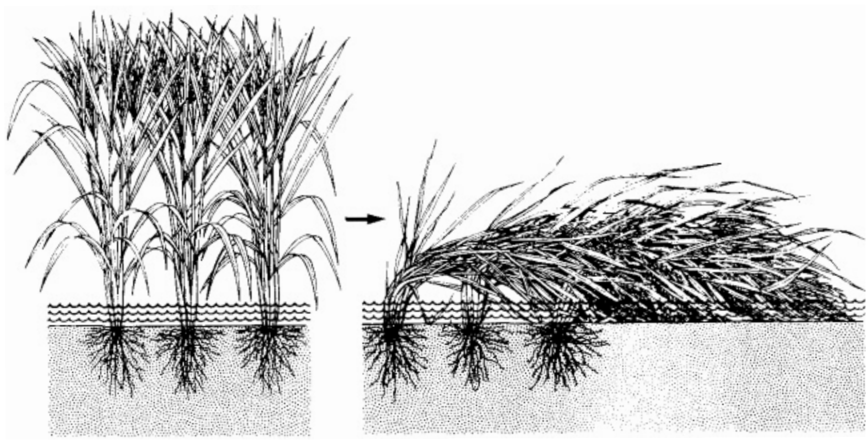
No lodging



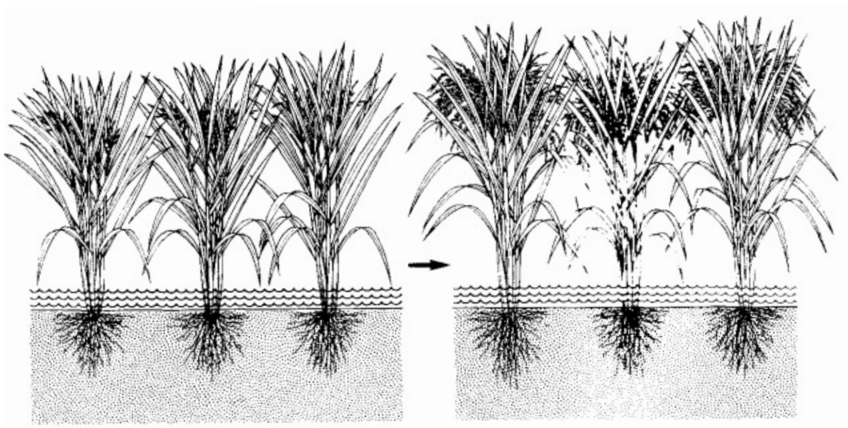
Lodged Not lodged

- ¢ Lodging may indicate
  - plants were too closely spaced,
  - too much fertilizer was used, or
  - the variety used was too tall for that area and for the planting season.

Lodging may indicate spacing was too close



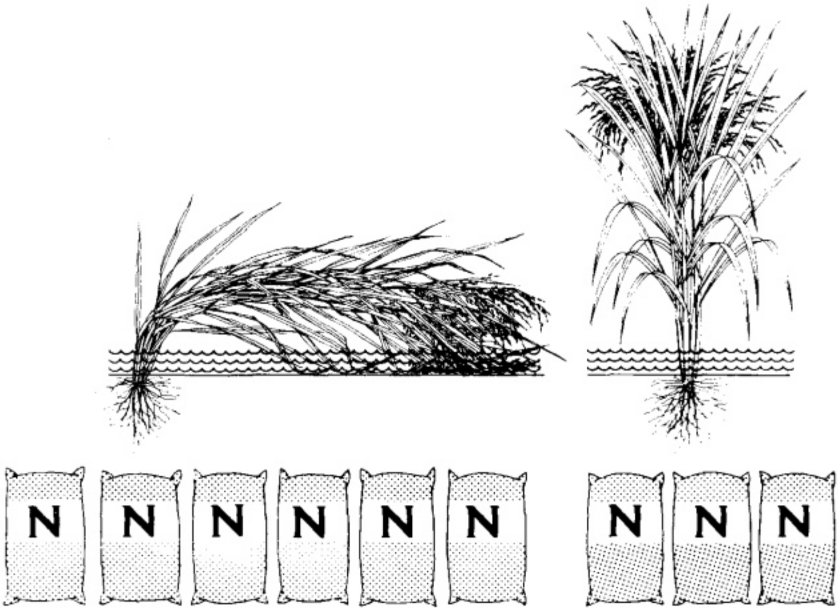
Spacing too close　　　　　Lodged



Correct spacing　　　　　Not lodged

¢ Correct spacing depends on
- the variety,
- soil fertility,
- the amount and type of fertilizer applied, and
- season of planting.

Lodging may indicate too much fertilizer was applied

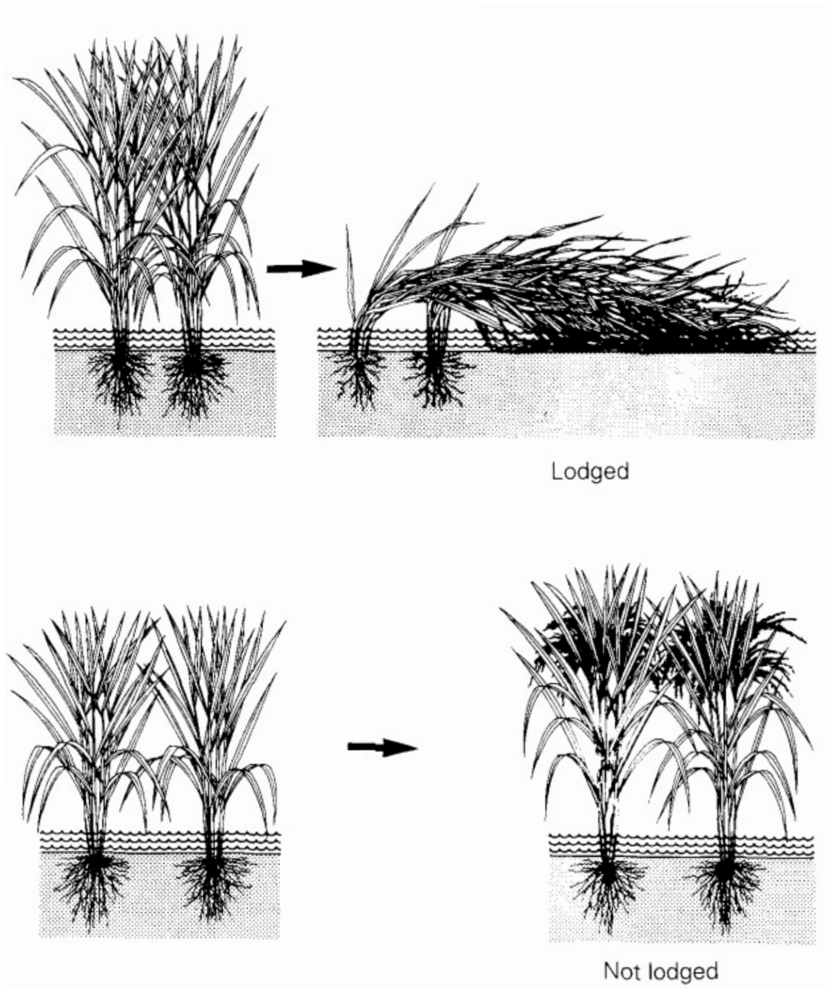


Too much fertilizer

Proper amount of fertilizer

- Too much fertilizer causes plants to grow tall; therefore they become more likely to lodge.

Lodging may indicate variety used was too tall

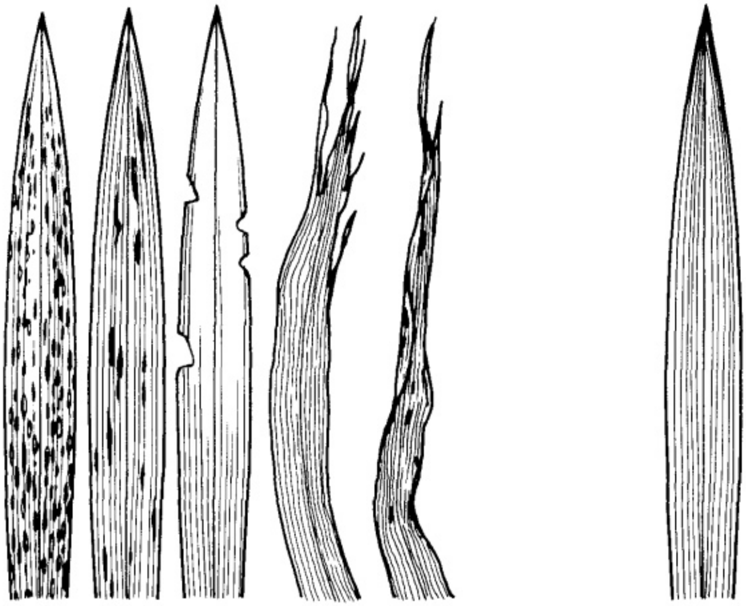


■ Select an appropriate variety to prevent lodging.

White to brown roots

¢ Black roots and a bad smell indicate something is wrong with the soil, such as:
- lack of drainage,
- lack of air,
- Iron toxicity, or
- presence of toxic substances.

Green, undamaged leaves

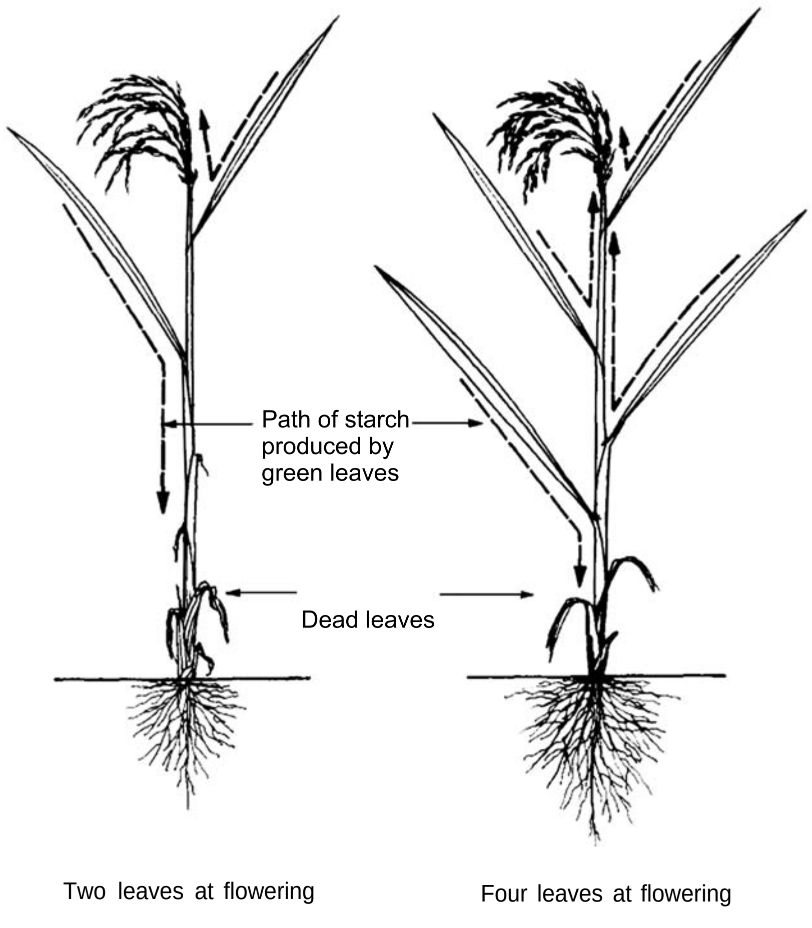


Damaged leaves

Green undamaged leaf

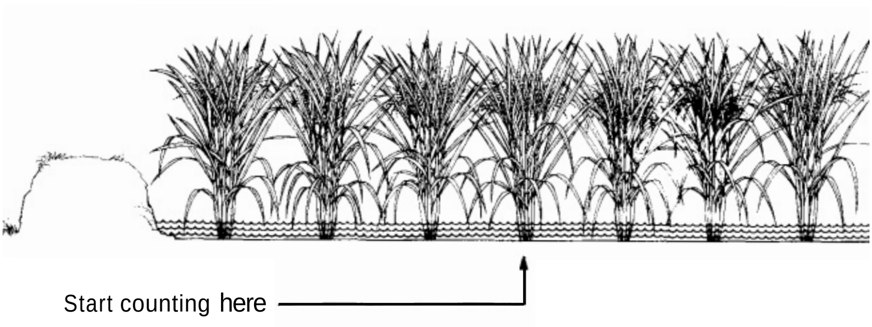
- Yellow leaves may indicate a lack of nitrogen or presence of disease.
- Jagged leaves may indicate attacks by pests.
- Spotted or discolored leaves may indicate disease, nutrient deficiency, or soil toxicity.

At least 3-4 leaves per tiller

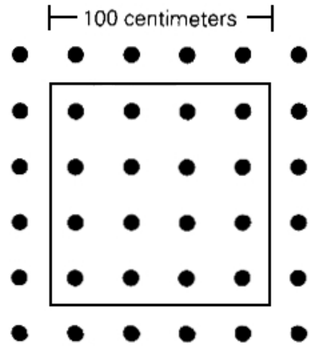


- A tiller needs 3-4 leaves
  - to provide the roots and other parts with food and
  - to fill the spikelets with starch produced in the leaves.
- Suspect a soil deficiency or water stress at an earlier growth stage if a tiller has only two leaves.

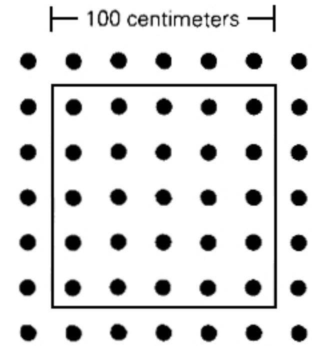
250-350 panicles per square meter



¢ Determine the number of panicles per hill by counting at least three hills inside the field. Use the average. Do not use hills in the first three rows from the levee.



25- x 25-centimeter spacing =
16 hills/square meter



20- x 20-centimeter spacing =
25 hills/square meter

¢ Figure out the spacing used and calculate the number of hills per square meter.

If the distance between hills is 25 centimeters, then the area per hill = 25 x 25 = 625 square centimeters
= 0.0625 square meter

$$\text{Number of hills per square meter} = \frac{\text{1 square meter}}{\text{area per hill}}$$

$$= \frac{\text{1 square meter}}{\text{0.0625 square meter}}$$

$$= 16$$

¢ Calculate the number of panicles per square meter assuming 20 panicles per hill (determined by counting) and 16 hills per square meter.

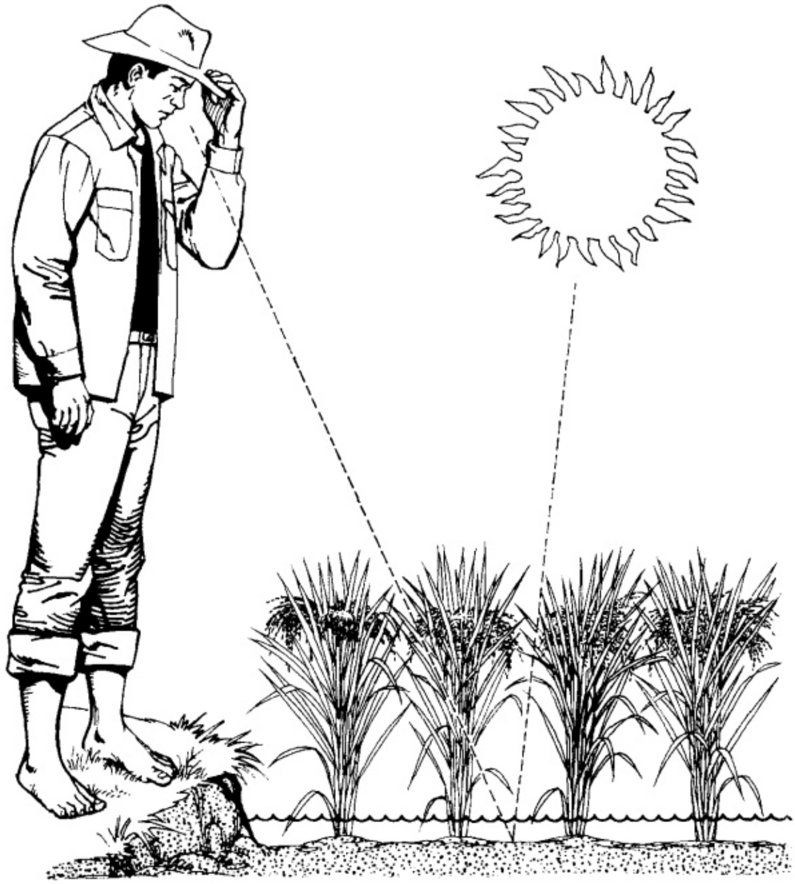
Number of panicles per square meter = Number of panicles per hill x number of hills per square meter

= 20 x 16

= 320

¢ If number of panicles per square meter is less than 250, something is wrong with the method of farming, the rice variety, or the soil. Also check spacing and fertilizer application.

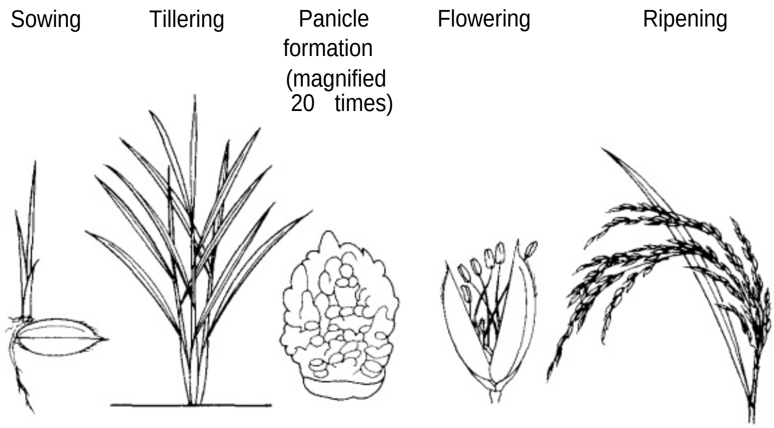
Correct plant density



- The correct number of plants per unit area can be checked by standing on a levee. If you can barely see the water or sun's rays sparkle, the plant density is good.
- If you cannot see the water, the spacing is probably too close, too much fertilizer has been applied, or the variety is too tall.

Yield components

Growth stages when yield components are determined



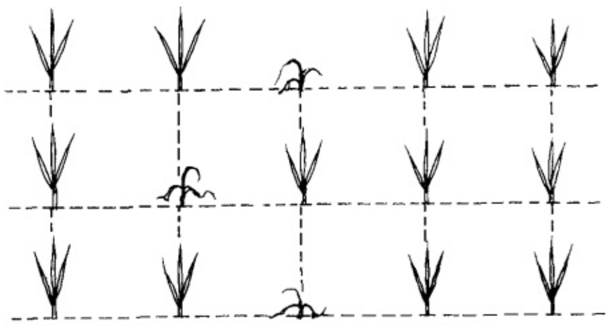
Grain yield = Panicles per unit area X Spikelets per panicle X Fertility of spikelets X Weight of a single grain

¢ Every stage of growth contributes to grain yield. Good management is necessary at all stages.

¢ Environmental factors affect every stage.

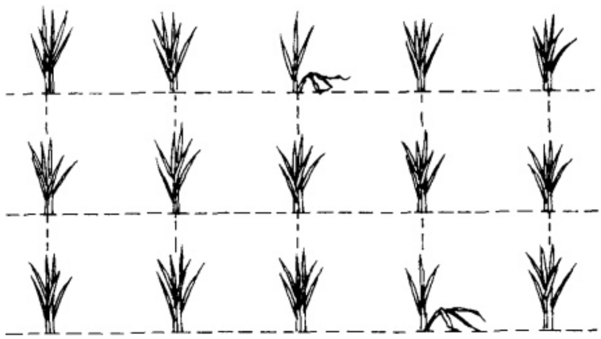
Sowing affects yield

One seedling per hill



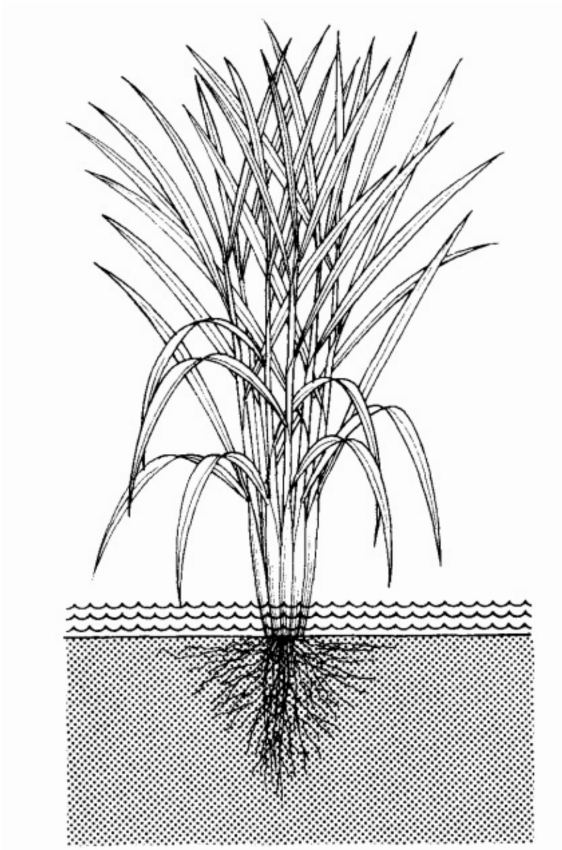
Dead seedlings result in poor growth or empty hills.

Two seedlings per hill



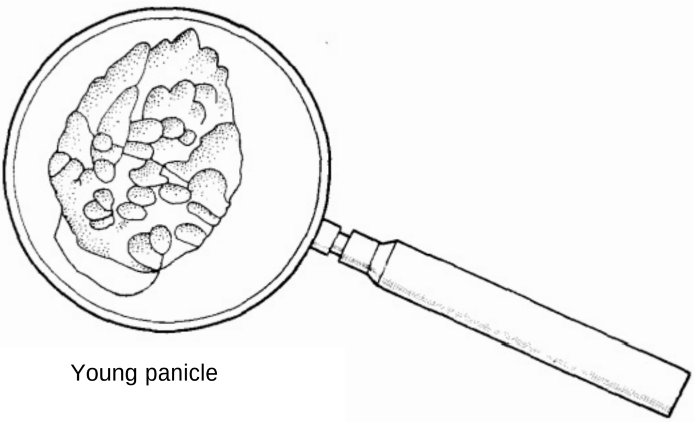
- Survival of the planted rice seedlings determines the number of tillers that will be produced.
- Healthy seedlings and careful transplanting help ensure that more plants live.
- Transplant at least two seedlings per hill.

Leaf development and tillering affect yield



- The number of tillers determines the number of panicles and is the most important factor in achieving high grain yield.
- Enough leaves are necessary to ensure many spikelets per panicle and also to fill these spikelets.
- Enough water, the right amount of fertillzer, proper spacing, and good weed control produce the most tillers.

Panicle formation affects yield



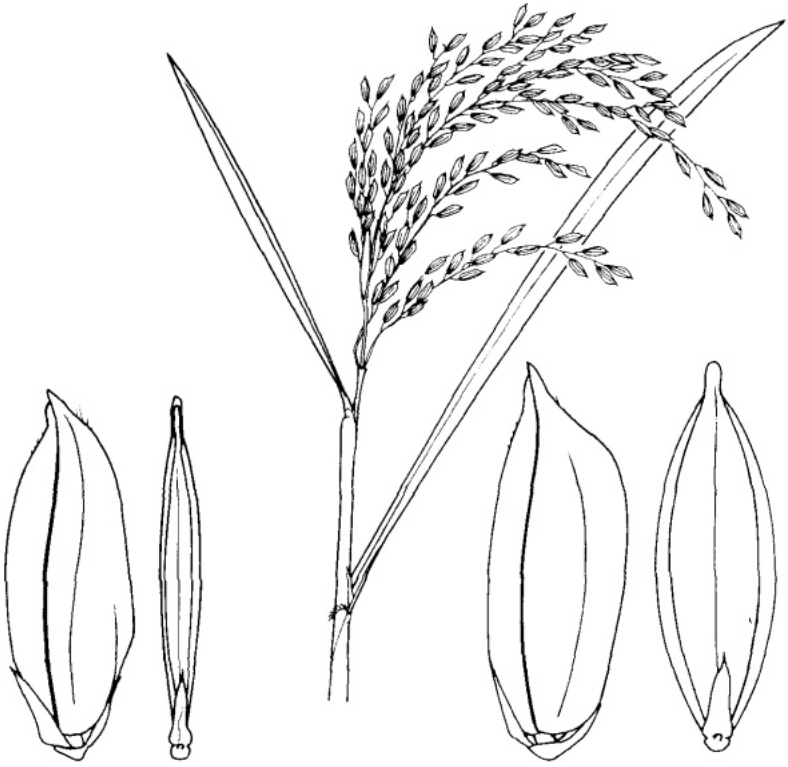
Young panicle

- ¢ The number of spikelets per panicle is determined at the panicle formation stage.
- ¢ Very low temperatures and low light intensity during this stage increase spikelet abortion.
- ¢ Spikelet abortion means lower yield.
- ¢ The amount of nitrogen in the plant can affect the number of spikelets per panicle.

Flowering affects yield

- ¢ Transfer of the male cell to the female cell located in the ovary occurs at flowering.
- ¢ Successful transfer will determine whether the spikelet develops into a grain.
- ¢ The percentage of spikelet fertility is an important yield component.

Ripening affects yield



Front view Side view
Partially filled spikelet

Front view Side view
Fully filled spikelet

¢ The weight of a single grain is determined at ripening.

¢ Drought and low light intensity between flowering and ripening can cause lower grain weight.

¢ Poor tillering or low tiller number per unit area can partially be compensated for by increasing spikelet fertility or the weight per grain.

Variations in yield components—panicle weight and number types

Few but large panicles—panicle weight type

Many but small panicles—panicle number type

- ¢ Increase in grain yield of panicle weight types is usually the result of an increase in the weight per panicle.
- ¢ Increase in grain yield of panicle number types is usually the result of an increase in the number of panicles.
- ¢ Most modern varieties are panicle number types. Traditional varieties are panicle weight types.

Importance of yield components

- ¢ Study the factors contributing to grain yield to understand why yields are high or low.
- ¢ Estimate yield by studying a representative area of 1 square meter.
- ¢ Each yield component shows wide variation. The number of spikelets per panicle in a variety can vary from about 50 to more than 200.
- ¢ The percentage of filled spikelets greatly depends on environmental conditions,

Importance of yield components

- Target yield = 4 tons/hectare or 400 grams/square meter
- Characteristics of the variety used:
  - Number of panicles per hill = 14
  - Spikelets per panicle = 100
  - Percentage of filled spikelets = 83.3%
  - Weight of a single grain = 0.025 gram
- Use this formula to determine the number of panicles per square meter needed to achieve the target yield:

$$\text{Yield in grams per square meter} = \text{Panicles per square meter} \times \text{Spikelets per panicle} \times \text{Percentage filled spikelets} \times \text{Weight of a single grain in grams}$$

$$400 \text{ grams} = (\text{panicles/square meter}) \times 100 \times \frac{83.3}{100} \times 0.025$$

$$\text{Panicles/square meter} = \frac{400}{100 \times 0.833 \times 0.025} = 192$$

- If the spacing used was 25 x 25 centimeters or 16 hills/square meter

$$\frac{192 \text{ panicles/square meter}}{16 \text{ hills/square meter}} = 12 \text{ panicles/hill}$$

- The variety used can produce more than 12 panicles per hill at 25- x 25-centimeter spacing. Target yield could be obtained.
- If the actual yield was below 400 grams/square meter, something was wrong with the crop. Study the yield components in detail to understand what possibly went wrong.

How to use yield components

Panicles per unit area

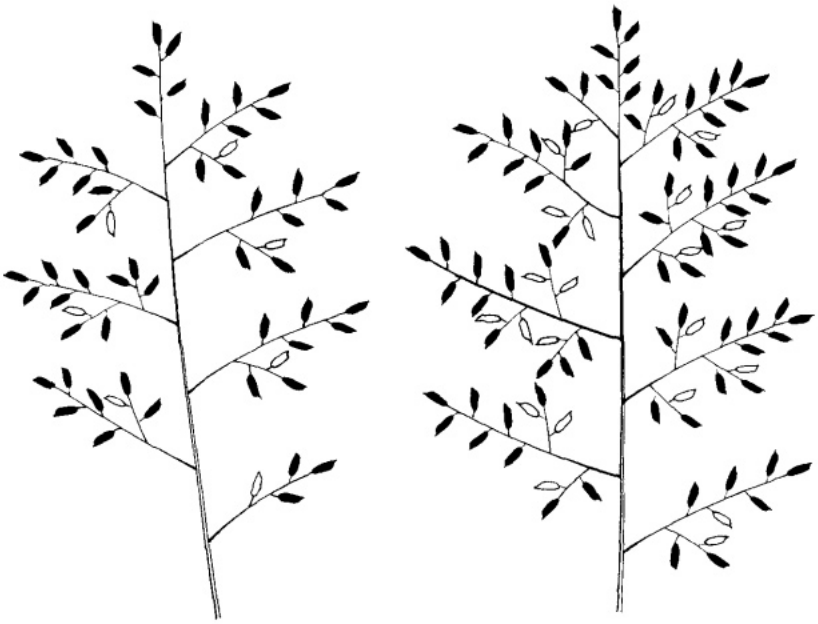
Actual:
6 panicles

Expected:
14 panicles

Problem: few panicles per square meter

¢ A soil deficiency or inadequate fertilizer application can reduce panicle number. Lack of water or pest/disease damage during early growth can also cause this.

Spikelets per panicle



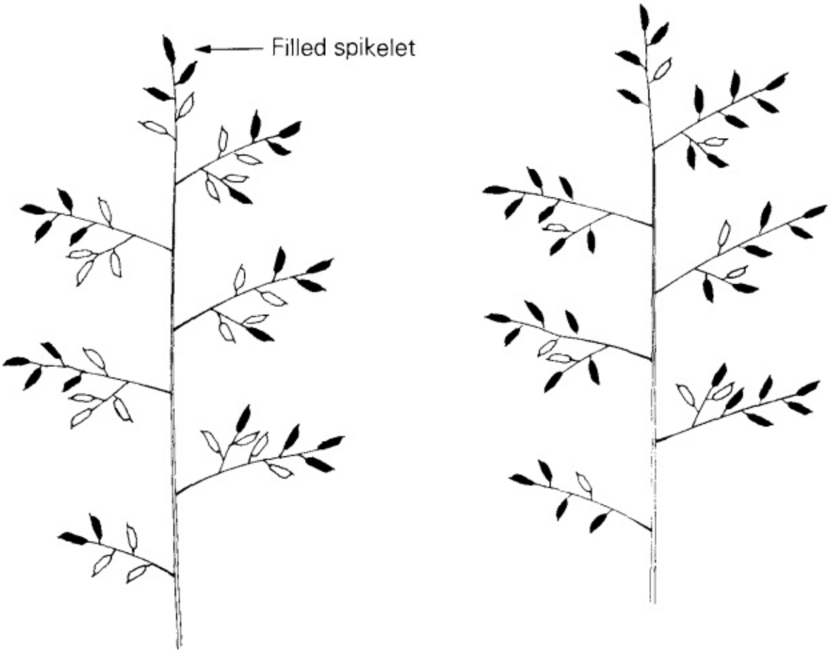
Actual:
60 spikelets

Expected:
100 spikelets

Problem: few spikelets per panicle

¢ The problem can occur a little before, during, or after spikelet formation (26-1 6 days before flowering). Lack of sunlight, lack of food or nutrients, or heavy disease or insect damage to the leaves can cause this problem.

Fertility of spikelets



Actual:
50% filled spikelets

Expected:
80% filled spikelets

Problem: low percentage of filled spikelets

¢ A low percentage of filled spikelets can result if temperature at flowering is too low (less than 20 °C) or too high (above 35 °C), the plants lodge, there is a lack of water at flowering, or too much nitrogen is applied at the panicle initiation stage.

Weight of a single grain

Actual:
20 grams per 1000 grains

Expected:
25 grams per 1000 grains

Problem: low weight of a single grain

- Unfavorable conditions after flowering, such as not enough food, not enough leaves to produce the food, or cloudy weather, can cause low grain weight.