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# Rice production manual

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# **Rice production manual**

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The Enhancing partnership among Africa RISING, NAFKA, and TUBORESHE CHAKULA Programs for fast tracking delivery and scaling of agricultural technologies in Tanzania is an interdisciplinary and inter-institutional project that aims to address smallholder farmers' needs in the semi-arid and sub-humid zones of Tanzania. The 3-year project is funded by the USAID Mission in Tanzania as part of the U.S. Government's Feed the Future initiative.

Through participatory and on-farm approaches, candidate technologies are being identified and evaluated for scaling by the project team. This is being achieved through the already established networks by Tanzania Staples Value Chain (NAFAKA), Tuboreshe Chakula (TUBOCHA), and other institutional grassroots organizations, creating an opportunity for mainstreaming into wider rural development programs, beyond Africa RISING's current zones of influence.

The project is led by the International Institute of Tropical Agriculture (IITA) and the USAID Tanzania mission-funded 'Feed the Future' programs NAFKA and TUBOCHA. Developmental activities addressing the project objectives are being implemented in Manyara, Dodoma, Morogoro, Iringa, and Mbeya Regions in Tanzania.

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# List of acronyms

ACDI/VOCA	Agricultural Cooperative Development International / Volunteers in Overseas Cooperative Assistance
Africa RISING	Africa Research in Sustainable Intensification for the Next Generation
CGIAR	Consortium of International Agricultural Research Centers
FTF	Feed the Future
IITA	International Institute of Tropical Agriculture
TARI	Tanzania Agricultural Research Institute
USAID	United States Agency for International Development

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# Introduction

This training manual is an important part in the design of a formal training program and ensures consistency in presentation. It brings together the skills, processes and all other information necessary to perform the tasks in one place.

The manual consists 9 modules. Module 1 is the concept of good rice varieties. In this section, the characteristics and merits of improved varieties publication are discussed. Module 2 is on land preparation whereby land clearing, tillage, soil pulverization, field levelling, and the making of bunds to enclose the rice fields are discussed. Module 3 deals with seed preparation to ensure good seed quality.

Module 4 is on rice planting where the main activity of crop establishment in the field is discussed. Module 5 deals with field water management and weeding. Module 6 presents the cropping calendar that allows better planning of farm activities and the cost of production.

Module 7 explains issues of salt-affected soils and their effects on rice productivity. Module 8 is on improving rice productivity on saline-sodic soils where some of the proven interventions are discussed. The last Module 9 is on improving rice productivity on calcareous soils where some of the proven intervention measures that ensure sustainable productivity of rice in such soils are discussed.



# Module 1

## Concept of good rice varieties

### Overview

In this section we shall discuss the characteristics and merits of improved rice varieties. Currently the majority of farmers do not use improved varieties. They mainly grow traditional, low-yielding varieties, many of which are also less tolerant to biotic and abiotic environmental constraints such as diseases and soil salinity.

**Duration of training:** 30 minutes

#### Training materials

The following training materials will be needed to make training successful:

- i. The training venue (a classroom or open space at the site of demonstration).
- ii. Seed samples of improved varieties.
- iii. Pens and exercise books for participants to take notes.
- iv. Flip charts and marker pens for the facilitators to illustrate important points during presentations.
- v. Printed notes for participants.
- vi. Participants will be asked to mention the characteristics of what they consider to be a good rice variety and the merits of planting improved varieties.

Such characteristics include:

- High yield.
- Good aroma.
- Tolerance to diseases and other stresses such as salinity, sodicity, or drought.
- Good milling qualities (translucent grains).
- Good threshability.
- Early maturity.

Generally a good variety is the one that is able to produce high yields in the farmers' agricultural environments and is preferred by consumers (fetches a good market price). TXD 306 and KOMBOKA are such varieties. The merits of growing improved varieties are improved productivity and consequently increased household incomes of producers.

Farmers will be strongly advised to look for improved varieties and seek expertise and advice from nearby agro-input suppliers, research centers, and other village based agricultural advisors (VBAA).

### Different types of rice varieties

Farmers will be exposed to different rice varieties and criteria for the selection of suitable varieties.

#### *i. Local rice varieties*

These are domesticated plants that have developed over time, through adaptation to the natural and cultural environment of agriculture, e.g., SUPA, Kisegese, and Mbawambili. They are usually tall aromatic plants and have good grain qualities but most are susceptible to pests and diseases, and have long growth periods and low rate of tillering which translates to a low yield.

#### *ii. Improved varieties*

These varieties are man-made through selection and hybridization, focusing on a specific performance target (high yield, tolerance to biotic and/or abiotic stresses and/or grain quality). These plants always have medium stature, high tillering, respond to high fertilizer rates, are tolerant to various challenges, shorter growth duration and are high yielding, e.g., Komboka, SARO5 (TXD306).

**Table 1.** Description of some improved rice varieties.

Variety	Attribute	Detailed information
TXD306 (SAR05)	<ul style="list-style-type: none"> <li>• High yielding</li> <li>• Medium duration maturity</li> <li>• Medium stature</li> <li>• High tillering ability</li> <li>• Good response to high fertilizer rate</li> <li>• Tolerant to various diseases</li> <li>• Good milling recovery</li> <li>• Good grain quality, with a good market</li> </ul>	<ul style="list-style-type: none"> <li>• Yield of 7-10 t/ha</li> <li>• Maturity 120-130 days</li> <li>• Plant height of 95-100cm</li> <li>• Number of tillers per hill 20-30</li> <li>• Resistant to lodging</li> <li>• Tolerate to bacteria and fungal diseases e.g blast, bacterial leaf blight, sheath rot</li> <li>• Good milling recovery 65%</li> <li>• Semi aromatic, no chalkiness, 29g in 1000 grain</li> </ul>
Komboka	<ul style="list-style-type: none"> <li>• High yielding</li> <li>• Medium duration maturity</li> <li>• Medium stature</li> <li>• High tillering ability</li> <li>• Good response to high fertilizer rate</li> <li>• Tolerant to various diseases</li> <li>• Good milling recovery</li> <li>• Good grain quality, with a good market</li> </ul>	<ul style="list-style-type: none"> <li>• Yield of 7-10 t/ha</li> <li>• Maturity 100-110 days</li> <li>• Plant height of 98-110cm</li> <li>• Number of tillers per hill 20-30</li> <li>• Resistant to lodging.</li> <li>• Tolerate to bacteria and fungal diseases e.g blast, bacterial leaf blight, sheath rot</li> <li>• Good milling recovery 65%</li> <li>• Semi aromatic, no chalkiness, 24g in 1000 grain</li> </ul>

SATO 1	<ul style="list-style-type: none"> <li>• High yielding</li> <li>• Salt tolerant</li> <li>• Medium duration maturity</li> <li>• Medium stature</li> <li>• High tillering ability</li> <li>• Good response to high fertilizer rate</li> <li>• Tolerant to various diseases</li> <li>• Good milling recovery</li> <li>• Good grain quality, with a good market</li> </ul>	<ul style="list-style-type: none"> <li>• Yield of 7-10 t/ha</li> <li>• Tolerate to sodic and saline-sodic soils</li> <li>• Maturity 110-120 days</li> <li>• Plant height 100-105 cm</li> <li>• Number of tillers per hill 19-22</li> <li>• Resistant to lodging.</li> <li>• Tolerate to bacteria and fungal diseases e.g blast, bacterial leaf blight, sheath rot</li> <li>• Good milling recovery 65%</li> <li>• No chalkiness, 28.9g in 1000 grain</li> </ul>
SATO 6	<ul style="list-style-type: none"> <li>• High yielding</li> <li>• Salt tolerant</li> <li>• Medium duration maturity</li> <li>• Medium stature</li> <li>• High tillering ability</li> <li>• Good response to high fertilizer rate</li> <li>• Tolerant to various diseases</li> <li>• Good milling recovery</li> <li>• Good grain quality, with a good market</li> </ul>	<ul style="list-style-type: none"> <li>• Yield of 7-10 t/ha</li> <li>• Tolerate to sodic and saline-sodic soils</li> <li>• Maturity 110-115 days</li> <li>• Plant height 100-105 cm</li> <li>• Number of tillers per hill 17-20</li> <li>• Resistant to lodging.</li> <li>• Tolerate to bacteria and fungal diseases e.g blast, bacterial leaf blight, sheath rot</li> <li>• Good milling recovery 60%</li> <li>• No chalkiness, 30g in 1000 grain</li> </ul>

# Module 2

## Land preparation

### Overview

Land preparation involves clearing, tillage, and soil pulverization, levelling fields, and making bunds to enclose the rice fields. Currently many farmers do not undertake such activities correctly, leading to poor water management.

**Duration of training:** one day of 5-7 hours

### Training materials

The following training materials will be needed to make training successful:

- i. Land to be prepared.
- ii. Hand hoes, machetes, rakes, spades.
- iii. Power tiller (small tractor) or ox-plough.
- iv. Sisal ropes.
- v. Wooden pegs.
- vi. Tape measure.
- vii. Pens and exercise books for participants to take notes.
- viii. Mallet or wooden rod to compact the soil.

The purpose of land clearing is to remove unwanted vegetation that could hinder proper cultivation.

Tillage and soil pulverization are necessary to improve physical conditions for proper aeration and water retention, to facilitate planting and quick seedling emergence and establishment. It is followed by leveling and bund-making. Bunds must be made around leveled fields for the purpose of proper water management (to facilitate the entry of adequate amounts of water and retain it in the field for use by the rice plants).

Farmers should appreciate the merit of early land preparation for timely planting. In rain-fed areas land should be prepared before the onset of rains to allow for many weeds to dry and die before planting.

### Land clearing

Farmers will have to clear the land using hand hoes, machetes, rakes, etc. (Figure 2.1).



**Figure 2.1.** Farmers clearing land as part of land preparation. Credit: Sophia Kashenge/TARI-Dakawa.

### Tillage and soil pulverization

Land cultivation (tillage) can be done manually (using hand hoes) or mechanically using tractor-drawn implements or ox-plows. Depending on the soil characteristics and weather conditions, tillage can be done just before the onset of rain when the soil is dry or at the beginning of the rainy season before the soil becomes too wet to handle.

In irrigated conditions, puddling normally follows land tillage for the purpose of creating muddy conditions that facilitate the transplanting of seedlings and improve the water retaining capacity of the soil (Figure 2.2).



**Figure 2.2.** Soil puddling using a tractor-drawn rotorvator. Photo credit: website: <https://www.quora.com/What-is-meant-by-puddling-in-agriculture>.

## Levelling

Levelling of seedbeds is a key important aspect in both rain-fed and irrigated conditions. It needs to be carried out owing to its noted advantages of ensuring the uniform distribution of water and fertilizers in the field. Plants on high and low spots in poorly levelled seedbeds have poor growth resulting in low yields.



(a)



(b)

**Figure 2.3.** Levelling the field after puddling using hand levels (a) and wooden leveling planks (b). Photo credit: Ibrahim Paul/TARI-Dakawa.

Low and high spots in the seedbed can easily be noted after introducing some water (shallow water depths). Levelling is achieved by cutting out high spots and filling in the low spots, i.e., removing crests and troughs in the seedbed using hand levels or wooden leveling planks (Figure 2.3 (a) and (b))

## Bund-making

Bund-making is of high importance in both irrigated and rain-fed rice farming for the purpose of retaining water in the seedbed. Make sure that there are water in-lets and out-lets for each “bunded” seedbed to facilitate proper water management (Figure 2.4).



**Figure 2.4** Bunds are made around leveled plots for proper water management. Credit: Charles Chuwa/TARI-Dakawa.

### Recommended dimensions of rice field bunds

- Top 30 to 50 cm wide.
- Depth (height) 40 to 50 cm deep/high.
- Base 130 to 160 cm wide.

### How to construct a banded rice seedbed

- i) Demarcate the boundaries of the seedbed using a tape measure, pegs, and sisal ropes.
- ii) Collect top soil to the center of the seedbed using a hand hoe or a spade.
- iii) Dig out the subsoil and use it to make dykes/bunds.
- iv) Compact the bunds.
- v) Level the plot using the subsoil and compact it.
- vi) Spread the top soil uniformly and gradually until the whole levelled area is covered.
- vii) Do the final levelling by allowing water in and cutting out high spots to fill low spots.

# Module 3

## Seed preparation

### Overview

#### How to ensure seed quality

Seeds are the foundation of any rice crop. In this section, we shall discuss the merits of planting well-prepared seeds. Participants will have to understand that seed preparation is of vital importance to obtain clean and healthy seeds. They should remember that healthy seeds will lead to healthy plants, thereafter to a good harvest.

**Duration of training:** 2 hours

#### Training materials

The following training materials will be needed to make training successful:

- i) The training venue (a classroom or open space at site of demonstration).
- ii) Seed samples of improved rice varieties.
- iii) Pens and exercise books for participants to take notes.
- iv) Flip charts and marker pens for the facilitators illustrate important points during presentations.
- v) Printed notes for participants.

#### Characteristics of good seeds

- i) Clean (without contaminants).
- ii) Pure (contain only one variety).
- iii) Healthy (fully mature, disease-free, no cracks).

#### Key advantages of using well-prepared seeds

- Reduced seed rate as many seeds will have a high percentage of germination.
- Healthy seedlings.
- Uniform crop stand and maturity.
- Reduced weed infestation.
- High yields.

#### How to prepare seeds

Farmers will have to appreciate the importance of early preparation of seeds for timely planting. The activity will involve the following steps:

- a) Obtaining seeds of the selected variety either from agro-input stores or by picking rice panicles from the field, drying and threshing them to obtain the seeds (of about 13% moisture content).
- b) Immersing the seeds in a salt solution (1.5 kg table salt dissolved in 10 liters of clean water) and removing the floaters.
- c) Washing the seeds with clean water to remove adhering salt solution.
- d) Drying the clean seeds again to 13%.
- e) Packaging the dry seeds in sisal bags or other suitable containers and keeping/storing them in a safe, dry, and well-ventilated place until planting.

#### Seed preparation for planting

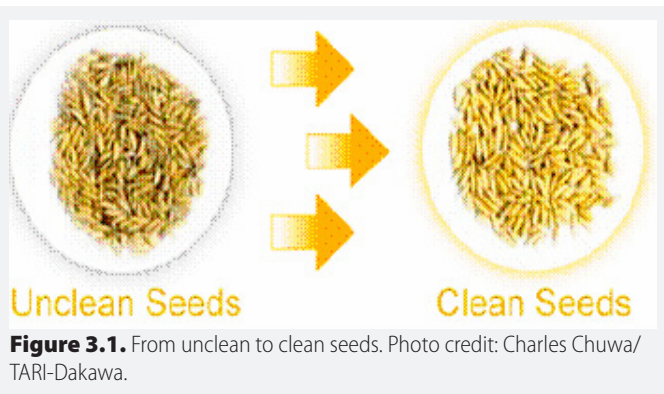
Farmers should appreciate the importance of preparing seeds to suit the type of planting that is intended to be practiced.

#### Steps in seed preparation

- Cleaning.
- Selection by floatation.
- Priming (soaking and incubation).

#### Seed cleaning by winnowing

Winnowing and cleaning are normal procedures to remove unfilled grains and chaff in order to obtain well-filled and clean seeds (Figure 3.1).



**Figure 3.1.** From unclean to clean seeds. Photo credit: Charles Chuwa/TARI-Dakawa.

### Seed cleaning using clean water

- For a good rice harvest, healthy seeds are essential. Unfilled grains or grains that have been damaged by insects are lighter in weight than healthy grains so they can be removed if floated in water before sowing. After winnowing, you'll see that partly filled grains and grains with holes in them are still mixed with the full, healthy grains. What you want to do is to separate these from your seeds by floating them in water. That's why this technique is called floatation.
- Grains with black or brown spots are also unhealthy but these grains are not necessarily lighter so they can't be removed by the floating method with normal clean water. Normally the farmer has to conduct manual seed sorting.

### Seed cleaning using salty water

Seeds can be cleaned using salty water. This is a better method to remove the seeds that were not removed by winnowing and clean water.

#### Requirements

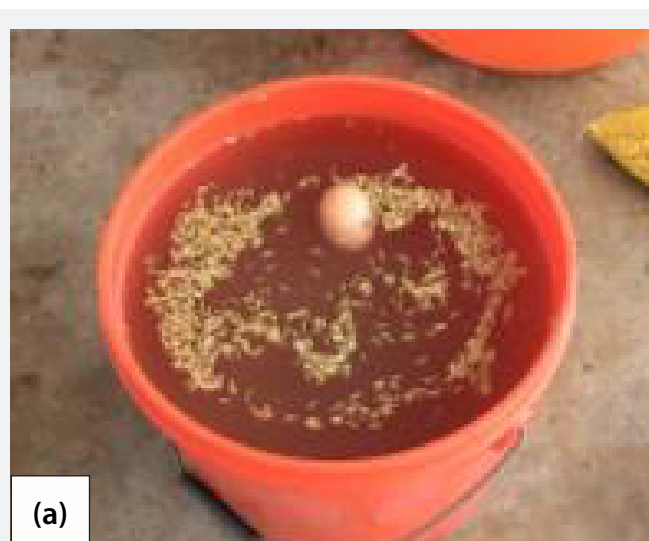
- Uncleaned seeds.
- 2 buckets (1 of 10 liters and another of 20 liters).
- A sieve.
- 10 liters of water.
- 1.5 kg of table salt.
- Mixing stick/stiring rod.
- One fresh chicken egg.

#### Procedures

- Measure 10 liters of clean water and slowly add 1.5 kg of salt into it.
- Stir the water-salt mixture to dissolve the salt and make a salt solution.
- Drop a fresh egg carefully in the salt solution, keep on

stiring and adding more salt until the egg half-floats (the solution is of appropriate density).

- Add the seeds (about 5 kg) and stir them very well with a stick; all the unfilled grains will float (Figure 3.2).
- Remove all the floating unfilled grains and keep on stiring until all the unfilled grains float.
- Remove the good seeds (heavy seeds) and wash them several times (up to five times) with clean water.
- Proceed with seed priming or dry the seeds under the sun for future use.



**Figure 3.2.** Seeds poured into a salt-solution (a) and well-stirred (b) to enable floatation of unfilled grains. Photo credit: Ndimubandi Mvukiye/TARI-Dakawa.

For direct sowing in relatively dry soil, no further seed preparation is required. (Refer to section II). But for direct sowing in a wet soil, the well-prepared seeds must undergo pre-sprouting before they are sown. Sowing of dry seeds in such conditions could result in the seeds rotting with poor seedling emergence. Seeds must also be sprouted prior to their sowing in a wet nursery intended to raise seedlings for transplanting.

## Pre-sprouting seeds (seed priming)

The process involves two activities: soaking and incubation.

The well-prepared dry seeds (calculated amount for the field) are soaked in clean water at room temperature for 24 hours to enable moisture adequate for sprouting to be absorbed.

The seeds are then removed from the water and spread on a mat/rag on a slated floor to facilitate the draining of excess water. The seeds are finally incubated by covering them with moist covers for around 48 hours to provide them with the heat necessary for sprouting (Figure 3.3).



**Figure 3.3.** Seed incubation (a) to obtain well-sprouted seeds (b). Photo credit: website: <http://www.rkmp.co.in/content/pre-germinating-seeds>.



# Module 4

## Rice planting

### Overview

In this section we shall discuss the main activity of crop establishment in the field. This activity is accomplished by either sowing seeds directly in the field or by transplanting the seedlings after they have been produced in the rice nurseries.

**Duration of training:** one day of 5-7 hours will be needed;

#### Training materials

- i) A well prepared seedbed (plot).
- ii) A rope marked with the decided plant spacing (in this case, 20 cm).
- iii) A small hand hoe or planting sticks for marking holes.
- iv) Rice seeds.
- v) Well-prepared rice seedlings.
- vi) Fertilizer for basal application.

#### Farmers will be asked to:

- State the relative advantages and disadvantages of using clean and Unclean seeds.
- State the characteristics of good seeds.
- State the relative advantages and disadvantages of direct seeding and transplanting.
- Explain where each method is feasible.

This will enable farmers to appreciate the use of good quality seeds and the fact that the most suitable planting technique depends on locality, soil type, and crop ecosystem.

Good seed quality increases the chance of attaining higher yields. Direct sowing is mainly suitable in upland environments or where the onset of rains is erratic.

Transplanting is suitable in areas with reliable rainfall or where irrigation is possible. Farmers are expected to state at least one of the advantages of transplanting, as follows:

- Low seed requirement (needs 6-10 kg per acre).
- Seedlings have better competition against weeds.
- Only strong and healthy seedlings are planted.
- Crop spends less time in the production field, hence less time of exposure to harsh field conditions.

And the disadvantage that include:

- Much more labour to establish the crop.

Farmers are also expected to state the advantages and disadvantages of direct sowing, as follows:

#### a) Profit

- Requires less labour to establish the crop.
- Early crop maturity.

#### b) Loss

- Much larger seed requirement (needs 40-80 kg per acre).
- Seeds are more vulnerable to soil-borne insects and pathogens.
- More labour is needed in controlling weeds.

### Direct sowing

Dry or pre-sprouted well-prepared seeds are directly sown by dibbling in dry soil or moist seedbed. Holes (not more than 3 cm deep) are dug in the soil at a spacing of 20 cm x 20 cm. This spacing is achieved by the use of the marked rope (Figure 4.1). Three to 4 seeds are put in each hole and then covered by a layer of soil.

If the soil moisture is adequate seedlings will emerge within 7 days after sowing. All other standard crop management activities in the field will thereafter be undertaken until the crop mature.



**Figure 4.1.** Direct planting at a specified plant spacing marked by a rope and rod. Photo credit: Charles Chuwa/ TARI-Dakawa.

## Transplanting

Strong and healthy rice seedlings should be transplanted on a well-prepared seedbed, normally after the incorporation of basal fertilizers. To produce strong and healthy seedlings, the well-prepared, pre-sprouted seeds of the selected variety should be sown in the nursery preferably a few days before preparation of the main field.

### Nursery preparation and management

The nursery should be located as close as possible to the main field. The site should preferably have fertile soil and adequate water and be well-protected from wild/farm animals.

In the field, the facilitator should ensure full participation of all participants in performing the following activities:

- Making seed beds of convenient sizes (figure 4.2).
- Puddling the field and leveling it.
- Dividing the field into 1 x 10 m nursery beds (40 of such beds per acre).
- Making furrows around each nursery bed.
- Doing final leveling of nursery beds.
- Applying basal fertilizer (in nutrient-deficient soils) (amixture of about 2.5 g urea, 1.0 g MOP, and 1.5 g DAP per 1 m<sup>2</sup>).

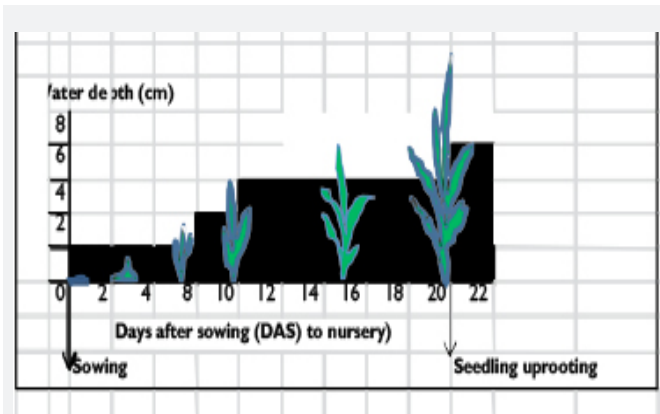


**Figure 4.2.** Farmers sowing seeds on raised nursery seedbeds with inter-bed furrows. Photo credit: N. Mvukiye/ TARI-Dakawa.

### Sowing and managing seedlings in the nursery

- Broadcasting (evenly) pre-sprouted seeds on nursery beds and tapping the seeds into the soil (400 g or at about one handful of seeds per 1 m<sup>2</sup>)
- Keep the soil moist/wet until one week after seedling emergence.
- Gradually raise the water level, from 1 to around 5 cm (depending on seedling height) until transplanting (figure 4.3).

- Keep the nursery beds free from weeds.
- Apply pesticides to manage diseases and insect pests where necessary.



**Figure 4.3.** Allowable water depths in a nursery over time. Photo credit: Ndimubandi Mvukiye/TARI-Dakawa.

### Some consideration for transplanting

Transplanting must be done in a well-prepared field (leveled and surrounded by bunds). In the field, the facilitator should ensure full participation of all participants in performing the following activities at least one day before transplanting seedlings:

- Introducing water into the field at shallow depth (around 3 cm if possible) or just to wet the soil.
- Broadcasting basal fertilizers (DAP, MOP, or manure) at recommended rates.
- Properly incorporating the basal fertilizers into the soil by final puddling (using rotorvator, hand hoe, or ox-plow).
- Performing final leveling of the field using rakes or any other suitable implements.

### Seedling preparation and planting

Farmers should note the proper age for transplanting seedling. Seedlings should be transplanted when they are old enough to be conveniently handled and not too old to produce many strong tillers. Preferably seedlings should be 15-30 days old at transplanting.

### Some considerations on how to prepare seedlings for transplanting

Seedlings should be uprooted and transplanted on the same day. Seedling preparation is achieved by the following procedure:

- Prior to pulling out seedlings, allow enough quantity of water into the nursery beds.
- Select quality seedlings with uniform height.

- iii) Grasp seedlings near the base and uproot at least three at a time.
- iv) Gently uproot the seedlings at an angle of about 30 degrees from the horizontal.
- v) Wash the seedlings thoroughly to remove soil adhering on roots.
- vi) Bundle the seedlings to facilitate transportation and handling during planting.
- vii) Place the seedlings in water during planting to prevent wilting.

### Transplanting

After the soil has settled in the puddled and well-leveled field, 2 to 3 seedlings should be planted per hill at a depth of about 3 cm and spaced at 20 cm between rows and 20 cm within a row. The use of the marked transplanting rope enables spacing to be kept constant throughout the field (Diagram 4.2). The spacing may be increased with decreasing soil fertility and water supply, and vice versa.

After transplanting of the whole field is complete, collect all remaining seedling bundles, untie them and plant them in one alley for future gap-filling to be accomplished within 10 days.



**Figure 4.4.** Line transplanting using a marked rope. Credit: Charles Chuwa TARI-Dakawa.

# Module 5

## Field Management

### Overview

In this module, management of water, weeds, soil fertility, and pests and diseases are presented. A well-managed field has few weeds, minimum pest, and disease infestation. It is also fertile and has adequate water for plant growth. Such a field enables plants to flourish and produce high yields of good quality produce. Farmers are expected to appreciate the importance of proper water management and the operations necessary to achieve it, how to properly manage weeds (including the use of mechanical weeders and safe use of herbicides), how to improve soil fertility (e.g., by the use of appropriate fertilizers) and how to manage pests and diseases at different growth phases.

**Duration of training:** two days will be needed

#### Training materials

The following training materials will be needed to make training more effective:

- i) Plants at different growth stages in the field.
- ii) A well-bunded field.
- iii) A well-maintained/clean plot and an unweeded plot.
- iv) Mechanical weeders.
- v) Different types of weeds.
- vi) Different herbicides and pesticides.
- vii) Different kinds of spraying equipment.
- viii) Diseased and insect-damaged plants.
- ix) Different types of fertilizers.
- x) Protective gear.

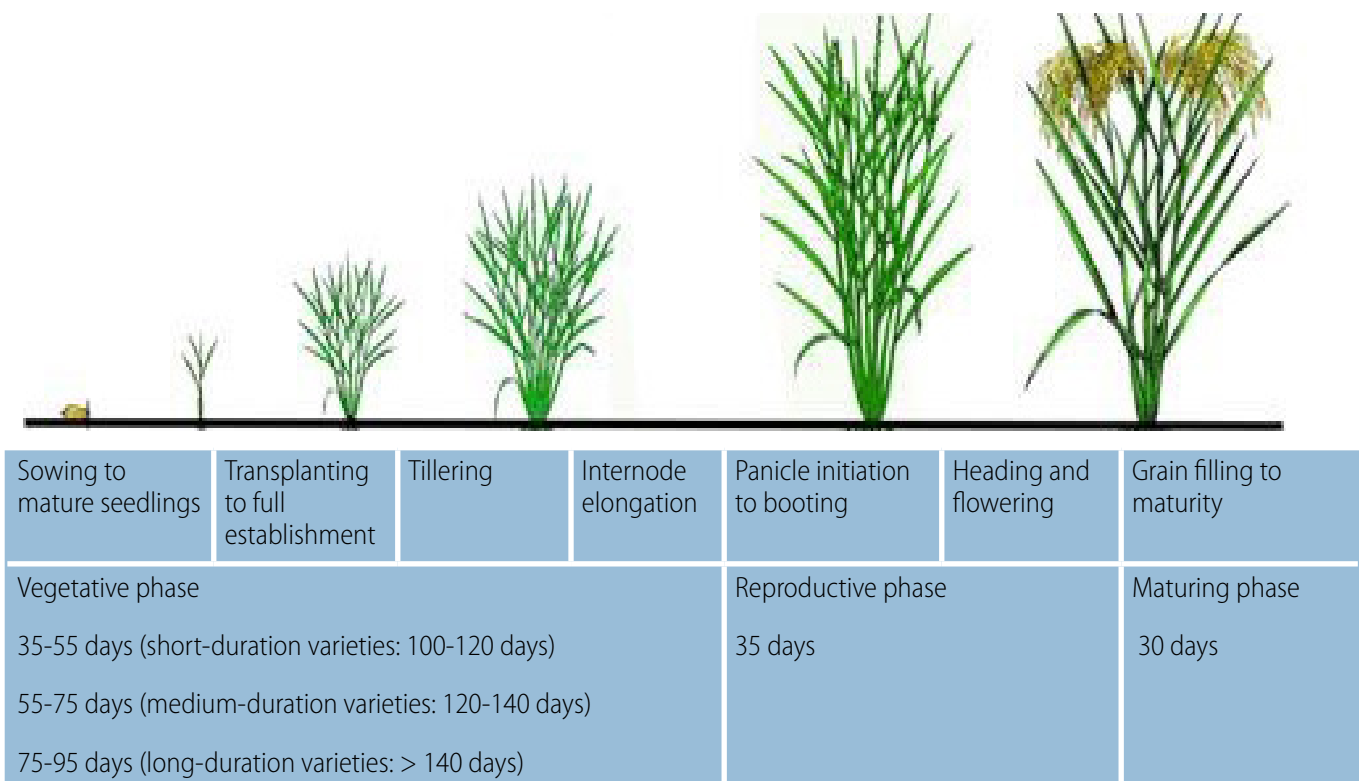
#### Farmers will be asked to:

- State what they understand about the safe use of water and water requirements in rice fields.
- Name the types of herbicides and pesticides.
- State the advantages and disadvantages of using herbicides and pesticides.
- Explain how they apply herbicides and pesticides.
- Explain the importance of fertilizers and when and how to apply them in the field.

- State the types and rates of fertilizers they use in their fields.
- State whether or not they use protective gear in applying agrochemicals.

### Growth phases and stages of the rice plant

The rice plant passes through three major growth phases from seedling emergence to maturity (Figure 5.1). These are the vegetative phase (number of days from seedling emergence to panicle initiation), reproductive phase (from panicle initiation to heading), and ripening phase (from heading to maturity). The length of the vegetative phase differs among varieties, but the reproductive and maturing phases are equal for all varieties (see figure 5.1).



**Figure 5.1.** Growth phases and stages of the rice plant (adapted from IRRI).

Farmers should understand the relationship between growth phases and management aspects of the rice plants for better yield and quality of the produce.

Knowledge of the growth phases enables the following:

- Required amount of water is made available for the crop (irrigated rice) at the right time.
- Thinning and gap filling are performed on time.
- Timely weed management is done to minimize competition with the crop for the limited resources: nutrients, water, sunlight energy, and spacing.
- Diseases and pests are controlled before economic damage to the crop.

## Water management

Water availability largely determines the potential crop yield. Good water control increases crop yields and grain quality as well as improving the use efficiency of other inputs such as fertilizer, herbicides, and pesticides. To maximize water -use efficiency:

- maintain the bunds,
- level the fields,
- puddle the fields where possible,
- use direct-seeding techniques,

- use short-duration crops; and
- harvest on time,

### *Key points to consider after crop establishment*

- Continuous flooding of water generally provides the best growth environment for rice.
- After transplanting, water levels should be around 3 cm initially and gradually increase to 5–10 cm (with increasing plant height) and remain at this level until the field is drained 7–10 days before harvest.
- For direct wet-seeded rice, the field should be flooded only once the plants are large enough to withstand shallow flooding (3-4 leaf stage).
- Lowland rice is extremely sensitive to water shortage (below saturation) at the flowering stage. Drought at flowering results in yield loss from increased spikelet sterility, thus fewer grains.
- Keep the water level in the fields at a minimum of 5 cm at all times from heading to the end of flowering.
- In case of water scarcity, apply water-saving technologies such as Safe Alternate Wetting and Drying (AWD) and consider changing the planting method from puddled transplanting to non-puddled transplanting or dry direct-seeding.

## What is AWD?

Alternate Wetting and Drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can apply to reduce their water use in irrigated fields. In AWD, irrigation water is applied to flood the field a certain number of days after the disappearance of ponded water. Hence, the field is alternately flooded and non-flooded. The number of days of non-flooded soil in AWD between irrigations can vary from 1 to more than 10.

## What is safe AWD?

The threshold of 15 cm water depth (below the surface) before irrigation is called "Safe AWD" as this will not cause any yield decline. In Safe AWD, use of irrigation water is about 15-30% less than in conventional irrigation.

## How to implement safe AWD

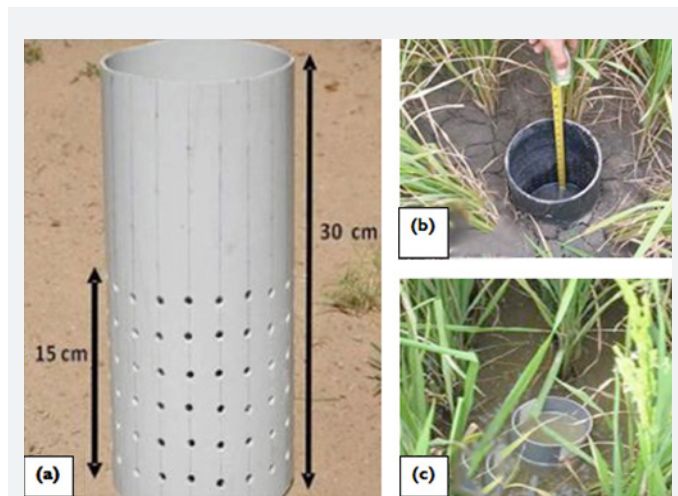
- A practical way to implement AWD is to monitor the depth of ponded water on the field using a Field Water Tube.
- After irrigation until 5 cm of water is ponded above the soil surface, the depth of ponded water will gradually decrease. When the ponded water has dropped to 15 cm below the surface of the soil, irrigation should be applied to re-flood the field with 5 cm of ponded water.
- From one week before flowering to one week afterwards, ponded water should always be kept at 5 cm depth.
- After flowering, during grain filling and ripening, the water level can drop again to 15 cm below the surface before re-irrigation.
- AWD can be started a few days after transplanting (or with a 10-cm tall crop in direct seeding).
- When many weeds are present, AWD can be postponed for 2-3 weeks until weeds have been suppressed by the ponded water.
- Local fertilizer recommendations as for flooded rice can be used. Apply fertilizer N preferably on dry soil just before irrigation.

## The field water tube

- A tube can be made of 30-cm long plastic pipe or bamboo and have a diameter of 15 cm or more so that the water table is easily visible. Perforate the tube with holes on all sides;
- dig the tube in the soil so that 5 cm protrudes above the soil surface;
- take care not to penetrate through the bottom of the plow pan. Remove the soil from the inside so that the bottom in the tube is visible at 15 cm depth;

- check that the water level is the same inside and outside the tube.

The tube should be placed in a level part of the field close to a bund, so it is easy to monitor the ponded water depth (Figure 5.2).



**Figure 5.2.** The diagram of a 30-cm Field Water Tube perforated to 15cm (a) being inserted into the soil at a designated depth prior to flooding (b) and after flooding (c). Photo credit: Charles Chuwa /TARI-Dakawa.



**Figure 5.3.** Examples of common weeds in rice fields. Photo credit: Sophia Kashenge and Ndimubandi Mvukiye /TARI-Dakawa.

## Weed management

Weed control is essential for economical rice production. Weeds reduce rice yields by competing for moisture, nutrients, and light during the growing season. Weed infestations can also interfere with combine operations at harvest and can significantly increase harvesting and drying costs. Weed seed contamination of rice grains lowers grain quality and may lower the cash value of the crop. Grassy weeds and broadleaved weeds are major problems in rice production (Figure 5.3).

Control of weeds during land preparation is crucial to reduce the amount of weed pressure in the field. Land preparation should start 3–4 weeks before planting. Ploughing destroys weeds and clears stubble remaining from the previous crop. Weeds should be allowed to grow before the next cultivation. In addition, a level field helps retain a constant water level that controls weeds.

### Methods of weeds control

There are three common methods of weed management:

- i) Manual weeding.
- ii) Mechanical weeding.
- iii) Chemical weeding.

#### Manual weeding

Manual weeding is normally done by pulling out weeds by hand (Figure 5.4). But it can also be done using hand hoes or sickles.



**Figure 5.4.** Farmers managing weeds by hand pulling. Photo credit: Charles Chuwa/ TARI-Dakawa.

Hand weeding is necessary when:

- weeding annual weeds and certain perennial weeds that usually do not regenerate from underground parts;
- weeds are to be removed within rows and hills where a cultivating implement, such as a push weeder, cannot be used.

#### Mechanical weeding

Mechanical weeding is most appropriate for crops transplanted in straight rows. This method requires less time and labour costs than manual weeding. Mechanical weeding using implements such as push- or rotary-weeders is common (Figure 5.5).

### Conditions to observe when using weeders

- Ensure that there is enough soil moisture before weeding. It could be difficult to use a weeder when the soil is very dry.
- Pass the weeder in between rows. This buries the weeds and cuts the root system so weeds die before they can

re-establish. Improper use of weeders can damage the rice plants.

Mechanical weeding may be less effective than hand weeding because weeds within the crop rows are not removed. Competition from weeds that survive can be harmful to rice crops.



**Figure 5.5:** A mechanical (motorized) weeder (a) and common types of push weeders (b) being utilized by farmers in the field (c). Photo credit: Sophia Kashenge/TARI-Dakawa.

### Chemical control

Herbicides are one of the first labor-saving technologies to be adopted as labor costs rise. Herbicides replace hand weeding and enable direct seeding rather than transplanting, which is less labor demanding.

### Classification of herbicides

Herbicides may be classified as:

- Selective
- Non-selective
- Pre-emergent
- Post-emergent

Most herbicides used in rice production are selective, controlling some or most weeds, while having a limited effect on the crop. Selectivity is not necessarily dependent upon the compounds but also on the rates, timing, and methods of application, and hence it is important to follow the manufacturer's recommendations.

Examples of selective herbicides are: 2,4-D (Amine), Nominee gold, Tiller gold and Solito

Non-selective herbicides such as glyphosate are sometimes used before establishing rice on weed infestations such as wild rice which are difficult to control with selective herbicides.

Examples of non-selective herbicides are:

- Glyphosate, e.g., Touchdown Forte
- Paraquat, e.g., gramoxone

Pre-emergent herbicides are applied to the soil and control weeds before they emerge, while post-emergent ones are

applied to weeds after they emerge.

Examples of pre-emergent herbicides are:

- Stomp 455CS
- RILOR 500EC
- Harness

Examples of post-emergent herbicides are:

- Tiller gold
- Solito
- Servian
- 2,4-D (Amine)

### Problems with herbicide application

Smallholder farmers often face a number of problems related to herbicide use, due to either an inadequate rate of herbicide being applied, or to the herbicides being applied too late to provide a good effect on the weeds. A major cause of this is likely to be the serious lack of information available to the farmer and the consequent limited understanding of herbicide application.

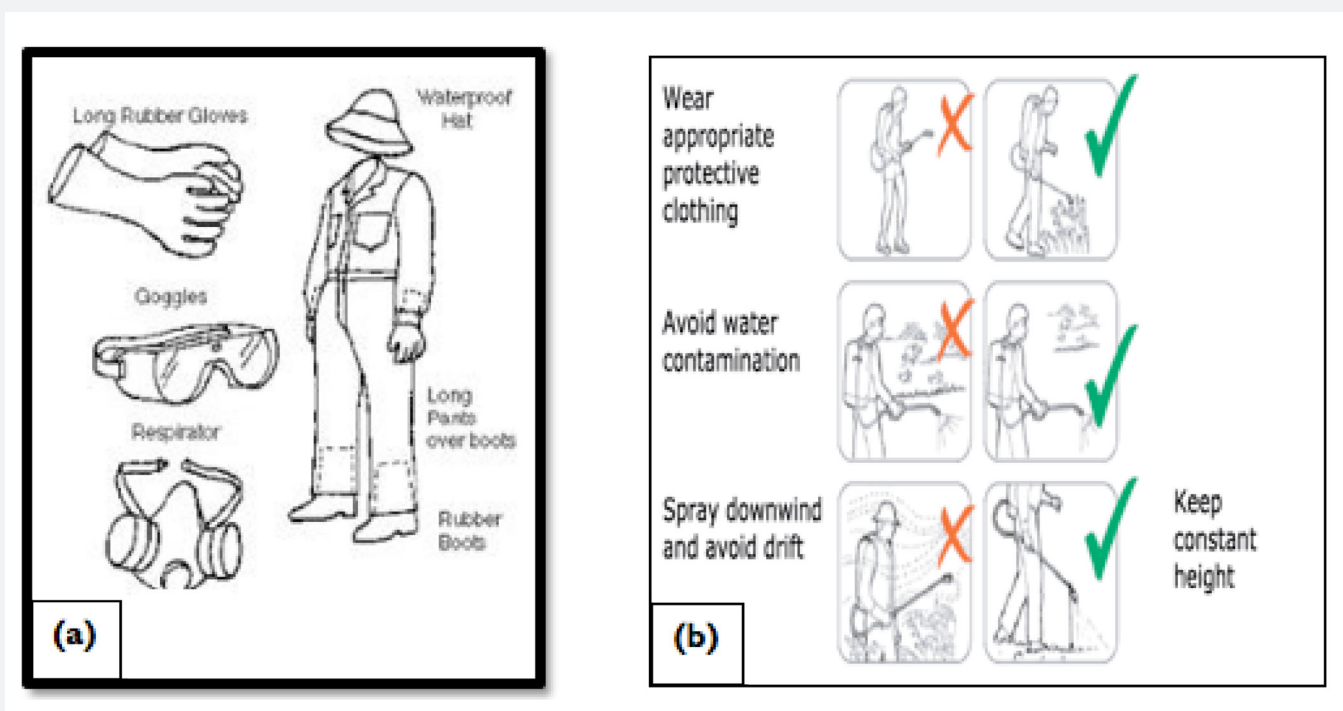
### Reminders about using pesticides/chemicals

- Always mix with clean water before application. Refrain from using muddy water as this reduces herbicide efficacy.
- Ensure all equipment, such as spray tanks, booms, and nozzles, are cleaned well after every use.
- Do not mix herbicides together unless this is recommended.



- Apply herbicides at a recommended rate.
- Remember to wear proper protective equipment (i.e., gloves, breathing mask, goggles, and protective clothing) when spraying.
- Protect yourself and do not allow children to handle pesticides/chemicals.
- Wash by clean water and soap any other parts of your body that may have come in contact with the pesticide.

Protective clothing that is used when pesticides are mixed, loaded, or applied provides a barrier between the pesticide and the human body. Even though it can be uncomfortable to wear, appropriate protective clothing and/or equipment should always be worn by anyone working with pesticides (Figure 5.6).



**Figure 5.6.** Some of the protective gear (a) and useful instructions for the safe use of pesticides (b). Photo credit: Sophia Kashenge/TARI-Dakawa.

## Soil fertility management

There are different ways to replenish nutrients in the soil. The major ones are as follows:

- Harvesting only the economic part of the crop, leaving the rest in the field to decompose.
- Returning all the residues to the field after harvesting.
- Applying organic manures; green manure, farmyard manure, compost, etc.
- Applying industrial/chemical fertilizers.

Out of the four ways above, the use of industrial fertilizers is inevitable because of its quick response when applied; it gives out the required nutrients on time owing to its quick solubility. Organic materials respond very slowly because of their low rates of decomposition when applied to the field.

## Chemical Fertilizers

- Fertilizers supply nutrients essential for the growth, nutrition, and health of the rice plant.
- Mineral fertilizers are manufactured. It is important to apply the right quantity of fertilizers timely to obtain optimum yields and protect the environment.

### Types of fertilizers

Straight (single) fertilizers: These supply only one primary nutrient (e.g., N, P or K) to the crop.

- Some examples: – Nitrogen: urea, ammonium sulfate, ammonium nitrate, calcium ammonium nitrate (CAN). – Phosphorus: single super-phosphate (SSP), triple super phosphate (TSP), and others. – Potassium: muriate of potash (MOP; KCl)

Compound fertilizers: these supply more than one nutrient (e.g., N, P, and K) to the crop.

- Some examples: – NPK 15-15-15 (15% N; 15% P 2O5; 15% K 2O); – NPK 20-10-10 (20% N; 10% P2O5; 10% K 2O); – NPK 30-10-0 (30% N; 10% P 2O5; 0% K 2O); – Ammonium phosphate nitrate (APN).

### Fertilizer application

- Fertilizer should be applied based on the recommendations.
- The farmer should strive to obtain fertilizer recommendations based on the analyses of soil samples.
- In situations where it is not possible to conduct a soil test owing to the high cost and unavailability of analytical services, or when the farmer is running out of time because the crop is subnormal in growth, the general recommendation is to apply 120 kg N, 40 kg P2O5, and 40 kg of K2O/ha.

### Time of application

#### Basal application of fertilizer

Apply P and K within one week before or after transplanting and work the fertilizer well into the soil.

- Phosphorus (P) –for strong roots establishment.
- Potassium (K)–for building up cellulose and reducing lodging. It helps to retard crop diseases.

#### Application of N fertilizer (e.g., urea)

Apply in at least two equal doses:

- First split at transplanting or at least one month after seedling emergence (for directly planted rice).
- Second split at panicle initiation to sometime before heading. Maintain the water level on the field at 3-5 cm at the time of fertilizer application to ensure efficient use of the applied fertilizer.
- Nitrogen (N) – for chlorophyll component.

#### Method of fertilizer application

Drain the field and apply the fertilizer by broadcasting. The field should be flooded immediately to prevent denitrification.



**Figure 5.7.** Application of basal (a) and top-dressing (b) fertilizers by broadcasting. Photo credit: Charles Chuwa/ TARI-Dakawa.

### Mixing fertilizers

- When it is required to apply two or more elements and the desired compound fertilizer is not available but the straight fertilizers are available, you may weigh and mix the fertilizers before application. This is particularly important for large mechanized rice farms.
- However, note that not all fertilizers are compatible when mixed. For example, if basal N is necessary and you need to apply N and P as basal, do not mix ammonium sulfate with rock phosphate, or urea with super-phosphate. The elements will react with one another and become less effective.

# Module 6

## Cropping calendar

### Overview

Using a cropping calendar allows better planning of activities related to rice production and the cost of production.

A cropping calendar is a schedule of the rice growing season from the fallow period and land preparation to crop establishment and maintenance and to harvest and storage.

In this section farmers will learn the advantages of having a cropping calendar and how to develop it, as it guides the farmer:

- plan for input purchase and use,
- develop a cash flow budget for the year,
- determine credit needs and period required, and
- determine labor requirements for each activity and plan for peak times of use.

In developing the calendar farmers will have to first determine the best date to plant and the time the variety takes from planting to harvest. This information can be gathered from local experience, agricultural advisors, and leading farmers in the district. The length of growing period is known for each

variety (Refer to Module 5, Figure 5.1 of this compendium). It may vary a little, depending on the growing conditions especially water availability and solar radiation. Farmers will understand the different categories of rice varieties based on their growth duration and how to develop the calendar suitable for each category.

### Procedures to develop a cropping calendar

- Mark on the calendar the date of planting and then when each other operation needs to be done (plowing, weeding, fertilizing, and harvesting) (Tables 6.1 (a) or (b)).
- Then determine how much labor, equipment, and finance will be required at each step during the growing period.
- Pin the calendar in a prominent place to remind you when things need to be done.

**Table 6.1 (a).** Typical crop calendar for a medium-duration rice variety.

Month	Week	Activity	Inputs required
1	1	Ploughing, Harrowing and cleaning nursery area	Labour, machinery
	2	Soaking and Incubating seed, making nursery beds, Sowing to nursery, ploughing main field	Labour, seed, machinery, land smoothing/leveling tools
	3	First and Second puddling of main field	Labour, machinery
	4	Inspecting nursery for insect pests and diseases, Last puddling and final leveling, Basal fertilizer application in the main field, Uprooting seedlings, Transplanting main field	Labour, machinery, fertilizer, transplanting tools
2	1	First weeding (if necessary), Filling in missing hills	Labour, weeding tools
	2	First fertilizer topdressing (nitrogenous fertilizers)	Labour, fertilizers, fertilizer handling tools
	3	First pesticide application (insecticides/fungicides) if necessary	Labour, pesticides, pesticide spraying equipment/tools
	4		

3	1		
	2		
	3	Second weeding if necessary	Labour, weeding tools
	4	Second fertilizer topdressing	Labour, fertilizers, fertilizer handling tools
4	1	Second pesticide application if necessary	Labour, pesticides, pesticide spraying equipment/tools
	2		
	3		
	4		
5	1	Final cleaning of the field (removal of mature weeds and off-types)	Labour, cleaning tools
	2		
	3	Field draining/drying for uniform maturity and harvesting	Labour
	4		
6	1	Harvesting, drying and cleaning grains for storage	Labour, machinery, grain processing tools, transport, store

Courtesy: Ndimubandi Mvukiye/ TARI-Dakawa.

**Note:**

- Field inspection for insect pests and diseases should be done regularly for timely management.
- For rainfed areas this calendar might require adjustment depending on rainfall pattern.

**Table 6.1 (b).** Detailed Typical crop calendar for a medium-duration rice variety.

Days before sowing nursery	Days before transplanting	Activity	Necessary inputs
13	31	Ploughing nursery area	Labour, machinery
7	25	Harrowing and cleaning nursery area	Labour, machinery
3	21	Soaking seed, ploughing main field	Labour, machinery
2	20	Incubating seed, making nursery beds	Labour, implement
0	18	Sowing seed in nursery	Labour
Days after sowing			
2	16	First puddling of main field	Labour, machinery
9	9	Second puddling of main field	Labour, machinery
15	3		
16	2	Last puddling and final leveling, Basal fertilizer application in the main field	Labour, machinery, fertilizer
17	1	Uprooting seedlings	Labour
18	0	Transplanting main field	Labour, transplanting tools
	Days after transplanting		
25	7		
28	10	First weeding (if necessary), Filling in missing hills	Labour
32	14	First fertilizer topdressing (nitrogenous fertilizers)	Labour, fertilizer
38	20	First pesticide application (insecticides/fungicides) if necessary	Labour, pesticides
68	50	Second weeding (if necessary)	Labour
73	55	Second fertilizer topdressing	Labour, fertilizer
78	60	Second pesticide application (if necessary)	Labour, pesticides
100-105	82-87	Final cleaning of the field	Labour
110-115	92-97	Field draining/drying	Labour
120-130	102-112	Harvesting, drying and cleaning grains for storage	Labour, machinery, tools, transport, store

Courtesy: Ndimubandi Mvukiye/ TARI-Dakawa.

**Note:**

- Field inspection for insect pests and diseases should be done regularly for timely management.
- For rainfed areas this calendar might require adjustment depending on rainfall pattern.

# Module 7

## Issues of salt-affected soils and rice productivity

### Overview

Accumulation of excessive salt in both irrigated and lowland rainfed soils can reduce crop yields, reduce the effectiveness of irrigation, ruin soil structure, and affect other soil properties.

In this module the effects of salt-affected soils and their management for improved are discussed. Currently the problem is increasingly threatening lowland rice productivity under both irrigated and lowland rain-fed ecosystems of Tanzania. Recent soil characterization reports for salt-affected soils conducted in some major rice irrigation schemes in Tanzania reveal that the problem is increasing. Farmers are increasingly complaining and the areas abandoned by rice farmers have been reported to increase. The problem threatens the performance of many irrigation schemes, even those which have been improved by the Government.

The welfare of rice farmers is at stake and the Government's effort to ensure that the country is self-sufficient in food (especially rice) will be rendered useless if farmers are not highly involved and become successful in managing the problem. Increasing farmers' awareness on the presence and management of salt-affected soils are therefore prerequisites to improved rice production in the country.

**Duration of training:** one day of 5-7 hours

### Training materials

- Salt-affected demo sites.
- Samples of saline, sodic, and saline-sodic soils.
- Pictures/photos of fields that are seriously affected by the salts (case studies).
- Pens and exercise books for participants to take notes.

### Salts

Salts are composed of positively charged ions (cations) and negatively charged ions (anions). They can be dissolved in water (soluble salts) or be present as solids. Salts in soil can originate from the soil's parent material; from irrigation water; or from fertilizers, manures, composts, or other amendments.

Salts in the root zone can reduce crop yield by making it difficult for roots to extract water from the soil. Salts increase the soil's osmotic potential, causing water to move from areas of lower salt concentration (plant tissue) into the soil where the

salt concentration is higher. High salt concentration in the soil can cause plants to wilt even when soil moisture is adequate.

### Categories of salt-affected soils

Participants should be able to distinguish (by their characteristics) different types of salt-affected soils as each type requires different management options (efforts) to make it productive. The soils that have been affected by salts are categorized into three types: sodic (or alkali), saline, and saline-sodic, depending on which type of salts dominates.

#### Saline soils

The predominant exchangeable cations in saline soils are calcium and magnesium. They typically have EC greater than 4 dS/m (mmhos/cm), SAR is less than 13, and/or ESP is less than 15. Saline soils commonly have visible salt deposits on the surface and are sometimes called "white alkali soils". Most salts in the soil solution have a positive effect on soil structure and water infiltration. Therefore, water penetration is not a major concern with saline soils. Saline soils may also contain sodium ions but are dominated by calcium and magnesium cations and soluble chloride and sulfate anions with pH values are much lower than in sodic soils.

#### Sodic soils

These have salts in which sodium ions dominate over other cations (magnesium and calcium) and have higher amounts of insoluble carbonate anions. They typically have EC is less than 4 dS/m (mmhos/cm), SAR greater than 13, and/or ESP greater than 15. Their pH is generally higher (> 8.5) than in other types. High exchangeable sodium, high pH, and low calcium and magnesium combine to cause the soil to disperse, meaning that individual soil particles act independently. The dispersion of soil particles destroys soil structure and prevents water movement into and through the soil by clogging pore spaces. Sodic soils often have a black color due to the dispersion of organic matter and a greasy or oily-looking surface with little or no vegetative growth. These soils have been called "black alkali" or "slick spots."

#### Saline-sodic soils

Saline-sodic soils are high in sodium and other salts. They typically have EC greater than 4 dS/m (mmhos/cm), SAR greater than 13, and/or ESP greater than 15. Soil pH can be above or below 8.5. Saline-sodic soils generally have good

soil structure and adequate water movement through the soil profile. They can have the characteristics of either a saline or sodic soil, depending on whether sodium or calcium dominates.

### What causes the salts to accumulate in rice fields?

It is very important for farmers to understand what causes the salts to accumulate in the soils so that they can (where possible) reduce or prevent further accumulation and ensure their soils' sustainable productivity.

Salts may originate naturally from salt-bearing rocks at shallow soil depths in the field. In such conditions, percolating water (from rain or irrigation) reaches the rocks and dissolves substantial amounts of salts which it then brings up into the root zone (upon raising of the water table) and leave them there when it evaporates. This process is more pronounced especially in aridic areas, characterized by generally higher water evaporation and transpiration than percolation due to high temperatures and low humidity.

Usually, however, salts normally build up in soils as a consequence of excessive use of irrigation water (especially in heavy soils) with inadequate drainage or the use of poor-quality (salty) irrigation water. Farmers can also cause salt accumulation from injudicious use of fertilizers and other agro-inputs.

### How do salts affect growth and production of the rice crop?

Salt affects plant growth mainly through:

- Toxicity from excessive uptake of salt substances such as sodium.
- Reduction in water uptake (known as water stress) and loss of cell water (water withdrawn from the root) when the salt concentrations in the soil are higher than inside the root cells.
- Reduction in uptake of essential nutrients particularly potassium and micronutrients.

### The negative effects of the salts on the soil and the rice crop:

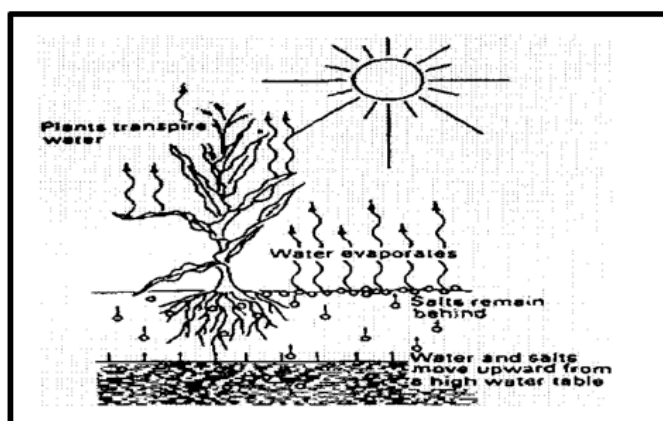
- Extremely high salt stress conditions kill the plant.
- Moderate to low salt stress affects the rate of plant growth.
- When combined with irrigation and poor drainage they can lead to permanent loss of soil fertility.
- Physically and chemically poor soils develop an accumulation of clay and silt sediments which are relatively impermeable with residual high content of salt; deep cracks spread across the surface of the soil.

### Visual symptoms of the negative effect of salts on rice plants

Farmers should be able to distinguish the symptoms of saline and sodic toxicity in the soils, whose overall effect is severe reduction in yield and quality of the grains, and, in extreme cases, cause early plant death.

Major symptoms of saline soils on rice plants are:

- Poor germination.
- Poor root growth.
- Patchy growth in field.
- Low tillering.
- Stunted plant growth (stems with shorter internodes).
- Change in flowering duration (staggered, non-uniform flowering).
- Leaf rolling.
- White leaf blotches.
- Leaf dying from the tips (white leaf tip followed by tip "burning") (Figure 7.2 (a)).
- Spikelet sterility (Figure 7.2 (b)).
- Few spikelets per panicle.
- Light weight of grains.



**Figure 7.2.** Diagrammatic presentation of the process of salt accumulation in the soil in aridic conditions. Credit: Sophia Kashenge/ TARI-Dakawa.

# Module 8

## Improving rice productivity on saline-sodic soils

### Overview

Saline-sodic soils have been identified as a problem in a majority of recently surveyed irrigation schemes in the country. Examples of these schemes are Pawaga and Idodi (Iringa Rural district), Luanda-Majenje, Bethania, Madibira, Mayanga and Gwiri (Mbarali district), Sakalilo and Mpete (Sumbawanga district), Ndungu (Same district), and Mombo (Korogwe district).

In saline-sodic soils, since they are a combination of salts, the management approaches have to be combined for both saline soils (mainly leaching with clean water through flooding the field and flushing) and sodic soils (use of soil amendments such as gypsum).

In this module, some of the proven interventions that ensure sustainable productivity of rice in saline-sodic soils are discussed.

**Duration of training:** one day of 5-7 hours

### Training materials

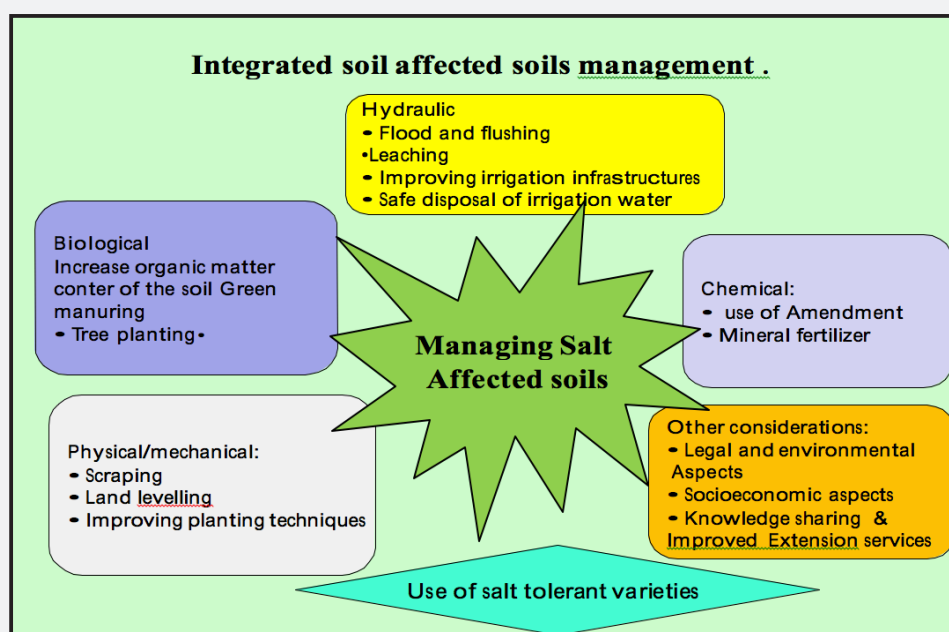
- i) The training venue (a classroom and the rice fields near the demonstration site that are salt-affected).
- ii) Pictures/photos taken on sites that are seriously affected by the salts (case studies).

- iii) Pens and exercise books for participants to take notes.

## Strategies to manage saline-sodic soils

An integrated approach is the best strategy to manage all types of salt-affected soils. This is a combination of different approaches depending on the existing salt problem (Figure 8.1). The facilitator should explain the integrated approaches, zooming in to the three approaches to manage salt-affected soils and encourage the participants to discuss each of them and agree on the best one to use in tackling the problem:

- Environment-modifying approach: Changing the environment to allow for the normal growth of plants.
- Crop-based approach: Selecting or developing crop varieties that can withstand the salt stress.
- Hybrid approach: Combining environment-modifying and plant-based approaches.



**Figure 8.1.** The integrated approach model for managing salt-affected soils. Photo credit: Sophia Kashenge/TARI-Dakawa.



## Environment-modifying approach

Leaching the root-zone with clean water (with low levels of salt).

- Providing good drainage infrastructure.
- Breaking of clay/silt layer (with or without mixing it with the soil underneath to increase infiltration/percolation).
- Removal of the surface layer.
- Application of gypsum (to replace sodium ions in the soil with calcium, and as a result, actively remove the sodium and improve soil percolation). This option is applicable only when the pH of the soil is higher than 8.5 (i.e., a sodic soil).
- Application of fertilizers (chemical and organic).

## Crop-based approach

Growing salt-tolerant crops, a practical option during the recovery process (Figure 8.2).



**Figure 8.2.** Salt-tolerant varieties (left) and susceptible varieties (right).  
Photo credit: Sophia Kashenge/ TARI-Dakawa.

## Integrated approach

- Combining all or some of the environment-modifying and plant-based approaches.

It should be emphasized that the integrated approach is the best of all three approaches to manage the soils that are affected by salts since, in most cases, all types of salt-affected soils exist at different levels in one particular field.

### The use of gypsum and improved salt-tolerant rice varieties as the strategy of improving rice productivity in saline-sodic soils

The facilitator should explain the technology of the use of gypsum and salt-tolerant rice varieties as one of the integrated approaches.

The technology involves using gypsum to displace sodium ions from soil colloids and then applying large quantities of water to wash out (leach) a substantial amount of salts (especially of sodium ions). The salts are sent either to depths beyond the effective root zone of the rice crop or out of the fields. Then salt-tolerant rice varieties are planted and properly managed in such a way as to ensure adequate nutrition and a suitable growing environment.

### Application of gypsum

Gypsum is evenly broadcast and soil-incorporated in a properly prepared field (well-leveled with bunds to retain water, the amount of gypsum depends on the nature of the salt-affected soil Table 8.1). This should be done 3-4 weeks prior to planting. Adequate water is then allowed into the field and the soil is stirred to assist in dislodging sodium ions from soil colloids and replace them with other cations (mainly calcium) on the exchangeable sites. The field is left in a flooded condition for not less than 2 weeks. After 2 weeks the flood water is drained out. This exercise of washing and draining out the field can be done 3-4 times to wash the soil.

### Transplanting in ameliorated soils

Prior to transplanting, matured farmyard manure and basal fertilizers (e.g., DAP and MOP) are evenly broadcast and soil-incorporated in the “washed” field. Then seedlings of the salt-tolerant varieties (such as SATO1) are transplanted at suitable plant spacing. The crop is subsequently well-managed to standard until it matures.

### Why might gypsum help and why leave a field in flooded conditions for 2 weeks before transplanting is done?

Gypsum provides calcium ions that dislodge and replace sodium ions from the soil's exchange complex to the soil solution where they dissolve and are easily removed from the soil through draining the water. At the same time the calcium ions help to flocculate the soil making it more porous to the soil solution that carries the dissolved sodium ions to depths well beyond the effective root zone of the rice crop. Gypsum is also a good source of sulfur which is one of the secondary essential plant nutrients for the crop. A minimum of 2 weeks of flooding is required for effective dislodging of the sodium ions by calcium ions from the exchange complex and effective flocculation of the soil particles.

### Using farmyard manure

Farmyard manure is applied after a substantial amount of salts have been removed upon draining the soil after gypsum has accomplished its task. The manure is important in that when it decays in the soil it releases some chemicals that help in further breaking down sodium salts and renders them more soluble in the salt solution. It also releases humic substances which also increases flocculation of the soil particles thereby

improving soil structure. Moreover, farm- yard manure is an organic fertilizer and helps to replenish some of the essential plant nutrients that are inevitably removed alongside the excess salts when the soil is drained. Farmyard manure also provides food for soil microbes that effect the mineralization of organic residues and fix atmospheric nitrogen. The overall effect is improved soil structure and availability of plant nutrients.

**Note:** A combination of gypsum and farmyard manure is more effective in improving the quality of the salt-affected soil than gypsum or farmyard manure alone. The actual rate of application of gypsum (gypsum requirement) and farmyard manure can better be determined after analysis of the saline-sodic soils.

### Why apply other fertilizers (basal and top-dressing)?

The fertilizers must be applied to ensure adequate nutrients for the crop, especially in such a situation where some plant nutrients are inevitably washed out of the soil alongside with sodium ions. The fertilizers are applied to replenish lost nutrients in the soil.

### The merit of planting salt-tolerant rice varieties

Since the salt-tolerant varieties flourish better than other varieties in comparatively higher salt levels (Table 8.2 and Plate 8.2), the cost of ameliorating the soil is therefore reduced as relatively smaller amounts of salts need to be removed if the salt-tolerant varieties are to be planted. The cost of ameliorating salt-affected soils increases with the amount of salts to be removed to attain the desirable salt levels.

**Table 8.2.** Performance of improved varieties in normal and salt-affected soils under rainfed lowland and irrigated agro-ecological systems.

Variety (Year released)	Aroma	Potential yield (t/ha)	Farmers yield (t/ ha)	Actual yield under salt levels of E <sub>c</sub> = 5-7 dS/m and SAR =15-23 (t/ha)
TXD306 (2001)	Semi-aromatic	6.0-7.0	4.5-5.5	0.6-3.0
Komboka (2012)	Semi-aromatic	5.0-6.2	3.5-4.0	0.3-2.5
SATO=Salt- tolerant (2016)	None	6.0-8.5	4.5-5.0	2.0-4.0

Courtesy: Sophia Kashenge/TARI-Dakawa



**Figure 8.3.** Luxuriant growth of a salt-tolerant variety (SATO1) in a soil amended with gypsum and farmyard manure. Photo credit: Sophia Kashenge/TARI-Dakawa

Typically, farmers will have to face some challenges associated with using gypsum and farmyard manure in ameliorating saline-sodic soils. These challenges may include such issues as accessibility of required inputs (farmyard manure, gypsum, water and suitable crop varieties), and impact on the environment (e.g. contamination of the discharge sites for the drained excess salts from the ameliorated fields). Therefore farmers will have to make an informed choice of adopting the technologies taking into consideration the anticipated yield benefit against the overall cost of ameliorating the soils in their environment set-ups.

# Module 9

## Improving rice productivity on calcareous soils

### Overview

Calcareous soils are soils that have been affected by calcium-based salts. Calcareous soils have often more than 15% CaCO<sub>3</sub> in the soil that may occur in various forms (powder, nodules, crusts, etc.,). The soils generally have low contents of organic matter, and nitrogen and phosphorus ions.

Soil characterization surveys have indicated that some areas of Dakawa Irrigation scheme in Mvomero have Calcareous soils (Figure 9.1 and 9.2). Farmers often confuse the symptoms with the effects of sodic soils.



**Figure 9.1.** Patchy growth of rice in a calcareous soil at Dakawa Irrigation scheme, Mvomero district. Photo credit: Sophia Kashenge TARI Dakawa.



**Figure 9.2.** Farmers appreciating the poor performance of a rice crop in the calcareous soil at Dakawa Irrigation scheme, Mvomero district. Photo credit: Charles Chuwa/TARI-Dakawa.

The presence of Calcareous soils in Dakawa Irrigation scheme is an eye-opener. There might be other areas in the country that are affected by the same salts but for which the information is still lacking. So it is very important for rice farmers to be aware of the presence of the problem, how it affects rice productivity, and the better management options to undertake to improve rice productivity in such cases.

In this section we discuss some of the proven intervention measures that ensure sustainable productivity of rice in Calcareous soils.

**Duration of training:** one day of 5-7 hours

#### Training materials

- The training venue (a classroom and the calcareous rice fields).
- Pictures/photos of crop performance taken on calcareous sites.
- Pens and exercise books for participants to take notes.

#### The cause of CaCO<sub>3</sub> accumulation in soils

The main source of the salts is normally the underlying CaCO<sub>3</sub>-laden rock at shallow depths of the soil. As in other problematic soils, the salts are brought to the root zone and surface of the soil by the evaporation of rain or irrigation water after the water has reached the rock and dissolved the salts. The soils are common in arid and semi-arid areas where evaporation normally is greater than precipitation.

### The issues with calcareous soils

- The affected soil has very high content of CaCO<sub>3</sub> soil (>50%) that makes it powdery or appear as pebbles.
- It is high pH values (7.5-8.5) which prevent/reduce the availability of many plant nutrients (nitrogen, phosphorus, magnesium, potassium, manganese, zinc, copper, and iron).
- The soils also have a low content of organic matter.
- The effect on the crop is detrimental. The plants either produce very low yields or die.

## *The best strategy (approach) to manage Calcareous soils*

The best approach to manage the calcareous soil is the use of acid-forming materials designed to lower the soil pH and create a suitable environment that improves the availability of much of the essential nutrients to the crop.

## **Details of the approach of managing calcareous soils for improved rice productivity**

A combination of acid-producing chemical fertilizers: Sulfate of Ammonia (SA) and Diammonium phosphate (DAP) is used with farmyard manure. Farmyard manure and DAP are evenly broadcast and soil-incorporated in a properly prepared field (well-leveled with bunds to retain water). Well-tended seedlings of the preferred rice variety (e.g. SATO 1) are transplanted SA

**Fertilizer is top-dressed in 2 or more splits at designated (standard) time intervals. Other agronomic management activities are followed until the crop matures.**

SA fertilizer is preferred to Urea because SA contains 2 essential (major) nutrients for the rice plants, nitrogen and sulfur which are not available or available only in little quantities

in calcareous soils. In addition, SA fertilizer is the most acid-forming among other nitrogenous fertilizers, therefore, on its dissolution it quickly produces comparatively more acids (sulfuric acid) which lowers the soil pH and increases the availability of more nutrients to the rice plants.

### **Farmyard manure is used owing to the following merits:**

- Upon decaying in the soil farmyard manure releases some chemicals (acids) that help in reducing soil pH and make much more of the nutrients available to the rice crop.
- Farmyard manure is also an organic fertilizer and helps to replenish some of the essential nutrients required for plant growth.
- Farmyard manure also provides food for soil microbes that effect the mineralization of organic residues and can fix atmospheric nitrogen. The result is improved availability of plant nutrients.

### **DAP fertilizer is applied because:**

- It provides the phosphorus that is usually lacking in calcareous soils.
- It is capable of forming acid (contains ammonium ions) that assist in the lowering of soil pH and improve the availability of more nutrients.
- It is essential for the early development of plant roots at the younger stages of plant growth.

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