Africa RISING – NAFAKA Project
Compendium of Rice Production Training Protocols

Sophia Kashenge-Killenga, Charles Chuwa, Ndimubandi Mvukiye, Joel Zakayo, Ibrahim Paul and Rajabu Kangile

Produced by Dakawa Agricultural Research Institute

Published by International Institute of Tropical Agriculture

June, 2017

www.africa-rising.net

The *Enhancing partnership among Africa RISING, NAFAKA, 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 programs NAFAKA and TUBOCHA. Developmental activities addressing the project objectives are being implemented in Manyara, Dodoma, Morogoro, Iringa, and Mbeya Regions in Tanzania.

This document was made possible with support from the American people delivered through the United States Agency for International Development (USAID) as part of the US Government's Feed the Future Initiative. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of USAID or the U.S. Government.

Contents

Acknowledgements

This training manual was made possible by a grant from the International Institute of Tropical Agriculture (IITA) through the Africa RISING project.

Special thanks to Dr Haroon Sseguya the Africa RISING technology scaling specialist and Mr Silvanus Mruma the NAFAKA Project Agricultural Productivity Manager for their sustained interest and encouragement.

Thanks to all members of Chollima Agro-Scientific Research Centre (ARI-Dakawa) for their direct and indirect support.

Sincere appreciation and heart-felt gratitude to all Africa RISING – ARI - DAKAWA RICE TEAM for their tireless work, patience, and support throughout the preparation of this manual

Introduction

The training manual plays an important role in designing and implementing a formal training program as it ensures consistency in the presentation of the subject matter. Another major advantage of the training manual is that skills, processes, and all other information necessary to perform the tasks are put together. Based on this importance, this training manual has been prepared. The subject matter is presented in 11 modules.

Module 1 is the concept of good rice varieties. In this section we shall discuss the characteristics and merits of improved varieties. Module 2 is on land preparation whereby land clearing, tillage, soil pulverization, field levelling and the making of bunds to enclose the rice fields will be 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 will be discussed. Module 5 deals with field water management and weeding. Module 6 is on soil fertility management. Module 7 is post-production. In this module, paddy harvesting activities that include reaping, stacking, handling, threshing, cleaning, and hauling are discussed. Module 8 displays the cropping calendar that allows better planning of all farm activities and the cost of production. Module 9 explains issues of salt-affected soils and their effects on rice productivity. Module 10 is on improving rice productivity on saline-sodic soils wheresome of the proven interventions are discussed. The last in this training manual is Module 11on improving rice productivity on calcaric soils where we discuss some of the proven interventions that ensure sustainable productivity of rice in such soils.

Learning goal of the training manual

This training manual focuses on the process of transferring skills to agricultural stakeholders in their areas or environments of rice production and helps in carrying out the capacity development process on a sustainable basis owing to the availability of management skills and interventions on rice.

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 more effective.

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 note down some important points during presentations.
v) Printed notes for participants.

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.

They will be expected to mention characteristics such as:

a) High yield
b) Good aroma
c) Tolerance to diseases and other stresses such as salinity, sodicity, or drought
d) Good milling qualities (translucent grains)
e) Good threshability
f) 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 many consumers (fetches a good market). 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 farmers to look for improved varieties and seek expertise and advice from nearby agro-input suppliers, research centers and other village-based agricultural advisors.

Different types of rice varieties

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

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. However, most of them are susceptible to pests and diseases, have long growth periods and a low rate of tillering which translate to a low yield.

ii) **Improved varieties**: These varieties are man-made through selection and hybridization focusing on a specific target such as high yield, tolerance to biotic and abiotic stresses and good grain quality. The plants always have medium stature, high tillering, good response to high fertilizer rates and are tolerant to various challenges.

They also have shorter growth duration and are higher yielding. Examples of such varieties are IR 64 and SARO5 (TXD306).

Characteristics of SARO5 (TXD306):

- A good rice variety developed by scientists at ARI-Dakawa Tanzania back in 1999, accepted in 2000 and released by ARI-KATRIN in 2002. TXD 360 means Tanzania Cross Dakawa selection number 306. The variety is semi-aromatic, that is why it is called SARO.
- Maturity - 120-130 days
- Harvests 20-40 bags (100 kg each) in one acre depending on management
- Good grain quality (aromatic with a good market)
- Medium plant stature, resistant to lodging and has good tillering ability (more than 20 tillers per hill depending on management).

Things to consider when selecting rice varieties

- Where exactly is the variety to be grown. There are specific varieties suitable for upland, lowland-rainfed conditions and irrigated areas.
- Existing challenges of the area (drought, low fertility, salinity problems, prominent type of diseases and inadequate soil moisture). Normally varieties that perform better in specific challenges are preferable, e.g., in dry areas with less water, varieties with shorter duration (100-115 days) are preferable.
- Yielding ability and marketability (Plant stature, tillering ability, grain quality). Normally short-statured, high-tillering and good-grain quality varieties e.g., SARO 5 (TXD 306) are preferred.

Module 2: Land preparation

Overview

In this section, we shall discuss land preparation which involves clearing, tillage, soil pulverization, levelling fields and making bunds to enclose the rice fields. Currently many farmers do not undertake such activities correctly, leading to improper water management.

Duration of training: One day of 5-7 hours

Training materials

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

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

The purpose of land clearing is to remove unwanted vegetation that could hinder proper cultivation. It is followed by levelling and bund-making.

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. 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 them 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.

Farmers clearing land as part of land preparation. Photo credit: Sophia Kashenge/ARI 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.

Soil puddling using a tractor-drawn rotorvator. Photo credit: Ndimubandi Mvukiye/ARI Dakawa.

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 leveled seedbeds have poor growth resulting in low yields.

Levelling the field after puddling using hand levelers (a) and wooden levelling planks (b). Photo credit: Ibrahim Paul/ARI 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.

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.

Bunds are made around leveled plots for proper water management. Photo credit: Charles Chuwa/ARI Dakawa.

Dimensions of rice field bunds

- top 30 to 50 cm wide
- depth (height) 40 to 50cm deep/high
- base 130 to 160cm wide

How to construct a bunded rice seedbed

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

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

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 that must be grown, harvested, and processed correctly for best yield and quality results. Participants will have to understand that seed selection 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 more effective:

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 to note down some 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

i) Reduced seed rate as many seeds will have a high percentage of germination.
ii) Healthy seedlings.
iii) Uniform crop stand and maturity.
iv) Reduced weed infestation.
v) 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:

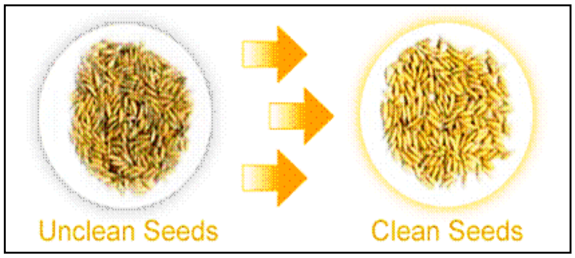
a) Obtaining seeds of the selected variety either from agro-input stores or by picking rice panicles from the field, drying and threshing them to obtain the seeds (of about 13% moisture content).
b) Immersing the seeds in a salt solution (1.5kg table salt dissolved in 10 liters of clean water) and removing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

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



From unclean to clean seeds. Photo credit: Charles Chuwa/ ARI Dakawa.

Seed cleaning by winnowing

Winnowing and cleaning are normal procedures to remove unfilled grains,

Seed cleaning by floatation in 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. The farmer has to conduct manual seed sorting.

Seed cleaning by floatation in 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 floating in clean water. The following steps can be followed:

Requirement

- Unclean seeds
- 2 buckets (1 of 10 liters and another of 20 liters)
- A sieve
- 10 liters of water
- 2 kg of table salt
- Stirring stick
- One fresh chicken egg

Procedures

- Measure 10 liters of water and mix 2 kg of salt into it.
- Drop an egg carefully in the salt solution, keep on stirring and adding more salt until the egg floats.
- Add the seeds and mix them very well with a stick; all the unfilled grains will float.
- Remove all the floating unfilled grains and keep on stirring 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 in proper sunshine for future use.


Seeds poured into a salt-solution (a) and well-stirred (b) to enable floatation of unfilled grains. Photo credit: Ndimubandi Mvukiye/ ARI 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 to the wet nursery intended to raise seedlings for anticipated 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.


Seed incubation (a) to obtain well-sprouted seeds (b). Photo credit: web.

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) Unclean rice seeds.
v) Well-prepared rice seedlings.
vi) Fertilizer for basal application.

Farmers will be asked to:

- State the relative advantages and disadvantages (if any) of using clean and unclean seeds.
- State the characteristics of good seeds.
- State the relative advantages and disadvantages (if any) 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 following advantages of transplanting:

- Low seed requirement (needs 6-10kg 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 disadvantages that include:

- o much more labor to establish the crop and
- o delayed crop maturity.

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

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

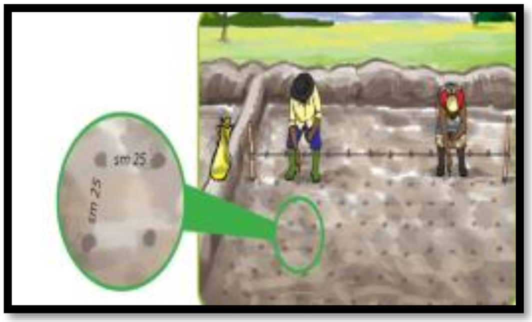
It has disadvantages that include:

- Much larger seed requirement (needs 40-80kg per acre),
- Seeds are more vulnerable to soil-borne insects and pathogens,
- More effort 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 20cm x 20cm. This spacing is achieved by the use of the marked rope. 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 matures.



Direct planting at a specified plant spacing using a marked rope. Photo credit: Charles Chuwa/ ARI Dakawa.

Marking planting holes by a marked rope and rod (direct seeding). Photo credit: Charles Chuwa/ARI 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:

- Puddling the field and levelling it
- Dividing the field into 1x10m nursery beds (40 of such beds per acre)
- Making furrows around each nursery bed
- Doing final levelling of nursery beds
- Applying basal fertilizer (in nutrient-deficient soils) (a mixture of about 2.5g urea, 1.0g MOP and 1.5g DAP per $1m^2$).
- Broadcasting (evenly) pre-sprouted seeds on nursery beds and tapping the seeds into the soil (40 g or at about one handful of seeds per $1m^2$)
- Keeping the soil moist/wet until one week after seedling emergence.
- Gradually raising the water level and keeping it at 1-5cm (depending on seedling height) until transplanting.
- Keeping the nursery beds free from weeds.
- Applying pesticides to manage diseases and insect pests where necessary.

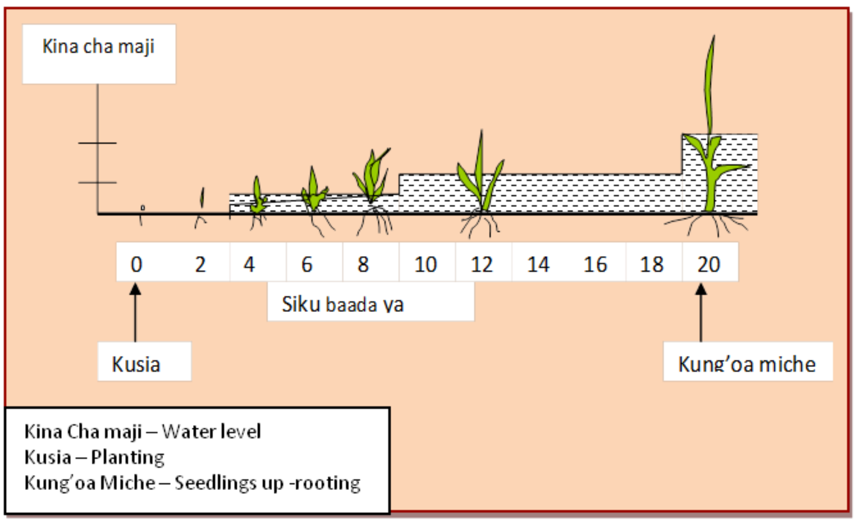
Some consideration for transplanting

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 3cm if possible) or just to wet the soil.
- Broadcasting basal fertilizers (DAP, MOP or manure) at calculated doses.
- Properly incorporating the basal fertilizers into the soil by final puddling (using rotorvator, hand hoe, or ox-plow).
- Performing final levelling of the field using rakes or any other suitable implements.

Seedling preparation and planting

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



Allowable water depths in a nursery over time. Photo credit: Ndimubandi Mvukiye/ARI Dakawa.

Some consideration on how to prepare seedlings for transplanting

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

- Prior to pulling out seedlings let enough quantity of water into the nursery beds.
- Select quality seedlings with uniform height.
- Grasp seedlings near the base and uproot at least three at a time.
- Gently uproot the seedlings at an angle about 30 degrees from the horizontal.
- Wash the seedlings thoroughly to remove soil adhering on roots.
- Bundle the seedlings in proper sizes to facilitate transportation and handling during planting.
- Place the seedlings in water during planting to prevent wilting.

Transplanting activity

- 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 3cm and conveniently spaced at 20cm between rows and 20 cm between plants in a row.

The use of the marked transplanting rope enables spacing to be kept constant throughout the field. 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 after transplanting.

Line transplanting using a marked rope. Photo credit: Charles Chuwa/ ARI Dakawa.

A well-established rice field as a result of transplanting at uniform plant spacing. Photo credit: Charles Chuwa/ ARI Dakawa.

Module 5: Field Management

Overview

In this module, management of water, weeds, soil fertility, and pests and diseases are discussed. A well-managed field has few weeds, and 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 in consideration of the rice plants' growth phases.

Duration of Training: Two days will be needed;

Training materials

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

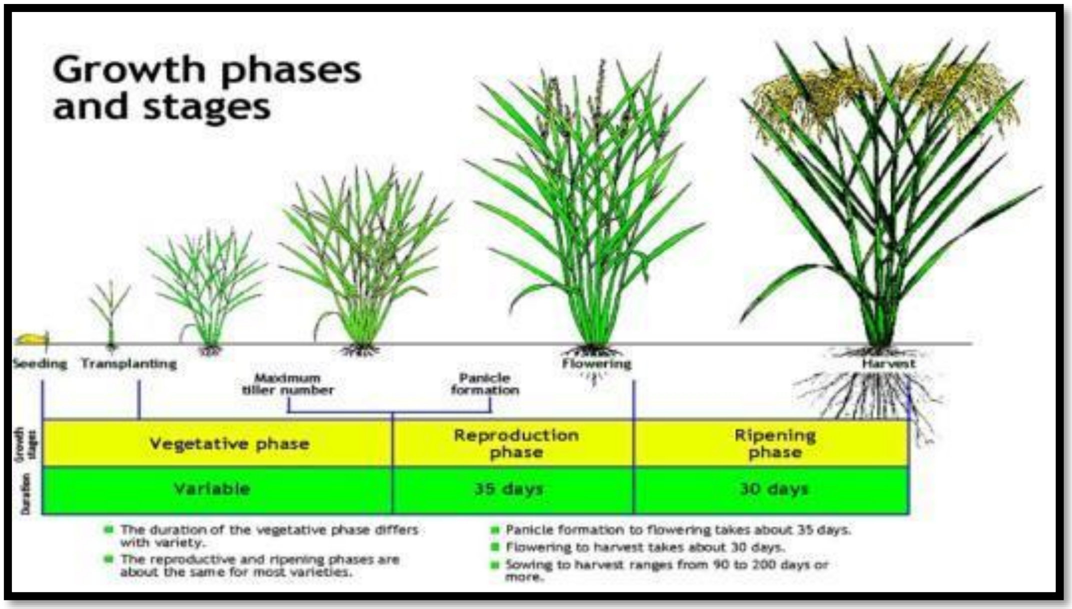
i) Plants at different growth stages.
ii) A well-bunded field.
iii) A well-maintained/clean plot and an un-weeded plot.
iv) Mechanical weeders.
v) Different types of weeds.
vi) Different herbicides and pesticides.
vii) Different kinds of spraying equipment.
viii) Diseased and insect-damaged plants.
ix) 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 plants passes through three major growth phases from seedling emergence to maturity. 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).



Growth phases and stages of the rice plant. Photo credit: Sophia Kashenge/ARI Dakawa.

Farmers should understand the relationship of 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 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 has been done, water levels should be around 3 cm initially and gradually increase to 5−10 cm (with increasing plant height) and remain there 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 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.

AWD Technology

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, water savings are in the order of 15-30%.

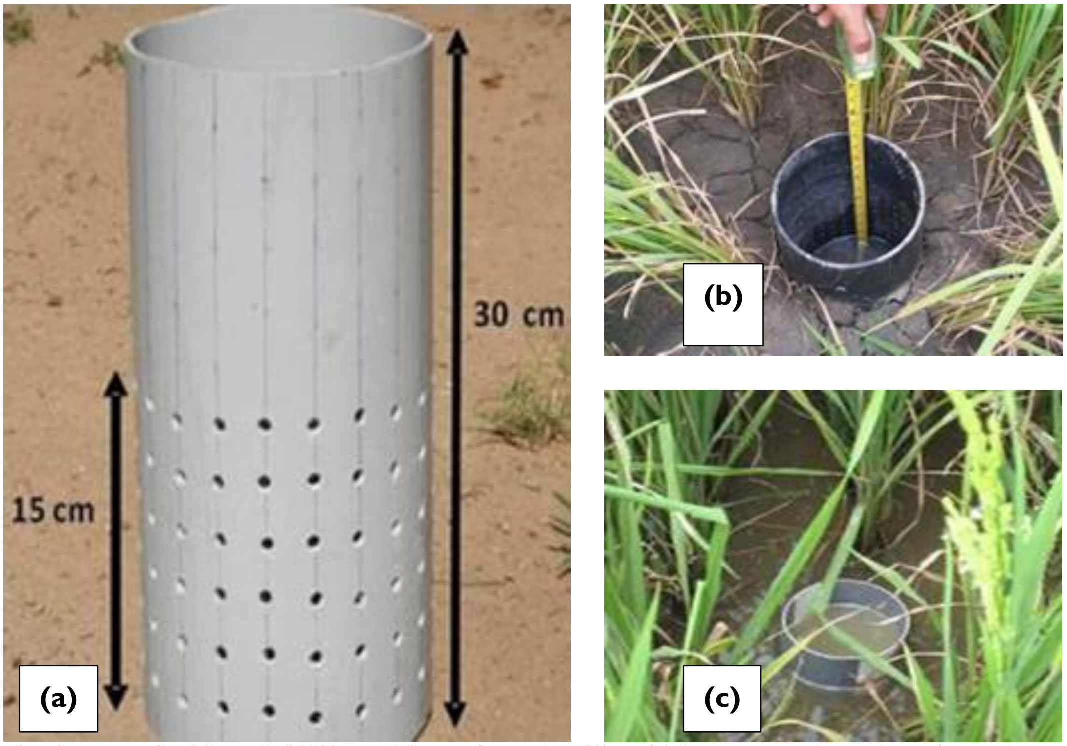
How to implement Safe AWD

- A practical way to implement AWD is to monitor the depth of ponded water on the field using a Field Water Tube.
- After irrigation, 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 40-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 20 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 of the tube is visible.
- Check that the water table is the same inside and outside the tube.

The tube can be placed in a flat part of the field close to a bund, so it is easy to monitor the ponded water depth



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 /ARI Dakawa.

Weed management

Successful 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.

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:

1. Manual weeding
2. Mechanical weeding
3. Chemical weeding

Manual weeding

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

Farmers managing weeds by hand pulling. Photo credit: Charles Chuwa/ ARI 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.

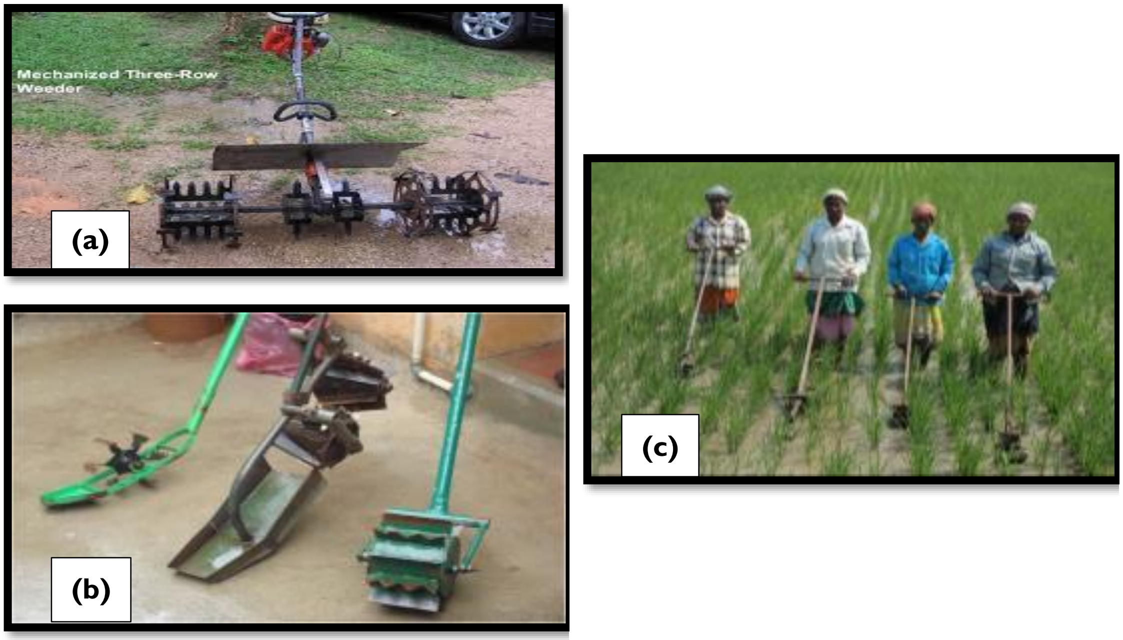
Mechanical weeding

Mechanical weeding is most appropriate for crops transplanted in straight rows. This method requires less time and labor costs than manual weeding. Mechanical weeding using implements such as push- or rotory weeders is common.

Conditions to observe when using weeders:

1. Ensure that there is enough soil moisture before weeding. It could be difficult to use a weeder when the soil is very dry.
2. 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.



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

1. Selective
2. Non-selective
3. Pre-emergence
4. Post-emergence

- 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.

- 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-emergence herbicides are applied to the soil and control weeds before they emerge, while post-emergence are applied to weeds after they emerge.

Examples of post-emergence 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 the herbicides being applied too late to provide 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 poor level of understanding that results.

Examples of common weeds in rice fields. Photo credit: Sophia Kashenge and Ndimubandi Mvukiye / ARI Dakawa.

Reminders about using pesticides/chemicals

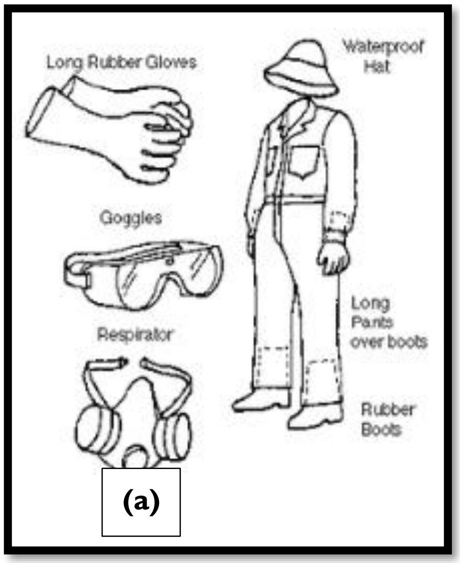
- Always mix with clean water before application. Refrain from using muddy water as this reduces herbicide efficacy.
- Ensure all equipment, such as spray tanks, booms, and nozzles are cleaned well after every use.
- Do not mix herbicides together unless this is recommended.
- Apply herbicides at a recommended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

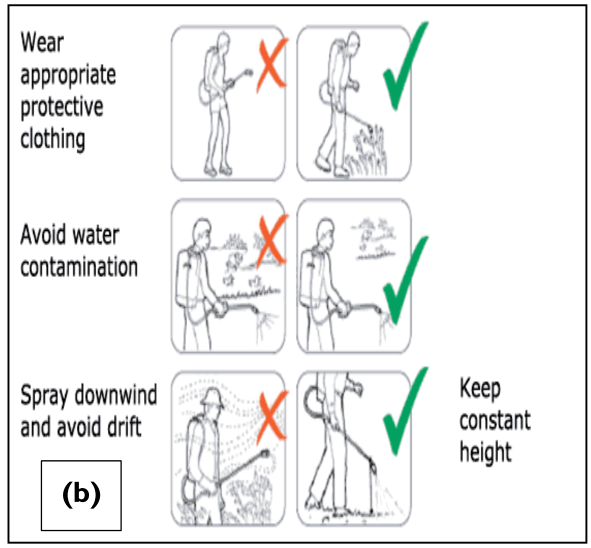
Protective clothing that is used when pesticides are mixed, loaded, or applied provides a barrier between the pesticide and the human body. Even though it can be uncomfortable to wear, appropriate protective clothing and/or equipment should always be worn by anyone working with pesticides.

After handling pesticides: Wash!
Remember to wash your gloves with soap and water before removing the gloves. This will protect your hands from the pesticide residue still left on the gloves.

- You can safely remove your gloves and wash your hands and face thoroughly with soap and water.

- Always wash your hands before eating, drinking, using tobacco products (smoking cigarettes or chewing tobacco), or using the bathroom.
- Wash any other parts of your body that may have come in contact with the pesticide.
- To prevent tracking pesticides inside the house, remove or rinse your boots or shoes before entering your home.





Some of the protective gear (a) and useful instructions for the safe use of pesticides. Photo credit: Sophia Kashenge/ARI 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.
- Using organic manures; green manure, farmyard manure, compost, etc.
- Using 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. On the other hand, 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 and at the right time to obtain optimum yields and protect the environment.

Types of chemical fertilizers

- **Straight (single) fertilizers:** These supply only one primary nutrient (e.g., Nitrogen, Phosphorus or Potassium) to the crop.
    - Some examples: – Nitrogen: urea, ammonium sulfate, ammonium nitrate, calcium ammonium nitrate (CAN), and others.
        - 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 residual nutrients found after soil testing, the expected yield, and the type of fertilizer materials available.
- 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 should serve as a guide.

It is generally recommended to apply 120 kg N, 40 kg P_2O_5, and 40 kg of K_2O/ha. However, the appropriate rates of fertilizers will depend on the status of the soil nutrient content.

Time of application

Basal application of phosphorus (P) and potassium (K)

- Apply P and K within one week before 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.
- Nitrogen (N) – for chlorophyll component.

Topdressing 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.

Methods of fertilizer application

The fertilizer can be applied in two ways:

1. For small areas: in irrigated systems, close the irrigation inlet and drainage outlet. Then apply the fertilizer between rows. Irrigate and close the canals for about 10 days to facilitate nutrient absorption.
2. Drain the field and apply the fertilizer by broadcasting. The field should be flooded immediately to prevent de-nitrification.

Application of basal (a) and top-dressing (b) fertilizers by broadcasting. Photo credit: Charles Chiuwa/ ARI 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: Post-production

Overview

Harvesting is the process of collecting the mature rice crop from the field. Paddy harvesting activities include reaping, stacking, handling, threshing, cleaning, and hauling. These can be done individually or a combine harvester can be used to perform the operations simultaneously. It is important to apply good harvesting methods to be able to maximize grain yield, and minimize grain damage and quality deterioration.

In this module the issues of proper harvesting and post-harvest management are discussed. Currently rice productivity is still low owing to a number of constraints that face rice farming in general. One of the major constraints is the additional grain losses that farmers incur during and after harvesting. The purpose of this module is to create or awaken the awareness of farmers on this problem and discuss with them the better ways to tackle it so as to improve rice productivity.

Duration of Training: one day of 5-7 hours

Training materials

i. The training venue (a classroom or open space at site of demonstration when the crop is mature
ii. Knives/sickles
iii. Baskets/harvesting bags/sacks
iv. Mats/thick clothes
v. Weighing balance
vi. Grain moisture meter
vii. Pens and exercise books for participants to take notes.
viii. Field notebooks/data collecting forms

Harvesting rice by hand using sickles. Photo credit: Ibrahim Paul/ ARI Dakawa.

The importance of correct and timely harvesting
Rice must be harvested correctly and at the right time to reduce crop losses and ensure good quality of the harvested grain.

If the rice is harvested before it is well-matured the following will happen:

a) Pre-mature grain will not thresh well (remain on panicles).
b) It will need more time for drying to attain the optimum moisture level which will have additional cost implications.
c) There will be a lot of grain crashing (breakage) on milling.
d) Pre-mature grain rots or forms mold in storage, resulting in loss of quality

Rice crop at maturity stage. Photo credit: Charles Chuwa/ARI Dakawa.

With delayed harvesting

a. A lot of grain may be consumed by field pests (birds, rats, etc.).
b. There will be grain losses due to shattering.
c. Plant stems will weaken; plants will lodge and make harvesting difficult.
d. Grains over-dry and crack, causing a lot of breakage on milling.

It is therefore imperative that farmers confidently tell when the crop is mature and therefore determine the proper time to harvest.

The facilitator should brainstorm with participants to get their knowledge on the good indicators of rice crop maturity, and the proper time for harvesting.

They should expect participants to mention some or all of the following indicators:

- Straw changing color from green through yellow then to grey/brown (beware of straw senescing symptoms due to diseases).
- Mature drooping panicles normally turn brownish or greyish and seeds can easily be removed from the panicles when these are squeezed by hand.
- About 80-85% of grain on a panicle has changed color to grey/brown.
- Grain has attained the moisture content of 20-25%.
- Lapse of time of about 30 days after plants' heading.

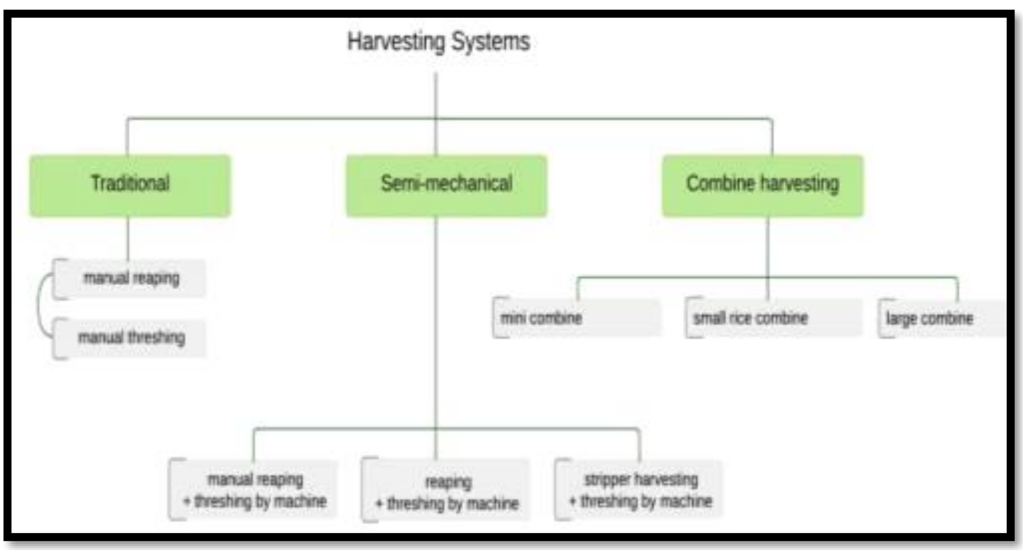
Necessary preparations prior to harvesting:

- Clean the field some few days before the crop fully matures to remove weeds and other rubbish that are potential contaminants and hindrances to proper harvesting.
- Ensure dryness of the field for easy and clean harvesting.
- Prepare harvesting tools or machinery, suitable areas for threshing (if applicable) and suitable facilities for transportation of the produce.
- Ensure that the plants are dry enough (are free from dew or raindrops) to ease harvesting.

Note: Harvesting can be done manually or mechanically (e.g., by combine harvesters).

Basic operations associated with harvesting
Harvesting rice consists of the basic operations which can be done in individual steps or in combination using a combine harvester.
Reaping - cutting the mature panicles and straw above ground

- **Threshing**- separating the paddy grain from the rest of cut crop
- **Cleaning** - removing immature, unfilled, non-grain materials
- **Hauling** - moving the cut crop to the threshing location
- **Field drying** - leaving the cut crop in the field and exposing it to the sun for drying *(optional)*
- **Stacking/piling** - temporarily storing the harvested crop in stacks or piles *(optional)*
- **Bagging** - putting the threshed grain in bags for transport and storage



Rice Harvesting systems. Photo credit: Sophia Kashenge/ ARI Dakawa.

Traditional harvesting activities such as field drying and stacking/piling are not recommended because they can lead to rapid quality deterioration and increased harvest losses.
Besides these, a variety of other activities can be included in harvesting such as gathering, reaping (gathering standing grain by cutting), bundling, and various forms of transporting the crop and grain

Procedure for manual harvesting
Manual harvesting involves two activities: cutting of rice straw and threshing to remove grains from panicles.

The facilitator should first demonstrate how to harvest and then engage the participants fully to accomplish harvesting. This activity will be done when taking yield data in the demo plots.

Cutting of rice straw
The activity will be accomplished by:

- Cutting rice straw at a convenient height above the ground (using sickles or knives) and piling them on threshing mats/thick clothes spread on a dry surface.
- Avoiding excessive shaking to minimize losses on shattering.

Threshing
The activity will be accomplished by:

- Holding a handful of straw by the base and beating it down at least three times to detach the grain from the panicles.
- Otherwise beating the panicles using a heavy stick to detach the grains.

Thresh preferably one day after cutting for easy detachment of the grain.

Rice threshing after cutting. Photo credit: Ndimubandi Mvukiye.

The harvested grain will have to undergo proper drying before it is processed for direct selling or milling. The grain should be packed and transported to the appropriate places.

NB: After threshing, the grain can be winnowed on the spot to reduce the amount of contaminants (chaff) before it is transported for further drying.

Rice harvesting by a combine harvester. Photo credit: Charles Chuwa/ ARI Dakawa.

Harvested rice in packs ready for transporting. Photo credit: Charles Chuwa/ ARI Dakawa.

Module 7: Post-harvest management

Overview

In the previous section we discussed issues of harvesting especially on how proper harvesting should be achieved so as to minimize the grain losses that occur due to improper harvesting and therefore to improve rice productivity. In this section, we discuss how to achieve proper post-harvest management of rice for the same purpose of minimizing grain losses and improving productivity.

The importance of proper post-harvest management is that it ensures and sustains the good quality of the rice for selling, milling, or storing. It also makes proper use of the rice production by-products. This not only contributes to increasing productivity but also reduces the possibility of imminent environmental pollution.

Duration of Training: 2 hours

Training materials:

a. The training venue (a classroom or open space at site of demonstration when the crop is mature
b. Mats/thick clothes
c. Weighing balance
d. Grain moisture meter
e. Pens and exercise books for participants to take notes

Drying and stirring rice grain for even drying (a) and transporting dried rice for storage (b).Photo credit: Charles Chuwa/ ARI Dakawa.

At the farm gate-level post-harvest management involves the drying, cleaning, and storage of the grain. It also involves the utilization of rice milling by-products (husks) and crop residues (straw).

Drying

Rice is usually harvested at 20-25% moisture content (MC) while 14% MC or less is considered safe for storage (for milling), 12% MC or less for storage of seeds. Paddy rice should be dried to a safe MC within 24 hours after harvesting to avoid damage and deterioration. Improper drying and storage practices lead to low grain or seed quality.

Drying is a process designed to reduce the MC to a level suitable for a planned purpose. Normally rice is produced for two purposes: for consumption (food for humans and animals) and for use as seeds (planting materials).

Farmers will therefore be advised to dry the grain in such a way that the product will be rice of the good quality that is preferred by consumers (when milled) or when used as good quality seeds for re-planting.

Grain quality issues associated with improper drying include the following:

a) Under-drying

Some problems related to incomplete or untimely drying or storage of paddy with a high MC are:

- Heat build-up from the natural respiration of stored, wet grain, particularly when it is stored in sacks in bulk. Heat will provide excellent growth conditions for molds, insects, and deteriorated quality.
- Molding that propagates diseases and may release toxins into the grain, making it unusable (unsafe) for use as food or livestock feed.
- Insect pest infestation in stored grain.
- Discoloration/yellowing of grain (as a result of heat build-up) that drastically reduces the market value of rice.

Grain discolored by molds. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

- Loss of germination and vigor of stored seeds as a result of active respiration of the grain during storage (that depletes the nutrition reserves required for germination or sprouting), molds, and diseases.
- Loss of freshness and development of musty (offensive) odor in rice due to insects, mold, or high humidity. This considerably reduces the market value.
- Reduced head rice yield as a result of the fissuring of rice kernels that develops either when wet grain is mixed with dry grain (in storage) or when dry grain is exposed to humid ambient air with a relatively higher humidity. Fissures in rice kernels usually lead to cracking during the milling process and thus reduce the head rice recovery.

b) Excessive drying

- unnecessary loss of weight which leads to reduced profit
- excessive breakage of rice kernels during milling.

Some points to note for effective rice grain drying
The MC of the rice grains at harvesting is still too high to for producing good quality rice on milling or even for storage. Therefore the farmer has to dry the crop either under the sun or in other suitable places until the MC reduces to 13-14% for milling or 10-12% for storage as seeds.

- Grain will dry better when dried slowly in moderate heat and air temperatures. Abrupt exposure to very high temperatures (e.g., the sun's heat at noon) for a long time causes fissures to develop from which the grain break on milling.
- Grain should be dried for not more than 3 hours a day in bright sunlight (hot sun). Thus about 4 days are required to dry rice to the optimum MC of 13-14% (for milling) or of 10-12% (if to be used as seeds).
- Better to avoid drying rice in dirty environments (e.g., with soil particles, pebbles, pieces of iron, etc.,) as they will deteriorate rice quality and affect the performance of milling machines.
- The grain should preferably be dried on mats, thick clothes, tarpaulins, or other similar materials.
- On the drying materials the grain should be spread in shallow layers (preferably less than 10 cm) and intermittently stirred (by dragging feet through the layers or by the use of rakes) so as to dry them uniformly.

Cleaning
- After drying, the grain must be winnowed to remove trash, pieces of straw, unfilled grains, and other contaminants.

A farmer winnowing rice using wind currents. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

Winnowing rice with a simple hand machine. Photo credit: Sophia Kashenge/ ARI Dakawa.

- After cleaning the grain should be packed in clean containers (sisal sacks, baskets etc.,) ready for milling or storage.

Storage:
Famers normally store rice either for future family consumption or for selling when the price is favorable. Farmers should note that a combination of excessive moisture and a dirty environment is a great enemy because it provides a fertile ground for breeding microbes such as fungi and bacteria which attack the grain and causes deterioration (i.e., grain rot or foul-colored moldy rice).

Rice sacks stacked on a raised platform in store. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

Some points to note for the effective storage of rice grain

- Rice grain should be stored in a safe and airy environment, free from contaminants. Normally a simple room with plenty of air openings and a leak-proof roof would serve as a good store (warehouse) for the common farmer.
- Sacks of grain should be arranged in stacks on a raised platform in the store. The arrangement allows air circulation.
- In case of the risk of damage by insect pests, the store should be fumigated with suitable pesticides before the grain is stored.

Proper utilization of rice milling by-products and crop residues
Rice milling by-products are husks and bran. Crop residues are rice straw.
There are two major types of residues of rice plants: rice husk and rice straw. In many rice production areas, rice husks and straw are considered a nuisance. Around rice milling facilities piles and heaps of rice husks are abundant. Currently the rice husks are being used mainly as fuel for burning mud bricks. At many rice milling facilities husks are just burned to ashes to get rid of them. The heavy smoke that results from burning becomes hazardous to the environment.

Straw that remains in the field after harvesting harbors some pests such as rodents and also hinders the proper operation of machinery during subsequent cultivation if left in piles.
Making proper use of the rice production by-products will, not only contribute to increasing productivity but also reduce the possibility of imminent environmental pollution.

Proper use of rice straw
1 t of rice paddy produces 290 kg rice straw
290 kg rice straw can produce 100 kWh of power
Calorific value = 2400 kcal/kg

As straight fertilizer:

- Chop the straw in small pieces and spread them evenly in the field and leave them to rot. They will release all their content in terms of plant nutrients.
- Spread it evenly in shallow layers and burn it so that burning doesn't also burn the soil and its inhabitants (beneficial microbes). This will release their phosphorus and potassium (plant nutrients).
- Chop the straw and use it to make compost (fertilizer).

As indirect fertilizer:

- Carry the straw to domestic animal pens. Some will be utilized as feed: some will be utilized as bedding. The combination of animal droppings and straw bedding will later form farmyard manure (fertilizer). The resulting manure should be applied to the field the following season.

Chopped rice straw and husks as bedding. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

Chopped rice straw as manure. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

Proper use of rice husks:
1 t of rice paddy produces 220 kg rice husks
1 t of rice husks is equivalent to 410-570 kWh electricity
Calorific value = 3000 kcal/kg
MC= 5-12%

Uses:

- Use the husks to make compost (fertilizer).
- Spread the husks evenly in the field and leave them to rot. They will release all their contents in terms of plant nutrients. They will also act as soil conditioners in problematic soils.
- Burn them to ashes in a safe place and carry the ashes to be spread in the field. The ash contains a lot of plant nutrients and can also raise the pH of acidic soils.
- Use them as mulching especially for upland crops. They will help to conserve soil moisture.
- Use them as beddings in animal pens. They provide necessary heat for the animals. They will later form good manure (fertilizer) for various crops.
- Use them as fuel. They burn excellently and provide energy for cooking food. However you will need to have special stoves.



Different cooking stoves using rice husks as fuel. Photo credit: Ndimubandi Mvukiye/ ARI Dakawa.

Proper use of rice bran:

- Use the rice bran as an ingredient in feeds for domestic animals (cattle, pigs, etc.)
- Bran also can make nutritious porridge (food).

Rice bran ready for utilization. Photo credit: Charles Chuwa/ ARI Dakawa.

Module 8: Cropping calendar

Overview

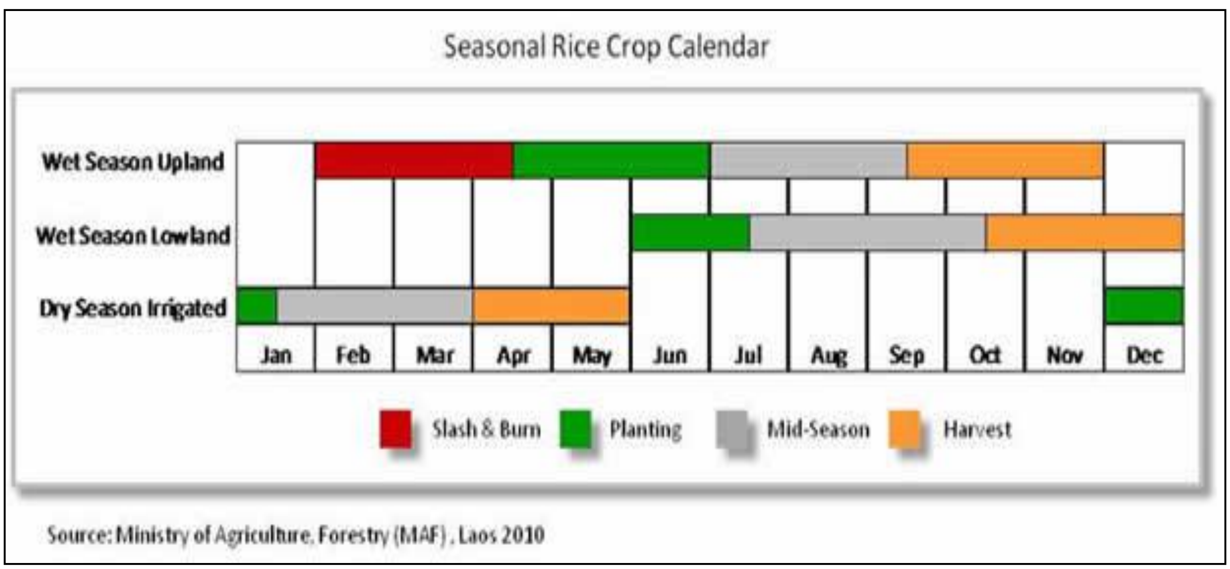
Using a cropping calendar allows better planning of all farm activities and the cost of production. A cropping calendar is a schedule of the rice growing season from the fallow period and land preparation to crop establishment and maintenance, and to harvest and storage.

In this section farmers will be taught the advantages of the farmers' cropping calendar as it allows a farmer to plan for input purchase and use, develop a cash flow budget for the year, determine credit needs and period required, determine labor requirements and plan for peak times of use and organize contractors for land preparation and harvesting.

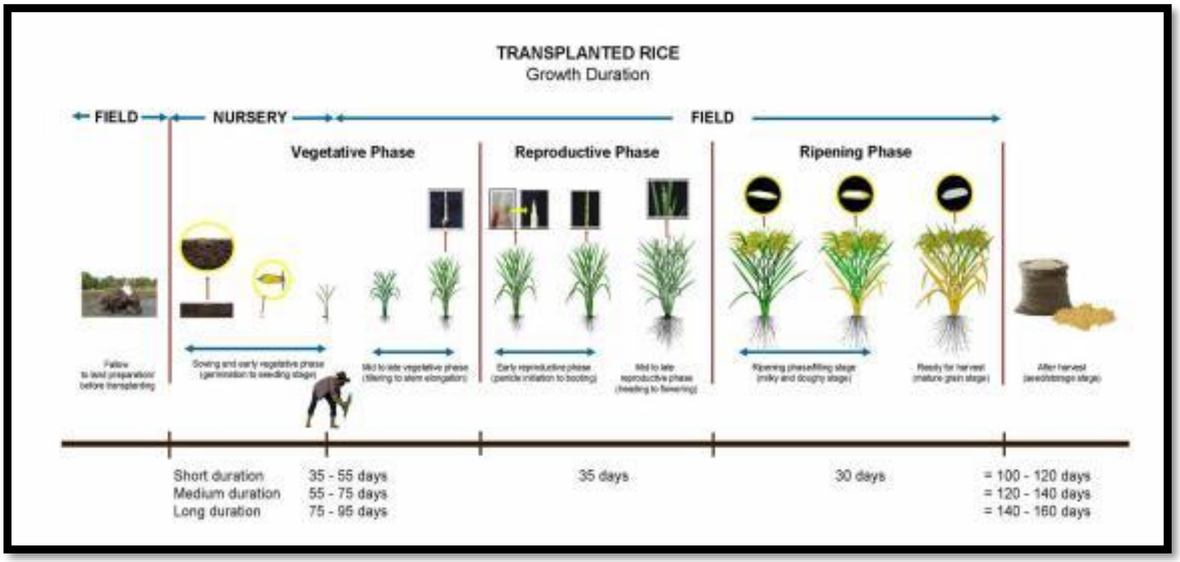
The calendar enables farmers to determine the best date to plant. This information can be gathered from local experience, agricultural advisors, and leading farmers in the district. They can bear in mind the time the variety takes from planting to harvest. The length of time is known for each variety. It may vary a little, depending on the growing conditions especially water availability and solar radiation. Normally short duration varieties take 100−120 days, medium duration 120−140 days, and long duration 160 days plus.

Procedures to make a crop calendar

- Mark on the calendar the date of planting and then when each other operation needs to be done (plowing, weeding, fertilizing, and harvesting).
- 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.



Example of a seasonal rice cropping calendar.



Rice crop growth phases and stages.

Module 9: Issues of salt-affected soils and rice productivity

Overview

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

In this module the issues of salt-affected soils and the effects on the productivity of rice in general are discussed. Currently the problem is increasingly threatening lowland rice productivity under both irrigated and lowland rain-fed ecosystems of our country. Recent report on soil characterization for salt-affected soils conducted in some major rice irrigation schemes in Tanzania reveals the huge extent of the problem. 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 who have been improved with huge amounts of money 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 solving the problem. Increasing famers' awareness on the presence and management of salt-affected soils is therefore a prerequisite to improved rice production in the country.

Duration of Training: One day of 5-7 hours

Training materials

i. Salt-affected demo sites.
ii. Samples of saline, sodic, and saline-sodic soils.
iii. Pictures/photos taken on sites that are seriously affected by the salts (case studies).
iv. 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 containing sodium ions 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. 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.

Sodic soils
These have salts in which sodium ions dominate over other cations (magnesium and calcium) and have higher amounts of insoluble carbonate anions. Their pH is generally higher (> 8.5) than in other types. 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.

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

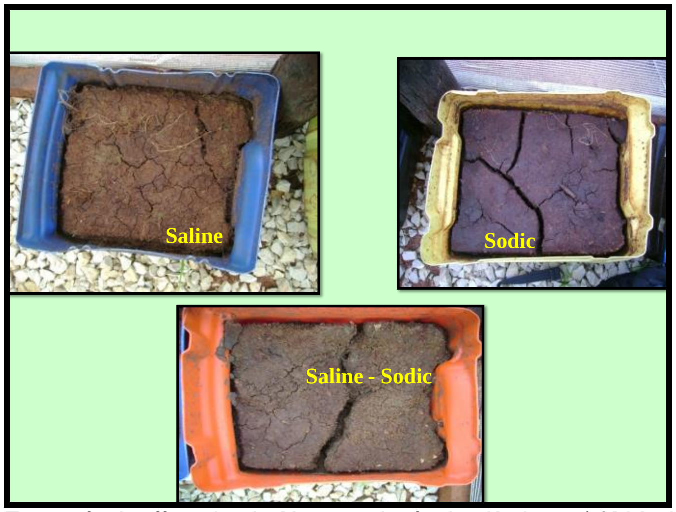
SODIC

SODIC

Appearance of saline and sodic soils and some indicator plants (salt bushes) for sodic soils. Photo credit: Sophia Kashenge/ ARI Dakawa.

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.



Types of salt-affected soils. Photo credit: Sophia Kashenge/ ARI Dakawa.

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 and leaves there when it evaporates.

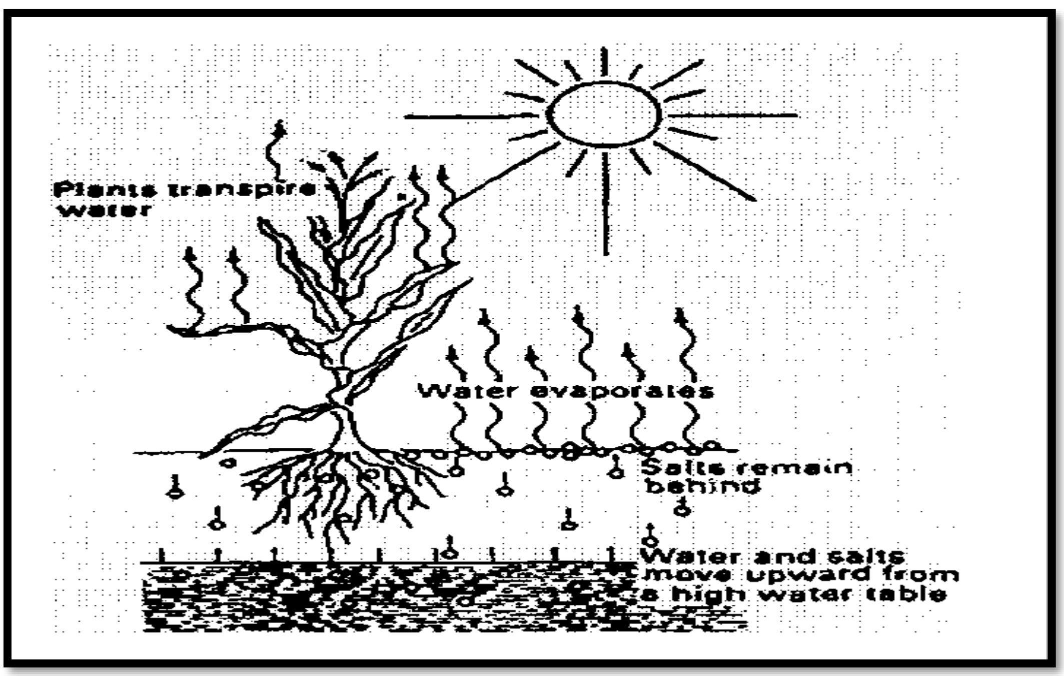


Diagram of the process of salt accumulation in the soil in aridic conditions (areas with less precipitation coupled with high evaporation). Photo credit: Sophia Kashenge/ ARI Dakawa.

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

How do salts affect growth and production of the rice crop?
Salt affects plant growth mainly through:

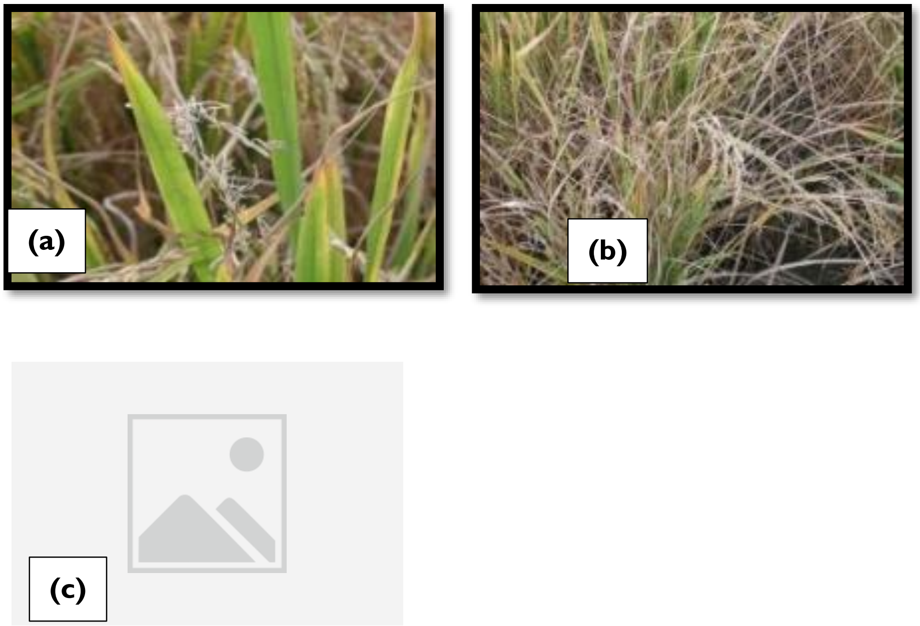
- toxicity from excessive uptake of salt substances such as sodium.
- reduction in water uptake (known as water stress) and loss of cell water (water withdrawn from the root) when the salt concentrations in the soil are higher than inside the root cells.
- reduction in uptake of essential nutrients particularly 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 saline on soils and rice plants
Farmers should be able to distinguish the symptoms of saline and sodic toxicity in the soils. Major symptoms of saline soils are as follows:

- Leaf dying from the tips (white leaf tip followed by tip “burning”)
- Poor germination
- Poor root growth
- Patchy growth in field
- Low tillering
- Change in flowering duration
- Leaf rolling
- White leaf blotches
- Spikelet sterility
- Few spikelets per panicle
- Light weight of grains
- In general, low grain yield
- Early plant death (extreme case)



Symptoms of rice affected by salts: (a & b) Leaf dying from the tips (tip "burning) and spikelet sterility (white spikes) and (c) poor plant stand (patchy growth).Photo credit: Sophia Kashenge/ ARI Dakawa.

Major symptoms of effects of sodic soils in rice plants

- Poor germination.
- Stunted plant growth (stems with shorter internodes).
- Poor root growth.
- Patchy growth in field.
- Change in flowering duration (late flowering).
- Plants become darker in color.
- Leaf browning and death.
- Spikelet sterility.
- Few spikelets per panicle.
- Lightweight grain.
- Generally, low grain yield.

Module 10: 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

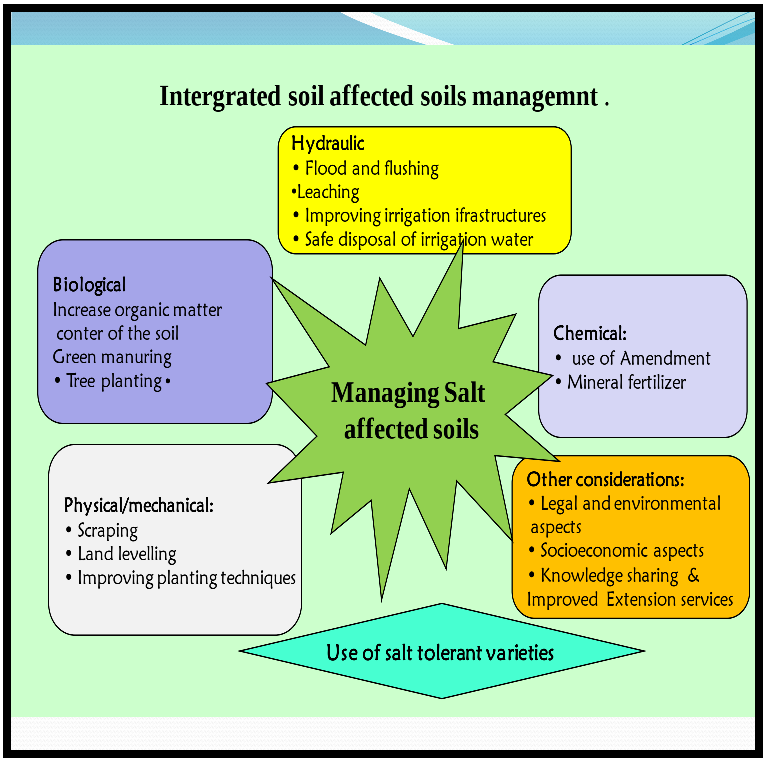
Training materials

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 (approaches) to manage saline-sodic soils

Mainly, an integrated approach is a feasible means to manage all types of salt-affected soils. This is a combination of different approaches depending on the existing salt problem.

The facilitator should explain the integrated approaches, zooming in 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.



The integrated (hybrid) approach model for managing salt-affected soils. Photo credit: Sophia Kashenge/ ARI Dakawa.

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

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.
- Monitoring the land and crop by observation and salinity checks.

Salt-tolerant varieties (left) and susceptible varieties (right). Photo credit: Sophia Kashenge/ ARI Dakawa.

Hybrid approach:

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

It should be emphasized that the hybrid 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 hybrid approaches.

The technology involves using 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.

Why might gypsum help?
Gypsum is calcium sulfate ($CaSO_4$) and is used for two reasons: 1) to improve soil structure on soils prone to crusting, hard-setting, and slow water infiltration and 2) as a good source of sulfur. Calcium sulfate can improve soil structure on heavy clays by making the soil aggregates more stable. The calcium in the gypsum replaces sodium on the surface of the clays which helps the clay particles to stay bound together when wet.

Description of the gypsum-based technology
Gypsum is evenly broadcast and soil-incorporated in a properly prepared field (well-leveled with bunds to retain water. 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 can be done 3-4 times to wash the soils.

Amount of gypsum to apply

Table 1: A guide to the rate of gypsum application required as affected by the exchangeable sodium percentage and pH of the soil.			
	Exchangeable sodium percentage	Gypsum application rate on alkaline soils (t/ha)	Gypsum application rate on acid soils (t/ha)
Slight Sodic	<6	1-2.5	0.5-1
Sodic	6-10	2.5-5	1-2.5
Extremely sodic	>15	5-10	5

Transplanting in saline-sodic 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 use gypsum 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. 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.

Why use farmyard manure?
Upon decaying in the soil farmyard manure releases some chemicals that help in breaking down sodium salts (and other salts) and renders them more soluble in the salt solution. In addition, farmyard manure releases humic substances that also flocculate the soil particles and make the soil more porous to the soil solution that carries the dissolved sodium ions away from the roots of the rice crop. Far-yard manure is also an organic fertilizer and helps to replenish some of the essential plant nutrients that are inevitably removed alongside salts when the soil is washed after gypsum has accomplished its task.

Farmyard manure also provides food for soil microbes that effect the mineralization of organic residues and fix atmospheric nitrogen. The result is improved availability of plant nutrients.

<u>Note:</u> 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.

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.

Why plant salt-tolerant rice varieties?
Even the so-called tolerant varieties do tolerate only some levels of soil salts. The soil can have higher salt levels so that even the known salt-tolerant varieties do succumb. Salt-tolerant varieties perform even better in soils that have been reclaimed than other varieties. On the other hand, relatively smaller amounts of salts need to be removed if the salt-tolerant varieties are to be planted since they flourish in comparatively higher salt level. The cost of ameliorating the soil is therefore reduced with the tolerant varieties.

Table 2: Rice varieties??

Variety (year of release)	Aroma	Agro-ecological system	Potential yield (t/ha)	Farmers yield (t/ha)	Yield under salt (Depending on salt levels) (ECe -5-7dS?mECE, SAR – 15-23)
TXD 306 *(2001)*	Semi aromatic	Rain-fed lowland and irrigated	6.0 – 7.0	4.5-5.5	0.6 – 3t/ha
Komboka (2012)	Semi aromatic	Rain-fed lowland and irrigated	5.0 – 6.2	3.5-4.0	0.3 -2.5t/ha
New SATO (2016) Salt tolerant	Non	Rain-fed lowland and irrigated	6.0 – 8.5	4.5-5.0	2 -4t/ha

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

Module 11: Improving rice productivity on calcaric soils

Overview

Calcaric soils, on the other hand, are soils that have been affected by calcium-based salts. Calcaric soils have often more than 15% $CaCO_3$ in the soil that may occur in various forms (powder, nodules, and crusts). The soils generally have low contents of organic matter, and nitrogen and phosphorus ions.

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

Soil characterization surveys conducted under iAGRI within USAID Feed-the-future program have indicated that some areas of Dakawa Irrigation scheme in Mvomero have calcaric soils. Farmers often confuse the symptoms with the effects of sodic soils.

The finding of the presence of calcaric 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. We feel 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.

Duration of Training: One day of 5-7 hours

Training materials

i) The training venue (a classroom and the rice fields near the demon 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.

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

The cause of $CaCO_3$ accumulation in soils

The main source of the salts is normally the underlying $CaCO_3$-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.

Patchy growth of rice in a calcareous soil at Dakawa Irrigation scheme, Mvomero district. Photo credit: Sophia Kashenge/ ARI Dakawa.

The issues with calcaric soils

- The affected soil has very high content of $CaCO_3$ soil (more than 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 calcaric soils

The best approach to manage the calcaric 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 technology (approach) of managing calcaric soils for rice productivity improvement:

A combination of acid-producing chemical fertilizers: Sulfate of Ammonia (SA) and Di-ammonium 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., TXD 306) 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.

Why is SA fertilizer preferred to Urea?

- SA fertilizer contains 2 essential (major) nutrients for the rice plants, nitrogen and sulfur which are not available or available only in little quantities in calcaric 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.

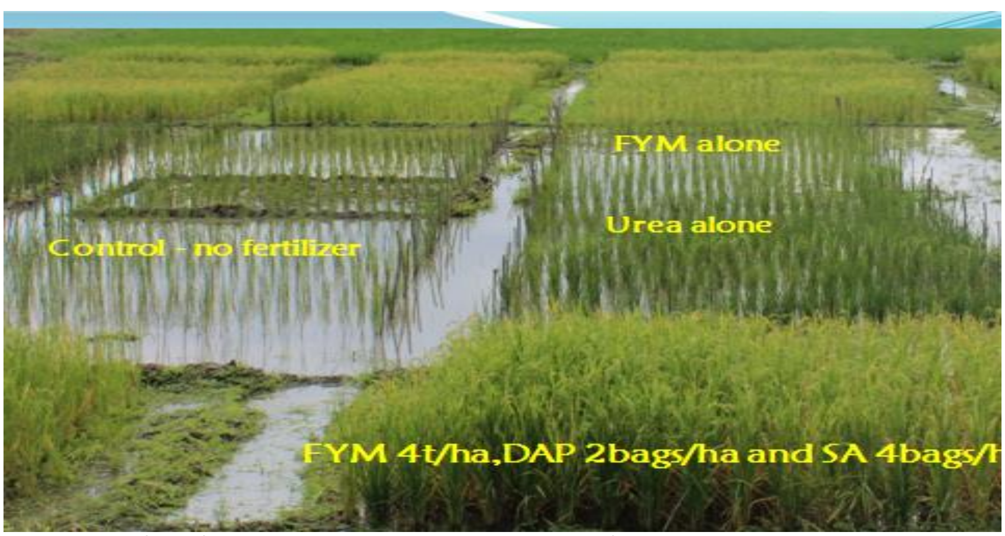
Why use farmyard manure?

- 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 fix atmospheric nitrogen. The result is improved availability of plant nutrients.

Why use DAP?

- 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.

<u>Note:</u> A combination of SA, DAP, and farmyard manure is more effective in improving the quality of calcaric soil than the use of any of them alone.



Appearance of rice field in an experiment on management of calcareous soil at Dakawa Irrigation scheme, Mvomero district. Photo credit: Sophia Kashenge/ ARI Dakawa.