RICE CULTIVATION MANUAL

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PREFACE

Based on accepted practices and latest verification of results from Rural Development Administration (RDA) of the Republic of Korea and Kenya Agricultural and Livestock Research Organization (KALRO) joint project on Rice Improvement (July 2012-June 2015) through Korea Project on International Agriculture (KOPIA), this manual covers rice cultivation with emphasis on best practices on rice cultivation that are cost effective and environmentally sound.

It provides information on nursery establishment, transplanting, spacing, fertilizer application and management of common pests and diseases in irrigated rice. The manual also covers best practices on rice post- harvest management, handling, value addition and utilization of food and non- food rice byproducts

We recommend this book to schools, students, extension workers and farmers and anyone working in rice who may wish to learn about rice cultivation.

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KOREA PROJECTS COORDINATOR
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1.0 THE RICE PLANT

The cultivated rice is an annual grass (Figure 1). Depending on the degree of sensitivity to light its growth duration may range from 60 to more than 200 days. Cultivated rice belongs to two species, *Oryza sativa* (which is more widely used) and *Oryza glaberrima*. Local names are, Swahili: mchele (milled and polished) / mpunga (paddy)

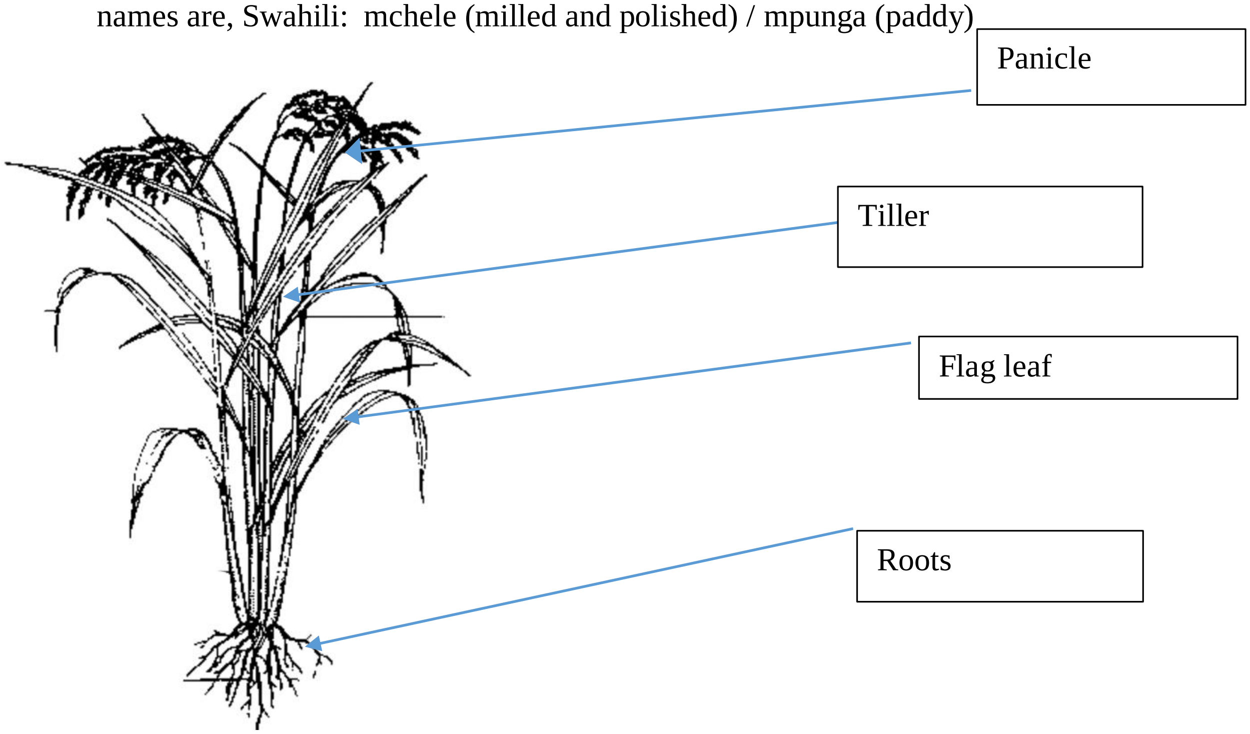

Figure 1: Parts of the rice plant

1.1 INTRODUCTION

In East Africa, rice is fast becoming an important food and cash crop with a per capita consumption range of 11 to 16 kg per person per year (USDA, 2010). In Kenya, the crop introduced in 1907, is grown in all rice production ecologies. National rice consumption is estimated at 300,000 metric tons compared to an annual production range of 45,000 to 80,000 metric tons. The deficit is met through imports whose value was KES 7 billion in 2008. The current rice production is estimated at 80,000 metric tons on about 20,000 hectares of land. This production meets only 16% of total demand which is expected to rise with increasing youth population and change in eating habits. Rice consumption is increasing at a rate of 12% annually as compared to 4% for wheat and 1% for maize.

Future increase in rice production will rely on improved yields, expanded area under production and reduction of field and storage losses. Currently rice is the third most important cereal crop after maize and wheat.

1.2 Agro-ecological Zones

The crop is grown by small-scale farmers for cash and food. In Kenya many areas are suitable for rice growing but low moisture and temperatures limit production (Figure 1). Rice production systems are classified according to ecology in terms of water as: (1) upland, (2) irrigated, (3) rain fed lowland, and (4) deep water (5) Systems of Rice Intensification, however 80% of rice production in Kenya comes from the irrigation schemes. The main schemes are Mwea (Central Kenya), West Kano, Ahero (Nyanza), Bunyala in Western Kenya, Hola and Bura irrigation schemes in Coast province under NIB (GOK, 2003). The remaining 20% is produced under rain fed conditions.

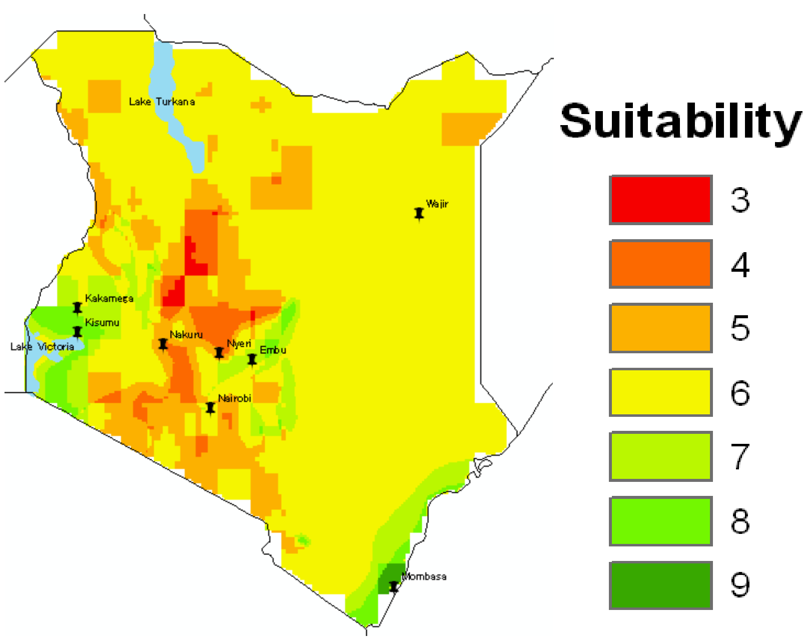

Figure 2: GIS map showing suitable areas for growing rice in Kenya on a scale of 1-9 with 9 being the most suitable.

1.3. Land preparation

1.3.1 under irrigation

This involves clearing the fields of weeds if fallow or stubble from previous harvest and then leveling. Animals are grazed in the harvested fields to trample and aerate the soils. Weeds are then slashed or gyro mowed and burned or incorporated in the soil. The fields may also be sprayed with non-selective herbicides. After which the weeds and stover from previous harvest are then ploughed in. In presence of adequate water, the fields are flooded to a depth of 10 cm and then cultivating them by use of tractor (40 to 75hp) equipped with rotavators. It is recommended that land should be tilled and immediately flooded at least 15 days before transplanting or direct sowing

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Figure 3: Burning the stubble in the rice fields at Mwea before flooding

Apply well decomposed manure before rotavation.

Flood for 2-3 days and then dig or rotavate. After flooding maintain the water above ground level (2-5cm).

Figure 4: Digging a flooded field at Mwea

The paddy fields are also puddled and then leveled before transplanting or direct seeding. This involves burying in the uprooted weeds in the wet soils and then leveling by using a tractor or ox-drawn leveler of which timber with spikes can be used. Poor and untimely land preparation cause serious weed problems and expose plants to harmful substances such as carbon dioxide and butyric acid, released by decaying organic matter in the soil.

Figure 5: A paddy field at Mwea being puddled

1.3.2 Rain fed rice cultivation

For this system, land is prepared before the onset of rains. The land is ploughed once and harrowed twice.

1.4 Rice Cultivars

There are a range of rice cultivars in Kenya with three of them Sindano, Basmati 217 and Basmati370 having been grown since the 1960s. "Sindano" is highly susceptible to Rice Yellow Mottle Virus (RYMV) and Basmati 217 and Basmati 370 are highly susceptible to blast and stem borers. A seed system has been developed and breeding is going on for alternative varieties of both irrigated and rain fed rice.

1.4.1 Variety and Seed selection

A good variety should have:

- Suitable grain quality (especially cooking characteristics, color, shape, taste and aroma, and head rice recovery) and be acceptable to farmers and the local market at a price that is acceptable to farmers.
- Adequate yield potential and stability over seasons.
- Resistance to major diseases and insects, and/or tolerance to local abiotic stresses (drought and flood, for example).
- Duration of growth that matches the season. Avoid varieties that need to be planted or harvested early or late compared to other rice fields in the surrounding area. Crops of inappropriate duration can result in:
- Increased attack from pests (for example, attack from birds during maturation), or growth problems when environmental conditions are bad (for example, late-maturing varieties may not get enough water).
- Adequate tillering capacity to shade out weeds and produce enough tillers for optimum yields.
- Resistance to lodging (falling over) under normal farm management.

1.4.2 Seed selection, Nursery establishment, land preparation and transplanting

1.4.3 Choice of seed

Use good quality seeds with no insect damage and no contaminants (weed seeds, stones, other seed types) with high percentage of viability (>80%).

1.4.4 Seed viability

Use filled grains of good quality seed. Add water to the seeds and discard all the floating seeds. When soaking seeds change water regularly to allow for oxygen supply.

To estimate percentage filled grains, select at random 100 seeds from the seed lots to be sown. Count the number of filled grains. If it is 100 then the filled grains % is 100.

When the seed viability is unknown it is important to carry out a simple germination test. Take 100 seeds randomly from the seed lot. Put them on moistened wood shavings, newsprint or carbonized rice husk and incubate for 7-10 days to allow for germination. Express the number of germinating seedlings as a percentage using the following formula;

(Number of seeds germinating/Total number of seeds) x100

If 80 seeds germinate it means that Germination percentage is 80%. Ideally a good seed lot should have more than 95% germination.

1.4.5 Seed rate

Seed required if the seed rate is 80kg/ha and germination is 80%

Seed required (kg/ha) = (seed rate (kg/ha) x Area to be planted/% germination) x % filled grains. We assume % filled grains to be 100%

Seed rate= (80kg/hax1 ha/0.80) x 1 Assuming 100% germination

= 100kg/ha

1.4.6 Seed dormancy

Dormancy is the failure of good quality mature seeds to germinate under favorable conditions. Dormancy of freshly harvested seed should be broken by using heat treatment at 50°C in an oven if available or by placing the seeds on a plastic sheet and covering with itself or another under direct sunlight for 1 or 2 days. Acid treatment may also be used.

Acid treatment: soak seeds for 16 to 24 hours in 6 ml of concentrated nitric acid (69% HNO_3) per liter of water for every 1kg of newly-harvested seeds. After soaking, drain acid solution off and sun-dry the seeds for 3 to 5 days to a moisture content of 14% and the store in dry conditions for sowing. Conduct germination test on seeds to establish rates to use based on seed viability. Hot water treatment: Soak seeds at 60 degrees Celsius for 15 minutes. This kills disease pathogens that might be on the seed surface

Sow healthy certified seeds. Apply carbonized rice husks (biochar) to minimize root damage during transplanting. Use a seed rate for the nursery should be 100 g/m2. Minimize or avoid applying fertilizer in the nursery

1.5 Types of rice nurseries

There are five types of a rice nursery; wet, Dapog, dry, or mat, hymeric and bubble trays.

1.5.1 Wet-bed Nursery

This is the most common in lowland irrigated rice production system. Locate the seedbed away from electric light in a fertile field that is easy to irrigate and drain. Irrigate, plow, puddle and level the field. Start preparing the seedbed 2 weeks before planting time and add organic manures and/or fertilizers. Prepare beds of 1 to 1.5 m width, 4-5 cm height and any convenient length. Pre-germinate the seeds 2 days before sowing: 24 h soaking & 24 h incubation. Sow the pre-germinated seeds on beds. About 50 kg of seed sown in 500 m2 of seedbed area is required to transplant one hectare of main field.

Figure 5: Wet nursery at Mwea

1.5.2 Dapog or mat nursery

This is just like the wet nursery but here the seeds are sown on plastic or banana leaves and this can be rolled up and be transported to the transplant fields. The seedlings from these nurseries are preferred for mechanical transplanting, it is easy transport of seedling-mats to main field, take shorter period of raising seedlings, and requires less labour for weeding and watering than the wet nursery.

Method

Select a level area near the household and/or a water source

Mark out 1 m wide and 10 to 20 m long plots

Spread a plastic sheet or banana leaves on the marked area

Form the boundary with bamboo splits or banana sheath

25kg of seed sown in 60-75 m^2 area is enough to plant one ha of main field. Alternatively pre-germinated seed can be spread on the mats at the rate of 1 kg per 1.5 m2 area

Sprinkle water immediately after sowing and then as and when needed

Protect the mat nursery from heavy rains for the first 5 DAS

Seedlings will be ready for sowing in 8 to 15 DAS

Roll out the seedling mats and transport them to the main field

1.5.3 Dry-bed Nursery

This has recently become important as a result of the introduction of upland rice varieties especially Duorado precoce and the NERICAs. Compute the seed and seedbed area: 50 kg seed and 500 m^2 seedbed area for transplanting one hectare of main field .Locate the seedbed away from electric light in a fertile field with light soil and easy access to a water source and. Start preparing the seedbed 2 weeks before planting time. Add enough organic manures / fertilizers in the beds. Prime the seeds and sow the primed seeds on raised beds and cover the seed lightly with soil or rice husks. Water the seedbed till saturation after sowing. Then water the bed periodically as seedlings emerge and grow. Amount of water supplied can also be regulated to control the rate of seedling growth. Seedling are ready to transplant at 25-30 DAS

Figure 6: Dry nursery

1.5.4. Hymeric nursery

This is like for a wet nursery, however carbonized rice husks (bio-char) is used as a substrate instead of soil. This is particularly important if the seeds are to be broadcasted. Use bio-char to pre-germinate the seeds and then plant in 5-10 days. This reduces labor cost for transplanting. This results in higher establishment rate and is a better way to raise NERICA rice varieties, however germination rate for Basmati 370 has been reported to be low.

Figure 7: Rice seedlings raised on carbonized husks

Source: Tamotsu SEIJI, JICA, 2012

1.5.5 Bubble tray nursery

Seedlings are raised on plastic trays of Size: 59 cm x 34 cm with 434 embedded holes. The requirements to plant on hectares is 750 trays and a seed bed area of 250 m^2 . The nursery can be in uplands, lowlands or near the house. In lowlands, 75 cm wide and 9-12 cm high seed beds are used. The seed rate to plant one hectare is 15-20kgs.

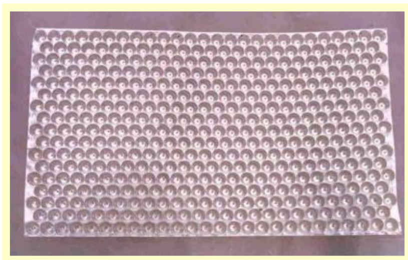
 Plastic bubble tray with seedling wells	 Seedlings from bubble tray with root balls

Figure 8: A bubble tray nursery (250ms for I ha)

Table 1: Area, seed rate and optimum age of seedlings in different nursery types

Nursery type	To plant 1 ha of main field		
	Nursery area m2	Seed rate kg/ha	Optimum seedling age(days)
Wet bed	400-500m2	50	20-25
Dry bed	500	50	25-30
Dapog(mat)	60-75	9-25	8-15
Hymeric	400-500m2	50	20-25
Bubble tray	250	15-20	12-15

Establish nursery two weeks before sowing

The nursery should be well leveled nursery, 1.0-1.2m in width and convenient length

Properly puddle the nursery preferably with well decomposed manure

Do seed water selection: Put seeds in a container and cover with water and decant the floating ones. Only plant seeds that sink and remain at the bottom of the container and remove the floating week seeds

Hot water treatment: Soak seeds at 60 degrees Celsius for 15 minutes. This kills disease pathogens that might be on the seed surface

Sow healthy certified seeds. Apply carbonized rice husks (biochar) to minimize root damage during transplanting.

Seed rate for the nursery should be 100 g/m2.

Minimize or avoid applying fertilizer in the nursery

Handpick and destroy rolled leaves which is an indication of Rice hispa and Stem borer attack in the nursery. Proper nursery management is important as this will ensure healthy and robust seedlings.

Effect of plant spacing & seedling number per hill on initial plant count and required tillers per plant

Seedling number per hill	Plant count per m² at transplanting	Needed tillers per plant	
		Dry season	Wet season
20 x 15 cm or 30 x 10 cm spacing			
1	30	20	14
2	60	10	7
3	90	6.5	4.5
4	120	5	3.5
20 x 20 cm spacing			
1	25	24	16
2	50	12	8
3	75	8	5.5
4	100	6	4
30 x 30 cm spacing (SRI)			
1	11	55	36
2	22	27	18
3	33	18	12
4	44	14	9

Figure 9: Spacing and tillering

Source: Balasubramanian IRRI, 1998

2.0 SEEDING/SOWING

2.1 Direct seeding/sowing

Direct seeding ensures that optimum plant population is maintained, allows the rice crop to establish on time and reduces labour input and drudgery. However it requires good land preparation and levelling, furrows to drain water, saturated soil for wet direct seeding (WDS) or moist soil for first 7-10 days for dry direct seeding (DDS). Suitable varieties are those that have early seedling vigor, fast canopy development and are non-lodging. Quality seed is also required and effective weed control whether cultural, mechanical, or use of herbicides is a must.

Figure 10: Leveled fields

Source: Balasubramanian IRRI, 1998

Method

Prepare land the normal way and rotavate and level. Drain the field before drilling

Pre- soak the seeds the same as for transplanting

Drill seed in lines or use a drum seeder

Maturity will be earlier in 2-3 weeks

Weed regularly and one may use selective herbicides

Advantages of direct seeding

Faster and easier crop establishment and reduced costs

Less labor need (1-2 vs. 25-30 for TP)

Earlier crop maturity by 7-10 days

More efficient water use and higher tolerance to water stress

Less methane emission

Figure 11: Drum seeder

Source: Balasubramanian IRRI, 1998

2.2 Transplanting

Transplant at 5th leaf stage 15 days after sowing

Seedlings must be handled carefully to avoid breakage and ensure fast revival and early growth after transplanting. Shallow transplanting at 1-2 cm depth is recommended. Optimum plant-to-plant spacing should be 20 x 20 cm to 25 x 25 cm and the optimum number of seedlings is 1-2 hill-1

Avoid over elongated sprouted seeds due to breaking and slowed growth.

Spacing should be 30cm*15cm for mechanical weeding or 25cm*15cm or 15cm*15cm for low tillering varieties like Basmati 370. Irrigate after transplanting at a depth of 2-5cm.

Clip the top of seedlings before transplanting to reduce the carry-over of stem borer and rice hispa eggs from the nursery to the main rice field. Avoid transplanting young seedlings and standing water in rice fields to manage rice caseworm. Plant in lines and use a guide rope during transplanting (Figure 12)

Figure 12: Planting in lines using a guide rope at Mwea

Optimum number of rice plants is obtained in fields where rice has been transplanted in lines and it is also possible to use mechanical weeders.

Figure 13: Rice transplanted in lines in a field at Mwea

2.3 Main field water management

Water is applied to the rice field for use by the rice plant and also for suppressing weed growth. Worldwide, water for agriculture is getting increasingly scarce. By 2025, 15-20 million hectares of irrigated rice may suffer water scarcity. In Mwea water was also rated as the number one rice yield constraints. Therefore, care must be taken to use water wisely and reduce water losses from rice fields. For this reason, it is important to practice appropriate water management throughout the growing period of a rice crop. In lowland rice fields, water comes from rainfall and irrigation. Water is lost by transpiration, evaporation, seepage and percolation.

This loss can be avoided through repairing levees to minimize seepage, removal of weeds to avoid competition with rice plants for water and increasing the height of levees to prevent surface run-off water. The critical stages when water is required in large quantities are:

For a period of three to seven days after transplanting cover the crop up to 80% of its height. This reduces transpiration and gives the plants a chance to re-establish their roots to be able to take up enough water from the soil. From the stage of booting to 14 days after heading, more water is required because the shedding of pollen and the process of fertilization requires very high moisture content in the air. Low moisture content in the air leads to sterile spikelets. Seven to ten days before harvesting, drain the field to harden the soil for good harvesting and also to hasten the drying and ripening of the rice grains.

WATER REQUIREMENT OF RICE CROP AT DIFFERENT GROWTH STAGES		
Stages of growth	Avg. water requirement (mm)	% of total water requirement (approx.)
Nursery	50-60	5
Main field preparation	200-250	20
Planting to Panicle initiation (PI)	400-550	40
P.I to flowering	400-450	30
flowering to maturity	100-150	5
Total	**1200-1460**	**100**

Figure 14: Water management

Source: Tamotsu SEIJI, JICA, 2012

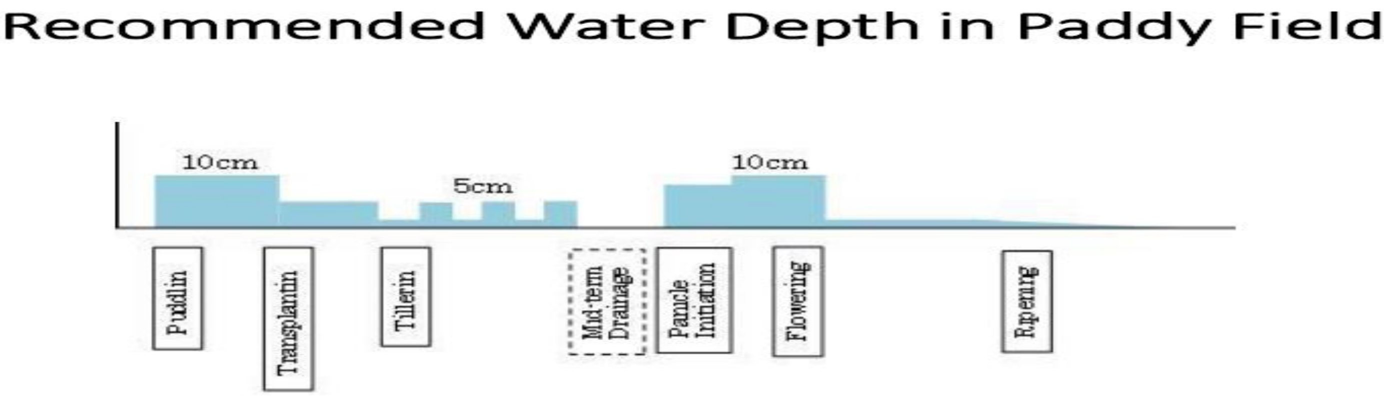
Generally, there are two main methods of water management in irrigated rice culture namely: continuous flooding(CF) and alternate wetting and drying (SRI). Under continuous flooding (CF), you constantly maintain a water level of 2 to 5 cm in the field. Water is added when the depth 2 cm is reached. Irrigation is stopped at 10-15 days before harvest.

Under alternate wetting and drying (SRI) – Water is added to a depth of 2-5 cm but only after the fields have been dry for 2-7 days. This method saves about 50% water.

The two methods give rice yields that are not significantly different. Consequently, SRI can be adopted without any yield compromise. It is can be used where irrigation water is a constraint.

2.4 Systems for rice intensification (SRI)

The system of rice intensification (SRI) is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients (Uphoff 2007). This system was first started in Madagascar in 1960 but is now commonly practiced in paddy rice fields in Tamil Nadu in India. Basically it involves intermittent drying and wetting or alternate flooding and wetting of the rice fields unlike the conventional method where the fields are permanently under water. The seedlings are transplanted early, little water is used and the paddy is planted with more spacing which makes it even easier to weed. “With the new system,



the paddy is transplanted after eight to 14 days in the nursery. This makes the seedlings adapt to the new environment early and make use of all the nutrients in the soil,” SRI technology does not require a lot of water like in the conventional way of paddy cultivation because small amount is sprinkled at intervals to the field to allow free circulation of air to the crops.

. Figure 15: Water management

Source: Tamotsu SEIJI, JICA, 2012

Apply basal fertilizers 1-1.5 bags TSP per acre. Apply 0.5-1 bag MOP per acre. Avoid excessive nitrogen application

3.0 WEED CONTROL

3.1 Introduction

Weeds can singly reduce grain yields of rice by 30 – 80% depending on cropping system and cultures. Weeds compete with crops for moisture, nutrients and space and reduce grain yields by 83% or even 100% in rain fed rice cultures. In rice based cropping systems weeds can come from plants associated with crops or from the seed.

3.2 Why control weeds

Weeds causes yield loss and lowers rice quality. They are also a nuisance to human and implements while some are poisonous and also allelopathic.

3.3.1 Weed control methods

Tillage

Hand weeding

Herbicides

Cultural - Crop rotation

Burning

3.3.2 Integrated Weed Management

Try to avoid weed problems by using weed free seeds at planting.

Properly manage farm implements and livestock. Keeping bunds (levees) and irrigation canals free of weeds prevents seeding of weeds in the field and spread of perennial weeds that reproduce vegetatively. Weeding is done manually by hand hoe at least 2 times at 20 & 50 days after sowing (DAS). Problematic weeds in irrigated rice include, *Echinochloa spp*., Black jack, Sedges and *Digitaria spp.* It is important to note that several methods of weed control may not singly and adequately smother weeds. For example hand weeding can be relatively ineffective, particularly in controlling many of the perennial weeds that have underground tubers and rhizomes from which they can rapidly re-establish (e.g. Cyperus spp.). The problem of weeds in rice is exacerbated by delayed and poor land preparation as well as inefficient weeding associated with broadcast sowing, random transplanting and inappropriate agricultural implements for mechanical control. Various weed types associated with rice require use of a combination of two or even five control methods that kill different types of weeds. Integrated management entails application of varied methods among them use tolerant rice cultivars, hand weeding, cultural practices, herbicides and a combination of some or all of these methods sustainably control weeds in rice. Towards this end, new broad spectrum herbicides have been tested and found suitable for rice weed management. Additionally, a walk behind rotary weeder has been designed and used in paddy fields and in SRI. Plant at spacing that allow mechanization to allow rice weed management.

As a rule of thumb, it is always important to keep rice paddies weed free. Weeding should be done every 2 weeks if a rotary weeder is used or 2-3 times during the season. Where herbicides (e.g. Dicopur, Satonil) are to be used commercial rates should apply. Read the label well before use and seek advice from relevant service providers if need be. Apply nitrogen in 3 splits – basal, tillering and at panicle initiation and encourage cover of Azolla to control whorl maggots and leaf miners.

4.0 RICE NUTRITION

4.1 Introduction

Plants require at least 16 elements for normal growth and for completion of their life cycle. Those used in the largest amounts, carbon (C), hydrogen (H) and oxygen (O), are non-mineral elements supplied by air and water. The other 13 elements are taken up by plants only in mineral form from the soil or must be added as fertilizers. Plants need relatively large amounts of nitrogen (N), phosphorus (P), and potassium (K). These nutrients are referred to as primary nutrients, and are the ones most frequently supplied to plants in fertilizers. The three secondary elements, calcium (Ca), magnesium (Mg), and sulfur (S), are required in smaller amounts than the primary nutrients. Calcium and Mg are usually supplied with liming materials, and S with fertilizer materials.

The micronutrients consist of seven essential elements: boron (Bo), copper (Cu), chlorine Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). These elements occur in very small amounts in both soils and plants, but their role is equally as important as the primary or secondary nutrients. A deficiency of one or more of the micronutrients can lead to severe depression in growth, yield, and crop quality. Some soils do not contain sufficient amounts of these nutrients to meet the plant's requirements for rapid growth and good production. In such cases, supplemental micronutrient applications in the form of commercial fertilizers or foliar sprays must be made.

Thus the soil supplies 13 of the 15 elements required for nutrition of higher plants. These elements must be available, continuously, and in balanced proportions to support photosynthesis and other metabolic processes of plants. If any one of these essential elements is missing, plant productivity will be limited, or the plant may cease to grow entirely. The principle of limiting factors, which states that the level of production can be no greater than that allowed by the most limiting of the essential plant growth factor, applies in both cropping systems and in natural ecosystems. Soils are tested chemically to assess the level of available plant nutrients.

Soil fertility is the quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants." (Brady and Weil, 1999 - The Nature and Properties of Soils).

4.2. Soil Fertility and Fertilizer recommendations

Soil testing for Mwea irrigation scheme conducted in 2012 revealed deficiency of the major and some trace plant nutrients in varying degrees. Majority of the soils were within the optimal soil pH above 5.5 except 5.5% which were just around the border line while about 45% of the soils had low organic carbon. 83% of the soils had plant deficient levels of Zn whilst about 32% soils were N deficient. The most widely deficient plant nutrient was potassium in approximately 100% of soils. Phosphorus was deficient in about 30% of the soils. Some of the nutrient levels are shown in Fig. 1 below. The deficient nutrients may be limiting rice productivity in various rice fields. Based on these results and agronomic trials conducted for the last three years, the following fertilizer recommendations were made.

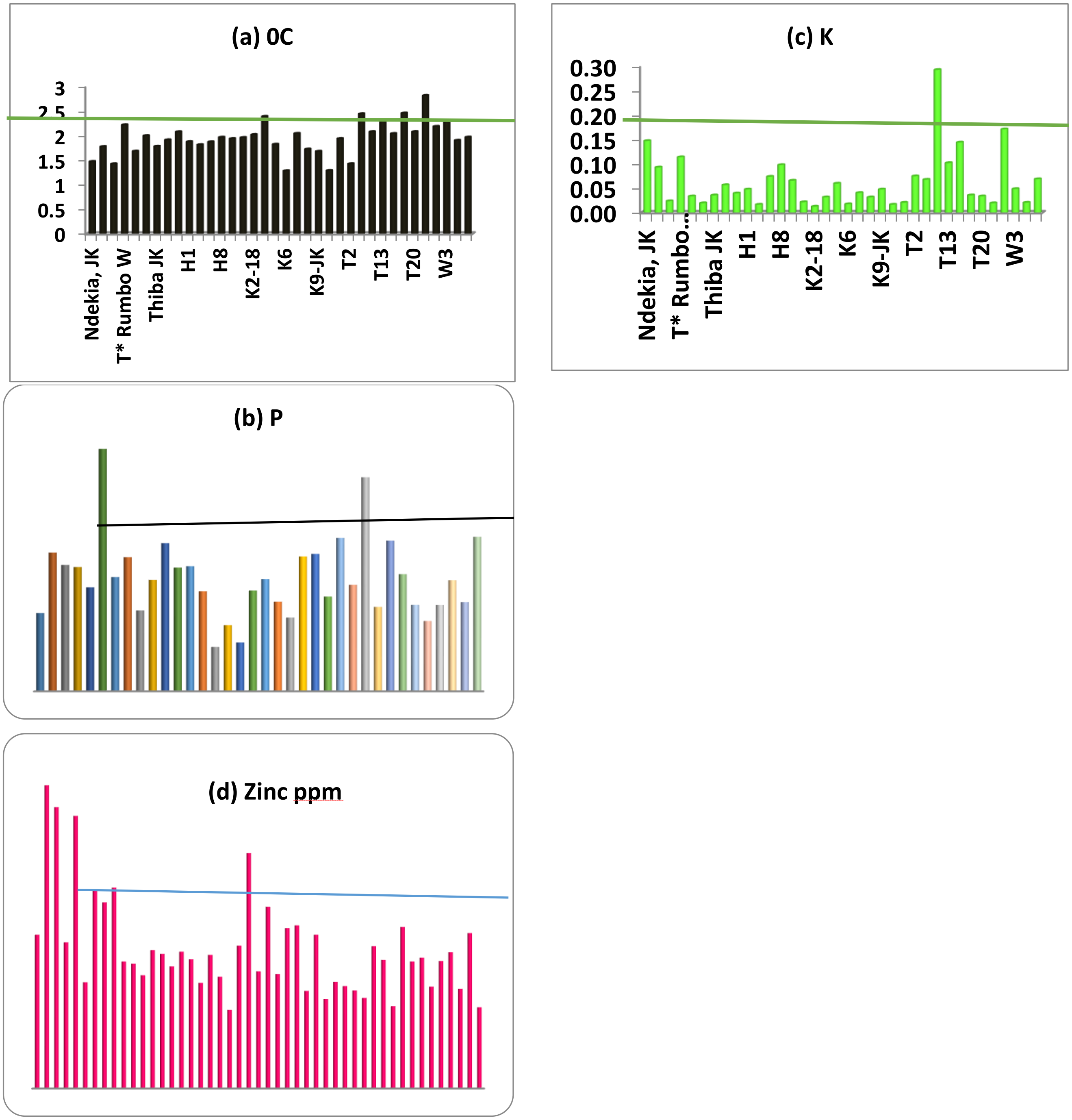


Figure 16: levels of available nutrients, organic carbon, phosphorus, Potassium and zinc respectively

Fig 16: a, b, c, and d shows the levels of available nutrients, organic carbon, phosphorus, Potassium and zinc respectively

The horizontal lines indicate the critical nutrient levels required implying and soils below the line are deficient of particular nutrient.

4.3 Fertilizers

Fertilizers can be applied in organic or inorganic (mineral) forms or both.

Fertilizer should be applied based on the residual nutrients in the soil from soil test results, the expected yield and the type of fertilizer materials available.

The farmer should strive to obtain fertilizer recommendations based on analysis of soil. Soil analysis is recommended after every 4 years and soil testing can be done at KALRO-Kabete. Soil sampling should be done with the help of agricultural extension staff in order to ensure a representative sample is taken. The samples can be sent to KALRO-Kabete through KALRO-Mwea.

4.4. General recommendations:

Nitrogenous fertilizer: The fertilizer commonly used in Mwea is Sulphate of Ammonia (21%N) and should be applied at 3-4 bags/acre in 2 equal splits, i.e. 1.5-2 bags/acre in the first split and a similar amount in the second split. The first split should be applied at 21 days after transplanting (DAT) and the second split should be applied at booting stage (45 DAT). The rates depend on the variety grown and the soil test results. Generally, basmati requires less Nitrogen fertilizer than BW.

Phosphatic fertilizer: Triple superphoshate (TSP with 48% P) is the recommended phosphatic fertilizer for rice. It should be applied at planting at a rate of 1-2 bags /acre depending on soil test phosphorus (P) levels.

Potash fertilizer: Murriate of potash (60%K2O) should be applied at 1 bag/acre at planting.

Zinc fertilizer: Apply Zinc sulphate should be applied at 12 kg/acre by broadcasting before planting. This should be repeated after every 2 seasons.

4.5 Integrated Nutrient management

Is has been shown that integrated nutrient sources including organic and inorganic give higher and more sustainable yields than inorganic fertilizers alone. It is therefore recommended to integrate the following;

½ the inorganic fertilizer + 2 tons/acre cattle manure

Fertilizer full rate + 2 tons/acre Rice husk powder or rice husk charcoal

Table 2: Summary of Fertilizer recommendations.

Nutrient	Recommended rate (kg nutrient/ha)	Fertilizer source	Rate (bags/acre)
Nitrogen	80 - 100 N	Ammonium Sulphate – 21% N	3 – 4 bags SA
Nitrogen	80-100 N	Ammonium sulphate nitrate (ASN)-26%N	2.5 – 3 bags ASN
Phosphorus	50-100 P2O5	Triple Superphosphate (TSP) – 48% P2O5	1 - 2 bags TSP
Potassium	50 K2O	Muriate of Potash (MOP)	1 bag MOP
Zinc	30 kg Zinc Sulphate	Zinc sulphate	12 kg Zinc Sulphate

4.6 Time of application

Apply P, K and Zinc at by broadcasting just before planting

Apply 1st split N (1 ½ -2 bags SA/acre) at 21 days after sowing

Apply 2nd split N (1 ½-2 bags SA/acre) at 45 days after sowing

Use of colour chart to guide Nitrogen Topdressing

When a leaf colour chart (LCC) is available. It should be used to guide topdressing when N deficiency is observed in the field.

Use LCC from the beginning of tillering (20 DAT) and take readings once every 7-10 days

Use the uppermost fully expanded leaf which best reflects the N status of rice. Take readings of 10 leaves randomly selected from hills. If colour is ≤ 3, topdressing is necessary.

NB: Always shade the leaf being measured with the body and measurements should be taken roughly same time of the day by the same person.

4.6 Some common Nutrient deficiency symptoms

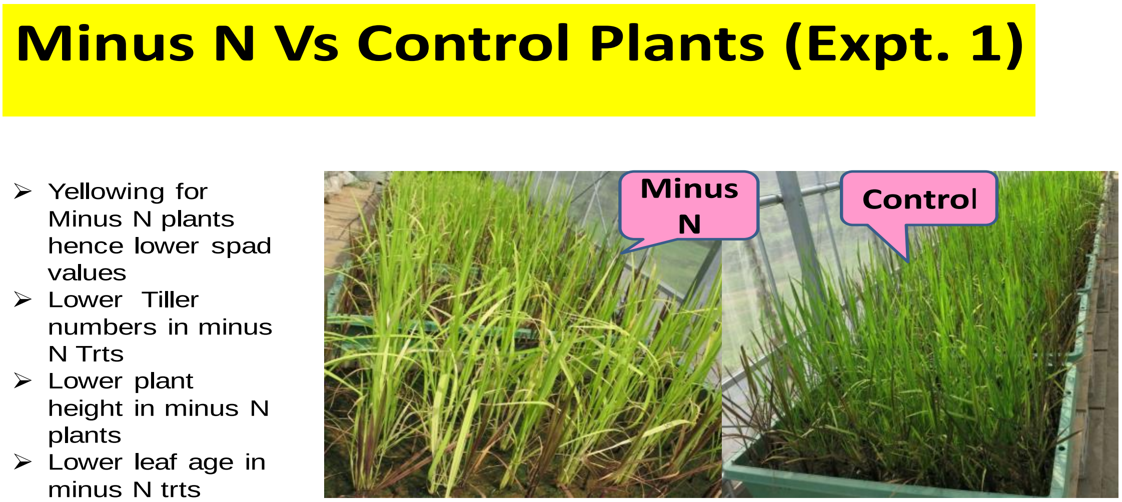


Figure 17: Nitrogen deficiency symptoms

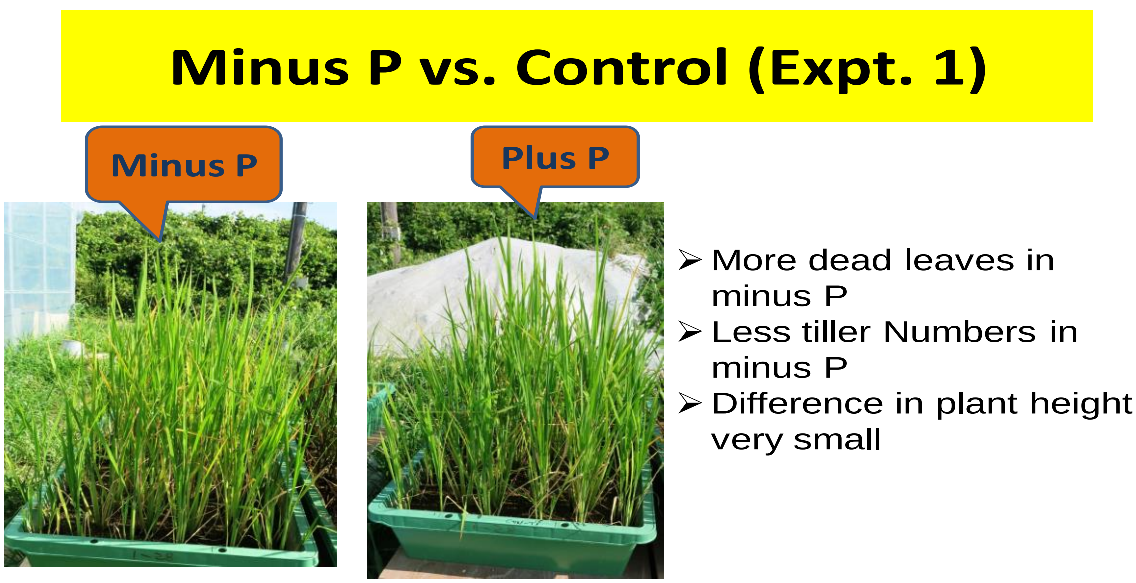


Figure 18: Phosphorus deficiency symptoms

Figure 19: Zinc deficiency symptoms

Figure 20: Potassium deficiency symptoms

4.7 Correcting common deficiencies

To correct iron deficiency

When seedlings turn yellow 1-2 weeks after emergence they may be suffering from iron deficiency.

Spray 1% ferrous sulphate with 0.2% citric acid once or twice (at two weeks-intervals) depending on the recovery of plants. Alternatively, apply iron chelates in between rows at 25kg/ha.

To correct Zinc deficiency

Zinc deficiency manifests mostly 3-4 weeks after seedling emergency and appears as small scattered light yellow spots on the older leaves that later enlarge and turn deep brown. The entire leaf turns rusty brown and dry within a month. White lines may appear sometimes along the leaf mid-rib starting from the 2nd or 3rd fully matured leaves.

Correction: Apply 30kg/ha Zinc sulphate (20% Zn) to the soil or spray 1% copper sulphate with 0.5% lime at 500L/ha to the base as symptoms are seen.

4.8 Crop rotation

Continuous rice monoculture systems results in decline in soil fertility due to over dependence on chemical fertilizer, and deterioration in physical properties of the soil like texture and microbial existence. To improve the situation, trials have been carried out on many potential rotation systems. Growing rice after a dual purpose grain legume in rotation can reduce the use of mineral fertilizer N, improve organic carbon content and improve rice plant health.

Soybeans, chick pea and green grams have shown a lot of potential in alleviating the problem. Such legumes can be cultivated during off-season at the time the land used to lie fallow. Promiscuous duo-purpose soybean can contribute fixed N to rice.

5. OPTIMUM PLANT SPACING/DENSITY FOR MAXIMUM RICE GRAIN YIELDS

5.1 Introduction

The crop plants depend largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional requirements. A thick population crop may have limitations in the maximum availability of these factors. It is, therefore, necessary to determine the optimum density of plant population per unit area for obtaining maximum yields.

A number of authors have reported that maintenance of a critical level of rice plant population in field was necessary to maximize grain yields.

Plant spacing is thus an important production factor in transplanted rice. Close planting of rice seedlings beyond the optimum level increases the cost of transplanting and chances for lodging. On the other hand, spacing rice wider than necessary may result in lower yields because the number of plants in the area may be less than the optimum needed for high yield. In many countries in south and south East Asia as well as Kenya, rice is planted at random spacing. However, straight row planting has the following advantages over the random planting;

A rotary weeder can be used for weeding

An optimum plant population is possible and is easier to apply insecticides, herbicides and topdressing fertilizers. There is no single spacing for all rice varieties. Optimum spacing of any variety depends on its tillering ability, soil fertility and water availability.

Observe the following in order to obtain maximum yields;

Basmati 370- 15x15 if manually cultivated but 25x15 for machine cultivated under the continuous flooding watering method

Basmati 370 – 25x25 if the rice crop is grown under the alternate watering and drying method (SRI)

BW196 and others – 20 cm x 20cm under the continuous flooding method.

6. RICE PESTS

6.1 Introduction

Rice is attacked by many species of insects which include grass hoppers (Orthoptera: Acrididae), crickets (Orthoptera: Gryllotalpidae), rice-sucking bugs (*Aspavia spp*), *Stenocoris spp*., *Mirperus spp* (Hemiptera: Alydidae), green stink bug *Nezara virudula* (Hemiptera: Pentatomidae), leaf hoppers *Cicadulina spectra* (Hemiptera: Cicadellidae), plant hoppers(Homoptera: Delphacidae), leaf mining beetles *Trichspa sericae* (Coleoptera: Hispidae),whorl maggot *Hydrellia spp* (Diptera: Ephydridaea) and rice caseworm, *Nymphula depunctalis* (Lepidoptera: Pyralidae). The stem borers that are the most important in terms of yield losses.

Four stem borer species have been reported on rice in Kenya namely stalk eyed fly, *Diopsis thoracica* (Dipera: Diopsidae), spotted stalk borer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae), pink stalk borer *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae). The most common is African white rice stem borer, *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae) which attacks rice crop at all the growth stages and causes high yield losses on late planted rice and the ratooned crop. Vertebrate pests such birds (Quelea birds and wild geese) rodents and storage pests are also important

Table 3: Pests at different stages of the rice plant

Phase	Growth stage	Pests	Symptoms
Vegetative	Nursery	Grass hoppers	Holes, dry edges
		Crickets	Dead hearts
		Stalk eyed fly borer	Serrated edges
		Ducks	
		Wild geese	
	Tillering	Leaf miners	Minute mines, dry leaf edges
		Rice caseworms	Ladder like serrations
		Rice gall midge	Floating larva cases
			Onion or silver shoots
Reproductive	Panicle initiation	Aphids	Black sooty mould
		White rice stem borer	White heads
Maturity	Maturity	Rice bugs	Pecky rice
			Discoloured grains
	Harvest	Rice weavils	Physical losses
		Weaver Birds, Quelea-	Spoilt grain
		Rodents	

Storage	Rice weavils	Spoilt grain
	Storage moths	Unpalatable grain
	Rats	

6.2 Pest management

Protection against pests and diseases in rice is routine and primarily consists of the application of pesticides that are, for the most part, recommended by manufacturers and applied on a calendar-based schedule, rather than on a need basis. In most cases they are applied when pest levels do not justify their use.

Development of economic thresholds is an important decision tool for the farmers on when to initiate control measures against the pests and diseases. Routine pesticide spraying also has attendant problems of environment pollution, contamination of aquatic habitats and development of resistance to pesticides. Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests and their damage through a combination of techniques such biological control, habitat manipulation, modification of cultural practices, use of resistant cultivars and judicious use of pesticides.

6.2.1 Action thresh holds and scouting protocols

On the basis of cost benefit ratio, the economic injury level per 25 tillers or 1M2 for African white rice stem borer is 6 and 8 egg batches for early and late infestation respectively. The corresponding economic threshold level is 4 egg batches/25 tillers in early infestation and 6 egg masses in late infestation.

6.2.2 Stem borers

There are 5 species of stem borers that belong to 3 families in 2 orders

White rice stem borer- *Maliarpha separatella*- Pyralidae, Lepidoptera, *Chilo partellus*-Lepidoptera, Stalk eyed fly- *Diopsis thoracica*, Diopsidae, Diptera and African gall midge-*Orseolia oryzivora*, Ceceidomyidae, Diptera.

Rice plants in the vegetative and early reproductive stages and rice fields receiving high rates of nitrogenous fertilizers are preferred for egg oviposition by stem borer moths.

African white head stem borer larvae

African white head stem borer adult moth

Figure 21: Stalk eyed rice stem borer

6.2.3 Stem borer management

Synchronized planting over a large area allows the most susceptible stage of rice to escape from stem borer and other pests' damage and also allows a planned non-rice break to occur during the year to interrupt the pest life cycle.

Apply calcium silicate to strengthen stem tissues and keep bases of stems always under water to control stalk eyed borers

Destroy alternative host plants such as rice ratoon crop, volunteers and wild red rice on the bunds to control rice gall midge. Combination of growing gall midge tolerant varieties with Paspalum grass management at the edge of rice fields reduces rice gall midge damage.

Control vectors like *Chaeoctna* beetles for virus diseases

Apply correct amounts of nitrogen in 3 splits – basal, tillering and panicle initiation

Carry out direct seeding as opposed to transplanting as transplanted rice has higher stem borer numbers than a direct seeded crop, because the former crop matures later in the season allowing the stem borers to build up on earlier plantings.

Seedlings of direct seeded rice crop which are grown without standing water during the vegetative stage are less attractive for egg laying by adult moths.

Use of soil amendments containing organic silica reduces leaf folder, stem borer and gall midge populations and increase rice yields and spraying with synthetic pyrethroids can be an effective control method when stem borer populations are high. However use of cultural control methods and the use of resistant varieties is the best management option.

Harvesting at ground level

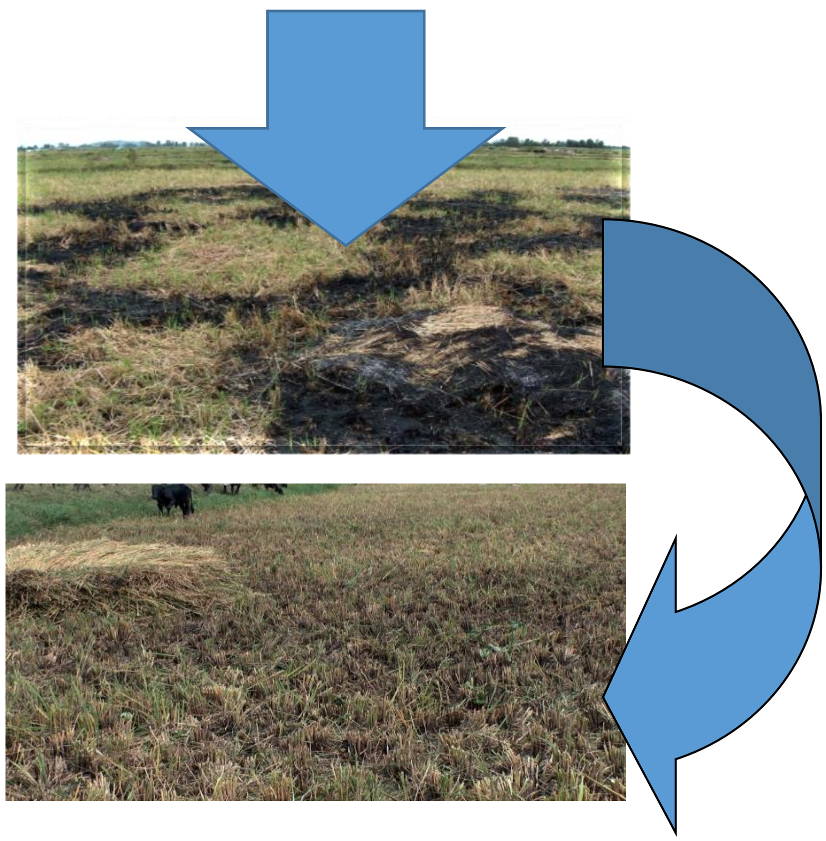


Figure 22: Harvesting at ground level and burning rice stubble

Keep bunds and surroundings levees free of grass weeds.

Destroy stubbles and avoid ratooning.

Ensure balanced nutrition-. Avoid excessive nitrogen application

6.3. Rice whorl maggots and rice leaf miners (*Hydrellia spp*)

6.3.1 Introduction

The rice whorl maggot *Hydrellia sp*. has been reported in Kenya (NIB, 1995). Adults of the rice whorl maggot and rice leaf miners are small flies (1.5 to 3 mm long), grey to black in colour with silvery white or golden brown markings on the lower part of the head. They lay white cigar-shaped eggs on the leaves. Upon hatching the maggots of the leaf miners penetrate the leaf tissue and feed in between the two layers of the leaf causing mines parallel to the veins. Maggots may pupate in an existing mine or migrate to a different leaf to form golden brown markings on the lower part of the head. High humidity (80-100% relative humidity) is required for leaf miner development, therefore, mines are typically observed in leaves close or lying on the water surface. Whorl maggots start feeding on the leaf margins causing large scarred areas giving the leaf a ragged appearance and causing eventual leaf collapse. Eventually the maggots enter the whorl and tunnel the plant's developing stem. Feeding damage by leaf miners retards plant development, reduces plant vigor and renders infested plants less competitive with weeds. Plant vigor and weather conditions affect the extent and seriousness of the damage caused by the rice leaf miner. Damage extent is closely related to the speed the plant growths erect and out of the water. Any factor affecting plant growth, which increases the number of leaves remaining lying on the water, or the length of time they are fully in contact with water will increase damage.

Figure 23: Rice whorl maggots

6.3.2 Control measures

The rice leaf miner can be controlled by managing the water level

Avoid leaf contact with water. However, this practice seems to intensify the whorl maggot problem. Field observations in Louisiana, USA showed that by draining fields, the maggot enters the plant whorl and stems without being drowned (LSU AgCenter).

Drain the water at intervals of 3 to 4 days during the first 30 days after transplanting reduces egg laying as the adult flies are more attracted to standing water.

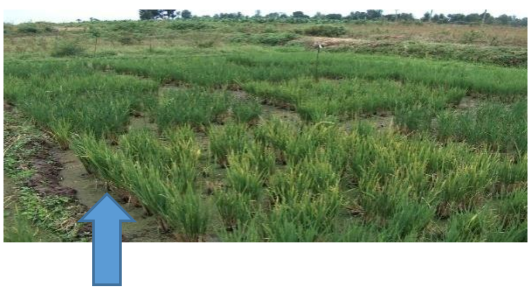
To reduce the potential for damage by the rice leaf miner encourage the rice to emerge quickly and grow erect. Level the field as accurately as possible and start the crop in 7-10 cm of water. Increase the water depth slowly after the leaves begin to grow upright. Monitor for rice leaf miners to determine the need to lower the water level. Begin monitoring two to four weeks after planting, just after most of the rice plants have emerged from beneath the water and the leaves are lying on the water surface. To control leaf miners and whorl maggots, drain the water at intervals of 3 to 4 days during the first 30 days after transplanting to reduce egg laying as the adult flies are more attracted to standing water.

Encourage cover of Azolla to control whorl maggots and leaf miners

To control leaf miners and whorl maggots, drain the water at intervals of 3 to 4 days during the first 30 days after transplanting to reduce egg laying as the adult flies are more attracted to standing water. During vegetative phase pests such as whorl maggots, root feeding midges, water weevils, caseworms, and others are suppressed when fields are drained for 1 or 2 days.

Leaf miner damage Whorl maggots

Figure 21: Leaf miners case worms and whorl maggots



Azolla cover controls leafminers and case worms

Flooded conditions encourage leaf miners and case worms

6.4. White tip nematode (*Aphelenchoides besseyi*)

6.4.1 Introduction

Rice is the main host for this pest. Other alternative host plants include; strawberry, onion, garlic, sweet corn, sweet potato, soybean, sugar cane, horseradish, lettuce, millet, many grasses, orchids, chrysanthemum, marigold, Mexican sunflower, African violets, and rubber plant (Hibiscus brachenridgii). The nematodes feed on leaf tips and the symptoms is whitening of the top 3 to 5 cm of the leaf leading to necrosis (described as "White Tip" of rice). The flag leaf that encloses the panicle can also become distorted. Infested plants are stunted, lack vigour and produce small panicles. Affected panicles are highly sterile and have distorted glumes and also

small kernels which are distorted

Figure 24: White tip nematode (Aphelenchoides besseyi). CABI 2002

6.4.2 Control measures

Plant nematode-free seeds in nematode-free areas

Plant resistant rice varieties if available

Treat seed with hot water. Hot water treatment of seed can be used to destroy this nematode infecting the seeds. Thermal wet treatment was the most effective at 55-60°C for 15 minutes

6.4.3 Storage Pests

The most serious pests of stored rice are the larger grain borer, *Prostephanus truncates*, the rice weevil (*Sitophilus oryzae*) and the lesser grain-borer (*Rhyzopertha dominica*). Good store hygiene plays an important role in limiting infestation by rice weevil. Rats especially *Praomys natalensis, Rattus rattus* and mice, (*Mus musculus*) are important vertebrate pests of rice in storage

Figure 25: Rice weevil (Sitophilus oryzae)

Control measures:

Remove infested residues from last season's harvest and protect the grain with an appropriate stored products insecticide

6.4.4 Vertebrate pests

Birds and rodents are the main vertebrate pests of rice, with the former being a major threat to production. Birds and other vertebrate pests are a serious threat to rice production in Kenya where several roosting sites are situated. The *Quelea quelea* and weaver birds (*Ploceus cucullatus abyssinicus*) cause extensive grain loss in rice. In unweeded rice land there is serious damage to seedlings and grain by the stripped Nile rat (*Arvicanthis niloticus*). Ducks and wild geese are important pests in the nursery and during tillering.

6.5 Control of vertebrate pests

6.5.1 Birds

In addition to direct losses from birds eating or damaging rice, there are substantial opportunity costs where rice is not grown in otherwise suitable areas, due to the risk of bird damage. Local reduction in numbers around crop sites is unachievable because flocks of young birds are often extremely mobile, moving distances of more than 50 km from their breeding area to feed. Decoy crops are a more effective and economical way to protect rice crop. Decoy crops should be everything the main crop is not - irregular, early, close to trees and power lines, and undisturbed. Growing crops specifically to be eaten by birds is hard for rice farmers to accept, and requires coordination on a regional basis for maximum effect. Use of nets to exclude birds from rice crop may be the only way of controlling birds in many situations given increasing concerns about the use of agricultural chemicals. Few chemicals are currently registered in Kenya for bird control. There is no limit to size of area covered but there are economies of scale. The decision on whether or not to net an area should be based on economics.

Rice farmers often consider netting as too expensive. However nNetting does not require much special expertise or sophisticated equipment. Throw-over nets give short term protection in the ripening period (Figure???). Nets can be mounted on light weight structures, however these have a high maintenance component and usually need to be replaced every 2-3 years. Use of scarecrows is used but overtime the birds habituate to these. Bird scaring which is labour intensive and costly is currently the method of choice for controlling birds due to its low technological requirement. However, red-billed quelea, *Quelea quelea*, a major pest of cereal crops in Africa and an important migratory pest at Mwea is controlled by destruction of breeding colonies either by aerial spraying with aphicides or by using explosives. This pest is controlled naturally and is a notifiable pest. Farmers should report the presence of this pest to the Ministry of Agriculture staff who will make the necessary arrangements to control the pest.

Figure 26: A rice field covered with a bird mist net at Mwea   A photograph of the netting

6.5.2 **IRRI-Tape Bird Deterrent**

Irri-Tape iridescent foil combines holography, wind and light, to irritate pest birds' senses and create an "off limits" zone against them. This is based on the functions of the scarecrow. Space Age technology and materials have been used to produce a new wrinkle on that age-old concept. The result is a lightweight, durable, maintenance-free bird repelling product. Irri-Tape is a Visual Bird Deterrent. It "flashes" as it moves with the wind. Reflecting sunlight, or any light, it produces constantly changing colors and patterns. This brilliant, flashing "ripple effect" is picked up by the bird pests as an unsettling danger signal. Whether seen as a predator (from a distance Irri-Tape has a reptilian sheen) or a rival for food or space, birds will not ignore this potential menace. Irri-Tape's properties keep unwanted bird pests away in several ways.

Birds are "rattled" by the fierce metallic noise the material gives off when caught by the slightest breeze. Irri-Tape has many applications for protecting crops from bird damage. Spiral it around free standing trees from top to bottom. Entire garden areas may be protected by hanging Irri-Tape from 2-3M poles to form high row deterrents. However this need to be done over large areas thus it must be community wide based control strategy.

Figure 27: Scare crow and IRRI-Tape for repelling birds

6.5.3 Rodents

Rodents breed throughout the year in ricefield areas, whenever food and cover are available; peak reproduction occurs during the wet season. Growing more than one crop per year and ratooning increase rodent populations and damage. Sustained baiting with anticoagulant rodenticides is a highly effective technique. It involves a self-monitoring system of weekly adjustment of bait station numbers in relation to bait consumption by rats. Bait made from locally available anticoagulant rodenticide concentrates, such as warfarin, diphacinone, or racumin, could be prepared on farm with broken rice. Baiting should start shortly after planting and be continued until grain heads began to harden. This can also be reinforced by use of break back traps(removal trapping) or Sherman traps or wire traps (live trapping).

7. RICE DISEASES

The most serious diseases of rice are: Rice blast disease (*Magnaporthe grisea*), Rice Yellow Mottle Virus (**Sobemovirus**), Bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*), brown spot (*Bipolaris oryzae*) and sheath and leaf blights (*Rhizoctonia solani*) Table 2.

Table 4: Diseases of rice in Kenya, rice plant parts that they affect and the causal organism

Disease	Part of plant affected	Causal organism
Blast	All aerial parts(leaves, nodes, panicles)	[*Pyricularia grisea* (Cooke) Sacc] ***
Rice yellow mottle	Whole plant	RYMV(Genus:Sobemovirus)***
Sheath rot	Flag leaf sheath	*Acrocylindrium oryzae*
Sheath blight	leaf sheath, leaves	*Rhizoctonia solani***
Brown spot	leaves, spikelets	*Helminthosporium oryzae***
Narrow brown leaf spot	leaves	Cercospora oryzae

Legend

*** Very important

** Important

7.1 Rice Blast *(Pyricularia oryzae)*

This disease can cause serious losses to susceptible varieties during periods of blast favourable weather. Depending on the part of the plant affected, the disease is often called leaf blast, rotten neck, or panicle blast. The fungus produces spots or lesions on leaves, nodes, panicles, and collar of the flag leaves. Leaf lesions range from somewhat diamond-shaped to elongated with tapered, pointed ends. The centre of the spot is usually grey and the margin brown or reddish-brown. Both the shape and colour of the spots may vary and resemble those of the brown leaf spot disease. Blast differs from brown leaf spot in that it causes longer lesions and develops more rapidly. The blast fungus frequently attacks the node at the base of the panicle and the branches of the panicle. If the panicle is attacked early in its development, the grain on the lower portion of the panicle may be blank giving the head a bleached whitish colour, giving the name "blasted" head or rice "blast". If the node at the base of the panicle is infected, the panicle breaks causing the "rotten neck" condition. In addition, the fungus may also attack the nodes or joints of the stem. When a node is infected, the sheath tissue rots and the part of the stem above the point of infection often is killed. In some cases, the node is weakened to the extent that the stem will break causing extensive lodging. Blast generally occurs scattered throughout a field rather than in a localized area of the field. Late planting, frequent showers, overcast skies, and warm weather favour development of blast. Spores of the fungus are produced in great abundance on blast lesions and can become airborne, disseminating the fungus a considerable distance. High nitrogen fertilization should be avoided in areas that have a history of blast.

Blast on the neck Blast on nodes Blast on panicles

Figure 28: Rice blast symptoms

7.2 Symptoms

Blast is identified particularly by characteristic spindle-shaped lesions. The disease starts as pin point lesions and can kill the entire leaf or plant in a favourable environment if it is a susceptible variety. The most serious stage of the disease is leaf blast, or neck rot seen as a blackish coated area at the base of the panicle. The rachis or rachilla becomes infected causing varying degrees of grain sterility.

7.2.1 Management

Plant resistant varieties

Apply recommended Nitrogen fertilizer rates. Heavy fertilization favours disease development

Avoid rate planting especially if heading is to coincide with wet weather and overcast skies

In heavy infections fungicides like Topsin can be applied.

7.3 Brown Spot (*Helminthosporium oryzae*)

Brown spot, caused by *Helminthosporium oryzae* Breda de Haan, attacks rice plants at all growth stages. It occurs primarily in rice suffering from potassium imbalance or grown on soils low in fertility, particularly those deficient in nitrogen, or on saline soils. Shading also aggravates the disease in intercropped rice fields.

Figure 29 : Brown spots symptoms

7. 4. Rice yellow mottle virus

Occurrence

RYMV causes severe infections mainly in irrigated rice and is transmitted by beetles (*Sesselia pusilla*, *Chaetocnema pulla*, *Trichispa sericea* and *Dicladispa viridicyanea*) and mechanically. It is not seed transmitted. Major symptoms of the disease are yellowing of leaves, stunting of affected plants, reduced tillering of the affected plants and sterility of the seed/grain. Although RYMV was first reported on Sindano rice variety at Kisumu in Kenya in 1974 and it is now found throughout East Africa. There are various modes of transmission which include mechanical transmission, by vector, seed and soil transmission. RYMV infection the influences the number of panicles, number of spikelets and seed yield. When a score of Rice Yellow Mottle Virus reaches 3, it means a 6-10% field infestation.

Figure 30: Rice yellow mottle infected plant and rice yellow mottle infection

7.5 Sheath blight (*Rhizoctonia solani*)

Sheath blight is caused by *Rhizoctonia solani* Kuhn. The fungus has many strains, which differ in morphological characters, rate of growth, and pathogenicity. High temperature and humidity in favours the development of the disease. Varieties, which require higher rates of fertilizer are more susceptible to sheath blight. The difference in susceptibility, however, is primarily due to intensive cultural practices. Use of resistant varieties combined with cultural practices is the best option for managing the disease.

7.6 Bakanae disease (Fusarium moniliforme)

Bakanae disease (*Fusarium moniliforme*) and *Khuskia oryzae,* both pathogenic fungi were reported at Mwea irrigation scheme by Seif and his co- workers. The latter causes minute leaf and grain spot of rice. Basmati 217 recorded the lowest incidence while BW 170, Farox 15, IR 27801-62-2 and IR2587-22-3-1 were highly susceptible. *Fusarium graminearum* is the cause of scab on both wheat and rice.

7.7 Damping-off diseases

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

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

Figure 31: Damping-off on rice

Control measures:

Use certified disease-free seeds for planting

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

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

Figure 32: Symptoms of Bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*)

Control measures:

Plant resistant varieties if available and use certified disease-free seeds

Practice rotation and good field sanitation. Plough or roll the stubble to hasten decay of the rice debris; this helps to manage the disease by destroying the tissue in which the bacterium is maintained.

7.8. Brown leaf spot (*Bipolaris oryzae*)

This disease was previously called *Helminthosporium* leaf spot. Most conspicuous symptoms of the disease occur on leaves and glumes of maturing plants. Symptoms also appear on young seedlings and the panicle branches in older plants. Brown leaf spot is a seed-borne disease. Leaf spots may be evident shortly after seedling emergence and continue to develop until maturity. Leaf spots vary in size and are circular to oval in shape. The smaller spots are dark brown to reddish brown, and the larger spots have a dark-brown margin and reddish brown to grey centres. Damage from brown spot is particularly noticeable when the crop is produced in nutritionally deficient or otherwise unfavorable soil conditions. Significant development of brown spot is often indicative of a soil fertility problem. These necessary conditions has led to the disease being referred to as a poor man's disease.

Figure 33: Brown leaf spot on rice with symptoms on leaves

Control measures:

Plant resistant varieties

Use certified high quality disease-free seeds

Ensure balanced fertilization

Practice crop rotation

8. PRE- HARVEST CONDITIONS FOR QUALITY AND HIGH RICE YIELDS

Rice yield is a factor of yield components. The numbers of harvest kernels per unit of land area is related to the total number of spikelets per unit land area and percentage of grain filling. Percentage of filled grain directly affects the filled grain number and thus the final grain yield if the total number of spikelets is sufficient. The percentage of filled grains depends on the grain filling rate and grain filling duration of superior and inferior grains, which may be fast synchronous, slow synchronous, or asynchronous. Rice grains at the apical primary branches of the panicle are classified as 'superior', while those at the proximal secondary branches are classified as 'inferior'. Fast synchronous grain filling usually results in high yields, while slow synchronous or asynchronous grain filling usually results in relatively low yields. Growing conditions can also influence the percentage of filled grains. In lowland rice, drought stress during late panicle development sharply decreases the percentage of filled grains. Reducing the irrigation (and hence increasing drought stress) decreases the percentage of filled grains.

Nitrogen application increases rice grain yield by increasing the total dry matter production, the number of panicles, and the panicle length. Nitrogen supply to spikelets has no direct effect on kernel number per unit land area, but improves the supply of assimilates to the grain. Application of a large proportion of fertilizer-N applied to the rice at early vegetative growth promotes tillering, and this contributes to final grain yield. Top dressing of fertilizer-N at heading reduces the percentage of filled grains under sufficient water supply, but helps plants to maintain a high photosynthesis rate, with a subsequent significant increase of grain-filling rate, grain-filling duration, and higher percentage of filled grains, compared with basal application or top dressing of N at tillering. Crop timing to allow the rice crop to escape low temperatures is also critical to realization of high yields. Planting of rice must be timed in such a way that heading does not coincide with periods when the daily average temperatures are less than 25^0 C.

8.0 Harvesting

Paddy crop should be harvested when physiologically mature. The leaves turn yellow, the grains become hard and contain about 20-22 percent moisture. Losses are greater, especially if harvesting is delayed with respect to the crop maturity date. In addition to the losses incurred in cutting, wind-rowing, sun-drying, collecting and bundling of the cut crop, there are those when the bundled paddy-in-straw is loaded onto the person's back to be carried to the house.

Harvesting before maturity means a low milling recovery and also a higher proportion of immature seeds, high percentage of broken rice, poor grain quality and more chances of disease attack during storage of grain. Cyclone bran or empty pods is as a result of early harvesting

Delay in harvesting results in grain shattering and cracking of rice in the husk and exposing the attack by insects, rodents and birds as well as lodging.

Figure 34: Rice field ready for harvesting at Mwea

Avoid harvesting during wet weather conditions. Avoid missing secondary tiller panicles.

Drain out the water from paddy field about a week or 10 days before the expected harvesting,

Harvesting can be manual by use of a sickle either by harvesting single panicles which results in low losses, but is tedious or hill harvesting which is much faster but results in skipping of secondary tiller panicles.

Protect the harvested paddy from rain and excessive dew by covering with tarpaulins. Combine harvesters and Walk behind rice reapers can be used for harvesting and a recirculating air batch dryer can be used. Fast drying may lead to more broken grains lowering milled rice quality.

Figure 35: Rice reaper at KALRO-Mwea

8.1 Threshing

During threshing the paddy kernel is detached from the panicle, an operation which can be carried out either by "rubbing", "impact" or "stripping". Rubbing may be done with trampling by humans, animals, trucks or tractor; however, the grain becomes damaged. Mechanical threshers adopt mainly the impact principle, but there is also a built-in stripping action. With a paddy thresher, the unthreshed paddy may be either held or thrown in. In the "hold-on" type, the paddy is held still in the cylinder while spikes or wire loops perform impact threshing. In a "throw-in" machine, whole paddy stalks are fed into the machine and a major portion of the grain is threshed by the initial impact caused by bars or spikes on the cylinder. Most common impact threshing is by hitting with a stick or against a log or a rock. All the panicles should be kept in one direction in order to ensure efficient threshing. Keep the harvested paddy separately for each variety, to get true to type variety (grains). The grain is separated from the straw by hand and then cleaned by winnowing. Losses may occur during threshing for various reasons: In manual threshing by beating, some grains remain in the bundle panicles and a repeat threshing is required. Grain is scattered when the bundles are lifted just before threshing. Grain can stick in the mud floor. Birds and domestic fowls feed on the grain. Therefore need to use covered floors.

Figure 36: Threshing of rice at Mwea irrigation scheme

Paddy can also be threshed by mechanical threshers. These include human power (Tredle or pedal driven) and motor or P.T.O driven threshers

Figure 33: P.T.O. driven thresher (left) and motorized drum thresher fabricated at KALRO-Mwea

8.2 Drying

The main cause of loss during drying is the cracking of grain kernels, some grains may also be lost during the drying process.

Failure to dry crops adequately can lead to much higher levels of loss than poor-quality drying, and may result in the entire harvest becoming inedible. Avoid direct sun drying, which leads to an increase in breakage of the grains during milling. In some places, the practice is to windrow the cut paddy in the field to dry for 3 to 7 days, depending upon the weather conditions.

If the threshing is delayed keep the harvested paddy stalk bundles in a dry well ventilated shady place, which facilitates air circulation and prevents excessive heating. Ideally, most grains should be dried to acceptable levels within 2-3 days of harvest.

The most appropriate method though expensive is to use mechanical driers

Figure 37: A recirculating air batch rice grain dryer at KALRO-Mwea

8.3 Transportation

In developing countries, transportation of paddy from the field to processing areas is performed mainly by humans and animals, and sometimes using mechanical power. These traditional methods of transport, which are related to the harvesting and field drying activities, very often result in high grain losses. In addition to losses incurred in cutting, wind-rowing, sun-drying, collecting and bundling of the cut crop, there are those when the bundled paddy-in-straw is loaded onto the person's back to be carried to the house. Grain then falls en route, especially with the transportation of shattering varieties, and also when the carrier stops to rest.

Thresh the paddy in the field itself and transport the grain in bags, which minimizes the grain losses. Pack the paddy in sound natural fiber jute bags rather than in polypropylene bags to avoid overheating which is possible in the latter type of bags. Avoid soil or stones contamination by threshing on tarpaulins and not on bare ground. Finally, commercial rice is bagged at the rice mill and normally transported to wholesale and retail markets by means of vehicles. This mechanized procedure results in much lower losses.

8.4 Milling

There are many ways of processing rice but mostly rice is milled and polished into white rice. White rice is used as a staple food almost over the entire world.

Hullers/ rice mills

Cleaned paddy on average yields 72 percent rice, 22 percent husk and 6 percent bran.

Main milling methods are by rice hullers, shellers and modern rice mills. Hullers give milling recovery of about 65 percent total yields with 20-30 percent brokens. It does not give completely cleaned rice. This is the most common method of rice milling in Kenya

The most modern rice mills (single Pass) are available in 2-4 tons per hour capacity. The mini modern rice mills are available with capacity of 150-550 kg per hour and yields higher recovery.

The modern rice mills give yield recovery of 70 percent with a grain breakage of 10 percent only.

8.5 Grading

Grading is the process of sorting of a given product according to the grades or classes. Ingrading of paddy, mainly thickness or length of grain is considered and graded accordingly.

Grading of paddy/rice is usually done through mechanical devices such as: rotating graders, plansifier, trieurs, circular purifier, colour grader/sorter. Paddy grains having the same length but different thickness are graded by rotating graders; whereas, grains with the same thickness but different lengths, are separated by trieurs. Sometimes both the rotating graders and the trieurs are used. In the market, the sale of paddy/rice is generally done on the basis of visual inspection of available sample and with local commercial name. Buyers offer price on the visual examination of whole lot considering the quality factors like size and colour of the grains, moisture content, aroma, broken grains, foreign matter and admixture of other varieties.

General quality Factors

Rice shall be safe and suitable for human consumption.

Rice shall be free from abnormal flavours, odours, living insects and mites.

Specific quality factors

Moisture Content 14% max

Lower moisture limits are normally required for specific markets outside the country

Extraneous Matter: is defined as organic and inorganic components other than kernels of rice.

Filth: impurities of animal origin (including dead insects) 0.1% m/m max

Other organic extraneous matter such as foreign seeds, husk, bran, fragments of straw and shall not exceed the following limits:

Maximum Level

Brown rice 1.5%

Milled Rice 0.5%

9. VALUE ADDED PRODUCTS AND BY PRODUCTS FROM RICE

After paddy rice has been harvested and milled, two types of rice are obtained

- Brown rice
- White rice /polished rice

Several products can be prepared from polished and brown rice.

- Rice crackies
- Germinated Brown Rice (GBR)/GABA Rice.
- Whole rice cookies.
- Rice cake
- Instant rice flour and Rice flour

9.1 Rice crackies

Ingredients

Ground rice (2-3 cups), wheat flour (1 cup), sugar (3tablespoons),Boiled water

Chilli/hot pepper (optional)

<u>Equipment</u>

Extruder, Draining paper, Tray Packaging papers, Jiko/stove, Strainer, Deep frying saucepan, Wooden spoon, Knife, spoons (Teaspoon and tablespoon) and a cup.

Method

- Measure all the ingredients.
- Sieve the dry ingredients into a mixing bowl.
- Add water a little at a time and mix until the dough gets sticky but wet.
- Put a little dough in the extruding equipment and test the dough. If the dough needs a lot of pressure to extrude then make it a little wet. If too wet add a little flour to make the right consistency.
- Heat the oil in a saucepan until hot enough.
- Extrude the dough into the hot oil. Cut with a knife to make them short.
- Fry until golden brown. Remove from the oil with a strainer and put on a tray to cool and then pack.

Figure 38: Ready rice crackies

9.2 Germinated Brown rice (GBR)/GABA RICE)
GABA (Gamma amino butyric acid) is an amino acid found in common everyday health foods.

Ingredients

Paddy rice (amount needed), Clean water, Sufuria /bucket/basin(enough to hold rice and water) plastic bag

Method

- Take Paddy rice with husk and sort to remove foreign objects.
- Clean with water.
- Steep (soak) rice for 12hrs at the ratio of 1to 3.
- Remove from water, enclose in a plastic bag and tie to germinate. Plastic bag prevents oxygen from entering. It takes 15hrs but one can incubate if the temperatures are low.
- Dry 11-12% MC for 3 hours.
- Dehull /dehusk by milling.

9.3 Whole rice cookies
Ingredients

Sticky rice (500g), Cooking oil (500ml), Table salt (1tbs)

Method

- Soak the sticky rice for 3 hrs.
- Steam for 30 minutes (Boil in the ratio of 1:2)
- Spread sticky rice to a flat surface.
- Dry the spread sticky rice for about 70^0C for about 2 hours.
- Deep fry until slightly brown.
- Season with table salt.
- Pack.

Figure 39: Rice cookies

9.4 Rice cake

Ingredients:

Rice flour(1 cup), wheat flour(1 cup), sugar (½ cup), margarine (½ cup), baking powder (2 teaspoons), eggs (2), vanilla(1 teaspoon), milk(1 cup), salt(a pinch)

Equipment

Oven, Digital weighing scale, Baking tin/cups, Cooling racks, Mixing bowls, Measuring cups, Wooden spoon, Mixer

Method

- Cream sugar and margarine till light.
- Sieve the flour baking powder and salt together.
- Add in the eggs with a little flour in to the sugar margarine mixture.
- Gradually add in the flour and milk mixing to a drop batter consistency.
- Pour the mixture into a lightly greased tin and bake at 180^{o}C till done.
- Put on a wire rack to cool.
- Apply icing if required before packaging.

Figure 40: Ready rice cakes

9.5 Instant rice flour

Raw Materials

Broken rice, water, fortifying ingredients (beans, soya, egg yolk-dried and cooked), fuel (Kerosene, charcoal, gas, electricity)

Equipment

Saucepan, stove, milling machine, Moisture meter

Method

- Boil the broken rice in to ratio 1:2 of rice and water until ready then dry to 11-12% Moisture Content.
- Mill the dried dough to get flour.
- Fortify rice flour (cooked, dried and milled) beans, soya, and egg yolk.
- The fortifying products have to be taken to the food nutrition laboratory to determine the calories contain.
- Blend with the broken rice flour to get instant rice and package

Figure 41: Instant rice flour

10. FOOD RICE BY-PRODUCTS

10.1 Rice Bran

- 100 kg paddy getting 5-8 kg of bran
- High protein, fat, ash, crude fiber, Vit.B
- High vitamin B, vitamin E & antioxidants
- High quality cooking oil.
- Livestock feed.

Figure 42: Rice bran oil

11. NON FOOD RICE BYPRODUCTS

11.0 Rice straws utilization

Can be fed to animals or bailed as livestock fodder

11.1 **Rice straw bails**

The effects of climate has made rice straw become an important fodder for ruminants (Cattle, goats and sheep) (Figure) and non-ruminants (Horses, donkeys and rabbits) in Kenya since the year 2010. Seasonality of fodder production and the fact that rice straw is available from irrigation schemes throughout the year has made this to be an attractive alternative fodder for animals.

Figure 43 Dairy animals being fed on rice straw at Mwea

Figure 44: Bailing of rice straw at Mwea (left) Loose rice straw on a lorry at Mwea (Right)

However it has high lignin and silica content and low digestibility and has only 3% crude protein. It is also low in minerals and vitamins. Ruminants require 7- 9% crude protein and feeding them with rice straw requires that the nutritive value of the straw is improved. One way of doing this is to treat the straw with urea.

Method

Treat rice straw with urea at a rate of 5kg urea per 100kg of rice straw.

The urea should first be dissolved in 50 liters of water and then sprinkled to the straw.

Mix the sprinkled rice straw and fill it into silage tube and compact in order to accommodate more straw.

The tube should be tied after filling to ensure the ammonia gas generated does not escape but penetrate the straw to bring the desired change.

Allow the sealed treated straw to stand for 14-21 days to mature before feeding. If the straw is baled, then weigh the bales and calculate the amount of urea solution you need for each bale and sprinkle on it. The treated bales should sealed with polythene sheet to prevent the generated ammonia gas from escaping.

Figure 45: Mixing and filling the treated straw in Tube silo

11.2 Other uses of straw

- Plough back into the fields as mulch to improve rice fields
- Can be used to weave several products such as straw hats, baskets, etc.
- Making paper.

11.3 Rice husks

- Obtained after de-hulling the paddy
- Make carbonized rice husk to improve the soil.
- Make rice husk briquettes used for cooking and heating e.g. in brooders.
- Can be used to make rice husk boards

Rice husk particle Board

Method

Rice husk received from the rice mill is winnowed and wind-sifted and then coated with synthetic resin adhesive in specially designed adhesive applicators. The resin coated husk is spread as an even mat on support cauls & consolidated under heat and pressure in a hydraulic hot press. The hot pressed panels are cooled and trimmed to the desired dimension.

Area of application

Construction industry, construction materials, furniture industry: wall paneling, furniture, false ceilings, roofing panels, insulation, partitioning flooring & general purpose.

Figure 46: Rice husk medium density boards

Rice husk briquettes

Raw materials

Carbonized rice husk, Water, Bidding agent-Cassava flour/soil (but not top soil)

Equipment

Briquette machine, carbonize, Spade, Watering can, 20 litre bucket, spreading canvas

Method

- Carbonize the rice husk using a open air carbonizes.

Figure 47: Open air carbonizers

- Add the bidding agent to the carbonized husk and mix thorough.
- Add water to make a consistency that is not too wet and not too dry. A simple test to determine if the consistency is right, is to squeeze the mixture in the palm of your hand as you fold your palm to make a fist. If the powder does not crumble upon the opening of your folded palm, the mixture is right and you can go ahead and feed the machine to make briquettes.
- Put the mixture in the hopper of the briquette machine and press.

Figure: Rice husk briquette machines

- Put the briquette in the sun to dry. It takes about 2-3 days when there is enough sunshine. It takes longer on wet days.

Figure 48: Drying rice (left) and ready husk briquettes for packaging

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