MANUAL FOR

“SAWAH” SYSTEM

OF

RICE PRODUCTION

（Draft）

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GENERAL INTRODUCTION:

In Ghana, despite the abundance of natural resources to support food production, food supply continues to fall short of demand. Consequently, the requirements of most food crops, particularly rice, are met largely from increasing amounts of imports. The country has over 700,000 ha of lowlands. These lowlands represent an important agricultural asset that can contribute to food security and poverty alleviation. The potentials of these environments to address food security are enormous and can therefore easily be tapped for the benefit of the farmer

There are four main rice-growing systems in Ghana. These include; (i) rain-fed upland, (ii) rain-fed lowlands, (iii) inland valley bottoms and swamps and (iv) irrigated paddies. While the rain-fed system is beset with many problems and hence unreliable, the uplands are rapidly and continuously being degraded. Lowland have specific hydrological conditions that have a high potential for the development of rice-based, smallholder farming systems. With improved water management, there is tremendous scope for intensification and diversification.

As a result, the Ghana government in its determination to raise the level of rice production in order to attain higher levels of self-sufficiency and reduce importation has set in motion, mechanisms and practices for the promotion of the cultivation of the crop. Development of simple, less expensive and environmentally friendly technologies through research, for the sustainable use of these rice-growing environments is paramount. One of such research innovations resulted in the development of the "sawah" system of rice production through a JICA/CSIR collaborative effort. "Sawah" refers to a well-levelled rice field surrounded by bunds with inlet and outlet connections for irrigation and drainage which has simple but effective water harvesting structures. This technology was introduced to some farming communities in the Ashanti region.

With the introduction of this new technology where water and soil nutrient management have tremendously improved, rice paddy yields have since increased from below 1.0t/ha under the traditional system to over 4.5t/ha under the "sawah" system.

This manual has therefore been prepared with the objective of serving as a working tool for both Ministry of Food and Agriculture extension staff and rice farmers. It is hoped that a proper and rapid grasp of the rudiments of the "sawah" technology will enhance its rapid adoption and accompanying increases in rice yields. The end result would be increased income for farmers and reduction in poverty levels.

SAWAH DEVELOPMENT AND MANAGEMENT

Introduction

"Sawah" is technically defined as a bunded and well-levelled rice field with inlet for irrigation and outlet for drainage. The essence of bunding, puddling and levelling is to ensure that the rice plant is supplied with adequate amount of water. Levelling avoids the ponding of water in some parts of the field while other parts receive little or no water. Rice is a water loving plant and performs poorly when water is inadequate.

Bund construction and levelling require earth movement. To reduce huge movement of soil bunds should be constructed to take care of areas of similar altitude. Difference in height within the area to be bunded should not be more than 30 cm. This will allow for easy levelling and hence uniformity of water spread/distribution

Land tenure and other social implications

The initial cost of bund construction, levelling and other activities related to "sawah" development is relatively expensive. It is important to ensure that the land is obtained for a long period to ensure profitability.

Land should be acquired from the rightful owner. All necessary transactions (security of tenure) regarding land acquisition should be with the rightful owner and never through an agent or a ‘middleman’. There is the need for a documented agreement with local and national recognition on full land and water-use rights for ten or more years.

Sites suitable for “sawah” development

Most valley bottoms are low-lying areas that are inundated for part or all of the year. Rice production is often restricted by either an excess or shortage of water in some seasons. They are often flat and are crossed by a stream or river with steep or gentle slopes. These valley bottoms often have permanent water- requiring drainage- thick vegetation and organic soils. Some could also be areas with high water table (hydromorphic) which looks dry most of the year and which floods only seasonally.

The valley bottom could be a virgin land or an area already farmed traditionally after partial clearing but with no water control systems. Good access from the village or motor roads to facilitate movement of equipments and transportation of inputs and outputs is necessary.

Technically “sawah” require both irrigation and drainage facilities. Broadly however, there are several categories of "sawah" which can be divided into 5 types: (i) Rain fed type, (ii) Pump type, (iii) spring type, (iv) integrated type and (v) Dyke-canal type. Good observation regarding sources of water and water available throughout or most part of the season is important. Check the availability of; i) springs and areas with high water table, ii) good rainfall (amount and distribution) and iii) irrigation systems and rivers. Either of these could be a good source of all year round water supply system.

The type of “sawah” to develop is greatly influenced or determined by the type of source of water. Relatively level topography (which will require less levelling), with light tree cover and gentle river meanders should be preferred.

(i) Rain fed type: Rain is the only source of water for the rice plant. Rice growth and yield is significantly determined by rainfall.

(ii) Spring type: Good observation of yields and duration of water supply by the spring are necessary. If yields are low due to inadequate water supply, then it is better to develop a small or medium size pond to collect water for irrigation

(iii) Dyke and canal type: The presence of a stream is very important. Dyke and canal should be sited at a relatively higher altitude than the rice fields. Water is harvested from the canal by gravity. The dyke and canal type can supply large volume of water.

(iv) Pump type: Water is delivered into the field by pumping. Stream, dug up well or a reservoir may be the water source.

(v) Integrated type: Water delivery may be both by pump and by gravity.

After being satisfied with water availability, the next important factor is the soil physical properties. Soils with sandy or sandy loam subsoil's should be avoided.

Bund construction, puddling and levelling.

Bund construction:

Bunds should be constructed to take care of areas within similar altitudes. The main bunds should be bigger (0.5 – 1.0m wide) and about 0.5m high.

- Peg and line the area where the bund is to be constructed (fig.)
- Dig from both sides of the pegged area and heap the soil into the area pegged
- Compact the bund by ramming tight with a shovel or a rammer to avoid leaving any holes. Clay soils are the best. Bunds must be strong enough to walk on and to resist the occasional flood.
- Dig more soil to obtain the required height if necessary
- Allow a less compacted spot, which can easily be opened to allow water into the field using bamboo, plastic or clay pipes or Watergates Allow another spot at the other end to allow drainage when necessary.

During the course of the growing season, reshape the bunds to avoid total collapse

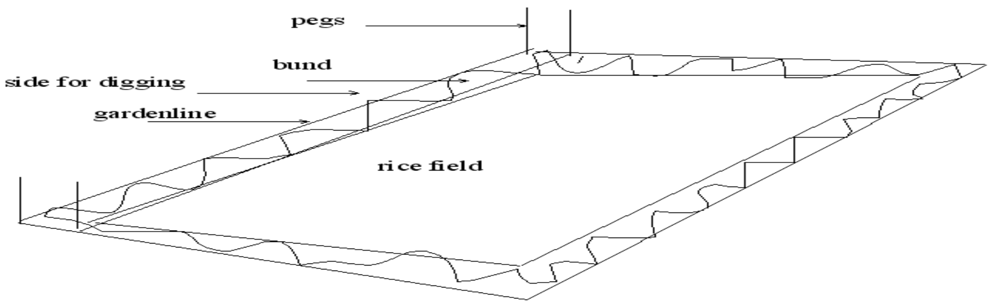

Figure 1. Layout for bund construction

Firming a bund with a wooden board

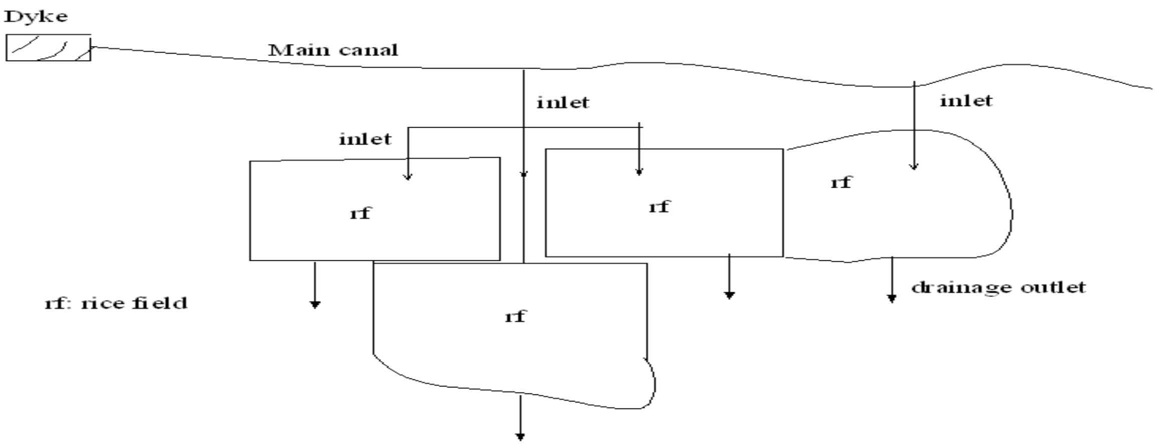

Figure 2. Possible layout of maincanal and rice fields

Puddling:

To puddle:

- The field is first ploughed.
- Water is allowed to soak the soil for about a day.
- The wet soil is then thoroughly mixed and smoothened into a fine and soft medium

During puddling add more water if necessary for easy movement of soil. Puddling ensures breakdown of soil structure with the improvement of water and nutrient retention. After an initial dry ploughing of the field, the field is then flooded. The flooding of the paddy field will accelerate the decomposition of any weeds and crop residue in the soil and reduce the release of N from decomposing organic matter. After flooding the field, allow it a few days before puddling. During puddling, continuously lower the level of water in the field. This will help identify high and low spots to be levelled subsequently.

All these operations should be completed a few days before transplanting in order to provide soil that will make transplanting and water management easier (i.e. weed free, soft and level).

Levelling:

During levelling, smoothening operations should be done using a wooden board. In a well-levelled field, the depth of water should be even over the entire surface. Soil is moved from higher to lower places. The objective is to provide a uniform depth of water across each field or paddy. Move soil from higher ground to the low spots but without exposing the subsoil. Depending on what is available, use power- tiller, tractor, oxen or hand- tools.

Loosen the high ground by digging, disking, ploughing, rotovating or chisel ploughing. Scrap the topsoil off to one side. Move the subsoil to the lower areas, using, shovel or wooden plank hooked behind a power tiller. To estimate the degree of levelling water is allowed into the field. Water depth over field helps to identify higher grounds, which can be easily moved. Levelling is continued until the whole field show similar water height. A poorly levelled field requires more water during irrigation than a well-levelled field. The amount of levelling required is higher when the slope gradient is high. Large rice field may require more energy for levelling.
Wood planks (Picture) and spades may be used to move soil from higher to lower spot especially on a large rice field. Hoes are equally effective on smaller fields.

Field levelling using a wooden plank tied to a power tiller


A well-levelled field

WATER MANAGEMENT (supply, distribution, drainage)

Water is lost from irrigated rice during the crop season through

1. Evaporation – loss of water from free water surfaces
2. Transpiration – loss of water through plant surfaces
3. Percolation (including seepage) loss of water to deeper layers and (walls of water containing structures in the field)

Evaporation from the rice field is highest during the early stages of crop growth. *Transpiration* losses become greater during the latter stages of growth when increases in leaf area become pronounced and surface cover by the rice plant is high.

Percolation, seepage and surface run off are controlled by edaphic factors such as topography and soil characteristics and are highly location specific. Percolation and seepage when combined determine the water retaining capacity of a field. The higher this value, the easier it is to control water and the better it is for the rice crop

Total water lost per day across rice fields averages 6-10mm. Thus about 180-300 mm water per month is needed to produce a reasonably good crop of rice. In field operations, a total of 1240 mm water is an average water requirement for an irrigated rice crop.

Factors to consider in water management under "sawah" rice production include:

1. Reliable water source and availability (dam, dyke, pond etc)
2. Strong and clear water ways (canals)
3. Well levelled and flat fields
4. Strong bunds

(a) Water management before planting (land preparation)

Water management in rice cultivation under the "sawah" system seriously starts during puddling and levelling. Puddling is the process of turning the soil into a fine medium (mud). Through this process the soil structure is practically destroyed or disorganized. It is necessary to build bunds where they are not available and to repair any broken ones. This improves the impounding of water. Levelling is the process of moving soil from one point to another in order to create an even and level surface.

Note: A rice crop seeded or transplanted into a well prepared weed free soil is much more likely to grow healthier, make maximum use of available water and give high yields than one grown in a poorly prepared soil with a haphazard water regime.

(b) Water management during planting (seeding and transplanting)

After nursing seeds, the nursery should only be kept moist and not flooded particularly when seeds were not pre-germinated before nursery establishment. After germination, a nursery can be intermittently flooded but never ponded (submerged seedlings die and surviving ones become weaker).

During seedlings removal:

Using the wet-bed method, seedlings are normally ready for transplanting 20 days after nursing. At this stage, the plant is at 4-5-leaf stage. Before pulling out seedlings, the nursery should be flooded for about a day. Do not drain water completely from the nursery before seedlings are pulled out. Soil surface should still be completely covered by water when removing seedlings.

After the field has been puddled, levelled and smoothened, minimum water levels of up to 5 cm should be left on the field, to prevent drying. During transplanting, the water level can be reduced to less than 5cm but the field surface should not be allowed to completely run dry. When transplanting in a field is completed, only a minimum level of water should be allowed on the field for the first two weeks

Note: At the seedling stage, the water requirement of the rice plant is lowest.

Water management at basal fertilizer application (vegetative growth stage)

Basal fertilizer should be applied to rice not later than a week after transplanting. The production of an adequate number of tillers is an important factor in achieving optimum yields. Immediately after transplanting, sufficient but minimum water should be provided to stimulate early rooting. Following this stage, a shallow depth of water will stimulate root development and tiller production, whilst excess will hamper rooting and decrease tiller production.

Water management at reproductive growth stage (maturity)

Reproductive growth starts when maximum tiller production is completed and includes the panicle initiation, booting, heading and flowering stages. A large amount of water is required during this stage. Consequently, if the plant suffers water stress at this stage, the results are reduced heading and flowering, and increased panicle sterility. In contrast, excess water causes a decrease in culms strength and so increase lodging. Fields should therefore be provided with adequate water (up to 15cm depth). However, during topdressing (second fertilizer application), water levels should be adjusted to very low levels (below 5cm). A few days later, water levels should be raised again (made deeper).

Water management at ripening stage (harvest)

This is the last stage of the growing period and is divided into the following sub-stages: milk, dough, yellowish and full ripening grain. Very little water is needed at this time. After the yellowish ripening stage, no water is required. Consequently the field should be drained (about 10- 14 days before harvest).

Note:
The peak water demand of rice is between maximum tillering and grain filling stages.

Water management at herbicide/Pesticide application

Herbicides are normally applied as a measure for weed control. Yield losses due to weed competition can be high and should be avoided at all cost. Weeds and pests do not only reduce yields significantly but also decrease quality and hence significant financial losses. Weeds compete with the rice crop for soil nutrients, water and light, and may also act as reservoirs for infection by diseases and pests. Under the “sawah” system, the best and economical method of controlling weeds is by the use of water. Strict adherence to proper water management methods can result in a weed reduction of about 70-80%.

Note:

- Water weeds (not affected by water), however, may be removed manually by hand in order to reduce cost. In addition, proper water management can result in increased fertilizer use efficiency
- Depending on the age of the crop, field water levels should be reduced but not completely drained when herbicides are being applied.
    - Large volume of water is required during puddling and levelling. Subsequently the amount of water required is determined by the stage of growth of the rice plant.

Water should be supplied directly into a rice field. Avoid the supply of water from one field to another.

- When water is supplied through pumping, pump directly into the rice field or into a canal that goes directly into the rice field. Avoid pumping water into a field and allowing water to run from that field into another.
- With the spring type water can be directed into a reservoir (pond) and then into the various rice fields via a canal.

Dyke and canal type. A dyke is constructed at an appropriate point on a stream. A main canal to where the rice fields are located directs water. Smaller canals into the rice fields further carry water. Canals (inlets) should be located such that water is directed into the rice fields directly. The main canal should be sited such that it is at a higher altitude (Figure 2) than the rice field for water to move into the rice fields under gravity.

Water distribution is essential when dealing with a group of farmers. Distribution (supply) should ensure that farmers get direct access to water. Figure 2 is a typical lay out that allow farmers to have almost equal access to water.

IRRIGATION MANAGEMENT AND DEVELOPMENT.

Introduction

In agriculture, crop yield is influenced by soil type, land preparation, plant spacing and population, nutrient supply, disease and pest infestation, weed control, salinity and soil pH, soil and water management and irrigation.

Irrigation is the science of artificial application of water to land in accordance with the crop requirements. The main objective to irrigate is to provide water to the field to improve the soil moisture conditions for the cultivation of crops by controlling the soil moisture tension in the root zone within the ranges prescribed by the crop been cultivated

The need to irrigate becomes apparent when rainfall and/or other precipitation cannot supply enough soil moisture to meet the requirements of a standing crop.

Water is needed by the plant for the following reasons:

1. It is the main constituent of the plant protoplasm. Sixty to ninety percent of the flesh weight of a plant is water.
2. Water helps to regulate the temperature of the plant through transpiration.
3. Water is the main solute for the transport of nutrients, gases and other solutes in plants.
4. Water is combines with carbon dioxide to for carbohydrates. It is thus an indispensable component of photosynthesis.
5. Water helps to provide structural support for plants by maintaining turgidity within living cells.

Plants absorb water from the soil. Root tips will grow in the direction of positive moisture gradients. Moisture stress in plants occurs whenever the transpiration rate exceeds the rate of water absorption by the roots. When a plant is undergoing a moisture stress some visual indicators are loss of turgidity, change in the colour of leaves, curling of leaves, and cessation of gluttation when plant is cut. When moisture stress occurs there are some measurements that can be made to know the plant or soil water status and to know the time to irrigate and quantity of water to apply. Some are directly on the plant and others done on the soil.

The soil types are;

1. Determination of soil moisture retention. Soil water is held to soil particles by adhesive and cohesive forces and these forces designated by soil physicist as matric potential and have given a relationship between the matric potential and soil moisture content.

Table 1

PF	Suction ψm (bar)	% Moisture	Moisture availability	Agronomic description
≥ 4.2	- 16000cm (≤-10)	≤ 11	Unavailable moisture	Permanent Wilting Point
2.0 – 2.3	-100 to -200cm (-0.1 to -10)	12 to 50	Available moisture	Field Capacity
≤ 1	$\leq -10^{-1}$ to-10^{-3} cm - 0.01		Gravitational water	Saturation

Others are resistance of soil to penetration, feel and appearance of soil, gravimetric determination, neutron probe, tensiometry etc.

Some simple Irrigation terminologies and their meanings

1. Infiltration into the soil
2. Percolation
3. Crop Water Requirements. The total quantity and the way a crop requires water from the time of planting to the time of harvest. It varies with the type of crop.
4. Delta is the total depth of water required by a crop to come to maturity.
5. The Duty of water for a crop is the number of hectares of land which the water can irrigate.

Sources of Irrigation Water.

In Ghana the main source of water for irrigation is surface flows from rivers and streams.

These flows are influenced by the seasonal pattern of rainfall with high flows in the rainy season and low flows in the dry season. Other natural sources that supplement irrigation water are rainfall, natural springs/ground water and capillary flux into root zone.

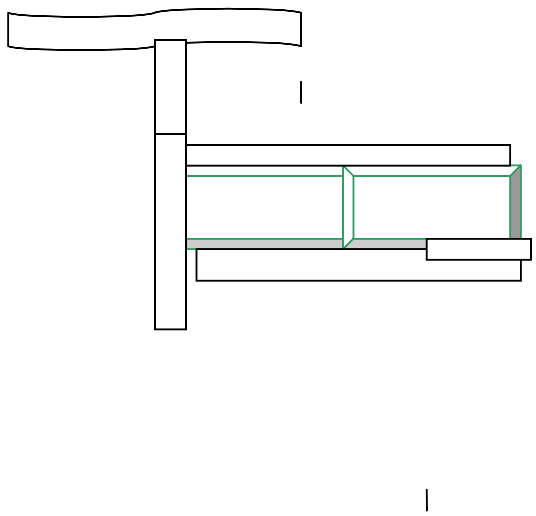

Figure 3

Non- uniformity of water distribution on the field especially due to poor levelling is not a problem in the “sawah” system.

Irrigation Requirements

The “Sawah” system is a field–to–field system with a continuous or intermittent delivery of water to the fields. Here water is delivered from a ditch to a series of fields receiving and or discharging water from and/or to each other by means of overflows. A drain ditch running alongside the last fields of the series evacuates the excess water. The water delivery to a series of fields is adjusted periodically according to irrigation requirements. The recommended water depth per development stage of rice is established by changing, periodically, the height of the field overflows. A lay out of the system is illustrated below

The irrigation requirement is determined so as to plan the allocation of the available water resources in a watershed, to establish the water delivery schedules for irrigation and to decide upon the capacity of canals, ditches and other structures.

In deciding when to irrigate rice the following irrigation scheduling has been established for farmers in the Ashanti Region of Ghana.

Soils of good paddy rice fields are always saturated. Decision to irrigate depends on the depth of water to be applied according to the stage of development.

1. After transplanting, a water depth of 2 cm is to be maintained on the field and the size of the plot is 20 m2. The volume of water needed is 400000 litres. Suppose the discharge rate of the canal feeding the plot is 200litres/s, the farmer should allow this volume of water to flow for about half an hour before the inlet is blocked.
2. After seedling establishment the depth of standing water required is 5cm.This calculates up to 1million litres of water for an area of 20m2. If the same discharge rate is supplied and all the 2cm of water applied at transplanting is used then the farmer should open the inlet to allow the water to flow for about one-and-half hours.

When to irrigate again depends on when the standing water will be consumed by evapotranspiration and percolation losses and the addition of water by rainfall.

In the semi deciduous forest of Ghana the average potential evapo-transpiration rate ETo is about 5mm/day for the period May to September when farmers crop rice. For growing rice kc (crop coefficient) value is 1.3. Thus actual evapotranspiration = 5mm x 1.3 = 6.5mm/day. Assume percolation loses for a clay-loam soil is 2mm/day. Daily water consumed = 8.5mm

Average effective rainfall for the period is 50mm for 10 days.

For the 5cm (50mm) standing on the field, effective rainfall that will be added for a 10 day period is 50mm = 100mm.

Average frequency of irrigation = 100mm/8.5 = 12 days.

The water requirement is made up of maintenance requirement and special requirements.

Maintenance requirements are made up of evapotranspiration requirement and percolation losses and these two components have to be into consideration anytime such estimation is been done. The Special requirement (**SR**) is the water needed to restore a certain layer of water in the field after a special operation such as water needed to saturate the soil before puddling, water layer restored on the field to promote the recovery of young transplants, for weed control, re-establishment of water level after fertilization. The special water requirement for any particular activity has to be added to the water requirement for better estimation.

D. Maintenance of Irrigation Facilities

Irrigation is a long-term investment and once the structures are laid down regular maintenance is required for efficient running. Routine maintenance of dams and canal such as blocking leakages, cleaning for efficient flow of discharge are necessary. Do not allow weeds to over-grow along the canals and the ditches, immediately reshape dams and bunds if the cave in plug leaking dams and bunds as soon as they are detected.

AGRONOMIC PRACTICES

Short Introduction:

Rice is becoming increasingly important as the staple diet of many African countries, including Ghana, but their farmers are unable to satisfy demand. Since most countries face considerable difficulties in importing this basic food, it is the objective of many governments to help increase local rice production wherever possible. It is hoped this manual will help increase local rice production in an economically acceptable manner through proper agronomic practices. Our aim is to contribute to a significant increase in rice production and a reduction of pre-harvest and post-harvest losses.

Land Preparation

Land is prepared in order to achieve the following objectives

- Break up hard soil and aerate it.
- Bury weeds and stubbles in the soil to decompose.

- Control weeds by encouraging the weed seeds to germinate early and burying them.
- Levelling the plots for water control.
- Produce a fine seedbed or soft soil for transplanting.
- Encourage rice roots to grow strongly and thereby reach more nutrients, avoid lodging, and ensure even growth and maturity
- Incorporate fertilizers more easily
- Produce a hard pan to retain water and nutrients.

Steps in Land Preparation

Land preparation starts with the complete removal of all vegetation, which may be buried completely to avoid re-growth through the pulverization of the soil to destroy lumps for proper levelling of the field. The order of the activities involved in land preparation is flexible and steps can be omitted or repeated according to specific needs.

1) Brush and clear field
2) Ploughing
3) Flooding
4) Harrowing, puddling and/or rotovation
5) Levelling and repair water control structures

Brushing and clearing

Cut stubble and weeds at ground level and leave them to rot or dry (Plate 5). Partial burning makes burying easier and accelerates decomposition. Complete burning may be justified if it speeds up operations, permits mechanical cultivation and/or kills weed seeds and rice pests. However, it is necessary to note that complete burning results in heavy nutrient losses.

Plate 5: **Brushing and clearing of bush**

Ploughing

The objectives of this activity are to bury the previous vegetation, loosen and aerate the soil, and bring leached nutrients back to the surface.

You should plough from two to four weeks before sowing or planting so as to give time for vegetation to rot /decompose.

Land preparation is heavy work and so is frequently mechanized. If you can afford it, select the right size of machine for the job. You should check comparative costs and benefits. Remember that power tillers and tractors need to be used if they are to be economical. In wet conditions dig with hoes, plough with oxen or rotovate with power-tiller or tractor. Work to a depth of 10-15cm.

In dry conditions, dig with hoes or spades, rotovate or disc harrow. Rice does not usually require deep soil cultivation, so use wide implements rather than those for deep digging.

Flooding

Keep bunds closed and flood the field or hold the rainwater, if under irrigation and rain-fed, respectively for three to four weeks before sowing or planting (Plate 6). The water makes the soil softer and germinates the weed seeds. It also encourages straw to decompose. Water also retains nitrogen in the soil.


Plate 6: Flood field prior to land preparation

Harrowing

Harrowing serves to break up clods of earth, to level the field and to make a good seedbed. It can be done under water or in 'dry' conditions after rain or irrigation. Ensure that all weeds are buried. Harrowing should be done with hoes, ox-driven harrows in water or tractor-disk harrow. It should be done until all weeds are completely buried. In the event of delay in sowing, harrowing should be repeated.

Puddling

Puddling serves to soften the soil for transplanting, make a pan for reducing percolation and help with levelling. Puddling should be done the day before planting or sowing. Puddled fields should not be allowed to stand for long before sowing/transplanting. It could be done under water by foot, with use of cattle, hoes, cage wheels and rotovators or by repeated wet harrowing.

Levelling

The objective of levelling in land preparation is to produce a flat field where water management and nutrient distribution can be made easier. It involves the movement of soil from higher (exposed) spots to lower spots; ending up with a smooth, level area before sowing or planting.

Method: If the soil is dry, irrigate to soften and to expose high ground. If the whole area is already flooded, then drain slowly to expose the high spots. Move the exposed soil to areas under water.

Keep the plot flooded until you are ready to sow or plant. This keeps the soil soft and allows weed seeds to float to the edge, ready for you to scoop off in the morning before beginning work.

Seed Selection

The objective is to produce strong, healthy seedlings that will give the maximum yield possible under prevailing conditions.

Method

Select a suitable variety

Obtain clean, healthy seeds

Test the germination rate

Pre-germinate the seeds

Sow in nurseries or directly into the field

Lift for transplanting, avoiding ‘shock’

Selecting a suitable variety

There are several varieties available worldwide. You should choose a variety that you know or one that is recommended by the extension service or researchers. When determining the best variety for your condition, the following must be considered.

Suitable condition refers to the best growing conditions-upland, inland valley swamp, deep water and possibly the soil types, organic, sandy, loam or clay.

Duration: Short – 80-120 days, medium- 120-150 days and long- more than 150days. Duration normally refers to the period from pre-germination to 85% maturity.

Growth forms: Modern varieties are erect, which allows sunlight to penetrate through their upright leaves

*Tillering ability***.** In the transplanting method, good tillering ability is needed to ensure that there are enough panicles per square metre. In the direct sowing method, low tillering varieties with a high seed rate are recommended for obtaining large panicles and a high percentage of filled grains per panicle.

Plant height. This is the distance from the ground to the tallest panicle at flowering. Dwarf varieties are under 80cm in height, Semi-dwarf means a height of less than 110cm, intermediate 111 to 130 cm and tall more than 130 cm.

Lodging: Select variety with high resistance to lodging. Such should have strong stem or thick culms that can withstand lodging under high nitrogen application

*Shattering***.** Select varieties that do not shatter even if this makes hand threshing more difficult.

*Response to fertilizers***:** You need a high response

Yield potential: At least four to five tons per hectare should be obtained

- Choose a traditional variety suitable for the local condition. Alternatively, you can choose a new variety recommended by researchers or extension service for your farming condition or system.

Seeding rates

The normal rates are 40-50kg per hectare for transplanting and 80kg per ha for direct sowing. However, these rates will vary according to:

- grain size, with big seeds sown at higher rates and small seeds at lower rates
- tillering ability
- germination rate
- expected losses caused by birds, diseases etc
- method of sowing- direct or transplanting

Your aim should always be to obtain from 250-350 panicles per m^2 at harvest

Seed rate for direct sowing under wet conditions = 80g/m2 = 80kg/ha

Example:

For a field of $1000m^2$, $\frac{1000 \times 80}{10,000} = 8$kg of seed

Pre-germinate 8kg of seed and divide the pre-germinated seed into equal parts for each plot. Walking in the trenches, broadcast one-half of the seed for a plot from one side and the remainder from the other side. Sow unto soft mud or into water and drain the next day.

Choice of sowing dates

Under rain-fed conditions, you must obviously wait for a period of reliable rains before sowing. Sowing must be finished early enough to be sure of rain for 20days before and after flowering. With irrigation, you can be more flexible. You should generally sow long-duration varieties early in the rainy season and medium and short duration varieties later. In the dry season, most farmers use short duration varieties only. Aim for ripening phase to occur during sunny weather and then calculate back for the best sowing date.

Obtaining Clean Healthy Seed

Be sure to buy seeds from a reliable source. Usually where available, buy certified seeds from a recognized seed farm with the following characteristics:

- Germination and seedling vigour (over 85percent)
- Genetic purity (98 to 100 percent)
- Moisture (12 to 14 percent)
- Infected seeds, insect pests, weed seeds inert residues (0 to 1 percent)

Note:

Your own seed or that bought from a neighbour are the cheapest. However, certified seed purchased from a seed farm costs more but has the following advantages:

- high germination rates, meaning less seed is needed
- purity of variety, allowing uniform height and maturity dates
- fewer weeds, less expense for weeding and better yields
- Improved varieties are usually available, providing higher yields and profits for the same effort and costs

Nursery Establishment

Testing Seed for Vigour and Germination Rates

Employ the following field technique to test for vigour and germination rates.

- Separate filled grains from the lights and empties by winnowing or floatation (as described under Pre-germination).
- Count out 100 grains and lay them in damp cloth, between sheet of wet paper, then cover them.
- Arrange the seeds in rows of say ten to ease counting. Replicate it four times.

- Label each set with name and dates. Wait three days. Keep seed moist but not too wet.
- Count the number of normal shoots measuring 5 to 8 mm in length; 80 or more per 100 is an acceptable rate; 60 to 80 means an extra measure for every three measures of seed will be required.

Pre-Germination

- Separate the good seeds from the damaged ones by winnowing or using the flotation method. Empty all the seed into containers filled with muddy water, stir and scoop off any floating seed (good seed is heavy and sinks)..
- Soak the clean seed for 24 hours either in containers of water or by putting jute bags of rice into a drum or canal of water. Stir occasionally.
- Drain off the water and incubate for two days or more, depending on the temperature. Keep the container of bags under cover in the shade so that they stay moist.
- . Do not wait until the roots appear as the seeds will be difficult to sow and the shoots will break off.

Do not pre-germinate seed for sowing in rained nurseries or fields.

METHODS OF SOWING

Three different methods employed for sowing rice are:

(i) Sowing in nursery and then transplanting

(ii) Sowing rice directly onto a dry (Rain fed condition) field.

(iii) Direct sowing pre-germinated seed onto wet “sawah” field

Sowing in Nurseries

This is the method used worldwide. It is most reliable method where there is adequate water or rain in swamps. The normal rates are 40 kg per hectare for transplanting.

These rates will however change according to:

- Grain size, with big seed sown at higher rates and small seeds at lower rates;
- Tillering ability;
- Germination rate;
- Expected losses caused by birds, rodents, disease etc.;

- Method of sowing- transplanting or direct.

You should aim at 250 to 350 panicles per m^2 at harvest.

Advantages include

- better weed control with land preparation and water
- better growth as a result of equal spacing between hills
- more flexibility with dates of planting and land preparation
- the possibility of preparing nurseries in advance to allow maximum use of good growing conditions. This is the only practical way to do multiple cropping

There are three types of nurseries:

- Dry bed nurseries
- Wet bed nurseries
- Dapog nurseries

Dry-bed nurseries

These nurseries are commonly used in mangrove swamp areas and in many rain-fed swamps in West Africa. Usually practiced under rain fed "sawah" systems.

Seed rate should be 40 to 50kg per hectare

-The seed-bed is brushed, manure applied and dug, then raked and made into beds of convenient dimensions. The seed is sown and lightly covered with soil.

- Use long grass, straw or palm leaves for one week to protect the seed against birds and prevent it from drying out.
- Keep the beds moist with rain or bucket water
- Lift seedlings from 15-30days

The objective is to produce strong seedlings (plate 8) which:

- recover quickly from transplanting and start tillering
- make early use of basal fertilizers
- resists diseases and pests
- establish themselves quickly and thus resists flooding and weeds.

Plate 8: Establish nurseries

Wet-bed nurseries

This method is more appropriate and recommended for irrigated “sawah” farming system.

- Dig a piece land where water can be let in and out and kept under control.
- Make a bund all round to separate the piece of land from the field and other nurseries.
- Peg out the beds and canals
- Dig the channels with a width of 20 to 30cm wide and a depth of 10 to 30cm, thus slightly raising the beds.
- Level all the beds uniformly
- Scatter the pre-germinated seeds evenly onto the muddy surface or into shallow water.
- Protect the seeds with palm leaves or long grass
- Ensure that excess water can be removed through the bunds or pipe at the bed level

Irrigate to keep the bed wet or submerged.

Dapog nursery

These are only suitable for well-developed “sawah” with inlet and outlet for irrigation and drainage. It is a quick and easy way to produce seedlings, with minimum disease or pest damage as well as limited land and water requirements.

- Select a shallow container that is adequate for the quantity of seed
- Banana leaves are laid in bamboo frame or alternatively use a box with a thin layer of soil.
- Sow the pre-germinated seed thickly but evenly and one or two seeds deep
- Using a brush all bundle of leaves, sprinkle water onto the seeds to keep them moist. They should be covered initially to reduce evaporation.
- Netting may be used to prevent insect damage.

When ready in 10 to 15 days, the carpet of seedlings is rolled up and taken to the “sawah” field. The bundle must not dry out and planting must be done the same day as lifting of each section

Direct sowing (dibbling and broadcasting)

Direct sowing is widely used in large-scale operations and in drier areas such as rain-fed upland rice farms.

Dibbling: This involves planting rice seeds in holes made by any pointed implement such as bamboo or wooden stick. The seed rate is 80kg per hectare for direct sowing. This rate rates will however change according to:

- Grain size, with big seed sown at higher rates and small seeds at lower rates;
- Tillering ability;
- Germination rate;
- Losses caused by birds and rodents

Broadcasting: There are two types of broadcasting rice seeds onto the field. There are

a) direct and uniform throwing of dry seed onto dry land and working it into soil

b) direct and uniform throwing of pre-germinated seed onto wet field

Direct sowing under dry conditions

Direct sowing is usually used in large-scale operations and in dryer areas such as rain fed rice farms.

Low labour costs for sowing, quick development of seedlings without transplanting shock are the main advantages of employing this method.

Need for extra seeds to compensate for irregular germination, poor seedlings and bed, rat and rainstorm damage and high weed incidence are the demerits.

- The seedbed should be crumbly, level and free of weeds.
- Sow some 80 to 100 kg per hectare of dry seed.
- You can broadcast the seed manually or with a tractor drawn planter.
- After sowing, lightly harrow and row the field to cover the grain and make good contact between the soil moisture and seed.

Direct sowing under wet conditions

- Plough, rotivate, puddle the land to produce clean and level seedbed.
- Make outlet and inlet for irrigation and drainage.
- Irrigate to keep seedbed wet.
- Sow 80 kg of pre-germinated seed onto soft mud.
- Fill any gaps with seedlings from the more densely sown patches from 15 to 18 days after sowing
- Irrigation to keep land submerged

Lifting of seedlings

Lifting of the seedlings in an appropriate way should be done without breaking the stems, without loosing too much leaf and root and avoiding transplanting shock.

- For the wet or dry-bed nurseries, seedling age should be from 18 to 25 days old.
- Dry bed nurseries are lifted in the mornings after rain or watering to soften the soil. The soil should be loosened by undercutting the roots with a spade.
- Wash off the soil to ease transportation and transplanting.
- In the case of wet-bed seedlings, hold two or three seedlings near the base and pull at an angle (30^o)
- Tie seedlings in small bundles.

- Keep in the shade and keep moist (preferably with roots in water) until planting.

With Dapog nurseries, the seedlings should be simply rolled up and carried to the field. Bits of the mat is cut off and placed in water close to the planters.

How to avoid transplanting shock

Having grown strong seedlings in the nursery, it is important to keep them strong while weaning them from the protection of the nursery to life in the field. If mistreated, they are liable to suffer shock and stop growing for 7-21 days, thus tillering much less.

Steps

1) Always soften the soil with water before lifting. Grasping about 4 seedlings between the thumb and forefinger as close to the base as possible, pull them out at an angle of about 30^o to the horizontal (ground surface).
2) pull two or three seedlings together at an angle of 30degrees, holding them near the base to avoid damaging the stem or leaves
3) wash and shake off surplus mud
4) tie in small bundles
5) keep in the shade and keep moist until planted, preferably with the roots in water
6) plant into water or wet mud the same day as lifted
7) keep moist after planting
8) Do not cut leaves or roots unless they are very long, as cuts may let in disease.

Spacing

The objective of spacing is to minimise competition. Aim at having 250-350 panicle per m^2. The normal procedure is to plant 2-3 seedlings per hill at 20 x 20 cm intervals. The planting distance can be changed depending on the situation. Plant in straight lines. Space the plants properly to allow access for fieldwork and to let sunlight reach all the leaves. Wider intervals (20 x 25 cm) could be adopted if tillering of the rice variety is profuse. When few tillers are expected, plant at either 20 x 15 cm or 20 x 10 cm.

Lining:

The following is a common procedure for lining a field before transplanting rice seedlings**.**

- Find a strong rope and tie the knots every 20 cm (or at whatever distance you need). Short ropes are better for greater number of transplanters.
- Insert pegs at a distance of 20 cm intervals along the width (two sides) of the field.
- The knotted or marked ropes should be tied on the opposite pegs for line planting.

Alternatively

- Use tracers to mark the planting lines in each direction for the planters to plant at the intersections

Even though lining is slower than random planting, the spacing is more exact, there are fewer weeds, access is easier and the results are tidier.

Transplanting

Aim at planting strong seedlings in clean ground so that they grow quickly to smoother weeds and resist flooding (plate 9)

Transplanting Procedure

- Use two fingers to make the hole, keep the roots down
- Plant seedlings 2 to 5 cm deep in the soil
- Plant a straight guideline from one end to the other near one side. Plant a second line parallel to the first. The process must continue until the entire field is fully planted to rice.
- Keep a few bundles ready in the field to be used filling any gaps (dead seedlings)
- Keep the field flooded to 3cm.
- Drain briefly after 4 to six days to help rooting.

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Plate 9: Transplant soon after puddling and levelling is complted

FERTILIZERS AND THEIR APPLICATION

What is a fertilizer?

Fertilizer is any material, organic or inorganic, natural or synthetic, that provides for plants one or more of the chemical elements necessary for normal growth and yield

There are therefore two main types of fertilizers.

- **(a)** natural fertilizers which come from natural sources such as plant or animal origin, and
- **(b)** artificial or mineral fertilizers that are fertilizers, which are manufactured from synthetic materials.

Nutrients are needed for the manufacturing of food for the plant, maintaining life, growth of roots and vegetation and for making the rice grain.

Nitrogen, phosphorus and potassium are the most commonly needed nutrients. Each nutrient is needed for one or more purposes, often at different life stages of the crop. Micronutrients are also essential and without them or excess of them, the rice will be unable to produce grains.

Mineral fertilizers

There are different commercial fertilizers available on the market and attention should be paid to the percentage content of each nutrient, as it varies depending on the producer.

Basal fertilizers

(i) NPK (15-15-15) ═ 15% N + 15% P_2O_5 + 15% K_2O

(ii) NPK (20-20-0) ═ 20% N + 20% P_2O_5 + no potash

(iii) NPK (23-15-5) ═ 25% N + 15% P_2O_5 + 5% K_2O

Topdressing fertilizers

(i) Urea

(ii) Ammonium sulphate

Basal fertilizer should be applied by broadcast a week after transplanting when plant roots would have been firmly established (plants uprooted need sometime for their roots to be firm before nutrient absorption begins).

Nitrogen fertilization and timing

Yield responses of 20 kg or more of grain per kg of nitrogen are often obtained.

A rate of 80 kg N/ha, N is recommended to be split applied especially in the sandy soils (50% as basal and 50% top dressing). Urea or ammonium nitrogen should be broadcast evenly into the floodwater.

Phosphorus fertilization and timing

Rice takes up about 8 kg P_2O_5 per tonne of grain produced. 60 kg P_2O_5/ha will be enough for improved varieties.

Phosphorus should be applied as basal dressing. Rock phosphate may be used on acid soils.

Potassium fertilization and timing

Total uptake of potassium by rice is much more than P but most of this remains in the straw. Improved rice varieties usually respond to potassium especially when given adequate nitrogen and phosphorus. For improved rice varieties application of 60 kg K_2O/ha is necessary. On most soils potassium fertilizer should be applied as basal.

METHODS OF FERTILIZER APPLICATION

The method used in applying fertilizer should be such that it will optimize the utilization of fertilizer nutrients by the target crop(s). Different fertilizer materials are used for different crops, soils, climate and management conditions. The following are common methods used in rice cultivation. During fertilizer application, farmers should walk through the field. Broadcast fertilizer uniformly on field. Avoid standing on bunds to draw fertilizer onto field.

Broadcasting	Is the uniform distribution of the fertilizer material over the whole area
Foliar application	Is the method of applying fertilizer to the foliage in solution form by spraying. It is the most efficient way to apply minor elements that are needed only in small quantities and which may become unavailable if applied to the soil. Alternatively, certain kinds of fertilizers might be applied in combination with insecticides or fungicides (e.g. Urea)

For fertilizer analysis and calculation of fertilizer rates, see appendix 2

Organic fertilizers:

Organic fertilizers can play an equally important role as mineral fertilizers in rice fertilization. They are cheaper but more bulky and difficult to carry. They, however, have longer lasting effect than mineral fertilizers. Common organic fertilizers are (i) Poultry manure and (ii) Cattle manure. These should be thoroughly worked into the soil at least two weeks before transplanting. Field trials within the semi-deciduous forest zone has shown that 6-8 t/ha of either poultry manure or Cattle manure will produce equal results as 80-60-60 kg/ha NPK or a combination of both mineral and organic fertilizers at half rates.

WATER MANAGEMENT

Supply, distribution, drainage:

The type of "sawah" to develop is greatly influenced or determined by the type of source of water. Relatively level topography (which will require less levelling), with light tree cover and gentle river meanders should be preferred.

Water requirement varies at different stages of the production process from land preparation to harvest. The amount of water required is determined by the stage of growth of the rice plant. The stages are briefly described below.

Water should be supplied directly into a rice field. Avoid the supply of water from one field to another. When water is supplied through pumping, pump directly into the rice field or into a canal that goes directly into the rice field. Avoid pumping water into a field and allowing water to run from that field into another.

With the spring type water can be directed into a reservoir (pond) and then into the various rice fields via a canal

Total water lost per day across rice fields averages 6-10mm. Thus about 180-300 mm water per month is needed to produce a reasonably good crop of rice. In field operations, a total of 1240 mm water is an average water requirement for an irrigated rice crop.

Factors to consider in water management under "sawah" rice production include:

5. Reliable water source and availability (dam, dyke, pond etc)
6. Strong and clear water ways (canals)
7. Well levelled and flat fields
8. Strong bunds

(a) Water management before planting (land preparation)

Water management in rice cultivation under the "sawah" system starts during puddling and levelling. Large volume of water is required at this stage, about 5 – 10cm depth of water. Puddling is the process of turning the soil into a fine medium (mud). Through this process the soil structure is practically destroyed or disorganized. It is necessary to build bunds where they are not available and to repair any broken ones. This improves the impounding of water. Levelling is the process of moving soil from one point to another in order to create an even and level surface.

Note: A rice crop seeded or transplanted into a well prepared weed free soil is much more likely to grow healthier, make maximum use of available water and give high yields than one grown in a poorly prepared soil with a haphazard water regime.

(b) Water management during planting (seeding and transplanting)

After nursing seeds, the nursery should only be kept moist and not flooded particularly when seeds were not pre-germinated before nursery establishment. After germination, a nursery can be intermittently flooded but never ponded (submerged seedlings die and surviving ones become weaker).

During seedlings removal:

Using the wet-bed method, seedlings are normally ready for transplanting 20 days after nursing. At this stage, the plant is at 4-5-leaf stage. Before pulling out seedlings, the nursery should be flooded for about a day. Do not drain water completely from the nursery before seedlings are pulled out. Soil surface should still be completely covered by water when removing seedlings.

After the field has been puddled, levelled and smoothened, minimum water levels of up to 5 cm should be left on the field, to prevent drying. During transplanting, the water level can be reduced to less than 5cm but the field surface should not be allowed to completely run dry. When transplanting in a field is completed, only a minimum level of water should be allowed on the field for the first two weeks

Note: At the seedling stage, the water requirement of the rice plant is lowest.

Water management at basal fertilizer application (vegetative growth stage)

Basal fertilizer should be applied to rice not later than a week after transplanting. The production of an adequate number of tillers is an important factor in achieving optimum yields. Immediately after transplanting, sufficient but minimum water should be provided to stimulate early rooting. Following this stage, a shallow depth of water will stimulate root development and tiller production, whilst excess will hamper rooting and decrease tiller production.

Water management at reproductive growth stage (maturity)

Reproductive growth starts when maximum tiller production is completed and includes the panicle initiation, booting, heading and flowering stages. A large amount of water is required during this stage. Consequently, if the plant suffers water stress at this stage, the results are reduced heading and flowering, and increased panicle sterility. In contrast, excess water causes a decrease in culms strength and so increase lodging. Fields should therefore be provided with adequate water (up to 15cm depth). However, during topdressing (second fertilizer application), water levels should be adjusted to very low levels (below 5cm). A few days later, water levels should be raised again (made deeper).

Water management at ripening stage (harvest)

This is the last stage of the growing period and is divided into the following sub-stages: milk, dough, yellowish and full ripening grain. Very little water is needed at this time. After the yellowish ripening stage, no water is required. Consequently the field should be drained (about 10- 14 days before harvest).

Note:
The peak water demand of rice is between maximum tillering and grain filling stages.

Water management at herbicide/Pesticide application

Herbicides are normally applied as a measure for weed control. Under the "sawah" system, the best and economical method of controlling weeds is by the use of water. Strict adherence to proper water management methods can result in a weed reduction of about 70-80%.

Note:

- Water weeds (not affected by water), however, may be removed manually by hand in order to reduce cost. In addition, proper water management can result in increased fertilizer use efficiency
- Depending on the age of the crop, field water levels should be reduced but not completely drained when herbicides are being applied.

WEED MANAGEMENT

Weeds are plants growing where they are not wanted. Weed control starts before sowing and continues until harvest. Weeds are costly because they reduce yields, serve as hosts for insect pests and diseases, compete with rice for space, nutrients and water and also contaminates the produce especially the seeds. Weeds must therefore be controlled before they harm the rice.

There are two alternatives in controlling weeds, by avoiding weeds (prevention) and killing weeds (cure).

Prevention

-To avoid weeds, use clean land.

- Always ensure that all weed foliage is completely buried, covered by water or separated from the roots.
- Good land preparation encourages rice to grow faster and thus smother weeds.
- Use clean seed that is free of rice-like grass weeds.
- Transplant or sow thickly and refill gaps quickly to smother weeds.

Cure

To kill weeds, you may use the following methods:

- Traditional hand-weeding: Weed twice, six weeks after sowing or three weeks after planting and three to four weeks later.

- **Rotary weeders** (if available)

- Chemical herbicides: These are simple and quick to apply, although chemicals and sprayers may not be readily available. Herbicides are classified according to their effects on weeds. The classifications are contact, systemic, non-selective, selective, persistent, non-persistent, pre-emergent, post emergent, straight and mixed herbicides. They are sold in various forms, including emulsifiable concentrate (EC), liquids, wetable powders (WP) or granules and they are sold in different formulations.

(Available herbicides on the market**)**

INSECT PEST MANAGEMENT

The damage caused by insects is inevitable in rice cultivation but if there is the need to control, one should find out if the damage caused by the insect remains below the economic threshold level. If the extent of damage is in general smaller, chemical spraying is not necessary. If there is the need to control chemically, pesticides that are effective against the target pests should be selected. Examples of some common insect pests of rice are: **Thrips, leafhoppers, stem borers, rice bugs** etc. If possible, take samples to be identified by specialists. Be careful to collect the insect that is actually causing the damage and not the harmless insect, which is merely in transit

Insect damage is inevitable in rice cultivation. There is no need for pest control if the degree of damage remains below the economic threshold level. When chemical control is required, select pesticides that are effective against the target pest(s) and spray them at optimal concentration and quantity. During the establishment of nurseries, chemicals such as furadan granules (carbo-furan) may be applied to reduce/minimise infection by stem borers, rice hispid, white fly and grain suckers among others. Where nurseries are not treated and insect pest emerge, spraying with recommended chemicals may be necessary

DISEASE MANAGEMENT:

Since there are two types of diseases, i.e., those caused by fungi, bacteria and viruses, and those of physiological origin associated soils or nutritional conditions, care should be taken not to confuse diseases of pathogenic origin with physiological disorders. It is better to use resistant varieties and to use clean, healthy and vigorous seeds to prevent diseases.

Some common rice diseases in Africa include: **Leaf blast, Brown spot, Bacterial blight, rice yellow mottle** etc. Fungicides are seldom economical unless yields are very high and it is not usually necessary if good agronomic practices are followed. Treatment involves spraying systemic, non-systemic or antibiotic fungicides two or three times per crop.

Some examples of diseases and their methods of control are:

*Rat control***:** Clearance of sheltering places for rats by cleaning up field plots and bund mounds should be as small as possible, not to become shelters for rats. It is also essential to develop an efficient control system at the village level.

Bird scarring:

Different ways of expelling birds exist. This includes scarecrows, scarekites etc but these become gradually ineffective since the birds recognize the devices with time. The most effective way is to cover fields with bird protection nets, but they are not economical. It is recommended to expel them by emitting loud noises if a large area must be covered. In this regard, 'bird boys' or scarer boys are hired.

Harvesting

Rice matures 25-35 days after flowering/ Harvest the crop when 80-85% of the total grains have become yellowish. To avoid shattering, harvesting can start when the bottom grain of the main panicles are hard (you squeeze them between your fingers).

A crop that is properly harvested at the right time attracts better market prices than one that is not. Better market prices for a crop will depend on (i) if the crop was harvested when it was fully ripe (ii) the crop was well dried (iii) crop was properly threshed and (iv) crop was properly stored.

Cutting:

Rice should only be cut when it is fully ripe. Rice is fully ripe when it has developed entirely yellowish heads. Cutting can be done using a sickle (plate) or a kitchen knife (plate). Hold the rice stalks about 10-15 cm from above ground surface, and gently slash it with either a sickle or knife. Cut rice should be neatly packed on the threshing floor or a tarpaulin while waiting threshing. Cut rice that is allowed to lye on the soil surface shatters thereby losing more grains. Cut rice that is also allowed to lye in water on mud grows mouldy and therefore develops poor quality.

Plate 10: Harvest grains at right time and heap them on concrete floor or tarpaulin

POST HARVEST

Threshing:

There several ways of threshing rice and varies according to convenience and suitability of location. The commonest methods include (i) Beating/hitting with stick on a concrete/hard floor (ii) Beating /hitting panicles against a hard surface (e.g. threshing wooden box, an empty barrel or a tree trunk) and (iii) the use of a thresher.

(i) Beating with a stick: Harvested rice is placed on a hard or concrete and hit hard with a stick until all grains are removed. The floor must, however, be clean and free of any foreign particles. The floor can be covered with a tarpaulin if available to help ease grain collection after threshing.

(ii) Hitting panicles against a hard surface: Hold a handful of harvested rice by the straw and hit it hard against a wooden box (plate), an empty barrel (plate) or a tree trunk (plate) until all grains are removed. The hard hitting surface (box, barrel or trunk should be placed on a tarpaulin to help ease collection of grains.

Plate 11: Thresh using empty drums but on a clean surface

(iii) Use of a rice thresher: This is a more sorphiscated method of rice threshing and involves the use of a simple machine as shown in plate. Harvested rice is manually fed into a leg-operated machine that automatically removed grains from straw.

Winnowing:

After rice has been threshed, it is important that, grains are made clean and free of chaff (unfilled grains) or any foreign materials. This is made possible through the process of winnowing. Rice is collected into a container (e.g. bowl, pan etc). It is then raised up to shoulder level and allowed to gradually pour (plate) onto a clean surface (e.g. a basin, basket, tarpaulin). Wind blowing through the rice as it falls cleans it of any chaff and allows only fully filled grains to collect. By this way, clean material is obtained.


Plate 12: Winnow on clean surfaces in order to obtain clean grain

Drying: Threshed and well-winnowed rice should be thoroughly dried in the sun for about 4-5 days. Rice grains should be dried on either a concrete floor or tarpaulin to prevent contamination by impurities such as stones, weed seeds etc. Grains should be dried to a moisture level of 12-14%. Grains that are not well dried will grow mouldy when stored

Storage:

Rice can be stored when milled or paddy. Milled or paddy rice should be stored in a well-ventilated room for free air circulation. Grains should be put in containers or sacks of any size based on convenience. Method to adapt will depend on storage facilities available

Milling:

Rice can either be milled raw or when par-boiled. Rice should be milled at a grain moisture level of 12-14%. Grains that are too dried (moisture level below 12%) results in too much breakage and hence poor quality.

MARKETING AND FINANCE

Introduction

Rice is one of the most popular consumed foods in Ghana. It is consumed in every household. Most urban population attributes its popularity partly to the ease of preparation, availability and preference

For this exercise, rice consumed in Ghana may be categorized into locally produced and imported rice. Ghana's consumption level is about 519,000 metric tones per annum (FAO, 2002). About 67% of the consumption is imported and the rest derived from local production.

Consumers generally have high preference for imported rice and the reasons normally given are that,

1. Imported rice is delicious and nutritious
2. It is free of dirt and makes cooking easy while locally produced rice contains a high level of dirt such as gravel and incomplete dehusking.

The Nature of the Market

Market available for the sale of rice is provided by public institutions (e.g. schools) and the open market. In all these markets, middlemen and women play a vital role by buying from the farmers and distributing to the centres. As individuals, most of the farmers who produce at a very small scale, may find it difficult selling directly to market women or the institutions. The link provided by the middlemen and women is therefore very important in ensuring market and income for the farmers.

Improving Rice Quality for the Ghanaian Market

Improvement in the quality of locally produced rice is required to change the negative perception on the produce. If this is achieved, it is expected to increase demand, attract good price and income to the farmer.

Therefore, quality concerns emanating from consumers should consider:

1. Good taste, which depends on the choice of appropriate variety
2. Minimum broken grains during milling
3. Ensuring dirt-free rice, which depends on careful post-harvest handling during threshing, winnowing, drying, storage and milling

Good packaging with labels attractive to consumers is also important. These measures could be carried out only at a certain level of production.

Most rice farmers' produce on a small scale and as individuals will find it difficult to ensure good quality and packaging due to differences in variety and mode of handling.

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To attain the desired quality and packaging, it is desirable that farmers constitute themselves into groups that will pool resources together; draw up regulations on the use of common variety, uniform processes regarding post harvest handling and the acquisition and use of simple machines.

It will also facilitate assistance from financial institutions, NGO's and the government.

AGROFORESRY AND "SAWAH"

Agro-forestry can be integrated into the "sawah" systems for sustainable rice production. The trees planted can recycle nutrients, conserve soil and water and provide environmental stability. They are best described as ecological engineers. The trees also produce fuel-wood, construction wood, food in terms of fruits and income from yield thus, providing alternative livelihood needs to rice farmers.

In *"sawah"* rice fields, bunds are constructed and periodically maintained. Cultivating short duration leguminous plants like *Cajanus cajan*, etc on them could stabilize the constructed bunds. This will stabilize the bunds year after year for long usage with minor or no repairs. The *C. cajan* nodulates, its leaves are rich in mineral nutrients more especially N. The leaves may drop into the rice field, decay, mineralise and supply nitrogen to the rice plant to reduce chemical nitrogen fertilizer use. The fruits of *C. cajan* also serve as food for the farmer to improve his protein diet.

Draw *Cajanus cajan* plant on bunds of a rice field

On the uplands of rice fields, leguminous tree species must be planted. Planting arrangement should be mixed plantation to produce higher biomass for mulching, ensure efficient nutrient recycling and to stabilize the upland soils by reducing soil erosion but rather, enhancing run off water with its dissolved nutrients from the up-slope to down the valleys to fertilize the lowlands of the rice fields. Plots measuring 12m x 12m established on the middle slope in the toposequence of the inland valley sites. Tree spacing (3m x 3m) of *Senna* plus *Leucaena leucocephala* mixed culture.

Draw mixed plantation of leguminous tree species on the upslope of a rice field

The tree species could be harvested periodically after rice harvests. The woody portions could be used for purposes like fuel wood, construction wood, etc, and the leaf, branchlet, etc, portions left in the rice field as green manure for the next cropping seasons.

AVERAGE COST OF "SAWAH" CONSTRUCTION

There are several types of "sawah" systems that have been tested. The cost of construction per hector of each system depends on slope of land, volume of soil movement, water availability, fuel for machinery, distance of site (accessibility) etc.

Estimated cost of construction and selected parameters for the different “sawah” types at the year 20000 are showed in Appendix 3.

APPENDIX 1

Glossary:

Some simple Irrigation terminologies and their meanings

6. Infiltration: The movement of water into the soil through the soil surface down the profile.
7. Percolation: It is the movement of water within the soil out of reach of the root zone.
8. Crop Water Requirements. The total quantity and the way a crop requires water from the time of planting to the time of harvest. It varies with the type of crop.
9. Delta is the total amount of water required by a crop to come to maturity measured in depth (mm). If rice takes 120 day to mature and it needs 6mm of water/day the delta of rice is 6 x 120 = 720 mm or 72 cm.
10. The Duty of water for a crop is the number of hectares of land cultivated to the crop under consideration, which the water can irrigate.
11. Infiltration into the soil
12. Percolation
13. Crop Water Requirements. The total quantity and the way a crop requires water from the time of planting to the time of harvest. It varies with the type of crop.
14. Delta is the total depth of water required by a crop to come to maturity.
15. The Duty of water for a crop is the number of hectares of land that the water can irrigate.

Table 1:

PF	Suction ψm (bar)	% Moisture	Moisture availability	Agronomic description
≥ 4.2	- 16000cm (≤-10)	≤ 11	Unavailable moisture	Permanent Wilting Point
2.0 – 2.3	-100 to -200cm (-0.1 to -10)	12 to 50	Available moisture	Field Capacity
≤ 1	≤-10^{-1} to-$10^{-3\ cm}$ - 0.01		Gravitational water	Saturation

Others are resistance of soil to penetration, feel and appearance of soil, gravimetric determination, neutron probe, tensiometry etc.

Water Depth for optimum Yield for different Growth Stages of Rice

The different growth stages of rice can be grouped as

1. Establishment Stage – nursery, germination and emergence and recovery after transplanting and development of new roots.
2. Vegetative stage – primary and secondary tillering, peak tillering and stem elongation.
3. Reproductive stage – panicle initiation, booting, heading and flowering.
4. Grain filling and maturity.

Each of these stages requires changes of water depth for optimum performance.

Too little or too much water reduces yield.

Growth Stage		Recommended depth of water (cm)
Land preparation (wet tillage)		5 – 10 cm
Nursery		
Transplanting		2 cm
Recovering		5 – 10 cm
Tillering		5 – 10 cm
Panicle development		5 – 10 cm
Yield formation		5 cm
Ripening		0 cm

Stress periods occur when there is no standing water for more than three days. They may reduce yield especially at panicle development.

APPENDIX 2

FERTILIZER ANALYSIS AND CALCULATION OF FERTILIZER RATES

After determining the nutrient status of a soil through analysis or fertilizer trials, we can determine the kind and quantities of the various fertilizer elements required. There are many mineral fertilizer types suitable for rice in the Ghanaian market and some of these include the following:

Name of fertilizer	Chemical formula	Contents of elements (%)
N-fertilizer		
Ammonium sulfate	$(NH_4)_2SO_4$	21 (N) – 24 (S)
Urea	$CO(NH_2)_2$	46 (N)
Ammonium chloride	NH_4Cl	26 (N)
P – fertilizers		
Single super phosphates		18-20 (P_2O_5) - 18 (Ca) – 12 (S)
Triple super phosphates	$Ca(H_2PO_4)_2$	45 (P_2O_5) – 14 (Ca) – 10 (S)
K – fertilizers		
Potassium chloride	KCl	60 (K_2O)
Potassium sulfate	K_2SO_4	53 (K_2O) – 18 (S)
Compound fertilizers		
NPK 15-15-15		15 (N) – 15 (P_2O_5) – 15 (K_2O)
NPK 20-20-0		20 (N) – 20 (P_2O_5) – 0 (K_2O)
NPK 25-15-5		25 (N) - 15 (P_2O_5) - 5 (K_2O)
NPK 17-17-17		17 (N) - 17 (P_2O_5) - 17 (K_2O)

Calculation for single (straight) element fertilizers

In deciding what fertilizer material to use, consider the following:

(a) Is it available locally?
(b) Is it the least expensive fertilizer available?
(c) Is it suitable for the target soil conditions?

List the necessary data (information available)

(a) Recommended rate of fertilizer application (R)
(b) % Concentration of nutrient element (C)
(c) Area to be fertilized in m^2 (A)

Calculate the amount (Q) of the fertilizer required per hectare (kg/ha)

$$Q = \frac{R \times 100}{C}$$

Calculate the amount of fertilizer required per square meter (kg/m^2)

$$Q1 = \frac{R \times 100}{10{,}000C} = \frac{R}{100C}$$

Calculate the amount of fertilizer required for the given area:

$$Q2 = \frac{R}{100C} \times \text{Area } (m^2)$$

Or

$$Q2 = \frac{R\ (kg/ha) \times \text{Area } (m^2)}{100 \times C}$$

Example

You are to apply fertilizer to rice at the rate of 90 kg N/ha, 60 kg P_2O_5 /ha and 60 kg K_2O/ha

Your plot size is 20 m x 30 m. If the fertilizers available are urea (46%N), triple super-phosphate (46% P_2O_5) and muriate of potash (60% K_2O). Calculate how much of these fertilizers will be required.

Nitrogen

Rate per ha = 90 kg N

Plot size = 20 x 30 m^2 = 600 m^2

The amount of urea required for 1 ha $= \frac{90 \times 100}{46} = 195.65$kg

Amount of urea required per m^2 $= Q1 = \frac{R \times 100}{10{,}000C} = \frac{R}{100C} = \frac{90kg}{100 \times 46} = 0.01956$ kg

If 1 m^2 requires 0.01956 kg urea, then 600 m^2 will require 600 x 0.01956 = 11.74 kg urea

Phosphorus

Rate per ha = 60 kg P_2O_5

Plot size = 600 m^2

The amount of TSP required per hectare $= \frac{60 \times 100}{46} = 130.43$ kg

Amount of TSP required per m^2 $= Q1 = \frac{R \times 100}{10{,}000C} = \frac{R}{100C} = \frac{60kg}{100 \times 46} = 0.013$ kg

If 1 m^2 requires 0.013 kg, then 600 m^2 will require 600 x 0.013 = 7.83 kg TSP

Potassium

Rate per ha = 60 kg K_2O

Plot size = 600 m^2

The amount of MOP required per hectare $= \frac{60 \times 100}{60} = 100$ kg

Amount of MOP required per m^2 = $Q1 = \frac{R \times 100}{10,000C} = \frac{R}{100C} = \frac{60kg}{100 \times 60} = 0.01kg$

If 1 m^2 requires 0.01 kg MOP, then 600 m^2 will require 600 x 0.01 = 6.0 kg MOP

Total fertilizer required for 20 m x 30 m plot = 11.72 kg urea + 7.83 kg TSP + 6.0 kg MoP

Calculations for compound fertilizers

In deciding what fertilizer material to use, consider the following:

(d) Is it available locally?

(e) Is it the least expensive fertilizer available?

(f) Is it suitable for the target soil conditions?

List the given data (information available)

- recommended rate of fertilizer application
- Area to be fertilized
- Recommended proportions of nutrient elements (e.g. NPK 15-15-15 + urea to satisfy the recommendation 80-60-60)

Calculate the amount of fertilizer that satisfies the element required in the smallest quantity.

In the above example, where the recommendation is 80-60-60, phosphorus (P) and potassium (K) are the least required. Therefore the amounts of these elements must be calculated first: the 15-15-15 supplies 60kg N, 60 kg P and 60kg K

$\frac{60 \times 100}{15}$ = 400kg of 15-15-15 or 8 bags (50kg each)

Calculate the remaining amount of the element required.

In the above example, 400 kg of 15-15-15 gives 60-60-60. Subtract this from 80-60-60

$$\begin{array}{r} 80\text{-}60\text{-}60 \\ \underline{-\ 60\text{-}60\text{-}60} \\ 20\text{-}00\text{-}00 \end{array}$$

20kg of N is yet to be supplied by urea. The weight of urea is calculated thus:

$$\frac{20 \times 100}{46} = 44.4 \text{ kg/ha urea or 2 bags (50 kg each)}$$

Total quantity of fertilizer required is therefore 8 bags (50 kg each) of 15-15-15 and 2 bags (50kg each) urea.

APPENDIX 3

Yield Estimation:

Grain yield = panicles/m2 x spikelets/panicle x % of filled spikelets x wt of 1000 grains

Example: If you have 350 panicles/m2 x 130 spikelets/panicle x 90% filled x 25g/1000 spikelets, then

$$\text{Yield} = 1024\text{g/m2} \times \frac{10000}{1000} = 10.24 \text{ t/ha}$$

With only 250 panicles per m2, the yield would drop to 7.31 t/ha.

The number of panicles per m2 depends on the plant density and tillering rates. Your aim is therefore 250-350 panicles per m2 for maximum yield.

APPENDIX 4

Engineering parameters of some "sawah" systems tested

"Sawah" type	Rain fed			Pump	Spring	Integrated	Dyke & Canal
Site	Danyame valley	Rice valley	Biemso II	Afreh site	Nicholas site	Potrikrom	Biemso I
Mean slope	2(1-3)%	0.7(0.5-1)%	0.95(0.4-1.5)%	4(3-5)%	1.5(1-2)%	0.6(0.2-1)%	0.55(0.1-1)%
"Sawah" + bund (ha) area	0.29 + 0.02	0.16 + 0.01	0.61+0.02	0.078+0.0050	0.39+0.02	0.62+0.02	1.22+0.05+0.06
Mean "sawah" size (m2)	200	335	485	166	276	531	444
Soil movement (m3/ha)							
Levelling	615	286	436	1067	518	287	213
Bunding	400	320	288	420	336	267	273
Pond	160	235	250	-	(973)*	25	-
(Termitaria)**	158	158	158	158	158	158	158
Dyke	-	-	-	-	-	-	12
Canal (m)	Negligible	Negligible	Negligible	Negligible	Negligible	56	200
Total (m3/ha)	1333	999	1132	1645	1012	793	856
Total labour cost ($/ha)***	3999	2997	3396	4935	3036	2379	2568
Drought problem	Severe	Severe	Severe	Severe	Nil	Less severe	Nil
Flooding problem	Nil	Nil	Slight	Nil	Slight	Slight	Slight
Fuel cost for pump	High	High	High	Very high	Low-Medium	Medium-High	Low
Operation of power tiller	Difficult	Easy but distance	Easy	Difficult	Difficult	Easy	Easy
Soil fertility	High	Medium	Low	Low	High	High	High
Occurrence of valley type	Many	Many	Many	Many	Few	Many	Many
Priority for sustainability	Medium	Medium	Medium	Low	High	High	High

Ds-Danyame valley: Rs-Rice valley: B2s-Biemso No 2: As-Afreh site: Ns-Nicholas site: Ps-Potrikrom: B1s-Biemso No 1; * area occupied by termite mounds; ** assuming 3 termite mounds per ha are destroyed; *** Labour cost for soil movement per cubic meter was about 3 dollars, which was equivalent to 7500 cedis before May 1999. In August 2000, $1 = 6000 cedis

Cost estimation of "sawah" development in dollars per ha including fuel and dyke materials as at 2000

"Sawah" type	Rain-fed			Pump	Spring	Integrated	Dyke + canal
	Danyame	Rice	Biemso	Afreh	Nicholas	Potrikrom	Biemso

	valley	valley	No 2	site	site		No 1
Area (ha)	0.29	0.16	0.61	0.078	0.60	0.62	1.22
Man days	5100	4800	3800	5900	4100	2400	2000
Soil movement	4040	3000	3400	5040	3100	2400	2700
Mean	4570	3900	3600	5500	3600	2400	2350
Machinery cost	960	960	960	960	960	960	960
Grand total	5530	4860	4560	6460	4560	3360	3310

Machinery cost was calculated as follows (life span = 5years); Power Tiller US$3500/5ha = $700/ha: Water pump US$500/5ha = $100/ha. Maintenance cost was calculated as 20% of total cost = $800/5years = $160/ha. Total = $960. Note that fuel cost was $50/ha and cost of dyke materials was $80/ha