JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES (JIRCAS)

Manual for Improving Rice Production in Africa

March, 2012

Acknowledgement

This manual is made based on a validity study in rain-fed lowland areas in Ghana (from 2009 to 2012) and Ethiopia (from 2010 to 2012). By utilizing the results from Ghana, it has being designed to improve farmland facilities and develop farmers' cultivation skills in rain-fed lowland areas.

The validity study was done with farmers at selected model sites on the following activities; establishing construction methods of farmland and simple irrigation facilities suitable for topography and water resource, selecting suitable varieties, improving cultivation techniques, organizing farmer groups to manage facilities, effective and efficient use of machinery and materials, helping to establish extension and support systems to disseminate technologies, and producing technical manual for extension staff and other technical field staff to utilize based on local condition.

On behalf of JIRCAS, I wish to thank all the counterpart personnel and farmers in Ghana and Ethiopia for their contribution in establishing this manual. I also extend my sincere gratitude to the Ministry of Agriculture, Forestry and Fisheries in Japan for its financial assistance.

Finally, I hope that this manual would be used by extension staff on sites in many African countries and would contribute to the increase of rice production.

March, 2012

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List of the Members who contributed to the revision for each chapter of this Manual

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1. Introduction

1.1 Background

The Japan International Research Center for Agricultural Sciences (JIRCAS) started a study on Developing Improved Infrastructure and Technology for Rice Production in Africa (DIITRPA) in 2008 with major financing from the Ministry of Agriculture, Forestry and Fisheries (MAFF) in Japan. The study focused on validating techniques that JIRCAS acquired through a three-year study in Ghana and a two-year study in Ethiopia. This technical manual is published to be disseminated to other countries in Africa.

1.2 Why JIRCAS started the study

Demographic studies show that there is rapid population growth in Africa. As a result, food shortage will become a world-wide serious problem in the near future. Since rice production in Africa is still not sufficient to meet demand, rice imports from Asia and other parts of the world is currently in force.

Since 1970s, rice consumption has been increasing in Africa. As a result governments of Western Africa assisted by FAO established an Agency (West Africa Rice Development Agency - WARDA, currently "Africa Rice Center"). Since its establishment WARDA has produced new rice varieties in Africa (NERICA) and its dissemination has been supported by Japan. However, NERICA is not popular yet in most African countries because of the poor experience of most societies in rice cultivation.

In May 2008, Japan started the concept of the Coalition for African Rice Development (CARD) together with the Alliance for Green Revolution in Africa (AGRA). Its goal is to double rice production in ten years, and this study was started to contribute towards achieving the goal of CARD.

1.3 The study

Since fiscal year 2008, JIRCAS has conducted several research studies in Ghana to verify the current issues on rice production and decided on two project sites each for two research institutes based in Kumasi, Crops Research Institute (CRI) and Soil Research Institute (SRI). At the four project sites near Kumasi, JIRCAS implemented validity studies to ensure the effectiveness of shifting the field into traditionally-practiced Asian paddy-field development. This included, (i) constructing bunds, leveling and puddling with inlet and outlet facilities for irrigation, (ii) applying appropriate fertilizers and (iii) introducing weeding and post-harvesting techniques.
The project sites are located in the target area as shown in Figure 1-1.

Understanding the importance of dissemination, JIRCAS asked the Ministry of Food and Agriculture (MOFA) in Ghana to help in technology transfer activities. As a result on-the-job trainings (OJTs) were conducted in collaboration with experts from CRI and SRI for Extension Staff of MOFA who have knowledge in land conditions of project sites. These extension staffs are expected to transfer their experience to farmers after the OJT programs.

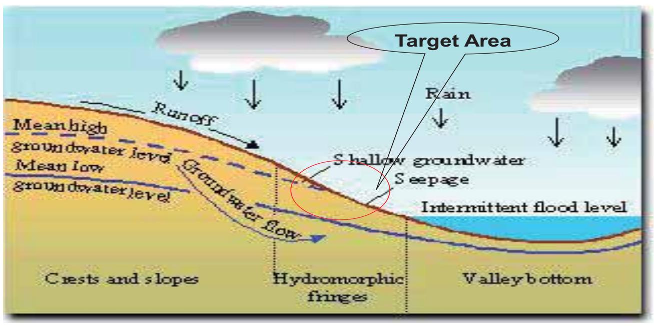


Figure 1-1 Target area of the study
Source: Africa Rice Center
http://www.africarice.org/

1.4 Environmental Condition

The Sawah technology is not always the only solution to solve the problem of low-level yield of rice. There are conditions that the Sawah technology can be applied to or successfully implemented. These conditions can be divided into two categories; natural and social conditions. Both are environmental conditions that cannot be usually changed by human power. Rather, it is the rice variety or cropping system that can be modified to suit a given environment.

1.4.1 Natural conditions

There are three main factors that can be considered under natural conditions for rice cultivation. These include; Rainfall, Temperature and Topography.

1.4.1.1 Rainfall

Water is indispensable to the start of any rice system. Adequate rainfall may be required for the proper operation of the sawah system. Literature states that annual rainfall between 800mm and 1300mm is adequate for rice cultivation.

Basically, less than 800mm of annual rainfall is not suitable for rice cultivation. For high-grade management under rice cultivation such as growing twice, thrice, or more crops per season or highly mechanized rice cultivation, annual rainfall amounts should be carefully checked in order to plan what kind of rice production system to adopt.

1.4.1.2 Temperature

Temperature is another important factor that affects rice cultivation. However, in Africa, temperatures are quite uniform for most areas and suitable for rice cultivation. In areas of high altitude, low tolerant temperature varieties may be bred and used.

For mountainous areas like Ethiopia, careful consideration for the lowest temperature during rice cultivation season, and special consideration/treatment should be applied, such as introducing low-temperature tolerant species of rice or counter-measure management, such as keeping deep water in the paddy field during the nights would be applied before or when cold air hit or is predicted to hit the area.

1.4.1.3 Topography (slope)

For easy land development and water management, relatively flat or gentle sloping areas are recommended for sawah systems. Gravity irrigation is easier to be applied under flat or gentle sloping conditions, such as inland valleys, than flood-plain conditions. This is because water management under flood-plain conditions requires higher investment for both irrigation and drainage facilities.

1.4.1.4 Accessibility (Nearness of Site)

For easy management such as movement of farm machinery (e.g. power tillers), farm inputs (seed, fertilizers, herbicides, etc.) and farm produce to and from the field, sites that are easy to access are preferable.

1.4.2 Social Conditions

Social conditions are important factors and can affect rice production. Some of these factors include; land tenancy issues, condition of extension staff, and stages of mechanization.

1.4.2.1 Land Tenancy Issue

Land ownership is a major factor for rice production. For farmers who do not own their land, it is important to secure long term land tenancy agreement. This is because land development under the Sawah system requires higher initial investment as compared to other systems.

For sustainability, long term agreements are therefore required in order to re-coop the investment.

1.4.2.2 Conditions of Extension Staff

For effective communication and technology transfer the technical knowledge, and working conditions of the extension staff should be considered. Extension staff should know the existing social conditions of farmers and should be able to communicate with them in languages they understand better. Extension staff should be mobile, motivated, and made to work with an optimum number of farmers.

1.4.2.3 State of Mechanization of the area

Mechanization is not easy to be achieved within a few years, since a power tiller needs continuous activities of operation and maintenance when they are introduced in a particular site. Spare parts are needed and sometimes blacksmiths can be trained to manufacture simple parts. Similarly, local mechanics and power tiller operators should be trained on routine operation and proper maintenance of machinery.

2. Site selection

2.1 Basic Feasibility

2.1.1 Water resources

- Common sources of irrigation water are usually rivers, streams, and springs. It is necessary to obtain data on the amount of precipitation and the availability of water from rivers and springs throughout the cropping season.
- For effective planning and irrigation scheduling, it is necessary to estimate the volume of water available for irrigation. Continuous monitoring of the water level is preferable for long term planning.

2.1.2 Soil and topographical condition

- The area selection should be made on a gentle slope or a broad humid basin.
- An example of the condition setting:

Slope should be gradual or gentle (less than 1/100). Stagnated water level in a site to be selected should be less than 35cm. (In case machinery use is envisaged, the bearing capacity of soil should be tested and over 0.5 kg/cm^2 is recommended.)

2.1.3 Accessibility

- Good access from the village or main roads to the farming area is necessary for transporting of equipment, other inputs to the field and products from the field to the village or market center.
- Farm roads surrounding the rice cultivating area enable access to the field and transportation of outputs.

2.1.4 Farmers' interest

- A prerequisite condition is that, farmers should be eager for improved infrastructure and technology on irrigated rice cultivation. Otherwise, the intervention will end in a futile attempt.

- Conducting interviews or sampling surveys of farmers are recommended prior to selecting sites.

2.1.5 Economic condition of farmers

- The ability of farmers to adopt new farming technologies depends on the farmers capacity to provide the needed resources and also the suitability of the existing land tenure systems.
- The other social conditions of farmers, such as machinery leasing systems and micro finance systems, should also be considered.

2.1.6Total Assessment

- The site should be considered in totality before selection. A sample selection criterion done by Dr. Fukuo (2010) is as shown in Table 2-1on page 2-3.

Table 2-1 A sample selection criterion

No.	Community name	Access	Dry season crop	Rice cultivation	Water resource	Soil condition (dry season)	Palm tree	Total (5～18)
		1～5*	Rice = 4 Vegetable = 2 No = 0	Yes = 2 No = 1	no flood = 3 flood (<1m) = 2 flood (>1m) = 1	Wet = 3 Wet and dry = 2 Dry = 0	Yes = 1 No = 2	
1)	Afari	4	4	2	2	3	2	17
2)	Manhyie Dkc	5	0	2	2	3	2	14
3)	Pakukrom	2	2	2	2	2	2	12
4)	Sabronum	2	2	2	3	3	2	14
5)	Akropong	4	4	2	2	3	2	17
6)	Amdum Adankwame	4	4	2	2	3	2	17
7)	Boatenkurom	4	4	2	1	2	2	15
8)	Kunsucamp	3	2	2	2	2	2	13
9)	Odoyefe	2	2	2	2	2	2	12
10)	Nyameadom	5	2	1	2	2	1	13
11)	Bronikrom	5	2	2	1	3	2	15
12)	Afresine Camp	3	2	2	1	2	1	11
13)	Afresini	2	4	1	1	0	2	10
14)	Akuapem	–	2	1	2	3	2	10
15)	Asebekrom	4	2	2	1	2	2	13
16)	Ademse	4	0	2	1	0	2	9
17)	Awia	–	2	1	–	–	2	5
18)	Senkyem	3	2	2	3	3	2	15
19)	Amanin	3	0	2	2	3	2	12
20)	Yawkobi	3	2	2	2	0	2	11
21)	Ohiapae	1	2	2	3	0	2	10
22)	Mehame	1	2	2	3	0	2	10
23)	Pasoro	5	4	2	2	3	1	17
24)	Aninkroma	5	2	2	2	3	2	16
25)	Amakye Bari	5	4	2	2	3	2	18
26)	Betinko	1	2	2	2	3	2	12
27)	Amoakokrom	4	2	2	2	3	2	15
28)	Biemtetrete	4	2	2	1	2	1	12
29)	Anyinasuso	5	2	2	1	3	2	15
30)	Banokrom	4	2	2	2	0	2	12
31)	Amoakkrom	4	2	2	2	2	2	14
32)	Amakon	5	0	2	2	0	2	11
33)	Pokuase	4	2	2	1	0	2	11
34)	Esienkyem	4	2	2	3	0	2	13
35)	Adugyama	5	2	2	3	0	2	14
36)	Achiese	4	2	2	2	0	2	12
37)	Attakrom	5	0	2	1	0	2	10

Source: Dr. Fukuo, 2nd Steering Committee Meeting (March, 2010)

2.2 Planning

2.2.1 Concept of water delivery and irrigation cycle

- To achieve equitable irrigation water distribution to all fields, the rotational irrigation method is recommended.
- Scheme area should be divided into a number of irrigation blocks.

- Water demand can be estimated based on crop water requirements, cropping pattern, and irrigation efficiency at the farm level.
- Water delivery plans (irrigation schedules) should be determined at a farmers' meeting, considering the availability of water, crop and other factors. This meeting should be held before the cropping season.

2.2.2 Cost estimation

Cost should be estimated on the following items:

- Machinery and tools; power tiller, pick axe, cutlass, mattock, shovel, spade, etc.
- Infrastructure; canal construction, reservoir construction, land clearing, de-stumping and debris collection, bund construction. Ploughing, puddling, and leveling.

2.2.3 Planning fields for rice production

- Area to be developed should be located along a reliable water source. A larger area is recommended (50 acres).
- The area should be divided into manageable and regular plot sizes.

2.2.4 Recommendation for improving rice fields based on JIRCAS project sites in Ghana

2.2.4.1 Shape and nature of the valley

• Inland valleys are variable in shape, e.g. convex shape, concave shape, etc.

• In times of flood, under the convex type, water would gather in the center of the land because of lower elevation relative to the other parts. (Reference-Figure 2-4, on page 2-7)

2.2.4.2 Dual-Canal type

• Naturally, waterways flow in the center of the valley.

• Canals should be constructed on either side of the natural water course.

• After canal construction the natural water course should become the drain. (Reference-Figure 2-1)

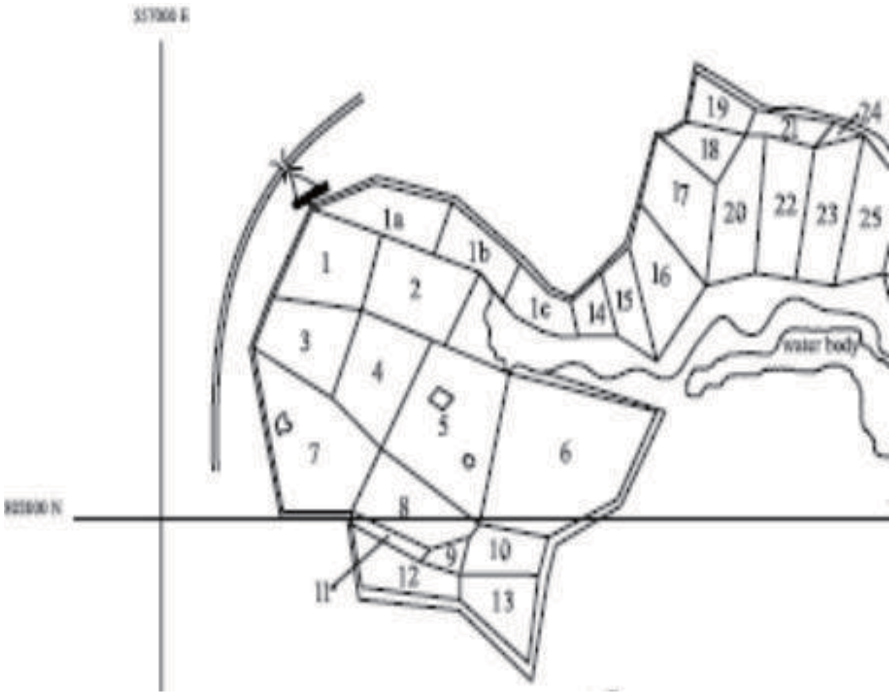


Figure 2-1 An example of designing divided canals type, Baniekrom-C site.Source: SRI

2.2.4.3 Weir and canal type

Under this situation, water source is near the land but there is no natural waterway to convey it onto the field.

• Weir and canal should be constructed to convey water onto the field.

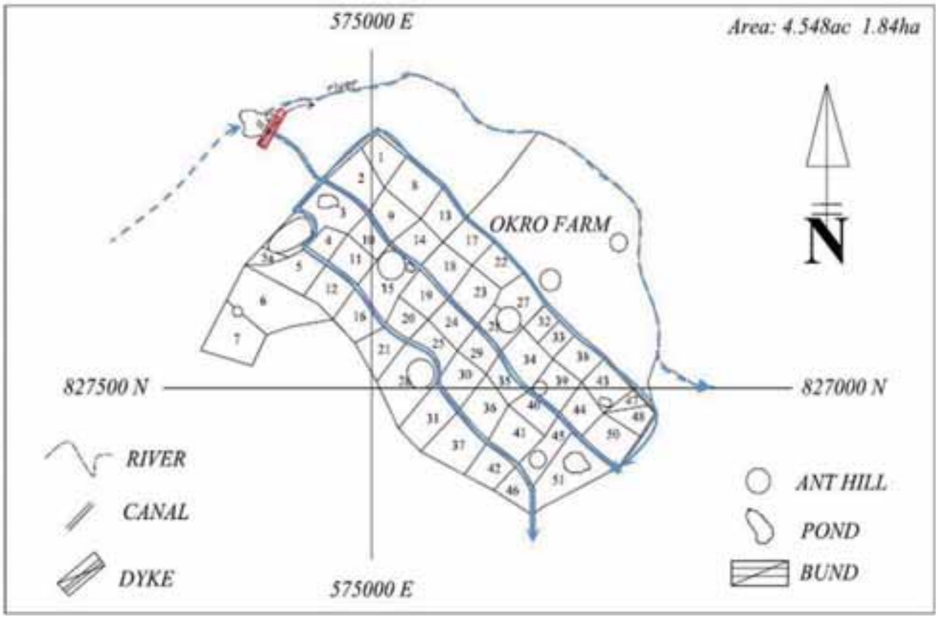


Figure 2-2 An example of designing Dyke-and-canal type, Nsutem-'A' site.Source: SRI

2.2.4.4 Pond type

Under this situation there is no running natural water source.

- Existing natural ponds should be desilted.
- A pond should be constructed if there is none.
- Water may be delivered by pumping.

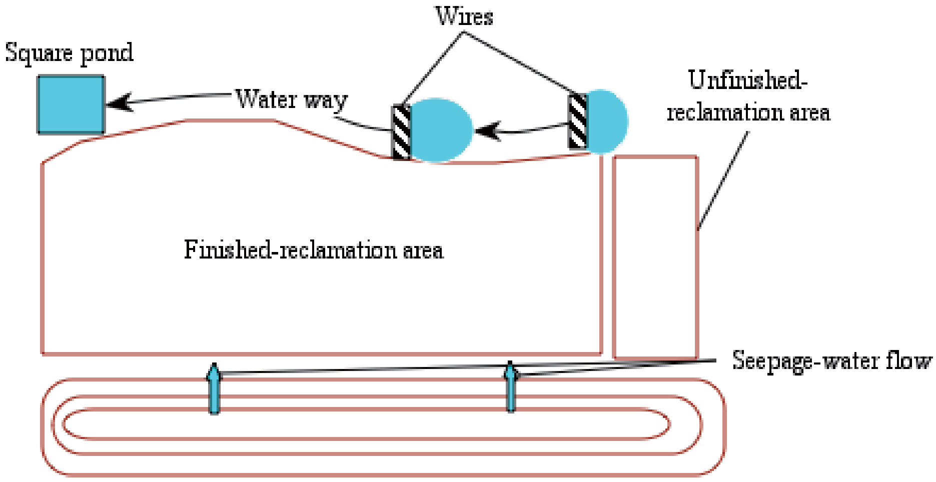


Figure 2-3 Image of collecting-ponds type, 'Kodadwen' site

<Current situation> <Recommended types for field construction (Betterment)>

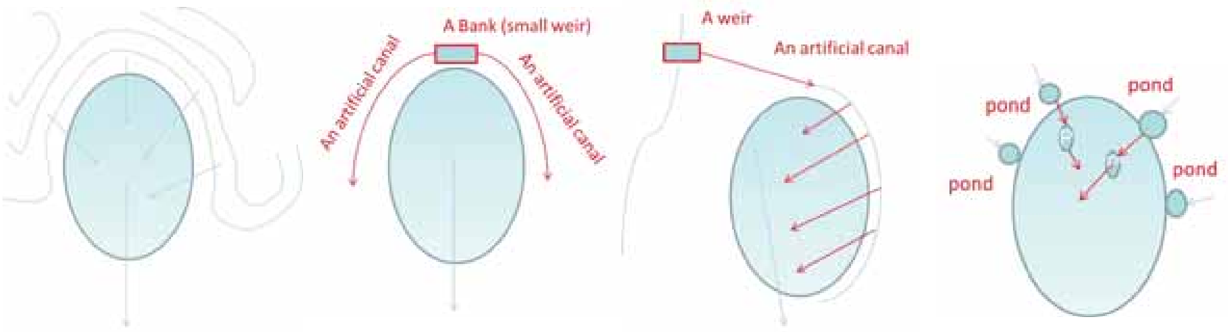


Figure 2-4 Image of current situation and three recommended types

3. Farmers Organization

3.1 Establishing a Farmers' Organization

The process of establishing a farmers' organization is as shown in Figure 3-1.

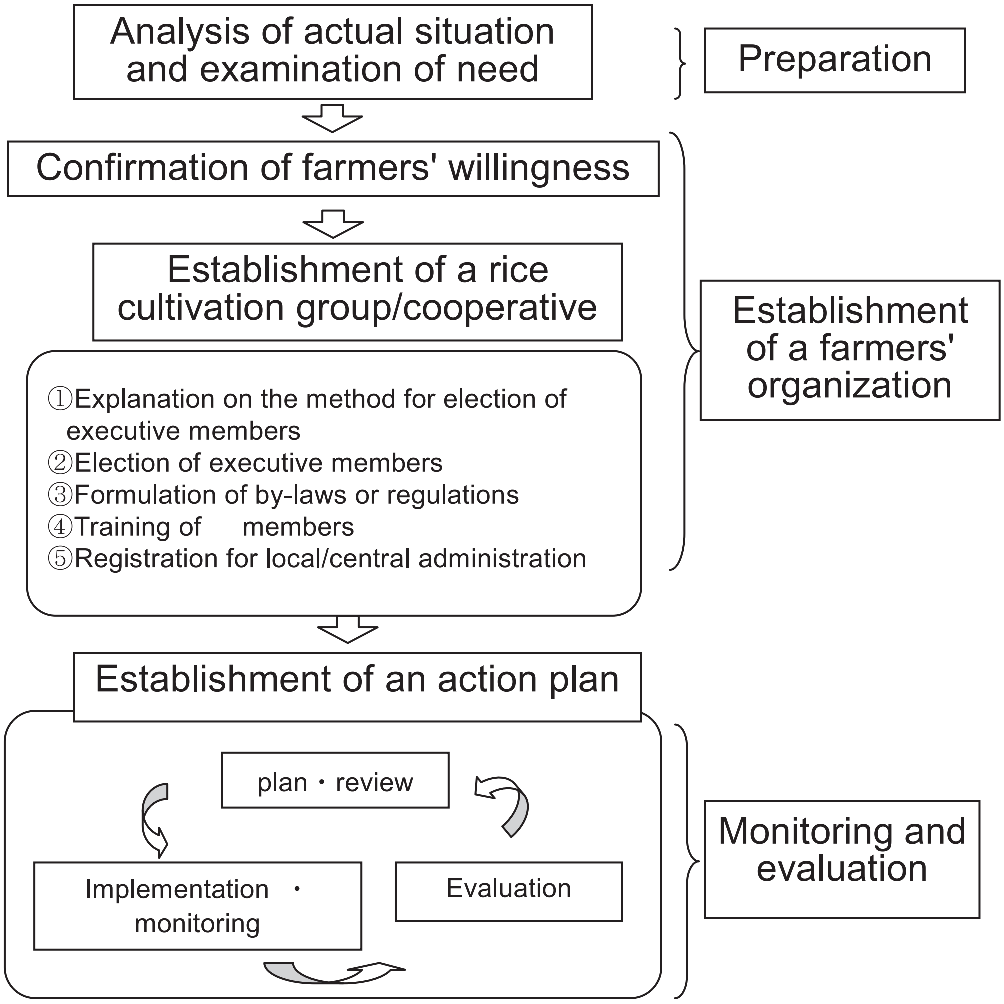


Figure 3-1 Flow chart of establishment of a farmers' organization

3.2 Advantages and disadvantages of group activities

Table 3-1 below shows the advantages and disadvantages of group activities during rice cultivation.

Table 3-1 Advantages and disadvantages of group activities

Advantages	• Group efforts can help in carrying out cultivation, nursery planting in a shorter time than in the case when a single worker is involved. • Group purchases can reduce overall expenses and transportation costs of equipment and materials, including fertilizers and agrochemicals. • Group sales can reduce the transportation costs of the harvested rice. A group is more likely to ensure sales from outside buyers if a sufficient harvest amount can be offered. The establishment of a farmer's group and registration with the government is likely to obtain outside support.
Disadvantages	• Per capita income decreases if total income is divided among members. Plan for any activity may be delayed unless all members follow the schedule.

As shown in the table, the advantages far outweigh the disadvantages. However, it is important to note that this system also poses challenges. There is a certain degree of difficulty in introducing group activities that depend on whether previous works have been collaborative in the area to be cultivated. Farmers should be allowed to make decisions independent of other members. The decision to participate in a group should not be forced on farmers.

3.3 Points of concern for group activities

If farmers select group activities, they should consider the following points, shown in Table 3-2 to minimize misunderstanding - and increase trust among group members.

Table 3-2 Points of to note for group activities

Items	Points of concern
Election of officials	• A minimum of five officials, including a chairperson, a deputy chairperson, a secretary, a treasurer, and an organizer, should be elected. This number may vary with the size of the group. • Consensus is recommended for elections among groups of limited sizes. However, secret voting is advisable, if possible, because it can reflect the actual intentions of the members. Therefore, the executives should be elected by secret voting.
Formulation of by-laws	• It is necessary to document the objectives of the group, items for collaborative work, scheduling and frequency

and regulations	of meetings, tenure of office for the elected officials, membership registration fee, membership fee, and penalties in the case of breaches of responsibilities. This documentation should be distributed among members.
Accounting report	• Management of membership registration fee, membership fee, and any expenses should be recorded in a ledger to ensure transparency. In addition, an audited accounting report should be presented during a general meeting.
Management of materials and machinery	• A manager should be appointed to supervise the group-owned farm equipment and materials such as power tiller, fertilizers and other inputs. • Inventory, user, and amount used should be recorded on each occasion, and the current status should be reported on, during each general meeting.

3.4. Land tenancy agreement

The farmer needs to have a land tenancy agreement if he wants to develop Sawah (Suiden) on rented land. He should conclude a written land tenancy agreement, and it is better to make the period as long as possible. The first year of Sawah development needs many infrastructures, such as water intake facilities, canals and drainage. The investment cost is high compared to upland field development. Therefore, if the landowner takes a developed land away after a short period of development there would be no motivation for the farmer. It would not be profitable as the farmer will not be able to re-coop his/her investment. Thus, the land tenancy agreement should be at least five years, but more than ten years is desirable.

An example of the land tenancy agreement is shown in Annex 2.

4. Land Development

Methods of site selection and planning have earlier been explained in chapter 2. Concrete procedures and methods of land development are explained in this chapter. The flow chart of land development is shown in Figure 4-1.

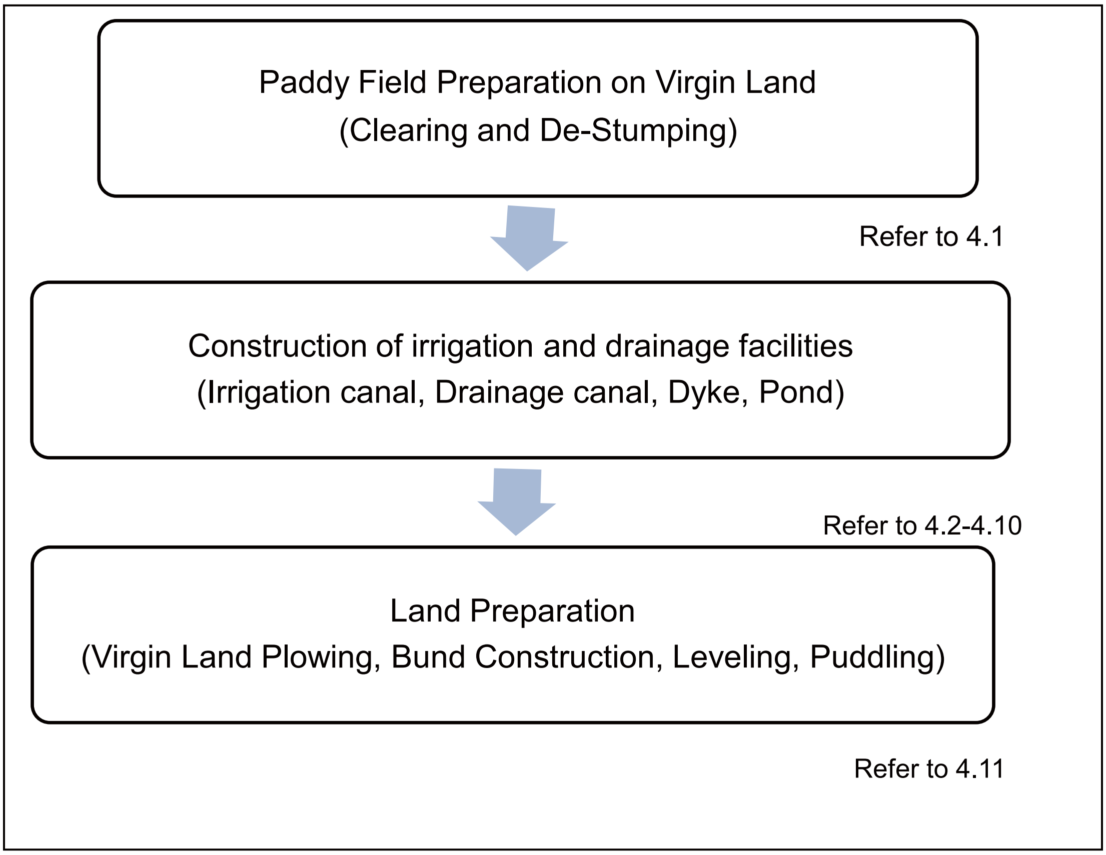


Figure 4-1 Flow chart of Land Development

4.1 Clearing

From the outset the area should be clean-cleared (weeds, shrubs, slashed, burned, and de-stumped).

- Slashing: Weeds and shrubs must be slashed or cut down using a cutlass or hoe.
- Burning: Slashed grasses and shrubs, and leaves of trees should be partially burned to make room for easy land development. The area to be burned should be less than 2 to 3 ha. The burning should be controlled to avoid causing bush-fired.
- De-Stumping: Trees and shrubs roots and trunks should be

removed.

Note: In addition larger size stones (e.g. size of an egg) can also be removed as these turn to negatively affect the operations of machinery.

4.2 Canal construction

In order to construct a canal the route should be considered first. It should always adapt to the shape of the side slopes of the river and valley. In doing so two main criteria are used;

- Position of the river route.
- Position of the water distribution point.

Factors to consider:

- The canal gradient should be more than 0.5% through its entire length but should not exceed 1.0% (if it is an earth canal) because water flows down by gravity. Depressions and negative gradients and excessively long canals should be avoided.
- Canals may differ in shape, length and gradient.
- It should adapt to the shape of the sides slope of the river and valley.

Note: The river route is naturally derived and that cannot be easily changed.

Figure 4-2 shows a river gradient of 1.44% and an average canal gradient of 0.5%. In the case of ‘A’, undulation is gentle, and the canal distance between the intake and distribution points is slightly longer than the river route.

Conversely, in the case of B, the canal must bypass the tributary. Accordingly, a long detour with a gradient of at least 0.5% is necessary.

Extending the canal length may result in the following:

- Increased construction and maintenance costs
- Increased loss of allocated water due to water leak and evaporation

- Increased complications with the surrounding land because the canal must traverse a larger area

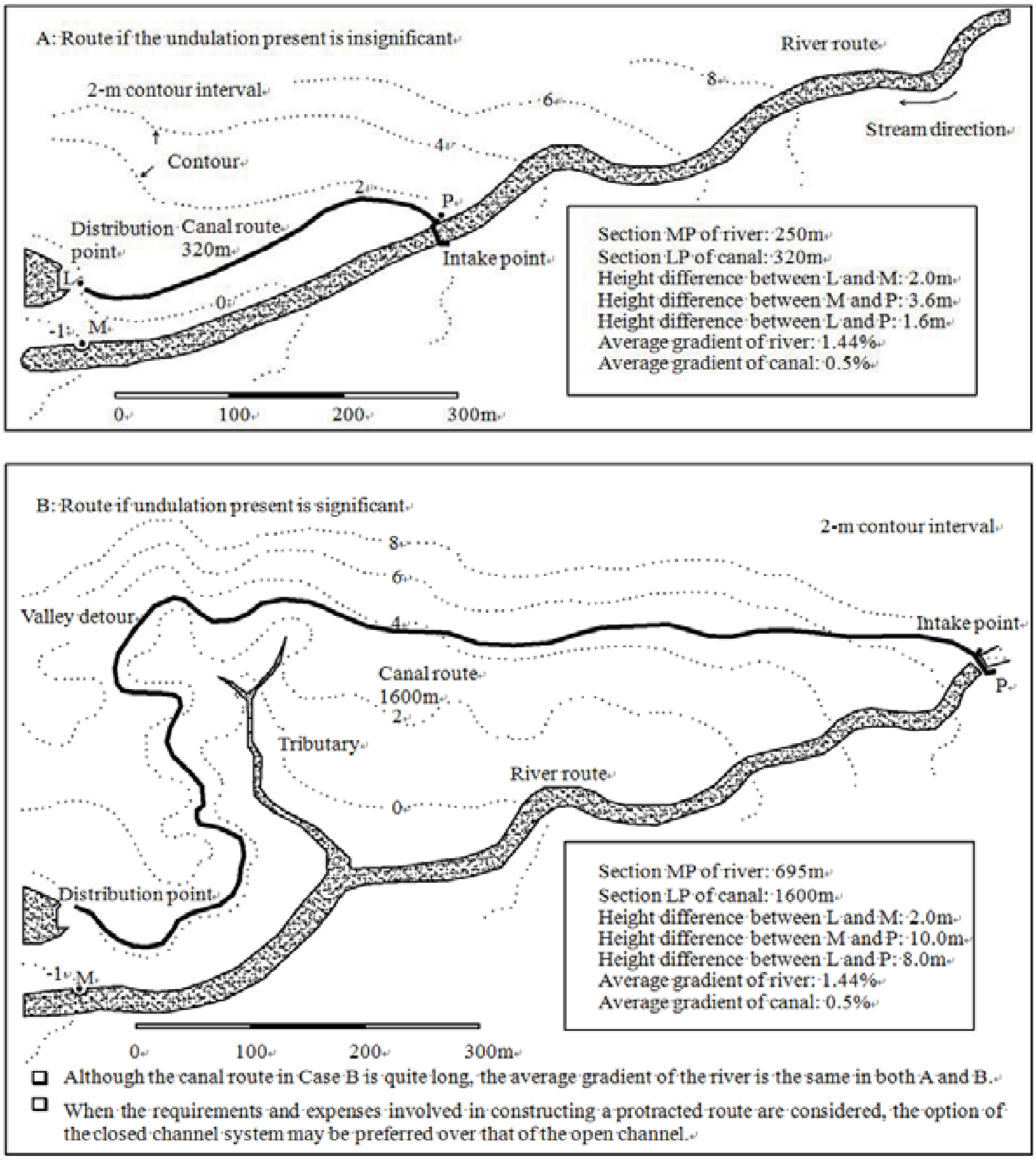


Figure 4-2 Determination of the length and bend of diversion canal by the terrain of the side slope.

(Source: Hugues Dupriez and Philippe De Leener, 1990)

4.3 Effects of Slope Canal

The side slopes of earth canals are exposed to the following:

- Running water scours sand and clay particles from the side slopes for rapid streams, backwater, and scarce vegetation. When this occurs, the cross section of the canal tends to expand.
- The scoured soil particles either settle onto the bottom of the canal or are deposited by drift far from the stream. Accordingly, the bottom is silted to shorten the height of the cross section.

Changes in the cross section cause various types of damage by such factors as deceleration and acceleration of the stream, changes in flow volume, flooding, clogging, and blockage by structures such as a distributor or a valve.

- If a small levee is constructed as an earth canal, the cross-sectional shape may change owing to the decreasing bund height caused by raindrop erosion, reduced bottom face through water scouring, and piping at narrow points.

The effects are illustrated in Fig 4-3. The principle of constructing the side slope parallel to the natural gradient should be applied to minimize these risks. It is necessary to heap materials on the sharp gradient as much as possible. Dried soil clods should be broken into small pieces before heaping. The gradient should be measured with a protractor.

No technical problems will arise even if this gradient is larger than that of the natural slope side created through the construction of a small levee. In this case, however, prevention of the bottom face of the bund from widening is highly unlikely. This increases the extent of sand movement, extends the wetted perimeter of the canal, and increases the number of land requirements.

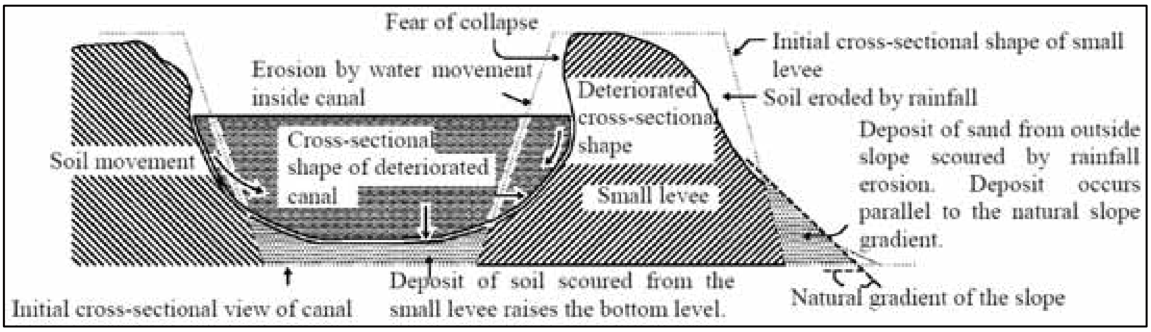


Figure 4-3 Deterioration of earth canal walls
(Source: Hugues Dupriez and Philippe De Leener, 1990)

4.4 Process of Canal construction

In order to construct Irrigation canals, the following procedure should be followed:

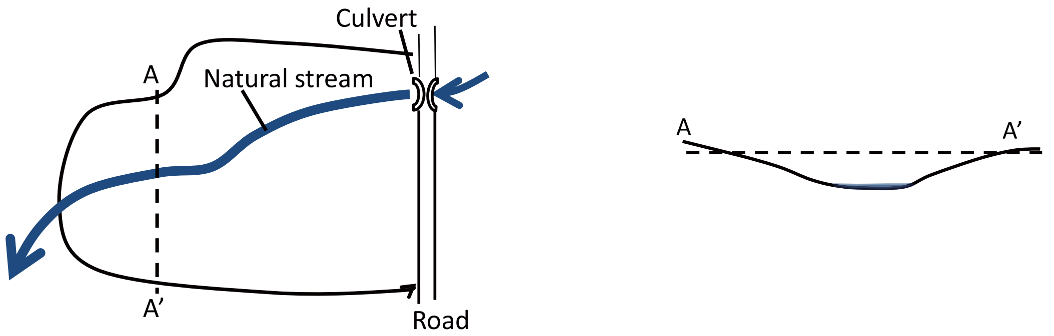
Step 1:

- The area marked for construction should be pegged with knotted strings at intervals of 3 -10m depending upon the layout. (Figure 4-4)

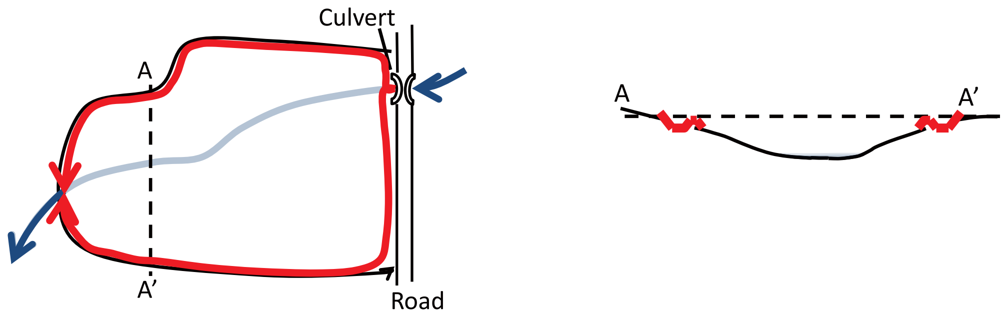
- Construct the canal by digging out and also filling depressions along its walls to give it a uniform height.
- Filled areas along the canal walls should be compacted to make it strong.
- Shaping the canal to a trapezoidal section is recommended to reduce erosion. (Figure 4-5).
- Construct a dyke on the upper stream and divert water into the constructed canal.

Ground plan **Cross-section**

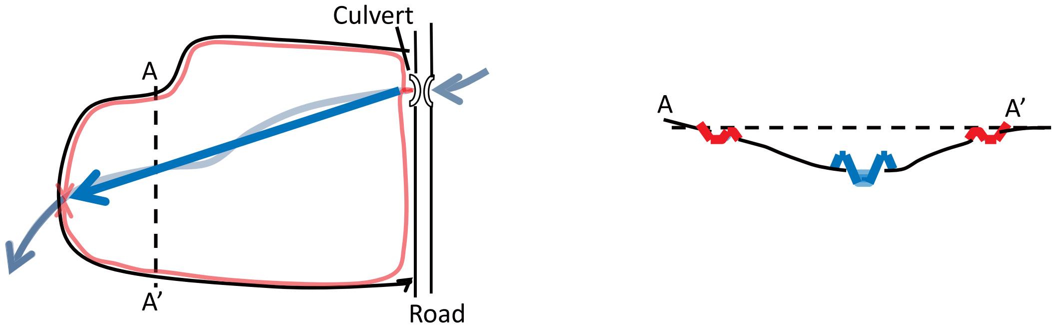
1) The planned field



2) The canal (Red-line) is constructed along with the outline of the planned field

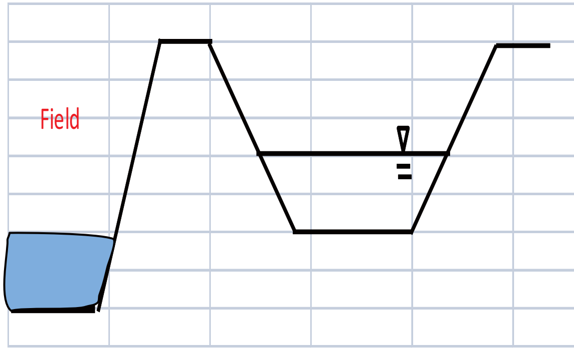


3) The main drainage(Blue-line) is constructed to promote the drainage.



Source: Chikako Hirose

Figure 4-4 Concept of Design the boundary of ridges and construction of canal



Source: Chikako Hirose

Figure 4-5 The trapezoidal lateral of canal

4.5 Canal Construction Material

Generally, unlined canals are constructed using earth materials. Various types of materials are used to reduce seepage loses and erosion. One of such materials is the Geomembrane sheet which is commonly used in Ethiopia (Figure 4-7).

Geomembrane sheet is a construction material made from polymeric material such as plastics.

Usually, earth canals that do not use Geomembrane sheets (Figure 4-6) have high conveyance losses.

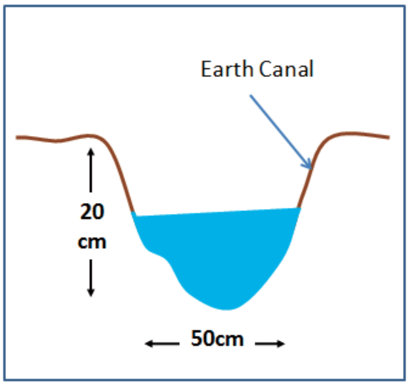


Figure 4-6 Earth canal (a) and Cross Section (b)

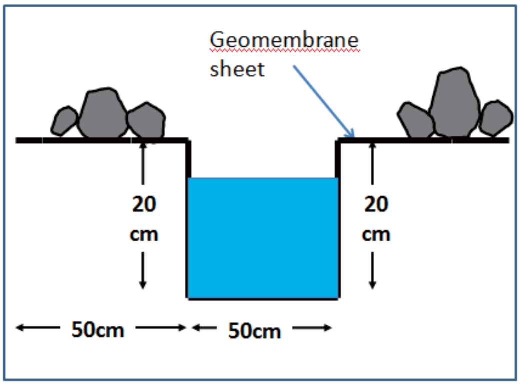


Figure 4-7 Canal covered with Geomembrane sheet (a) and Cross Section (b)

4.6 Plot-to-plot irrigation

Plot-to-plot irrigation is to send the water taken in the uppermost plot from the canal to downstream plot one after the other through the plot (Figure 4-8). If all the plots do not have intakes from the canal this irrigation system is usually applied. Irrigation and drainage of this system is constrained by the water movement from one plot to another. Instead of this constraint this system has the advantage of water saving and easy construction.

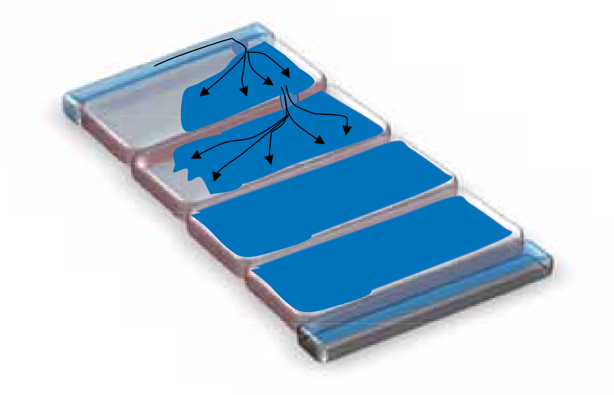


Figure 4-8 plot to plot irrigation

4.7 Drainage canal

The drainage canal should be constructed at the lowest portion or existing stream if that is the lowest. By improving drainage on the field, workability is improved and power tiller operations enhanced. An example of a drain constructed in the middle of the field is as shown Figure 4-9. In order to improve the flow of drainage water from the fields it is recommended to have a straight layout.

4.8 Intake

An intake is a structure designed to take water from a river into a canal or from the canal into the field. Intakes are generally composed of the following structures:

- An Intake Weir; is designed to raise the water level to allow flow through by gravity. Several types of materials such as sandbags, stones, bricks, concrete, and wood are used for its construction. The durability of the structure depends on the type of material used.

  An intake point is the starting point of a diversion canal and should be constructed perpendicular to the natural stream direction at the point where the river runs slowly. Intake points should not be constructed at points where the flowing water deposits alluvial soil. The flow volume inside the diversion canal should be adjusted by a check structure.
- Spillways; are designed to maintain a desire water level in the field. They can be adjustable or fixed. The spill level determines the water level. It is important to select the positions of the intake point and the bed height appropriately. Improper selection may cause considerable flooding.

4.9 Division Work

An intake structure constructed to distribute water to various fields from the same point. Division works can be done with earth or constructed with hard materials (see Figure 4-9 on page 4-10).

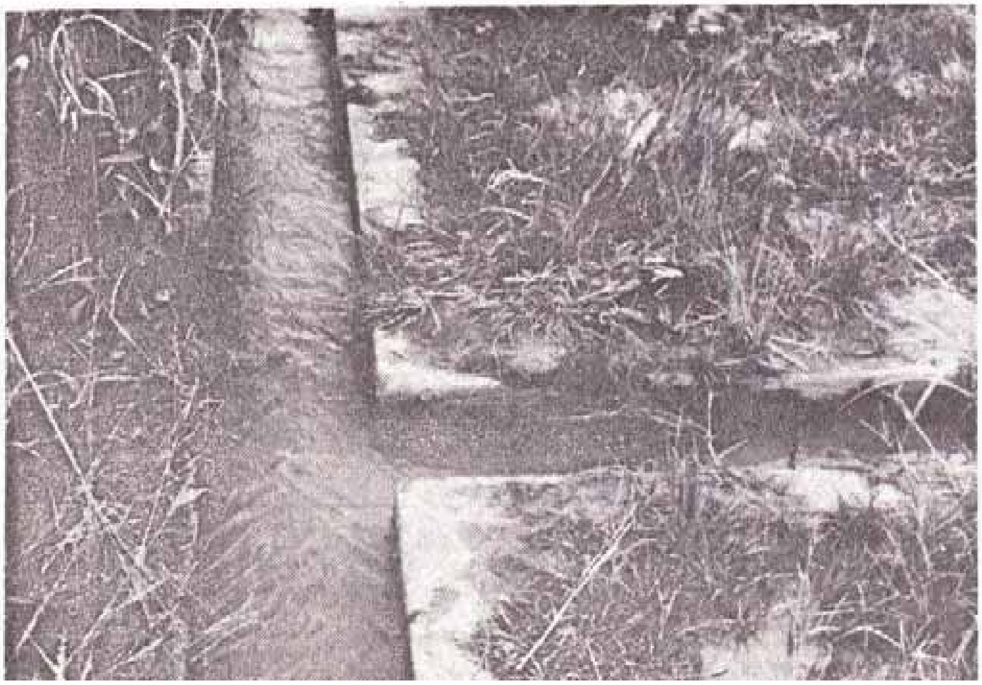


Figure 4-9 Division Works
(Source: Hugues Dupriez and Philippe De Leener, 1990)

4.10 Pond

Farm pond is a facility for storing irrigated water which is used during the period of water shortage. It has an intake facility and a considerable storage capacity to store water.

For a small-scale irrigation as envisaged in this manual, the standard capacity should be about $30m^3$ and the depth within the range of 0.5m -1.5m.

In view of easy access to maintenance, ponds should be situated near the farm land.

From economic point of view, a pond should be located at the upper stream so that the irrigated water is taken onto the field by gravity.

Figure 4-10 Farm Pond

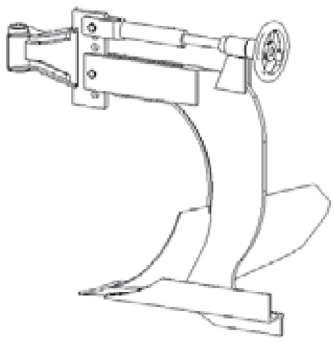
4.11 Land Preparation

4.11.1 Ploughing

The purpose of ploughing is to make the soil medium smooth and fine to enhance rice growth.

Plough the land to bury weeds. This allows the weeds to rot after flooding. Use a single plough (Figure 4-11) if a power tiller is to be used under dry conditions and a rotary tine under wet conditions.

Rotary tine (Figure4-12) can be used in the first year if there is enough moisture. When Rotary tine is used under dry soil conditions, the blade and power transmission devices get damaged, and subsequently break down the power tiller.



Source: Yanmar

Figure 4-11 Single plough

Figure 4-12 Rotary tine

If power tiller is not available, it is recommended to do cattle ploughing as in the case of Ethiopia (Figures 4-13 and 4-14).

Figure 4-13 Ploughing by Animal Power

Figure 4-14 Cattle Plough

4.11.2 Bund Construction

Bunds are constructed to help improve water and nutrient management. Bunds should be constructed according to the topography of the field and at manageable intervals depending on the flatness of the field. Bunds should be strong and high enough to contain enough water when irrigated (Figure 4-15). They should be compacted to prevent leakages (helps prevent water and nutrient losses). A paddy field should be sectioned by bunds. (Figure 4-16)

Figure4-15 Bund Construction

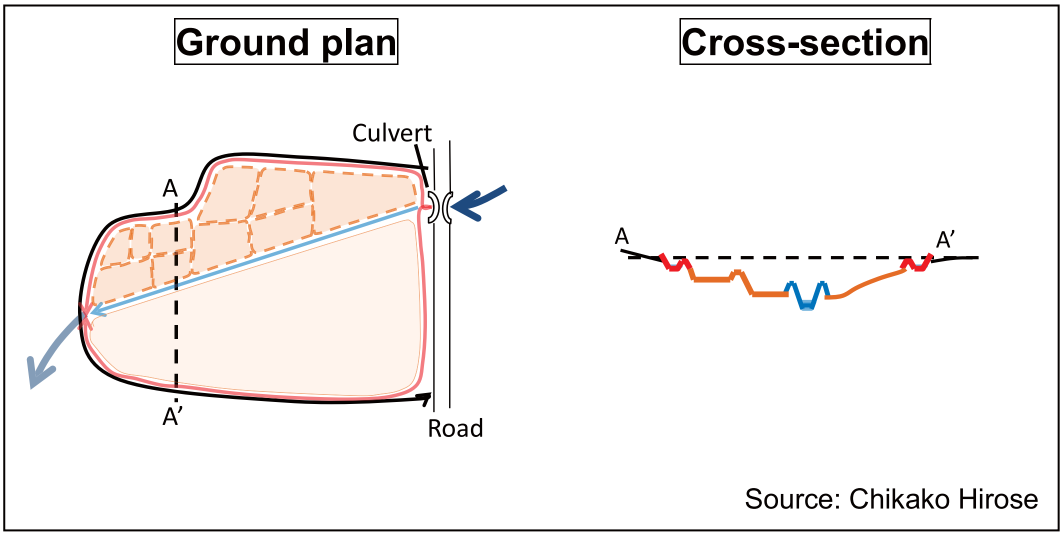


Figure 4-16 Concept of Bund Construction

4.11.3 Puddling

The purpose of Puddling is to thoroughly mix, soften, and make the soil medium fine and smooth. It also helps to eliminate already growing weeds. Puddling can be done using the rotary tine attached to the power tiller or manually (Figure 4-17).

Figure 4-17 Puddling

4.11.4 Leveling

Leveling is done to improve and enhance easy water management, and uniform nutrient distribution. It can be done using a hoe or a wooden plank that is drawn by oxen (Figure 4-18) or by a power tiller (Figure 4-19). The size of the wooden plank can vary depending on the soil type.

Figure 4-18 Leveling by two cattle in Ethiopia

Figure 4-19 Leveling by power tiller in Ghana

4.12 Maintenance of irrigation facilities

Irrigation facilities include intake weir, canals (irrigation and drainage), intake structures (inlets & outlets), division boxes, etc. Each facility has a specific function that needs to be maintained. The size of the structure depends on the size of the field.

Irrigation facilities are subject to deterioration due to age and damages. For sustainable farming and effective water utilization, maintenance of such facilities is important. A well-planned maintenance schedule that responds to facility size and use is necessary.

4.12.1 Water losses and its causes

Water losses are usually classified into two groups: (a) conveyance losses: losses in the canal and intake facilities. Such losses include seepage through the canal walls and leakages through cracks in the canals. (b) Field losses: losses after the water has reached the fields. These losses are due to broken field bunds, seepage through uncompacted bunds, field percolation.

Water losses are inevitable but can be minimized through proper compaction of bunds and other maintenance procedures.

4.12.2 Canal maintenance planning

Proper maintenance is vital for irrigation facilities. Maintenance planning in accordance with farming schedules will result in higher irrigation efficiency,

Maintenance activities should be carried throughout the various stages of cropping period.

(i) Before puddling

- Weed in and around the canals and drains.
- Desilt sand inside canals and drains. Mend and compact broken canals and bunds (see Figure 4-20).

Note: Check for the presence of cracks inside the canal, bund, and field.

Figure 4-20 compaction tool

(ii) After puddling

- Repair parts of bunds damaged by the power tiller.

(iii) After Heavy Rains or Flooding

- Check and repair damaged facilities.

Check and remove any other unwanted materials. Remove any obnoxious weeds such as water weed (Figure 4-21) near the canal. Holes created by rodents, crabs. should be mended to re-fortify such bunds (Figure 4-22).

Figure 4-21 Waterweed in canal

Figure 4-22 Hole of soft-crab

4.13 Repair of Broken down Irrigation Facilities

4.13.1 Wooden Fence

This is used to strengthen the section of the irrigation or drainage canal that is being washed away by run-off water or drainage by land slide (Figure 4-23). The materials and tools (Figure 4-24) needed are the following: wooden boards, wooden pegs, sandbags, strings, hammer, field level. The depth of canal should be less than 1 meter.

The following table is an example of quantities for a project site.

(Per 40m: 2 steps)

Item	Description	Unit	Quantity	Comments
Board	L=3.0m, W=0.25m, T=0.03m	Piece	28	
Peg	L=2.0m, W=0.1m,	Piece	42	
Labour	Removal of soil from canal and making a datum line	Hour	9	
	Fixing of pegs and boards	Hour	30	

L = Length, T = Thickness, W = Width

Procedures shown as following

a) Remove the soil

- The sand of the bottom of canal is removed to install a Wooden boards horizontally.

b) Fixed ruler (To make a datum line)

- The purpose of datum line is to show and guide the position of the structure to be based.
- Pegs are driven at the temporal peg side, with a string struck over the temporary pegs.

c) Drive the pegs

- The pegs are driven to fix the sand of canal side and the board.
- The pegs are driven vertically with a hammer by using stretched string as a mark (Figure 4-25).
- The tip of the peg is sharpened with a cutlass beforehand.
- The embedded length of a peg is half, to two-third of the full length.
- The interval of each peg is around 1m (in the case of 3m

board).

- The head of the peg is covered with a cloth to prevent it from broking, when force is applied by a hammer.

d) Set the board

- The board is set between a peg and the side of canal.
- The distance between the boards and canal side should be made as narrow as possible.
- The board is set horizontally on the bottom of canal by using a level guide(Refer to 4.13.4).
- When there is a space between the boards and canal side, sandbag(s) is/are packed into the space.

Figure 4-23 Damaged canal from landslide

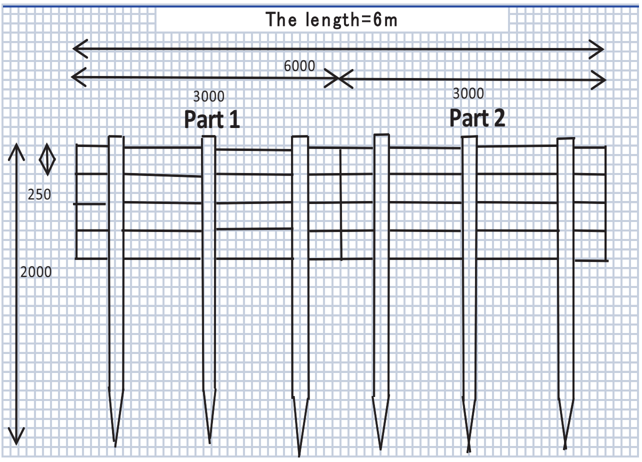


Figure 4-24 Planning map of a Wooden fence

Figure 4-25 Pegging for Wooden fence

4.13.2 Bamboo Fence

i) Purpose

- To protect a section of the irrigation canal from erosion.

ii) Range of Application

- Irrigation canal
- Depth of the water 0.3m or less
- Not applicable at the place where earth pressure comes from the back side

iii) Materials and tools needed.

- Bamboo
- String
- Hammer
- Shovel
- Cutlass or Knife

iv) Quantity per unit for construction

(Per 10m, One side)

Item	Description	Unit	Quantity	Comments
Bamboo	L=3.0m, D=0.07m	piece	15	
Farmer	Cutting	hour	3.2	
	Split- Drive	hour	4.8	

(Source: Chikako Hirose)

v) Method

a) Cutting

- The bamboo is cut with a saw to make a peg.
- The embedded length of the peg is half, to two-third of the full length.

b) Split

- The cut bamboo is split is halves with a hammer and a cutlass.

c) Make a tip of the peg

- The tip of the split bamboo is sharpened into a V-shape with a cutlass (Figure 4-27).

d) Drive pegs

- The pegs are driven using a hammer
- Between the bamboo pegs and canal side, it is made as narrow as possible (Figure 4-28).
- The head of the peg should be covered with cloth to prevent it from breaking when being hit with a hammer

Figure 4-26 Damaged canal from water erosion

Figure 4-27 Make a tip of the bamboo peg

Figure 4-28 Bamboo Fence

4.13.3 Dyke (Gated diversion weir)

i) Purpose

- To direct irrigation water through an intake by constructing a dyke across the river.

ii) Conditions for Application

- Depth of the water, 0.6m or less
- The water level at the source of the river rises due to the dyke.
- Both the landowner of upper area and users of the upper stream should agree beforehand.
- The farmers and other beneficiaries can do the maintenance

and repair work such as operating the gate or changing of damaged old sandbags by themselves.

iii) Materials and tools needed

- Wood pegs
- Wood boards
- Sandbags
- Bamboo
- String
- Hammer
- Level guide (Refer to 4.13.4)
- Shovel

iv) Quantity per unit for construction

(Per 12m:Dyke 6m, Side wood fence 6m)

Item	Description	Unit	Quantity	Comments
Board	L=3.0m, W=0.25m, t=0.03m	piece	27	
Peg	L=2.0m, W=0.1m,	piece	38	
Bamboo	L=2.0m, D=0.03-0.05m	piece	3	
Sandbag		piece	470	
Labour	Remove the damaged old dyke and soil at the bottom of stream - Set the sandbag	hour	8.3	

v) Procedure

a) Remove the old dyke and clean around new dyke

- Remove the damaged old dyke and soil at the bottom of stream.

b) Fix a ruler (To make a datum line)

- The purpose of datum line is to show and guide the position where the structure is to be based.
- Pegs are driven at the side of the temporal peg, and a string stretched over the pegs.

c) Drive pegs into the ground

- The pegs are driven vertically with a hammer by using the stretched string as a guide.

- The embedded length of a peg should be half, to two-third of the full length.
- The tip of the peg should be sharpened with a cutlass beforehand.
- The interval of each peg should be around 1m, in the case of 3 m-boards
- The head of the peg must be covered with a cloth to avoid it being broken by a hammer.

d) Set board

- The board is set between the pegs.
- The board is set horizontally on the bottom of stream by using a level guide(Refer to 4.13.4).
- The board is hammered to implant in the ground in order to prevent the leakage.

e) Set sandbag

- The sandbags are set between the boards.
- The horizontal side of the sandbag is placed at right angles to the direction of the stream.
- The sandbags are bedded layer by layer and swatted with a hammer to fix to the ground.

f) Set an apron

- The sandbags are set at the downstream side of the dyke to prevent the bottom of a stream from causing erosion.
- The sandbags are fixed by bamboo pegs on the ground.

A picture of a damaged dyke and new dyke are shown in Figure 4-29 and in Figure 4-30 respectively.

Figure 4-29 Damaged old dyke

Figure 4-30 New dyke (Gated diversion weir)

4.13.4 Simple level tool for construction

Procedure

How to make the tool

i) Fill a plastic bottle approximately half way with water
Lay the bottle horizontally.

ii) Mark level of water on both sides of the bottle

iii) Place the bottle in a reverse position at the same place.

iv) Mark the water level as c) (A2 and B2).

v) Get the center of each side and mark as A3 &B3.

vi) Draw a line from A3 to B3 with a marker.

Refer to Figure 4-31 for pictorial procedure.

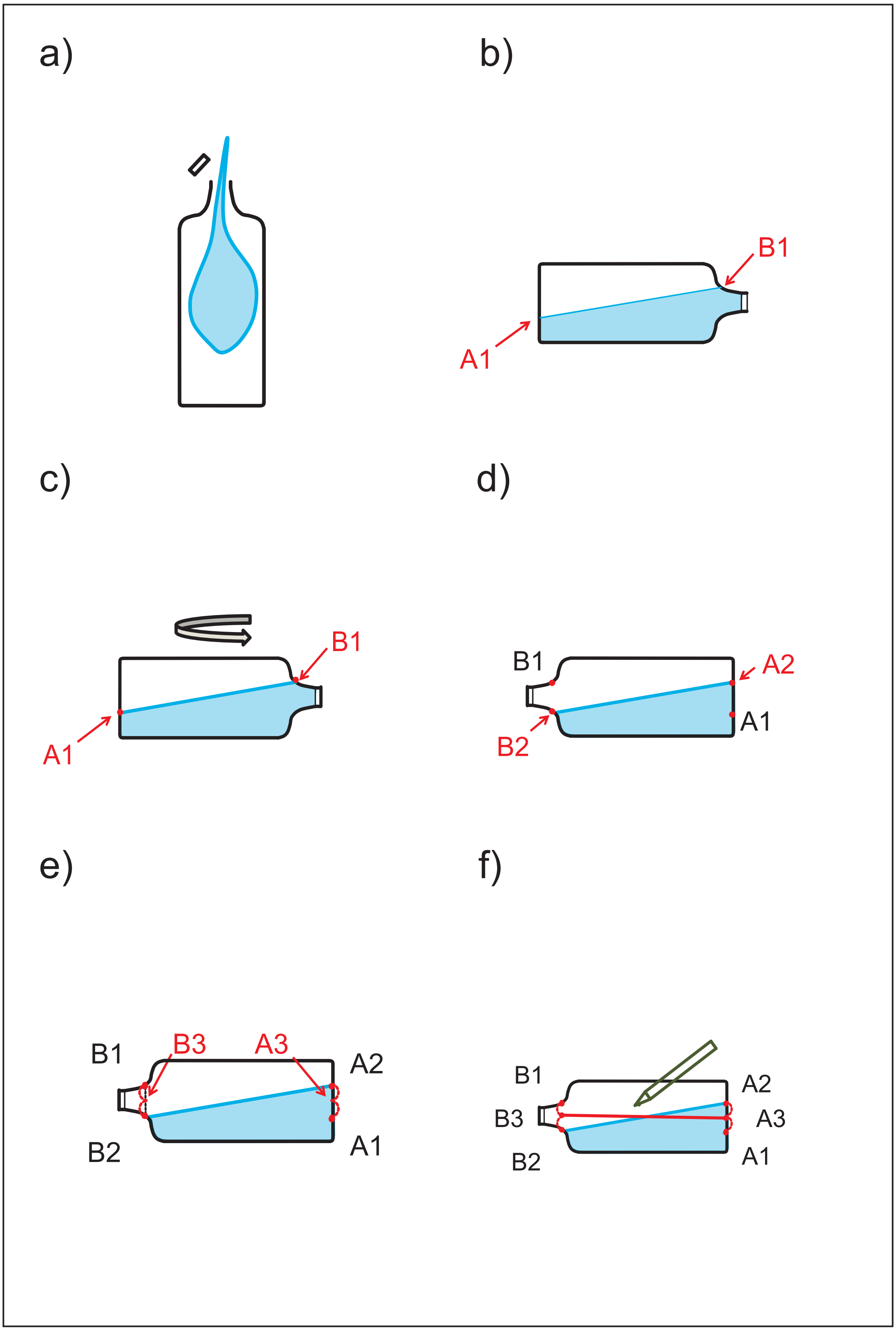


Figure 4-31 How to make simple level tool for construction

How to use simple level

- Lay the level on the structure horizontally (Figure 4-32).
- Compare the level of water inside the plastic bottle with the line drawn outside.
- A structure is installed so that both lines become parallel.

Figure 4-32 Simple level tool

5.1 Basic knowledge for rice cultivation

Knowledge and experience are very important for rice cultivation. Sometimes farmers do not follow the suggestions of extension workers because they do not consider them seriously. Extension workers should teach farmers the theoretical methods of rice cultivation. They should explain to farmers the reasons for those activities. For example, farmers should understand why they apply fertilizer on time or why they properly manage water depending on the rice growing stage. Extension workers should understand in detail. The mechanism of rice cultivation in order to give the farmer an in-depth explanation of the theory.

5.1.1 Main factors for rice growing

Plants grow by the use of sunlight, water, and soil (nutrient). Plants transform carbon from CO_2 in the air to carbohydrate by using solar energy, and this process is known as photosynthesis. (Figure 5-1). The main factors are CO_2, solar energy, water, and nutrients for rice cultivation. Rice should be cultivated with the above factors always in mind. For example, we should grow rice by always taking into

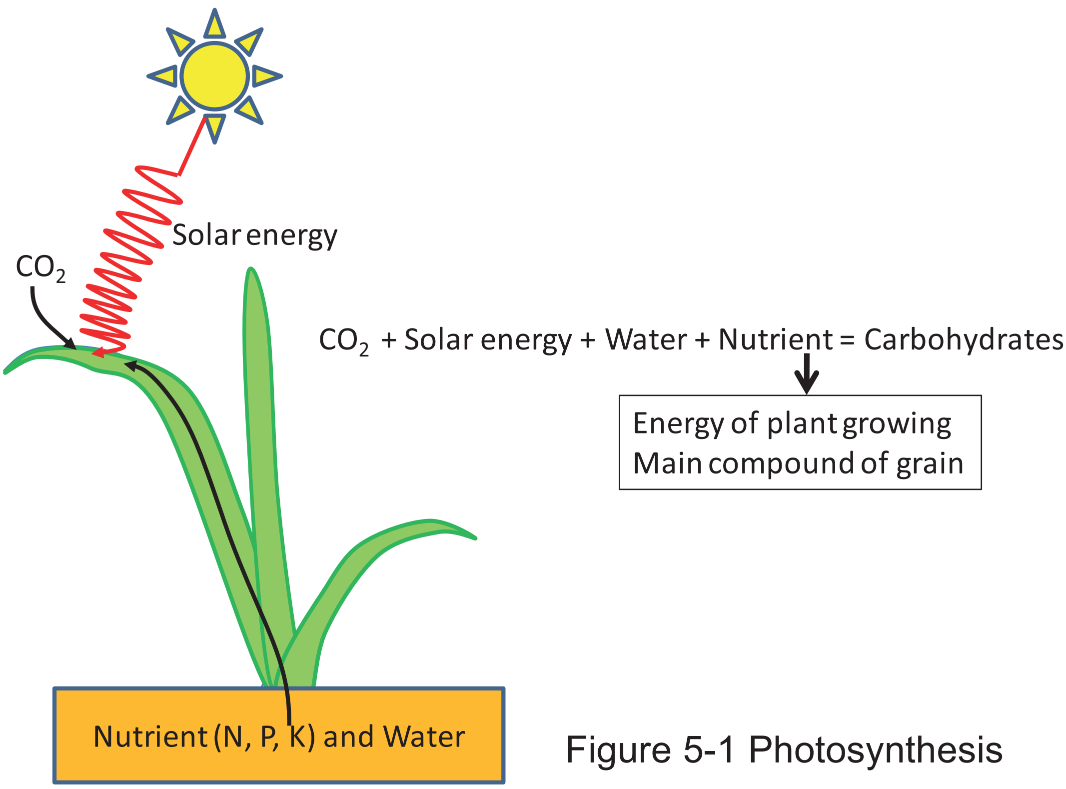


Figure 5-1 Photosynthesis

consideration how solar energy can reach all the leaves or how CO_2 can be absorbed by the plant without limitation.

5.1.2 Sunlight

The energy of sunlight influences the yield of rice. Sunlight cannot be controlled directly, but it can be used effectively.

(i) How to use sunlight effectively

Rice should be observed as a canopy structure not as individual plant.

(ii) Management of the canopy structure of rice plants

When rice is planted at high density or excessive amounts of fertilizer are applied, the upper leaves prevent the penetration of sunlight into the whole rice plant (Figure 5-2). Therefore, sunlight can reach only the upper leaves and most of the leaves cannot absorb the sunlight, which result in less production of carbohydrate by photosynthesis.

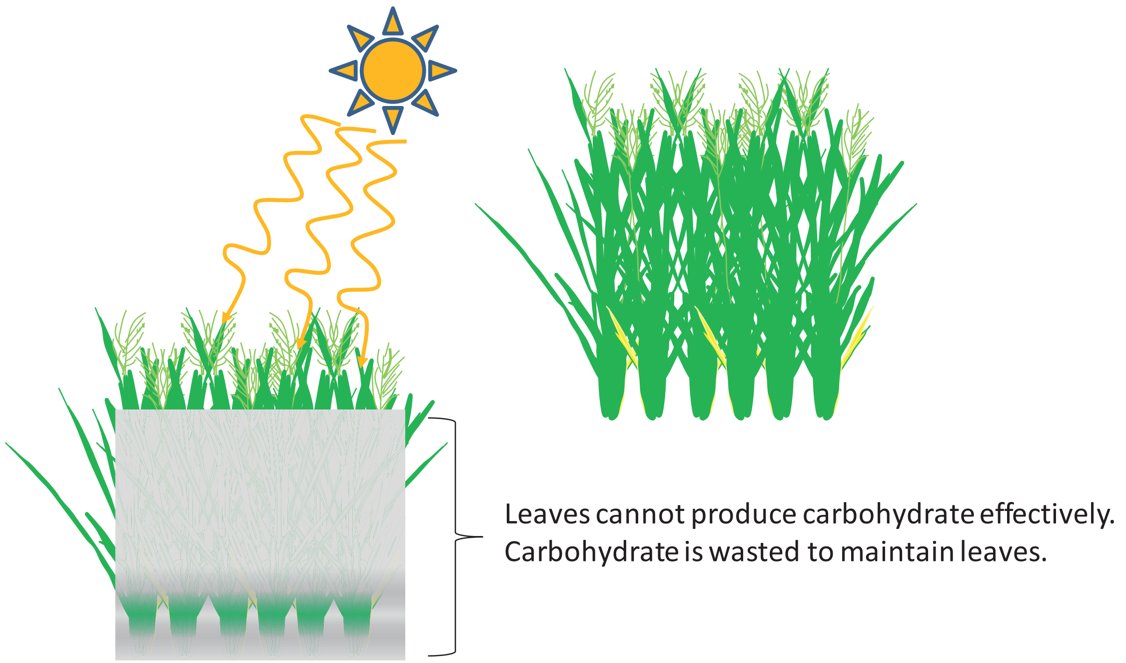


Figure 5-2 Canopy structure at high density

When rice is planted at the appropriate density and adequate amount of fertilizer is applied, sunlight reaches most of the leaves (Figure 5-3). The production of carbohydrate increases due to the increased photosynthetic activities.

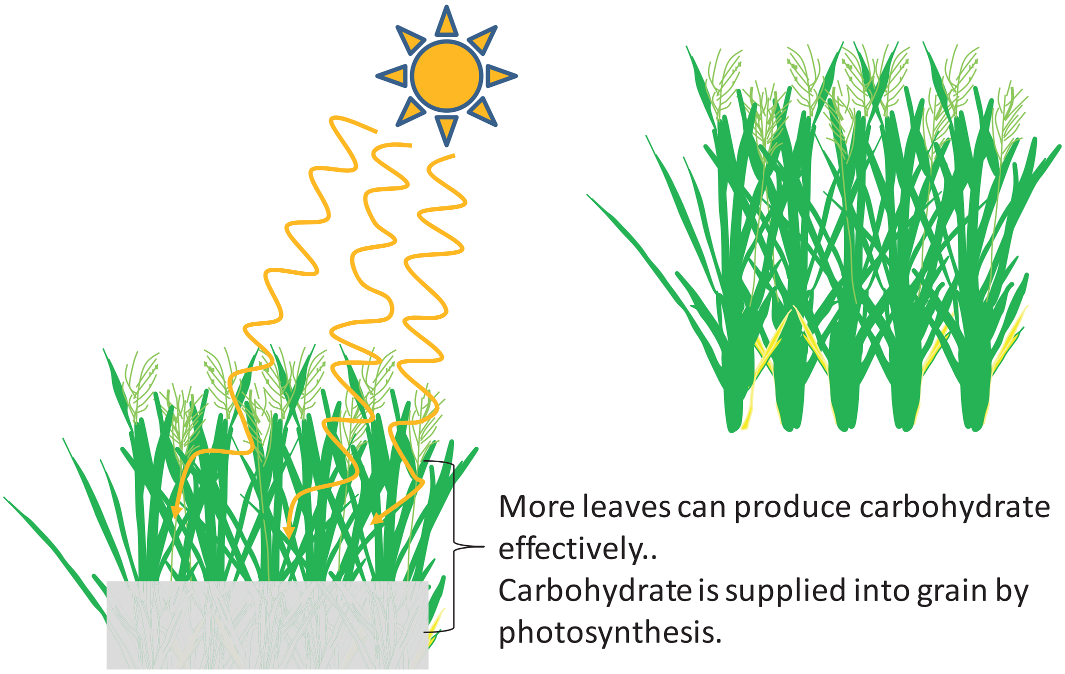


Figure 5-3 Canopy structure at adequate density

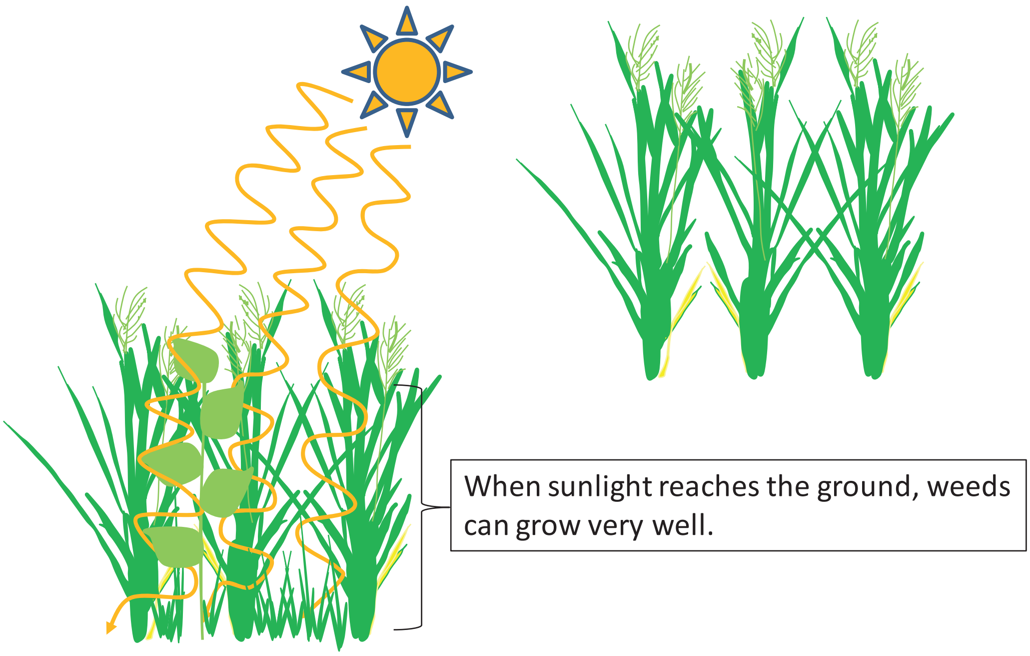


Figure 5-4 Canopy structure at low density

When rice is planted at low density or the growth of rice is poor, sunlight can reach the ground (Figure 5-4).
Weeds can grow very well, and it is difficult to control weeds.

(iii) Adaptation of rice cultivation to seasonal changes in sunlight

The amount of sunlight differs between the wet season and the dry season. In the wet season, sunlight is one of the factors for the yield. Therefore, we cannot expect yields in the wet season to be the same as in the dry season from the application of the same amount of fertilizer (Figure 5-5). We should decrease the amount of fertilizer in the wet season.

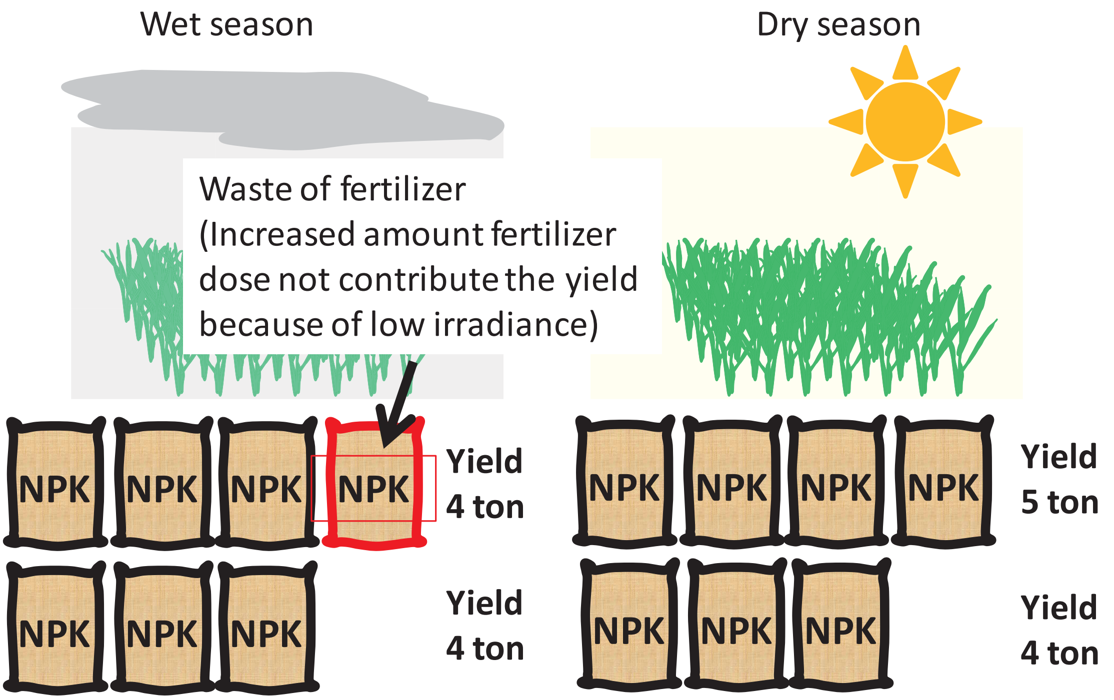


Figure 5-5 Difference of effect on fertilizer between wet season and dry season

5.1.3 Water

Water and soil fertility are the most important factors for increasing the yield. One of the aims of land reclamation is to control water. Most farmers sometimes ignore the management of water, which decreases the effectiveness of land reclamation.

(i) Why is it necessary to manage water in rice cultivation to increase yield?

In the Ashanti region, rice can be mostly cultivated with water from rainfall during the rainy season. However, to increase the rice yield (above 4 tons per ha), the control of water is necessary.

(ii) Rice needs water to survive.

Water plays an important role in the metabolic activity in rice.

(a) It is a vital constituent of the cell protoplasm.
(b) It is a reactant or reagent in chemical reactions.
(c) It is a solvent for organic and inorganic solutes, gases, and facilitates their translocation within the plant.
(d) It gives mechanical strength to the plant by enhancing turgidity.

(iii) Drought stress causes serious decrease in yield.

Effects of drought stress:

(a) Leaf rolling

When you observe the leaf rolling, rice suffers from drought stress. When rice suffers drought stress, the stoma is closed to prevent water loss from the leaf (Figure 5-6). When the stoma is closed, rice cannot absorb CO_2, which result in decreasing photosynthetic activity. When rice suffers drought stress, it is still able to survive but cannot produce enough carbohydrate for the grain.

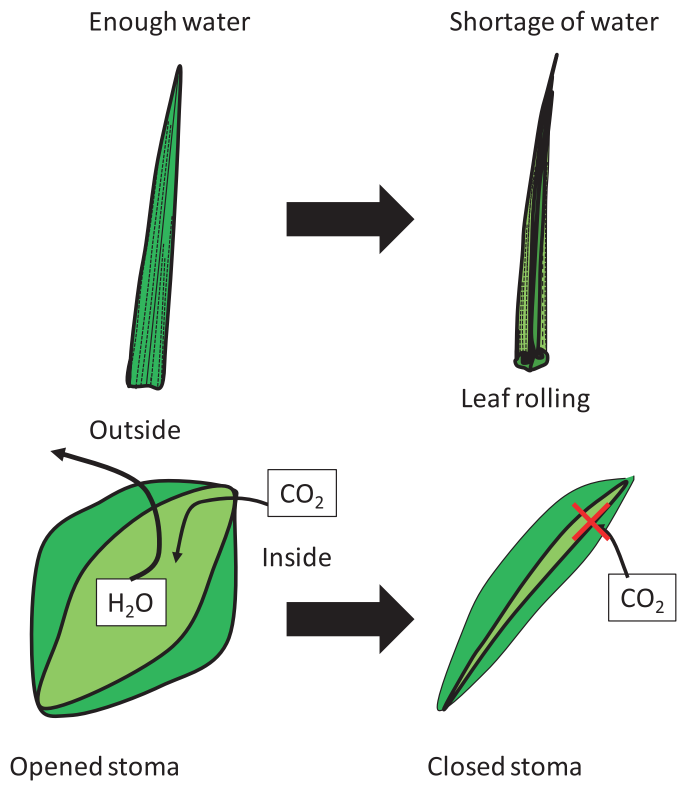


Figure 5-6 Closed of stoma inhibits the absorption of CO_2

(iv) Management of water

During the wet season, rice can grow with only rainfall. However, we cannot expect a sustainable yield above 4 tons per ha without the management of water, because the demand for water is different at each stage of rice growth. Also, adequate management of water increases the efficiency of weed control.

Most farmers supply water to the field when the surface of the soil is dry. However, they mostly ignore the control of water. They do not close the bund to keep water inside the field when they supply water to the field, because they are familiar with the irrigation of upland fields (Figure 5-7). The management of water means to keep water at the desired water depth followed by the condition of rice growing. They should be aware of the difference in irrigation between upland and lowland fields.

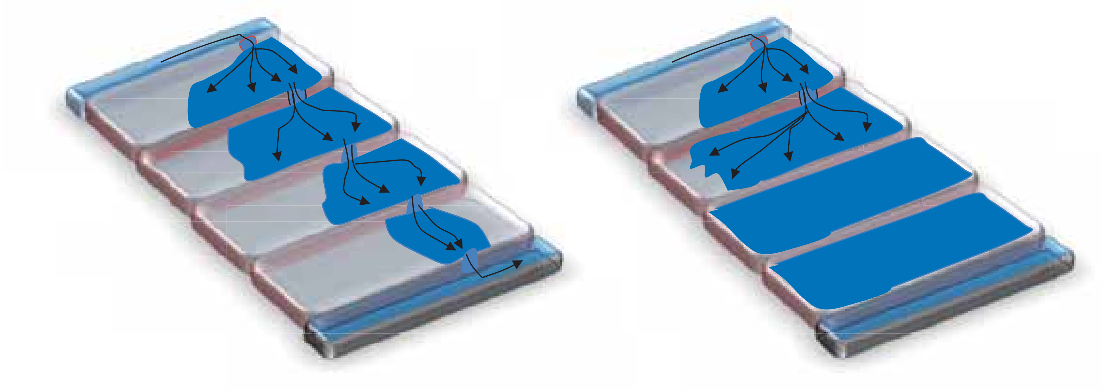


Figure 5-7 Irrigation of the paddy field
Most farmers supply water without closed bund (left), which cannot irrigate the whole field.

5.1.4 Soil

Soil is very important because most of the nutrients for rice production originate from the soil. Rice absorbs around 60% of nitrogen from the soil, not from fertilizer. Moreover, the average recovery rate of the applied N, P, and K is estimated to be only 30% of N and K, and 20% of P. The recovery rate is the percentage of fertilizer absorbed by the plant. Moreover, the recovery rate depends on the characteristics of the soil.

(i) Type of paddy field

Figure 5-8 shows the type of paddy field in West Africa.

(a) Well-drained paddy field: Gley horizon cannot be detected up to 80 cm depth. This type of field is frequently observed in lowland areas with water only during the wet season.

(b) Intermediate-drained paddy field: Gley horizon cannot be detected up to 30 cm to 80 cm depth. This type of field is observed in lowland areas with water during the whole year.

(c) Poorly-drained paddy field: Gley horizon can be detected within 30 cm depth. The hard pan cannot be detected sometimes. This type of the field is frequently observed in lowland areas with water during the whole year. In general, working and operation of the power tiller is difficult.

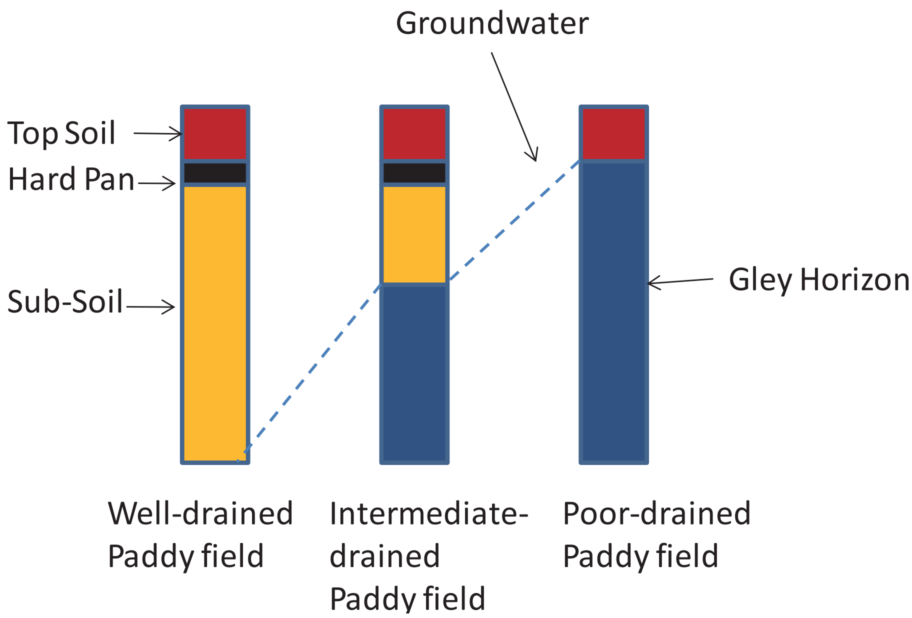


Figure 5-8 Type of paddy field

(ii) Characteristics of paddy soil for rice cultivation

Depth of top soil

It is better to have the depth of top soil ranging from 10 cm to 15 cm. When the depth of top soil (from surface to hardpan) is above 40 cm, we cannot use the power tiller, because it will sink in the soil and eventually break down.

(a) Viscosity of top soil

When the top soil is very sticky, the rice may grow well. However, it is difficult to operate the power tiller.

(b) Total water loss

Total water loss is shown as the water requirement rate. Total water loss can be estimated by measuring the difference in the depth of water for 24 hours. In general, the best requirement rate is 30 mm per day. If it is below 10 mm per day, the reducibility of the soil is very high, and results in damaging the roots. If it is above 100 mm per day, the nutrients in the soil are washed away.

(iv) Effect of poor drainage

If the gley horizon can be detected within a depth of 30 cm, the roots will be damaged by a shortage of oxygen or organic acid.

(v) Characteristics of soil texture for rice cultivation

The characteristic of the soil affects the total water loss, the effectiveness of the fertilizer, and working conditions. Table 5-1 shows the characteristic of each soil texture.

Table 5-1 Characteristics of each soil

Characteristics	**Clay**	**Loam**	**Sandy loam**	**Sandy**	**Gravelly**
Viscosity	Sticky	A little sticky	Not sticky	Not sticky	Not sticky
Drainage	Slow	Average	Fast	Fast	Fast
Capacity to retain water	High	Average	Low	Low	Low
Capacity to retain nutrient	High	Average	Low	Low	Low
Organic matter content	High	Average	Low	Low	Nothing
Easiness to plough soil in wet conditions	Difficult	Average	Easy	Easy	Impossible
Erosion by run-off	Low	High	Low (high for fine sand)	Low (high for fine sand)	Low
Wind erosion	Low	High	Low (high for fine sand)	Low (high for fine sand)	Low

(vi) Soil fertility

The degree of soil fertility affects rice production directly. Therefore, the degree of soil fertility at the site should be understood. The detail soil fertility of the site can be analyzed in the laboratory, however, it is difficult to analyze the soil at each site. You should estimate soil fertility by the color, texture, and information about the rice growing status from previous season. The color of the soil is determined by organic matter and iron.

(a) Black (Figure 5-9)

A lot of organic matters are not decomposed, because of anaerobic conditions. Sulfide may damage the roots. Therefore drainage is necessary. After drainage, organic matter is decomposed in aerobic conditions, which result in high fertility of the soil.

(b) Red or yellow (Figure 5-10)

The soil is oxidized but organic matter is very small.

(c) White or gray (Figure 5-11)

This soil has a little nutrient.

(d) Greenish blue (Figure 5-12)

The soil is reduced because of anaerobic conditions and has become very acidic.

(e) Blackish brown (Figure 5-13)

This color is the best for rice, because it contains a lot of organic matter.

Figure 5-9
Color is black.

Figure 5-10
Color is red.

Figure 5-11
Color is white.

Figure 5-12
Color is greenish blue.

Figure 5-13
Color is blackish brown .

(vii) Soil fertility in the inland valleys of Ghana

Table 5-2 shows the results of soil analysis in Ghana, West Africa, and Asia.

Table 5-2 Soil fertility

Parameter	Apamu vall (Ashanti)	Apunapuna (Ashanti)	Forest lowlands (Ghana)	Savannah lowland (Ghana)	Lowland (West Africa)	Paddy field Asia
pH (water)	5.3	5.6	5.7	4.6	5.3	6
Org. Carbon (%)	0.99	1.43	1.2	0.61	1.23	1.41
Total Nitrogen %)	0.09	0.11	0.11	0.065	0.108	0.13
Organic Matter (%)	1.7	2.46	2.06	1.05	2.11	2.42
Av. Phosphorus (mg kg−1)	5	5.9	4.9	1.5	8.4	17.6
Ex. K {cmol(+) kg−1}	0.2	0.4	0.4	0.2	0.3	0.4
Ex. Ca {cmol(+) kg−1}	1.9	3.6	7.5	2.1	2.8	10.4
Ex. Mg {cmol(+) kg−1}	1	1.1	4.1	1	1.3	5.5
Ex. Na {cmol(+) kg−1}	0.9	0.4	0.3	0.1	0.3	1.5
Ex. Ac {cmol(+) kg−1}	0.9	1	0.3	1	0.9	
eCEC {cmol(+) kg−1}	4.3	6.4	12.7	4.4	5.8	17.8
Clay (%)	10	6	8	7	23	38

(viii) Explanation of each parameter

(a) pH: The appropriate pH is from 5.5 to 6.5 for rice. In general, the pH of lowland soil is low.

(b) Organic C: Organic carbon in the soil influences many of the physical, chemical, and biological properties of the soil. Some of the properties influenced by organic matter include soil structure, water holding capacity, nutrient contributions, biological activity, water and air infiltration rate, and pesticide activity.

(c) Total N: Total N shows the amount of nitrogen supplied by the soil. When the value is above 0.2%, the soil contains a lot of nitrogen. When the value is below 0.1%, the soil contains a small amount of nitrogen.

(d) Organic Matter: If the amount of organic matter is high, the value of CEC (Cation Exchange Capacity): is high.

(e) Available P: Amount of phosphorous can be absorbed by the plant.

(f) CEC (Cation Exchange Capacity): Soil is made up of many components. A significant percentage of most soil is clay. A small percentage of organic matter in most soil is also important for several reasons. Both of these soil fractions have a large number of negative charges (-) on their surface, thus they attract cation elements (+) and contribute to a higher CEC. At the same time, they also repel anion nutrients ("like" charges).

The fertility of soil can be estimated by the value of CEC (cation exchange capacity). If the value of CEC is below 10 $cmolkg^{-1}$, the soil fertility is very low (Figure 5-14). Some important elements with a positive electrical charge in their plant-available form include potassium (K^+), ammonium (NH_4^+), magnesium (Mg^{++}), calcium (Ca^{++}), zinc (Zn^+), manganese (Mn^{++}), iron (Fe^{++}), copper (Cu^+), and hydrogen (H^+). While hydrogen is not a nutrient, it affects the degree of acidity (pH) of the soil, so it is also important. Some other nutrients have a negative electrical charge in their plant-available form. These are called anions and include nitrate (NO_3^-), phosphate ($H_2PO_4^-$ and HPO_4^{--}), sulfate (SO_4^-), borate (BO_3^-), and molybdate (MoO_4^{--}). Phosphates are unique among the negatively charged anions in that, they are not mobile in the soil. This is because they are highly reactive, and nearly all of them will combine with other elements or compounds in the soil, other than clay and organic matter. The resulting compounds are not soluble, thus they precipitate out of soil solution. In this state, they are unavailable to plants, and form the phosphorus reserve in the soil. In general, the value of CEC in West Africa is lower than that in Asia, because of lower content of clay (Table 5-2). Soil should be improved by the application of the organic matter for the sustainable high production of rice.

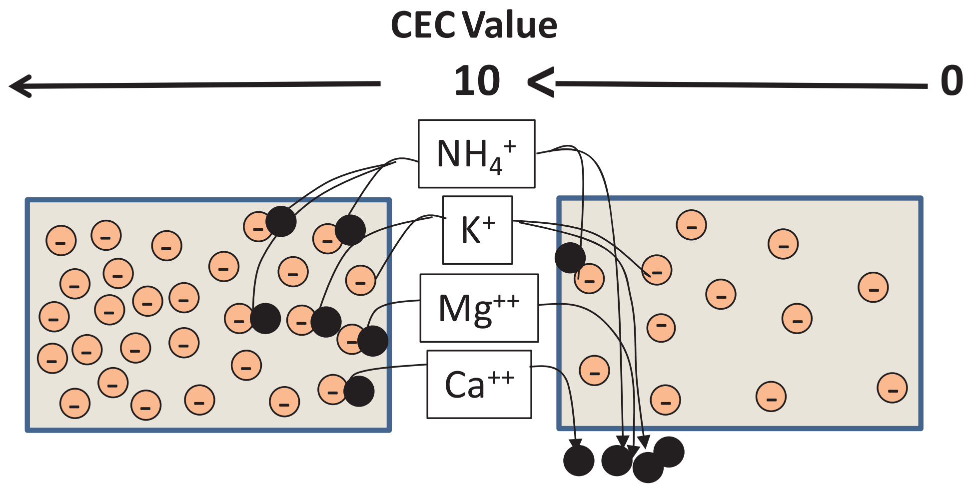


Figure 5-14 Effect of CEC on the soil fertility

(Reference (5): Spectrum Analytic Inc.)

(ix) How rice grows.

The physiological development of rice should be understood because water management and the time of application of fertilizer should be done by following the physiological condition of rice for effective rice cultivation.

Rice undergoes three stages of development (Figure 5-15). They are;

Vegetative stage, which runs from germination to panicle initiation.
Reproductive stage, which runs from panicle initiation to flowering.
Ripening stage, which runs from flowering to full maturity.

(a) Vegetative stage (germination of seed, emergence and growth of seedlings, recovery from damage of transplanting, and tiller production)

Vegetative stage is for increasing tillers. Number of tiller is decided in this stage.

(b) Reproductive stage (panicle initiation, panicle differentiation, meiosis, flowering)

The reproductive stage is marked by the initiation of a panicle. Panicles are developed during this stage. The number of grain is decided in this stage. The ratio of maturity of the grain is decided in this and ripening stage. Rice is more sensitive to the environment in this stage than in other stages and therefore a lot of care should be taken in this stage.

(c) Ripening stage (milk grain stage, mature grain stage)

The ratio of maturity of grain and the quality of grain are decided in this stage.

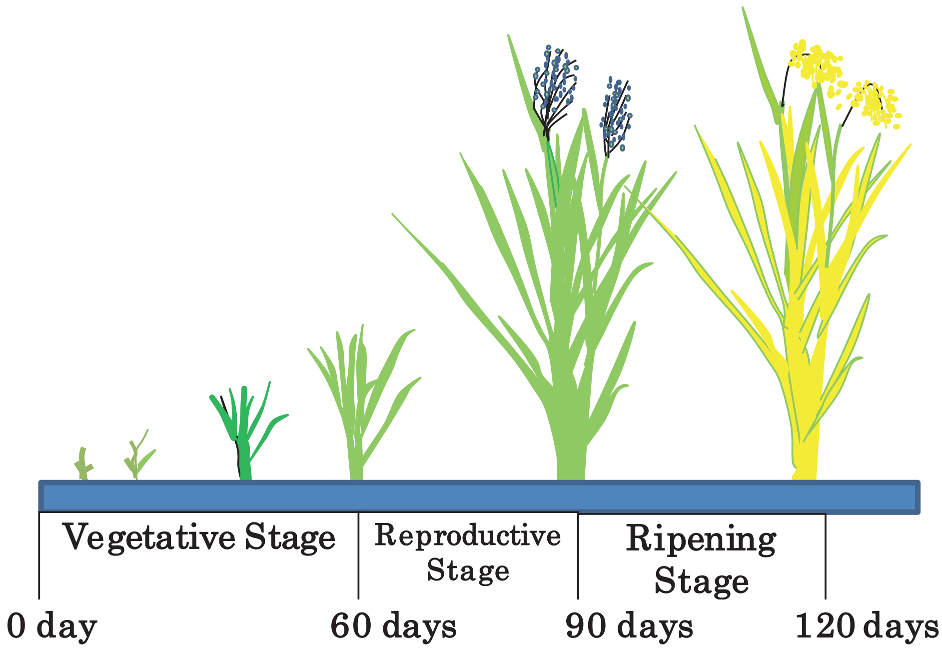


Figure 5-15 Diagram of growth stages of 120-day variety

5.2 Cropping calendar

It is important for the effective cultivation of rice to understand the various development stages of rice and the natural environment (amount of rainfall, and water level in the stream). Extension workers should understand the right time for sowing, transplanting, and applying fertilizer, and discuss them with the farmers. The farmers and extension worker should make a plan for the activities.

5.2.1 Time schedule of activities for planting the rice

Table 5-3 shows the estimation of required days for activities (1 ha) of planting the rice cultivation with a growing period of around 120-days (sikamo and jasmine).

Table 5-4 shows the time schedule of rice cultivation. It will take around 150 days from land preparation to end of post-harvest.

Table 5-3 Estimation of the required days for activities for one hector

Activities		Days / ha
Clearing	Application of hericide	1
	Wating period for weeds to die	7
	Slashing	3
Maintaing the dyke		2
Maintaing the canal		3
Maintaing the bond		3
Maintaing the pond		2
Ploughing	Operating power-tiller	3
	Drying soil	3
Puddling	Operating power-tiller	3
Leveling	Operating power-tiller	3
	Flooding the field	3
Nursurly	Pregermination	3
	Establising nursurly	1
	Sowing	1
Transplanting	Draining the field	1
	Transplanting	4
Applying harbicide		3
Manual weeding		4
Applying fertilizer	1st application	4
	2nd application	3
Scaring bird		30
Harvesting		10
Threshing and winnowing		10
Drying		3

Table 5-4 Time schedule

Stage	Weeks and Days		Water management	Activities
Preparation of land	-S3	-21		Apply non-selective herbicide
	- S2	-14		Slush , Repare the dyke, the canal, the bund, and the pond
	- S1	-7		
	0	0		Plooough, Pre-germination of seeds, Preparing the nursurey bed
			Drying soil for 3 days	Dry soil, Sow seeds
Vegetative stage	S1	7	Irrigation (5 cm to 10 cm)	Puddle, and level
				Flooding at least for 3 days
	S2	14	Drainage (transplanting)	Transplant
			Irrigation (2 cm)	
	S3	21	Drainage (herbicide and fertilizer)	Apply selective herbicide or 1st weeding
				Apply fertilizer (N,P,K) and fungicide and insectcide, and 2nd maual weeding
	S4	28	Irrigation (2 cm)	
	S5	35		
	S6	42		
	S7	49		
	S8	56		
Reproductive stage	S9	63	Irrigation (5 cm to 10 cm)	
	S10	70		Apply fertilizer
	S11	77		
	S12	84		
				Apply fungicide
	S13	91	Irrigation (1 cm)	Scare the birds
Ripening stage	S14	98		
	S15	105		
	S16	112	Dranage (Harvest)	
	S17	119		Harvest
Post harvest	PH1	126		
	PH2	133		Thresh and winnow
	PH3	140		Dry

5.2.2 Cropping calendar in case of Ashanti region (Ghana).

Figure 5-16 shows the average precipitation in the Atwima Nwabiagya District in the Ashanti region from 2004 to 2009, and the right time for rice cultivation. The concern should be the four important issues: water for leveling, water for reproductive stage of rice, enough solar radiation at reproductive and ripening stage, and dry period at post-harvest. However, the water availability is the first priority, dry period at post-harvest is the second priority, and then solar radiation during the reproductive and ripening stages is the third priority.

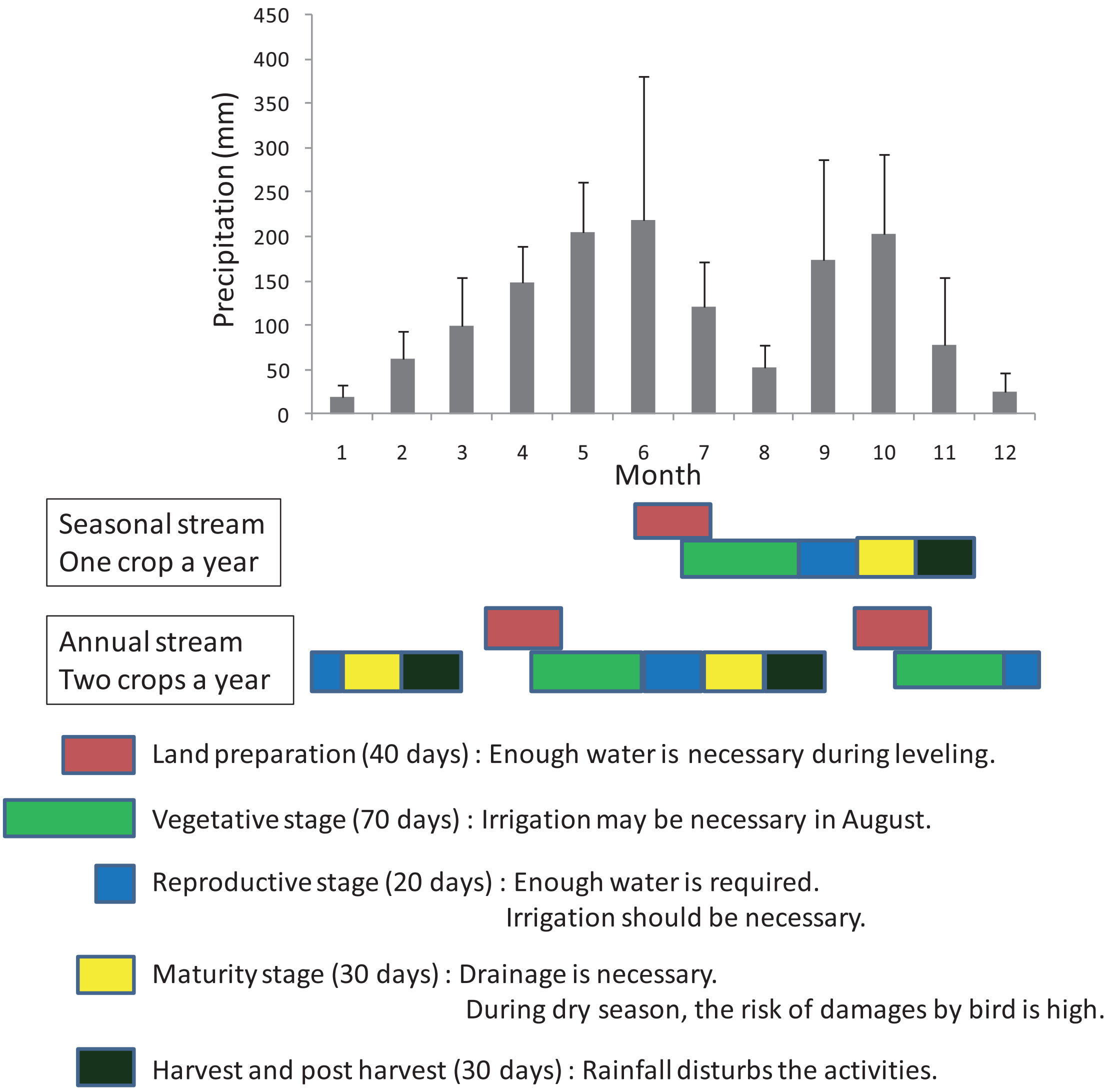


Figure 5-16 Precipitation and Cropping calendar

(Footnote)

Rice cultivation with different growing stages in one field is not recommended. Sometimes we can see rice in the maturity stage in the field located just beside a field where the seedlings are transplanted. In such fields, we cannot control water following the rice growing stages. Moreover, there is risk of infection from disease to seedlings from older rice plants.

5.3 Paddy Field Preparation

Preparation of the land includes clearing, maintenance of canals, bunds, dykes and ponds, ploughing, paddling, and leveling.

5.3.1 Clearing

Weeds grow vigorously in tropical areas making canals and bunds difficult to identify at only one month after harvesting.

(i) Purpose

The purpose of clearing the fields is as follows.

(a) Removing the weeds for ploughing
(b) Killing and burning the weeds and remaining rice plants from the previous season to prevent the transfer of disease from weeds to rice.
(c) Removing the weeds to check in the broken part of the facilities (bund, canal, and dyke).

(ii) Procedure

(a) Apply non-selective herbicide (glyphosate, 5 L per ha).
(b) Weeds die seven days after applying the herbicide.
(c) Slash, gather weeds, and burn the weeds. This is to prevent disease infection.

5.3.2 Ploughing

After maintenance of the canal, dyke, bund, and pond, you can start ploughing.

(i) Purpose

(a) Ease of transplanting.
(b) Killing weeds.
(c) Increasing soil porosity, and aeration to promote decomposition of organic matter.

(ii) Procedure

(a) The soil should be moist.
(b) Plough to turn over the soil.
The depth of ploughing should be about 15 cm. When using the power tiller, it is recommended to use a single plough (Figure 5-17).
(c) Ideally, it is better to keep the soil dry for one or two weeks to decompose organic matter. It is difficult for most bacteria to decompose organic matter under anaerobic conditions.

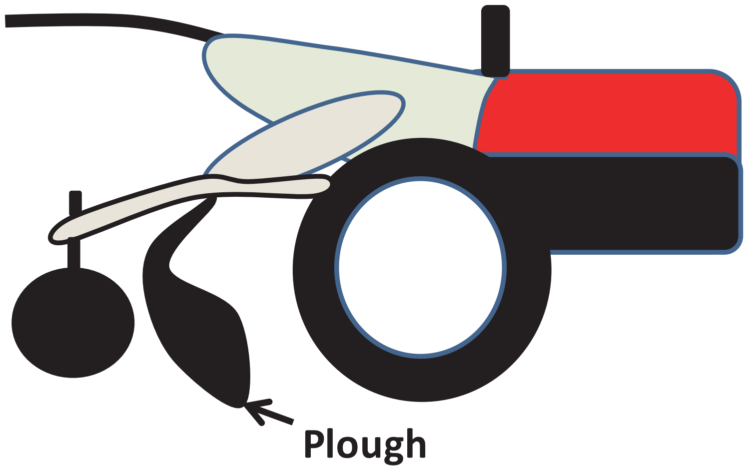


Figure 5-17 Power tiller with a single plough

5.3.3 Puddling

Puddling is to crush the bulk of soil.

(i) Purpose

(a) Crushing the soil bulk.
(b) Killing weeds

(ii) Procedure

(a) Saturate the soil by irrigation

(b) Crash the soil. When using the power tiller, it is recommended to use a rotary type (Figure 5-18).

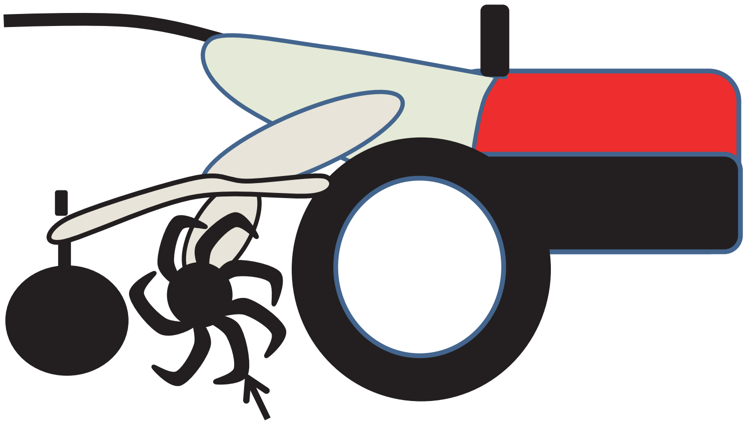


Figure 5-18 Power tiller with the rotary

5.3.4 Leveling

After paddling, leveling should be done. Farmers mostly transplant just after paddling. If you transplant just after paddling, the land will be uneven, and there would be the risk that many weeds will grow. Actually, there are many seeds of weeds inside the soil. The seeds inside the dried soil are dormant and waiting for moisture to germinate. The seeds start germinating during ploughing, because of adequate moisture and aeration from turning over the soil (Figure 5-19). If the clods are big, water holding capacity becomes low. It is better to make the soil fine (Figure 5-20).

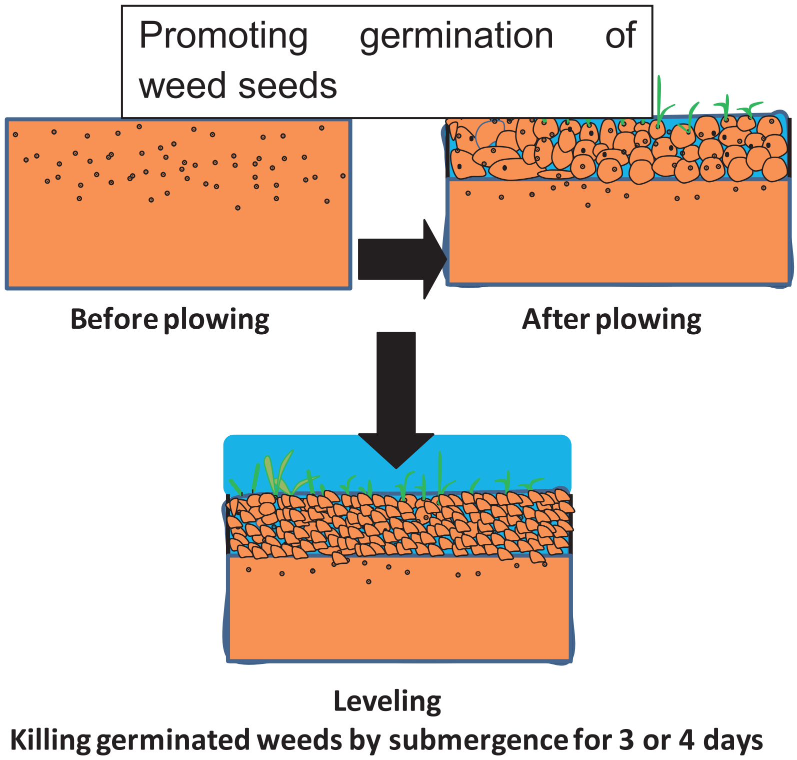


Figure 5-19 Killing germinated weeds by submergence

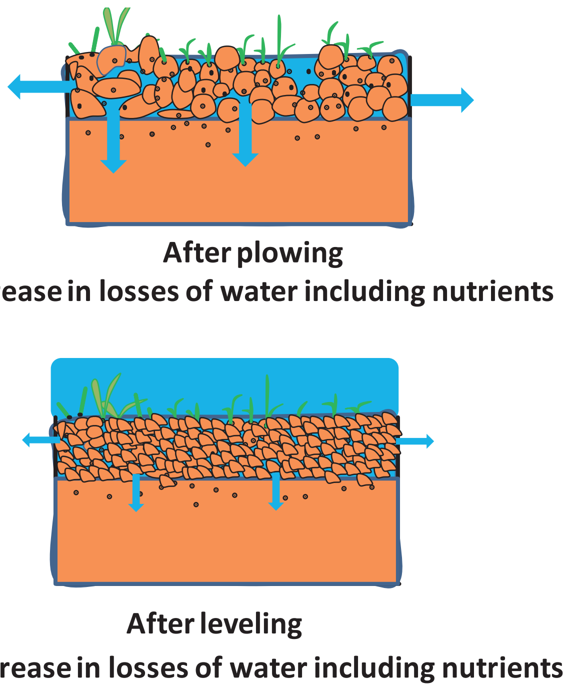


Figure 5-20 Increasing water and nutrient holding capacity by paddling and leveling

(i) Purpose

(a) Killing germinated weeds (Figure 5-19)
(b) Crushing the soil and making it fine to increase the water and nutrient holding capacity (Figure 5-20)
(c) Leveling the soil for easier management of water

(ii) Procedure

(a) Flood field from 5 cm to 10 cm.
(b)Level with the power tiller with a rake or wooden plank. (Figure 5-21).
(c) Keep flood at least for 3 days.
Flooding for one week is recommended to kill weeds. Farmers mostly start draining for transplanting soon after leveling. However, this may cause loss of fine soil and nutrients (Figure 5-22). We must therefore wait until the fine soil and nutrients settle within three days.

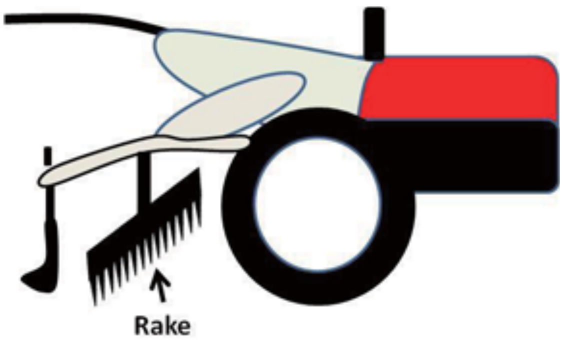
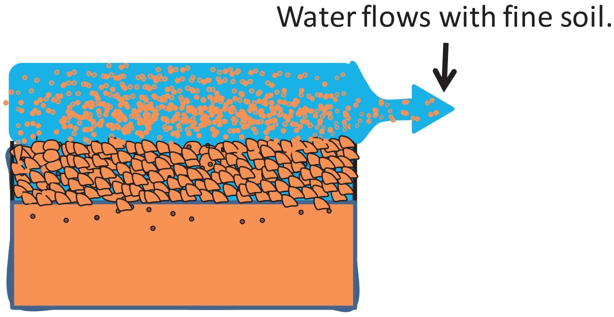
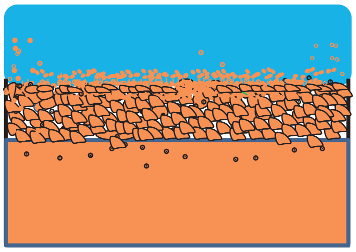


Figure 5-21 Power tiller with the rake



After leveling
Fine soil including nutrient is mixed with water by leveling.



At 3 or 4 days after leveling
Fine soil including nutrient settles.

Figure 5-22 Importance of keeping field flooded

5.4 Vegetative Stage

The vegetative stage is sub-divided into three phases: seedlings in the nursery bed, recovery from damage by transplanting, and tillering.

5.4.1 Pre-germination treatment

In Ghana, the system of seed production for rice is not well developed. It is therefore difficult for farmers to acquire good seeds. Farmers use seeds produced by themselves in the previous season or buy from neighboring farmers. Therefore, the quality of the seeds is not good. The seeds are a mixture of different varieties, immature kernels, and diseased seeds. Sometimes the diseased seeds cause bakane, brown spot, and blast, which result in a serious decrease in production. Therefore, much attention should be paid to the seeds. Some diseases can be prevented by disinfecting the seeds during pre-germination treatment.

Pre-germination includes selecting good seeds and preventing disease. The seed starts growing after absorbing enough water (Figure 5-23).

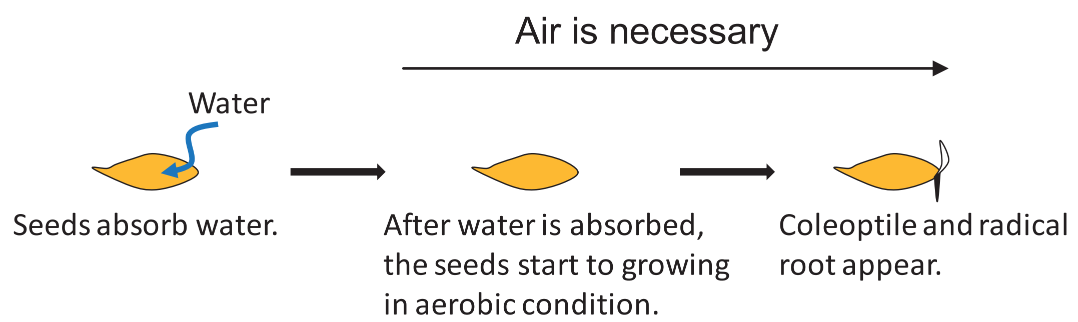


Figure 5-23 Mechanism of germination

(i) Purpose

(a) Improving the uniformity of seedlings
(b) Selecting mature seeds
(c) Disinfecting seeds

(ii) Procedure

(a) Prepare around 40 kg of seeds per hectare
(b) Select mature seeds (Figure 5-24 and 5-25)

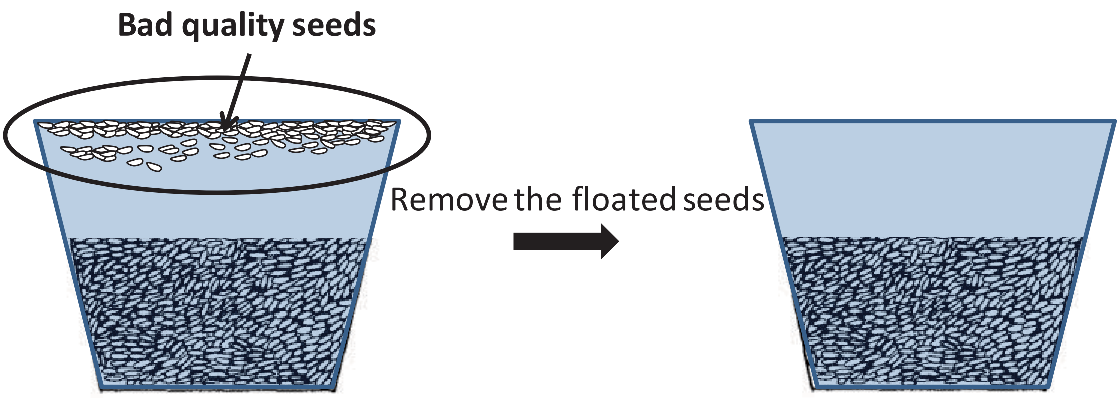


Figure 5-24 Selecting good quality seeds by water

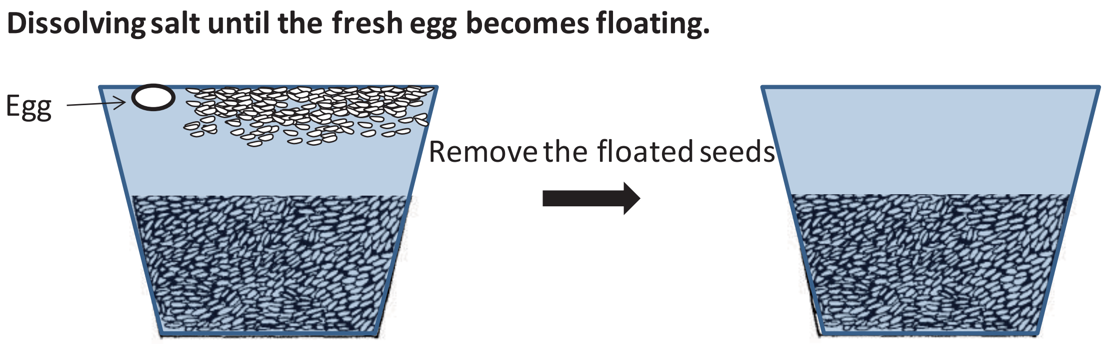


Figure 5-25 More serious selection of good quality seeds using salt water

(c) Disinfecting seeds: Good seeds are treated with agrochemicals. In Ghana, Seed plus 20 WS is available. Pre-wet 1 kg of seed with about 30 ml of water in a plastic bag and shake for a few seconds, then add 1 sachet (10 g) and shake for about 30 seconds. After removing the seeds from the plastic bag, the seed are dried overnight.
(d) Soak the seeds for one night in water (Figure 5-26)

(e) Incubate seeds for two days (Figure 5-27).

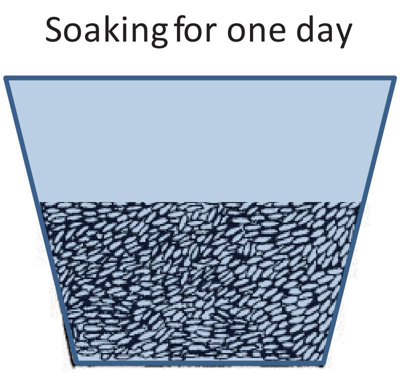


Figure 5-26 Soaking seeds

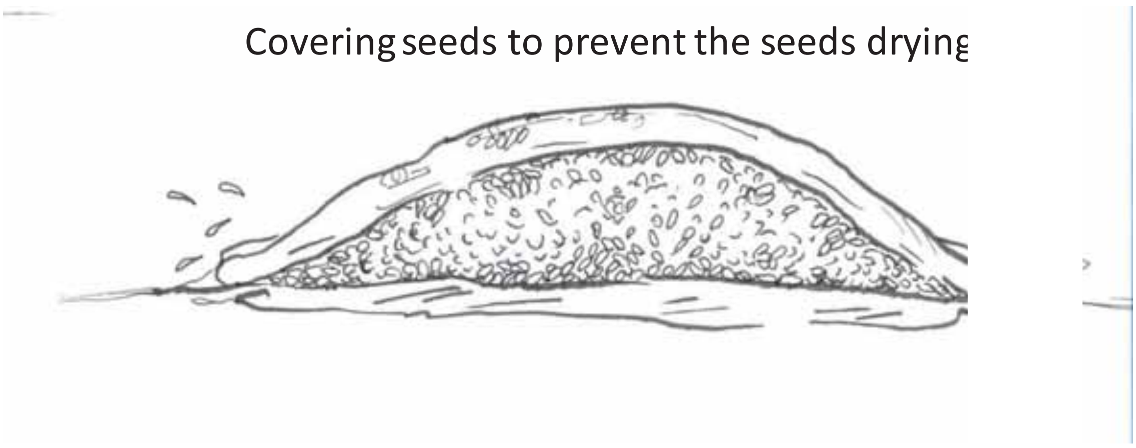


Figure 5-27 Incubation of seeds for two days

(Footnote)

(a) Farmers mostly keep the floated seeds, but the extension worker should tell the farmers never to use floated seeds.

(b) Every morning, farmer should wet the seeds.

5.4.2 Nursery Management

(i) Establishing the nursery bed

There are two kinds of nursery bed. One is an upland nursery, another is a lowland nursery (Figure 5-28). Each nursery bed has advantages and disadvantages.

(ii) Upland nursery and lowland nursery

An upland nursery is established upland. In the case of an inland valley, it is established on a hillside. A lowland nursery is established on a leveled field.

(a) Advantages of an upland nursery
> Not an obstacle to the preparation of land
> Healthy roots develop
> Less risk of flood

(b) Disadvantages of an upland nursery
> Risk of drought
> Pulling the seedlings for transplanting is difficult, sometimes the roots are damaged.
> The growing rate is different depending on the moisture in the soil.

(c) Advantages of a lowland nursery
> Irrigation is easy.
> The growing rate is the same.
> Pulling the seedlings for transplanting is easy without serious damage to the roots.

(d) Disadvantages of a lowland nursery
> There is risk of flood.
> The growth of the roots is not good.
> Preparation of the land takes more time for a lowland nursery than for an upland nursery.

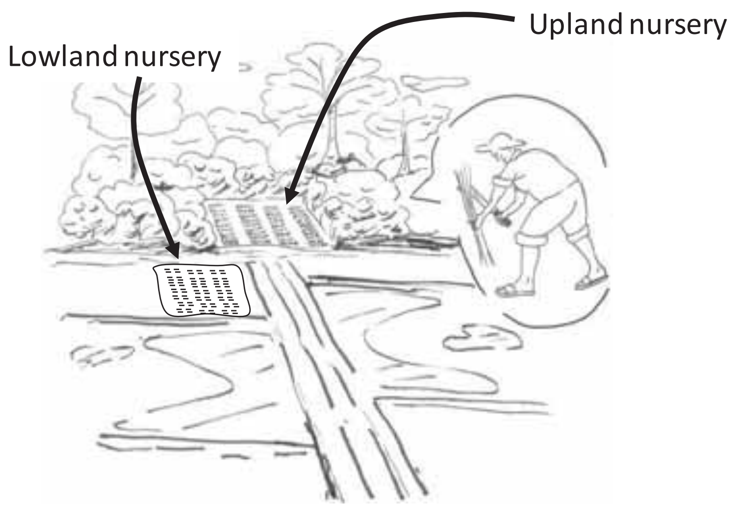


Figure 5-28 Lowland nursery and upland nursery

(iii) Procedure of nursery establishment and sowing

(a) Establish the nursery bed
The size of the nursery bed is 1 m (width) × 5 m (length) × 10 cm (height) (Figure 5-29).
(b) Level the ground and water until the soil is saturated.

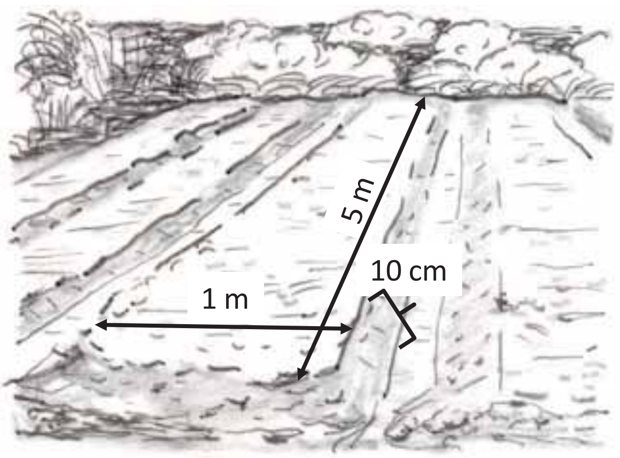


Figure 5-29 The size of the nursery bed

(c) Sow 1 kg of seeds on the nursery bed (1 m × 5 m) (Figure 5-31).

Farmers mostly sow the seeds at high density. Forty nursery beds should be prepared for transplanting for a one-hectare field because 40 kg of seeds is required for each hectare. When seeds are sown at high density, the seedlings become very weak and prone to disease, and the production of tiller is inhibited, resulting in a decrease in yield. You can estimate the weight of the seeds from the volume of a 1.5 L plastic bottle. The 2/3 volume of a 1.5 L plastic bottle is around 0.5 kg of seeds (Figure 5-30).

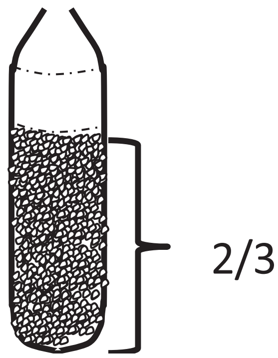


Figure 5-30 0.5 kg of seeds

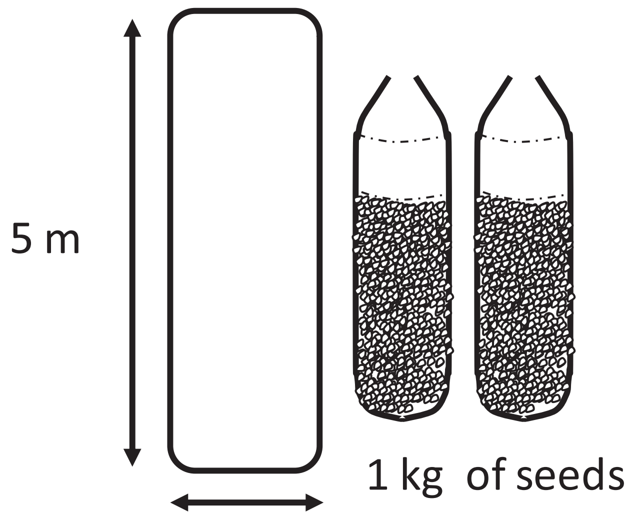


Figure 5-31 Amount of seeds for the nursery bed (5 m^2)

(d) Cover the seeds with fine soil (1 cm of thickness). Dried fine soil is recommended. After covering the seeds, never add water, because aerobic conditions are necessary at this time.
(e) Cover the surface of soil with palm leaves for five days.
(f) Watering is necessary every day for an upland nursery. In the case of a lowland nursery, you should be careful that the seedlings are not submerged from a flood.

5.4.3 Transplanting

It takes more time and cost to transplant than do direct seeding or broad casting. However, transplanting has an advantage over the direct seeding.

> **Uniform growth**.
> **Rice seedlings have a head start over weeds.**
> **Weed control is simpler in straight row transplanting than broad casting**.

However, if you do not transplant properly, the effect of transplanting will be less effective. Attention should be paid to the following when transplanting:

(i) Raising good seedlings in the nursery bed.

The quality of seedlings affects the recovery from damage by transplanting and tiller production (Figure 5-32).

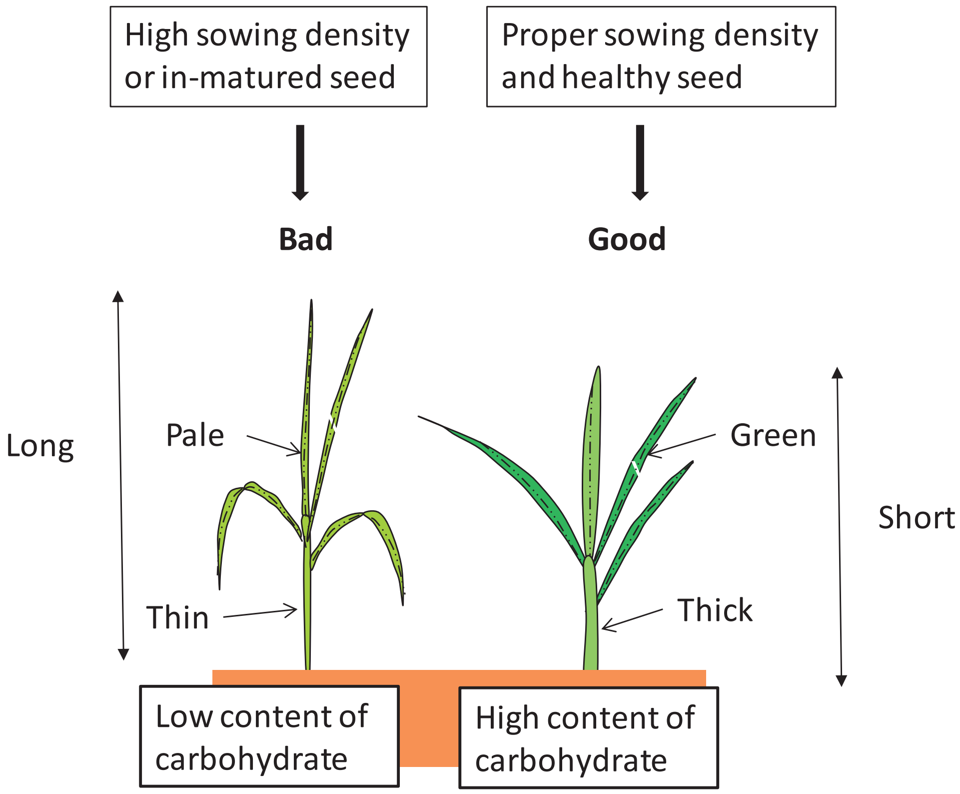


Figure 5-32 Bad seedlings and good seedlings

(ii) Appropriate time of transplanting is from 14 days to 21 days old

The long life of seedlings on nursery bed causes serious reduction in the number of tiller (Figure 5-33).

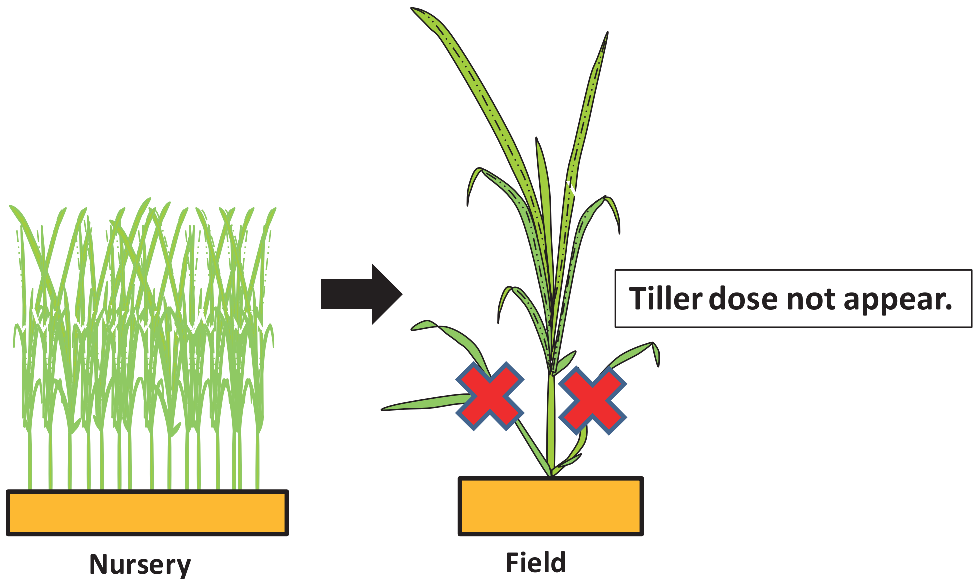


Figure 5-33 Seedlings planted in the nursery bed for long periods

(iii) Careful removal of seedlings from the nursery

Most farmers mostly pull out seedlings from the nursery bed (Figure 5-34). When seedlings are pulled from the nursery bed, particularly in an upland nursery, most of the roots of the seedlings are destroyed, which result in a slow recovery from damage due to transplanting, or sometimes the death of the seedlings.

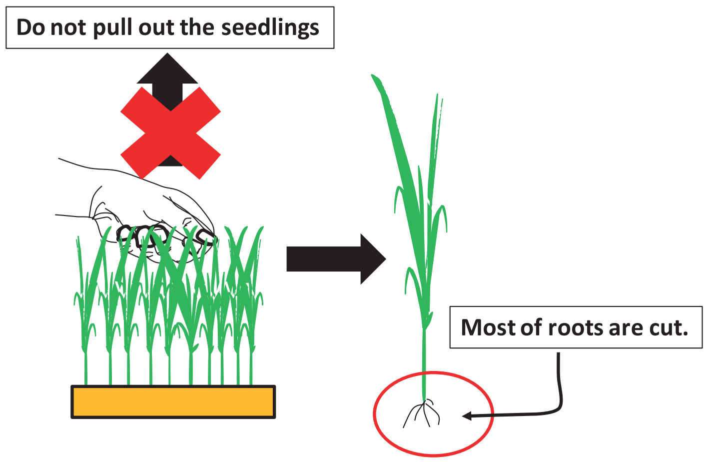


Figure 5-34 Damaged seedlings from pulling out seedlings

(iv) Procedure

(a) Drain the field at one day before transplanting (Figure 5-35).

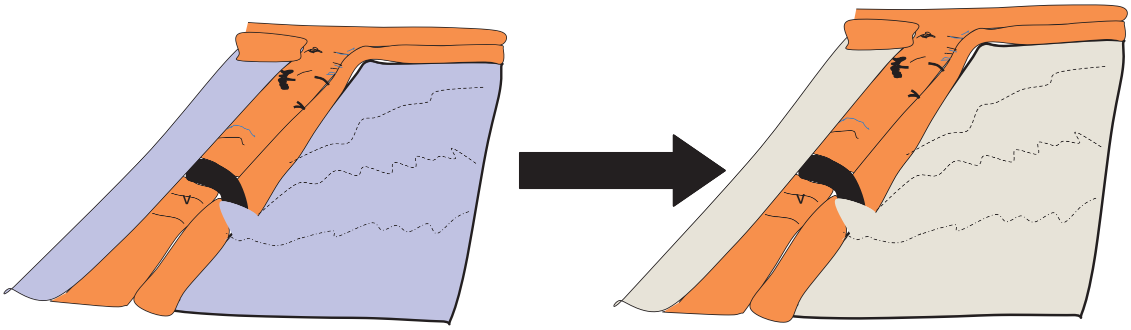


Figure 5-35 Drainage of the field

(b) Remove the seedlings from the upland nursery bed

The roots of seedlings pulled from upland soil are seriously damaged due to the hardness of the soil. Care should therefore be taken when removing seedlings from the nursery.

(c) Water to make the soil soft (Figure 5-36)

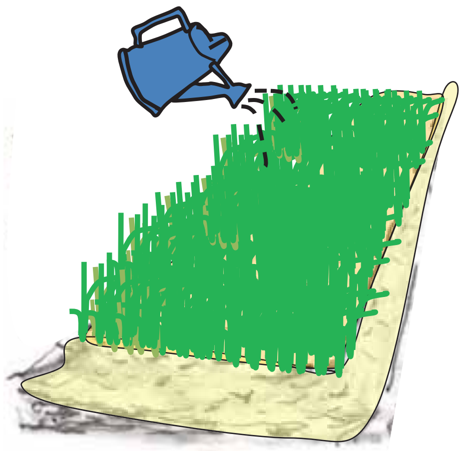


Figure 5-36 Soften the soil by watering

(d) Remove seedlings from the nursery bed using a shovel (Figure 5-37)

Seedlings should never be pulled out. When seedlings are pulled out, most of their roots are destroyed. Seedlings with small roots are often not able to recover from the damage of transplanting due to the unbalanced condition between evaporation and water absorption (Figure 5-38). Also, seedlings with small roots are easily carried away by water because of their weak establishment (Figure 5-38).

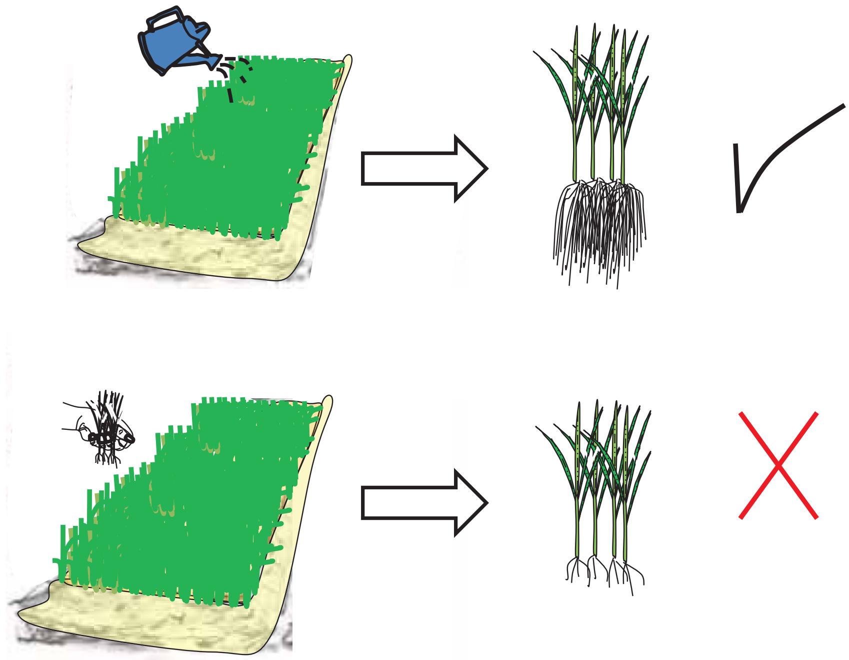


Figure 5-37 Removing seedlings from the nursery

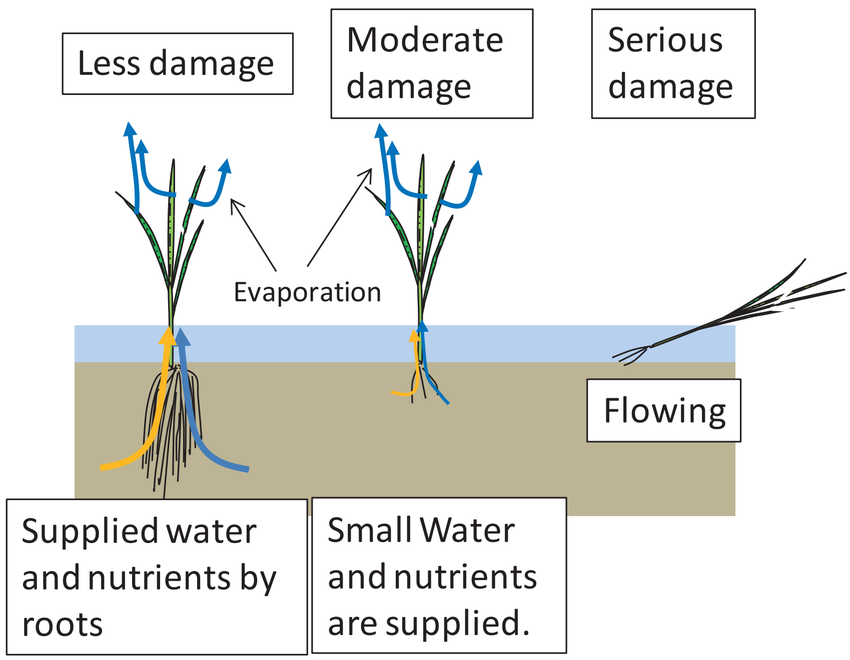


Figure 5-38 Less damaged seedlings and heavy damaged seedlings

If farmers do not exercise enough care in removing seedlings from nursery beds, their whole efforts of selection of seeds and caring for seedlings in the nursery bed will be fruitless.

(e) Keep the roots in water (Figure 5-39)

After removing seedlings from the nursery bed with a shovel, the roots of the seedlings should be kept in water.

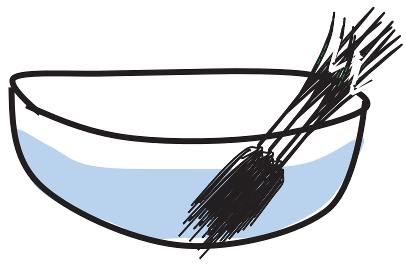


Figure 5-39 Keep root in water

(f) Transplant [space: 20 cm x 20 cm (Figure 5-40) or 30 cm x 10 cm]

(g) Prepare measuring stick at 20 cm length and rope in case of 20 cm x 20 cm

(h) Stretch the rope at 20 cm from the end of field (1st line) in case of 20 cm x 20 cm

(i) Transplant two or three seedlings per hill following the 1st line to leave a space of 20 cm using a stick in case of 20 cm x 20 cm.

(j) Stretch three ropes (2nd, 3rd and 4th line)

(k)Transplant two or three seedlings per hill following the line to leave a space of 20 cm in the same position of the seedling planted in the 1st line in case of 20 cm x20cm.

(l) The depth of transplanting should be 2 cm.

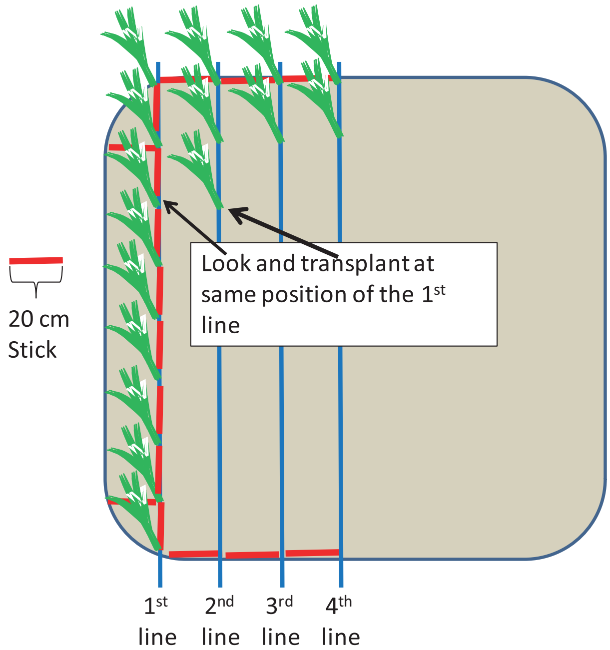


Figure 5-40 Transplanting at 20 cm x 20 cm space

(j) Irrigate the field and close the bund (Figure 5-41)

Most farmers do not irrigate their field after transplanting. If the field is not irrigated after transplanting, the seedlings suffer drought stress because of damage to the roots. Enough water should be supplied onto the field to relieve the burden of the damaged roots at 2 cm of water depth. After irrigation, the bund should be closed.

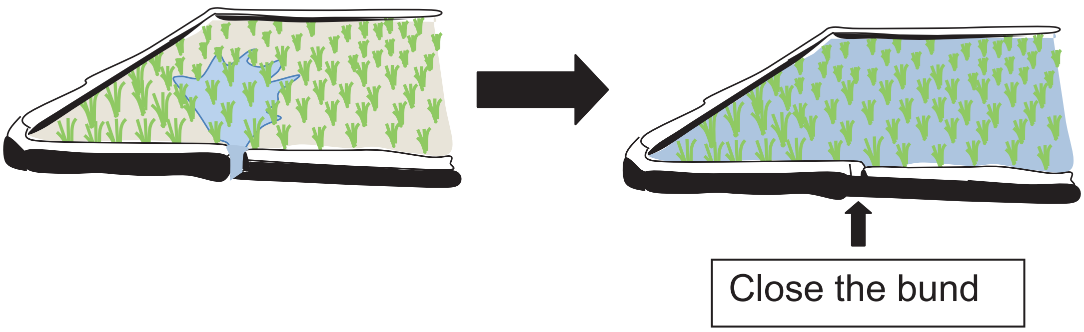


Figure 5-41 Water management after transplanting

(k) Refilling

Seedlings are often carried away by floods. Refilling should be done in such situations. If there is a large vacant space in the field, weeds grow vigorously in the later stage (Figure 5-42).

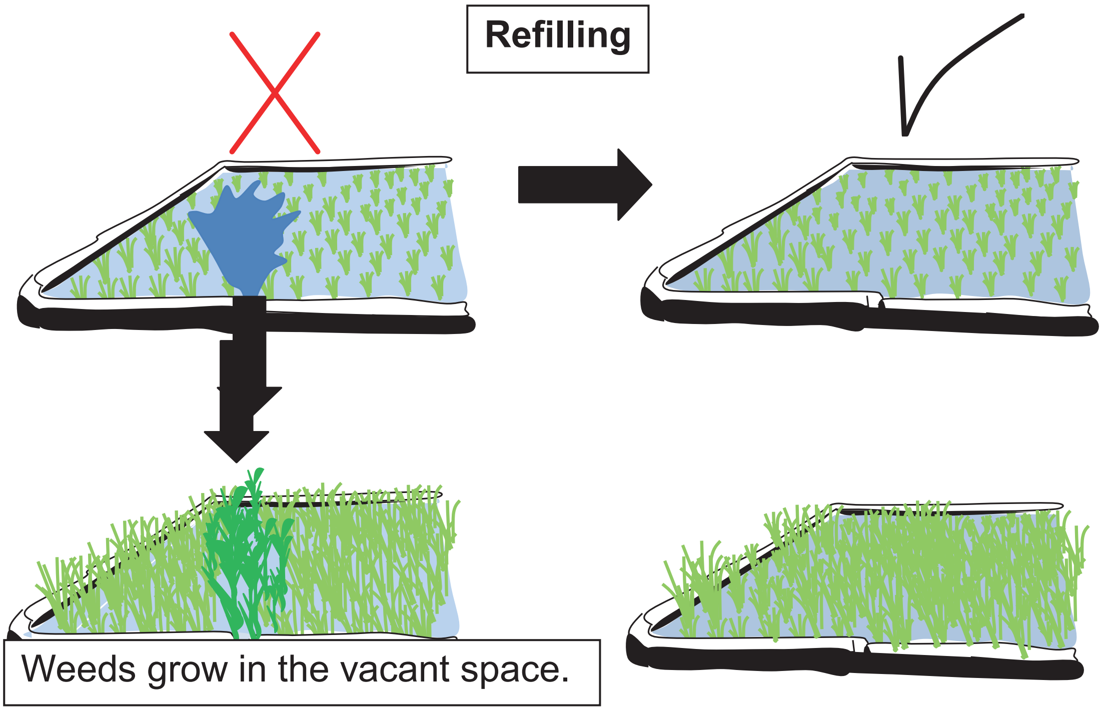


Figure 5-42 Importance of refilling for weed management

5.4.4 Recovery phase from damage due to transplanting

After transplanting new roots grow (Figure 5-43). These new roots contribute to the growth of rice. The recovery phase is the establishment of the new roots and adaptation to new environment. After the recovery phase (around 10 days), the tillers appear. In general, fertilizer should be applied to enhance the growth of new roots at this time. However, the growth of weeds is vigorous in tropical environment.

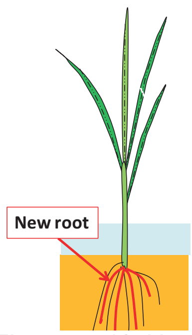


Figure 5-43 New roots growing

(i) Importance of the recovery phase from damage due to transplanting

If the recovery from damage due to transplanting is slow, fewer tillers form, which result in a lower yield. We should therefore pay attention to this phase.

(ii) Procedure in the recovery phase

(a) Irrigate the field to 2 cm of water depth
(b) Close the bund after irrigation (Figure 5-44).
(c) Keep water at a 2 cm depth for five to seven days.

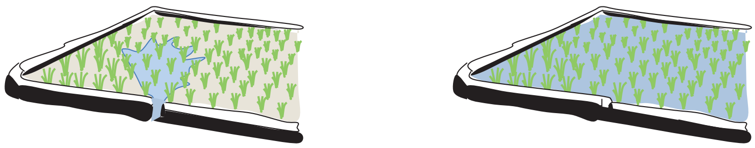


Figure 5-44 Water management after transplanting

(d) Five to seven days after transplanting, weeding should be done. Weeding is done by application of a selective herbicide or manual weeding using simple implements, such as.

5.4.5 Weeding

5.4.5.1 Applying a selective herbicide

The characteristics of the herbicide must be understood (Figure 5-45). The herbicide action can be divided into two mechanisms. One is a contact herbicide, which destroys the cells of the leaves by penetrating the leaves. Another is a systematic herbicide, which kills the whole weed plant through absorption from the roots and penetration of the leaves.

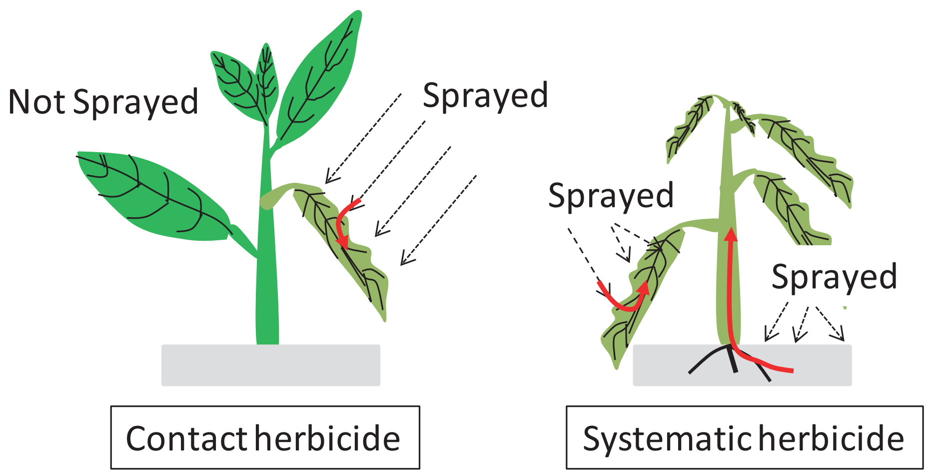


Figure 5-45 Characteristics of the herbicide

It is recommended to use the systematic herbicide.

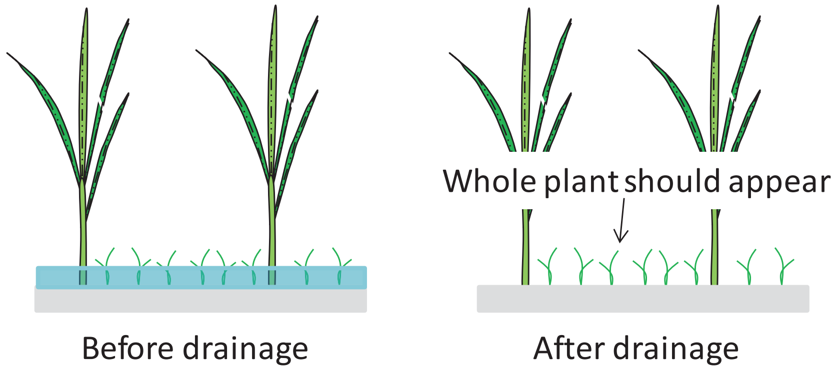


Figure 5-46 The field is drained before application of the herbicide

(i) Procedure

(a) Apply the herbicide to the whole plant (drain water from the field for the appearance of the whole weed). (Figure 5-46)
(b) Selective herbicide is effective for only young weeds. (The herbicide should be applied within 10 days after transplanting.)
(c) Never apply the herbicide during or before rain. (The chemical will be washed away.)
(d) Apply the herbicide at the appropriate concentration. (Even rice can be damaged by high concentration of the herbicide. The explanatory pamphlet should be read.)
(e) Before or after applying the herbicide, the bund should be closed to prevent the water from draining from the field. The water, including the herbicide, goes into the river when the bund is open after irrigation.
(f) Farmers should protect themselves from herbicide with wearing long pants, long shirts, goggles, and masks.

5.4.5.2 Manual weeding with simple implements (weeder or hoe)

When you use the weeder (Figure 5-47), the field should be irrigated and the soil should be softened. The equipment is effective for young weeds. You cannot use it on dry soil because the soil is hard.

Weeding two times is recommended with the first seven days after transplanting, while the second should be seven days after the first weeding.

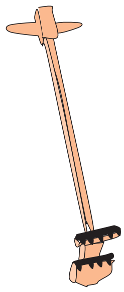


Figure 5-47
Weeder

5.4.6 Application of fertilizer

Within two weeks after transplanting, the fertilizer should be applied. In West Africa, the soil fertility is low as mentioned before. The application of fertilizer is necessary for tiller production. However, it is not beneficial to apply excessive amount of fertilizer. The application of excessive amounts of fertilizer will cause less of a benefit. The total amount of fertilizer is from 30 kg to 90 kg per hectare for nitrogen, and 30 kg to 60 kg per hectare for phosphate and potassium.

(i) Procedure

(a) Prepare fertilizer

NPK is used as the based application.

Table5-5 Conversion table

N,P,K (kg/ha)	$N_{15}P_{15}K_{15}$ (kg/ha)	$N_{15}P_{15}K_{15}$ 50kg bag
30	200	4 bags
60	400	8 bags

The 50 kg per bag should be divided into 10 bags (5 kg per bag), in order to equally apply the fertilizer onto the field (Figure 5-48). Five kilograms of $N_{15}P_{15}K_{15}$ is 60 kg of NPK per 0.0125 ha (around 11 to 13 steps × 11 to 13 steps) (Figure 5-49).

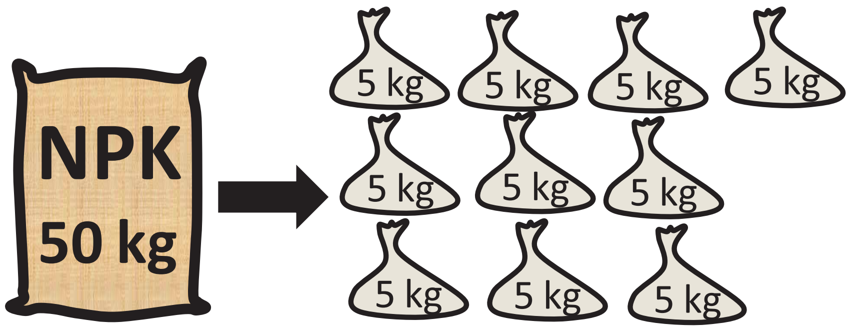


Figure 5-48 NPK (50 kg /bag) is divided into 10 bags (5 kg / bag)

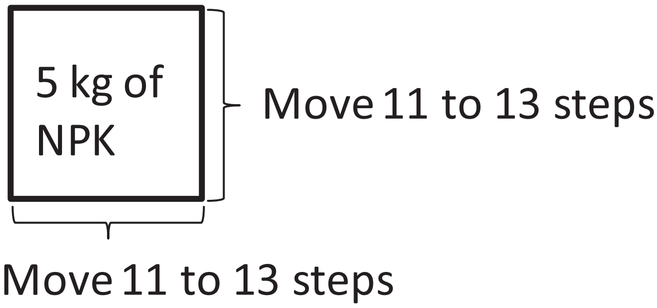


Figure 5-49 Area of application of 5 kg of NPK

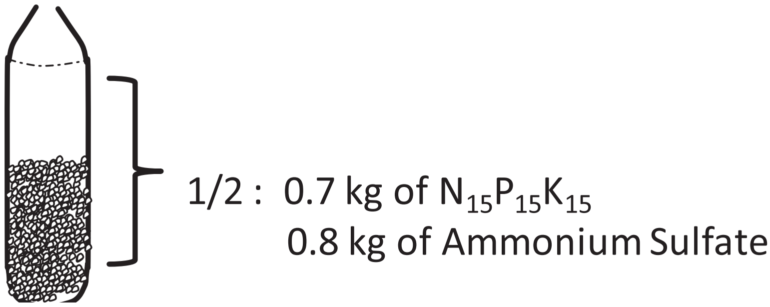


Figure 5-50 Amount of fertilizer of half volume of 1.5 L plastic bottle

Also you can estimate the weight of fertilizer from the volume of a 1.5 L plastic bottle. The 1/2 volume of a 1.5 L plastic bottle is around 0.7 kg of $N_{15}P_{15}K_{15}$ and 0.8 kg of ammonium Sulfate. (Figure 5-50).

(b) Drain the field

(c) Apply fertilizer (Figure 5-51)

Farmers mostly apply fertilizer from the bund. This kind of work causes the application of unequal amounts of fertilizer. We often observe vigorously growing rice on the edge of the bund while pale rice grows in the center of the field.

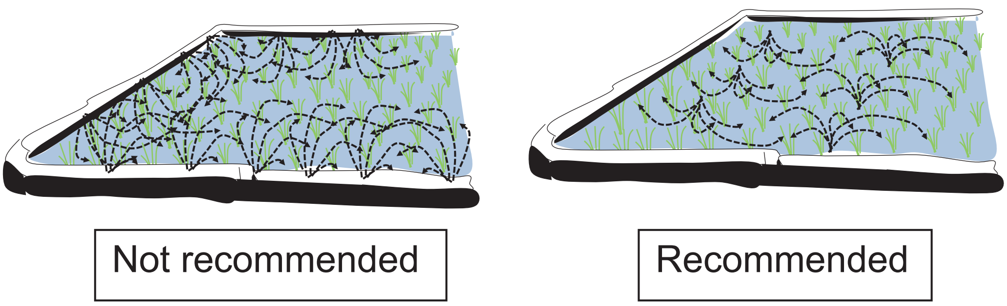


Figure 5-51 Application of equal amounts of fertilizer

(d) Irrigate the field and close the bund.

After application of fertilizer, water should be supplied and kept in the field. Bund should be closed after applying fertilizer. However, if the bund is opened, the dissolved fertilizer drains from the field. After application of nitrogen fertilizer, ammonia is changed into nitric acid by the activity of bacteria in aerobic conditions (nitrification) (Figure 5-52). Ammonia (NH_4^+) can be fixed in the soil, but nitrites (NO_2^-) and nitrates (NO_3^-) cannot be fixed in the soil and drains away from the topsoil with the seepage of water. Most farmers ignore water management after transplanting; therefore, the importance of water management after application of fertilizer should be explained to farmers.

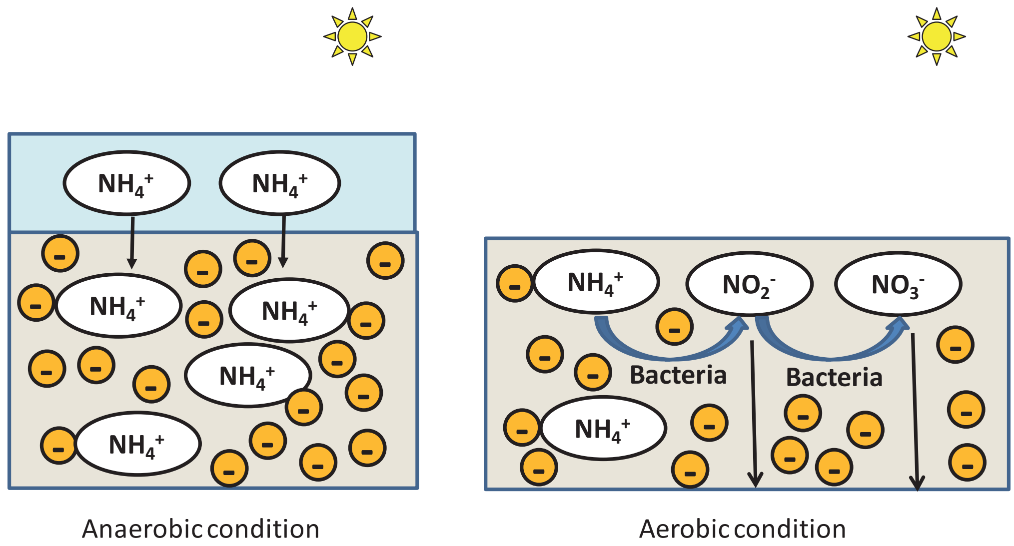


Figure 5-52 Loss of nitrogen through nitrification

Footnote:

The amount of fertilizer depends on the soil fertility or the technical level and the economic condition of farmers. However, it is difficult to determine soil fertility in a farmer's field, and it is strongly advised to take into account the amount of applied fertilizer and rice growing conditions of the previous season.

5.4.7 Pest and disease

After transplanting, the seedlings are damaged by diseases and insects. It is better to protect them early before serious damage.
The main diseases and damage caused by insects after transplanting are as follows.

(a) Bacterial blight
(b) Brown spot
(c) Stem borer

After the application of fertilizer, it is better to apply fungicide and insecticide.


Figure 5-53 Bacterial bright


Figure 5-54 Stem borer

5.4.8 Tillering

After recovering from the damage of transplanting, the tiller appears. The tiller has a very close correlation to the yield. The number of grain is composed by number of hill per unit area, number of panicle per unit area, and number of grain per panicle. Therefore, farmers should get some degree of the number of tillers for a high yield in this stage. To increase the number of tillers, management of the effective use of fertilizer and water is very important.

(i) How many tillers per hill are necessary to produce more than four tons per hectare? (Sikamo and jasmine)

Figure 5-55 shows a diagram of tiller production.

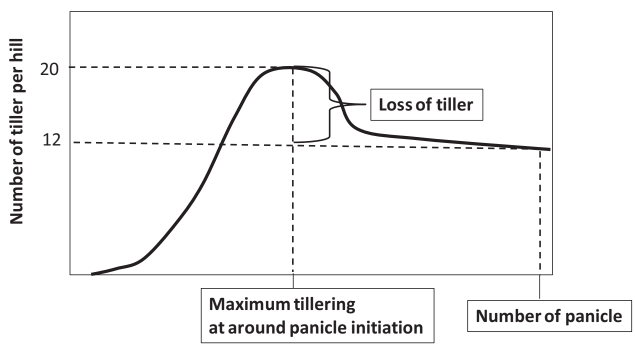


Figure 5-55 Diagram of tiller production

The number of tiller reaches its optimum at panicle initiation. After that, some tillers die. Around 60% of tillers will survive and have panicles (from the results of the JIRCAS project sites in 2010). For sikamo or jasmine, it is necessary to have at least 17 tillers per hill to get more than four tons per ha from the following formula.

0.4 kg / m^2 = 25 (number of hills per square meter) $\times$ **A** (number of tillers/hill) $\times$ 0.6 (ratio of panicles) $\times$ 100 (number of grains/panicle) $\times$ 0.8 (ratio of mature grains) $\times$ 0.028 g (weight of grain) $\times$ 0.7 (concerning 30% loss post-harvest)

A = 17

(ii) Cultivation to get optimum number of tillers

(ii)-1 Water control

During the tillering, water should be shallow (2 cm of water depth). Drainage sometimes enhances tiller production, due to the increase in root activity under aerobic conditions. However, the repetition of submergence and drainage causes denitrification (Figure 5-56). Therefore, skill and experience is necessary to increase the number of tillers using both the repletion of submergence and drainage. It is not risky to keep 2 or 3 cm of water in the field during the tillering stage. Very deep water (above 20 cm of water depth) inhibits tiller production.

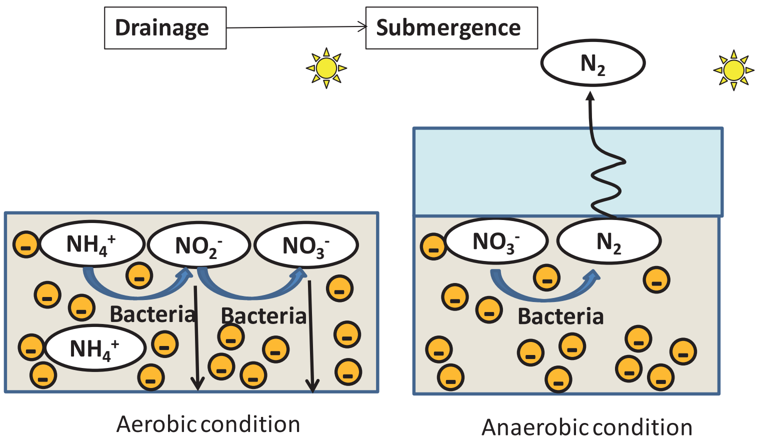


Figure 5-56 Denitrification

(ii)-2 Weed control

When weeds are controlled properly after transplanting, the problem of weeds may not be serious during the tillering. However, due to unequal leveling, some portions of the field are not submerged. Weeds surpass the growth of the rice in such areas, and manual weeding should be done in those places.

(ii)-3 Diseases control

In general, rice can withstand diseases during the tillering. However, rice growing in low soil fertility, such as sandy soil, is easily infected with brown spots or bacterial blight. It is recommended to apply fungicide in such places to prevent the spread of diseases.

(ii)-4 Canopy structure (Figure 5-57)

Even though tillers contribute to higher yields, excessive tillering decreases yields. Too vigorous growth during tillering will cause serious problems like lodging or diseases in the ripening phase. If you can see the water surface in the field when you stand on the bund, the canopy structure is ideal.

Most farmers tend to be satisfied with a high density canopy structure during tillering, but actually, they may be disappointed by lodging and serious disease during the ripening stage. Lodging and serious disease during the ripening stage make all the effort and work come to nothing. Therefore, much attention should be given to the canopy structure during the tillering.

- ✓ Excessive amounts of fertilizer or high density spaces in transplanting cause a high density canopy structure.
- ✓ Application of fertilizer around 30 days before heading is not recommended (*see chapter 5.5)*.

Dark green leaves or dropping leaves are symptoms of excessive fertilizer application. When excessive fertilizer is applied, and any of the above symptoms are observed, the field should be dried to inhibit the absorption of nitrogen.

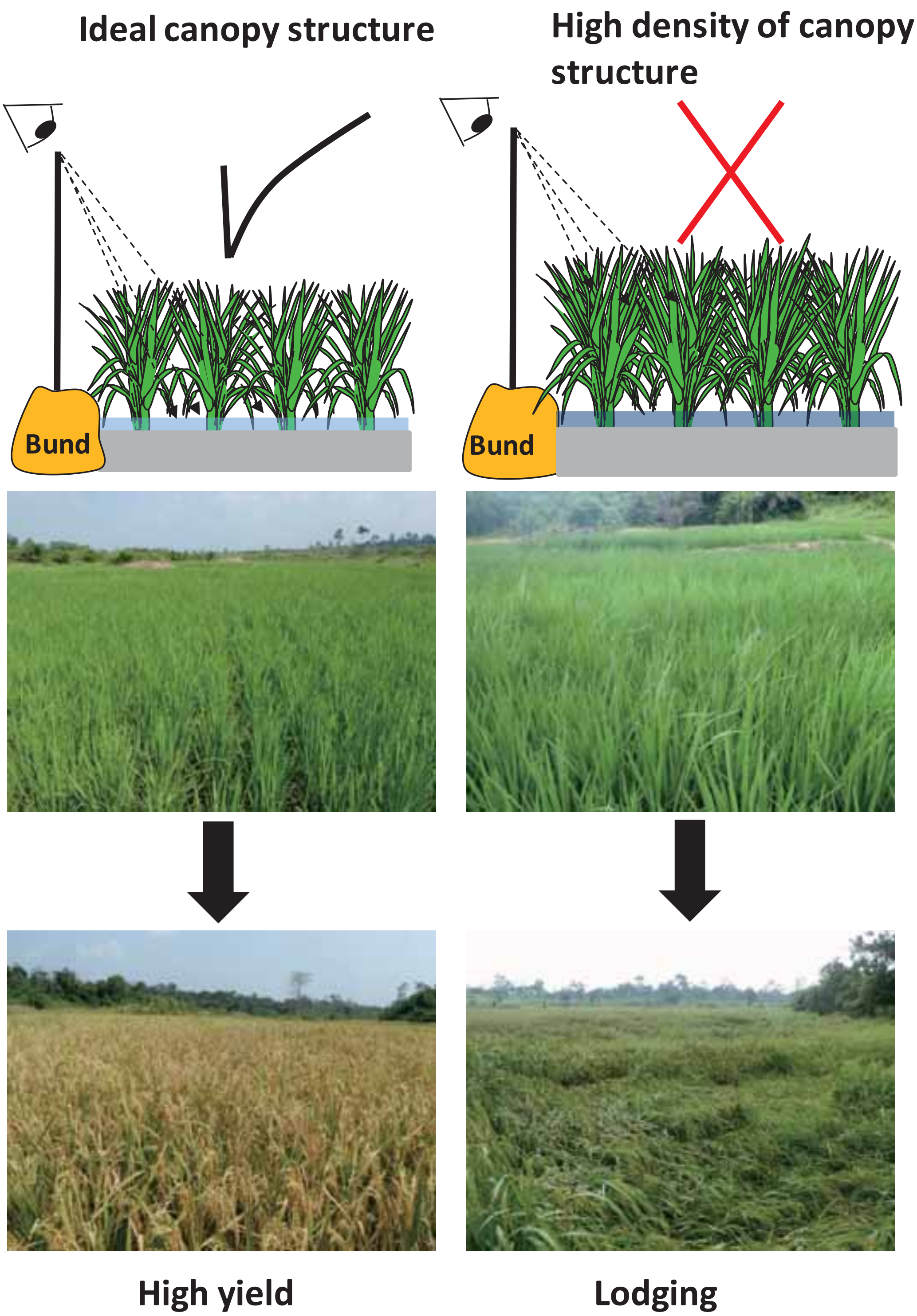


Figure 5-57 Effect of canopy structure on yield

5.5 Reproductive stage

The reproductive stage is from panicle initiation to flowering. Rice is the most sensitive to environmental stress in this stage. If rice does not grow under good conditions, yield may be affected. The following figure shows the important parts of the rice in the ripening stage (Figure 5-58). In the reproductive stage, the organs that relate to yield directly are differentiated and developed.

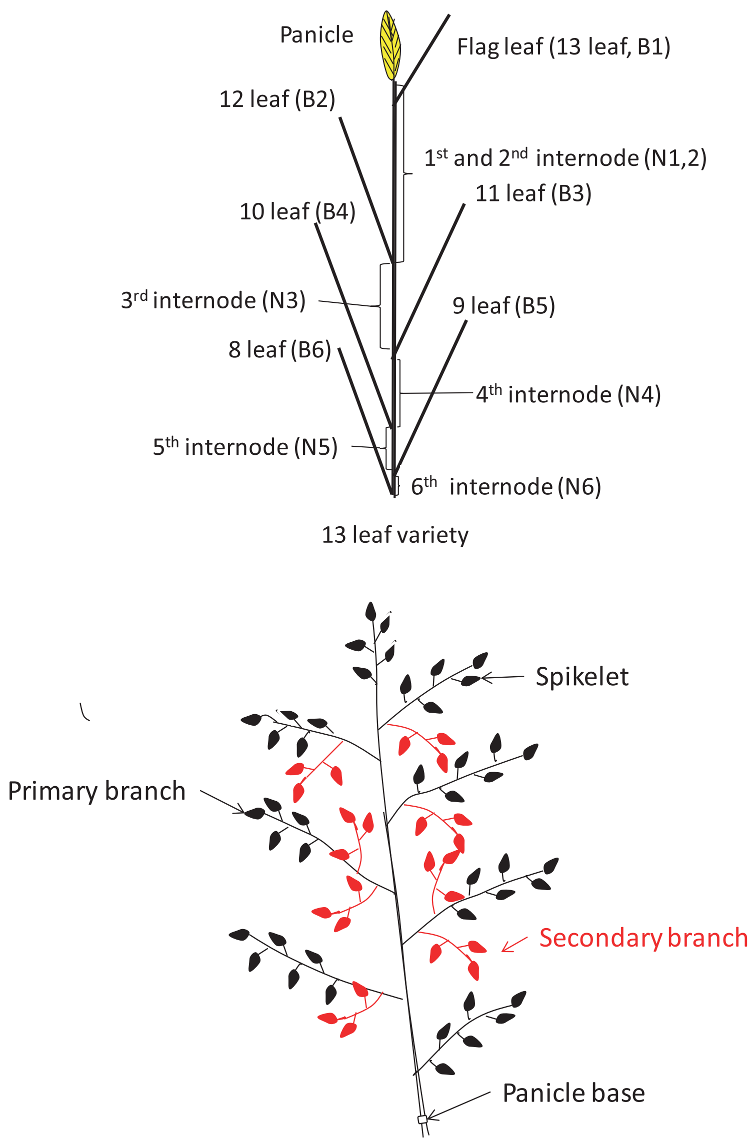


Figure 5-58 Structure of rice (up) and panicle (down) in the ripening stage

The figure 5-59 is a diagram of the development of the organs related to the ripening stage. The metabolism of rice increases from the differentiation of the panicle to flowering. Therefore, rice needs a lot of water. The water shortage during this period decreases the number of grain and matured grain.
. The attention to the management of water is very necessary.

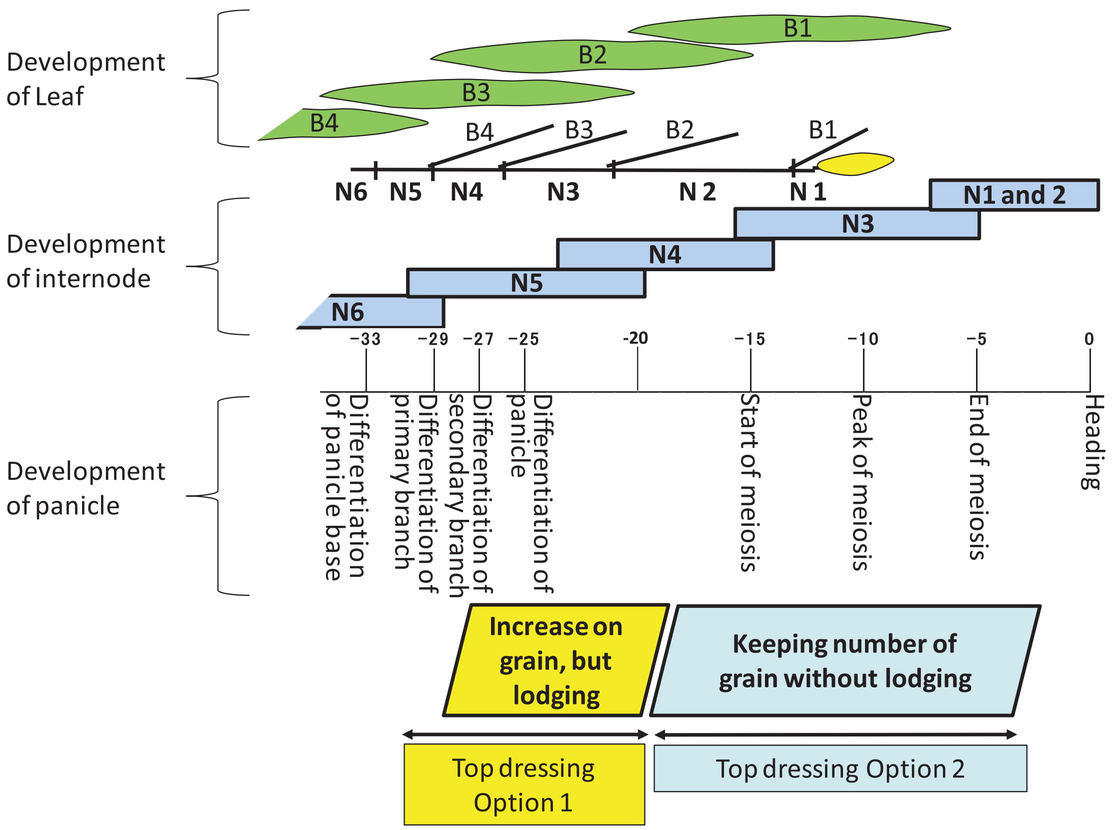


Figure 5-59 Diagram of development of the panicle

(i) **Water management** (in case of 120 days variety)

Around 30 days before heading (around 60 days after sowing), the field should be irrigated from 5 to 10 cm of water depth. The bund should be closed after irrigation and water kept in the field. The field should remain flooded until the end of flowering.

(ii) **Application of fertilizer**

The color of the leaves turns light green during the maximum tillering, because of the shortage of nutrients in the soil. Generally, additional fertilizer (ammonium sulfate or urea) is applied at this stage. However, lodging is possible by the application of fertilizer (Top dressing option 1 in Figure 5-59).

(iii) Mechanism of lodging

Fifth and fourth internode elongation cause lodging (Figure 5-60). Big upper leaves (B1, B2, and B3 in the figure) cause lodging. To prevent lodging, internode elongation and development of the upper leaves should be limited. The ability for elongation depends on the nutrient conditions inside rice and the climatic condition during the period of internodes developing. If you apply fertilizer just before the development of the internodes and leaves, elongation of the internodes and enlargement of the leaves are enhanced.

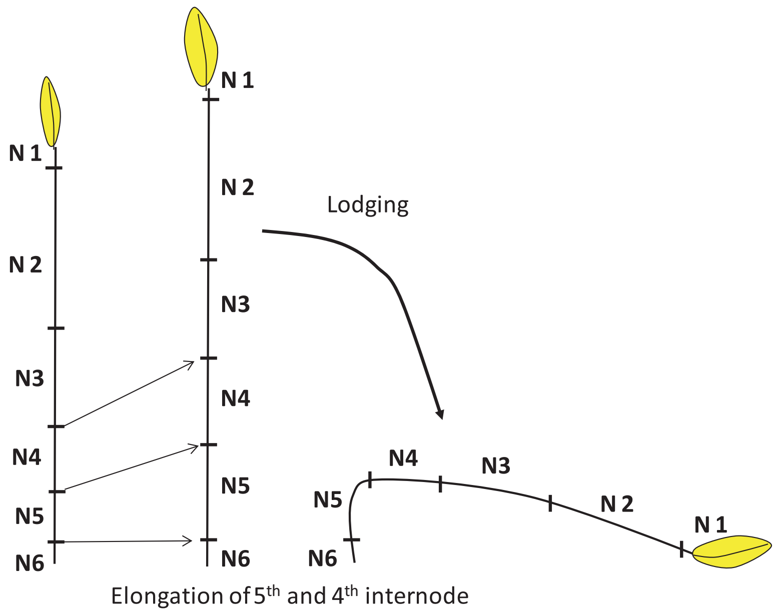


Figure 5-60 Elongation of 4th and 5th internodes cause the lodging

(iv) The nutrient condition and the number of grain.

The number of grain is an important factor in yield. Therefore, additional fertilizer is applied at this stage. At differentiation of the branch, the number of branches is increased by fertilizer. At differentiation of the panicle, the number of grain is increased by fertilizer. However, the increases in the branches and grain are retrograded around 20 days before heading. The degree of keeping number of grain depends on the nutrient condition of rice and the climate condition during this period. If rice has sufficient nutrients during this period, the number of grain is kept.

You should apply fertilizer with concern for the above mechanism. If you want to increase the number of grain, you should apply fertilizer (Top dressing option 1 in the figure 5-59) from 30 days to 20 days before heading. However, the application of fertilizer during this period enhances the elongation of the fourth and fifth internodes and the development of the upper leaves, which result in lodging (Figure 5-59, 5-60).

On the other hand, the application of fertilizer after the end of the elongation of the fourth and fifth internodes (Top dressing option 2 in the figure 5-59) does not affect elongation so much within 20 days before heading, and the fertilizer keeps the number of grain (Figure 5-61).

Concerning the risk of lodging, the Top dressing option 2 is recommended. However, if the leaves turn very light green in the reproductive stage, it is better to apply fertilizer around 30 days before heading to increase the number of grain. In this case, the rice may not lodge from the application of fertilizer, because of poor growth.

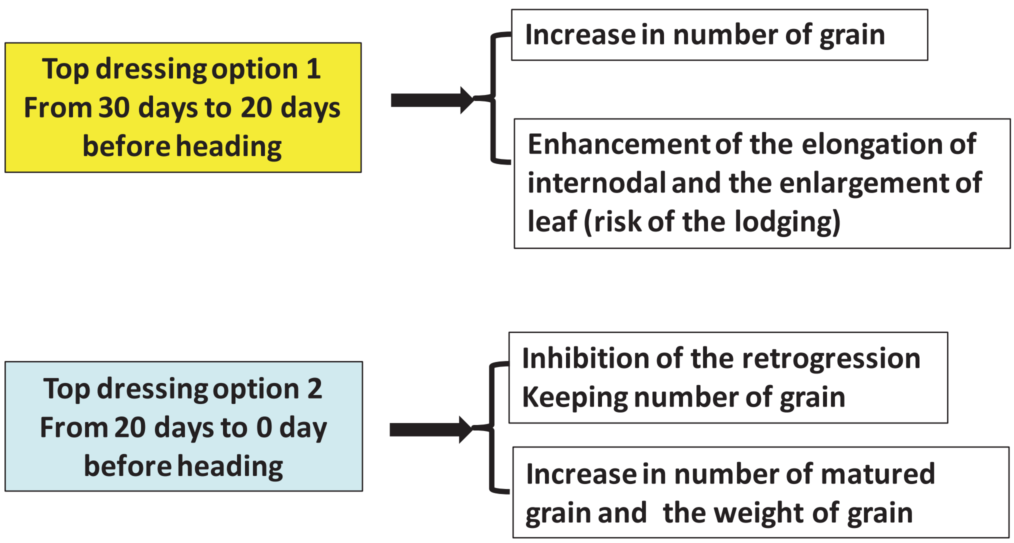


Figure 5-61 Timing of the application of fertilizer

(v) Procedure (in case of 120 days variety)

(a) Irrigate the field to 5 cm to 10 cm of water depth at 30 days before heading (60 days after sowing),
(b) In case of poor growth: Apply ammonium sulfate or urea 30 days before heading (from 10 to 30 kg (N) / ha) (Figure 5-62).
(c) In the case of normal growth: Ammonium sulfate or urea from 20 to 0 days before heading (from 10 to 30 kg (N) / ha) (Figure 5-62).
(d) Apply fungicide from five days to zero days of heading to prevent brown spot or blast disease in the ripening stage.

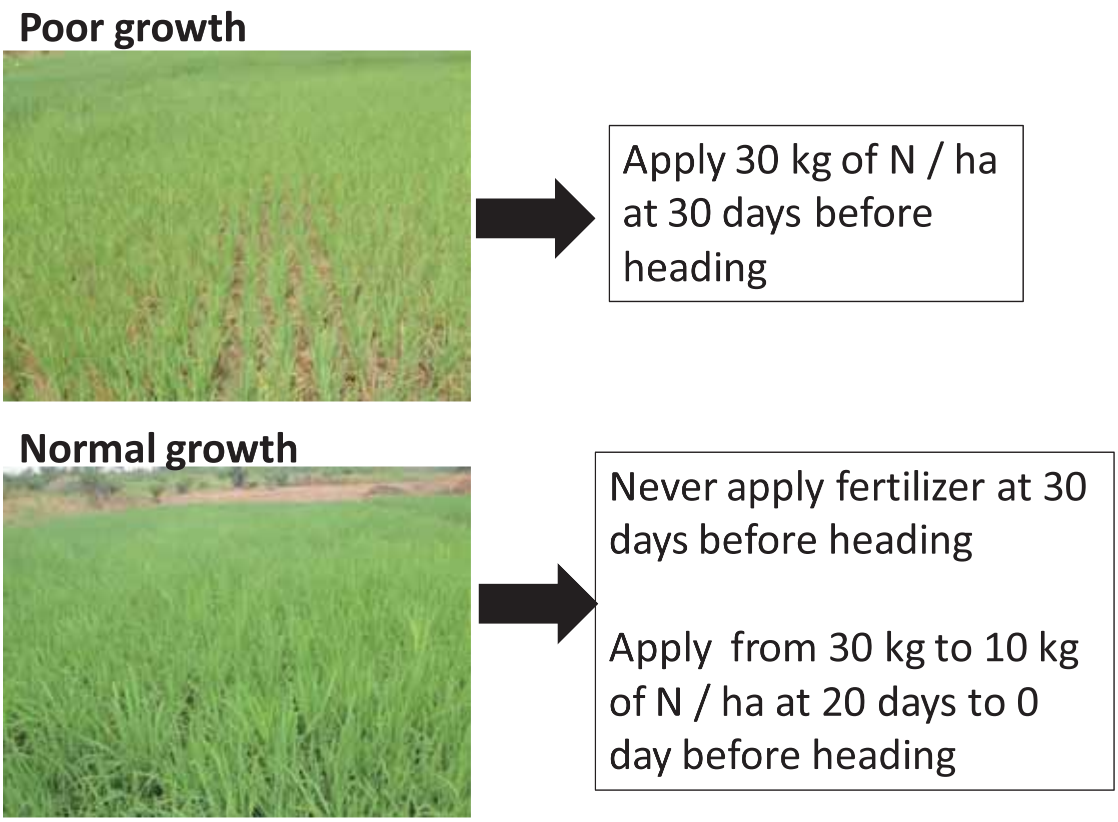


Figure 5-62 Timing of the application of fertilizer for poor and normal growth

(Footnote)

(i) Actual practice in Jasmine and Sikamo variety

Heading date of Jasmine and Sikamo are 94 days and 103 days after sowing in farmer's field respectively. However the condition of vegetative stage affects the date of heading. The shortage of water or nutrient during vegetative stage causes the delay of date of heading (Figure 5-63, 5-64). Therefore it is difficult to predict the date of heading and timing of application of fertilizer for farmer. Figure 5-66 showed the diagram of ratio of heading after sowing of Jasmine and Sikamo. Both varieties indicate that it takes around 2 weeks from begging of heading to 80 % of heading, which means that the date of heading of a few rice becomes a mark of application of fertilizer (Figure 5-66).

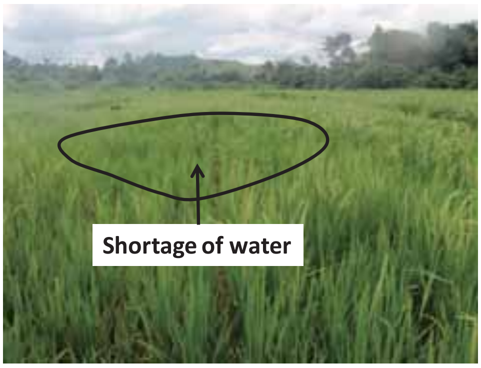


Figure 5-63 Shortage of water causes delay of heading

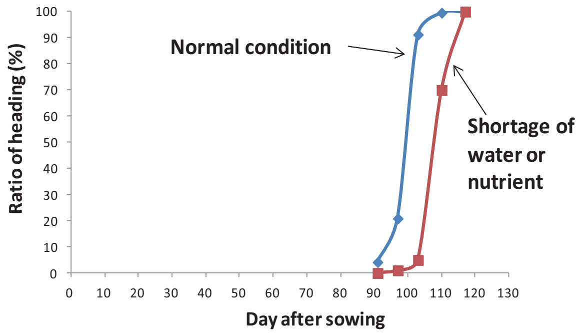


Figure 5-64 Shortage of water causes around 10 days delay of heading

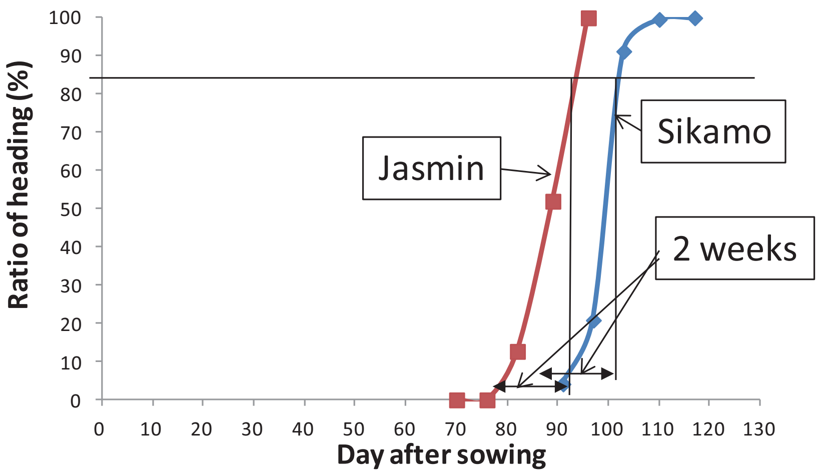


Figure5-65 Diagram of ratio of heading of Jasmine and Sikamo

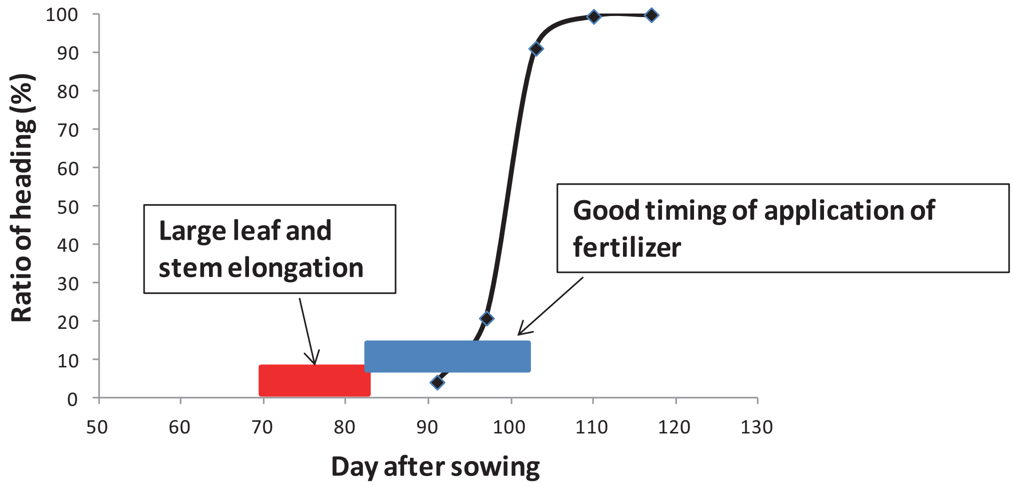


Figure 5-66 The date of heading of a few rice plants becomes mark of timing of application of fertilizer

(ii) Equivalent of fertilizer

(a) Ammonium sulfate contains 21% nitrogen. In the case of 30 kg of nitrogen, 30 kg of nitrogen per hectare is 143 kg of ammonium sulfate per hectare (30 kg ÷ 0.21).

(b) Urea contains 45% nitrogen. In the case of 30 kg of nitrogen, 30 kg of nitrogen per hector is 67 kg of urea per hectare (30 kg ÷ 0.45).

5.6 Ripening stage

Ripening stage is from flowering to harvesting. During the vegetative and the reproductive stage, the number and size of grains (sink) are produced, and then inside, the grains are filled with carbohydrates (source) during the ripening stage. As a simple example, the vegetative and reproductive stages are like making the bowl, and the ripening stage is the filling of the prepared bowl with soup (Figure 5-67). To achieve high production, the bowl should be large, and the bowl should be filled with enough soup.

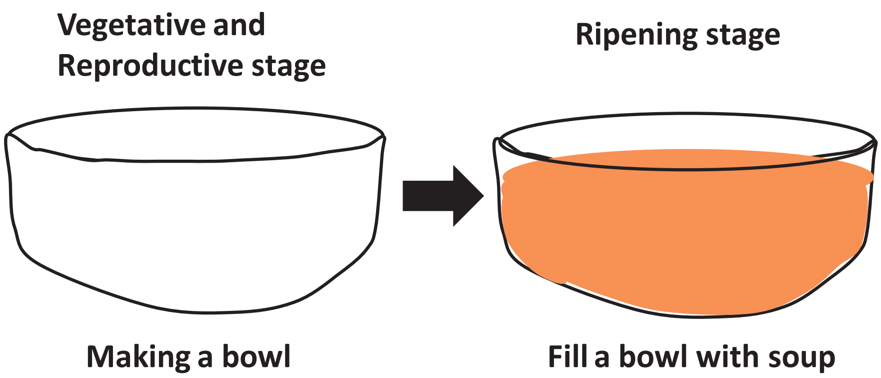


Figure 5-67 Simple example of the relationship between sink and source

Concern should be on how to fill the grain with carbohydrate during the ripening stage. The source of carbohydrate in the grain comes from the stored carbohydrate in the leaf and stem, and photosynthetic activity during the ripening stage (Figure 5-68). Therefore, photosynthesis is very important in filling the grain during the ripening stage. The main carbohydrate for the grain is produced in the upper leaves (flag leaf, 2nd and 3rd youngest leaves). On the other hand, the main carbohydrate for the roots is produced in the lower leaves. The nutrient from the roots is necessary to maintain the high capacity of photosynthesis in the upper leaves.

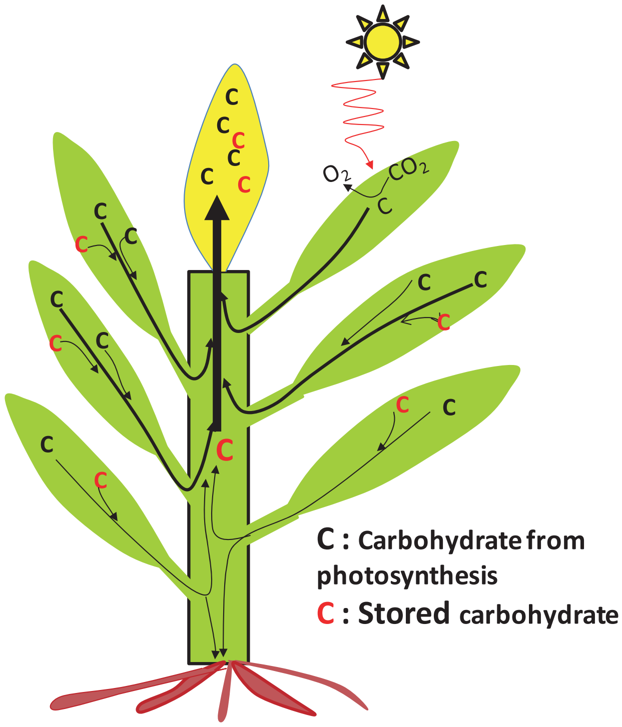


Figure 5-68 Sources of carbohydrate for the grain

5.6.1 Photosynthesis during the ripening stage.

The important factors are solar energy and water for photosynthesis (*See 5.1*).

In the ripening stage, rice has many leaves that overlap each other. The concern should be the canopy structure for the high photosynthetic activity. At the ripening stage, the canopy structure is already established. Therefore, the management of the canopy structure is important as mentioned in *6-2*. Figure 5-69 shows the ideal canopy structure in Japan. (The yield is around 7 tons per ha.)

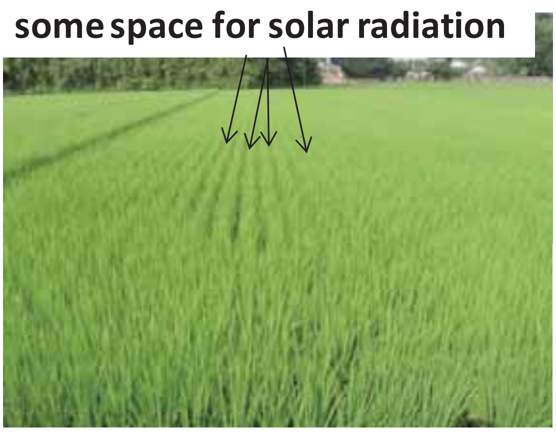


Figure 5-69 Ideal canopy structure in the heading stage.
Photo in Tsukuba, Japan

5.6.2 Root activity

After flowering, the aging of roots is rapid. Root activity, in particular, drops to very low levels in a field with poor drainage, because of the shortage of oxygen. To maintain root activity, the soil should contain enough oxygen. The water depth should be 1 cm for 20 days (the grain is filled with carbohydrate 20 days after flowering).

5.6.3 Protection from birds

The most serious problem is damage by birds at this stage. Particularly, the damage is more serious in the dry season than in the wet season because many birds move to the south from the north in the dry season to search for food.

The birds come at dawn and disappear at sunset. Therefore, bird scaring should be done from sunrise to sunset. Nets are recommended to protect the crop from birds.

5.6.4 Protection from disease

During this stage, rice is damaged by many diseases.

(a) Brown spot (Figure 5-70)

This disease appears on rice growing in the poor nutrient conditions (sandy and gravel soil). Particularly, the shortage of potassium enhances the disease.

(Protection)

The fertilizer N.P.K. should be applied by split. If a large amount of fertilizer is applied at once, most of the nutrient will be leached away from the topsoil, because the sandy or gravel soil cannot retain the nutrient (*See 5.1*). The fungicide is applied five to zero days before heading.

(b) Blast (Figure 5-71)

This disease appears on rice containing excessive nitrogen. When excessive amount of fertilizer is applied, rice has large leaves, and the canopy structure becomes high density. In such a place, this disease is inclined to appear.

(Protection)

The seeds should be treated with fungicide before pre-germination treatment. Appropriate amount of fertilizer should be applied. The fungicide is applied from zero to five days before heading.

(c) Kernel smut (Figure 5-72) and False smut (Figure 5-73)

High humidity causes these diseases. When the canopy structure is vey dense, the wind cannot penetrate, resulting in high humidity.

(Protection)

Appropriate amount of fertilizer should be applied to maintain the ideal canopy structure. A fungicide is applied from zero to five days before heading. When many grains are covered by black powder, the fungicide is applied.

Figure 5-70 Brown spot (right and left)


Figure 5-71 Blast (right and left) Source: Dr. E Moses (CRI)

Figure 5-72 Kernel smut

Figure 5-73 False smut
Source: Dr. E Moses (CRI)

(Footnote)
In the case of sandy soil or gravel soil, it is better to apply N.P.K. fertilizer (around from 5 kg to 10 kg per ha) and fungicide just after flowering to prevent brown spot disease.

5.7 Harvest

Harvesting timing is between 30 to 42 days after flowering in the rainy season and between 28 to 34 days after flowering in the dry season, when approximately 80% of the straw and the grain on the panicle turn yellow. Early harvesting results in an increase in the number of immature grain. Late harvesting increases the loss of grain due to over drying. Over dried grain is poor quality and has greater fragility.

The appropriate harvesting time is indicated by 20%–25% moisture.

The field should be drained at from 1 to 2 weeks before harvesting. The harvested rice should be carried to a drying place immediately (Figure 5-74).

Figure 5-74 Rice Harvesting

5.8 Post Harvest

5.8.1 Threshing

In this process, the grain is separated from the panicle. The following methods for threshing are commonly employed:

(i) Manual threshing

(a) Beating

The panicle is knocked against a wooden frame, empty drum, log, or other objects to dislodge the grain.

Figure 5-75 Beating

(b) Striking rice by the stick

Spread the harvested rice on the strong plastic sheet, and strike it by the stick.

(ii) Pedal thresher and threshing machine (Figure 5-76)

This method, whereby a machine operates by rotating a wired drum, results in fewer crushed grains and less damage than that created by beating. In addition, fewer human operators are required. The risk of serious injury is greater, however, and operators should exercise care to prevent arms from becoming tangled in the machinery. Straw roots need to be tightly grasped to enable the panicle to move to the drum. Therefore, rice should be cut with the longest possible stem intact for this method because rice with short stems are difficult to thresh. Threshing should be performed on a plastic sheet to decrease the loss of seeds and increase the rice quality by preventing incorporation of stones or soil.

Figure 5-76 Threshing machine

5.8.2 Winnowing

In this method, grain, immature grain, and dust are separated. The grain is placed in a sieve agitated by the wind and is slowly separated from undesirable particles. This process should be accomplished on a plastic sheet to prevent incorporation of ground soil and dust. Large particles such as stones should be manually removed prior to winnowing because they interfere with the process.

5.8.3 Drying

Harvested grain has a moisture content of 20%–25%, which needs to be reduced to approximately 14% for milling and storage (Table 5-6). Drying is a crucial procedure. Insufficiently dried grain is more likely to break during the milling process and is susceptible to diseases and pests. Over drying also creates a high breakage rate during milling. Proper drying of grain by sunlight is a slow process.

In the case of drying by sunlight, drying should begin within 12 hours to 24 hours after harvesting. In general, two methods of sun drying are used. In the first method, the harvested rice is placed in loose bundles and left to dry in the field for several days, the length of drying time depends on the weather, practices in the area, and the availability of a thresher. In the second method, immediately after threshing, the wet grains are spread on a floor or a plastic sheet 2–4 cm thick and dried for 2–3 days. Any stones or dust should be removed from the drying surface beforehand. Because rapid drying creates higher breakage rates in milling, the grain should be stirred in 30-minute intervals to ensure uniform drying.

Table 5-6 Suitable moisture content of grain for various processes

Process	Moisture percentage in grain	Cautions
Harvesting	20–25	Over drying increases the probability of dropped panicles.
Mechanical threshing	20–25	
Hand threshing	< 20	
Milling	14	Inappropriate moisture content results in breakages.
Storage	13–14	Store in the form of unhusked rice for several months to 1 year.
	< 9	Store in the form of grain as food for more than 1 year.

5.8.4 Storage

Grain and milled grain should be stored in separate bags in cool, dark places. Bags containing grain should be placed on drain boards for better ventilation and prevention of pests and decay. Moisture content determines the storage periods and use. Grain with a moisture content of 14% can be stored for several months. However, inherent problems include breeding of fungus and bugs in addition to loss of weight due to respiration. Although grain with a moisture content of 13% can be stored for approximately one year, the bug issues remain.

5.9 Basic Rice Cultivation Problems

Extension workers face many problems in rice cultivation. The main problems are soil, water, power tiller, diseases, and low yield.

5.9.1 Soil problem

Some parts of the field or the whole field are sandy soil and gravel soil. Sandy soil and gravel soil cannot retain nutrients.

Figure 5-77 shows the poor growth of rice in problem soil. The topsoil is around 10 cm and the subsoil is gravel. Figure 5-78 shows sandy soil. Rice in both types of soil grows poorly. Even if fertilizer were applied, most of the nutrient would be leached away from the top soil, because of low CEC. Therefore, the less effective fertilizer inhibits the growth of rice (Figure 5-79).

Brown spot disease attacks the rice plants in these soils (Figure 5-80) because of the shortage of potassium (Figure 5-81).

These soils can be improved by application of organic matters, bio-char or clay soil.

As for emergency measures, the application of fertilizer is divided into several times, not once. Figure 5-82 shows an example of the application of fertilizer in problem soil.

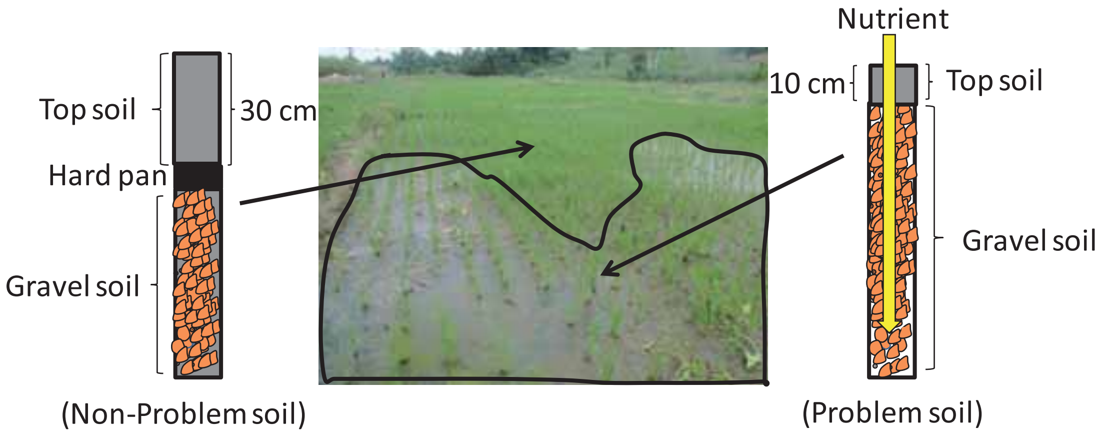


Figure 5-77 Gravel soil

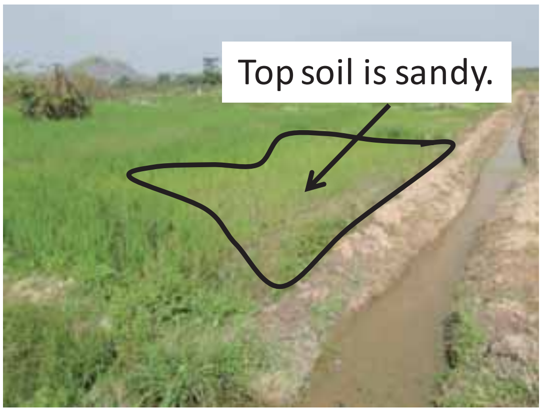


Figure 5-78 Sandy Soil

Figure 5-79 Less effective of the fertilizer in the problem soil

Figure 5-80 Rice plants attacked by brown spot

Figure 5-81 Symptoms of potassium deficiency (old leaves become yellowish-brown)

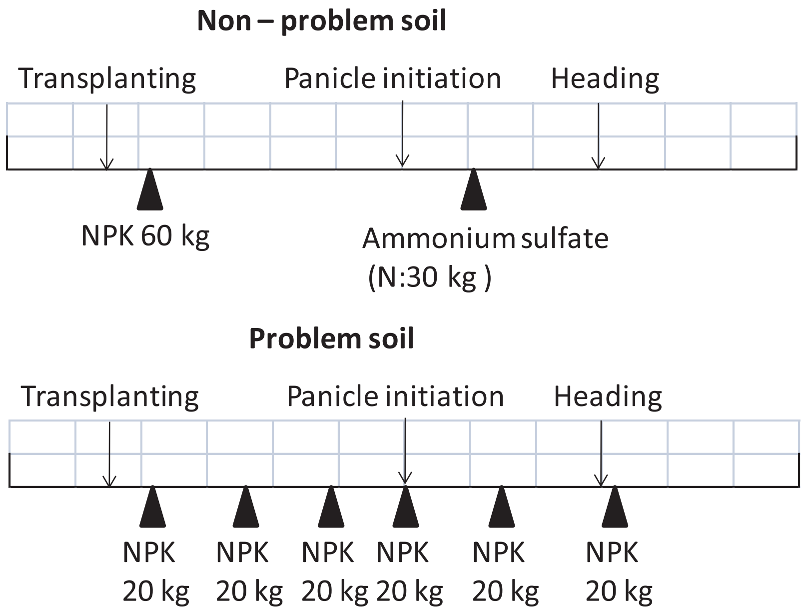


Figure 5-82 Example of the timing of fertilizer application in problem soil. Amount of fertilizer is per hectare.

5.9.2 Water problem

Sometimes, water cannot be delivered into all areas of the farmer's field. We can observe a field that is located on a higher place than the canal (Figure 5-83). In such a place, water cannot be delivered by gravity. Therefore, it is necessary to use a motor pump to irrigate. However, it is costly to use motor pumps. We should consider effective irrigation via pumps.

For pump irrigation, the water is supplied once every three or five days depending on the soil conditions. If the soil is sandy, the irrigation should be done once every three days. If the higher part occupies the large area, the rotational irrigation is recommended (Figure 5-84).

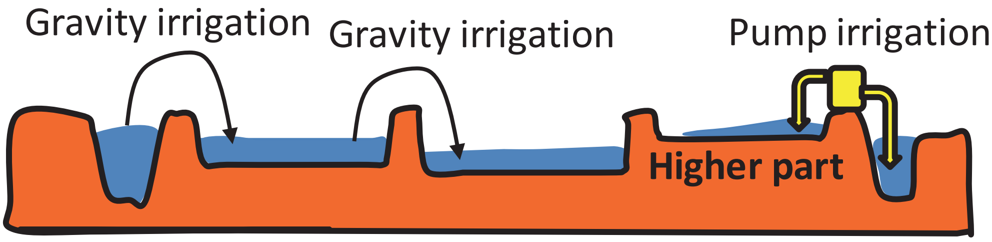


Figure 5-83 Irrigation of higher field than the canal by motor pump

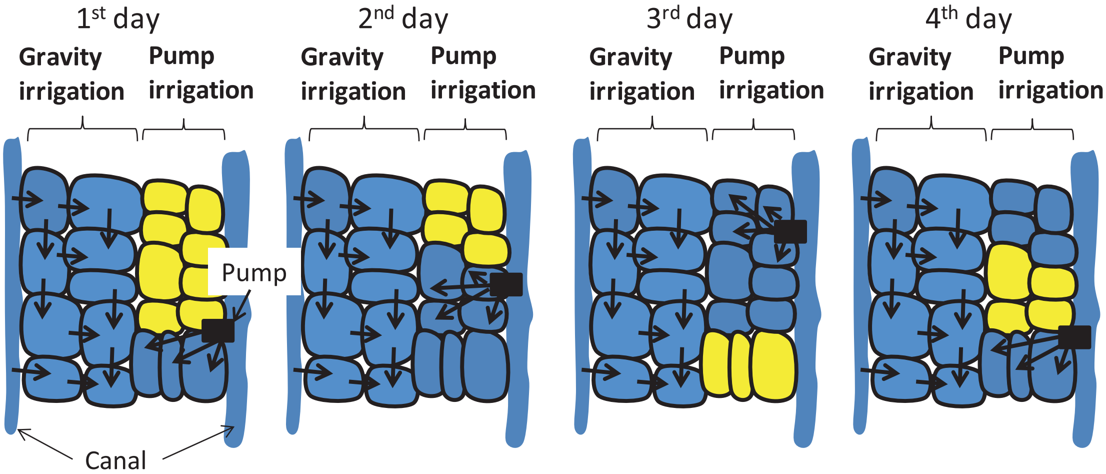


Figure 5-84 Rotational irrigation

5.9.3 Problem of lower yield

Unexpected lower yield happens in farmers' field often. Extension workers should help solve the problems and advise farmers on rice cultivation for the next season.

(i) How to solve the problems

To solve problems of yield, you should consider the yield component. Figure 5-85 shows the relationship between the yield component and factors for lower yield.

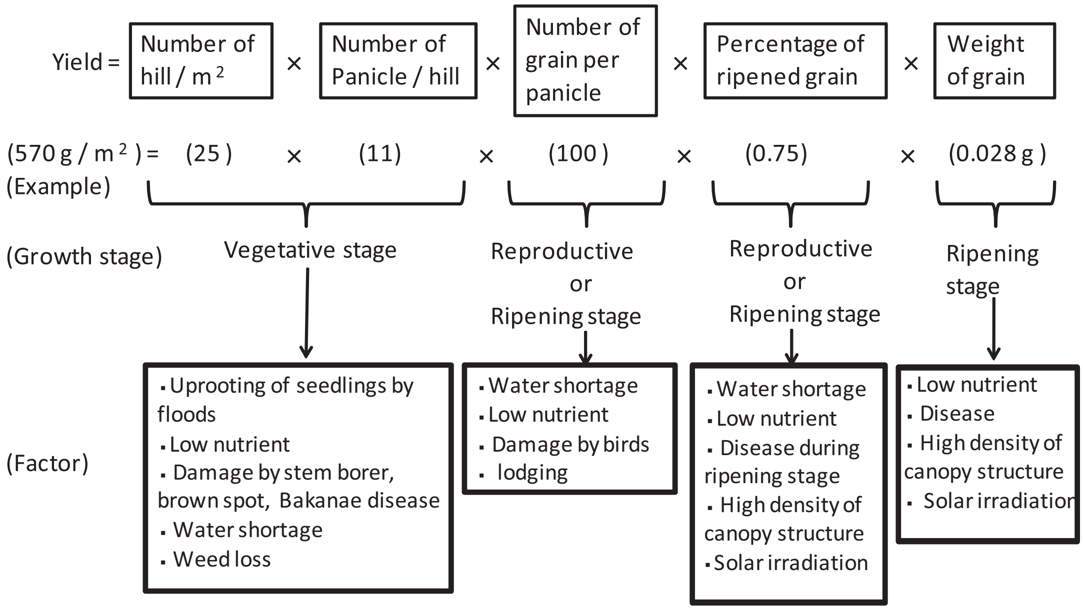


Figure 5-85 Relation between yield component and factors in low yield
(The example is 5.7 tons per ha of yield of sikamo or jasmine variety.)

6. Power Tiller

The relationship between the operation and maintenance of the power tiller is as follows.

Operation of power tiller ⇔ Maintenance of power tiller

6.1 Advantages of using the power tiller in rice cultivation

Effective use of the power tiller is expected to reduce labour, improve working efficiency, and increase crop yields. However, improper utilization decreases working efficiency and increases maintenance costs.

Points to be considered for the proper use and maintenance of power tillers to reduce maintenance expenses are summarized below.

6.2 Operation of the power tiller

The power tiller is a farm machine used for ploughing, puddling and leveling the soil. The power tiller should be used for difficult operations associated with cultivation of new lands for cropping. It is advisable to use the power tiller to prepare wet fields.

6.2.1 Clutch

Clutch is the most damaged part of the power tiller due to the use of extra force on the clutch by many operators (farmers). Therefore the following precautions should be taken to eliminate damage to the clutch:

(i) It is important to confirm that the clutch is in the neutral position before starting the power tiller.

(ii) Clutch wire tension should be checked before operating the power tiller.

(iii) Clutch wire loosens with continued use; therefore, a loose clutch wire should be adjusted with the clutch adjuster to ensure the proper interlock.

(iv) Third gear of the main clutch allows for maximum speed, therefore proper care should be taken during land preparation.

(v) Operation on dry surfaces requires lower clutch speeds.

(vi) The clutch must be disengaged after each use.

6.2.2 Rotary Tines

The rotary tines are damaged most often by forcible operation. Therefore, it is advisable to use the machine on wet land. The engine should be shut down before entangled grass in the rotary tines are removed.

6.2.3 Oil filter

The oil filter deteriorates rapidly if inappropriate oil is used; therefore, only the oil recommended by the manufacturer should be used.

6.2.4 Air Cleaner

Dust sucked into the air cleaner sticks to the element and lowers the engine power when built up. Therefore, always check and clean the air cleaner element.

6.2.5 Radiator Fin

When the radiator becomes dirty, the cooling capacity is reduced and causes the engine to overheat. Always ensure that the fins are clean to avoid overheating.

6.2.6 Precautions during operation of a power tiller

The following points should be noted closely before operating a power tiller:

(i) Soil conditions

Attachments to the power tiller should be selected in accordance with the soil conditions, to operate efficiently during land preparation in a paddy field. Power tiller usage should be avoided in hard soil conditions as the use of force in such situations could result in machine damage.

(ii) Attachments

Suitable attachments should be selected in accordance with the type of power tiller. The rotary tines of a power tiller should be checked before and after operations.

6.2.7 Precautions before starting a power tiller

The following should be observed:

(i) Inspection of the power tiller before operation

(ii) Confirmation of the conditions and amount of fuel in addition to the rotary tine conditions

(iii) Inspection and maintenance of the power tiller on a flat, dry surface

(iv) Regular washing of the power tiller after every use

6.3 Maintenance of the power tiller

The objectives of inspection and maintenance are to (i) prevent accidents, (ii) operate a power tiller in the perfect condition, and (iii) ensure long machine life.

Figure 6-1 illustrates the number and frequency of reported accidents in one year during farming projects in Sokwae, Nsutem, Kodadwen, and Barniekrom.

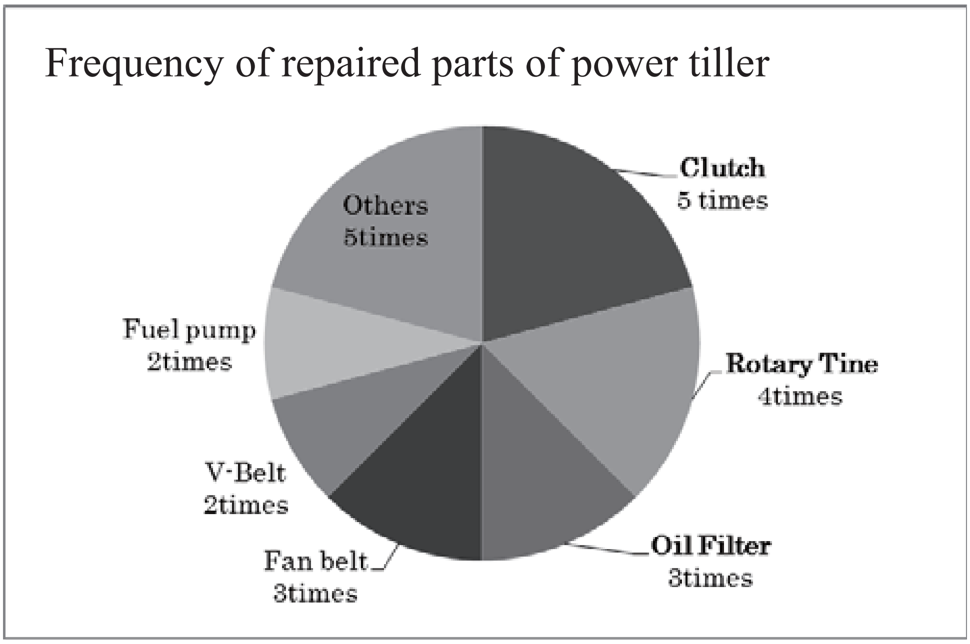


Figure 6-1

Figure 6-2 illustrates the maintenance expenses for each part.

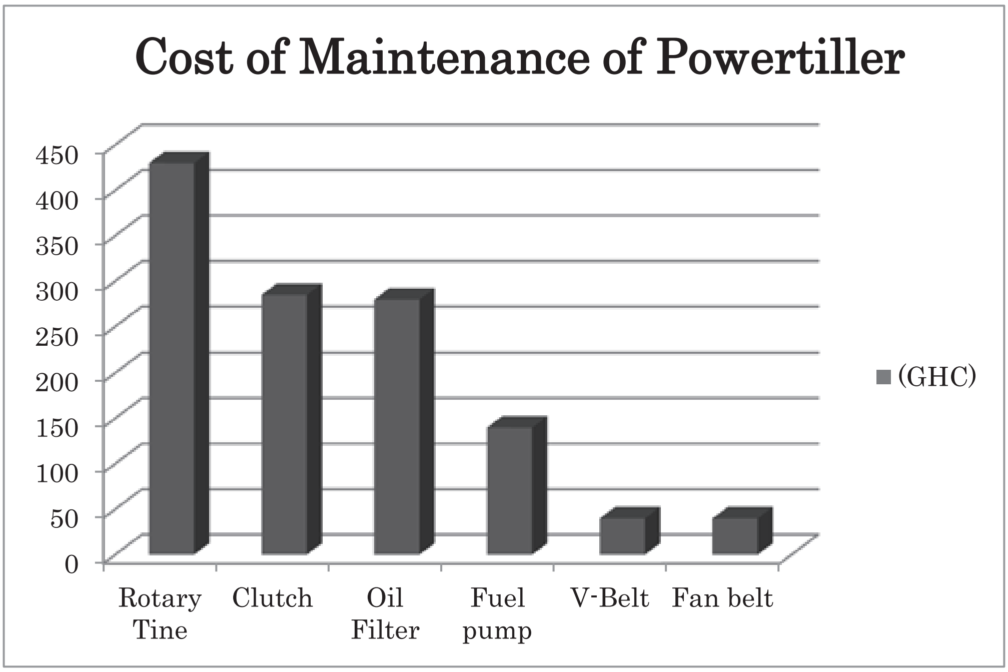


Figure 6-2 illustrates the maintenance expenses for each part

These two figures indicate that the clutch, rotary tines, and oil filter were problematic and required expensive maintenance. The operation and maintenance methods employed for addressing the problems associated with the use of the above mentioned components are discussed in the following section. Attached manual of a power tiller shows the general handling and operation parameters of the machine.

It is advisable to establish a management association for effective power tiller maintenance. The Power tiller users should become members of this association, and user fees should be charged for repairs and maintenance. The association should have rules and regulations for power tiller use and maintenance. In addition, transparency in fund management should be encouraged. The association should be managed as per the objectives stated in Item 3.

6.4 Common Usage of the power tiller by Farmer Based Organizations

(i) Decide the person in charge of the organization.
(ii) Make rules for using the power tiller.
(iii) Collect a user fee.
(iv) Power tiller should be quickly repaired when breakdown occur.
(v) Association members should have equal access to the power tiller.

ANNEX i　Quick guide for rice cultivation

(1) Preparation of seeds:

40 kg per ha

(2) Preparation of fertilizer

(i) For 60 kg per ha of N,P,K, 400 kg of N_{15} P_{15} K_{15} should be applied. For 30 kg per ha of N, 143 kg of ammonium sulfate or 67 kg of urea should be applied.

(ii) Schedule of application of the fertilizer (Figure i-1)

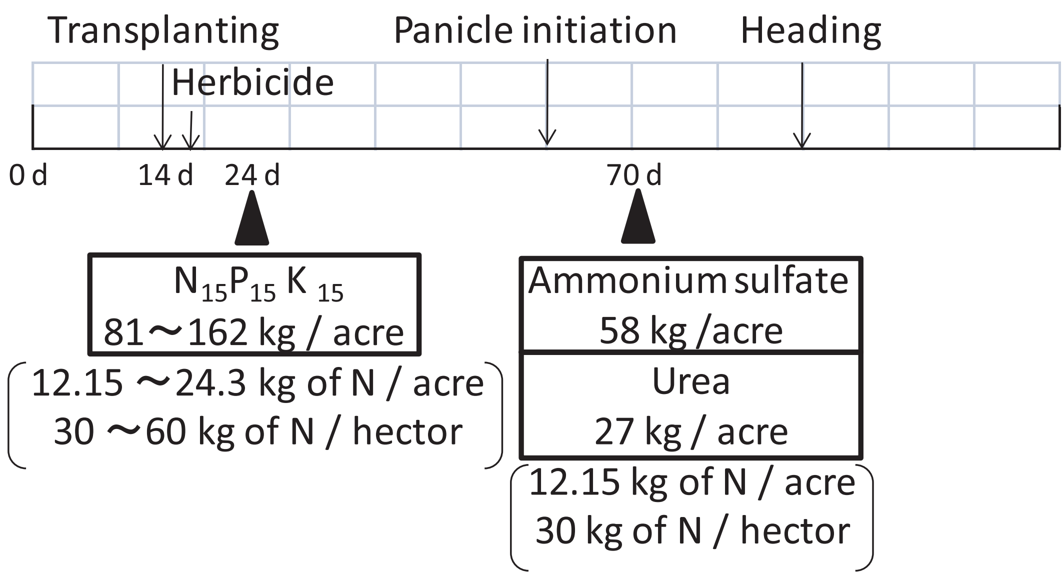


Figure i-1　Schedule of the application of fertilizer

(3) Water management (Figure i-2)

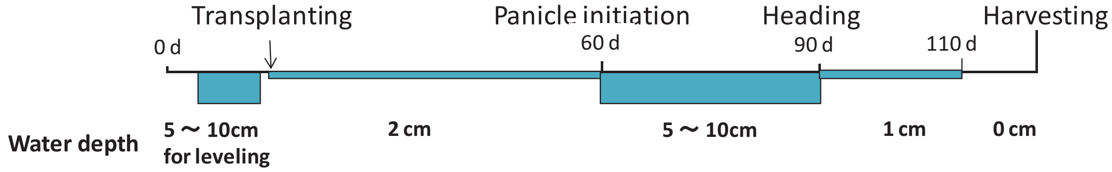


Figure i-2　Water requirement

(4) Weed management (Figure i-3)

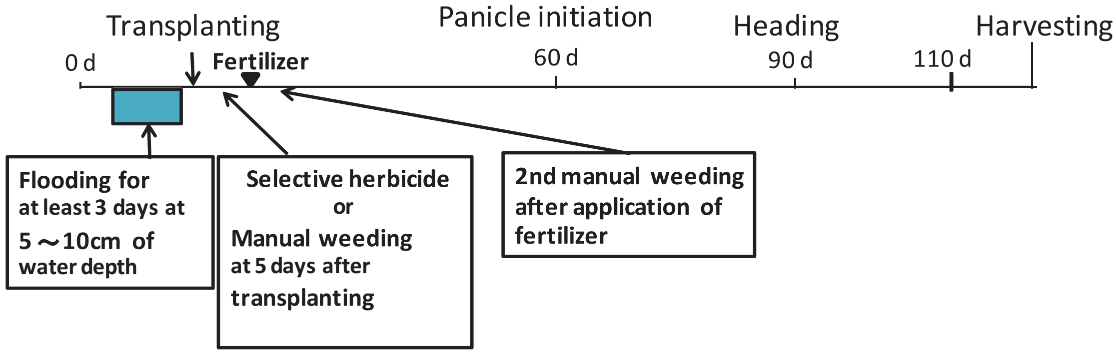


Figure i-3　Diagram of weed management

(5) Management of disease and insects (Figure i-4)

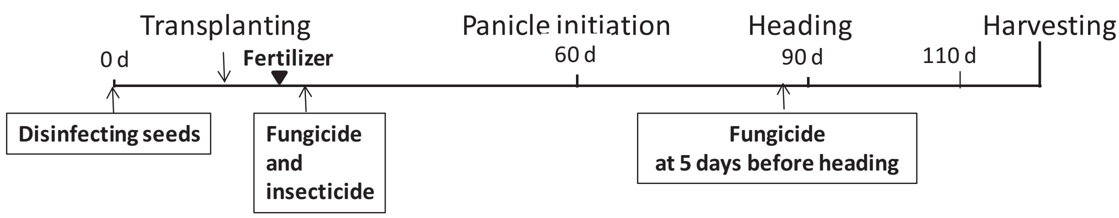


Figure i-4　Diagram of management of disease and insects

Annex ii: Land Tenancy Agreement

LAND AGREEMENT FOR THE "DEVELOPMENT OF IMPROVED INFRASTRUCTURE AND IMPROVED TECHNOLOGIES FOR RICE PRODUCTION"

This is a rent agreement for the development of infrastructure and improved technologies for rice production, for rice farmers in Nsutem, a town within the Ahafo Ano South district of the Ashanti region, Ghana.

It is an agreement for the period of .... years, covering an area of .... acres starting from the 2009 rice cropping season. The lowland provided by the land owner (name indicated below) to the rice farmer (name indicated below) is to be primarily used for rice production over the agreed period. The farmer has therefore undertaken to pay an annual amount of .... or its equivalent in kind, to the land owner as rent which can be subjected to review only when the agreed period expires.

LAND OWNER
Name: ....
Signature: ....
Date: ....

FARMER
Name: ....
Signature: ....
Date: ....

WITNESS
Name: ....
Signature: ....
Date: ....

WITNESS
Name: ....
Signature: ....
Date: ....

ANNEX iii : Power Tiller Lending Agreement

POWER TILLER AGREEMENT

JIRCAS LENDING OF YANMAR DIESEL POWER TILLER YZC – D (11.0HP) TO FARMERS GROUP UNDER JIRCAS RICE DEVELOPMENT STUDY PROJECT AND MINISTRY OF FOOD AND AGRICULTURE'S OFFICE OF ATWIMA NWABIAGYADISTRICT

1. JIRCAS (hereinafter lender) represented by Mr Kofi Kankam – Coordinator – agrees to lend a Yanmar Diesel Power Tiller YZC –D (11.0) with accessories to Farmers' Group under the JIRCAS Rice Study Development Project and Ministry of Food and Agriculture (Atwima Nwabiagya District) and represented by the Chairperson and Secretary of the group.

Below is a table showing type of Equipment, Brand, Accessories, and Quantity.

NO.	EQUIPMENT	QUANTITY	BRAND	ACCESSORIES	QUANTITY
1.	Power Tiller	1	Yanmar YZC – D (11.0HP)	- Rotary - Spanner - Screw Driver	1 2 1

2. Borrower agrees to use above equipment and its accessories properly and solely for JIRCAS' Rice Study Development Project.
3. If the above equipment or any of its accessories is/are broken, borrower has a responsibility to repair them as soon as possible.
4. Borrower takes full responsibility of the equipment and its accessories in the event of an accident.
5. The property rights of the equipment and its accessories as listed above belong to JIRCAS.
6. Lender shall inform borrower one (1) month ahead of time to the end of this agreement.
7. Borrower shall ensure to return to JIRCAS all the above listed equipment and its accessories in their perfect condition at the end of this agreement.

For JIRCAS

Name: **Mr Kofi Kankam**

Position: Coordinator

Date:

Signature:

For Farmers' Group

Name of Site: **Sokwae A, B, & C**

Name:

Position: **Chairperson of Farmers' Group**

Date:

Signature:

Name:

Position: **Secretary of Farmers' Group**

Date:

Signature:

Name:

Position: **Extension Officer (MOFA)**

Date:

Signature:

ANNEX iv : Current State and Future Prospect of Rice Production in Ghana

THE CURRENT STATE AND FUTURE PROSPECTS OF RICE PRODUCTION IN GHANA

PRESENTED BY KWAKU NICOL

AG. DIRECTOR OF CROP SERVICES

1.0 BACKGROUND

Rice has become the second most important staple food after maize in Ghana and its consumption keeps increasing as a result of population growth, urbanization and change in consumer habits. Between 1996 and 2005, paddy production was in the range of 200,000 and 280,000 tons (130,000 to 182,000 tons of milled rice) with large annual fluctuations. The annual production fluctuations are largely due to the area (ha) put under rice cultivation, rather than yield variations (t/ha). Rice is cultivated in Ghana both as a food crop and as a cash crop.

The total rice consumption of Ghana in 2003 amounted to about 500,000 metric tonnes (JICA, 2007), with an annual per capita consumption of 22 kg. Although suitable climatic conditions exist in most parts of the country for rice production, the country is unable to produce enough to meet its national requirements. Currently, Ghana produces less than 40% of its national requirement. The self-sufficiency ratio of rice in Ghana has declined from 38% in 1999 to 24% in 2006 (CIRAD, 2007).

Ghana imports large volumes of rice annually to make up for shortages in domestic supply. On the average, the annual import is about 400,000 metric tonnes. In 2009, for instance, Ghana imported 383,985 metric tonnes with a corresponding value of US$ 218.5 million.

From the above, the need to increase domestic rice production cannot be over emphasized. It would lead to foreign currency savings for the country, improve the livelihood of farmers towards poverty reduction and improve food security of the country. Over the years, successive governments of Ghana have initiated policies and programmes which were aimed at ensuring increased and sustained domestic production of good quality rice for food security and import substitution.

2.0 RICE PRODUCTION IN GHANA

Rice does well in almost all the agro-ecological zones in Ghana. However, the guinea savanna zone is the most suitable for rice production. The Northern, Upper East and Volta regions are the largest producers. These three regions account for over 70% of the national production. Rice is cultivated in Ghana under three main production systems namely: rainfed upland, rainfed lowland and irrigation. The rainfed lowland ecology is dominant, covering over 78% of total cropped area. The irrigated ecology covers 16% of total rice area while the upland area covers 6%. The area put to rice (paddy) cultivation in the various regions in 2009 and the corresponding outputs in metric tonnes are indicated in Table 1 below.

Table 1. (Area and Production of Rice in the Regions, 2009)

Region	Area (Ha)	Average yield (mt)	Production (mt)
Western	15,218	1.32	20,088
Central	4,158	1.22	5,073
Eastern	7,310	1.70	12,427
Greater Accra	2,005	1.47	2,947
Volta	20,460	2.97	60,766
Ashanti	9,614	1.30	12,498
Brong Ahafo	3,709	1.56	5,786
Northern	72,841	2.61	190,115
Upper West	4,200	1.67	7,014
Upper East	39,834	2.79	111,137
Total	179,349	2.39	427,845

Source: Statistics Research and Information Directorate, MoFA.

2.1 THE NATIONAL TREND

There are annual fluctuations in the production of rice (paddy) in Ghana. The national production trend over the last ten years is indicated in Table 2 below.

Table 2. (Area and Production of Rice in Ghana, 2000-2009)

Year	Area ('000 Ha)	Production ('000 Mt)
2000	93.6	214.6
2001	88.0	253.2
2002	112.8	280
2003	117.7	239.0
2004	119.4	241.8
2005	120.0	236.5
2006	125.0	250.0
2007	108.9	185.3
2008	132.8	301.9
2009	179.3	427.8

Source: Statistics Research and Information Directorate, MoFA.

2.2 QUANTITY AND VALUE OF RICE IMPORTS

Ghana imports large volumes of rice annually to meet its national requirement. The quantities of rice imported into Ghana and the corresponding value in United States dollars are indicted in Table 3 below.

Table 3. (Quantity and Value of Rice Imports, 2005-2009)

Year	Quantity (Mt)	Value (US$'000)
2005	484,513	138.94
2006	389,660	159.47
2007	442,073	157.87
2008	395,400	187.28
2009	383,985	218.50

Source: World Food Programme

SOME RICE VARIETIES IN GHANA

Over the years, the research institutions have developed and released some varieties of rice which are suitable for the various ecologies. The names of some of these varieties and their maturity days are indicated in the Table 4 below.

Table 4 (Some Rice Varieties and their maturity Days)

No.	Name of variety	Maturity period (days)
1	Gbewa Rice	100 -120
2	Nabugo rice	120 – 130
3	Kantanga Rice	130 – 140
4	NERICA 1	95 -100
5	NERICA 2	95 -100

3.0 REVIEW OF THE NATIONAL RICE SECTOR

3.1 Status of Rice in National Policies

Policy strategies over the years, as captured in FASDEP I, GPRS I & II, MTADP, AAGDS and other MoFA policy documents, have sought to promote rice production to address food security and poverty reduction. FASDEP II, which is the current sector development policy guideline (2008 – 2010), lists rice as one of the commodities for increased food security and import substitution. Specific measures, among others, to reach this level of production are increased mechanization, increased cultivation of inland valleys and efficient utilization of existing irrigation systems. In addition, varietal improvement and increased seed production and utilization are to be pursued vigorously.

4.0 MAJOR PRODUCTION CONTRAINTS FACING THE NATIONAL RICE SECTOR

4.1 Land Tenure

The land tenure system is a constraint to rice production in Ghana because of its general effects on both access and security. The system tends to limit the size of holdings and investments towards land improvement, especially in the lowland rain-fed ecology. There is general gender bias in favour of men in the allocation of land. The country has a large rain-fed lowland ecology that is suitable for rice production but remains largely unexploited.

4.2 Erratic Rainfall Pattern

Both the rain-fed lowland and upland ecologies are affected by erratic rainfall patterns. The rain-fed lowland ecology has water management problems as a result of frequent flooding from ground water and precipitation. However, when well developed (with simple water management techniques) and mechanized, its yield potential can be substantially enhanced. The upland ecology also has a problem of inadequate or excessive rainfall. There are also problems of weed competition, low soil fertility and pest damage. Rice varieties suitable for the ecology are short duration and drought-tolerant types.

4.3 Poor Quality seed

Most rice farmers do not use certified seeds of improved varieties even though improved varieties suitable for both upland and lowland ecologies have been developed and released by the research institutions. The seed growers are unable to produce adequate certified seeds of the improved varieties for farmers. Accessibility to certified seed is also poor. Farmers end up planting poor quality seed resulting in low yields.

Other major production constraints are;

(i) poor leveling of paddy fields and lack of bunds to retain rain water,
(ii) difficult access to agricultural credit,
(iii) inadequate use of fertilizers and agro-chemicals due to high cost,
(iv) damage from birds and pest and disease
(v) delay in planting
(vi) deterioration in irrigation facilities
(vii) delay in harvesting.

There are also postharvest and marketing problems such as contamination with foreign materials and over dried grain which affects the milling quality.

5.0 RICE RELATED PROJECTS AND PROGRAMMES

Due to the importance successive governments of Ghana attach to rice production, loan and grants have been sourced from Banks and development partners for the executions of rice related projects. Table 5 shows on-going rice related projects and their funding agencies.

Table 5 (On-going Rice Projects)

Project title	Period	Agency (Donor)
Rice Sector Support Project	2008-2014	AFD
Inland Valley Rice Development Project	2004- 2011	AfDB
Nerica Rice Dissemination Project	2006 – 2010	AfDB
Ghana Rice Inter-professional Body	2004- 2012	AFD
Study for the Development of Improve Infrastructure & Technology For Rice Production	2009 - 2015	JIRCAS
Project for Sustainable Development of Rain-fed Lowland Rice	2009 – 2014	JICA

6.0 PROSPECTS OF RICE PRODUCTION IN GHANA

Huge prospects exist in the rice industry of Ghana. The benefits of promoting the production of rice in the country cannot be overemphasized. It will enhance the output and income levels of farmers and eventually improve their livelihood and will also generate employment for famers, processor, etc. It will also lead to reduction in rice imports.

Due to the importance of rice to the food security of the country, several policies and programmes have been initiated and implemented by successive governments. In May, 2008, the government of Ghana launched the Ghana National Rice Development Strategy (G-NRDS). The vision of the strategy is to double rice production in the country within 10 years. The strategy which covers the period 2008 to 2018 is a response to forestall the effects of the global food crisis. The strategy proposes to double rice production taking into consideration the comparative production capacities of the three major ecologies (rain-fed upland, rain-fed lowland and irrigated) and growth of consumption. Over the last 10 years (1999-2008) per capita rice consumption increased from 17.5 kg to 38.0 kg. By 2018 it is estimated that it will grow to 63 kg as a result of rapid population growth and urbanization.

In developing the strategy, the Ministry of Food and Agriculture (MoFA) benefited from inputs of national experts with multi-sectoral backgrounds as well as other stakeholder groups operating in Ghana. Major constraints such as land development and land tenure arrangements, seed quality and availability, high cost of fertilizer, inadequate human resource capacity, inadequate harvesting and post harvest management technology, weak local rice marketing system and the role of Government and related agencies have been considered. A governance structure comprising the key actors in the rice sector has been proposed.

Seven (7) thematic strategy areas have been identified namely: Seed System; Fertilizer Marketing and Distribution; Post-Harvest Handling and Marketing; as well as Irrigation and Water Control Investment. Others are Equipment Access and Maintenance; Research and Technology Development; and Community Mobilization, Farmer-Based Organizations and Credit Management. For each of the thematic areas, some key actions have been proposed. Some of the proposed measures the strategy seeks to put in place to achieve this objective in the thematic areas are as follows:

6.1 Seed system

Proposed Actions

- Production of adequate quantities of breeder, foundation and certified seed from released rice varieties adaptable to rice growing ecologies
- Rehabilitate existing cold storage facilities for seed
- Develop an efficient system of distribution for breeder, foundation and certified seed
- Organize and train certified seed growers

6.2 Fertilizer Marketing and Distribution Strategy

- Enhancement of access and affordability of fertilizers
- Establishment of fertilizer production facility where possible
- Involvement of the private sector in the blending of appropriate straight fertilizers based on the ecology, soil type and variety adopted by farmers

- Encourage the use of organic fertilizers

6.3 Logistical requirement for fertilizer use, distribution and marketing strategy

Proposed Actions

- Develop an efficient system of storage and distribution (in affordable packages) of recommended fertilizers to enhance availability

- Facilitate timely access to fertilizer through the provision of efficient credit systems and enforceable distribution guidelines

- Encourage use of organic fertilizer through awareness creation, training and demonstrations

6.4 Post- Harvest and Marketing Strategy

Proposed Actions

- The use of appropriate harvesting and threshing facilities (small–medium scale harvesters and threshers) will be encouraged
- Paddy will be processed into acceptable national minimum standards by providing standard rice mills (equipped with pre-cleaners, de-stoners, hullers, polishers, paddy separators, aspirators, and graders).
- Existing one-pass mills will be improved by adding attachments while processing centers will be equipped with storage facilities for paddy/milled rice.

6.5 Logistics Requirement for Post- Harvest and Marketing Strategies

Proposed Actions

- Enhance quality of milled rice to meet national/ISO standards through provision of appropriate machinery and capacity building in post harvest handling of produce

- Provide adequate storage facilities in the major rice producing and consumption areas

- Develop suitable packaging, labeling and branding of locally produced rice as a way of promoting its consumption

- Develop a sustainable rice value chain by enhancing capacity of all actors to adhere to strict quality control procedures

- Develop reliable price and market information system for use by stakeholders along the value chain

6.6 Logistic Requirements for Irrigation and Water Control Investment Strategies

Proposed Actions

- Rehabilitate and expand existing irrigation infrastructure

- Encourage public-private partnership in developing and managing new irrigation schemes and to promote the use of small scale pumps along perennial water bodies.

- Design alternative water control systems in characterized inland valleys and lowlands for enhanced water management for rice cultivation.

6.7 Research and Technology Dissemination Strategy

Proposed Actions

- Development of improved varieties and disseminated to farmers.
- Enhancement of farmers capacity to ensure adaptation to good agricultural practices (GAPs) for rice cultivation
- Development and dissemination of training manuals, videos, fact sheets on the rice value chain.
- Training on improved processing technologies and value addition and information dissemination through ICT will be promoted

6.8 Logistic Requirement for Research and Technology Dissemination Strategy

Proposed Actions

- Strengthen the capacity of national research institutions through training and adequate budgetary allocation

- Foster collaboration between national research institutions and with their international counterparts like Africa Rice Centre, IRRI and IITA

- Enhance dissemination of research findings through strong research-extension-farmer linkages and the use of ICT.

6.9 Community Mobilization, Farmer Based Organizations and Credit Management Strategy

Proposed Actions

- Promote linkage of farmers to credit sources and ensure easy access to inputs, equipment and market.
- Training of FBOs in effective management of credit will be pursued. Agricultural credit management regimes over the years will be reviewed and suitable options identified for adoption.

- Promote the involvement of the youth in rice production and processing for employment and income generation through training and access to credit, mechanized services and land.

6.9. 1 Requirements for Farmer Based Organization and Credit Management Strategy

Proposed Actions

- Dialogue with identifiable stakeholders along the rice value chain to ensure their interests are well defined in the strategy implementation

- Mobilize interest groups along the value chain in the communities where facilities or resources have been earmarked for improvement and further ensure easy access to such facilities

- Facilitate the formation of cohesive FBOs for easy access to credit towards rice value chain activities.

7.0 CONCLUSION

Considering the importance of rice in the food security and socio-economy of the country, there is the urgent need to increase production. Pragmatic policies and programmes need to be initiated to address the numerous challenges in the sector.

Proposal in the Ghana National Rice Development Strategy together with other rice policies need to be vigorously pursued to ensure the country's self sufficiency in rice production.

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