Ministry of Agriculture, Forestry and Food Security
The Republic of Sierra Leone

The Agricultural Development Project in Kambia in the Republic of Sierra Leone

Final Report

Agricultural Technical Support Guidelines

Part II
Agricultural Technical Package

March 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

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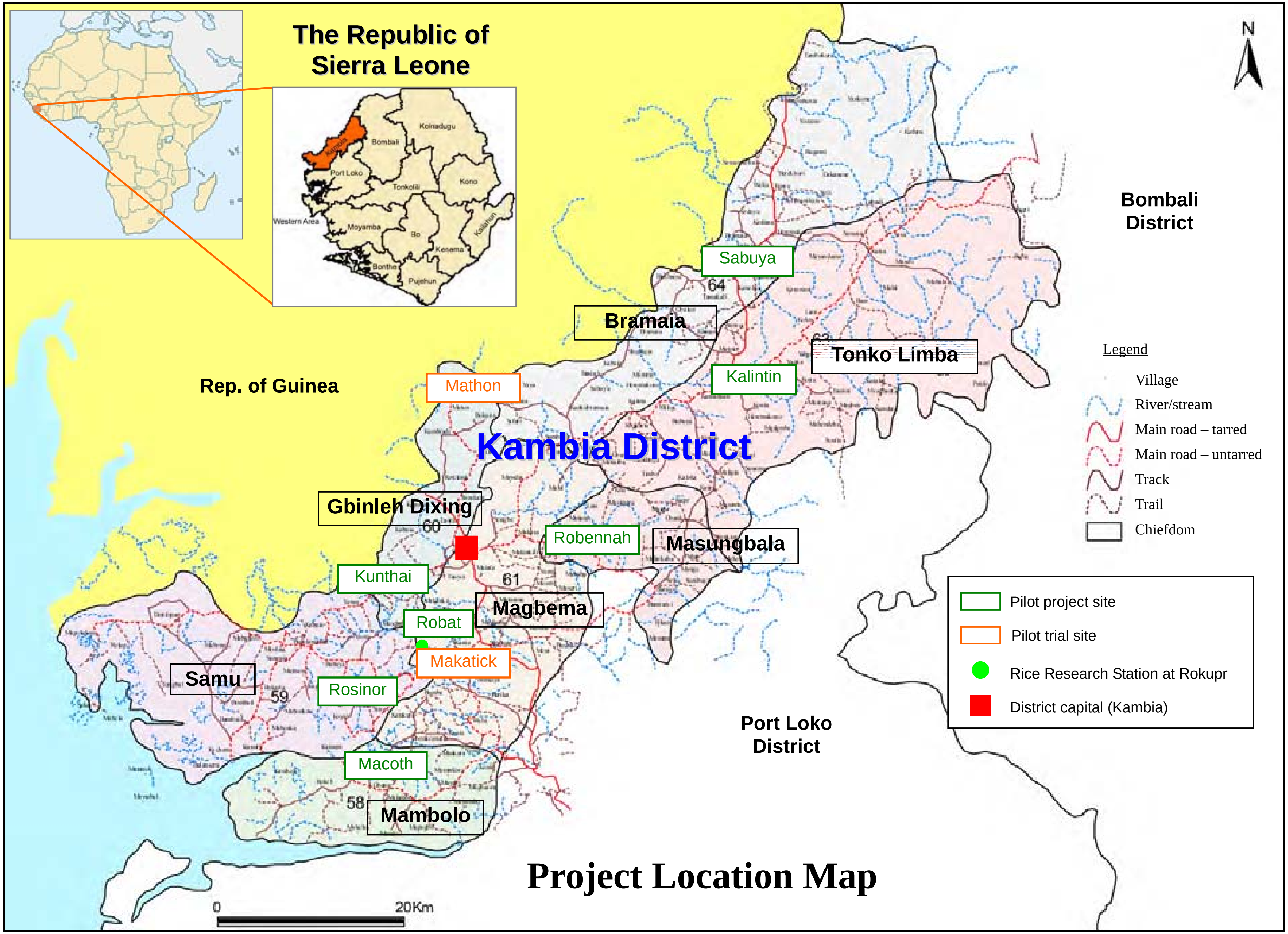
List of Reports



Project Location Map

The Agricultural Development Project in Kambia in the Republic of Sierra Leone

Final Report

Agricultural Technical Support Guidelines

Part II Agricultural Technical Packages

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Abbreviations

FAO	Food and Agriculture Organization
FEW	Frontline extension worker
IVS	Inland valley swamp
JICA	Japan International Cooperation Agency
MAFFS-K	Ministry of Agriculture, Forestry and Food Security Kambia District Office
PMMoV	Pepper mild mottle virus
PP	Pilot project
PT	Pilot trial
RRS-R	Rice Research Station at Rokupr
TP	Agricultural Technical Package
T-Pan	Three pence pan
TMV	Tobacco mosaic virus

Exchange Rate (January, 2009)		
US$ 1.00	=	Le 3,000
Le 1.00	=	US$ 0.0003
US$ 1.00	=	Yen 90.44

Chapter 1 Introduction

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Agricultural Technical Packages (TPs) were developed through a series of field trials to contribute to the enhancement of the livelihood of farmers by improving the productivity of rice and vegetable crops. The TPs are designed to present farming practices and activities that improve crop yields and profits along with cost-benefit analysis of farming activities. The TPs highlight those practices and activities to which the farmers should pay attention while explaining the theories behind. The users of the TPs should bear in mind that the present TPs are only a prototype and it is therefore intended that they be revised to reflect further field experience.

1.1 Composition of the Agricultural Technical Packages

The TPs are divided into two parts: (i) TP on rice production, and (ii) TP on vegetable production. The former presents recommended farming practices in rice cultivation, cost-benefit analysis and recommended post-harvest handling techniques. The latter, offers recommended cultivation techniques for three vegetables and cost-benefit analysis of their production.

1.1.1 Technical Package on rice production

The TP on rice production starts with rice cultivation techniques, followed by cost-benefit analysis and post harvest handling. In the sections on the rice cultivation techniques, an overall view of the life cycle of rice is presented with reference to the timing of farming practices in upland and lowland, followed by an explanation of the yield components of rice production. This provides readers with the basic information to understand the importance of respecting the cropping calendar in farming – the reasons for pursuing timely farming practices. Then the key recommended techniques to improve the grain yield of rice are presented.

Individual farming practices such as land preparation, nursery preparation and sowing, transplanting, weeding, water management, fertilizer application, bird scaring, pest control, and harvesting follow according to the sequence of farming practices. The improvement of rice culture practices is emphasized, especially the operation of the nursery at the vegetative growth stage when the number of tillers is determined, which is an important factor in assessing the yield.

In the section on cost-benefit analysis, the financial aspects of rice cultivation are explained. It introduces the concept of the break-even point in rice cultivation to enable the farmers involved to consider farming as a business. The effects of fertilizer application on the rice yield as well as farm incomes are also analyzed based on the results of the pilot projects.

The section for the post-harvest handling of rice describes the ways to minimize losses at harvest time, post-harvest activities (e.g., drying), threshing, and winnowing, processing (e.g., parboiling and milling), and storage. Appropriate tasks to be carried out in each process are described.

As most post-harvest and handling works are similar regardless of the agro-ecologies, explanations presented in this section apply to all the agro-ecologies, unless otherwise mentioned. Issues regarding agricultural equipment and machinery that were introduced in the pilot projects are again raised in this section.

1.1.2 Technical Package on vegetable production

The TP on vegetable production deals with three crops: watermelons, eggplants and peppers. It starts with a presentation of the key techniques that have proven to be effective in increasing the yield for each crop. Then the cultivation techniques for each vegetable crop are explained through the sequence of farming practices from nursery preparation to harvesting.

Practices include raising seedlings in nurseries, transplanting, fertilizer application, pruning, and the use of products of the neem tree for insect control. The system of cost-benefit analysis is also presented for each vegetable crop based on the results of the pilot trials.

1.2 Utilization of the Agricultural Technical Packages

The TPs are intended primarily for the use of frontline extension workers (FEWs) who work closely with farmers at the grassroots level. These extension workers are required to understand the background theory in order to recommend farming practices and techniques and explain the introduced techniques to the farmers with confidence. Advanced or educated farmers may also use the TPs as a guide to adopting new techniques. The TPs are more effective when accompanied by Agricultural Technical Manuals (Part III), especially when the extension workers explain them to the farmers.

1.3 Issues to Be Considered and Addressed

(1) Measurement units used in the text

In the TPs, metric units are used as the primary measurement units. However, other measurement units commonly used in the rural areas of Kambia District are also included along with the metric units. As mentioned in the previous section, the TPs are intended primarily for the use of FEWs, who are expected to disseminate the TPs to the farmers.

Since the rural farmers are not familiar with metric units, FEWs need to convert metric units into other measurement units commonly used in the area when they explain to the farmers. However, during the implementation of the pilot projects, it was revealed that not many FEWs could do such calculations. To deal with this variation in measurement units, several measurement units such as bushels, three-pence pans (T-pan), buttercups, bags, etc., are used throughout the text along with their equivalent in the units of measurement of the metric system.

(2) Issues on measurement units

Agricultural commodities are exclusively measured by volume in Sierra Leone. As for rough rice (paddy), the official volumetric weight is defined as 25 kg per bushel. The farmers estimate a cropped area by the quantity of seeds sown for rice: the planted area sown with one bushel of seeds is considered to be equivalent to one acre, irrespective of the planting methods (direct sowing or transplanting). However, in reality, there is a wide variation in the volumetric weight of rough rice measured using a T-pan, a small container widely used in Kambia District.

The conversion rate between the T-pan and the bushel varies from 11 to 22 T-pans per bushel, while the volumetric weight of one T-pan of rough rice also varies from 2.2 to 3.5 kg, according to a survey of the seven pilot project villages. As a result, the volumetric weight of rough rice ranges from 30 kg to 52 kg per bushel. It is obvious that the official volumetric weight measurement is grossly inadequate in Kambia District. The detailed survey results have been compiled and are attached in Part IV Annex 3.6.

The above findings imply that the farmers use more seed rice than the recommended dosages or that the farmers sell rice for prices less than they should be paid. It also could be that errors might have occurred in converting the number of T-pans into bushels, bushels into kilograms, bushels into acres, etc., as was the case in the Baseline Survey results. It is fervently hoped that the volumetric weight measurement system will be standardized and strictly applied throughout the country.

(3) Purity of seed rice as an important determinant of the yield

In the pilot project implementation, several varieties of seed rice were procured from the Seed Multiplication Project at Kobia in the first year (2007), and the Rice Research Station at Rokupr (RRS-R) in the second year (2008). However, in both years the purity of the seed rice was dubious, for it was found that seeds of different varieties were mixed. If such seeds were planted together in the same field at the same time, timely harvest would be difficult since some plants reach maturity faster than other plants.

If this matured rice is harvested, the younger plants become disturbed, resulting in a loss in the overall yield. On the other hand, if these younger panicles are allowed to mature, the panicles that have already matured will shatter and the rice grains from them will be lost.

In the TP on rice cultivation, the use of fertilizer is not recommended. Through the pilot projects, it was proven that the grain yield of rice increased by 0.5 to 1.0 ton/ha due to the application of fertilizer. However, this yield increase is not sufficient to cover the cost of the fertilizer under the current economic conditions. To ensure that the application of fertilizer is feasible, crop management, including timely farming and water control, should be improved so that the yield can be further increased.

In addition for better crop management, pure seeds must be secured to reduce losses at harvest time. The Government is responsible for controlling the quality of the seed rice. Seed multiplication should be carefully supervised and regulated to ensure the supply of pure seed rice to the farmers.

Chapter 2 Technical Package on Rice Production

Chapter 2 Technical Package on Rice Production

2.1 Rice Cultivation

2.1.1 Introduction

(1) Planting methods focused on

This section focuses on two methods of planting rice: (i) direct sowing on uplands and (ii) transplanting in the lowlands (IVS, boliland and mangrove swamp areas). The cultivation of rice in these agro-ecological systems is widely practiced by the farmers in Kambia District during the main cropping season (i.e., the rainy season). Since the two methods differ in their crop management from land preparation to sowing or transplanting, they are described separately under the sub-section describing crop establishment.

Once the rice plants are established in the main fields, the subsequent variation in crop management (e.g., pest control and fertilizer management) is less between the two methods, so they are described together. Seed handling, an important subject in rice cultivation, is described in the final section. Although nutritional disorders are an important determinant of plant growth in the region, they are not discussed in detail here since there are no practical remedies. They are briefly referred to in the sub-sections on diseases (2.1.3) and fertilizer management (2.1.4).

(2) Plant growth and yield component analysis

1) Growth development and farming activities

Rice plants sown or transplanted in the field develop a new leaf successively every 5 to 7 days under wet tropical conditions and produce tillers, grow taller, and increase their body weight. A turning point in this development occurs with panicle initiation (about 30 days before heading or flowering), after which the plants develop their panicles and their reproductive organs to be consumed by humans for food. Crop management refers to what the farmers do to provide favorable conditions for the crops in order to grow healthy and strong so that they can produce a high yield of grain. To accomplish this goal, any changes in the plants should be carefully observed throughout their growth and timely and necessary action should also be taken to ensure this.

In the case of upland rice cultivation, farmers have long experience in the management of rice plants, and their rice farms are relatively well maintained, although grain yields are still very low. One of the key points in upland rice cultivation is timely weeding (Figure 2.1-1, upper part). Among various crops, rice is particularly susceptible to weed competition: rice is always the first crop to be cultivated after forest clearing or fallow-bush, and the farmers would never grow it where weeds thrive in the second year after the farm has been cleared.

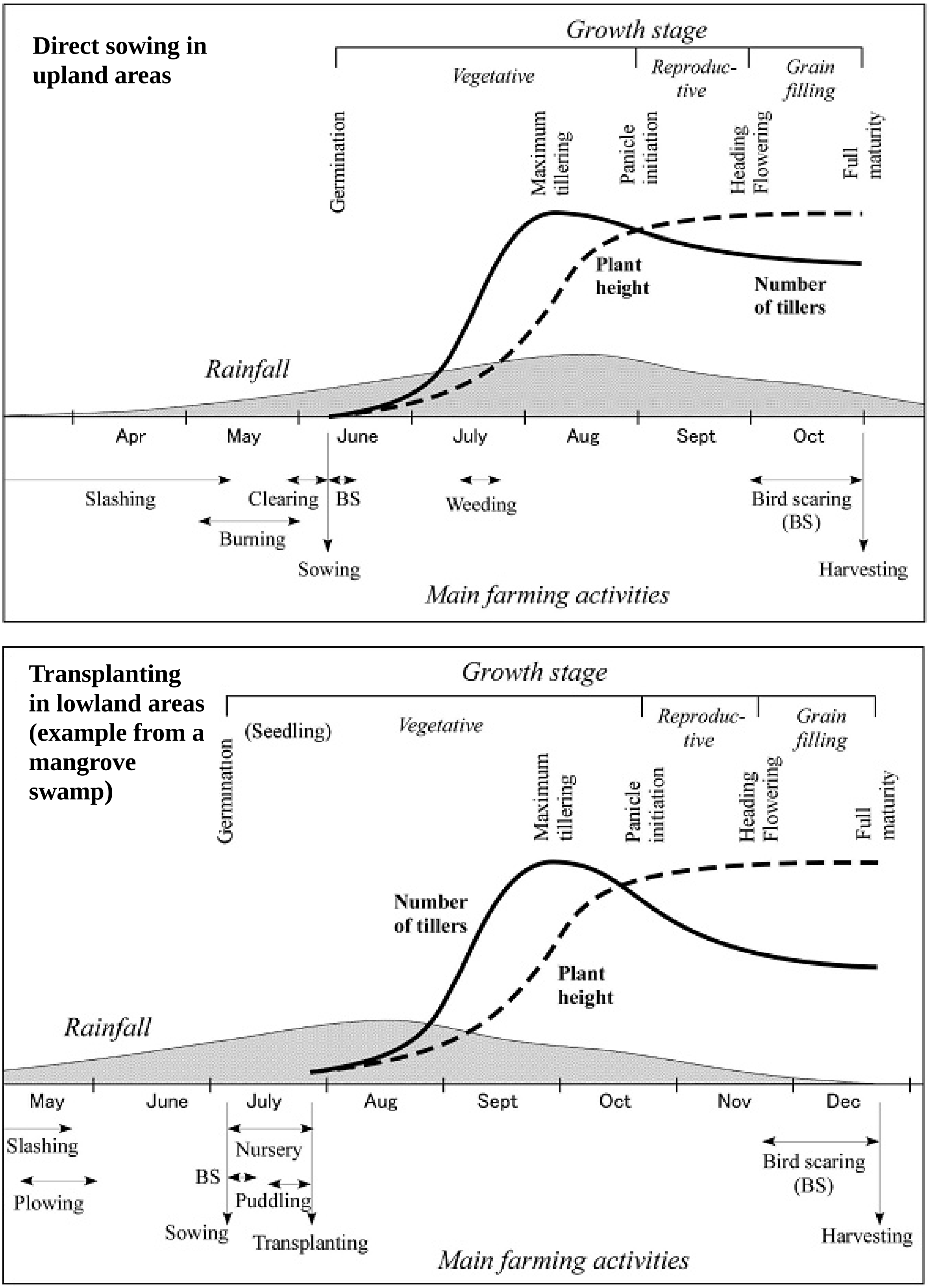


Figure 2.1-1 Growth of the Rice Plants and the Main Farming Activities in the Two Methods of Planting

Note: Direct sowing in the uplands and transplanting in the lowlands (example from a mangrove swamp). In these cases, the upland rice was a medium-long duration variety and the mangrove swamp rice a long duration variety.

As for transplanted lowland rice cultivation, the timely transplanting of healthy seedlings is of primary importance in ensuring good production (Figure 2.1-1, lower part). The optimal nursery period is three weeks (4 weeks for cultivation in mangrove swamp areas to enhance salt tolerance). In practice, however, the transplanting of old seedlings, sometimes two months old, is not unusual mainly due to delays in land preparation, especially plowing.

Farmers frequently sow the seeds in a nursery before completing land preparation. All the field activities should be planned in advance before the planting season, taking into account the availability of labor and the area of land to be cultivated. In planning these activities, first the transplanting date is set and, counting backwards from the nursery period, the sowing date in the nursery is determined. The plowing of the main field should be completed before sowing the seeds in the nursery since plowing is the most laborious and time-consuming work in lowland rice cultivation.

2) Grain yield and yield components

The final product obtained from the rice plants is not simply a mass of grains but consists biologically of several components (e.g., the number of panicles per hill and the number of grains per panicle) as shown in Figure 2.1-2. It should be noted that in this chapter the term "grain" refers to rough rice (brown rice and the husk or paddy). The developmental process of the yield components was extensively studied and documented, including the relationships among the components, and the effects of environmental factors on the components.

In yield analysis, various components and different combinations of these components are used. Some examples are presented below.

a) Relationship between the grain yield and the yield components

$$\text{Yield} = A \times B \times D \times E \times G = A \times B \times F \times G = C \times F \times G$$

where,

Yield: Grain weight per unit field area

Yield components	(Example)
A: Number of hills per unit field area	15 hills/m^2 = 150,000 hills/ha
B: Number of panicles per hill	8 panicles/hill
C: Number of panicles per unit field area	= A x B = 120 panicles/m^2
D: Number of spikelets per panicle	100 spikelets/panicle
E: Proportion of filled grains (% ripened)	0.85 (85% of the spikelets matured into filled grains)
F: Number of filled grains per panicle	= D x E = 85 grains/panicle
G: 1,000-grain weight	25g/1,000 grains= 0.025g/grain = 25 mg/grain

b) In actuality, the yield = A x B x F x G = 15 x 8 x 85 x 0.025
= 255 g/m^2 = 2.55 ton/ha = *ca*. 41 bu/acre (as 1 bu = 25 kg)

It should be noted that the unit of the bushel (bu) for grains is converted at the official rate of 25 kg/bu.

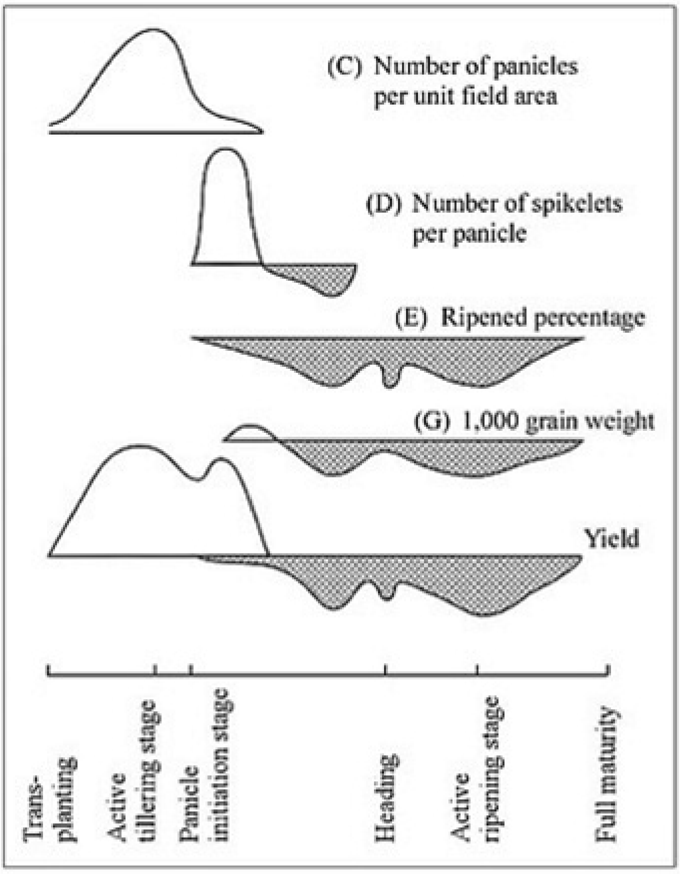


Figure 2.1-2 Schematic Diagram of the Processes of the Yield and Yield Component Formation in Rice Plants
(Based on Matsushima, 1959)

Note: The positive (blank areas) and negative (hatched areas) represent the effects of the environment.

c) Formula to estimate the number of filled grains per panicle (F):

F = Yield / (A x B x G) = 255 / (15 x 8 x 0.025) = 85 grains per panicle

The grain size (commonly measured in terms of the 1,000-grain weight) varies a little with the culture practices (e.g., plant density and fertilizer application). Thus the number of grains either per hill (or per plant) or per unit field area is the dominant factor contributing to the grain yield. The number of grains is first determined by the number of panicles and second by the number of grains per panicle. In other words, crop management to help plant growth at the beginning is important since the number of tillers (eventually panicles) produced at the early stage of growth is the key determinant of grain yield.

(3) Summary of the pilot project on rice cultivation

1) Goal

The pilot project aimed at obtaining 1.0 to 1.5 ton/ha (= 16-24 bu/acre) of grain yield by improving rice culture practices, since the average yield was about 0.5 ton/ha (= 8 bu/acre) in the past (JICA et al., 2007).

2) Key techniques introduced

a) Timely farming activities based on a well-planned cropping calendar

b) Rational seeding rates

c) Proper land preparation

d) Proper water control such as dike (bund) construction

e) Efficient fertilizer application

f) Appropriate transplanting in the lowlands with:

f-1) Use of young (3-week-old) seedlings

f-2) Shallow planting (2 to 3 cm deep)

f-3) Reduced number of seedlings per hill (2 to 3 per hill)

In addition, a short-stature variety (ROK 14) was planted on a trial basis to pursue higher yields in the fertile soil of an associated mangrove swamp.

3) Main results

The main results obtained in the pilot projects (2007 and 2008) were as follows. The details results of the pilot projects are described in Part IV Annex 1.

a) A grain yield of 1 ton/ha (= 16 bu/acre) was attained at almost every sites in the different agro-ecologies with the improvement of rice culture practices (without fertilizer application).

b) The fertilizer response was about 0.5 ton/ha (= 8 bu/acre) at an application rate of 4 bags/ha (= about 1.5 bags/acre: 50 kg/bag): the low fertilizer response was a result of poor water management and improper crop management.

c) Plant growth and the grain yield were not reduced with a fewer number of seedlings per hill, which helped the farmers to substantially save on seed costs (1/4 or 1/5 of the present).

d) Nearly 4 ton/ha (= 64 bu/acre) of grain yield was feasible with the short-stature variety combined with improved crop management.

It should be borne in mind that no single factor was responsible for raising yields, but this involved an integrated approach that led to yield increases under low-input conditions.

2.1.2 Crop establishment

2.1.2.1 Upland rice cultivation

(1) Site selection

A suitable area of bush is first located that has been fallow for at least 7 to 10 years and where the majority of gramineous seeds have died out. A gentle slope of 4 to 5% at the maximum should be selected for upland crops. Clearing a steep slope may cause soil erosion and nutrient leaching, which could lead to soil degradation.

The density of palms around the cultivated fields affects the growth and yield of the rice if it is higher than about 25 trees/ha (20 m x 20 m). Palm trees block the sunlight and may hinder rice growth. On the other hand, the shading mitigates drought stress that affects the rice plants.

(2) Land preparation - slashing, burning, and clearing

In the selected area of fallow bush, (i) the undergrowth is slashed (brushed out), (ii) the trees are felled and (iii) the vegetation is allowed to dry. This operation spans from January to May.

The direction of the burning of the slashed trees and shrubs is from the lower to the upper slopes. Unburned branches and trunks are removed from the fields. (The farmers utilize these branches as firewood.) The fields should be burned no later than May before the period of heavy rainfall starts. All sprouting should be cut back and the field should be thoroughly cleared shortly before sowing.

(3) Sowing

1) Seeding rates

A seeding rate of 60 to 80 kg/ha is recommended for direct sowing in upland and boliland areas (MAFS, 2005; RRS-R, 2005). Currently, a seeding rate of one bu/acre (= 63 kg/ha) is widely adopted by the farmers, which is within the recommended range and thus not necessarily high for the direct sowing cultivation of rice.

2) Pre-treatment of the seeds

Seed selection using water (or salt water with a specific gravity of 1.05) is unnecessary as long as the seeds are properly winnowed. By eliminating this process the extra work required to dry the moistened seeds can be avoided, since dried seeds are essential for uniform broadcasting. Incubation of the seeds is not recommended. If the seeds are incubated, their sprouting (emergence of the juvenile plants in the field) will be greatly inhibited if rain does not occur at the right time, resulting in low plant standing.

3) Seed broadcasting and tillage

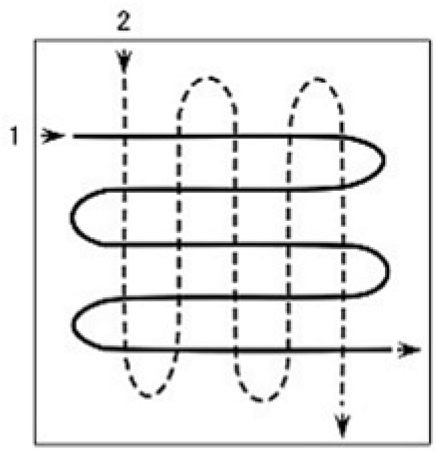
The seeds are broadcasted in the fields and covered by shallow tillage at a depth of a few centimeters. A small hoe is the most convenient tool since it does not excessively disturb the topsoil, in which the roots of the shrubs and trees are able to develop to prevent soil erosion. The farmers commonly mix sorghum seeds with the rice seeds. This mixture does not affect the rice yield as long as the mixing rate is 1% (10 g sorghum seeds to 10 kg of rice seeds) or less.

Note on Uniform Seed Broadcasting

The method of uniform seed broadcasting is as follows:

(1) Divide the field into several sub-plots of nearly equal size and divide the seeds equally according to the number of the sub-plots.
(2) In each sub-plot, broadcast two-thirds of the amount of seeds that have been divided for each sub-plot.
(3) Broadcast the remaining one-third to even out any uneven distribution of the seeds that were broadcast in (2).

Note: The first and second broadcasting should be carried out transversely (see below).



4) Timing of the sowing

Sowing is generally carried out at the beginning of the rainy season in May and June. However, the decision on the sowing day can have uncertain consequences and thus it must be made carefully. If there is heavy rainfall shortly after the sowing, the seeds will be washed away, or if there is no rain for a prolonged period, their germination will be disrupted and they will also become exposed on the soil surface due to the shallow tillage, making them prone to bird damage. For timely sowing, the farmers are encouraged to consult with those who have extensive experience of rice cultivation in the area.

2.1.2.2 Lowland rice cultivation

(1) Site selection

In the lowlands, the farmers grow rice in the same fields every year and thus fully understand the gradations in soil fertility in the area and the potential problems (e.g., weed infestation, pests, and flooding).

(2) Land preparation

1) Slashing the vegetation and weed handling

The traditional method of land preparation is acceptable. It reflects the outcome of trial and error by the farmers over the years and their extensive knowledge and experience of the conditions in their fields. The vegetation in the field is slashed (brushed out), dried and then burned.

If there are early rains or the slashing is delayed, the slashed weeds are removed to an area outside the main field or heaped at designated spots (see "Note on Weed Handling" below).

Note on Weed Handling

Weed control plays a key role in rice cultivation regardless of whether it is in the uplands or lowlands. By plowing organic matter (e.g., the weeds) into the soil, nutrients are released as this matter is decomposed. However, this only applies where there are well-aerated conditions, as in upland cultivation.

Under oxygen-deficient conditions as in case of submergence, the decomposition of organic matter leads to an increase in iron in the soil, which the rice plant can absorb (as ferrous is converted into ferric iron), especially when there is a deficiency of minerals in the soil.

A healthy rice plant can tolerate a certain level of iron since it actively expels ferric iron. When the ferric concentration in the soil exceeds the threshold or when the nutritional conditions of the plant are unfavorable, however, the plant will suffer from iron toxicity since this is prevalent in many lowlands, especially in IVS areas.

Drainage helps to wash out and oxidize ferric iron, but it is difficult to drain water from fields in the lower areas of lowlands and this requires lengthy and laborious work. The farmers should try to remove as many of the weeds from the main field as possible to keep them from being mixed into the soil and prevent iron toxicity where it is expected.

2) Dike (bund) construction

Running water in rice fields causes the soil to erode, nutrients to leach from the component soil minerals and applied fertilizer, and transplanted seedlings to flow away. Nutrient supply carried in by water is limited in such areas. To avoid or minimize the negative effects of running water, the water should be controlled.

Small-scale dikes and drainage structures are recommended in IVS, boliland and associated mangrove swamp areas. Firstly, water drainage needs to be considered. Dikes are constructed after slashing or plowing and before puddling. Because there is no hydrological data for Kambia District at present, the farmers and experts should work together in the field utilizing the farmers' experience and observation as a source of hydrological information.

3) Plowing (digging)

The plowing practices currently adopted by the farmers are acceptable, in which soils are plowed using a long-handled large hoe designed for the heavy clay soils in the area. Deep plowing (20 to 30 cm deep) is recommended, although it is often difficult to plow beyond 10 cm deep with manual plowing.

The main field should be plowed before sowing in the nursery. In the mangrove swamp areas, the rice fields should be plowed well before nursery preparation starts to allow sufficient time for any accumulated salts to be washed out of the soil.

4) Seedling raising in the nurseries

In the transplanting method, the first step in attaining a high yield is to raise healthy and sturdy seedlings. Such seedlings are ready to extend new roots into the soil of the main field with sufficiently accumulated carbohydrate and mineral nutrients, and autonomous growth will start within a few days after transplanting. Excessive elongation of the shoots (etiolation) should be avoided, for etiolated seedlings lack nutrient accumulation in their body even though they grow tall.

a) Nursery preparation: Since nursery preparation does not require much labor, it should be started after plowing is completed. For rice cultivation in the mangrove swamp areas, first the transplanting date is determined during a low-tide period and then the date of sowing in the nursery is set counting backwards from the transplantation, based on the optimum duration (4 weeks) to raise the seedlings.

b) Location: A spot well exposed to the sun should be selected for the nursery. If the nursery is shaded, the seedlings will become etiolated.

c) Nursing period: The seedling quality deteriorates if the nursery period is too long. The recommended nursing period is three weeks for IVS and boliland areas and four weeks for mangrove swamp areas as older seedlings have greater salt tolerance.

d) Seed requirements and the nursery area (Table 2.1-1): Assuming that the germination rate is 80%, the plant density is 20 hills/m^2, the number of seedlings is three per hill, the emerging (sprouting) rate in situ is 75%, and the 1,000-grain weight is 25 g, the quantity of seeds needed in order to cover one hectare (= 2.5 acre) of land is calculated as follows:

$$20 \text{ x } 3 \text{ x } 25 / (1{,}000 \text{ x } 0.8 \text{ x } 0.75) = \textit{ca.}\ 25 \text{ kg/ha} \qquad \text{(eq. 1)}$$

$$= \textit{ca.}10 \text{ kg/acre} = 0.4 \text{ bu/acre}$$

When the planned field area is large and transplanting cannot be completed within a few days, it is prudent to sow the seeds in the nurseries on different days according to the transplanting schedule. It should be borne in mind again that the first priority is to keep the seedling in the nurseries for just the right period of time so that they are at the optimal level of maturity for transplanting.

Table 2.1-1 Seed Requirements to Transplant the Seedlings in the Main Field

No. of seedlings /hill	Seed requirement (kg/ha) (a)			Nursery area (m^2)	Seed requirement (kg/ha) (a)			Nursery area (sq.yard)
	1,000-grain weight (g)				1,000-grain weight(g)			
	20	25	30	(b)	20	25	30	(b)
1	7	8	10	120	0.1	0.1	0.2	60
2	13	17	20	250	0.2	0.3	0.3	120
3	20	25	30	350	0.3	0.4	0.5	170
4	27	33	40	500	0.4	0.5	0.6	230
6	40	50	60	700	0.6	0.8	1.0	350
10	67	83	100	1,200	1.1	1.3	1.6	570

(a) Calculated on the basis of 20 hill/m^2 as hill density, 80% germination by incubation, and 75% emergence (sprout) in nursery. Conversion rate; 1 bu (bushel) = 25kg (official rate): 1acre = ca. 0.4 ha: 1 square (sq.) yard = 0.836 m^2.

(b) The given nursery area is only applicable to 3-week-old seedlings with a variation allowance of 20%.

e) Seeding rate: A seeding rate of one bu/acre (= 63 kg/ha) is adopted for lowland rice transplanting, which is the same as that for upland areas. However, this rate is too high since it is based on the number of seedlings for transplanting at a rate of 6 to 10 per hill. Transplanting 2 to 3 seedlings/hill is sufficient to produce the necessary number of panicles for a reasonably high yield. It should be kept in mind that one advantage of transplanting is to save seed rice.

f) Nursery size: The information on the nursery size in Table 2.1-1 is for reference only, since the sprouting rate of seeds in nurseries is unstable. The sprouting rate is highly site-specific and is prone to be affected by the properties of the soil and climatic conditions.

   In general, a sparse density (wider nursery area for a given quantity of seeds) is favorable for the healthy growth of the seedlings since there is less competition for light and nutrients. For mangrove swamps, the nursery area for 4-week-old seedlings should be 1.5 times that shown in Table 2.1-1.

g) Dry versus wet nurseries: As long as the land is available, a dry nursery is strongly recommended. A suitable area of dry land is located and a nursery is prepared with fine tillage. Based on the Pilot Project (Part IV Annex 1) and observations of the farmers' nurseries, various disadvantages of a wet nursery have been noted, such as the frequent occurrence of iron toxicity, diseases and seedling etiolation. In Kambia District, a few farmers sow the seeds under water, but many farmers do so on the lower ground near lowlands.

   The nursery is dry at the sowing time but it soon becomes saturated or submerged by rain or water seepage. Such seedling beds can be broadly categorized as a wet nursery. In wet nurseries, iron toxicity is prevalent due to soil reduction caused by submergence. In addition, the high level of moisture leads to fungal diseases and, combined with high temperatures, promotes etiolation of the seedlings.

h) Uniform broadcasting and tillage: For uniform broadcasting, the seeds are divided into three at a 1:2 ratio, of which 2/3 is broadcast first and the remaining 1/3 is used to even out any uneven distribution of the seeds in the field (see the details in the note on "Uniform Seed Broadcasting" for upland rice). The field is shallow-tilled immediately after the broadcasting.

i) Mulching: Mulching with palm fronds, etc., for a few days after sowing is recommended to protect the seedlings from heavy rains, as has been practiced by many farmers. This practice also helps prevent bird damage.

j) Bird scaring: Birds should be scared away for a week or so, starting immediately after sowing.

k) Weeding: Timely weeding is advised as necessary. If the seeding rate is appropriate, regular weeding will not be necessary.

5) Puddling

Sufficient puddling is essential for shallow planting (Figure 2.1-3) that allows first the new roots and then the tillers to develop rapidly and vigorously. For efficient transplanting, large clods should be broken into small pieces until they become like mud. However, proper puddling is rarely observed in Kambia District.

The farmers generally stop after breaking the large clods (20 to 40 cm) made by plowing into smaller clods (5 to 20 cm). (They call this activity 'turn-over'.) Some farmers do better by stamping their feet on the clods to further break them down into mud over the spot (a few square meters) required for a handful of seedlings.

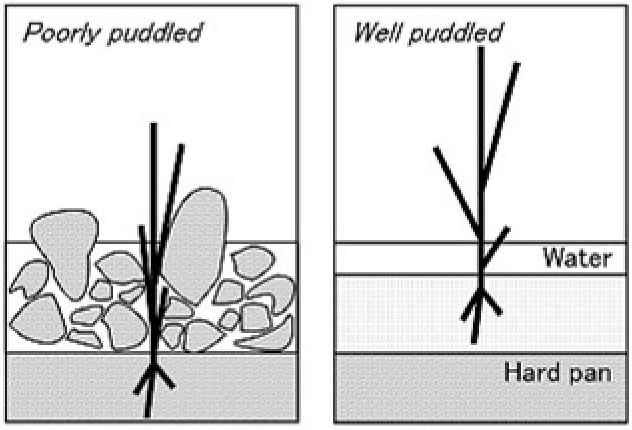


Figure 2.1-3 Poor and Good Puddling

Note: Shallow transplanting is possible only when the main field is well puddled.

(3) Transplanting

If transplanted properly, healthy seedlings start to develop new roots in a day or a few days at the latest and successively develop tillers from every leaf node (Photo 2.1-1). Thus, when good seedlings are transplanted, a sufficient number of tillers (eventually panicles) foretelling a high yield may grow at an early stage of growth.

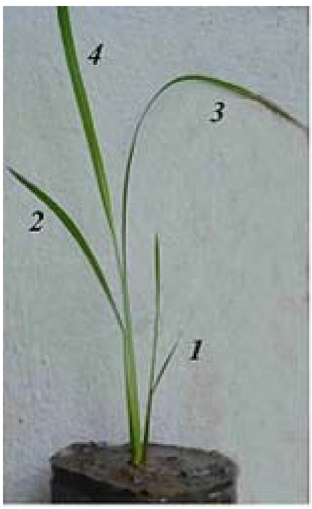


Photo 2.1-1 Rice Plant at the 4th Leaf Stage

Note: The first tiller emerges at the 1st leaf node. The figure indicates the numerical order of the growth of the leaves on the main stem.

1) Date and timing of transplanting

In IVS and boliland, the seedlings can be transplanted at any time between June and September, depending on the growth duration of the varieties used, the environmental conditions (especially water availability at the late grain-filling period), and the preference of the farmer. In the mangrove swamp areas, on the other hand, the transplanting season is from late July to early September after the salts have been washed out of the soil.

The time of transplanting should be during a neap tide, which allows shallow transplanting. The tidal movement is predictable according to the phase of the moon with a waxing or waning crescent at a low tide. Although it is within the season, late August should be avoided since heavy rain is expected and the planted seedlings may be swept away by flooding.

2) Uprooting

The seedlings should be uprooted from the nursery beds on the same day they are to be transplanted. If old and tall seedlings must be used for any reason, they should be trimmed since trimming lessens the water loss from transpiration and mitigates damage after transplanting.

The roots of the seedlings developed in the nursery become inactive as new roots develop from the stem base and extend into the soil to take a firm hold in the main field. The stem base should therefore not to be damaged, and attention should be paid to avoid knocking the seedlings hard with the hands or feet when the mud is being removed from them.

It is prudent to pick only a few seedlings at a time so that by gently shaking or brushing them the mud can be removed, as some farmers do. It is an easy and fast way to remove the mud, and it is almost as fast as pulling out a handful of seedlings at a time. Trimming the roots does not affect the quality of the seedlings. Washing the roots in water is also an appropriate way to remove the soil.

3) Planting (hill) density

The recommended planting density is about 20 hill/m^2 (hill spacing: 20 cm x 25 cm) for medium to late growth duration varieties. Because the tillering ability of many varieties currently used in the area is high, they adapt themselves to irregular plant spacing. Nevertheless, spacing them too close should be avoided.

The number of panicles per unit field area does not increase in proportion to any increase in the planting density: it is controlled by the availability of nutrients and solar radiation, in addition to the varietal traits. Besides, close spacing induces vertical growth in the plant, rendering it susceptible to lodging. However, slightly closer spacing can be recommended for short duration (90 to 100 days) varieties (e.g., Buttercup, Kissy fundy, etc.). Line transplanting makes weeding easy. However, it is optional because it is more time consuming and labor intensive than random transplanting.

4) Number of seedlings per hill

The recommended number of seedlings per hill is 2 to 3 regardless of the agro-ecological regime, including mangrove swamp areas. The number of panicles per unit field area (eventually grain yield) does not increase with the number of seedlings per hill. The reason is the same as for the planting density mentioned above. Using fewer seedlings means economizing on seeds. By planting fewer seedlings per hill, the farmers can easily cut their seed costs by up to 1/4 or 1/5 of the present cost of planting 10 seedlings/hill or even some who plant a higher number per hill (Table 2.1-1).

5) Planting depth

The recommended transplanting depth is 2 to 3 cm. This shallow planting promotes the rapid development of new roots and tillers (Figure 2.1-4) and eventually a greater number of panicles, which is a dominant component of grain yield. The farmers should pay attention to avoiding transplanting too deeply and also avoid folding the stem of the seedling, especially when using a planting fork (Photo 2.1-2 and Figure 2.1-5). In the mangrove swamp areas, transplanting during a low tide is essential to prevent a loss of seedlings when the ebb tide occurs.

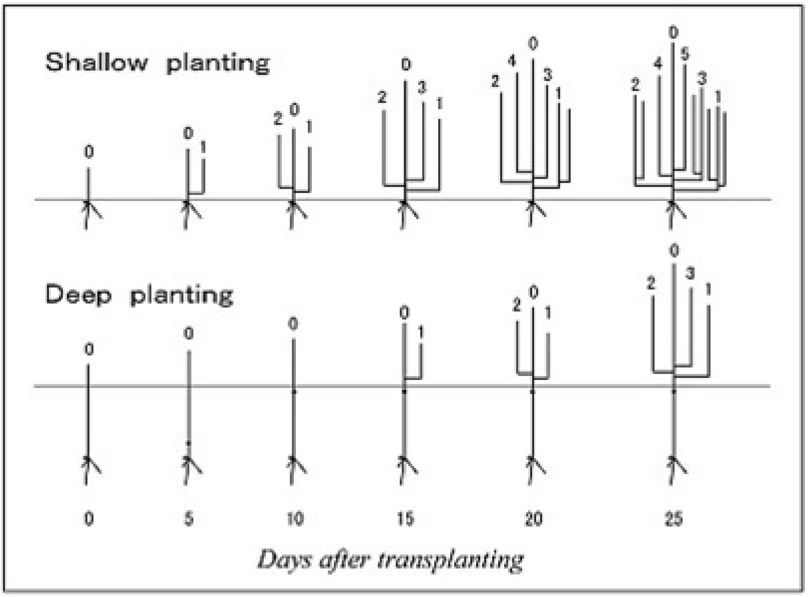


Figure 2.1-4　Tiller Development by Shallow and Deep Transplanting

Note: The figures indicate the numerical order of the growth of the leaves on the main stem.

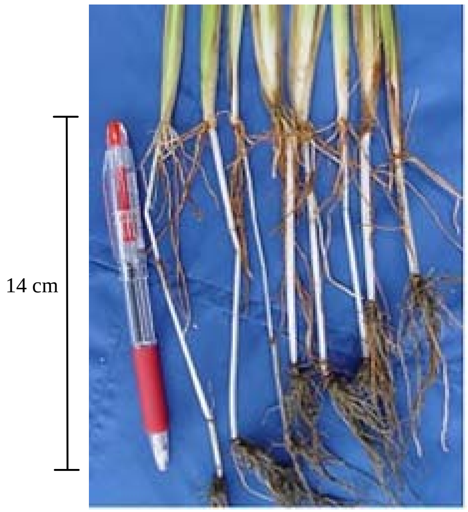


Photo 2.1-2 Elongated Mesocotyls Due to Deep Transplanting

Note: Deep transplanting causes a delay in tiller development.

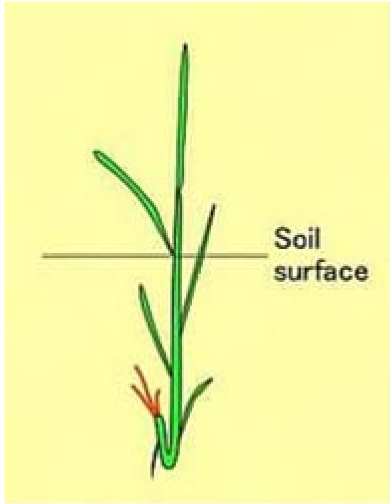


Figure 2.1-5 Folded Stem of a Seedling Due to the Improper Use of a Planting Fork

6) Filling the missing hills

The missing hills must be filled starting on the day following transplanting for about a week. At the same time, any disturbance to the main field should be carefully monitored, such as from the inflow of heaped weeds from the surrounding fields after a heavy rain or high tide.

2.1.3 Weed and pest control

The growth of rice plants is affected by weeds and various pests. Some dominant pests in the various agro-ecologies in Kambia District are shown in Table 2.1-2. It should be noted that the use of agrochemicals for pest control is not included in this section.

Table 2.1-2 Frequent Occurrence of Weed and Pest Damage in Various Agro-ecologies of Rice Cultivation

Pest		Upland	IVS	Boliland	Mangrove swamp
Weed		○	○	○	
Rodent	Cutting-grass	○	○	○	
Bird	Weaver	○	○	○	○
	Bush fowl	○			
	Water duck				○
Crab					○
Insect	Gall midge		○	○	○
	Case-worm		○	○	
	Leafhopper	○	○	○	
	Rice bug	○	○	○	○
Disease	Brown spot	○	○	○	○
	Leaf scald	○	○	○	○

(1) Weeds

The prevalent weeds are grasses, sedges, broad-leaved weeds, etc., which are all site-specific. One complete weeding 4 to 6 weeks after sowing or transplanting is a must. Pulling weeds by hand is the traditional and most direct way of controlling weeds in rice fields. As the rice plants grow normally, they form a canopy that suppresses weed growth by blocking the sunlight. However, when the growth of the rice plants is retarded (due to improper transplanting, malnutrition, etc.), continuous weeding may be required until the plants reach the level of normal growth.

The nursery, the main field and the surrounding area should be kept clean at all times. Cleaning helps prevent rodent attacks and the occurrence of diseases as well as insect damage. In the mangrove swamp areas, weeding is not necessary because the growth of the dominant weed ('kireh-kireh') is suppressed by the rice plants growing over it.

(2) Rodents

Cutting-grass (cane rats) sometimes cause serious damage to the rice plants because they move in groups and feed on the plants and rice. They are common in upland, IVS and boliland areas, and in many cases, their attack is site specific. Any site where an attack is expected should be protected using fencing and traps. Hunting nets may be used to catch them, and slashing the bush around the rice fields is also effective. In the northern part of Kambia District, several villages cooperate with each other and concentrate their farms to guard against rodents.

(3) Birds

In the main field, bird scaring (mainly for weaverbirds) should start immediately after flowering regardless of the agro-ecologies. Bird scaring is essential at the time of broadcasting upland rice seeds and when transplanting from the nursery and should be started on the day of sowing. If the area intended for the nursery is not large, it is prudent to prepare the nursery in the backyard of the house, as is practiced by many farmers. Water ducks sometimes cause serious damage to the seeds in nurseries prepared in mangrove swamps.

(4) Crabs (in the mangrove swamp)

Several species of crabs attack young rice in the mangrove swamp 2 to 3 weeks after transplanting. These crabs feed on the tissues of the rice plant by cutting its stem or leaves. Old seedlings are less likely to be attacked by the crabs. This could be the reason why the farmers tend to delay transplantation in the mangrove swamps. Crab damage may be severe along small creeks at the border of the high and low tide zone. Transplanting in August or September during the incubation (inactive) period of the crabs is one way to prevent possible crab damage. It should be noted that no close relationship between the number of seedlings and crab damage was found (Part IV Annex1).

(5) Insects

Generally, the occurrence of insect damage in Kambia District is low, possibly due to the heavy rains during the cropping season. Nevertheless, two species of insect are frequently observed.

1) Gall midge

The maggot-like larva of the gall midge, a small fly similar in appearance and size to a mosquito, feeds on the rice plant inside its developing tillers, causing their base to swell as galls (Reissig, et al., 1986) and the leaves to turn into an onion-like form. As long as the extent of the infection is confined to 10% of the total number of hills and 1 to 2 tillers per hill at the maximum (usual in Kambia District), its effects on the final yield will be minimal since other or new tillers compensate for the loss.

Nevertheless, the damage can be serious, as farmers in some parts of Samu chiefdom reportedly abandoned the affected rice fields because of gall midge damage. Varieties resistant to the insect are available; however, there are many biotypes of the gall midge and the selected variety may be vulnerable to the type of gall midge in the area (Reissing, et al., 1986).

2) Caseworm

The larvae of the caseworm cut parts of the leaves of young rice plants and roll them into tubes called cases (Reissing, et al., 1986). The pattern of caseworm damage in the fields is not uniform since the larvae living in their cases are often carried from one side of the rice field to another by the wind or water currents. The damage can be controlled by early planting and drainage.

Infection by the aforementioned two insect species occurs only up to the active tillering stage of the rice plant. Other pest insects of rice include the leafhopper and rice bug. Stem-borer and stalked-eye fly can be observed, but are rare.

(6) Diseases

Brown spot and related fungal diseases are common and found across all the rice agro-ecologies. Brown spot (Photo 2.1-3) is a physiological disease, caused by a nutrient imbalance in the rice plant. It is rare in rice plants grown in fertile soils (IRRI, 1986). The leaves of a rice plant affected by brown spot often show potassium deficiency symptoms and low potassium concentration. Potassium fertilizer or NPK compound fertilizer is effective in remedying the disease.

Leaf-scald (Photo 2.1-4) is a fungal as well as a physiological disease. To prevent this disease, the sole use of nitrogenous fertilizer should be avoided. Rice blast is often found in old seedlings in nurseries but is not common in upland rice possibly because of the favorable rainfall in the uplands. Viral diseases such as rice yellow mottle virus disease are rare in Kambia District.

Photo 2.1-3 Brown Spot

Photo 2.1-4 Leaf-scald

2.1.4 Fertilizer management

(1) Dosage of fertilizer applications

The recommended application of fertilizer is two bags (50 kg/bag) of compound fertilizer per hectare as a basal application and one bag each of compound fertilizer and urea as a top-dressing at the panicle initiation stage. The recommended type of compound fertilizer is either of 15-15-15 or 17-17-17. The amount of nutrients to be applied eventually is about 55:25:25 kg/ha of $N:P_2O_5:K_2O$. It should be noted that the application rate per acre may be nearly 1 bag of compound fertilizer as a basal application and one-half bag each of compound fertilizer and urea as a top-dressing.

The recommended fertilizer rate may be modified according to the type of soil. For example, two bags of compound fertilizer per hectare are recommended for both basal and top-dressing in tropical peat soils as found in Sabuya IVS, one of the pilot project sites. As organic matter is decomposed by drainage, nitrogen is released. If nitrogen is added further through the application of fertilizer, the nutrients in the soil will become imbalanced.

(2) Supplementary information

1) Timing of fertilizer application

Based on the development process of various yield components (Figure 2.1-2), fertilizer is first applied at sowing for upland rice and at transplanting for lowland rice to promote tillering at the early stage of growth, since tillers produce panicles, a dominant component of the yield. Fertilizer is applied next at the panicle initiation stage, during which spikelets are formed on the developing panicles.

2) Uniform application of fertilizers

As described in the "Note on Uniform Seed Broadcasting" (p.2-7), an equal amount of fertilizers should be applied to each of the sub-plots in the field. The fertilizers should be mixed with dried soil (e.g., sand, etc.) if the quantity is limited.

3) Nutrient status of soils and plants

The recommended dose of fertilizers somewhat emphasizes the importance of phosphorus and potassium, reflecting the general nutritional status of soils and plants. Firstly, the nutritional status of the soils in Kambia District (that are probably similar in other parts of Sierra Leone) is generally poor (Part IV Annex 3, 3.2). Not only nitrogen, but also potassium, phosphorus and micronutrients are lacking in many soils. Since plant growth is limited by the nutrient that is in the least supply, it is necessary to find the limiting nutrient to identify the optimal combination of fertilizer elements. Besides, the limiting nutrient varies from place to place. Without chemical analysis, the nutrient levels of the plants and soils can hardly be diagnosed. However, such facilities are not easily accessible at present.

Secondly, several nutritional disorders have been identified based on the results of chemical analysis of plants and soils (Part IV Annex 3, 3.2), in the pilot projects (Part IV Annex 1) and also as a result of observation of the plants in the farmers' fields. Potassium deficiency is most common, resulting in the prevalence of brown spot. Leaf discoloration to yellow-orange is also common, likely induced by phosphorus deficiency.

In addition, iron toxicity is observed in the lowlands. It is caused by a lack of oxygen derived from the decomposition of organic matter (weeds) in the soil along with a shortage of minerals in the soil and the malnutrition in the plants. In some patches close to the fringe of a mangrove swamp, hydrogen sulfide (H_2S) toxicity is found, which disturbs the respiratory metabolism of plants killing them even at a low level. Because the areas affected by H_2S are specific and identified and also mitigation measures are costly, it is advised not to grow rice in such areas.

4) Water control for fertilizer application

It should be common knowledge that the majority of chemical fertilizers easily dissolve in water. Chemical fertilizers must not be put into running water, since the effects are disastrous. Heavy rains also cause runoff. To prevent such water losses, dikes (bunds) must be constructed in IVS and boliland areas. In the mangrove swamp areas, high tides during the spring tide period cannot be controlled by ordinary dikes. Fertilizers can be applied only to limited areas where the soil surface is not submerged by tidewater for at least one week in the neap tide period. Such areas should be identified before the fertilizers are applied.

5) Cost-benefit ratio with fertilizer applications

Through the Pilot Project in 2007 and 2008, the fertilizer response of grain yield was found to be about 0.5 ton/ha (= 8 bu/acre) on average and 1.0 ton/ha (= 16 bu/acre) at the maximum (Part IV Annex 1). The fertilizer costs cannot be covered by such a low increment in the rice yield under the present economic conditions in Sierra Leone.

The yield response can be increased with improvements in crop management. Yield increases of up to 1 ton/ha at the maximum are possible with the recommended use of fertilizer. It should be kept in mind that fertilizer itself is not a universal remedy and its full benefits are gained only with good cultivation practices.

(2) Fertilizer application to nurseries

In general, fertilizer application to nurseries is not recommended although some dose of fertilizer may be applied to seedbeds. The use of fertilizer in the nursery should be carefully considered. Fertilizer application is acceptable when it is sunny but it should be avoided when cloudy days continue or the seedlings are growing in wet conditions. Under such conditions, the seedlings become etiolated and prone to diseases. The sole use of nitrogenous fertilizer is not recommended. Instead, PK or NPK compound fertilizers (e.g., 15-15-15) should be used, if necessary.

2.1.5 Harvesting

The maturity of the grains can be inferred from some indicators: (a) when the majority (about 85%) of the grains turns brown or golden in color, (b) dryness and hardness judging from biting them (c) the degree of grain shattering, and (d) when the color at the panicle base and uppermost internode turns to yellow (or a dried state). When the color of the husk (hull) turns brown, violet or black, any one of the latter three indicators above ((b), (c) or (d)) or a combination of these indicators may be used.

Matured grains should be harvested early in the morning if they are fully ripe. Harvesting in the mid afternoon especially during the harmattan period predisposes the panicles to grain shattering or panicle breakage. It is strongly advised to sharpen knives frequently during harvesting as is practiced by many farmers.

2.1.6 Seed handling

(1) Germination test

The germination rate of seed rice should always be tested to estimate the quantity of the seeds needed and to evaluate their viability as well. The rate should preferably be higher than 80%. If it is less than 80%, it is advisable to discard the stock and try to find better quality seeds.

A germination test is performed as follows.

a) Place a sheet of clean absorbent paper or cloth in a shallow container (100 to 200 mm in diameter).
b) Select 100 seeds randomly from a stock and spread them evenly on the paper or cloth in the container.
c) Pour a sufficient amount of water for the seeds to become soaked and cover the container with any material that prevents excess evaporation.
d) Leave the container in a room for 4 to 5 days.
e) Count the number of germinated seeds in the container.

(2) Seed production

1) Securing pure seeds

All subsistence farmers should rely on the seeds that they produce themselves. Only the farmers themselves can guarantee the purity and viability of the seeds. For the present level of grain yield (2 to 3 ton/ha at the maximum), mixing varieties would not affect the production substantially despite different maturation periods and physical characteristics. Because of this, many farmers do not pay much attention to the purity of the seeds they use.

Mixing seeds of different varieties, however, makes it difficult to determine the timing of the harvest. Under the present conditions in which the rate of grain shattering is high in many varieties grown in Kambia District and panicle harvesting is not common, the farmers are destined to lose part of the expected production of either early or late maturing varieties if the seeds that they use are impure.

The surest way to obtain pure seeds is to visit a rice field regularly (e.g., twice a month throughout the rice growth) and pull out or rogue any off-type plants that are different from the majority of the plants in the field, as soon as they are found. At present, the farmers sometimes rogue off-type plants (often by cutting the panicles only) shortly before the harvesting time and use them for food (to save wastage of the transplanted plants). With this practice, late maturing genotypes cannot be rouged since the grains of these types are able to germinate even though they are not fully matured.

2) Self supply of seed stock

Seed supply is the lifeline of the farmers. If the required quantity of seeds cannot be stocked in a single year, the farmer must make efforts to stock at least a portion of the required quantity every year. Through such efforts, farmers will eventually be able to secure their own seeds in a few years.

(3) Some plant traits of ROK and other varieties

Some traits of selected varieties of ROK series are summarized in Table 2.1-3. Unfortunately, their genetic background and such important traits as plant type, lodging resistance, details of disease tolerance, grain type, degree of shattering, seed dormancy, etc., are not available.

Table 2.1-3 Some Traits of Selected ROK Varieties

Variety	Agro-ecology adapted				Growth duration	Plant height	Potential yield	1,000-grain weight	Tolerance (e)				
(b)	Up-land	IVS	Boli-land	MS (c)	(day) (d)	(cm)	(ton/ha)	(g)	Blast	Lodg-ing	Salt	Iron toxi-city	Deep water (f)
ROK 3	x	x	x		125-150	110-140	1.5-3.5	27-28	R	R			
ROK 5				x	135-160	135	2.5-4.5	28-29	MS	S	MR		
ROK 10		x	x	x	130-190	130-140	1.5-3.5	20			MR		MR
ROK 14		x			140	95	2.5-6.0	23					
ROK 16	x				120	120	2.0-3.0	-					
ROK 20	x				115	105	2.0-3.0	-					
ROK 22				x	125	110	2.5-4.5	-			MR		
ROK 24		x			145	115	2.0-3.5	20				MR	
ROK 30			x		170	130	2.0-4.0	-					
ROK 31		x			130	90	2.0-3.5	-					

a) Source: RRS-R (2005), personal communication and field observation. All varieties have been selected for tolerance to major pests and diseases in Sierra Leone (MAFS, et al., 2005).
b) Many varieties like ROK 3, ROK 5, ROK 10, ROK 14 and ROK 24 are high in tillering ability (Annex 1.4)
c) MS: mangrove swamp
d) ROK 14 is suitable for double cropping (RRS-R, 2005).
e) R: resistant, MR: moderately resistant, MS: moderately susceptible, S: susceptible.
f) ROK 10: tolerate up to about 50 cm depth.

ROK 10 can survive in water 40 to 50 cm deep if planted early enough (Part IV Annex 1). In the flood-prone boliland, Indochina Blanc, a floating rice variety, is the only choice, which has already been grown in Kambia District. The farmers grow various native and introduced cultivars the duration of whose growth period ranges from 3 to 6 months and each one possesses unique characteristics. Some are likely to be superior to ROK varieties in certain locations. When the farmers obtain a new variety based on available information, they should test it in a small plot first and evaluate it by themselves as to its suitability to their field conditions. It should be borne in mind that there is no such thing as a versatile cultivar.

2.1.7 Terminology and conversion rates

(1) Terminology

gall midge: *Orseolia oryzae* (*Pachydiplosis oryzae*)
blast: *Magnaporthe grisea* (*Pyricularia oryzae*)
brown spot: *Cochliobolus miyabeanus* (*Helminthosporium oryzae*)

bush fowl: *Francolins bicolcoratus*
case-worm: *Nymphula depunctalis, Parapoynx stagnalis*
cutting-grass: *Thyronomis swinderiannus*. In other regions of West Africa, it is called grass-cutter.
crawling grass: *Paspalum vaginatum*, indigenous species in the area. In the local language, 'kireh-kireh (or kiri-kiri)'.
leaf scald: *Metasphaeria albescens*, *Fusariumn ivale* & *Rhynchosporium oryzae*
leafhopper: *Nephotettix spp.*
oil palm: *Elaeis guineensis*
rice bug: *Scotinophra spp.*
plant-hopper: *Nilaparvata spp.*, *Sogatella spp.*
stalked-eye fly: *Diopsis thoracica*
stem-borer: *Chilo spp.*, *Maliarpha spp.*
water duck: 'ealele' in Temne
weaver: *Ploceus cucullatus, Quelea quelea*

(2) Conversion rates

bu (bushel): The official rate is 25 kg/bu for rough rice (brown rice with husk or paddy). However, the going rate is 32 to 33 kg/bu in Mambolo, Samu, Gbinleh Dixing and Magbema chiefdoms and 48 to 52 kg/bu in Masungbala, Tonko Limba and Bramaia chiefdoms (Part IV, Annex 3.6).

1 bag of fertilizer = 50 kg

1 ha = *ca*. 2.5 acre, or 1 acre = *ca*. 0.4 ha

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2.2 Cost-Benefit Analysis

2.2.1 Procedures for conducting a cost-benefit analysis

The purpose of a cost-benefit analysis is to clarify the profitability of rice cultivation activities in the field. The cost-benefit ratio for rice production is analyzed as follows.

Clarify the production volume per hectare (yield)

↓

Clarify and determine the sales price of rice (rice with husk) per ton

↓

Calculate the gross income (yield × sales price)

↓

Calculate the cost of rice production per hectare

↓

Calculate profitability per acre (gross income – production cost)

2.2.2 Calculation of profitability

(1) Determination of the preconditions for the calculation of profitability

To calculate profitability, yield, unit price and production costs should be estimated as follows.

1) Yield

Yield is expressed in tons per hectare (ha).

Note: 1 ton/ha = 16 bushel/acre (1,000 kg/ 25 kg/bushel x 0.4 acre/ha)
1 ton = 1,000kg, 1 bu = 25kg, 1 acre = 0.4 ha

2) Sales price of rice (rice with husk)

The sales price of rice with the husk changes through the year. Generally, it is the lowest in December and January and the lowest price is used for the calculation of profitability. The reason for using the lowest price is to avoid inflating profitability based on speculation that rice will sell at higher prices during the year.

Note: The average sales price of rice per annum is Le 716,000/ton (Le 716/kg x 1,000 kg) = Le 17,900/bu (25 kg/bushel x Le 716/kg). The base sales price (Le 716/kg) was obtained from field surveys in the seven pilot project villages (2008).

3) Production costs

The production costs are calculated separately for variable expenses and fixed expenses.

(a) Variable expenses

Seed rice

The price of seed rice adopted is Le 50,000 per 25 kg, which was the purchase price in Kobia in 2007.

Note: The seed price/kg is Le 2,000 (Le 50,000/25 kg). The sowing rate/ha is 75 kg in the pilot projects. Converted into bu/acre, it is 1.2 bu/acre (75 kg/ha x 0.4 = 30 kg/acre; 30 kg/acre/25 kg per bushel =1.2 bushel/acre).

Fertilizer

The purchase price of fertilizer used is Le 145,000/bag (50kg) in the Barmoi Luma market (2008).

Note: Fertilizer inputs 4 bags/ha = 200 kg/ha (50 kg x 4 bags) in the pilot projects (i.e., 200 kg/bu (25 kg) = 8 bu/acre).

Labor costs

Labor costs are based on the results of interviews conducted in the seven pilot project villages in 2008. The average labor requirement in one cropping season for rice is about 55 persons from land preparation until harvest. The wage for a laborer per day ranges from Le 3,000 to Le 5,000. Family labor costs are excluded from the production costs.

(b) Fixed expenses

Farming tools

The cost of farming tools is obtained from MAFFS-K field survey data in 2008, which is Le 35,000/ha (Le 35,000 x 0.4 = Le 14,000/acre).

(2) Profitability estimate

Tables 2.2-1 and 2.2-2 show the estimated profitability of rice cultivation per hectare in different cases of yield. The following can be pointed out from the tables.

a) It is important to disseminate those techniques that will lead to yield increases without significant labor costs, which account for 75% of the total production costs under the *no fertilizer application* condition.

b) To reduce labor costs, the introduction of agricultural machinery is an option. However, the farmers generally cannot afford this under their present economic conditions, so it is not a feasible option.

c) Under the *fertilizer application* condition, the share of the production costs is about the same for labor costs and fertilizer costs. If the yield reached two tons or more per hectare, the fertilizer costs can be paid for from the profits. The price of fertilizer was Le 135,000 per bag in 2007 but rose to Le 145,000 in 2008. Fertilizer costs tend to increase year by year.

d) As mentioned above, the family labor costs are excluded from the production costs. The total family labor requirement in one cropping season is about 60 persons, which may be converted into Le 600,000. The total production costs reach about Le 2,000,000 if family labor costs are added. In this case, a yield of three tons or more is necessary to turn a profit.

Table 2.2-1 Estimated Profitability under the No Fertilizer Application Condition

Yield: 1.0 ton/ha

Components	Without fertilizer application			
I. Income				
I-1 Sales price			716,000	Le/ton
I-2 Gross income			716,000	Le/ha
II. Production cost	Unit price	Quantities	Total	%
II-1 Variable expense	(Le/ha)	(kg)	(Le/ha)	
Seed	2,000	75	150,000	21
Fertilizer	-	-	-	
Labor *	4,000	55	528,000	74
II-2 Fixed expense				
Farming tools		1set/season	35,000	5
II-3 Total cost (I-1+I-2)			713,000	100
III. Profit (I-2-II-3)			3,000	Le/ha
IV. Profit ratio (III/I-2)			0.4	%

*The figure for the amount of labor refer to the labor requirements for one cropping season.

Table 2.2-2 Estimated Profitability under the Fertilizer Application Condition

Yield 2.0 ton/ha

Components	With fertilizer application			
I. Income				
I-1. Sales price			716,000	Le/ton
I-2 Gross income			1,432,000	Le/ha
II. Production cost	Unit price	Quantities	Total	%
II-1 Variable expense	(Le/ha)	(kg)	(Le/ha)	
Seed	2,000	75	150,000	12
Fertilizer	2,900	200	580,000	45
Labor *	4,000	55	528,000	41
II-2 Fixed expense				
Farming tools		1set/season	35,000	3
II-3 Total cost (I-1+I-2)			1,293,000	100
III. Profit (I-2-II-3)			139,000	Le/ha
IV. Profit ratio (III/I-2)			9.7	%

*The figure for the amount of labor refer to the labor requirements for one cropping season.

2.2.3 Breakeven point

Through the calculation of profitability, the breakeven point between the yield and the price can be estimated as follows.

a) The breakeven point in the yield represents the level of yield necessary to cover all the production costs given a fixed price for the rice. Through a breakeven analysis, the level of the yield required to produce a profit can be determined according to the sales price as presented below.

Breakeven point in yield = Total production costs/rice sales price

b) The breakeven point in the price represents the sales price of rice necessary to cover all the production costs given a fixed level of yield. In the breakeven analysis, the price that is required in order to secure a profit can be determined from the level of the yield as presented below.

Breakeven point in price = Total production costs/yield

As shown in Table 2.2-1, the total production costs are estimated at Le 712,500 per ha, and in this case the breakeven point in price is calculated as shown in Table 2.2-3.

Table 2.2-3 Estimated Breakeven Points in the Yield and the Price

Sales price (Le/ton)	Breakeven point in the yield (ton/ha)	Yield (ton/ha)	Breakeven point in the sales price (Le/ton)
300,000	2.4	1.0	713,000
600,000	1.2	3.0	238,000
800,000	0.8	5.0	143,000

Assuming that the sale price is fixed at Le 300,000/ton, at least 2.4 ton/ha of rice must be produced to make a profit. Otherwise, only a loss will be incurred as inferred from Table 2.2-3. Conversely, when 1.0 ton/ha is produced, the sale price must be over Le 713,000/ton to turn a profit.

2.3 Post-harvest Handling of Rice

2.3.1 Introduction

(1) Overview on post-harvest handling

The post-harvest processes in rice production from harvest to storage can be divided into three categories: (i) handling, (ii) processing and (iii) storage. The operations and tasks in each process are summarized in Table 2.3-1.

Table 2.3-1 Post-harvest Handling Process and Operations

Process Operation	**Task**
1. Handling of rice	
1) Harvesting	Cut straws.
2) Drying	Transport harvested rice to drying area.
3) Threshing	Separate grains from straws.
4) Cleaning	Winnow to remove straws, unfilled grains and other impurities.
2. Processing of rice	
5) Parboiling	Soak, boil and steam paddy rice.
6) Milling	Remove husks and bran from grains.
7) Cleaning	Winnow to remove husks and bran from milled rice.
3. Storage	
8) Storage	Bag and store processed rice.

(2) Causal factors of post-harvest handling losses

By FAO's definition (1994), post harvest loss means any measurable quantitative and qualitative loss ensued from the post harvest handling of a given crop. However, in this TP it refers to quantitative loss that mainly occurs during harvest and post harvest processing. The total post-harvest handling loss in Sierra Leone is said to be about 30% (personal communication with MAFFS-K officials). However, there is no reliable data or information on causes or contributing factors of post harvest loss. According to the results of the interview survey using a questionnaire conducted in the seven pilot project villages, most losses occur during the handling process from harvest to cleaning as shown in Table 2.3-2. One objective of the present TP is to contribute to reducing losses in post harvest handling. In the subsequent sections, appropriate post harvest operations are described with recommended techniques to reduce losses.

Table 2.3-2 Post-harvest Losses Estimated by Farmers in the Pilot Project Villages

Operation	Loss (%)		Main causes
	Average	(Range)*	
1. Handling of rice	**19.2**		
1) Cutting	9.7	(3.2-16.7)	Over-dried panicles, variety and poor harvesting method
2) Drying of sheaves	3.6	(0.8-6.8)	Variety, poor harvesting method, pests, transportation, and lack of tarpaulin
3) Threshing	3.0	(1.3-6.2)	Variety and lack of tarpaulin
4) Cleaning	2.9	(1.5-5.4)	Lack of tarpaulin
2. Processing of rice	**2.6**		
5) Parboiling	0		-
6) Milling	1.5	(0.2-2.6)	Over-dried grains, transportation and rice huller operation
7) Cleaning	1.1	(0.1-2.8)	Lack of tarpaulin
3. Storage	**0.7**		
8) Storage	0.7	(0.1-1.3)	Pests and poor storage facilities
Total losses	**22.5**		

*In the surveyed seven villages

2.3.2 Handling of rice

(1) Cutting

1) Timely cutting

Proper cutting at the right time is essential in attaining the maximum grain yield with the minimum grain losses and quality deterioration. The day of harvest must be carefully determined and the work on the day should be planned in advance. If the optimal time were missed, grains would shatter. The right harvest time is when 80-85% of the grains are straw (yellow) colored (GSI-FAO-Rome, 1999).

The rice field should be visited frequently as the end of the maturity period of rice approaches, and the harvest time is determined from the plant conditions in the field. The work schedule for rice handling on the harvest day should be planned in advance. Accordingly, a suitable site for drying and threshing should be located, and laborers for the handling tasks should be mobilized beforehand.

2) Cutting and making bunches

A typical manual cutting method is to grasp straws at about two third of the straw length above the ground and them with a small straight knife. To minimize the risk of shattering grains, knives should be sharpened before cutting and during cutting as necessary. The cut panicles with straw are held in one hand and as more panicles are cut, they are added to the bundle in the hand. When the bundle is large enough, it is tied with a wisp of straw, and when there are six or seven bundles, they are carried to the drying place.

Straws should be cut a little longer so that the panicles lower on the stems are not rolled in the bunch. By doing this, ventilation to the panicles is improved so that they can be dried faster. Also, with longer straws, the panicles can be threshed by not only a pedal-thresher but also beating or trampling (cf. “field drying”). Then, the bundles or bunches of rice are bound before they are carried to the drying place. It is recommended that binding be done in a container such as large pan or basket, for rice is likely to fall from the bundled panicles during the work. The use of the container is to reduce shattering loss while binding.

(2) Drying of sheaves

1) Transporting

The bound bundles of rice are carried to the place where they are dried. To transport the bundles, a big pan, basket or cloth is recommended for shattering rice as in case of bundling mentioned in the previous section. If the drying place is far away and the crop needs to be transported a long distance, however, there is a risk of handling loss.

2) Field drying

The drying place should be clean and as flat and leveled as possible. Use of bamboo or palm leaf mats for underlay is recommended not only to collect shattered grains but also to prevent the grains from mixing with gravel. Tarpaulin sheets may also be used as underlay but care should be taken not to use them when rain is expected since tarpaulin does not let water through. If there are not enough tarpaulin sheets for both drying and threshing, they should be used for threshing that has priority.

Bunches are collected and stacked at the drying place but they must not be laid directly on the ground, especially in the rainy season. The inside of the stack becomes hot and that would degrade the rice quality because a) molds grow quickly and infest the grains, b) discoloration of the grains may result within the first day of field drying, and c) dry grains may absorb moisture again from wet straw, causing the grains to crack, thereby leading to less head rice after milling.

(3) Threshing

As soon as the bunched rice panicles are adequately dried, they are threshed (to separate grains from straw). The ground preparation for threshing is the same as for drying with bamboo or palm leaf mats over the level ground (that may be covered with tarpaulin). Threshing methods are as follows.

a) Foot threshing or trampling: By trampling on the crop spread on the ground with bare feet

b) Beating against a threshing rack: By striking the crop against a mortar or any hard object (e.g., steel oil drum) set on the ground

c) Beating with stick: By striking the crop spread on the ground with a stick

Any of the above methods is fine as long as the ground is clean and level. Use of tarpaulin would help prevent contamination with impurities (e.g., sand and small stones).

(4) Cleaning

Cleaning works include a) hand sorting and sifting of the bits of straws, chaff and other large and dense materials from the grain piles; b) drying of grains for a few hours; c) winnowing by winnowers (*Kateme* in Temne) or by dropping grains from a basket through a crosswind (practiced mainly in Mambolo and Samu chiefdoms).

Tarpaulin, bamboo mats and palm leaf mats are recommended as underlay to reduce handling losses of rice. For example, tarpaulin on the ground makes it easy collect the paddy and helps prevent contamination of the paddy with impurities.

2.3.3 Processing

(1) Parboiling

In Sierra Leone, rice is mainly sold and consumed as food in the form of parboiled rice. Although the parboiling process is labor intensive, the farmers prefer parboiling rice for the following reasons.

a) Parboiled rice is less likely to break during milling than unprocessed rice.
b) Parboiled rice has better marketing potential (since there is consumers' demand).
c) Parboiling increases the volume of rice through the processing.

The parboiling process has three important steps as follows:

a) Soaking paddy in water to increase its moisture content (to about 30%)
b) Steaming to complete gelatinization
c) Drying paddy to a moisture level safe for milling

Proper drying after gelatinization of starch makes the grains hard and resistant to breakage during milling. Overheating rice by excess boiling or steaming spoils gelatinization. Overheated parboiled rice is thus more prone to breakage after milling than appropriately parboiled rice. Steaming or boiling of grains must be stopped as soon as their husks start to split.

The following steps are indispensable to stop gelatinizing after boiling and steaming:

a) After boiling, remove all the grains and put them in another container.
b) Add fresh cold water until the grains are completely submerged to cool down.
c) Remove all the grains from the container and put them in another container.
d) Add some water and heat it until the steam is visible over the grains in the container.
e) Remove all the grains from the container and allow them to cool down on a mat, tarpaulin or drying floor.

(2) Hulling

Hulling is the process of removing or separating husks (hulls) and bran from the grains to produce the edible portion for consumption. In long-grain varieties, the hull accounts for 18-28% of the grain weight and the brown rice for 72-83%. The brown rice consists of 5-8% bran, 2-3% embryo and 89-94% edible portion. After industrial milling, 100 kg of rough rice yields about 60 kg of white rice, 10 kg of broken grains, 10 kg of bran and flour, and 20 kg of hulls (AGSI-FAO, 1999). In other words, the weight of rice decreases by 40% after hulling (head rice). There are two types of hulling methods observed in Kambia District, manual hulling by pestle and mortar and mechanized hulling by rice huller. In manual hulling, grains are dehulled and whitened gradually as they are ground and pounded in the mortar. However, excessive impact and pressure result in grain breakage in the milled rice. To reduce breakage, rough rice should be duhulled in a small amount at a time. On the other hand, in mechanized hulling, husks are removed or separated from grains together with bran by force of friction in the milling chamber. The huller must be properly operated to minimize milling loss. However, skill and experience are required to operate a huller properly. General characteristics of these hulling methods are presented in Table 2.3-3.

1) Reduction of loss during hulling

The loss of the edible portion of rice by breakage during hulling may be attributed to various factors. However, breakage can be reduced if grains are properly dried prior to hulling and the drying of grains can be easily controlled by the farmers. To prevent excessive drying, grains should be mixed and tuned over at some intervals while they are dried.

2) Mechanized hulling

Husks and bran are separated from grains in two operations (two-pass) in Kambia district. After one pass, its byproduct (a mixture of husks and bran) is used to improve the milling recovery for the second pass. The operator can select one operation (one-pass) by controlling the retention time of grains in the hulling chamber with the adjustment of “feed valve” and “discharge valve”. However, more fuel is required for one-pass than two-pass since one-pass operation is more taxing to the engine for keeping high pressure in the chamber.

Table 2.3-3 General Characteristics of Two Hulling Methods

Tool/equipment	Description	Process	Additional information	Comment
Mortar and pestle	Consists of wooden mortar and long heavy wooden pestle, with which to pound the paddy repeatedly against the inner wall of mortar	Dehulling and polishing to produce milled rice	Mortar is not sunk in the ground. Several people may work together in synchronous action.	Byproducts (bran and broken) are lost with husks.
Rice huller (Engelberg type)	Consists of fluted cylinder on shaft enclosed in hollow cylinder with cast iron top and perforated metal bottom, an adjustable blade, hopper, a pulley, and metal frame.	Dehulling by two operations in Kambia: 1) Helical ribs at inlet (auger) push paddy to discharge side. 2) Straight ribs on cylinder rotate grains inside while the blade stops rotation of grains causing intense pressure and friction, separating husks, bran, germs and broken that fall on screen perforation. Milled rice is discharged from outlet.	Ground husks, bran, broken, germs, and powdery debris are discharged mixed.	Small capacity millings done in one pass. Generally poor milling performance due to improper operation. Can be used as polisher or whitener to remove bran.

Source: AGSI-FAO (1999).

2.3.4 Storage

The following measures should be taken to reduce losses during storage in Kambia district.

1) Proper drying before storage

Biting the grain is a popular method to test its dryness practiced by the farmers. The grain moisture, however, can be checked more reliably by the following method.

a) Place a handful of grains in a small glass jar (with a screw top if possible).

b) Sprinkle a spoonful of ordinary salt over the grains at the bottom and seal the top of the jar.

c) Store for 24 hours.

d) Examine the contents of the jar. If the salt clumps together, the grains are too moist to mill or store. If the salt remains dispersed, the grains have moisture content of 15% or less and can safely be milled or stored in bags.

2) Use of pallet

Bags filled with grains should be placed on a pallet but never directly on the floor. Pallets are indispensable for keeping the bags away from moisture seeping through the storage floor. If a pallet is not available, timbers are collected and assembled side by side on the floor to put the bags on.

3) Rodents control

To keep rodents off, the storage should be properly managed as follows.

a) Keep the storage place free of fallen grains, garbage, cloths, etc. so that there is nothing for the rodents to feed on, hide or nest in/under.

b) Store bags on pallets, ensuring that grains in the bags remain dry.

4) Insects control

Low humidity generally slows down or even stops reproduction of pest insects. If insects are found in storage bags, the grains should be taken out of the bags and dried under the sun.

5) Microorganisms control

Microorganisms also thrive in humid environment. They can be controlled by:

a) Drying the grains properly before storage

b) Checking the grain in the storage regularly.

c) Drying the grains immediately if they are wet

2.3.5 Issues on introduction of post-harvest machinery

Given the chronic labor shortage and farmers' excess workload in Kambia district, mechanization of agricultural activities is a must in the long-term development strategy, although the present economic conditions in the rural areas do not allow immediate or drastic change.

In the Project, three types of agro-machinery were introduced to ease the farmers' workload: pedal thresher, manual winnower and motorized rice huller. With no or little experience in handling these machines, it will take some time for the rural farmers to develop skills in and become accustomed to operating them.

(1) Pedal thresher

A pedal thresher consists of a threshing drum, base, transmission unit, and a foot crank. When pedaled, the threshing drum rotates, and as panicles are pushed into the rotating drum, they are threshed. Because small straws, chaff and foreign matters are mixed in with the threshed grains, subsequent winnowing is a must to separate the grains from other objects. The amount and frequency of the mixing of impurities becomes less as the farmers develop their knack for handling the machine.

Covering the threshing drum with tarpaulin prevents rough rice from scattering out of the thresher, and laying a sheet over the ground under the thresher reduces contamination of the grains with impurities from the ground and makes it easy to collect the threshed grains that fall off the thresher.

For the smooth, safe and efficient operation of a pedal thresher, straws should be cut longer than they are at present. It should be noted that the current model of pedal thresher needs further improvement. It is too heavy to carry to a threshing place far away from the village. To make it more mobile, the size and weight can be reduced modifying the design as well as using other materials for the parts.

(2) Manual winnower

The farmers seem to accept winnowers more easily for its simple structure, easy handling and effectiveness. It can be utilized for not only separating straws and unfilled grains from filled grains after threshing but also cleaning rice bran and husks of the grains after milling.

However, the efficiency of the currently available winnower can be improved further. In the present model, the wind created by the fan does not pass effectively. Also, the partition separating the two outlets is too low and inflexible, and the handle to rotate the fan is attached directly to the axis so that it takes some effort to turn it. Moreover, it can be downsized and made lighter.

(3) Motorized rice huller

As mentioned in section 2.3.3 (2), the operation of a motorized rice huller requires experience and skill. It will take time and effort for ordinary farmers to become familiar with its use. Furthermore, for the management of a rice huller, knowledge and skill in bookkeeping is necessary since it involves running and maintenance costs (e.g., fuel, spare parts, etc.). Management skill is much more difficult for the farmers to obtain.

Community owned motorized hullers tend to have shorter lives than those privately owned according to the results of the agricultural machinery survey (Part IV Annex 3.3). The accountability and responsibility for the management of the machine must be clearly understood and shared by the community members should agricultural machinery be owned communally.

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Chapter 3 Technical Package on Vegetable Production

Chapter 3 Technical Package on Vegetable Production

3.1 Vegetable Cultivation

3.1.1 Introduction

(1) Focused crops

The Agricultural Technical Package on vegetable cultivation (hereinafter TP-V) deals with three vegetable crops: watermelon, eggplant and pepper. Eggplant and pepper are commonly cultivated in Kambia district, and watermelon is expected to have high profit potential.

(2) Key techniques

Expansion in vegetable production is expected to contribute to the improvement of the nutritional conditions as well as cash income of the farmers and eventually lead to advancement of women because they are the main producer of vegetables in the area. The TP-V offers low input, simple techniques that can be easily adopted by women's groups. The contents of TP-V include key techniques formulated through the pilot trial (hereinafter PT) focusing on the following.

1) Raising quality seedlings

Raising quality seedlings is the most important process in vegetable cultivation. The quality of seedlings determines later growth after transplanting and affects yield substantially. Raising seedlings in pots is introduced for watermelon, while drilling seeds on the nursery with proper sowing rates for eggplant and pepper. Nursery management methods are also introduced.

2) Thinning out

Thinning out (pinching off) corrects the posture of plants for better growth and higher yield. This technique doesn't seem to be practiced in Kambia district. Techniques on thinning out superfluous vines, shoots or fruits are introduced.

3) Rational use of chemical fertilizer

Because of low soil fertility, application of fertilizer is unavoidable to obtain higher yield of vegetables. However, chemical fertilizers are too expensive for most farmers to afford in a large quantity. The TP-V introduces effective and efficient methods of fertilizer application, by which the farmers can attain maximum yield with minimum use of fertilizer.

4) Bio-pesticide using locally available materials

Chemical pest control agents work on vegetables immediately but they also have many harmful effects on human health. Also, they are often expensive and unaffordable. On the other hand, bio-insecticides are easily prepared with locally available materials, environmentally safe and not harmful to human and animals. As they take effect slowly, the farmers can use them as a preventive measure. Thus, a bio-insecticide made of neem extract is introduced as low cost pest control.

3.1.2 Watermelon cultivation

(1) Fruits and flowers

Watermelon fruits grow from on the vine and the plant has separate male and female flowers. The fruit grows from a pollinated female flower. Normally, the female flowers appear on every five nodes and the male flowers occupy on other nodes, but the sex of a flower is affected by environmental and nutritional conditions as well as plant vigor.

(2) Obtaining seeds

It is recommended to obtain watermelon seeds from harvested fruits, which are considered to be more viable and reliable in germination than commercial seeds. Otherwise, they can be collected from fresh fruits available in the market. As a final option during the off-season when fresh fruits are not found, commercial seeds can be purchased in Freetown. In any case, a germination test is recommended to examine the viability of seeds prior to sowing. Take 10 seeds randomly, sow them into any container with sufficient water and count the number of seeds germinated after a week. If more than 4 seeds germinate, it can be said viable.

<u>Treatment of seeds from fresh fruits:</u>

(a) Obtain several fresh fruits. Keep seeds in separate container. One fruit contains 200 to 400 seeds in general.

(b) Wash the seeds thoroughly to remove fruit pulp and juice. Put the seeds in socks or wrap them with a cloth, and rub them in fresh water.

   <u>Note</u>: If fruit pulp or juice remains on the seeds, they will not germinate. They must be washed several times changing water.

(c) Dry the seeds under sunlight.

(d) After drying, the seeds are ready for sowing.

(3) Growth duration and planting time

Under the climatic conditions in Kambia district, watermelon can grow all year round. It takes 100 to 120 days from sowing to harvest. The planting time should be determined considering the availability of irrigation water, occurrences of diseases and insects especially melonfly, distribution of land and labor for other crops as well as market price. Most farmers in Kambia District plant watermelon in October and November immediately after rice is harvested, while some farmers do earlier between July and September.

(4) Procedure for raising seedlings

1) Nursery conditions

The location of a nursery is the most important determinant of the quality of seedlings. The watermelon seedling requires full sunlight and it becomes elongated even in the shade of a tree, house or anything that blocks sunlight. Soil can be brought from other places if original soil is not enough fertile.

Another important factor is accessibility to a water source. Frequent watering is required almost every day. It is advisable to locate the nursery near a residential area so that seedling can be easily accessed and well kept.

2) Shade and rain shelter

A shade or rain shelter is not necessary for the nursery.

3) Raising seedlings

Watermelon is sensitive to transplant shock, which sometimes causes the plant damage beyond recovery. By using pots, the seedlings can be transplanted with a complete soil block without damaging the root system.

A small plastic cup of 50 mm (top) and 35 mm (bottom) in diameter and about 50 mm in height can be utilized as a planting pot for raising seedlings so that the root system can be fully protected. The size of the cup may vary depending on the availability but it should be no larger than a butter cup and no smaller than a tomato tin.

4) Preparation of nursery soil

Topsoil with low clay content and not much contamination with pathogenic fungi is recommended. It's better to use manure with low organic contents for the prevention of disease infection

<u>Procedure</u>

(a) For 100 pots, collect 10 liter (half a bucket) of virgin soil for topsoil.

(b) Sieve the soil with a fishing net or any screen net.

(c) Add 200 g (3 hand grips or 3 tomato tins) of compound fertilizer (15:15:15) and mix it with the soil well by a shovel.

<u>Notes:</u>

(a) A colored cup is more suitable for the root development because roots elongate to dark condition.

(b) A few holes must be made in the bottom of the pot for draining by a nail head heated with fire.

(c) The prepared soil is put in the pot up to about 80% from the bottom and put in order (Figure 3.1-1).

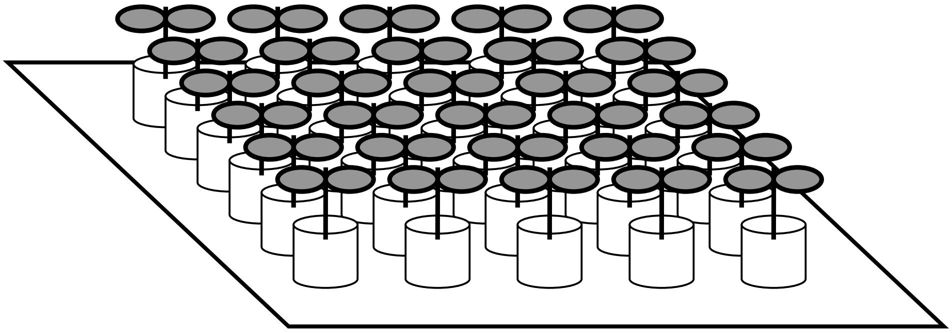

Figure 3.1-1 Raising Seedlings in Pots

5) Sowing and germination

The seeds are sowed 1 cm deep in each pot and covered with fine soil to level. The number of seeds to be sown is one or two per pot, depending on the germination rate. To get rough idea, sow 2 seeds if germination rate is below 60%. Then the pots are watered enough to keep the soil wet for four days until the seeds germinate. The top of the pot is covered with palm fronds or any dry grass to prevent evaporation.

If vital, the seeds are expected to germinate in four days. The covers must be removed from the cups on the seeds' sprouting; otherwise the seedlings will be elongated. If there are two seedlings in a pot, one seedling should be removed when their cotyledons are fully open.

Caution:

The soil condition must be carefully observed, especially the moisture in the daytime. Because of the limited volume of a pot, the soil dries up quickly compared to a nursery on the ground. When it is hot, the pots should be watered more than twice a day. If the soil is found dry in the daytime, it must be watered without delay.

(5) Land preparation

In the dry season, accessibility to a water source is the most important factor for the watermelon field. After the land is plowed, ridges are made as shown in Figure 3.1-2. The planting bed should be 1 m wide keeping 0.8m for a passage in between. The bed height should be between 10 and 20 cm depending on the climatic and drainage conditions.

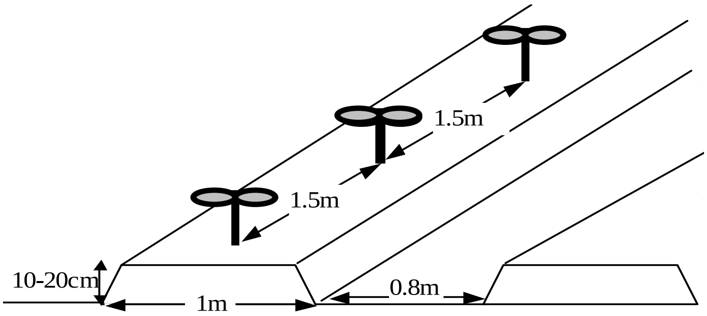

Figure 3.1-2 Plant Spacing for Watermelon

(6) Transplanting

The seedlings are ready for transplanting two to three weeks after sowing. The land preparation must be completed before the expected transplanting day. In transplanting, the seedlings must be handled with care not to give any damage especially to the root system.

Procedure:

(a) Harden seedlings by reducing water from 2 to 3 days before transplanting.

(b) Dig planting holes about 10-15 cm deep at 1.5 m intervals on one side of the bed in the field.

(c) Drench the pots with water 1 hour before transplanting for the seedlings to come out of the pots smoothly.

(d) Dissolve 3 handgrips or 3 tomato tins (200 g) of compound fertilizer (15:15:15) into 20 liter of water and mix them well.

(e) Apply 0.5 liter of (d) to the planting holes.

(f) Take the seedlings out of the pots by turning the pot upside down with the whole soil block (Photo 3.1-1, 3.1-2).

(g) Put the seedlings with the soil block in the planting holes gently.

(h) Cover the planting holes with the soil around.

Photo 3.1-1
Taking out Seedling from Pot

Photo 3.1-2
Seedling Taken out from Pot

(7) Fertilizer application

As the minimum basal application, 40 kg/ha of dioxide potassium (K_2O) based fertilizer is recommended for watermelon. Additional 60 kg/ha of K_2O-based fertilizer should be reserved for top dressing, which may be applied later depending on the plant vigor. The basal fertilizer should be applied 3-4 days after transplanting when the plants recover from transplant shock. Fertilizer is applied according to the following procedure.

Procedure:

(a) Make a ring ditch in the soil about 15-20 cm wide around the plants.

(b) Hold a handful of fertilizer (74 g) and sprinkle it in the ditch around the plants.

(c) Cover the ditch with the soil around.

Calculation of fertilizer dose for each plant

(a) Forty (40) kg/ha (= 16 kg/acre) of K_2O-based fertilizer is equivalent to 267 kg/ha (= 106 kg/acre) of NPK compound (15:15:15).

(b) The amount of fertilizer per plant is calculated by dividing 267 kg/ha of compound (15:15:15) by 3,600 (no. of plants per ha = 1,440/acre), which is equal to 74 g.

Top dressing

In addition, more K_2O-based fertilizer is applied as top dressing beyond the tip of each vine with 60 kg/ha (= 24 kg/acre) at the maximum as soon as fruits are set. Separately, 111 g of fertilizer is applied per plant for 3-4 times and at weekly intervals at least. The dose of application is adjusted depending on the plant vigor. It should be increased up to the maximum amount when the following symptoms are observed:

(a) Short inter nodes

(b) Many flowers open near the tip of a vine

(c) Leaves with angular, notched edges

(d) Tips of vines growing upward

(8) Watering

The frequency of watering the plants depends on the season. The plants must be watered regularly in the dry season.

Note:

It is advisable not to submerge the root area of the crop. If watering can is not available, use a bowl bored with tiny holes at the bottom to avoid heavy water drops since watermelon has weak stems.

(9) Mulching

Mulching is to cover the surface of the plant bed around the growing plants with dry grass or rice straws. The plant bed should be mulched after the basal fertilizer is applied. This practice is important for the following reasons:

(a) Protection of the plant from drought
(b) Control of weed propagation
(c) Control of the soil temperature
(d) Prevention of diseases transmitted through rain drops (e.g., bacterial spot)
(e) Prevention of soil erosion
(f) Improvement of physical characteristics of the soil

Mulches should be spread all over the surface of the plant bed. When weeds appear from the gaps between the mulches or in the furrows, they should be removed.

(10) Thinning out, vine training and fruit setting

For plants to bear larger and better quality fruits, it is necessary to thin out flowers and vines and to train the vines. As shown in the Figure 3.1-3, watermelon has male and female flowers from the same plant. With thinning out and vine training, plant growth and fruit setting can be regulated and controlled. To obtain larger fruits, fruits must be set at higher positions on the vine above the 10th node at least because for a fruit to grow large, the more the number of leaves below it. the better.

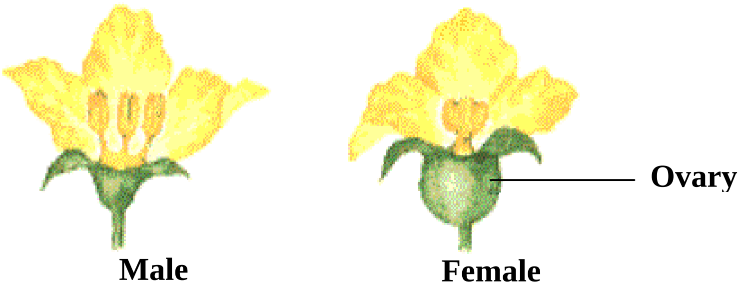

Figure 3.1-3 Male and Female Flowers

Procedure:

(a) Select 4 vigorous vines including 1 primary vine and 3 secondary vines with two vines on each side, training them to grow in the same direction.
(b) Thin out all the tertiary vines and female flowers below the fruit set position.
(c) Remove all the fruits below the 10th node of the selected vines.
(d) The first fruit on each vine must be beyond the 10th leaf.
(e) Leave all the tertiary vines below the fruit set position.
(f) The total number of fruits on each plant should be limited to 2 to 3 only.
(g) Remove all the fruits growing below the 10th node
(h) As secondary vines grow longer, if any fruit is set outside the plant bed, pull back the vine with the fruit to be on the bed.

This procedure is depicted in Figure 3.1-4.

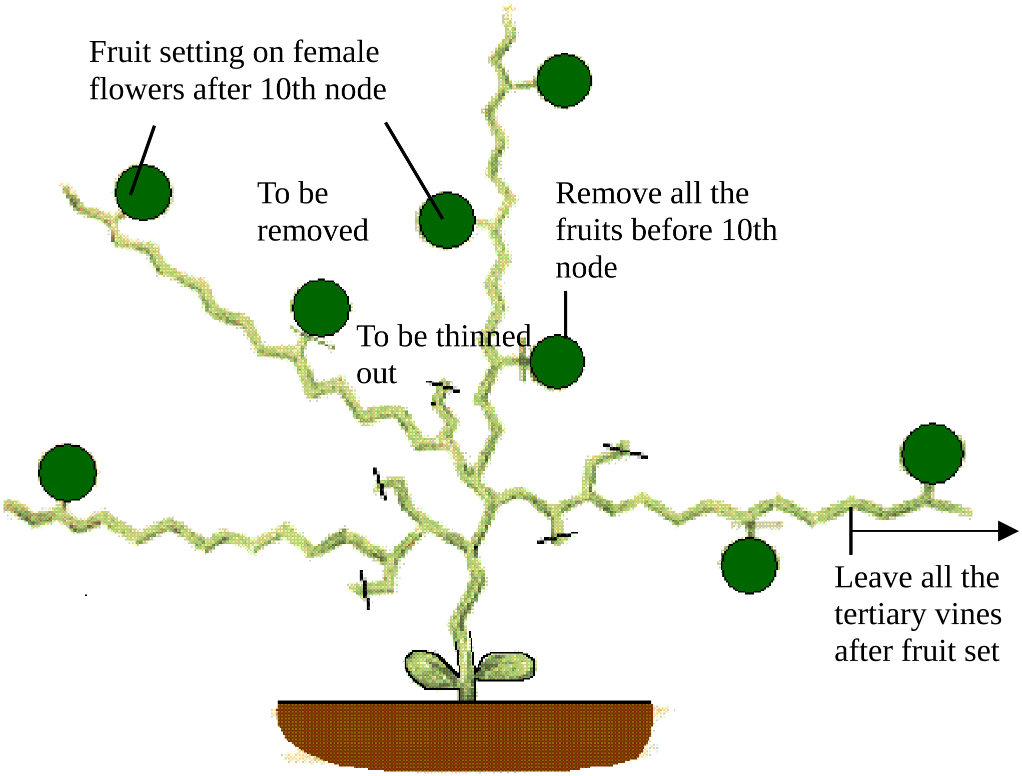

Figure 3.1-4 Thinning out, Training of Vines and Fruit Setting for Watermelon

(11) Hand pollination

The watermelon flower is entomophilous, which is a form of pollination whereby pollens are carried by insects, particularly bees. If the female flower does not receive pollen on its stigma, it will not produce a fruit. In the dry season, bees fly from male flowers to female flowers carrying pollen. However, when it rains intermittently, bees become inactive and the chance of female flowers to be pollinated by bees becomes less likely. Then, they may need to be pollinated artificially. Hand pollination is a technique to carry pollen to female flower instead of bees, which is performed as follows.

<u>Procedure:</u>

(a) Cut off an open male flower from a different plant and bring it to the female flower to be pollinated.

(b) Apply the pollen of the male flower by rubbing it off on the stigma of the female flower.

<u>Note:</u>

Hand pollination should be completed by 10:00am before pollen becomes unviable.

2) Pest insects and diseases

1) Major pest insects and diseases for watermelon and control measures

As in other vegetables, watermelon also has insect pests and diseases. Major pest insects and diseases for watermelon and their control measures are summarized in Tables 3.1-1 and 3.1-2.

Table 3.1-1 Major Pest Insects for Watermelon and Control Measures

Insect	Damage	Control measure
Melonfly *Bactrocera cucurbitae*	Adult lays eggs on the fruit, and as hatched larvae feed on the fruit, they move into it, resulting in rotten pulp.	Applicable insecticide: Furadan Application method: - Dilute with 500 times or more water and mix with detergent as solvent. - Solution is to be spread on the ovary or fruit with a painting brush. Caution: It must be carefully handled not to splash any drop on leaves, which may affect them if high concentration.
Cucurbit leaf beetle *Aulacophora femoralis*	Adult flies from plant to plant chewing holes in the leaves.	Applicable insecticide: Organic phosphorus compounds such as Malathion, Endosulfan and Cyflane Application method: - Dilute with 2,000-3,000 times water. - Spray regularly for prevention at seedling stage. Caution: It should be sprayed before transplanting.
Melonworm *Diaphania hyalinata*	Larvae feed on the foliage of cucurbit plants (but rarely enter vines or leaf petioles).	The same as above

Table 3.1-2 Major Diseases for Watermelon and Control Measures

Disease	Symptom	Control measure
Damping off	Darkened and softened spindles (from seeds and/or soil infected with fungus)	Applicable control measure: None Use virgin soil (less contaminated with pathogens) if possible
Stem gummy blight	- Circular, dark leaf spots start appearing on the leaf margins, and then main stems canker sometimes with water-soaked edges. - Plant dies when symptoms spread to the entire body.	Applicable fungicide: Topsin, Benlate Application method: - Dilute with 500-1,000 times water - Spray immediately when symptom appears. Caution: Immediate action must be taken on first symptom in leaf margins.
Water-soaked fruit	- Fruit pulp gets soaked like watermelon juice with no apparent rotting.	Applicable control measure: Cover the fruit with leaves on tertiary vines. If the leaves cannot cover the entire

Disease	Symptom	Control measure
	- No visible symptom on fruit surface. - Caused by physiological disorder, not derived from pathogenic causes. - Usually occurs when fruit is exposed to strong sunlight and high temperature with less translocation of nutrient and water to the fruits.	fruit, wrap the fruit with newspaper temporally while it is enlarging. Caution: All the fruits should be shaded with leaves for prevention especially on rainy days.

2) Use of bio-insecticide

The neem tree (*Azadirachta indica*), known for its extract as bio-insecticide, is native to tropics and sub-tropics. Its extract contains a natural chemical substance called azadirachtin that is effective in keeping hundreds of pests away. The substance is found in every part of the tree. But it is much more concentrated in the fruit, especially in the kernel. In Kambia district, however, the tree has only been recognized as a roadside tree, not as useful local resources. Neem-based pesticides are suitable because the active ingredient can be easily extracted without expensive and complicated equipment.

All in all, as the neem-based pesticide is effective on various insects and it takes effect slowly, its application is highly recommended as a preventive measure. It should be noted, however, that its effectiveness has been confirmed for aphid and grasshoppers but not so far for melonfly, the most harmful pest on watermelon.

<u>Preparation of neem extract and its use;</u>

Azadirachtin can be extracted from any part of the neem tree. However, the use of extract from leaves and kernels is described here.

Preparation and use of kernel extract:

(a) Obtain kernels from 150 g of dried neem fruits by removing seed pulp and husk.
(b) Grind the kernels into powder (neem powder).
(c) Put the powder in a basin and pour 3 liter of lukewarm water into it.
(d) Keep (c) in the shade for over 24 hours.
(e) Filter (d) through a fine cloth into a sprayer.
(f) Add 3-7g of mashed soap as spreading agent.
(g) Spray or brush (f) on vegetables in the afternoon around 4:00PM to 6:00PM.
(h) Use up the extract within 48 hours.
(i) Spray or brush the extract once a week

Notes:

(a) Three liter of kernel extract is enough for spraying 70 plants of watermelon twice after transplantation and once in the fruit growth stage.

(b) Because neem extract is greasy, the spray bottle should be used exclusively for the extract.

Preparation of leaf extract;

(a) Grind 1.5 kg of dried neem leaves and 10-17 dried pepper fruits together.

(b) Put the powder (a) in a basin and pour 3 liter of lukewarm water into it.

(c) The processes and use of leaf extract hereafter are the same as (d)-(i) above for kernel extract.

3) Chemical control

The main problem found in the field after transplanting is melonfly damage to the fruits. This insect damage occurs after fruit setting. There is a chemical called Furadan, which is used exclusively for melonfly control and readily available in Sierra Leone. Because of melonfly, the use of this chemical insecticide is indispensable for watermelon production as a preventive measure.

Other major insects are cucurbit leaf beetle and melonworm. Damage by these insects is mostly to young plants, for they feed on fresh and soft leaves. They should be thoroughly controlled by spraying insecticide in the nursery before transplanting.

Although it was not observed in PT, stem gummy blight caused by a fungus is widely spread in the tropics. Since the climatic conditions in Kambia district are favorable for this fungous disease, it is advised to keep at least one fungicide such as Benlate ready in case of urgent use.

Regardless, chemicals could be extremely dangerous if poorly managed or handled. They should not be touched with bare hands or breathed in and must be kept out of reach of children. Also, chemical application should be stopped at least two weeks prior to harvest because of residues.

(13) Harvesting

The best harvesting time can be determined by the number of days after flowering. In the climatic condition of Kambia district, it normally takes about 40-45 days for fruits to mature after flowering. The disappearance of stripes on the fruit surface is also an indicator of the harvesting time. Normally, 10-14 days after the stripes disappear is considered to be the right time. The farmers have also relied on the fruit size and the sound the fruit makes when knocked to make a decision on the timing of harvest.

3.1.3 Eggplant cultivation

(1) Growth habit

Eggplant is an indeterminate crop, which develops into some stems that do not top off and continue developing until the end of its life. This growth habit is different from pepper that tops off and develops into some other stems that also top off. The first flower of eggplant appears between the 8th and 10th nodes on the main stem, and the lateral shoots that emerge under the first flowers are normally more vigorous than others. Under normal conditions, flowers appear every two to four leaves toward the upper side on each stem.

(2) Growth duration and planting time

Eggplant is one of the most commonly produced vegetables by the local farmers all year around. Eggplant can be harvested continuously over a long period if carefully managed. This makes it quite a practical option for the farmers to incorporate eggplant production in their farming activities as a supplemental income source.

Eggplant fruits can be harvested 50-60 days after transplanting or 80-90 days from sowing. The time of planting should be determined considering availability of irrigation water, disease and insect occurrence, and land and labor distribution with regard to other crops as well as market price.

(3) Procedure for raising seedlings

1) Nursery conditions

The sunlight is an essential factor in photosynthesis and generally vegetable seedlings should be grown under sufficient sunlight. Unlike watermelon, however, eggplant does not require full sunlight at the seedling stage since they take longer time to develop stems and leaves.

Soil texture and condition are an important factor for an eggplant nursery because seedlings are grown in the ground soil. A nursery should be located where the soil is as little contaminated with pathogens as possible. For that, a plot that has never been used for crop cultivation is recommended since its soil is less likely to be contaminated with pathogens than the soil of farmland. If the soil is not fertile enough, nutrients can be supplemented by fertilizer application. The fertilizer cost could be justified considering the potential loss from the disease infection to which eggplant is prone.

2) Shade and rain shelter

A shade or rain shelter is not necessary for the nursery.

3) Raising seedlings

In Kambia district, at present the farmers pay less attention to the quality of seedlings than the germination of seeds in the nursery. However, it is the former that determines the quality and quantity of fruits to be harvested eventually. The purpose of raising seedlings is to grow healthy seedlings that will produce many good fruits through intensive and careful nursery management. In other words, by raising quality seedlings, the farmers have a better chance of making profits in the end though it takes time and effort on their part. Therefore, the farmers should be made aware of the importance of raising seedlings.

4) Preparation of nursery and sowing

If possible, a plot that has never been cultivated for crops is used for the nursery. Once the nursery location is determined, fertilizer is applied to the soil.

The area of the nursery is calculated from the following indices:

- Volume of seeds: 15cc (1 spoon)
- Number of seeds: 1,200-1,500
- Nursery area necessary for sowing: 1 m^2 (1m×1m)

Before the nursery preparation, the germination rate of seeds also must be considered. If enough seeds can be procured, it is advised to sow twice as many seeds as the number of seedlings that will be transplanted.

The procedure of nursery preparation and sowing is as follows.

Procedure:

(a) Determine the size of the nursery from the amount of seeds to be sowed.

(b) Remove stones and weeds from the area.

(c) Apply 200 g/m^2 (3 hand grips or 3 tomato tins) of NPK compound (15:15:15) and mix it with the soil well digging up the seedbed at least 10 cm deep.

(d) Heap up the soil about 10-20 cm high depending on the season and level the seedbed for sowing.

(e) Dig ditches for drainage around the seedbed.

(f) Dig 5 sowing holes/m^2 1-1.5 cm deep at 20 cm intervals on the seedbed.

(g) Drill the measured seeds uniformly in the holes.

(h) Cover the holes with the soil around.

(i) Shade the nursery with palm fronds or any dry grass.

(j) Water the seedbed sufficiently for 5-6 days until the seeds germinate.

(k) Remove the shade immediately after the seeds' germination.

(4) Land preparation

The land is plowed and then ridged at 1.6 m intervals as shown in Figure 3.1-5. The planting bed is 1 m wide with a 0.6 m-wide passage in between. The bed height should be between 10 and 20 cm depending on the climate and the drainage period.

Comparison with conventional mound planting:

It is common to cultivate vegetable crops on a raised mound. This mound planting has some advantages, for instance, good drainage, effective use of fertile topsoil, well-loosened soil, etc. However, it makes difficult to manage each plant because the plants are in the middle of the mound. In contrast, the bed planting is more convenient for the handling and management of the plants.

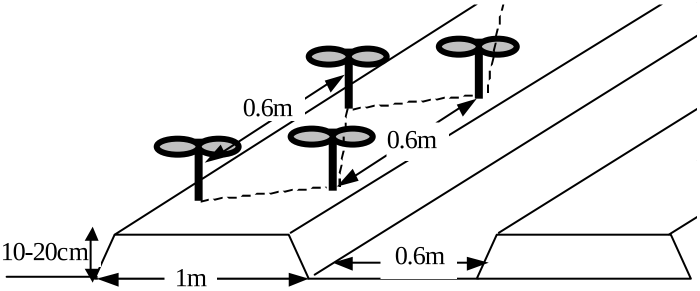

Fig. 3.1-5 Plant Spacing for Eggplant

(5) Transplanting

The seedlings are ready for transplanting 25-35 days after sowing when 4-5 leaves are open. The land preparation must be completed before the expected transplanting day.

It is recommended that the space between the rows of the plants in the nursery be cut through with a knife prior to transplanting. This causes slight damage to the roots of the plants, and the damage prompts the plants to accelerate the growth of new roots in their effort to recover. By transplanting the seedlings in the process of growing fresh roots, transplant shock can be mitigated to some extent. This inter-row cutting should be performed three days before transplanting so that the seedlings will be about to shoot new roots at the time of transplanting. It is a matter of course that each seedling must be carefully uprooted with the soil block around it.

Procedure:

(a) Harden seedlings by reducing watering from 3 days before transplanting.
(b) Dig planting holes about 5-10 cm deep at 60 cm intervals in two rows on both sides of the bed for staggered row planting.
(c) Water the seedlings sufficiently 1 hour before transplanting for smooth uprooting from the nursery.
(d) Dissolve 200 g (3 handgrips or 3 tomato tins) of compound fertilizer (15:15:15) into

20 liter of water and mix them well.

(e) Apply 0.25 liter of (d) to the planting holes.

(f) Uproot healthy seedlings from the nursery with soil blocks around the roots.

(g) Immediately after uprooting, carry the seedlings to the field and transplant them into the planting holes on the bed immediately.

(h) Cover the planting holes with the soil around. In so doing, push the surrounding soil softly into the holes and be careful not to bear down the stems of the seedlings.

(6) Fertilizer application

As the minimum basal application, 40 kg/ha (= 16 kg/acre) of K_2O-based fertilizer is recommended. Additional 60 kg/ha of K_2O-based fertilizer should be reserved for top dressing, which may be applied later depending on the plant vigor. The basal fertilizer should be applied 5-7 days after transplanting when the plants recover from transplant shock. Fertilizer is applied as follows.

<u>Procedure:</u>

(a) Dig straight ditches about 20 cm long in two rows between the two rows of the plants on the bed.

(b) Hold 1 spoonful or 1 pinch (with a thumb and 2 fingers) of fertilizer (roughly 13 g), and sprinkle it into the ditches.

(c) Cover the ditches with the soil around.

<u>Calculation of fertilizer dose to each plant</u>

(a) Forty (40) kg/ha (= 16 kg/acre) of K_2O-based fertilizer is equivalent to 267 kg/ha (= 106 kg/acre) of NPK compound (15:15:15).

(b) The amount of fertilizer per plant is about 13 g calculated by dividing 267 kg/ha of compound (15:15:15) by 20,000 (no. of plants per ha = 8,000/acre).

<u>Top dressing</u>

In addition, more K_2O-based fertilizer, 60 kg/10ha (= 24 kg/acre) at the maximum, is applied as top dressing after first fruits are set. The fertilizer is sprinkled into two rows of straight ditches about 20 cm long dug between the rows of the plants. Separately, 20 g of fertilizer is applied per plant for several times and at weekly intervals at least. The dose of application is adjusted depending on the plant vigor by observing leaf area and shape, plant height, flower shape, growth speed, etc.

(7) Watering: Refer to 3.1.2 (8).

(8) Mulching: Refer to 3.1.2 (9).

(9) Thinning out, training of stems and fruit setting

Lateral shoots should be thinned out and stems should be trained to facilitate growth and increase the fruit set ratio. According to the results of PT, by training 3-4 stems on a plant the best performance in plant vigor, yield and fruit quality was achieved with less occurrence of disease due to ventilation through the inter-row space between the plants.

The procedure for thinning out, training and fruit setting is as follows.

Procedure:

(a) Thin out all the lateral shoots under the first flower leaving 2 shoots just below the flower and one more shoot under that.

(b) Train 3 stems including the main stem and 2 stems under the first flower.

(c) Leave all the lateral shoots from the trained 3 stems for fruit set.

(d) Pinch off old leaves for ventilation and exposure as necessary when leaves start to grow over each other.

(e) Do not pinch the first flower since it regulates plant growth and make sure to set a fruit on the first flower.

Thinning out and stem training for eggplant are depicted in Figure 3.1-6.

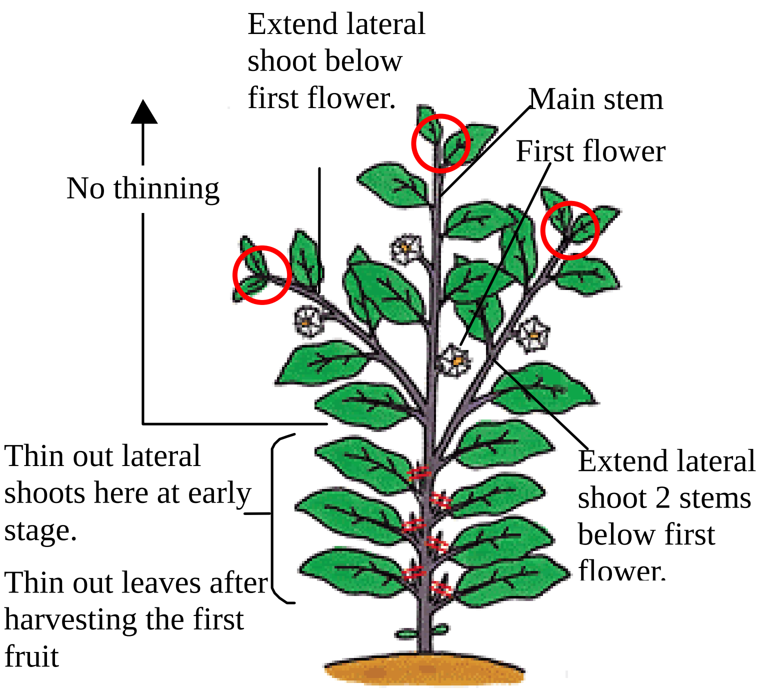

Figure 3.1-6 Thinning out and Stem Training for Eggplant

(10) Pest insects and diseases

1) Major pest insects and disease for eggplant and control measures

Major pest insects and disease for eggplant and their control measures are summarized in Tables 3.1-3 and 3.1-4.

Table 3.1-3 Major Pest Insects for Eggplant and Control Measures

Insect	Damage	Control measure
Grasshopper	Grasshopper bites off a whole seedling in a few hours, leaving only its spindle.	Applicable insecticide: Organic phosphorus compound such as Malathion, Endosulfan and Cyflane Application method: - Dilute with 2,000-3,000 times water. - Spray immediately when grasshopper is found at the nursery. Caution: - Spray several times for complete control. - Spray 2nd time 3 days after 1st time.
Cluster caterpillar *Spodoptera litura*	- Young larvae feed on leaves leaving only leaf vines. - When larger and more solitary larvae feed on leaves, the rolled up effect of leaves becomes apparent. - Large larvae may feed on fruits scarring fruit skins.	Applicable insecticide: Organic phosphorus compound such as Malathion, Endosulfan and Cyflane Application method: - Dilute with 2,000-3,000 times water. - Spray immediately when cluster caterpillar is found at the nursery. Caution: The back of leaves must be sprayed as well.
Aphid	- Aphids swarm on the back of leaves and suck up juice from the plant. - Damage is gradual. - Most serious damage is virus transmission –infection will spread fast from on e plant to another. (Virus transmission by aphid was not observed in PT.)	Applicable insecticide: Pyrethroid compound or organic phosphorus compound such as Malathion, Endosulfan and Cyflane Application method: - Dilute with 2,000-3,000 times water. - Spray immediately when aphid is found at the nursery.

Table 3.1-4 Major Disease for Eggplant and Control Measures

Disease	Symptom	Control measure
Damping off	Darkened and softened spindles caused by fungous infection from contaminated soil	Applicable control measure: N/A Use virgin soil with less pathogenic contamination

2) Use of bio-insecticide: Refer to 3.1.2 (12) 1).

3) Chemical control

In PT, some minor insect damage to the plants was observed in the nursery but no serious damage occurred after transplanting. This indicates the importance of insect control for seedlings in the nursery. For insect control, bio-insecticide is preferable. However, if it is found to be ineffective, chemical insecticide may be used.

Grasshopper, diamondback moth and cluster caterpillar feed on seedlings that are fresh and soft. Grasshopper is the worst insect of all for eggplant because it can kill its seedlings. Still, all these pest insects including grasshopper can be controlled by intensive chemical spraying. Chemical application should be stopped, however, two weeks before harvest because of residues.

(11) Harvesting

The first fruit can be harvested 50-60 days after transplanting. As mentioned above, the first fruit on the first flower must be carefully set and grown. The first fruit setting contributes to regulating plant growth and facilitating smooth reproductive growth by inhibiting excessive vegetative growth.

3.1.4 Pepper Cultivation

(1) Growth habit

Pepper is a determinate crop, which tops off and develops into some more stems that top off again, branching out many lateral stems one after another. This growth habit is different from that of cucurbit crops such as watermelon and eggplant. The first flower appears between the 8th and 10th nodes on the main stem. The lateral shoot just below the first flower is normally more vigorous. In normal conditions, flowers appear in every node continuously.

(2) Growth duration and planting time

Pepper can be planted all year round. Viral infection is a limiting factor for the plant life. However, the farmers often continue to cultivate pepper even in face of virus infection that wilts the plants in the field.

It takes 55-70 days for pepper to grow from transplanting to harvest. The planting time should be determined considering various factors such as climatic conditions, market price, land and labor distribution with other crops, availability of irrigation, and field vacancy.

(3) Procedure for raising seedlings

Basically, the method of raising pepper seedlings is same as eggplant seedlings, for both belong to the same *Solanaceae* family. Nevertheless, the procedure for raising pepper seedlings is described below.

1) Nursery conditions

The requirements of the nursery location are as follows.

(a) Sufficient exposure to sunlight

(b) Soil with less pathogenic contamination, relatively fine and light

(c) Easy access to a water source for frequent irrigation

All these requirements should be met. Soil fertility is not an important factor in selecting the location for a nursery since nutrients in the soil can be supplemented by fertilizer application. For the soil suitable for pepper cultivation, such factors as the level of pathogenic contamination and the physical property (e.g., low rock content) are more important. If a plot near a water source that has never been cultivated for crops were available, it would be ideal for the nursery. Otherwise, a plot that is not in much contact with human life is appropriate, for it is less likely for byproducts of human activities to have contaminated the soil. It should be kept in mind that soil borne diseases infected in the nursery incur serious damage to the seedlings.

2) Raising seedlings

In Kambia district, the farmers have long history of pepper cultivation. However, as mentioned in Section 3.1.3 (3), 3) on eggplant seedlings, at present they are less concerned about raising seedlings than germination. To reiterate the previous section, the farmers should become aware that the nursery is not a place to germinate seeds only.

3) Shade and rain shelter: Refer to 3.1.3 (3) 2)

4) Preparation of nursery and sowing: Refer to 3.1.3 (3) 4)

The area of the nursery is determined by the necessary amount of seeds to be sown and the number of plants to be transplanted in the field. The area is calculated based on the following indices.

- Volume of seeds: 15 cc (1 spoon)
- Number of seeds: 1,200 to 1,500
- Nursery area necessary for sowing: 1 m^2 (1 m×1 m)
- Number of plants to be transplanted: About 25,000 plants/ha

As in case of eggplant, the germination rate of seeds also must be considered before the nursery preparation. If the farmers can obtain enough seeds, they should sow twice as many seeds as the number of seedlings to be transplanted.

The procedure of nursery preparation and sowing for pepper is as follows.

<u>Procedure:</u>

(a) Plot the area for the nursery based on the amount of seeds to be sowed.

(b) Remove stones and weeds from the area

(c) Apply 200 g/m^2 (3 hand grips or 3 tomato tins) of NPK compound (15:15:15) and mix it with the soil well, digging up the seedbed at least 10 cm deep.

(d) Heap up about 10 to 20 cm high depending on season, and level the area for sowing

(e) Excavate ditch for drainage around the bed

(f) Dig 5 sowing holes/m^2 1-1.5 cm deep at 20 cm intervals on the seedbed.

(g) Drill the measured seeds uniformly in the holes.
(h) Cover the holes with the soil around.
(i) Shade the nursery with palm fronds or any dry grass.
(j) Water the seedbed sufficiently for 5-6 days until the seeds germinate.
(k) Remove the shade immediately after the seeds' germination.

(4) Land preparation

Pepper is more sensitive to transplanting than eggplant. The land must be prepared to good condition so that transplant shock can be mitigated to certain extent. The land should be plowed and then ridged at 1.6 m intervals. The planting bed is 1 m wide with a 0.6 m-wide passage in between. The bed height should be 10-20 cm high depending on the climate and the drainage period. The land preparation is the same for pepper and eggplant as depicted in Figure 3.1-5.

(5) Transplanting

The seedlings are ready for transplanting 25-35 days after sowing when 6-7 leaves are open. The field must be fully prepared by the expected day of transplanting. Cutting through the space between the rows of plants on the bed by knife is recommended prior to transplanting as in case of eggplant (cf. 3.1.3 (5)).

<u>Procedure:</u>

(a) Harden seedlings by reducing watering from 3 days before transplanting.
(b) Dig planting holes about 5-10 cm deep at 45 cm intervals in two rows on both sides of the bed for staggered row planting.
(c) Water the seedlings sufficiently 1 hour before transplanting for smooth uprooting from the nursery
(d) Dissolve 200 g (3 handgrips or 3 tomato tins) of compound fertilizer (15:15:15) into 20 liter of water and mix them well.
(e) Apply 0.25 liter of (d) to the planting holes.
(f) Uproot healthy seedlings from the nursery with soil block around the roots.
(g) Carry the uprooted seedlings to the field and transplant them into the planting holes on the bed immediately.
(h) Cover the planting holes with the soil around. In so doing, push the surrounding soil softly into the holes and be careful not to bear down the stems of the seedlings.

(6) Fertilizer application

As the minimum basal application, 40 kg/ha (= 16 kg/acre) of K_2O-based fertilizer is recommended. Additional 60 kg/ha of K_2O-based fertilizer should be reserved for top dressing, which may be applied later depending on the plant vigor. The basal fertilizer should be applied 7-10 days after transplanting when the plants recover from transplant shock. Fertilizer is applied according to the following procedure.

Procedure:

(a) Dig straight ditches about 20 cm long in two rows between the two rows of the plants on the bed.

(b) Hold 1 spoonful or 1 pinch (with a thumb and 2 fingers) of fertilizer (roughly 11 g), and apply it to the ditches.

(c) Cover the ditches with the soil around.

Calculation of fertilizer dose to each plant

(a) Forty (40) kg/ha (= 16 kg/acre) of K_2O-based fertilizer is equivalent to 267 kg/ha (= 106 kg/acre) of NPK compound (15:15:15).

(b) The amount of fertilizer per plant is about 11 g calculated by dividing 267 kg/ha of compound (15:15:15) by 25,000 (no. of plants per ha = 10,000/acre).

Top dressing

In addition, more K_2O-based fertilizer, 60 kg/10ha (= 24 kg/acre) at the maximum, is applied as top dressing after first fruits are set. The fertilizer is sprinkled into two rows of straight ditches about 20 cm long dug between the rows of the plants. Separately, 16 g of fertilizer is applied per plant for several times and at weekly intervals at least. The dose of application is adjusted depending on the plant vigor by observing leaf area and shape, plant height, flower shape, growth speed, etc.

(7) Watering: Refer to 3.1.2 (8).

(8) Mulching: Refer to 3.1.2 (9).

(9) Thinning out, training of stems and fruit setting

Lateral shoots should be thinned out and stems should be trained to facilitate growth and increase the fruit set ratio. According to the results of PT, by training 4 stems on a plant the best performance in plant vigor, yield and fruit quality was achieved. The procedure for thinning out, training and fruit setting is described below.

Procedure:

(a) Thin out all the lateral shoots under the first flower leaving 1 shoot just below the flower and one more shoot under that.

(b) Train 4 stems including the main stem, the secondary stem, one from the second node on the main stem and the other from the first node on the secondary stem.

(c) Leave all the lateral shoots from the 4 trained stems for fruit set.

(d) Pinch off old leaves for ventilation and exposure as necessary when leaves start to grow over each other.

Thinning out and stem training for pepper are shown in Figure 3.1-8.

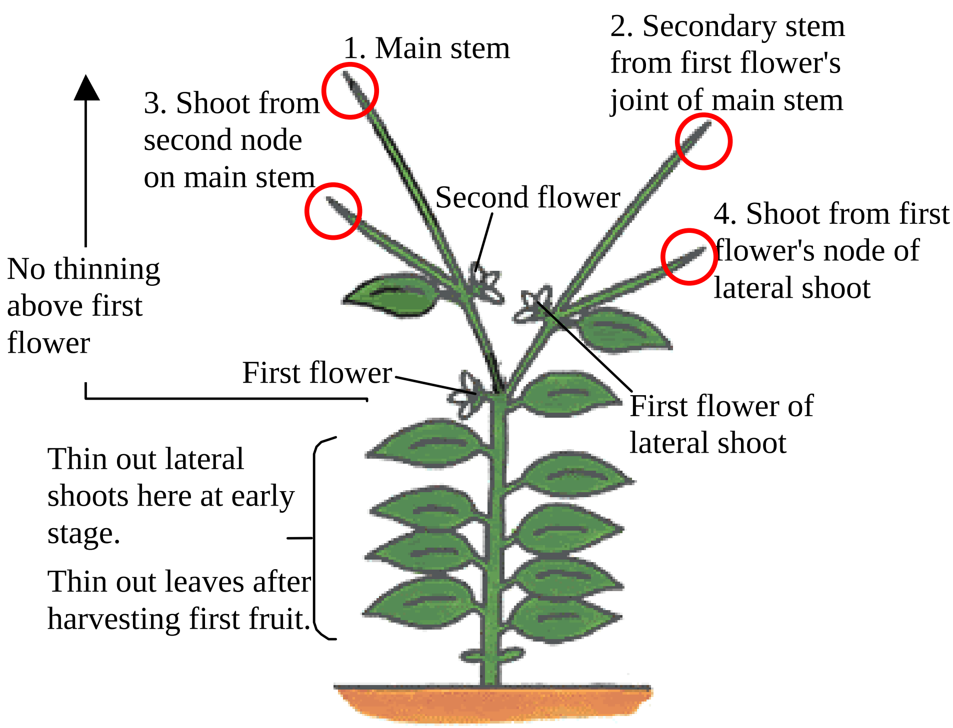

Figure 3.1-8 Thinning out and Stem Training for Pepper

(10) Pest insects and diseases

1) Major pest insects and diseases for pepper and control measures

Major pest insects and diseases for pepper and their control measures are summarized in Tables 3.1-5 and 3.1-6.

Table 3.1-5 Major Pest Insects for Pepper and Control Measures

Insect	Damage	Control measure
Grasshopper	Cf. Table 3.1-3	Cf. Table 3.1-3
Aphid	Cf. Table 3.1-3	Cf. Table 3.1-3

Table 3.1-6 Major Diseases for Pepper and Control Mesures

Disease	Symptom	Control measure
Damping off	Cf. Table 3.1-4	Cf. Table 3.1-4
- TMV (tobacco mosaic virus) - PMMoV (pepper mild mottle virus)	- First, yellowish discoloration of young leaves - Then, yellow spots on young leaves that spread in corrugate mosaic patterns - Finally, the whole plant dwarfed	- No anti-virus chemical available. - Indirect control such as complete eradication of vector insects (e.g., aphid) - Change seeds to commercial varieties from homegrown seeds or locally distributed seeds

2) Use of bio- insecticide: Refer to 3.1.2 (12) 1).

3) Chemical control

Virus occurrence discouraged the farmers who participated in PT on pepper plants in both the dry and rainy seasons. Virus infection is the most serious problem in pepper cultivation. Yield of pepper is drastically affected by the degree to which the plants in the field are damaged by virus infection. Unfortunately, however, there is no chemical agent available that is effective in treating virus infection.

Infection by a seed-borne virus is immediately apparent from the appearance of the symptoms on the plant, and it is most likely by Tobacco Mosaic Virus (TMV or also called PMMoV) particularly common in pepper. TMV is a very strong infectious virus, which can be transmitted even by contact through soil and seeds as well as vector insects such as aphid. Therefore, the virus is difficult to control unless the seeds are replaced by varieties free of the virus or resistant to infection by the virus.

Probably, aphid control is the only practical measure for this virus infection. Intensive control should be executed in the nursery by spraying a chemical insecticide. However, as a matter of course, the use of the chemical agent should be stopped two weeks before harvest because of the residues.

(11) Harvesting

The first fruit can be harvested 55-70 days after transplanting or 85-100 days after sowing. Harvesting should be timely when fruits are fully mature.

3.2 Cost-Benefit Analysis

3.2.1 Preconditions for calculation of profitability

The target crops for cost-benefit analysis are watermelon and eggplant cultivated in the pilot project (PP). Pepper was excluded from the analysis because its yield was too small to be used for the calculation. The preconditions for the calculation of profitability are as follows.

1) Yield

Yield is estimated based on the number of fruits harvested per 100m^2.

2) Sales price of vegetables

The sales price of vegetables fluctuates throughout the year. The sales price of watermelon ranges from Le 1,500 to Le 3,000 per fruit. On the other hand, the range of sales price per fruit for eggplant is Le 500-600 in Makatick and Le 30-200 in Mathon. In the calculation, a lower price is usually adopted to reflect the reality that the sales price is not always high. Nevertheless, an intermediate price of Le 350 is adopted for eggplant due to the considerable gap in the price range between Makatick and Mathon.

3) Production cost

The composition of the production cost is as follows.

<u>Seed</u>

For watermelon, the farmers obtain seeds from a fruit purchased at a local market, which contains enough seeds to sow 100 m^2. Thus, the seed cost is the purchase price of one watermelon that is Le 5,000 (in 2008). For eggplant, on the other hand, the farmers obtain seeds from the fruits that they produce, and thus there is no seed cost.

<u>Fertilizer</u>

The purchase price of fertilizer at Barmoi Luma market is Le 145,000/bag (50 kg) in 2008. The amount of fertilizer required for 100 m^2 is 4 kg and thus the fertilizer cost is Le 11,600 (i.e., 145,000/50 x 4), which is the same for both watermelon and eggplant.

<u>Farming tools</u>

The cost of farming tools is based on the field study data obtained by MAFFS-K, which is Le 35,000/ha (i.e., Le 35,000 x 0.01ha = Le 350). For watermelon, the cost of plastic cups (Le 6,500 for 100 cups) is added and the total cost of farming tools is Le 6,850 ((Le 350 + Le 6,500).

3.2.2 Calculation of profitability

The estimated profitability of watermelon and eggplant is presented in Table 3.2-1 and 3.2-2, and the results of the cost-benefit analysis for watermelon and eggplant are summarized as follows.

1) The profit margins for watermelon and eggplant are well over 60%.
2) The profit margin can be further increased through reducing the costs of fertilizer and farming tools (e.g., plastic cups for watermelon).
3) Labor cost is not included because the cultivation area is small.
4) Vegetable production is labor intensive. Expansion of the cultivation area increases labor cost and decreases profitability. As implied by the cost-benefit analysis, vegetables should be produced in a small area that can be managed by the farmer's family members only.
5) Family labor expenses are excluded from the production cost. The total family labor requirements for one cropping season are about 10 persons, whose cost can be converted to Le 50,000. Therefore, for watermelon, the estimated profitability is Le 850 and the profit ratio is 1.1 % whereas for eggplant, the estimated profitability is Le –9,100 and the profit ratio is –17.0 %.

Table 3.2-1 Estimated Profitability: Watermelon

In case of 100m^2

Components				
I. Income				
1. Yield (fruits/100m^2)			50	
2. Sales price (Le/seed)			1,500	
3. Gross income (1x 2)			75,000	
II. Production cost	Unit price	Quantities	Total	%
1. Variable expense				
Seed(Le/fruit)	25	200	5,000	20.7
Fertilizer(Le/kg)	2,900	4	11,600	48.0
Insecticide(Le/liter)	70,000	0.01	700	2.9
2. Fixed expense				
Farming tools(Le/a)			6,850	28.4
3. Total cost (1+2)			24,150	100.0
III. Profit (Le/100 m^2) I.3-II.3			50,850	
IV. Profit ratio (%) III/I.3			67.8	

Note: Quantity of insecticide is 10cc

Table 3.2-2 Estimated Profitability: Eggplant

In case of 100m^2

Components				
I. Income				
1. Yield (fruits/100m^2)			153	
2. Sales price (Le/fruit)			350	
3. Gross income (1x 2)			53,550	
II. Production cost	Unit price	Quantities	Total	%
1. Variable expense				
Seed(Le/fruit)	0	0.0	0	0.0
Fertilizer(Le/kg)	2,900	4.0	11,600	91.7
Insecticide(Le/liter)	70,000	0.01	700	5.5
2. Fixed expense				
Farming tools(Le/a)			350	2.8
3. Total cost (1+2)			12,650	100.0
III. Profit (Le/100 m^2) I.3-II.3			40,900	
IV. Profit ratio (%) III/I.3			76.4	

Note: Quantity of insecticide is 10cc