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

Japan International
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# Technical Package on Rice Production

## Revised Edition

November 2014

Sustainable Rice Development Project
in Sierra Leone
(JICA-SRDP)

Technical Package on Rice Production (Revised Edition)

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Contents

# Summary

a. For higher rice grain yield, it is important to secure better growing environment for the rice plant, particularly in its vegetative growth stage, as grain yield depends on the number of panicles per unit area, which is determined during the stage.

b. For higher rice grain yield, two measures are necessary: improvement of farming practices and fertilizer application. Both are necessary to attain the target yield of 3 ton/ha; however, the former is more important, for the effects of the latter would be limited without the former.

c. The revised TP-R contains techniques in land preparation, variety selection, seedling raising, uprooting and transplanting, weed and pest management, harvest and post-harvest, fertilizer management, and water management (see the table in the next page). All the techniques aim to create better environment for the rice plant to grow healthily and to utilize applied fertilizer effectively and efficiently.

d. Fertilizer application accelerates the growth of rice and thereby enhances yield. However, this can happen only when improved farming practices are adopted. A pre-condition for effective fertilizer application is to ensure proper water control in the rice field. Proper development of IVS including construction of irrigation and drainage canals, bund construction, and land levelling, is required for rice farmers to enjoy better harvest.

e. Improved farming practices as well as fertilizer should be applied at the right time according to the growth of rice. A proper farming plan and a cropping calendar should be prepared to guide timely farming.

f. Use of pure seeds helps enhance yield. Rice seeds should be produced by the rice farmers themselves under the current situation in Sierra Leone that quality seeds of any variety are almost nonexistent. A seed multiplication field should be established at the farmer’s rice field and the seeds of a target variety should be produced by special practices.

g. For sustainable rice production, rice farming should be a profitable business. Improved farming practices should be adopted first to enhance rice yield and make a profit even if the yield does not reach 3.0 ton/ha. Fertilizer application is the next step to increase the yield further up to 3.0 ton/ha.

h. To clarify the constraints on yield increase and find ways to enhance rice yield in IVS, the following experimental trials should be carried out:

(a) Periodical planting throughout the year with solar radiation measurement,
(b) Field trials with phosphorus (P) dose to amend P deficiency,
(c) Field trials with sulfur (S) treatment, and
(d) Fertilizer trials with various combinations of nutrients.

## Summary of Technical Package on Rice Production

| No. | Farming practice | Important points |
|---|---|---|
| A. | Land preparation | • Timely start of preparation<br>• Sufficient puddling<br>• Proper land levelling (smoothing) |
| B. | Variety selection | • Consideration of the characteristics of each variety, especially growth duration and disease/pest tolerance |
| C. | Seedling raising | • Use of good seeds<br>• Selection of proper nursery site (in an open area with sunlight)<br>• Proper size of nursery bed according to seed quantity (1 kg/10 $m^2$)<br>• Sufficient amount of seed for the main field (about 30 kg/ha)<br>• Uniform sowing in nursery beds |
| D. | Uprooting and transplanting | • Uprooting of 2- to 3-week old seedlings for transplanting<br>• Careful and gentle uprooting and removal of soil from seedlings' roots<br>• Immediate transplanting of uprooted seedlings<br>• Shallow transplanting (2–3 cm deep) of 2–3 seedlings per hill<br>• Uniform planting with 20–25 hills/$m^2$ |
| E. | Weed and pest management | • Timely weeding (1st weeding 2–3 weeks after transplanting, followed by occasional weeding depending on the degree of weed infestation)<br>• Fencing and setting traps to prevent "cutting-grass" (grasscutters or cane rats) damage to rice plants<br>• Keeping water in the field during the ripening stage; weeding of surrounding areas to prevent rat damage<br>• Preparation of a nursery in the backyard of the farmer's house or covering nursery beds until full germination to prevent bird attack<br>• Control of host plants of African rice gall midge, such as ratoons and volunteers of cultivated rice and wild rice (*Oryza longistaminata*)<br>• Early planting before the peak rainy season, intermittent irrigation with small quantities of water; occasional drainage to control case worm<br>• Well balanced nutrient supply to control diseases including brown spot. |
| F. | Harvest and post-harvest handling | • Timely harvest (at full maturity) to minimize loss<br>• Proper drying before and/or after threshing for storage<br>• Cleaning of threshing floor (ground) to avoid contamination with small stones and impurities<br>• Elimination of impurities through winnowing and cleaning |
| G. | Fertilizer application | • Recommended dose: N-$P_2O_5$-$K_2O$ = 40-40-40 kg/ha<br>• Two split application: 1st with N-$P_2O_5$-$K_2O$ = 27-27-27 kg/ha at puddling (just before transplanting); 2nd with 13-13-13 kg/ha at panicle initiation (about 2 months before harvest)<br>• Uniform application throughout the field<br>• No rain or dew when applying fertilizer |
| H. | Water management | • Sufficient water for puddling<br>• Low water level at fertilizer application<br>• Low water level maintained for several days after transplanting<br>• Sufficient water during the reproductive period<br>• Draining water about 2 weeks before harvest |

# 1. Introduction

## 1-1. Concept (premise) of the Revised TP-R

1) To increase crop production in a country, it is essential to raise the productivity of farmers. It is particularly so when the crop is the staple food and the majority of the population are engaged in farming. Rice production in Sierra Leone is largely dependent on subsistence farmers (Table 1-1). The average rice area per household is about 1.6 ha, and rice farming is basically carried out by family members.

Table 1-1. Rice planting acreage and household composition of farmers in Sierra Leone (a).

| Rice acreage (ha/HH) | |
|---|---|
| Upland | 0.7 |
| IVS | 0.5 |
| Others (b) | 0.3 |
| Total | 1.6 |

| Household (HH) composition | |
|---|---|
| Number of persons/HH | 6.5 |
| No. of persons in agricultural work/HH | 2.8 |

a) Interviewed survey on about 4,500 HHs. GoSL/WFP/UNDP/UNICEF/WHO /FAO (2006).
b) Boliland, riverine and mangrove swamp.

2) The revised TP-R focuses on the improvement of rice culture in inland valley swamps (IVS) though rice is grown in other agro-ecologies in Sierra Leone. Rice production in upland is hardly enhanced by cultural improvement, and in mangrove swamp, boliland, and riverine grassland, full water control is almost impossible without considerable investment. On the other hand, in IVS, water can be controlled by human power to some extent, and field improvement can be maintained by farmers' effort. Such lowland development has been implemented by the rice farmers in Asia since several hundred years before, at least.

3) Most information contained herein was obtained in Kambia District where the SRDP activities were concentrated throughout the project period. However, its content is applicable all over the country, as it was found by the Project that there was fundamentally no difference in farming system or soil fertility between Kambia District and other districts in these agro-ecologies including IVS.

4) Under the current farming system in lowlands including IVS, rice is cultivated mostly without water control, and no heavy farm work is performed until harvest except rough land plowing and transplanting. The primary objective of the revised TP-R is to increase rice grain yield from about 1 ton/ha to 3 ton/ha and make a profit.

5) Because of the poor soil fertility owing to the geographical history, anthropogenic fertilizer application is essential to improve rice grain yield. Although both organic and chemical (or inorganic) fertilizers can be used, the latter is more practical. With an application of 40 kg/ha of N, $P_2O_5$, and $K_2O$ each, grain yield of 3 ton/ha can be attained. On the other hand, proper water management is the precondition for yield increase. It should also be kept in mind that fertilizer is not a panacea and that its full benefits are gained only when combined with good cultivation practices.

6) Fertilizer application promotes productivity as long as water is properly controlled. It does not, however, always lead to a profit because yield response to fertilizer application is often not large enough to recover the fertilizer cost under the current socio-economic situation. Continued efforts to improve cultural practices are necessary to make rice farming a profitable business.

7) The effects of the fertilizer recommended in the revised TP-R on the environment are minimal because its rate of 40 kg/ha of N, $P_2O_5$, and $K_2O$ each is relatively small.

8) The principles of rice cultural practices in the revised TP-R apply to small-scale farming at the fringes (small percentage) of mangrove swamp, boliland, and riverine grassland and to large-scale farming. In fact, the cultural practices in small-scale farming are similar between IVS and the other agro-ecologies. Large-scale farming is beyond the scope of the revised TP-R because its investment requirements (e.g., mechanization and farm management) are incomparable to subsistence farming.

### 1-2. Simulation of grain yield evolution

The current rice grain yield in Sierra Leone is estimated at around 1 ton/ha (see the section 9. Appendices, A1.6-1). The SRDP recommends improved cultural management, especially for short and medium growth duration cultivars (Table 1-2). Grain yield of 2 ton/ha is feasible by improved cultural management (Fig. 1-1).

Table 1-2. Some key points of farming activities in improved (recommended) culture methods (a)

| Item | Conven-tional | Im-proved | (unit) | Contribution to yield |
|---|---|---|---|---|
| Seedling age | 4-10 | 2 - 3 | weeks | Large |
| Planting depth | 5-15 | 2 - 3 | cm | Large |
| Hill density | 15-50 | 25 | hill $m^{-2}$ | Fairly |
| Weeding | none | 2 - 3 | weeks after T/P | Large |
| No. of plants | 5-10 | 2 - 3 | per hill | Marginal (b) |
| Water management | none | Properly | | Large |

T/P: transplanting.

a) Most effective to cultivars with growth duration of 100-120 days.

b) Greatly contribute to the seed saving.

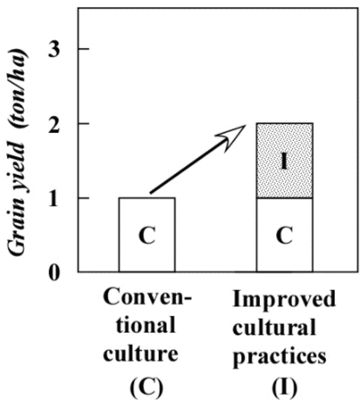



Fig. 1-1. Rice grain yield increase by cultural practice improvement

Fertilizer itself does not much enhance productivity if it is simply applied in the conventional farming system (Fig. 1-2, left). For one, even with fertilizer, overaged seedlings do not develop a sufficient number of tillers (panicles at full maturity; the dominant yield component). For another, fertilizer will be washed away if applied shortly before a heavy rain in a field without properly constructed bunds (dikes).

Proper water control is a must for fertilizer application because the amount of rainfall reaches nearly 2,000 mm during the main rice cropping season in Sierra Leone. Given proper water control and fertilizer application of 40 kg/ha of N, $P_2O_5$, and $K_2O$, yield may be increased by 1 ton/ha. However, if improved cultural practices are adopted, grain yield can be increased to about 3 ton/ha (Fig. 1-2, right).

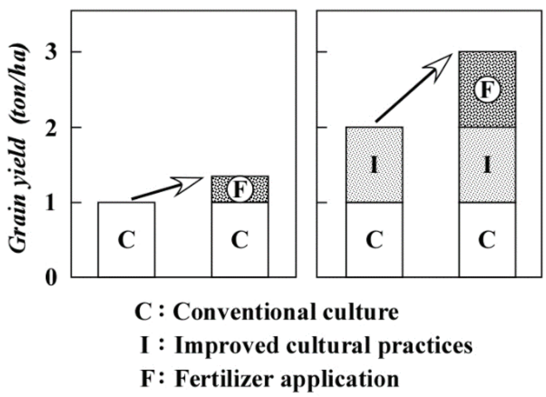



Fig. 1-2. Fertilizer effects on grain yield

## 2. Growth Development and Yield Components

### 2-1. Growth stages of rice plant

Rice plants sown or transplanted in the field develop a new leaf successively about every 4 days under tropical lowland conditions and produce tillers, grow taller, and increase their body weight (Fig. 2-1). A turning point in development occurs with panicle initiation about 30 days before heading or flowering (Fig. 2-2). After that, the plants develop panicles (their reproductive organs), which will be consumed by humans as food. Hence, the rice plant goes through three stages in its growth: (1) vegetative growth, (2) reproductive growth, and (3) ripening (grain-filling). It should be noted that the length of the latter two stages is about one month each, irrespective of the cultivar with the same or different growth duration.

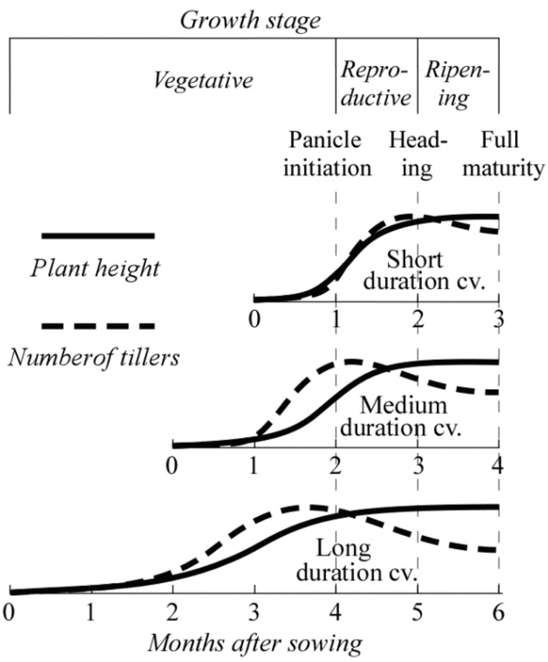



Fig. 2-1. Growth stages of various cultivars with different growth duration.

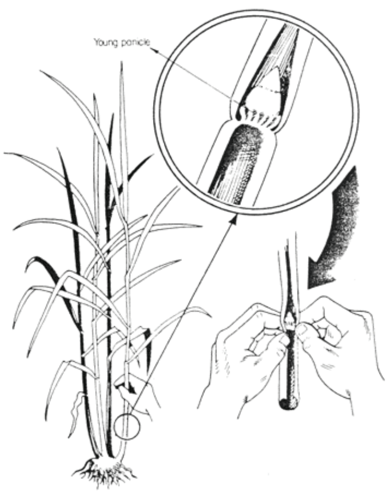



Fig. 2-2. Rice primordium shortly after panicle initiation (Vergara, 1992): Flowering occurs about 30 days after the start of panicle formation under tropical lowland conditions.

Crop management refers to what and how farmers provide to crops for them to grow healthily and strongly and to obtain high yield. To do this right and attain the goal, any change in the plants should be carefully observed throughout their growth stages, and necessary action should be taken timely.

### 2-2. Yield components

The final product obtained from the rice plant is not simply a mass of grains but that which consists of several biological components (e.g., the number of panicles per hill and the number of grains per panicle). The term, *grain*, refers to rough rice (also called paddy, unhulled rice, or unhusked rice) hereunder.

The development of yield components has been extensively studied and documented, including the relationships among the components and the effects of environmental factors on the components. External factors like solar radiation, water, and nutrients affect the development of respective yield components at a specific growth stage (Fig. 2-3).

Favorable conditions promote the growth (and thus the number) of tillers and spikelets per panicle. In contrast, unfavorable conditions such as low solar radiation and lack of nutrients negatively affect grain size (often expressed in 1000-grain weight) and ripened grain rate (grain-filling ratio). However, such environmental factors have more negative effects on the former than the latter. The grain size depends more on the glume size than any other factor. On the other hand, grain-filling can be determined 100% by environmental conditions. After all, it is the number of tillers and spikelets that contributes to the final grain yield, not the grain size.

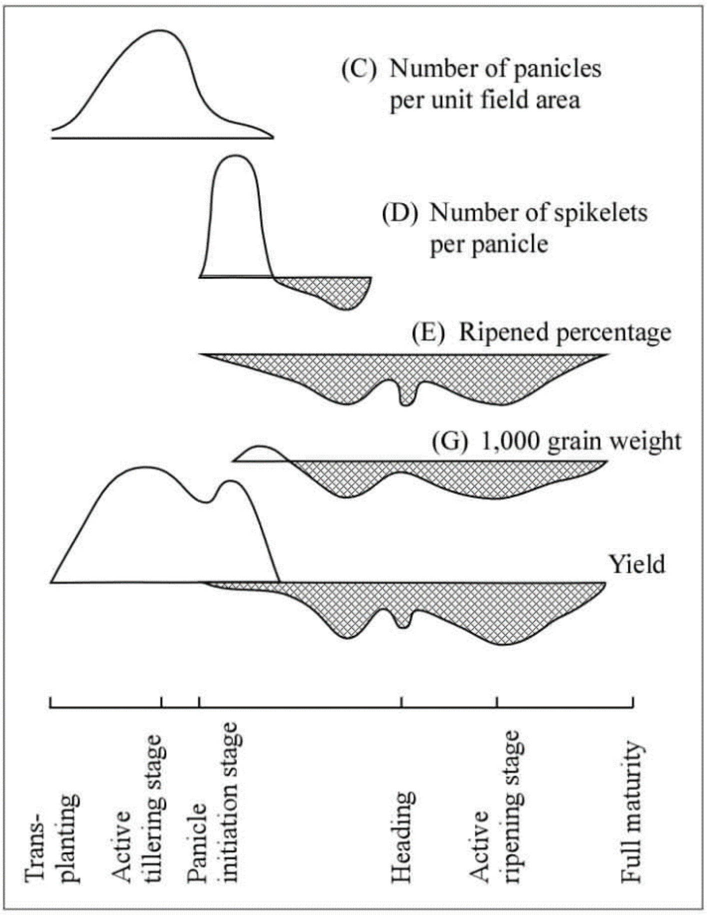



Fig. 2-3. Process of yield and development of yield components of the rice plant (based on Matsushima, 1959). Effects of environment at different growth stages: positive (blank) and negative (shaded).

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

1) Relationship between grain yield and yield components:

$$\begin{aligned} \text{Yield} &= A \text{ x } B \text{ x } D \text{ x } E \text{ x } G \\ &= A \text{ x } B \text{ x } F \text{ x } G \\ &= C \text{ x } F \text{ x } G \end{aligned}$$

where,

Yield: Grain weight per unit field area

Yield components (with sample value)

*A*: Number of hills per unit field area (e.g., 20 hills/$m^2$ = 200,000 hills/ha)
*B*: Number of panicles per hill (e.g., 6 panicles/hill)
*C*: Number of panicles per unit field area (A x B = 120 panicles/$m^2$)
*D*: Number of spikelets per panicle (e.g., 100 spikelets/panicle)
*E*: Proportion of filled grains (e.g., 0.85—85% of spikelets matured into filled grains)
*F*: Number of filled grains per panicle (D x E = 85 grains [filled]/panicle)
*G*: 1,000-grain weight (e.g., 25g/1,000 grains = 0.025 g/grain = 25 mg/grain)

2) Actual yield = A x B x F x G = 20 x 6 x 85 x 0.025

= 255 g/$m^2$ = 2.55 ton/ha ≅ 41 bu/acre

Note: The unit of bushel (bu) for grains (rough rice) is converted at the official rate of 25 kg/bu (see the section A3. Conversion table).

## 3. Rice Culture Management

### 3-1. Land preparation

Land preparation works include slashing, clearing, plowing (digging), puddling, and leveling.

#### 3-1-1. Site selection

In the IVS ecology, farmers grow rice in the same fields every year and thus understand the site conditions including soil fertility and potential problems (e.g., weed infestation, pests, and flooding). If a new area is to be cultivated for rice, flat lowland should be given priority, and necessary water control facilities such as drainage canals, bunds, peripheral canals, and a head bund should be constructed.

#### 3-1-2. Canal maintenance

During the dry season (February–May or before the rainy season starts), maintenance and/or rehabilitation of drainage and peripheral canals should be done for proper water control in lowlands. The drainage canal should be dredged to remove sediment deposited during the previous rainy season. Peripheral canals should also be dredged to restore their discharge capacity.

The bunds should be repaired as necessary not to allow water to flow in or out of the field. Damaged bunds are rehabilitated or strengthened with dug soil that is moistened with water and firmly compacted.

#### 3-1-3. Slashing the vegetation and weed handling

The traditional method of land preparation practiced by farmers is acceptable. The vegetation in the field is slashed (brushed out), dried, and then burned. In case of early rains or delay in slashing, slashed weeds are moved to an area outside the main field or heaped at designated spots.

***Note on weed handling***

Weed control plays a key role in rice cultivation regardless of whether it is in uplands or lowlands. By burying organic matter (e.g., weeds), nutrients are released from it through decomposition. However, this could only be applied under well-aerated conditions as in upland cultivation.

Under oxygen-deficient conditions as in the 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. 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, which requires lengthy and laborious work. The farmers should try to remove as many weeds from their main field as possible to keep them out of the soil and prevent iron toxicity where it is expected.

#### 3-1-4. Plowing (digging)

The plowing practices currently adopted by the farmers are acceptable; soils are plowed by a long-handled large hoe designed for the heavy clay soils in the area. Deep plowing (about 20 cm deep) is recommended, although it is often difficult to plow beyond 10 cm by manual plowing. Because plowing is the hardest work and time-consuming, the main field should be plowed before sowing in the nursery.

Use of cattle for plowing should be promoted. Work oxen are common in some parts of Samu and Mambolo chiefdoms in Kambia District. Mechanization of plowing by tractor and power tiller is costly, especially in maintenance. The Government has supported mechanized plowing with a heavily subsidized scheme (Spencer, 1981).

***Plowing in mangrove swamp***

In mangrove swamp areas, rice fields should be plowed well before nursery preparation starts to allow sufficient time for any accumulated salt to be washed out of the soil by freshwater, either rain or river water.

### 3-1-5. Puddling and field leveling (smoothing)

Sufficient puddling is essential for shallow planting (Fig. 3-1) that allows new roots and then 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 farmers' fields.

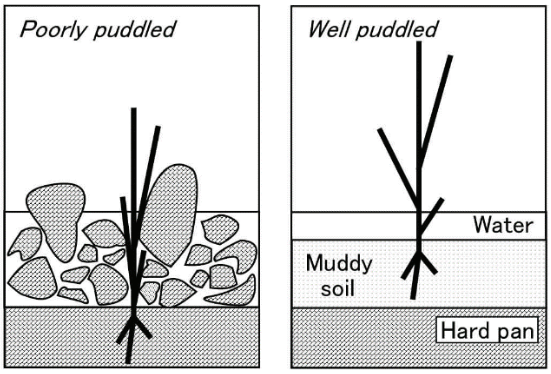



Fig. 3-1. Poorly and well puddled lowland rice fields. Note: Shallow transplanting is possible only when the main field is well puddled and flattened.

Farmers generally stop puddling after breaking large clods (20–40 cm) into smaller clods (5–20 cm): They call this activity “turn-over”. Some farmers do better by stamping the clods on the spot (a few square meters) to further break them into mud.

Land is leveled (smoothed) with flat rakes made of wood. This leveling work together with good puddling creates uniform environment in terms of water depth and nutrient supply so that the planted seedlings grow uniformly in the field.

## 3-2. Cultivar selection

1) It should be kept in mind that there is no such thing as a perfect cultivar (variety) in the world. It is mainly because rice plants are grown in diverse conditions. High-yielding cultivars are often susceptible to diseases and unable to survive in deep water, for instance.

2) To secure stable and better production, the most important criteria for cultivar selection would be growth duration, followed by disease tolerance and then, perhaps, palatability.

   As for growth duration, cultivars that are photoperiod-sensitive with long growth duration are selected when flooding is likely to occur for a certain period: ROK 10 is one of such cultivars, for instance.

These cultivars can grow in deep water owing to their tall stature, and they have an advantage in that they can be harvested after the rainy season.

Because the majority of rice fields are not developed with water control facilities and thus water is the primary limiting factor in the dry season cropping, cultivar selection should be made considering when and how long water is available. In many cases, the only choice is a short-duration cultivar, especially in IVS with a semi- or non-perennial stream.

3) Cultural management differs according to cultivars, especially their growing period. A strong photoperiod-sensitive cultivar has a long vegetative growth period and generally grows tall, so its yield will be moderate and stable without much cultural management. Such cultivars can survive long inundation or deep planting even with old seedlings. Moreover, they can even compete with weeds.

   In case of a modern, improved cultivar, on the other hand, high yield cannot be obtained without careful crop management like shallow planting of young seedlings and proper water control. The main reason is that most of such cultivars have a relatively short vegetative growth period and short stature. The nursery period becomes critical when cultivars with short duration like 90 to 100 days are used because its vegetative growth duration is only 30 to 40 days. When seedlings stay in a nursery for one month or longer, common for indigenous (local or traditional) cultivars, panicle formation begins soon after transplanting. Under such condition, the number of spikelets will likely be as small as 4 to 10 in each panicle (Photo 3-1).

Photo 3-1. Unexpected flowering of short duration cultivar (*Eitori*: 3 mos.) 2 weeks after transplanting. One-month old seedlings were transplanted. (Mapila in Port Loko).

4) Some selected cultivars grown in the country are summarized in Table 3-1. Unfortunately, information on their planted area, genetic backgrounds, and important traits (e.g., plant type, lodging resistance, disease tolerance, grain type, degree of shattering, seed dormancy, etc.) is not available. Notwithstanding, the farmers observe the plant characteristics of various cultivars and rationally select cultivars according to the topographical and climatic condition (Table 3-2).

5) The number of tillers is generally 3 to 5 per hill regardless of the cultivars in the conventional farming system. However, the majority of the cultivars grown in Sierra Leone have high capacity to develop tillers in general. ROK 5 and ROK 10, for example, easily produce 50 to 60 tillers/plant under favorable conditions (Fig. 3-2). Because the number of panicles is a dominant factor among various yield components in determining yield, it is most crucial that the rice plant develops as many tillers as it can in the early growth stages. Light and nutrients are two most important determinants of how vigorously rice plants will develop tillers.

Table 3-1. Selected rice cultivars grown in various regions of Sierra Leone (a).

| Cultivar | Region (b) | Agro-ecology (c) | Planting years | Growth duration (month) (d) | Plant height (cm) |
|---|---|---|---|---|---|
| | | *Indegeneous (local) cultivars* | | | |
| Bako | N | Upland | 100+ | 5 | - |
| Benbe | S | Upland | 100+ | 5 | - |
| Beyaya | N | IVS | 100+ | 5 | - |
| Bongbo | S | Upland | 100+ | 4 | - |
| DC (Pa DC) | N | Upland | 100+ | 6 | - |
| Fei | S | Upland | 100+ | 4 | - |
| Gawai | S | Rv | 100+ | 6 | - |
| Kambame | S | Rv | 100+ | 6 | 120 |
| Kayankalia | N | IVS | 100+ | 6-7 | - |
| Kogbatei | S | Rv | 100+ | 6 | - |
| Kpenei | S | Rv | 100+ | 6 | - |
| Kulma | N | Boli | 100+ | 6-7 | - |
| Layana | N | IVS | 100+ | 7-8 | - |
| Pakailahun | N | IVS | 100+ | 6 | 120 |
| Parmoi | S | Upland | 100+ | 4 | - |
| Patei | E, S | IVS | - | 5-6 | 90 |
| Quatikandor | N | IVS | 100+ | 5-5.5 | 150 |
| Sinkariyana | N | IVS | 100+ | 5 | - |
| Soronkadi | N | IVS | 100+ | 4-5 | 85-100 |
| Wusie | E, S | IVS | 100+ | 4-6 | 90-150 |
| Yagbassay | N, E, S | IVS, Upland, MS | 100+ | 4-5 | 60-100 |
| Yainkendeo | E | Upland | 100+ | 5-6 | 100-130 |
| Yaraduca | N | IVS | 100+ | 7-8 | 120-150 |
| Yornjorwa | E | IVS, Upland | 100+ | 6-7 | 110-120 |
| | | *Improved/Semi-improved cultivars* | | | Rv |
| Butter cup (e) | N | IVS | 10 | 3.5 | 110-130 |
| CP4 | S | IVS, Boli | 30 | 6-9 | - |
| Indochina | N | Rv, Boli | 30 | 6 | 150-200 |
| Kori-Korie | N | Upland, IVS, Boli | 2 | 4 | 60 |
| LAC 23 | E, S | Upland | 40-50 | 4-5 | 120-150 |
| Nerica L19 | N, E, S, W | IVS | 3-5 | 4 | 80-120 |
| Pakiamp (f) | N, E, S, W | Upland, IVS, Boli, MS, Rv | 10 | 4-5 | 110-150 |
| CCA (g) | N | IVS | - | 3.5 | 80 |
| ROK 3 | N, E, S | Upland, IVS, Boli, MS | 30 | 4.5-5 | 100-120 |
| ROK 5 | N, S | IVS, MS, Upland | 30 | 4-5 | 130-150 |
| ROK 10 (h) | N, E, S | MS, IVS, Boli, Rv | 30 | 5-6 | 130-150 |
| ROK 14 (i) | W | IVS | 30 | 4 | 120 |
| Sinoa | N | IVS | 50 ? | 3.5 | - |
| Yeffin | N | IVS | 2 | 3.5 | 120-140 |

a) Most information collected during the training on TP-R for MAFFS staff by SRDP/JICA (2014). b) N: Northern, E: Eastern, S: Southern, and W: Western. c) IVS: inland valley swamp, Boli: boliland, Rv: riverine grassland, and MS: mangrove swamp. d) Growth duration of photoperiod-sensitive cultivars vary with planting season. e) Synonym: Patele. f) Locally called as Rizis in the east. g) 'Chen-chu-ai'. Synonym: Patheden. h) Synonym: Tonsor Kayrain and Gbasnin in the north. i) Formarly called as Mange 2.

Table 3-2. Reasons for cultivar choice (a).

1) Preference of indigenous cultivars.

| Reason |
|---|
| *Growth trait* |
| High tillering ability |
| Short duration (b) |
| Lodging resistance (c) |
| Tolerance to deep flooding |
| Stable harvesting time (d) |
| *Abiotic resistance* |
| Resistant to diseases |
| Resistant to insect damage (e) |
| *Grain quality* |
| High palatability (tasty) (f) |
| High market price |
| Red rice |
| High filled grain (g) |

a) See Table 3-1 for information source.
b) The item might contradict to (c), but it does not: there are both photo-sensitive and non-sensitive cultivars.
c) Some cultivars are susceptible to lodging.
d) Regardless of planting time due to strong photo-sensibility.
e) e.g., gall nudge.
f) Grow for home consumption while growing improved cultivars for selling.
g) Might be related to low yield due to a small number of spikelets.

2) Choice of improved cultivars (h).

| Reason |
|---|
| *Advantage* |
| High grain yield (i) |
| High GY without fertilizer |
| High yield in marginal, infertile soils |
| High tillering (large number of panicles) |
| Tolerance to flooding |
| Resistant to lodging |
| Tolerance to salinity |
| Tolerance to pests |
| Resist. to rice blast |
| Resistant to diseases |
| Resistant to rats |
| high palatability |
| Good quality overnight in cooked rice |
| *Disadvantage* |
| Fertilizer need for high yield |
| Susceptible to lodging. |
| Susceptible to pests |
| Susceptible to rice blast |
| Susceptible to case worm |
| Susceptible to weeds |
| Susceptible to rats |

h) Several reasons contradict each other between advantage and disadvantage.
i) Called as business rice due to poor palatability.

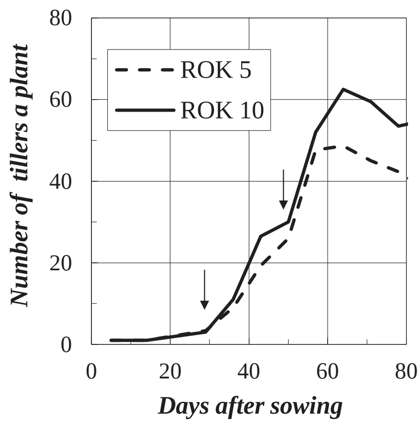



Fig. 3-2. Examples of tiller development capability in selected cultivars (pot culture) (ADPK, 2008).

Arrows show the time of top dressing at 0.3 g/pot of N, $P_2O_5$, and $K_2O$ each. No basal fertilizer was applied. Note that fertilizer supply was controlled so that the plants would not develop excess tillers.

6) It is always recommended to grow several cultivars with different traits in a season as some farmers do. This will help mitigate possible damage to rice from climatic (especially rainfall) and hydrological fluctuations as most rice fields are currently under poor water control. A combination of short, medium, and long duration cultivars is advised. The area to be planted with the cultivars are split into plots of equal or different sizes, one for each cultivar: the plot size for each cultivar depends on the environmental factors and the farmers’ strategy. Cultivation of cultivars with different growth duration improves yield stability and reduces the period of food shortage. If there is any extra production in a lean season, farmers can sell the surplus at higher prices.

7) Many cultivars have the ability to develop a sufficient number of tillers as long as they have enough nutrients. Given this, the majority of the current cultivars have potential to produce grain yield of 4 to 5 ton/ha.

8) Farmers often try exotic cultivars that they obtain from their neighboring villages and even from other regions and countries. Newly introduced cultivars should be planted in small scale in the first year even if they performed well in the areas where they come from. The plant growth must be carefully watched, especially for pest occurrence. Because pests are endemic, a cultivar from other area may suffer from an unexpected disease in a different environment. Similar cautious observation is also needed to examine the difference in growth between the rainy and dry season cropping. Gradual increase of planting area is strongly recommended for newly introduced cultivars.

9) A cultivar is often given different names; ROK 10 is occasionally called *Gbas-nin* or *Tonsor Kayrain*, for example.

10) Farmers often claim that grain yield can be increased again by changing a cultivar when the yield of the existing cultivar declines. The rationale for such a claim is hard to come by. Nevertheless, breeding of cultivars tolerant to low-nutrient conditions is widespread in the world (SRDP, 2014), and this issue should be addressed with full attention. The fields become barren if the farmers keep growing tolerant cultivars. Such cultivars gobble up what little nutrients remain in the soil, and eventually all the nutrients will be exhausted. Therefore, careless introduction of low-nutrient tolerant cultivars should be avoided in coping with soils of low fertility.

### 3-3. Seedling raising

In transplanting, the first step towards attaining 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 sufficient carbohydrate and mineral nutrients, and they start to grow autonomously within a few days after transplanting. The excessive elongation of shoots (etiolation) should be avoided because etiolated seedlings do not have enough nutrients accumulated in their body even though they grow tall. Etiolation is facilitated by dense planting, prolonged growth, and shade (insufficient sunlight).

#### 3-3-1. Seed selection

Seeds with high purity are obtained by sorting. The seeds of weeds and other rice varieties are removed. The seeds of a target variety are discernable from those of mixed cultivars by color, size, shape, length, etc. Immature seeds are also removed. However, seeds with different plant traits like growth duration and height sorting cannot be eliminated by sorting. The best and first approach to obtain pure seeds is complete roguing in the seed multiplication field, as described later (in the section 6. Seed Production).

Fully filled grains are selected by soaking. Seeds are put in a large bowl or bucket of water, and those that float are sterile or unfilled grains to be removed. Use of salt solution is recommended. By using a salt solution with a specific gravity of 1.13 g $cm^{-3}$ (2.1 kg of table salt dissolved in 10 L of water), fully filled seeds can be selected.

#### 3-3-2. Germination test

The germination rate of seeds should always be tested to determine the quantity of seeds needed and to evaluate their viability. It should preferably be higher than 80%. If it is less than 80%, it is advisable to discard the stock and find better quality seeds. If other seeds are unavailable, use the tested seeds but increase the amount of sowing seed considering the low germination percentage. Irregular germination and growth is often observed in seeds with low germination rates.

A germination test is performed as follows:

a) Place a sheet of clean absorbent paper or cloth in a shallow container (about 10 cm in diameter or square).
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 to soak the seeds and cover the container with any material that prevents excess evaporation.
d) Leave the container in a room for 4 to 5 days or 1 week at the maximum.
e) Count the number of germinated seeds in the container.

***Transplanting and direct sowing***

Lowland rice culture in Sierra Leone is practiced both with transplanting and direct sowing methods. Small-scale farmers mostly adopt the former in all agro-ecologies, including mangrove swamp, and do the latter in very limited cases. The advantages of transplanting method are the relative ease of weed control, adaptability to irregularity of field surface, and seed saving.

In contrast, large-scale, mechanized farming in boliland and riverain is mostly practiced with direct sowing. Well levelling of fields and full water control are essential to attain high yield under the direct sowing method. Because such fields are unavailable in the country, rice plants are often grown with deep water condition in the major growth stages: floating rice is not rare. Seeds in direct-sowing system are sown in dry land, being not in wet land. The revised TP-R focuses on transplanting system, which is practiced by most farmers.

### 3-3-3. Nursery preparation

1) Dry and wet nurseries: For the rainy season cropping, a dry nursery is recommended. Based on the observations of farmers' nurseries, various disadvantages of a wet nursery during the rainy season are noted, such as the frequent occurrence of submergence, diseases and seedling etiolation. A few farmers sow the seeds under water, but many farmers do so on the lower ground near lowlands. Such nurseries soon becomes saturated or submerged by rain or water seepage. They can be broadly categorized as a wet nursery. For the dry season cropping, a wet nursery is the only choice.

2) Nursery preparation: Since nursery preparation does not require much labor, it should be started after plowing is completed. It will help avoid the risk of prolonged nursery period that may happen when land preparation is delayed.

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

4) Seed requirements and the nursery area: Assuming that the germination rate is 80%, the plant density is 25 hills/$m^2$, the number of seedlings is three per hill, the emerging (sprouting) rate in situ is 80%, 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:

$$25 \times 3 \times 25/(1{,}000 \times 0.8 \times 0.8) = 2.9 \text{ g/m}^2 = 29 \text{ kg/ha} \cong 30 \text{ kg/ha}$$

$$\cong 12 \text{ kg/acre} \cong 0.5 \text{ bu/acre}$$

Seed requirement is largely affected with the number of seedlings planted per hill (Table 3-3). The larger the number of seedlings per hill, the larger the seed requirement.

Table 3-3. Seed quantity required for transplanting seedlings in main field with various combination of 1,000-grain weight of seeds and the number of seedlings per hill (a).

| Number of seedlings /hill | Seed requirement (kg/ha) 1,000-grain weight (g) | | | Nursery area ($m^2$) (b) |
|---|---|---|---|---|
| | 20 | 25 | 30 | |
| 1 | 8 | 10 | 12 | 100 |
| 2 | 16 | 20 | 23 | 200 |
| 3 | 23 | 29 | 35 | 290 |
| 5 | 39 | 49 | 59 | 490 |
| 10 | 78 | 98 | 117 | 980 |

a) Calculated on the basis of 25 hill/$m^2$, 80% germination by incubation, and 80% emergence (sprout) in nursery.

b) Nursery area is applicable only to 2-3 week-old seedlings with ±20% allowance.

Note that seeding rate of 1 bu/acre (= 63 kg/ha) is widely 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 reduce seed requirement.

5) 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. The first priority is to keep the seedling in the nurseries for just the right period, 2 to 3 weeks.

6) Nursery size: The information on the nursery size in Table 3-3 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.

7) Seed beds preparation and sowing: For uniform sowing, the seeds are divided into two at a 1:2 ratio, of which 2/3 is sown first, and the remaining 1/3 is used to even out any uneven distribution of the seeds on the seed bed. The field is shallow-tilled or covered with light soils after the sowing.

8) Mulching: Mulching with rice straw, 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 and keep favorable humidity even though there is a dry spell.

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

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

***Fertilizer application to nursery***

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 or shaded conditions. Under such conditions, the seedlings become etiolated and prone to diseases. The sole use of nitrogenous fertilizer is not recommended. Instead, NPK compound fertilizers (e.g., 15-15-15) should be used, if applied.

### 3-4. Transplanting

#### 3-4-1. Seedling age

The recommended seedling age for transplanting is at 4th leaf stage on the main culm, when a plant starts to develop tillers (Photo 3-2). It corresponds to 2 to 3 weeks after sowing depending on temperature. The higher the temperature is, the faster the growth is. The seedling quality deteriorates if the nursery period is too long. If transplanted properly, healthy (sturdy) seedlings start to develop new roots within a few days at the latest and successively develop tillers from every leaf node. Thus, when healthy and active seedlings are transplanted, a sufficient number of tillers (eventually panicles) foretells a high yield at an early stage of growth.

Use of young seedlings is especially critical in short duration cultivars (i.e., 3 months). When old seedlings are used, plants emerge panicle primordia soon after transplanting. Such a practice induces plants to produce only a few number of spikelets (Photo 3-1) because plants are not able to produce a large number of spikelets due to limited time.


Photo 3-2. Rice plant at the 4th leaf stage. Note that the first tiller emerges at the 1st leaf node. The number indicates the order of the growth of the leaves on the main stem.

Note that a disadvantage of old seedlings is not applicable to traditional, photoperiod- sensitive cultivars (Fig. 3-3). Their vegetative growth duration is long enough to sustain active growth when they are planted in the early rainy season. This is the one of the reasons why farmers prefer to grow long duration cultivars under the conventional culture condition.

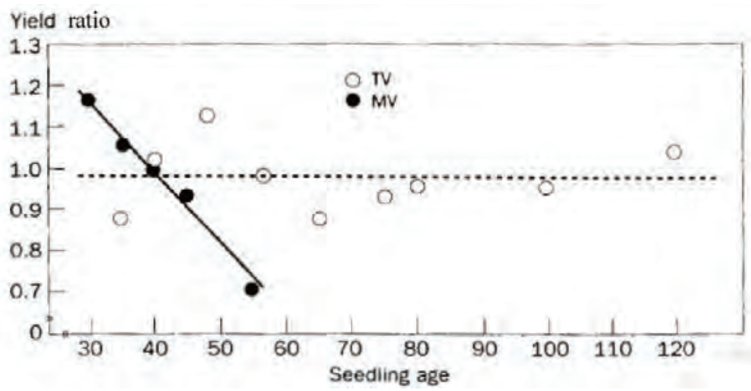



Fig. 3-3. Grain yield of traditional (TV) and modern (MV) cultivars, expressed as ratio of yield to yield of 40-day old seedlings (Gines et al., 1985).

***Seedling age for mangrove swamp***

For mangrove swamp, the seedlings age for transplanting can be as old as 4 weeks, because young seedlings are known to be susceptible to salt injury. Salts still remain at the time of transplanting. The nursery area for 4-week old seedlings should be 1.5 of that shown in Table 3-3.

### 3-4-2. Uprooting

The seedlings should be uprooted from the nursery beds on the day they are transplanted. The roots of the seedlings developed in the nursery become inactive because 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 the mud can be removed by gently shaking or brushing them, 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 little affects the quality of the seedlings. Cutting-off the roots at a few cm depth by a shovel is alternative for uprooting. Washing the roots in water is also an appropriate way to remove the soil if water is abundantly available.

If old and tall seedlings must be used for any reasons, their elongated leaves should be trimmed since trimming lessens the water loss from transpiration and mitigates damage after transplanting. Trimming will help shallow planting too.

### 3-4-3. Hill (planting) density

The recommended planting density is about 25 hills/m$^2$ (e.g., hill spacing: 20 cm x 20 cm) for medium to long growth duration cultivars. Because the tillering ability of many cultivars currently used in the area is high (Fig. 3-2), they adapt themselves to a given plant spacing. The number of panicles per unit field area does not increase in proportion to an increase of the planting density: it is controlled by the availability of nutrients and solar radiation, in addition to the varietal traits. Eventually, the final yield is little affected with a wide variation of the density (Fig. 3-4). Spacing the seedlings too close should be avoided.

Besides, close spacing promotes vertical growth in the plant, rendering it susceptible to lodging. However, slightly closer spacing can be recommended for short duration (90–100 days) cultivars (e.g., Buttercup, Kissy fundy, etc.), especially in dry season cropping.

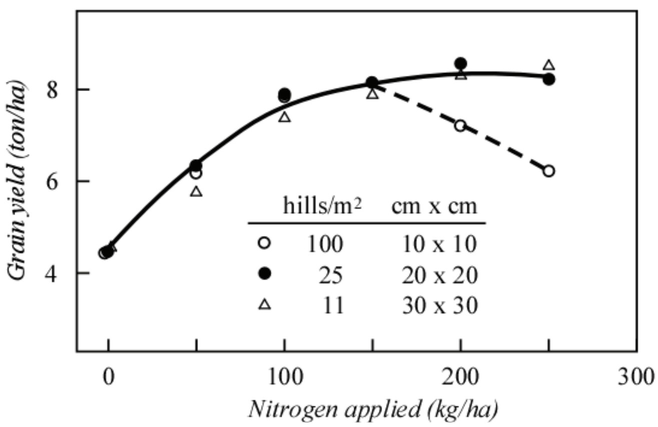



Fig. 3-4. Effects of nitrogen application on grain yield in relation to planting density (Kurashima, 1970).
(Variety: IR 8. Dry season at IRRI)

### 3-4-4. Planting depth

The recommended transplanting depth is 2 to 3 cm. This shallow planting promotes the rapid development of new roots and tillers and eventually a greater number of panicles (Fig. 3-5), which is a dominant component of grain yield. Farmers should be careful not to transplant too deeply or fold the seedling stem, especially when using a planting fork (Fig. 3-6).

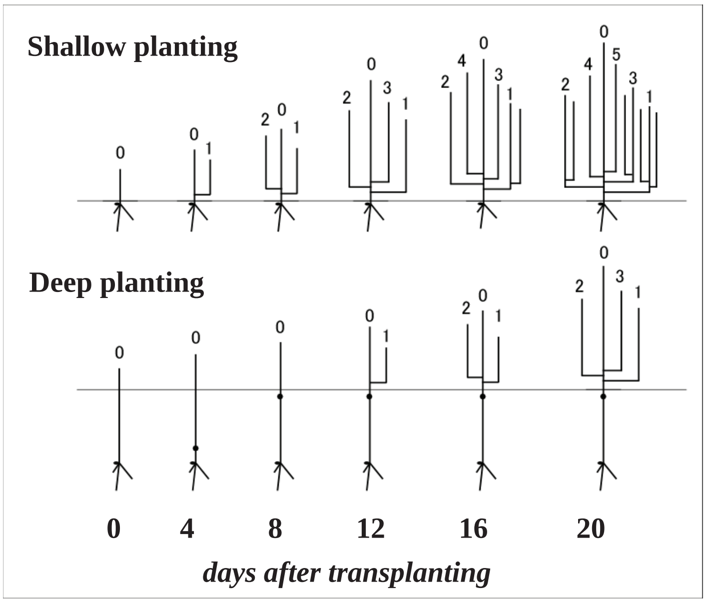



Fig. 3-5. Tiller development affected with planting depth.

Note that proper planting depth will be affected with soil physical properties. When the soils are soft and fragile with loamy and peaty characters under ill-drainage condition, the soil surface should be settled down by puddling the fields a few days before transplanting. If necessary, make the planting depth deeper than the recommended one.

When plants are deeply planted, they elongate mesocotyl until the stem base reaches closer to the ground surface, and then they start tiller development (Photo 3-3). Time wasted for unnecessary elongation results in reduced number of tillers (Fig. 3-5).

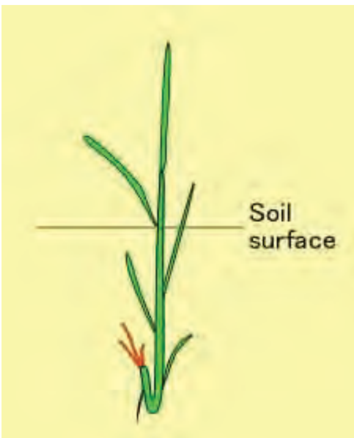



Fig. 3-6. Folded stem of a seedling due to the improper use of a planting fork

Photo 3-3. Elongated mesocotyls due to deep transplanting. Deep transplanting causes a delay in tiller development.

### 3-4-5. 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 (a dominant yield component) is little affected with the number of seedlings per hill. The reason is the same as that for the planting density mentioned above. Using fewer seedlings is to economize on seeds. By planting fewer seedlings per hill, the farmers can easily cut their seed costs up to 1/4 or 1/5 of the present cost of planting 10 seedlings/hill or even more (Table 3-3). One seedling/hill is also allowed, because such a practice does not affect productivity.

### 3-4-6. 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 the inflow of heaped weeds from the surrounding fields after a heavy rain.

### 3-4-7. Planting pattern

Random planting, currently practiced by farmers, is acceptable. Rice plants are capable of producing many tillers so that they easily adjust an irregular gap (Fig. 3-7). Line transplanting makes weeding easy. However, it is optional because it is time consuming and labor intensive than random transplanting. Line planting take considerable advantages on the use of a rotary weeder.

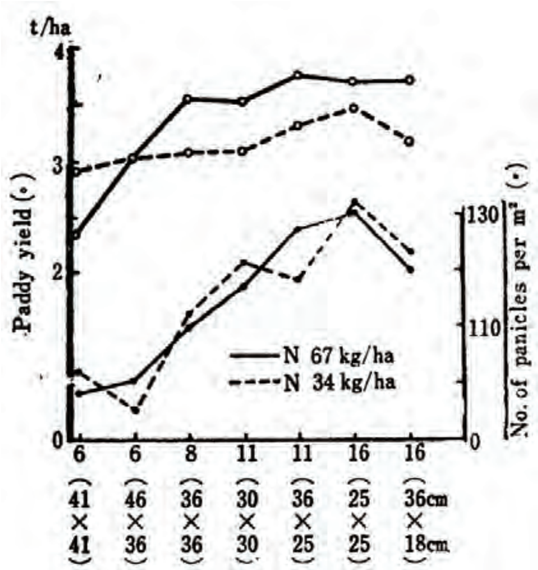



Fig. 3-7. Grain yield and the number of panicles affected with nitrogen application rate and planting pattern (Sugimoto, 1975).

Variety: Radini China 4. Malaysia.

## 3-5. Weed and pest control

The growth of rice plants is affected by various weeds, rodents, birds, insects, and diseases. The use of agrochemicals for pest control is not included in the revised TP-R: consult Reissig, et al. (1986) and FAO (2005) for details when necessary.

The surrounding area of the nurseries and the main fields should be kept clean at all times. Cleaning helps prevent rodent attacks, the occurrence of diseases, insect damage.

### 3-5-1. Weed control

Rice plants compete with weeds for nutrients and sunlight. Common weeds are grasses, sedges, and broadleaf weeds. They are site-specific and proliferate at different times according to the soil and water conditions. Hence, the timing and frequency of weeding depend on the location. The SRDP recommends one thorough weeding 2 to 3 weeks after transplanting when weeds are still small.

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.), repeated weeding will be required until the plants reach the level of normal growth. Several experiments show the better result with double weeding (Table 3-4).

Tabale 3-4. Effect of frequency and time of hand weeding on rice grain yield (ton/ha) of ROK 14 in IVS (RARC, 1995) (a)

| Number of hand weeding | Time of weeding (WAT) | Grain yield (ton/ha) | (b) |
|---|---|---|---|
| 0 | - | 1.7 | f |
| 1 | 4 | 2.8 | cde |
| 1 | 6 | 3.0 | abcd |
| 2 | 4 & 10 | 3.3 | abcd |
| 2 | 6 & 10 | 3.1 | abcd |
| 3 | 2, 6 & 10 | 3.6 | abcd |

WAT = weeks after transplanting
a) Average over three seasons at Rokupr and Bo.
b) Means having the same letters are not different by DMRT.

***Weed control relevant to nutrient replenishment***

Farmers in Sierra Leone adopt several methods to control weed for preparing lowland rice fields.

a) Slush, dry for a few weeks, and burned, when weed growth is exuberant and there is enough time to dry them,
b) Slush and removed, when the site is wet or rain comes earlier than expected,
c) Incorporate weeds into soils with plowing, when weeds are not thick,
d) Ridge or mound building with incorporating weeds, leave for about several weeks to decompose them, and then level down.

Choice of the practice is subject to the vegetation and water regime in respective environment. Nutrient enrichment would be large by (d) and small by (b). Mounds and ridges in lowland during dry season are prepared for upland crops like vegetables, sweet potato, groundnuts, etc. in a similar manner to (d). The quantity of nutrients released and contributed to rice growth should be estimated through chemical analyses and field trials.

Farmers are used to applying compost to vegetables and to mulching the mound with rice straw during the dry season after the rainy season rice is harvested. The straw is completely decomposed during the vegetable growth so that released nutrients contribute to subsequent rice growth because those mounds are levelled down for rice culture.

***Weeding in mangrove swamp***

In a mangrove swamp area, weeding is unnecessary because the growth of the most dominant weed, crawling grass (*kireh-kireh*), is suppressed by the growth of the rice plants.

### 3-5-2. Rodents

*Cutting-grass* (grasscutters or cane rats) sometimes cause serious damage to the rice plants because they move in groups and feed on the plants and rice. 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 open their big farms together (in a scale of several hundred hectares) to dilute the damage. Yet, rice fields adjacent to the bush suffer more and sometimes a rodent family nestles in a large farm.

Maintaining water during the ripening stages is an appropriate measure in addition to weeding in the surrounding area to prevent rat damage.

### 3-5-3. Birds

Bird scaring is essential at the time of sowing seeds on nursery and ripening stages. 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. For a relatively large nursery, mulching is an adequate measure to prevent seedlings from bird attach. In the main field, bird scaring (mainly for weaverbirds) should start immediately after flowering regardless of the agro-ecologies.

### 3-5-4. Insects

Generally, the occurrence of insect damage in Sierra Leone is low, possibly due to the heavy rains during the main rice cropping season (rainy season). Nevertheless, several species of insects like African rice gall midge, case worm, stem borer, and stalked-eye fly are observed.

1) African rice gall midge

African rice gall midge's "larvae attack the growing points of rice tillers and cause the leaf sheath tissues to form a tube-like structure called a 'silver shoot gall' that resembles an onion leaf" (Nwilene, et al., 2006). 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, its effects on the final yield will be minimal since other hills or new tillers compensate for the loss.

Nevertheless, the damage can be serious, as farmers in the western parts of Kambia District reportedly abandoned the affected rice fields because of gall midge damage. Host plants of African rice gall midge such as wild rice (*Oryza longistaminata*) and ratoons and volunteers of cultivated rice plants should be controlled during the dry season to reduce the number of population (Nwilene, et al., 2006). Cultivars resistant to the insect such as Cisadane are available; however, there are many biotypes of the gall midge and the selected cultivar may be vulnerable to the type of gall midge in the area (Reissig, 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 (Reissig, 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 before the peak rainy season and by drainage. Inflow of runoff water into the field should be prevented by constructing dikes along peripheral canals as it exacerbates the damage. If irrigation water is supplied, it should not be much in quantity in one time.

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 their serious damage has not been reported.

### 3-5-5. Diseases

Brown spot and several other fungal diseases are common and found across all the rice agro-ecologies (Photo 3-5 to 3-7). These fungal diseases are closely related with a physiological condition, caused by a nutrient imbalance in the rice plant, so that they are called as physiological diseases.

Brown spot Leaf scald Early stage of rice blast

Photo 3-4. Several diseases observed in Kambia District

Brown spot is rare in rice plants grown in fertile soils (IRRI, 1986). The leaves of a rice plant affected with brown spot often show potassium deficiency symptoms, and is low in potassium concentration in the plant. Potassium fertilizer or NPK compound fertilizer is effective in remedying the disease.

Leaf-scald (Photo 3-6) is a fungal as well. 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 are rare in the country.

## 3-6. Harvesting and post-harvest management

The rice field should be frequently visited 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.

### 3-6-1. Harvesting

1) Timely cutting

Proper cutting at the right time is essential in attaining the maximum 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 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 above b), c), or d); or a combination of these may be used.

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

2) Cutting straw or panicle picking

Straw cutting by a sickle is commonly practiced in the northern region, and panicle harvesting (Photo 3-5) in the eastern region. The latter possesses an advantage of picking fully matured panicles only under the condition of mixed cultivars with different growth duration, but a disadvantage on time consuming. Sickle harvesting is described in the following text.

Photo 3-5. Panicle harvesting

A typical manual cutting method is to grasp straws at about two third of the straw length above the ground and cut them with a small straight (kitchen) knife. To minimize the risk of shattering grains, knives should be sharpened before cutting and during cutting as necessary. The cut straw is held in one hand and as more panicles are cut, and they are added to the bundle (or bunch) in the hand. When the handful bundle is large enough, it is put on the nearby convenient place. Several handful bundles piled up are tied them with a wisp of straw or palm leaves.

Rice straws are preferably cut a little longer than the length that farmers commonly do, so that the panicles with short straw are not rolled in the bundle. By doing this, ventilation to the panicles is improved so that they can be dried faster. With longer straws, the panicles can be easily threshed by beating or stamping. It is recommended that binding be done in a container such as large pan or basket: without it, grains are fallen from the bundled panicles during the work. The use of the container is to reduce shattering loss while binding.

3) Transporting

The bound bundles of rice are carried to the place where they are dried and/or threshed. If the drying place is far away from the field, and if the crop needs to be transported a long distance, there is a risk of handling loss. To transport the bundles, a big pan, basket or cloth is recommended to prevent shattering rice.

4) 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 gravels. Any sheets (tarpaulin, plastics sheet, or thick fabric) may also be used as underlay. If there are not enough tarpaulin for both drying and threshing, they should be used for threshing that has priority.

Bundles 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 (1) molds grow quickly and infest the grains, (2) discoloration of the grains may result within the first day of field drying, and (3) dry grains may absorb moisture again from wet straw, causing the grains to crack, thereby leading to less head rice after milling.

### 3-6-2. Threshing and winnowing

1) Threshing

When the bundled 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.

Several threshing methods are practiced by farmers.

a) Foot threshing or stamping: By trampling on the bundle of panicles spread on the ground with bare feet,

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

c) Beating with stick: By striking the bundle of panicles spread on the ground with a stick.

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

2) Winnowing

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 dropping grains from a basket or bucket through a crosswind or by winnowers if available. Tarpaulin, bamboo mats or palm leaf mats are recommended as underlay to reduce handling losses. Tarpaulin on the ground makes it easy to collect rice grains and helps prevent contamination with impurities.

### 3-6-3. Hulling (dehusking)

Hulling is the process of removing or separating husks (hulls) and bran from rough rice to produce the edible portion for human consumption. In long-grain varieties, the husk accounts for 18-28% of the grain weight and the brown rice for 72-82%. 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 milled (polished or white) rice, 10 kg of broken grains, 10 kg of bran and flour, and 20 kg of husks (AGSI-FAO, 1999). In other words, the weight of rice decreases by 40% after hulling.

There are two types of hulling methods, manual hulling by wooden pestle and mortar and mechanized hulling by rice huller (Table 3-5). In manual hulling, grains are dehulled and whitened gradually as they are pounded in the mortar. 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. Careful farmers separate duhulled rice from other several times during pounding.

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.

1) Reduction of loss during hulling

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

Table 3-5. General characteristics of two hulling methods (AGSI-FAO, 1999).

| Hulling means | 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 husk. (a) |
| 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; 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. |

a) Bran and broken rice are fully fed by chicken (SRDP).

2) Mechanized hulling

Husks and bran are separated from grains in two operations (two-pass). 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.

### 3-6-4. Storage

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

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 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; and
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 avoiding their direct contact with the floor. Pallets are indispensable for keeping the bags away from moisture seeping through the storage floor. If a pallet is not available, timbers or wooden sticks are collected and assembled side by side on the floor as substitute.

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.
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.

***Parboiling***

Parboiling is common in the northern area, but not in the eastern or southern area in Sierra Leone. Although the parboiling process is labor intensive, some people prefer parboiled rice to white rice (milled rice without parboiling). The reasons are:

a) Milling recovery is larger in parboiled rice than unprocessed rice due to less breakage during milling;
b) Parboiled rice increases the volume more than white rice does when it is cooked. Note that net weight is unchanged; and,
c) It has a high market demand, especially for exporting to Guinea.

The parboiling is conducted with the following three important steps:

a) Soaking paddy in water to increase its moisture content (to about 30%);
b) Steaming to complete gelatinization; and,
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 properly parboiled. Steaming or boiling of grains must be stopped before 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; and,
e) Remove all the grains from the container and allow them to cool down on a mat, tarpaulin or drying floor.

## 4. Fertilizer Manipulation

### 4-1. Fertilizer application and rice yield

Soils in Sierra Leone broadly belong to Oxisols or Ferralsols (See 9. Appendices, A1.3-1 and A1.3-2), which are highly weathered. Because of poor soil fertility, rice grain yield will be increased by 1 ton/ha only with the sole application of improved cultural practices. When anyone intends to exceed the limit of such a yield barrier, nutrient supplement by fertilizers is prerequisite.

The revised TP-R tentatively recommends the fertilizer application rate of 40-40-40 kg/ha of N-$P_2O_5$-$K_2O$ to attain the target yield of 3 ton/ha. Again it should be reminded that a) Proper water control by drainage and irrigation, and b) Full application of cultural improvement practices, are prerequisite to realize it.

### 4-2. Timing of fertilizer application

When fertilizers are applied, they should always be efficiently absorbed and utilized by crops. Fertilizer application to rice plants in the revised TP-R is recommended as:

a) The total quantity (40-40-40 kg/ha of N-$P_2O_5$-$K_2O$) is split into two: 2/3 (27-27-27 kg/ha) and 1/3 (13-13-13 kg/ha). The first is applied at the time of puddling just before transplanting as basal dressing. The second is at the panicle initiation stage, about two months before full maturity (harvesting time), as a top-dressing; and,

b) Top-dressing is applied in a middle of the day. Avoid it when it rains.

As shown in the development process of yield components (Fig. 2-3), the first application promotes tillering at the early growth stage, where tillers later produce panicles, being the most important yield component. The timing of top-dressing coincides with the period when spikelets are formed on the developing panicles.

Fertilizers should not be applied to the area where water is moving, whatever the reason is. All chemical fertilizers being a kind of salts, they are easily dissolved in water. To minimize the application loss cause by water or rain, fertilizer application would possibly be split into several times.

The timing of fertilizer application depends on soil fertility. When it is relatively high, nutrients required to the initial growth of planted seedlings can be supplied from the soil. So, the first application can be made at a few weeks after transplanting. RRSR (1991) recommended the basal application at 2 weeks after transplanting at Mawirr, associated mangrove swamp and at Mange, irrigated rice field enriched with continuous fertilizer application: both sites are high in soil fertility. In contrast, nutrient status of most lowland soils is low and thus, tiller development responds to fertilizer application quickly after transplanting (Fig. 4-1).

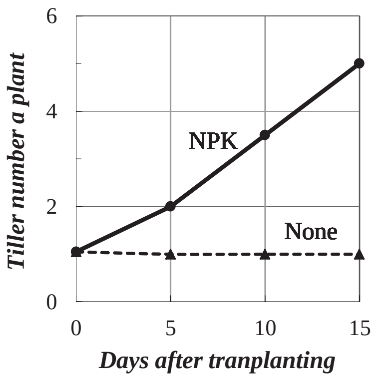



Fig. 4-1. An example of fertilizer effect on tiller development shortly after transplanting (cv. ROK 24. Pot culture with riverine soil at Tambi, Kambia District).

**4-3. Uniform application of fertilizers**

The method of uniform fertilizer broadcasting is:

a) Divide the field into several sub-plots of nearly equal size and divide the fertilizers proportionally;

b) In each sub-plot, broadcast two-thirds of the amount of fertilizers allocated for each sub-plot; and,

c) Broadcast the remaining one-third to even out the distribution of the fertilizer broadcast first.

Note: The first and second broadcasting should be carried out transversely (Fig. 4-2).

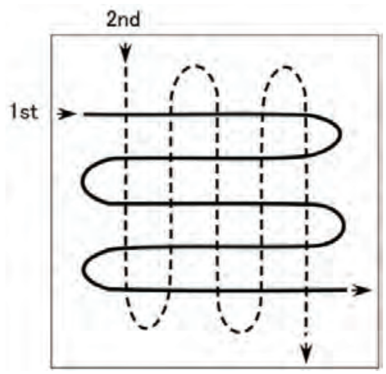



Fig. 4-2. Uniform application of fertilizers in fields.

**4-4. Issues for better fertilizer choice**

**4-4-1. Principles of plant nutrients**

Nutrients are essential to plant growth (A1.1-1). Plants grow to some extent in almost all soils under the natural condition (without fertilizer addition) as far as water and temperature are not limiting factor. The extent of plant growth depends on nutrient availability naturally supplied. When human being intends to grow plants larger than the growth depended on the natural supply, he or she needs to add nutrients. This practice is called as fertilizer application (Fig. 4-3).

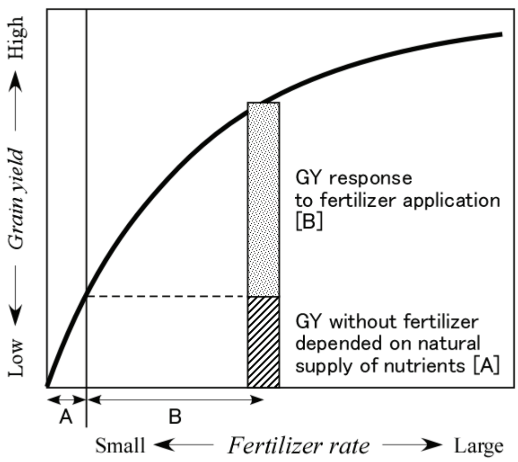



Fig. 4-3. Two components of grain yield (GY) under fertilized condition. Total production consists of A and B.

The law of the minimum shows that plant growth is limited by the nutrient of the shortest supply (Fig. 4-4). When we intend to increase crop productivity effectively and efficiently, we have to apply fertilizers according to the nutrient status of a given soil. If we add a nutrient being abundant in the soil, the addition is not effective, but a loss. At the same time, nutrient requirement varies depending on the mass of plant growth or final product. Fertilizers application rate should match the nutrient status of soils and requirement of the plants. We are able to utilize fertilizer efficiently if we know the nutrient status of the soil. This section provides certain information on the two aspects of fertilizers: the nutrient status of soils in the country and the magnitude of yield response to fertilizer application.

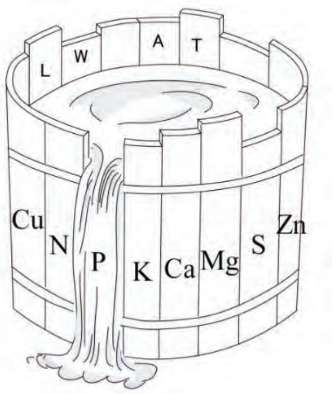



Fig. 4-4. Liebig's law of the minimum (Dobenecks barrel). L: light, W: water, A: air, and T: temperature.

**4-4-2. Soil nutrient status and grain production**

1) Chemical properties of soils

Chemical analysis is useful method to grasp the general nutrient status of soils. As a preliminary approach, various soils in Kambia District were collected and analyzed. Many nutrients like phosphorus (P), sulfur (S), nitrogen (N) are frequently deficient in soils, although nutrient shortage varies among agro-ecologies (Table 4-1). Not only macronutrients but also several micronutrients like zinc (Zn) and cupper (Cu) are deficient in smaller or larger extent.

Table 4-1. Frequency (%) of soils with possible nutritional problems (deficiency and excess of of nutrients, and acidity) diagnosed with chemical analyses (a) in various rice agro-ecologies agro-ecologies of Kambia district.

| Agro-ecology | n | | Deficiency | | | | | | | B excess | High salt | Low pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | S | Zn | Cu | Si | | | |
| Upland | 12 | (0) | 8 | 17 | 17 | 50 | 42 | 17 | 58 | 0 | 0 | 8 |
| Inland valley swamp | 14 | (1) | 7 | 36 | 57 | 71 | 29 | 0 | 71 | 0 | 0 | 86 |
| Boliland | 15 | (3) | 20 | 20 | 27 | 73 | 47 | 0 | 53 | 0 | 0 | 33 |
| Riverain grassland | 2 | (0) | 50 | 50 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 50 |
| Associated MS | 6 | (1) | 17 | 50 | 0 | 33 | 17 | 0 | 17 | 0 | 0 | 100 |
| Mangrove swamp (MS) | 14 | (2) | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 79 | 71 | 29 |

n: the number of soil entries, including plural samples at the same site (the number is in parentheses) on different dates.

2) Nutrient deficiency level evaluated by pot culture

Soils were collected countrywide (A1.4 (1)-1 and -2), and rice plants were grown in pots under various nutrient conditions for about one month. Some examples of plant growth are shown in Photo 4-1. In both soils, plant growth was poor at None (no nutrient added) and -P (no P added but N and K; +NK) treatments, while large at NPK, +S and +Zn treatments. Plant growth at -N treatment was similar to that at NPK and +S treatments in Musaia soil, but it was poorer in Rolako soil.

The deficiency level of each element was quantified based on the relative dry matter production (DMP) between the reference treatment (NPK or NPK+S) and the nutrient treatments for each soil. The deficiency level is divided into five classes (Table 4-2). Phosphorus (P) deficiency is the severest, and widely distributed over the country. Sulfur (S), potassium (K) and nitrogen (N) are deficient in many locations, while zinc (Zn) lacks in specific sites only. No apparent difference in soil fertility is found between Kambia and other districts (A1.4 (1)-3). The deficiency level in N, P, K, S, and Zn is 30, 70, 30, 40, and 10 on average nationwide, respectively (Table 4-3).

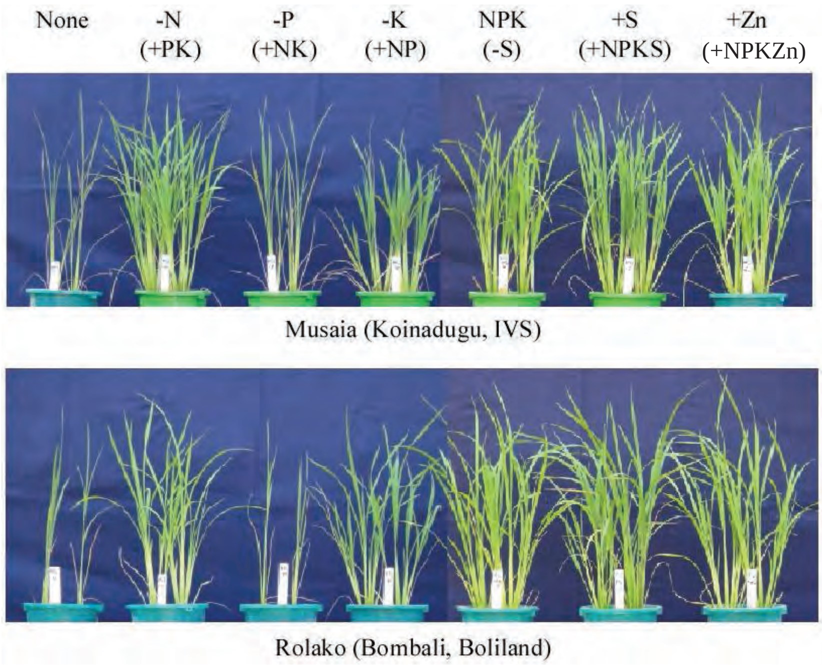



Photo 4-1. Examples of plant growth in the nutrient deficiency evaluation trial with Musaia and Rolako soils (25 days after transplanting).

Table 4-2. Nutrient deficiency level classified in respective soils

a) in Kambia district

| Ser. no. | Soil | abbr. | Element N | P | K | S | Zn |
|---|---|---|---|---|---|---|---|
| 2 | Robennah (u) | Ru | ++ | +++ | + | * | - |
| 8 | Misra | Ms | - | +++ | + | + | * |
| 9 | Makaliso | Mk | - | +++ | - | - | +++ |
| 10 | Kunthai | Kn | + | +++ | + | - | - |
| 11 | Masineh | Mh | - | + | - | * | * |
| 12 | Mathon | Mt | + | +++ | ++ | +++ | - |
| 13 | Kamaranka | Km | - | +++ | + | +++ | * |
| 14 | Karawani | Kr | ++ | +++ | ++ | + | - |
| 15 | Rokon | Ro | - | ++ | - | - | - |
| 16 | Sinbeck | Sb | - | +++ | ++ | + | + |
| 17 | Pintekili | Pt | +++ | +++ | +++ | +++ | ++ |
| 18 | Robennah | Rn | + | +++ | ++ | ++ | - |
| 19 | Bassia | Bs | + | +++ | - | ++ | + |
| 20 | Kamathothor | Kt | + | +++ | ++ | ++ | - |
| 21 | Tolokuray-U | T-U | + | +++ | ++ | + | * |
| 22 | Tolokuray-L | T-L | +++ | +++ | ++ | +++ | + |
| 27 | Kalintin | Kl | + | ++ | + | ++ | + |
| 28 | Tambi | Tb | - | +++ | + | * | + |
| 30 | Robana | Rb | + | +++ | - | - | - |
| 31 | Robis-bana | Rm | - | +++ | - | - | + |
| 33 | Kibanka | Kb | - | ++ | + | - | - |
| 34 | Marwirr | Mw | ++ | ++ | + | - | * |
| 35 | Rokel | Rk | - | + | - | - | - |
| 36 | Rosinor | Rs | + | ++ | + | - | a |
| 37 | Robat | Rt | + | ++ | - | a | * |

b) in other districts

| Ser. no. | Soil | abbr. | Element N | P | K | S | Zn |
|---|---|---|---|---|---|---|---|
| 1 | Kpuabu | Kp | - | +++ | + | a | a |
| 3 | Buline | Bl | - | +++ | + | + | - |
| 4 | Nyandeyama | Ny | - | - | + | +++ | - |
| 5 | Giema | Gm | + | +++ | + | ++++ | - |
| 6 | Kamaranka II | K2 | - | ++ | - | ++++ | - |
| 7 | Kanikay | Kk | a | + | - | + | - |
| 23 | Musaia | Mu | a | ++ | - | + | - |
| 24 | Tikonko | Tk | - | - | + | +++ | - |
| 25 | Mandu | Md | - | +++ | - | - | + |
| 26 | Rolako | Rl | + | +++ | + | + | - |
| 29 | Mayatha | My | - | +++ | - | - | - |
| 32 | Torma-Bum | Tr | - | + | + | ++ | - |

| Nutrient deficiecny level | Le-gend | Deficiency level from | to |
|---|---|---|---|
| Severely | ++++ | 101 | 150 |
| Highly | +++ | 76 | 100 |
| Intermediately | ++ | 51 | 75 |
| Fairly | + | 26 | 50 |
| Least | - | -24 | 25 |
| Likely abundance | a | | |
| Pending | * | | |

Table 4-3. Rounded nutrient deficiency level in various agro-ecologies of Sierra Leone

| Agro-ecology | | Nutrient | | | | |
|---|---|---|---|---|---|---|
| | *n* | N | P | K | S | Zn |
| Upland | 3 | 30 | 90 | 40 | 50 | 0 |
| Inland valley swamp | 22 | 30 | 70 | 30 | 60 | 10 |
| Boliland | 4 | 20 | 80 | 30 | 40 | 20 |
| Riverain | 3 | 20 | 70 | 30 | 30 | 10 |
| Mangrove swamp | 5 | 30 | 60 | 20 | 10 | -10 |
| Mean (weighted) | 37 | 30 | 70 | 30 | 40 | 10 |

DMP without fertilizer tends to be smaller with upland, and larger in mangrove swamp (Fig. 4-5). DMP with fertilizer is larger in boliland, riverain grassland and mangrove swamp than in IVS. Soils of relatively high fertility are found in lower areas where sedimentary materials are deposited.

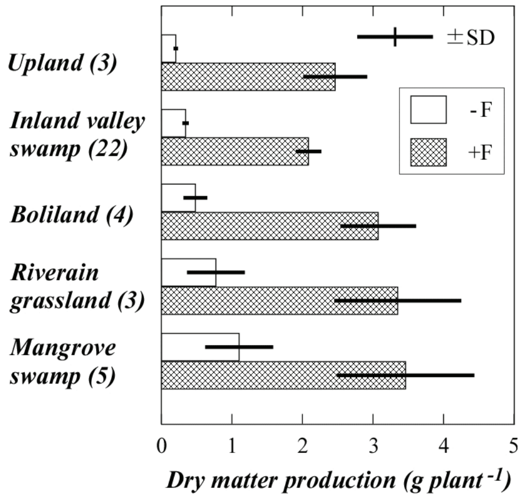



Fig. 4-5. Dry matter production (DMP) with (+F) and without (-F) fertilizers in various agro-ecologies. The number of soil entries in respective agro-ecologies was in parentheses.

3) On-farm fertilizer trials

Fertilizer trials were conducted at FBO group farms of seven IVSs in Kambia District in the rainy season, 2013, and in the dry season in 2013–2014 (A1.4 (2)-1). Rice plants were grown with and without fertilizer, applying full improved cultural management practices. Four fertilized treatments, combining 20-60 N, 40-100 $P_2O_5$, 40 $K_2O$, and 0-10 S kg/ha, were set, referring to the results of pot experiment. The mean of fertilized treatments was at 30 N, 55 $P_2O_5$, 40 $K_2O$ and 6 S kg/ha respectively. As a result, no apparent difference in grain yield among treatments was observed.

Grain yield with and without fertilizer varies 2.1 to 4.0 and 1.2 to 2.7 ton/ha, respectively, and there is a positive relationship between them (Fig. 4-6). Grain yield with fertilizer is lower under poor water control condition than under well controlled condition. Mean yield response to fertilizer application (Rf) is 1.1 (0.6–1.8) ton/ha under well water controlled condition. The highest yield was 4.0 ton/ha when the natural supply was high.

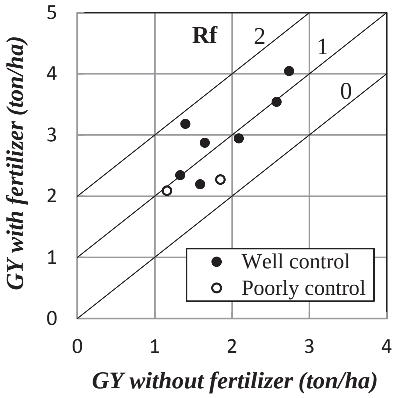



Fig. 4-6. Relationship between grain yield (GY) with and without fertilizer. Rf: response to fertilizer application (ton/ha). 'Well and poorly control' are on water control conditions.

4) Fertilizer trials in the past: literature review

Various fertilizer trials have been carried out in Sierra Leone during her long history of rice research at RARC in close collaboration with IITA, FAO, UNDP, EC, etc. Published data (A1.4 (3)) were compiled to find soil fertility variation countywide through rice production and response to fertilizer application. Fertilized rate ranged from 30-20-20 to 120-80-80 kg/ha.

Grain yield in upland varied 0.5 to 3.2 (mean 1.7) and 0.2 to 2.3 (0.9) ton/ha respectively, under with and without fertilizer application, and that in IVS did 0.5 to 4.0 (2.2) and 0.2 to 2.5 (1.2) ton/ha, respectively, under the same conditions as upland (Fig. 4-7). In general, when the grain yield was larger without fertilizer, it was larger with fertilizer too. Yield response was -0.5 to 2.0 (0.7) ton/ha in upland and 0.0 to 2.8 (0.9) ton/ha in IVS.

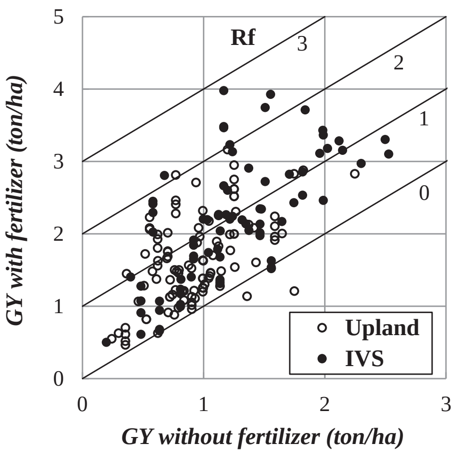



Fig. 4-7. Relationship between grain yield (GY) with and without fertilizer (A1.4 (3)-1). Rf (isogram): response to fertilizer application (ton/ha).

Although grain yield without fertilizer much varied, its distribution was more frequent within the range of 0.5 to 1.0 ton/ha in upland and 1.0 to 1.5 ton/ha in IVS respectively (Fig. 4-8). All results were based on a kind of research experiments so that even the plot without fertilizer was assumed to be managed with some improved cultural practices. The fact suggests that it is not easy to obtain grain yield higher than 2 ton/ha without fertilizer.

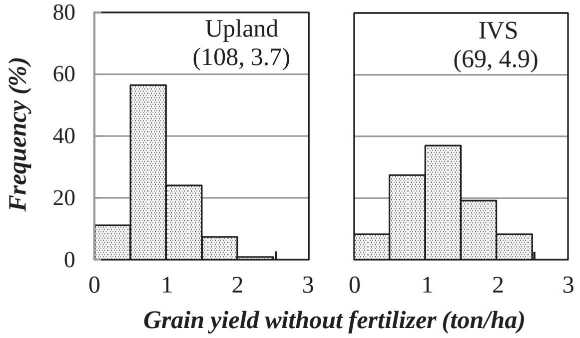



Fig. 4-8. Frequency of grain yield of rice plants grown without fertilizer in upland and inland valley swamp (IVS). The former and the latter figures in parentheses signify respectively the total number of entries and the average number of trials in each

Yield response to fertilizer application varies from -0.5 to 2.0 (mean 0.7) ton/ha in upland and from 0.0 to 2.8 ton/ha (0.9) in IVS, respectively (Fig. 4-7). Response to fertilizer application in upland was smaller at low rates and increased with an increase of application rates (Fig. 4-9). In contrast, the response was maintained at a similar level, 0.8-1.0 ton/ha regardless of fertilizer rates in IVS. The phenomenon of the latter is unusual: why rice yield did not respond to an increase of fertilizer rate. The result might be affected with various reasons: water control, cultivars, etc., or human error.

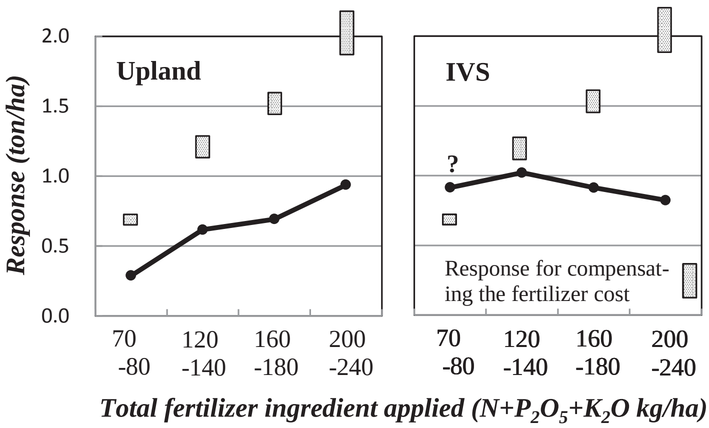



Fig. 4-9. Yield response to various fertilizer application rates in upland and IVS (A4-4).

Grain yield without fertilizer entirely depends on soil fertility. Fertility trend among regions is inconsistent as far as the past fertilizer trials are concerned. For example, the productivity in IVS is larger and that in upland is smaller in the southern region (Fig. 4-10). The tendency is contrary to the other regions. The productivity inconsistency denotes that the soil fertilizer little differed among regions in a broad sense. The fact is also supported by the result of pot trials (A1.4 (1)-3).

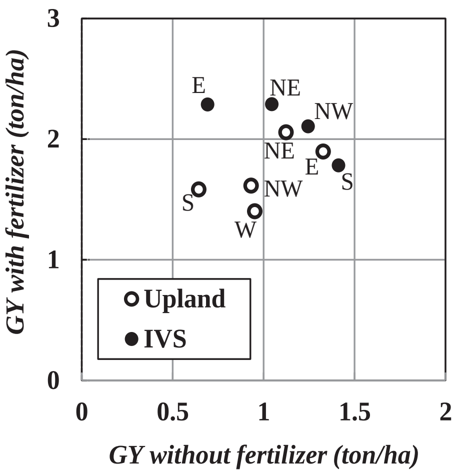



Fig. 4-10. Relationship of grain yield (GY) with and without fertilizer in various regions (A4-4). Abbr.: NE, Northeast; NW, Northwest; S, Southern; E, Eastern; W, Western.

## 4-5. Ways to wise fertilizer use

### 4-5-1. Fundamentals

The SRDP supported and monitored FBO's farming activities and grain yield from 2011 rainy season to 2013–2014 dry season. Grain yield largely varied among FBO farms and its variation showed a bimodal tendency with a large peak at 0.5 to 1 ton/ha and 1.5 to 2.5 ton/ha (Fig. 4-11). To find the reasons for a large variation in productivity among FBO farms, cultural management between a high-yielding FBO group (higher than 2.5 ton/ha) and a low-yielding group (lower than 1 ton/ha) was compared.

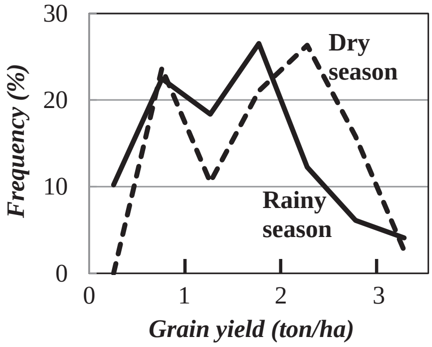



Fig. 4-11. Frequency distribution of grain yields in FBO communal farms in Kambia District.

As for farming practices, shallow planting was more frequently practiced by the high-yielding group than the low-yielding one, and proper leveling (land smoothing) percentage was also higher by the former (Table 4-4). At the same time, the proportions of cropping calendar preparation, germination test, and land preparation before sowing were high in FBOs who obtained high yield. These practices show farmers' challenging attitude towards farming activity, and their effort was rewarded with better yield. Respective farming activities will contribute to yield improvement at a limited extent, but integrated practices will greatly help to enhance productivity.

Table 4-4. Proportion (%) of recommended farming activities practiced by high- and low-yielding FBO farms.

| Farming activity | High yielders (≧ 2.5 ton/ha) | Low yielders (≧1.0 ton/ha) |
|---|---|---|
| Cropping calendar preparation | 44 | 0 |
| Germination test | 50 | 5 |
| Use of young seedlings | 100 | 56 |
| A few seedlings/hill | 94 | 45 |
| Shallow planting | 100 | 20 |
| Field leveling | 88 | 10 |
| Land preparation before sowing | 88 | 24 |
| Bund and drainage maintenance | 81 | 36 |

### 4-5-2. Yield response to fertilizer and cost recovery

When fertilizers are applied, grain yield more or less increased (Figs. 4-6 and 4-7). The cost of fertilizer rate of 40-40-40 kg/ha of N-$P_2O_5$-$K_2O$ is nearly equivalent to the price of one ton of rough rice at the farm gate at present: Refer to Chapter 8. Economic Analysis on Rice Production. This fact implies that the rice business is almost break-even if the yield response is 1 ton/ha with the said quantity of fertilizer.

Figs. 4-6 and 4-7 show that the averaged response to fertilizer application is about 1 ton/ha in many cases. Therefore, a chance to make net profit by fertilizer application is small at present.

### 4-5-3. Standard fertilizer rate and its modification

1) Standard fertilizer rate

The result of the pot experiment is unable to reflect directly the field nutrient condition. Yet, deficiency level of the nutrients in soils show the potential status, or the field nutrient status in the long run. Overall nutrient deficiency level estimated by the pot trial is around 30 N, 70 $P_2O_5$, 30 $K_2O$, and 40 S (Table 4-3), where P deficiency was severe and widely prevails. The result suggests that favorable fertilizer composition would be 30-70-30-40. Yet, the recommended fertilizer rate in the revised TP-R is tentatively set at 40 N- 40 $P_2O_5$- 40 $K_2O$ kg/ha, because single source of P and S fertilizers is currently unavailable in the market. The equal nutrient composition like 40-40-40 matches NPK compound fertilizer (15-15-15) readily available in the present market.

At the same time, a high dose of fertilizer like 80-80-80 kg/ha is not adopted, because heavy dose of fertilizer does not necessarily enhance production (Fig. 4-9) under the present condition, and because of the law of diminishing return (Fig. 4-12): the smaller the input, the larger the return.

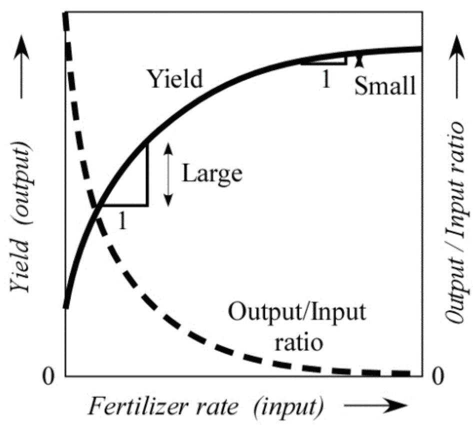



Fig. 4-12. The law of diminishing return (Mitscherlich, 1909).

2) Fertilizer adjustment on soil fertility

The recommended fertilizer rate must be modified according to the soil fertility. The standard rate is not more than the value reflecting the general nutrient status in the soils and the compromised result considering various conditions. In fact, soil nutrient status differs little among regions in broad perspective (Table 4-2, Fig. 4-10, and A1.4 (1)-3).

Nevertheless, soil productivity differs more or less, not only among regions but also among adjacent plots even in a same IVS (e.g., Figs. 4-6, 4-7 and 4-8). There is no backbone to support plot-wise soil diagnosis in the country. Thus, it is recommended to apply the standard rate of the fertilizer to the field in the beginning, of which soil fertility is unknown, and observe the result whether the rate was reasonable. The rationality here denotes whether the fertilizer dose produce sufficient incremental yield to bear net profit or not. Based on the analyses, he may increase or reduce the fertilizer rate in the succeeding cropping. An option of no fertilizer use could be chosen. Needless to say, application of full package of improved cultural practice and water control are prerequisite.

### 4-5-4. Soil fertility and response to fertilizer

Grain yield without fertilizer varies greatly. For example, in IVS, its variation was 1.3 to 2.8 ton/ha by the fertilizer trials (Fig. 4-6) and 0.2 to 2.7 ton/ha in the literature review (Fig. 4-7). All these trials were assumed to be conducted applying the same culture practices, and thus, grain yield variation is mainly derived from the difference in soil fertility.

Let's assume that there are two sites differed in soil fertility, which is equivalent to produce grain yield as 1.5 and 2.5 ton/ha under the improved cultural practice, and their grain yield reaches 3 ton/ha with fertilizer application. Yield response to fertilizer application is 1.5 and 0.5 ton/ha respectively (Fig. 4-13). In the example, while the former surely would have yielded much profit, the latter would have involved a loss. In fertilizer application, it is not a critical issue how high the yield (like 3 ton/ha) is produced, but it is a main concern whether fertilizer applied brings a sufficient yield response to recover the cost and make a profit. Yield itself largely depends on natural soil fertility. We should strictly pursue how efficiently fertilizer promotes productivity.

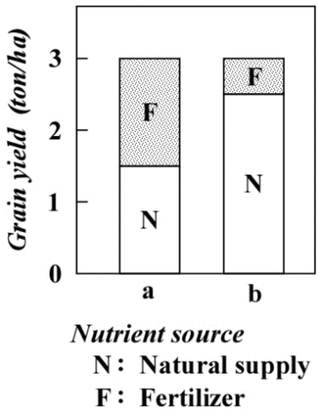



Fig. 4-13. Grain production with different responses to fertilizer application under two natural supply statuses Rice plants were grown with improved culture management in both cases.

**4-5-5. Related matters**

1) Season choice

Rice in Sierra Leone is generally grown in the rainy season, when rainfall reaches as much as 2000 mm or even more during the cropping period. Besides, fully developed IVS rice fields are uncommon: only three irrigated rice fields are currently available at Lambayama, Makali, and Mange, where total acreage is about 100 ha. In the majority of lowlands, rice culture is practiced under the rainfed condition without proper water control. Hence, fertilizer application during the rainy season holds a high risk of washing away. Under the present situation, fertilizer application may had better be confined to the dry season cropping, when the chance to obtain higher yield is high (Fig. 4-11).

2) Nutrient supply through organic matter

Nutrients contained in organic matter are as effective as those in chemical fertilizers for rice plants (Fig. 4-14). Farmers in Sierra Leone are used to apply a kind of compost to their vegetables. They would have acquired how to maintain soil fertility through their experiences, and understand its importance for better production. Compost incorporation into rice fields, however, would be unrealistic due to a large requirement. In several areas, farmers are smart enough to utilize nutrient contained in weeds for rice culture: see the box column 'Weed control relevant to nutrient replenishment'. Nutrient manipulation with green manure is unknown.

3) Soil acidification by fertilizer application

It is well-known that over-use of chemical fertilizers often induces soil acidification. Yet, the recommended fertilizer rate in the revised TP-R will not cause the problem, because the quantity is small enough to simply supplement the shortage so that all nutrients added will be absorbed by a crop. Besides, it is well known that soil pH is neutralized under the submerged condition regardless of the original pHs (Fig. 4-15).

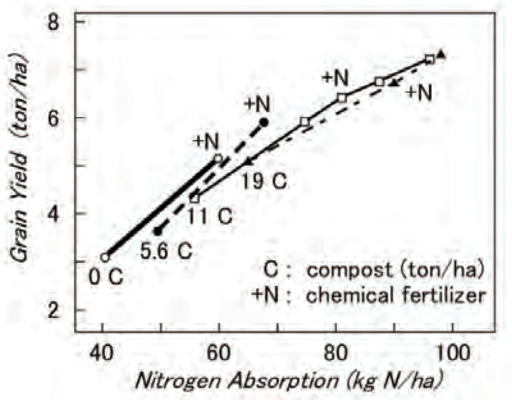



Fig. 4-14. Relationship between nitrogen absorption and grain yield with various combinations of organic matter and chemical fertilizer (ammonium sulfate). Average of 1953-1958 (Shiga).

<There is no difference in yield production between organic and chemical fertilizers.>

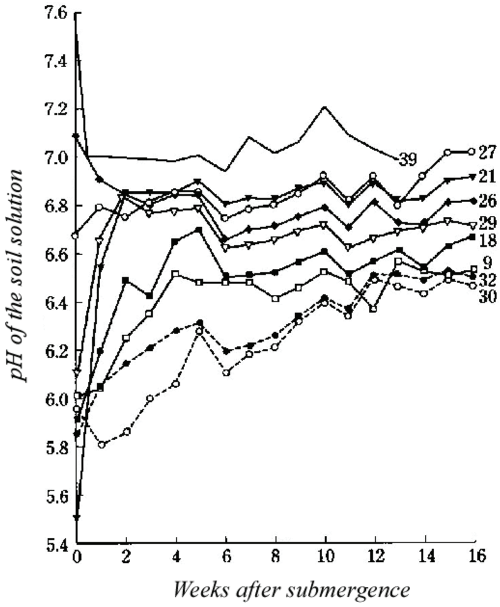



Fig. 4-15. pH changes after submergence (Ponnamperuma et al, 1966). No. 9, 18, 21, etc. signifies the soil entry number.

#### 4-5-6. Suggested scientific approach for future development

Grain yield can be as large as 4 ton/ha when we apply the full package of cultural improvement with sufficient dose of fertilizers. Yet, the maximum yield has hardly exceeded beyond that level. Some causes out of cultural practices must have hindered the productivity. Further, the result obtained through the pot trials has not yet verified in the field. Hence, many research issues remain unclear how we can efficiently approach to increase productivity. Several topics suggested in a scientific aspect are the following.

1) Periodical planting throughout a year

Among various factors controlling crop production (A1.2-1), two external factors, solar radiation and temperature, are hardly manipulated with human power. Temperature will not be a limiting factor in the country (A1.5-1). Solar radiation is only a source for dry matter production, and hence rice productivity is greatly affected with it as examples in Asia and Africa clearly show (A1.2-2 to A1.2-4). Because of heavy rainfall in the middle of main rice cropping period, sunshine hours are less in Sierra Leone (A1.5-1). Solar radiation will be a main cause of low productivity in the country. Periodical (every 4-month or monthly) planting will find the effect of solar radiation on plant growth and grain yield. The trial should be carried out under full water control. Radiation measurement is prerequisite.

2) Phosphorus trial in field

The pot trial result shows that the P deficiency prevails in the country. P adsorption coefficient (PAC) as large as 10 g P $kg^{-1}$ is not rare by the chemical analysis. The value is equivalent to 23,000 (= 10 x 1,000 x

2.3) $P_2O_5$ kg $ha^{-1}$, assuming that the specific gravity of a soil is 1 g $cm^{-3}$ and field depth is 10 cm. To amend the P deficiency in fields, 10% of PAC equivalent is commonly proposed, so that the maximum application rate must be 2,300 $P_2O_5$ kg $ha^{-1}$, or up to 1,000 $P_2O_5$ kg $ha^{-1}$ at least. PAC analysis of various soils will provide valuable information to establish the standard fertilizer rate.

3) S treatment

Sulfur is deficient in many soils as has been observed (Tables 4-1 and 4-2). Its deficiency is very likely when we consider general soil background and the evidences in neighboring countries (Yamaguchi, 1997 and 1999). It can be one of the important elements limiting the yield in the country.

4) Fertilizer trial with various combinations of nutrients

A series of fertilizer trials should be carried out with various combinations of nutrients at a wide variation of their rates. As described previously, nutrient composition in addition to the fertilizer rate is critical to maximize the efficiency. For example, the mean yield response to fertilizer application was merely 0.4 to 0.6 ton/ha in ADPK trials, where P proportion was one quarter or one half of N (A1.4 (2)-2). Anyone should be in mind that scientific approach is different from economic one as a preliminary stage of fertilizer trials. Once we obtain the maximum limit, we are able to easily fit the result for the real demand.

***$H_2S$ injury***

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. Sulfate is reduced under submerged condition as redox potential (Eh) decreases (A1.3-3).

***Weed handling and Iron toxicity***

Weed control plays a key role in rice cultivation regardless of agro-ecologies. By plowing organic matter (e.g., the weeds) into the soil, nutrients are released because organic matter is decomposed. However, the decomposition process only occurs where there are well-aerated conditions.

Under reduced (oxygen-deficient) conditions as in case of submergence, ferrous is converted into ferric iron. The decomposition of organic matter leads to an increase in ferric iron in the soil, which the rice plants absorb, 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 excludes ferric iron. When the ferric concentration in the soil exceeds the threshold (300 mg $Fe^{2+}$ $L^{-1}$ soil solution) or when the nutritional conditions of the plant are unfavorable, however, the plant will suffer from iron toxicity (Tanaka and Yoshida, 1970).

Iron layer on the water surface is often observed in lowlands. Typical Fe toxicity symptom on plants was scarcely found, however, especially in the rainy season, probably because of runoff by heavy rain. If thick layer is found, drainage helps to wash out and oxidize ferric iron. Yet, it is difficult to drain water from fields in the lower part 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.

## 5. Cropping Calendar

### 5-1. Cropping season

Because of long rice culture history (200-300 years?), farmers maintain various indigenous cultivars with difference traits each other (Table 3-1). In addition, many cultivars have been recently introduced from various sources and RARC has released several varieties too. To select cultivar(s) to plant in their own farms, farmers are required to consider several criteria. They are: growth duration, plant characteristics to be adapted to the environments given, product use (for home consumption or marketing), and fertilizer response if it is available.

Farmers must first select a cultivar of the most appropriate growth duration well fit to the given natural condition (e.g., water condition relevant to topography), which holds primary importance among all plant traits. Fig. 5-1 presents several examples of cropping seasons of cultivars with different growth duration. All characters other than growth duration will be selected among cultivars with similar growth duration.

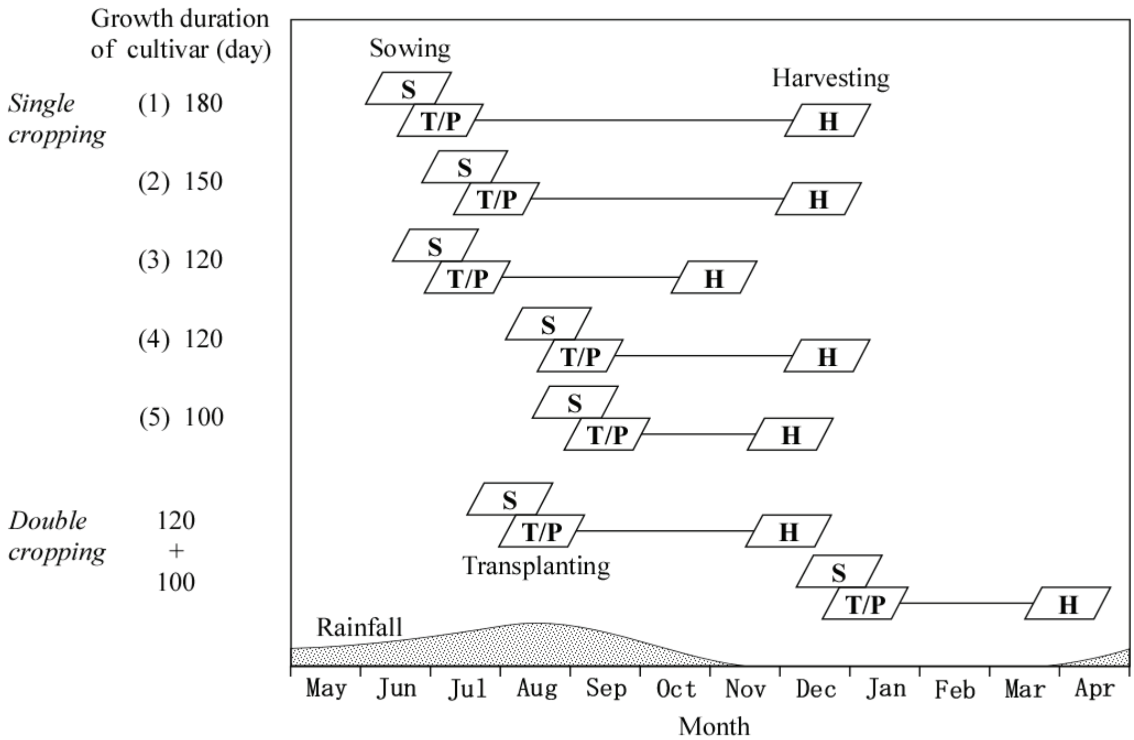



Fig. 5-1. Choice of cropping seasons in inland valley swamp. Rainfall period and intensity are approximated to the countywide average.

Longer growth duration (at least 4.5 months) cultivars will preferably be used in the rainy season to minimize the loss of applied fertilizer by rain. When the farmers practice double cropping, the rainy season crop should be harvested by the end of December. In the dry season, shorter growth duration cultivars would often only be the choice due to water shortage during its ripening stage.

When a cultivar is photoperiod-sensitive, one must consider that the growth duration varies with planting season (A1.1-2). In Pakiamp, for instance, total growth duration (from sowing to full maturity) is longer than 150 days when it is sown early June, and becomes about 120 days when it is sown early August (Fig. 5-2).

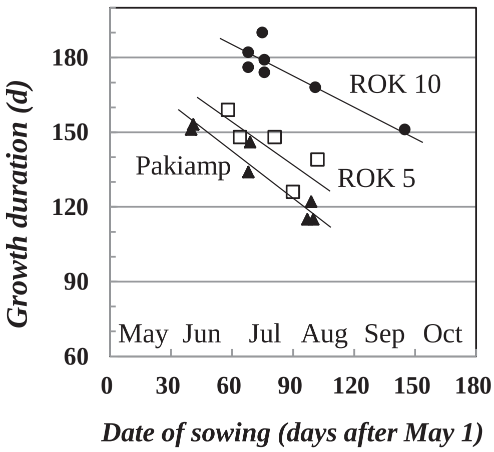



Fig. 5-2. Growth duration (from sowing to full maturity) of selected cultivars affected with sowing dates in rainy seasons (SRDP, 2014).

Proper cropping season varies from place to place depending on natural condition, cultivar used, and culture system. Fig. 5-3 shows the variation of rice cropping season countrywide for reference. One should find the best choice subject to the own condition.

## 5-2. Farming calendar

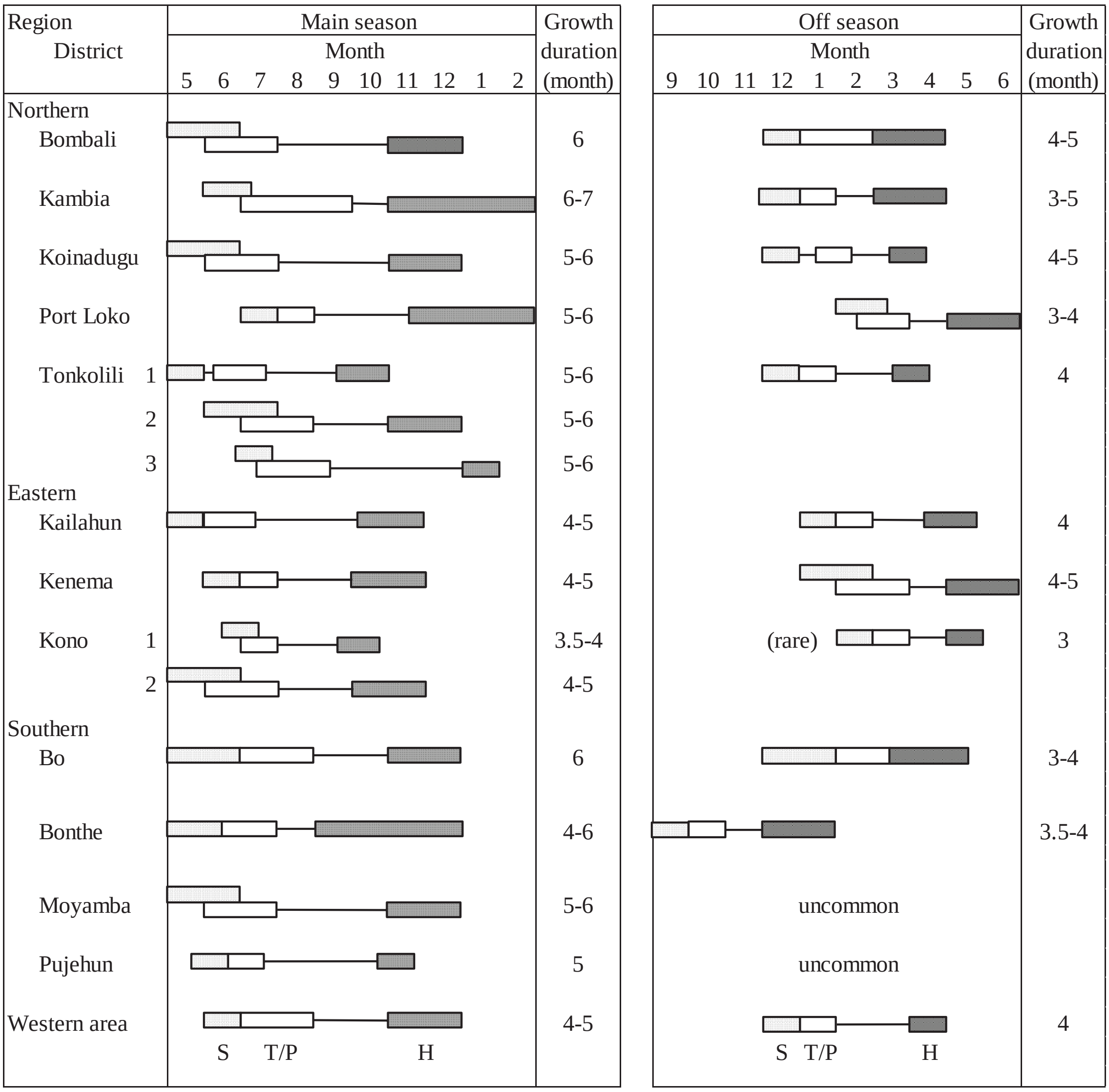
As for transplanted lowland rice cultivation, the timely transplanting of healthy seedlings is of primary importance in ensuring good production. The optimal nursery period is 2 to 3 weeks. In practice, however, the transplanting of old seedlings, sometimes two months old, is not rare mainly due to delay in land preparation, especially plowing. Farmers often sow the seeds on nursery bed before completing plow.

All the field activities should be planned in advance before the planting season starts, taking into account all conditions like cultivars, the availability of labor and input, the area of land to be cultivated, and also all necessary burden in upland cultivation. In planning activities for rice culture in lowlands, first cultivar to be used and transplanting date should be set, while one should consider to avoid the peak rainy season for top dressing and to fit sunny days for the ripening stage (Table 5-1, A1.5-1). Then, 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 laorious and time-consuming work in lowland rice cultivation.

***Seed dormancy***

Almost of all cultivars possess seed dormancy no matter what the degrees may be. This is favorable trait for rice plants by preventing germination during ripening stage even though temperature and moisture condition is suitable for it. Furthermore, the trait protects shattered and dropped seeds on the ground from unusual germination: if they germinate, they might be killed with drought during the coming dry season. Yet, it is unfavorable character when one intends to plant year round.

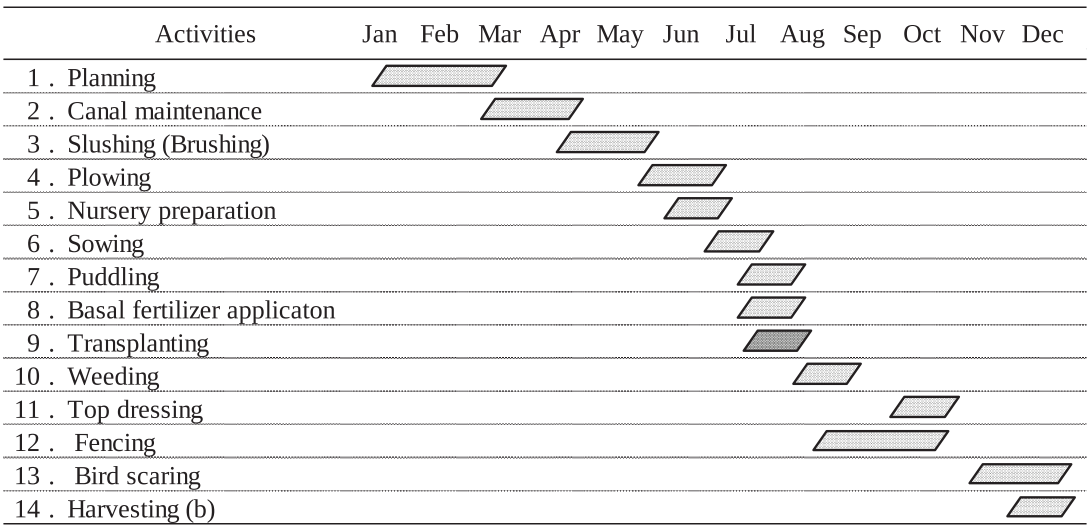
Heat or acids artificially break the dormancy, but such treatment is impracticable by ordinary farmers. Seed dormancy is gradually diminished with time of storage. In general, the period of dormancy is longer by strong photoperiod-sensitive cultivars (sometimes a few months under natural condition), and shorter by weak photoperiod- sensitive cultivars (e.g., 2-4 weeks). Modern high-yielding cultivars are selected to possess weak dormancy, because they are released to be good for double cropping a year.




S: sowing, T/P: transplanting, H: harvesting.

Fig. 5-3. Some examples of rice cropping season in inland valley swamp in various districts of Sierra Leone. Information collected during the training on TP-R for MAFFS staff by SRDP/JICA in 2014.

Table 5-1. Proposed farming calendar for rice cultivation in IVS ecology (a).




a) Cultivar of 5-month growth duration with transplanting method.
b) Including threshing, winnowing, drying, and bagging.

## 6. Seed Production

Use of quality seed is another precondition to obtain high yield. Quality here corresponds to high purity and high germination rate. Refer to the section of 3-3. Seedling raising. The main topic in this section is the former.

1) Securing pure seeds

Sorting-out of mixed seeds at planting time is better to be done, but it is insufficient and too late because the procedure allows only the elimination of grains different in appearance like shape and color. Plant stature, growth duration, tillering habit and other important characters relevant to dry matter production are impossible to eliminate after harvesting. At the same time, farmers often complain a mixture of their own seeds and appeal the seed shortage. However, as there is no responsible seed producer in the country at present, it is only the farmers who take the responsibility of all these issues.

All subsistence farmers should rely on the seeds that they produce. They themselves are only able to guarantee the purity and viability of the seeds. For the present level of grain yield (about 1 ton/ha), mixed cultivars would not substantially affect the production. Because of this, many farmers do not pay much attention to the purity of the seeds they use.

Mixing seeds of different cultivars, however, makes it difficult to determine the timing of the harvest. Under the present conditions that the shattering rate is high in many cultivars, the farmers are destined to lose part of the expected production of either early or late maturing cultivars if the seeds that they use are not pure. Panicle harvesting commonly practices in the eastern parts of the country helps avoid the problem, although labor burden is much larger than harvesting by sickles.

2) Seed multiplication field and roguing

Recommended hill spacing is 30 cm by 30 cm (square planting) and a single plant per hill in seed multiplication fields. This practice easily makes to rogue off-type plants in frequent walking around in fields on foot. Roguing frequency is twice each during the vegetative growth and ripening stages in addition to one roguing at heading or flowering. Pull out or rogue any off-type plants (hills) that are different from the majority of the plants in the field.

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: saving wastage of the transplanted rice. With this practice, late maturing genotypes cannot be rogued since the grains of these types are able to germinate even though they are not fully matured. It is wise that when the maturity of plants is obviously late at harvesting time, farmers are used to remain them in the field until next round of harvesting. Yet, the practice is tedious and time consuming.

3) Seed handling

One should pay full attention to keep the seed purity obtained in the field in harvest and post-harvest processes: cutting, threshing, drying, bagging and storage. Among various reasons for seed mixture, mechanical mixture is the most possible and preventive. Cleaning of the threshing ground and storage bags are the first to do.

4) Self stock of seeds

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 within a few years.

***Seed viability***

Seeds require temperature and water (moisture) for their germination. When the two conditions are provided, seeds start various biochemical activities ready for germination using stored energy, and gradually lessen their viability and vigor (seed deterioration) with time prolonged. Under the tropical lowland condition, temperature is usually adequate for plant growth. Hence, rice seeds are ready to start germination whenever they get moistened.

In Sierra Leone, air humidity is kept high during the long rainy season. Rice seeds are put in bags, which are piled up one on top of another during storage so that poor ventilation easily induces seeds moistening. Hence, seed viability (germination rate) is often decreased, or even totally lost, when the seeds are passed over a rainy season. In some cases, mold infects the storing seeds. Whenever one intends to grow dry season culture, seed production of intended cultivars is strongly recommended during a preceding rainy season, although many experienced farmers have practiced the seed renewal.

Panicle-harvested bunches are stored by hanging them from a crossbeam in a cooking place by some farmers. This storage method is favorable for grains or seeds, because the hanging above fire and smoke make free from moisture and insects. Seed quantity recommended by the Package (Table 3-3) is much less than the conventional methods, sickle harvesting farmers can adopt the above-mentioned method for seed storage.

# 7. Lowland Development and Water Control

Land development is essential for lowland rice culture. Proper water control helps grow plants healthy, make fertilizer use efficient, and eventually produce high yield. Because rice in the country is mainly grown in the rainy season, proper water control is a must. The total rainfall amounts to about 2000 mm during a growth season in many areas (A1.5-2). Daily rainfall exceeding 200 mm is not rare during the peak rainy season in many locations of Sierra Leone (A1.5-3).

Heavy rain causes flood, which wash applied fertilizer away from the field. To prevent such losses, drainage construction, bund making, and land leveling, are required in lowland rice fields. Without proper water control measures, fertilizer application is not recommended.

## 7-1. Bund (dike) construction

Running water in rice fields causes the soil to erode, nutrients to leach out, and transplanted seedlings to flow away. Fertilizer application under running water should be avoided in such areas. To avoid or minimize the negative effects of running water, the water should be controlled.

Small-scale bunds and drainage structures are recommended in lowland rice fields. First, water drainage needs to be considered. Bunds are constructed after slashing or plowing. Because there is no hydrological data at present, engineers should work together with the farmers in the field, consulting the farmers about their experience and observation on rainfall and water discharge.

## 7-2. Land levelling

Lowland rice fields should be levelled to make water control easy. Height difference in a plot is ideally within 5 cm, or 10 cm at its maximum, though the land levelling work is really a laborious.

When a plot size is 100 m x 100 m with 0.2 m height difference (Fig. 7-1), for example, the soil volume (or weight) needed to be levelled is:

$$100 \times 100/2 \times 0.1 \times ½ = 250\ m^3 \text{ or}$$
$$= 250 \text{ ton (assuming that the specific weight is } 1\ g/cm^3)$$

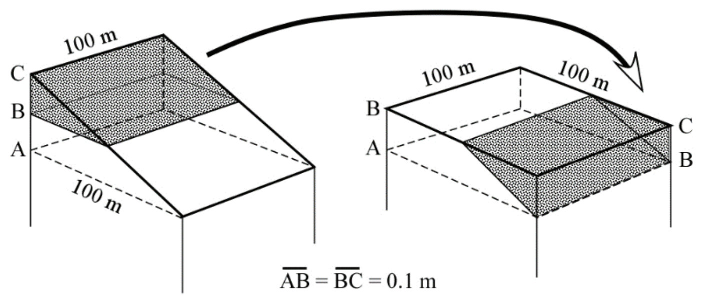



Fig. 7-1. Levelling of a sloping field (acreage: 1 ha).

Plot levelling requires a hard work because such a large quantity of soil is needed to move 50 m distance (an average) in the case of the above-mentioned example. Therefore, it is recommended that bunds are always constructed along contour line whenever one intends to develop lowlands (Fig. 7-2).

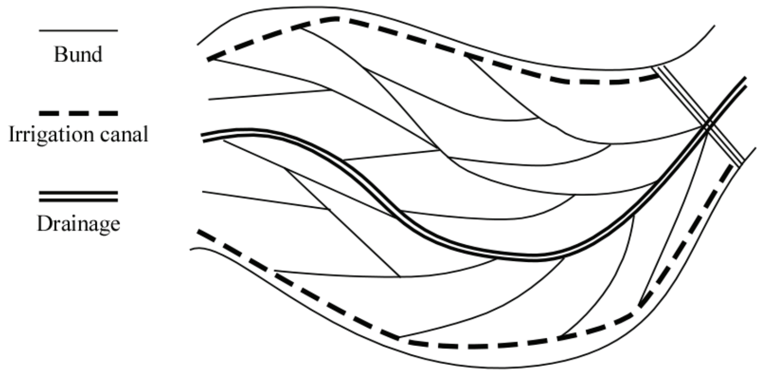



Fig. 7-2. An example of contour bunding in a small inland valley swamp.

Whatever a plot size becomes small, levelling the plot holds a priority. Because all field works like plowing, transplanting and harvesting are manually practiced at present, small plot size does not hinder the work efficiency. Only when the plot size is too small and inconvenient for mechanization, one can extend the plot size.

### 7-3. 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. Keep shallow water depth when one applies fertilizers.

Photo 7-1. A primitive but effective barrage.

## 8. Economic Analysis of Rice Production

### 8-1. Basic information and condition on economic analysis

1) Basic data necessary to estimate cost-benefit analysis are:

   a) Labor requirement in respective farming activities;

   b) Family labor and hired labor;

   c) Daily wage (income);

   d) Cost of variables; and

   e) Rough rice price.

2) Cost and benefit are analyzed on the presumption that:

   a) Agro-ecology is lowlands (mainly IVS) with transplanting system;

   b) Farming activities are manually practiced as the majority of farmers do;

   c) Grain yield is 1 ton/ha under the conventional farming system, is increased to 2 ton/ha with the improved culture practices, and further to 3 ton/ha with fertilizer application (Figs. 1-1 and 1-2); and,

   d) Land rental if any, contribution to the community, etc. are not subtracted from grain production.

3) Basic information obtained

   a) Labor requirement for rice culture: Information on labor cost, the results in literatures were summarized in Table 8-1, including the results not only in Sierra Leone but also in other countries. Total labor requirement for one rice culture varied so large, 102-484 person-d/ha. The values were mainly based on conventional farming. The total labor cost in Case 5 is small because extensive agriculture farming would have been practiced. Case 9, a case of traditional practices in Japan showing a modest labor requirement, utilizes draft animal for land preparation. Larger values (440-484 person-d/ha) in the cases 2 and 8 was difficult to explain. Cases 3 and 4 seem to provide more or less reasonable labor requirement by man-power.

Table 8-1. Labor requirement for rice farming depended on mostly manual work.

| Case | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | | Sierra Leone | | | | | | Ghana | Uganda | Japan |
| Agro-ecologies | | Upland | IVS | IVS | IVS | Boli | MS | Lowland | Lowland | Irrig. |
| Grain yield (ton/ha) | | 0.8-1.3 | 1.2 | - | 2.2-2.7 | 0.96 | 1.9 | Ghana | 2.5 | 3.8 |
| Total labor (person-d/ha) | | 205-238 | 440 | 308 | 274-356 | 112 | 136 | 102 | 484 | 260 |
| Labor proportion (%) | Land preparation (clearing, plowing, maintaining bunds and canals, puddling, etc.) | - | 46 | 35 | - | - | 11 | - | 28 | - |
| | Crop establishment (nursery preparation, uprooting, transplanting, etc.) | - | 17 | 28 | - | - | 36 | - | 9 | - |
| | Crop care (weeding, bird scaring, etc.) | - | 17 | 10 | - | - | 0 | - | 44 | - |
| | Harvesting (harvesting and threshing, winnowing, drying, bagging, etc.) | - | 20 | 28 | - | - | 53 | - | 20 | - |
| Note | | | | | | (a) | | | (b) | (c) |
| Reference | | Spencer (1981) | SRDP (2013) | SRDP (2014c) | Spencer (1981) | Spencer (1981) | JICA (1983) | Kijima (2013) | Kijima (2013) | Kyuma (2011) |

- no data. a) By manual farming. b) 30% for bird scaring. c) 1945-1950. Plowed with cattle. Spent 20% for manual weeding. Abbreviations: Boli: boliland, MS: mangrove swamp, Irrig.: irrigated rice field.

b) When family labors cannot provide work force to complete any specific farm work by a required time, the farmers employ labors from outside to supplement the workforce. According to interview survey, the daily wage (income) of hired labor is reported within the range between Le 5,000 and Le 10,000 per person-day. Family labors are not paid, and there are many cases of exchanging of work without paying in a community.

c) The number of active agricultural family members is assumed at 2.8 persons/HH (Table 1-1).

d) Cost of variables (tools, bags, etc.) are estimated at Le 164,200/y (Table 8-2). The cost of NPK compound fertilizer (15-15-15) is Le 4,000/kg as the market price in 2013. Seed requirement is 30 kg/ha (Table 3-3), which are supposed to be supplied from their own product. Cost of seeds are same as the price of rice: Le 1,240/kg.

Table 8-2. Cost for expendables (a).

| Item | Unit price (Le/piece) | Life span (y) | No. of pieces needed (/ha.y) | Tool cost (Le/ha) |
|---|---|---|---|---|
| Hoe | 40,000 | 2 | 5 | 100,000 |
| Knife (sickle) | 20,000 | 4 | 2 | 10,000 |
| Tarpaulin, palm mat, etc. | 90,000 | 3 | 1 | 30,000 |
| Winnower | 7,000 | 5 | 3 | 4,200 |
| Rice bag (b) | 1,000 | 1 | 20 | 20,000 |
| Total | | | | 164,200 |

a) Modified the information obtained at PEMSD, MAFFS-K.
Expendables cost except rice bags is the same regardless production.
b) Rough rice capacity = 50 kg/bag. Grain production of 1 ton/ha needs 20 bags.

e) Mean farm gate price of rough rice was Le 1,240/kg averaged over all chiefdoms in Kambia District at harvest season, 2014 (Table 8-3).

Table 8-3. Measurement unit and rough rice (paddy) price in Kambia district (SRDP, 2013).

| Geo-code | Chiefdom | No. of vill-ages | No. of farmers /village | Measurement unit | | | Rough rice price (Le/kg) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | TP/bu | kg/TP | kg/bu | mean | min | max |
| 58 | Mambolo | 1 | 7 | 12 | 3.0 | 36 | 1,470 | 830 | 2,220 |
| 59 | Samu | 1 | 3 | 24 | 1.8 | 43 | 930 | 930 | 930 |
| 60 | Gbinleh Dixon | 3 | 4-7 | 22 | 1.9-2.7 | 42-59 | 1,260 | 680 | 1,580 |
| 61 | Magbema | 2 | 4-5 | 11-22 | 2.7-3.3 | 30-59 | 1,480 | 840 | 2,020 |
| 62 | Masungbala | 2 | 8 | 20-22 | 2.4-2.6 | 48-57 | 1,110 | 770 | 1,460 |
| 63 | Tonko Limba | 3 | 2-5 | 22 | 2.3-2.4 | 51-53 | 1,050 | 800 | 1,250 |
| 64 | Bramaia | 1 | 5 | 22 | 2.3 | 51 | 1,450 | 1,300 | 1,740 |
| | Kambia district (weighted mean) | | | | | | 1,240 (SD = 331) | 680 | 2,220 |

Paddy price at Le1,240/kg at farm gate was nearly equivalent to Le580/cup (290 g/cup) of parboiled milled rice assuming that the milling recovery is 60%. The latter was sold at Le800/cup at Kambia market in Jan. 2014. About 30% difference was reasonable about costs for parboiling, milling, and transportion, and a retail margin.

### 8-2. Cost-benefit analysis

#### 8-2-1. Costs

1) Total cropped area of subsistence farm is calculated as 3.0 ha/HH based on 1.6 ha/HH of rice field (including 0.7 ha/HH of upland rice) (Table 1-1), assuming that upland crops were grown separately at two places, each of which has the same size as the upland rice area.
2) Assuming that 4/5 of the persons in agricultural work (2.8/HH, Table 1-1) are engaged in farming (others in processing palm oil, cassava flour, etc.), that net farm farming days are 300 d/year (10 months / year), and that 30% of labor requirement depends on hired labors (in land preparation, weeding and harvesting), the total capacity of farm works is calculated as about 870 (= 2.8 x (4/5) x 300 x 1.3)person-d/HH. As total cropped area is 3.0 ha / HH, average labor requirement per unit farm area is calculated as about 290 (= 870 / 3.0) person-d/ha).
3) Labor requirement for land preparation, crop establishment, crop management, and harvesting are assumed respectively to be 40, 25, 15, and 20% based on Table 8-1. As the total labor requirement is set as 300 person-d/ha, labor requirement in respective activities is calculated as 105, 75, 45, and 75 person-d/ha.
4) Labor cost is estimated at Le 3,500/person-day, about half of the actual cost of hired labor, considering the opportunity cost of labors in the rural area, and work load of the respective farming practices including bird scaring. The labor cost per unit field area is calculated as Le 1,015,000 (= 3,500 x 290)/ha.
5) Thus, the total cost is estimated at Le 1,216,400/ha by summing costs of labor, variables (Le 164,200/ha, Table 8-2), and seeds (Le 37,200/ha; 30 x 1,240).

#### 8-2-2. Benefit

1) Gross benefit

Based on the estimated rice grain yield of 1.0 ton/ha under the conventional farming system, and the farm gate price of rough rice at Le 1,240/kg (Table 8-3), the sale price of whole production is calculated as Le 1,240,000/ha.

2) Net benefit

Net benefit of rice production under the conventional farming system becomes Le 23,600 (1,240,000 - 1,216,400)/ha. Net benefit of the rice production under conventional farming system is as small as 1.9% of the total cost, almost break-even.

Farmers would have accepted it, as most of the production is destined for home-consumption, loan repayment, and seed for next cropping, not for sale. When one wants to orient the rice production to business, incremental production has to come with profit.

### 8-3. Cost-benefit analysis of different culture systems

Based on the result of the cost-benefit analysis under the conventional farming system presented in the previous section, the analysis under two other practices are made. Presumptions for the analysis are enumerated below.

a) Total labor requirement and its distribution by farming activities under improved cultural management system and fertilizer application are assumed as shown in Table 8-4. Labor requirement in land preparation works increases in improved cultural management as bund and canal maintenance work is added. That in harvesting works also increases due to yield increase.

Labor requirement in crop management increases under fertilizer application as the works for fertilizer application and water management, as well as weed management are added.

Table 8-4. Estimated labor requirement and its distribution by activities

| Farm and crop management activity | Conventional management | | Improved management | | Improved management and fertilizer application | |
|---|---|---|---|---|---|---|
| | Person-day | % | Person-day | % | Person-day | % |
| Land preparation | 120 | 40 | 144 | 41 | 144 | 36 |
| Crop establishment | 75 | 25 | 75 | 21 | 75 | 19 |
| Crop management | 45 | 15 | 45 | 13 | 60 | 15 |
| Harvest | 60 | 20 | 90 | 25 | 120 | 30 |
| Total | 300 | 100 | 354 | 100 | 399 | 100 |

b) Cost of variables was the same as in Table 8-2 except the number of rice bags, which is proportionally adjusted with a yield level.

c) Fertilizer ($N$-$P_2O_5$-$K_2O$) dose is set at 40-40-40 kg/ha with the use of the NPK compound fertilizer (15-15-15).

1) Cost-benefit analysis in three cultural systems

Production cost, value of rough rice, and net profit under three cultural systems is shown in Fig. 8-1. Because total cost largely increases with an application of fertilizer, net profit by fertilizer is larger than that of conventional farming, but smaller than that without fertilizer under improved cultural system

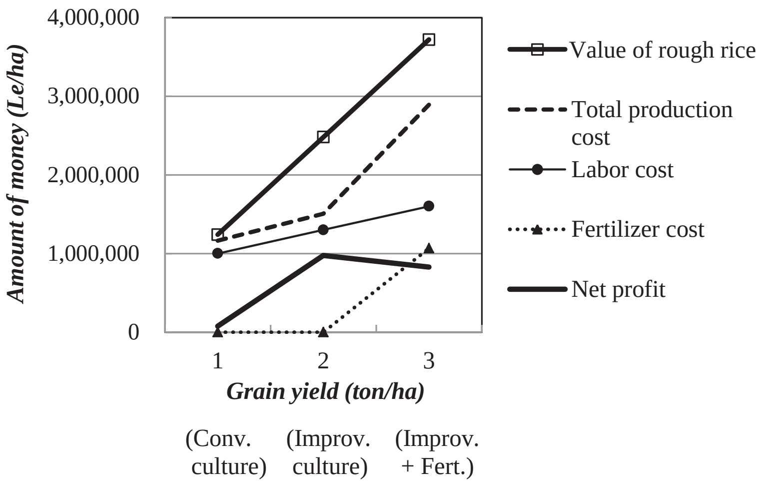



Fig. 8-1. Production cost, value of rough rice, and net profit under conventional rice culture and under improved culture system with and without fertilizer.

## 8-4. Sensitivity analysis of fertilizer application

### 8-4-1. Sensitivity analysis relevant to yield response

1) Background

Fertilizer cost at 40-40-40 kg/ha of N-$P_2O_5$-$K_2O$ is about Le 1,070,000 (i.e. 4,000 x 40/0.15) with NPK compound fertilizer (15-15-15). Increase in the costs of labor and variables as a result of fertilizer application is Le 177,500/ha. The total of cost increase is equivalent to the market value of 1.01 (i.e. 1,247,500 / (1,240 x 1,000)) ton/ha of rough rice. A proportion of the equivalent value of rice, and fertilizer and labor costs is defined herein simply as a fertilizer recovery ratio. When 1.01 ton/ha of rice is produced with 40-40-40 kg/ha of fertilizer as in the above case, the fertilizer recovery ratio is one.

When the fertilizer recovery ratio is less than 1 or the yield increment (the response) with fertilizer is less than 1.01 ton/ha, it is impossible to recover the fertilizer cost itself. The response varied 0.6 to 1.8 (mean 1.1) ton/ha under the well water controlled condition by the SRDP fertilizer trial (Fig. 4-6) and 0.0 to 2.8 (0.9) ton/ha in IVS by various past fertilizer trials by RARC (Fig. 4-7). These results show that it is almost break even if the fertilizer response attains the average.

2) Profit variation affected with yield response

Net profit affected with yield response was simulated under the conventional and improved culture systems assuming that grain yield is at 1 and 2 ton/ha, respectively. In the former, fertilizer application induces a negative profit when the response is lower than 1.01 ton/ha (Fig. 8-2). In the latter, it brings a small profit even when the response is as low as 0.2 ton/ha, because the profit is secured with the profit with improved culture practices that provides about 1 ton/ha of the response.

3) Suggestion to fertilizer application

Rice productivity must first be enhanced with improved culture practices and then fertilizer application follows. Improved culture system alone provides about Le 1,000,000 worth profit (Fig. 8-1). By applying fertilizers, the yield response should be larger than 1.2 ton/ha (Fig. 8-2), when one intends to earn the same or larger profit than the one obtained with the adoption of improved culture practices over the conventional system. As many past examples show, an opportunity to realize such a large response is infrequent (Figs. 4-6 and 4-7).

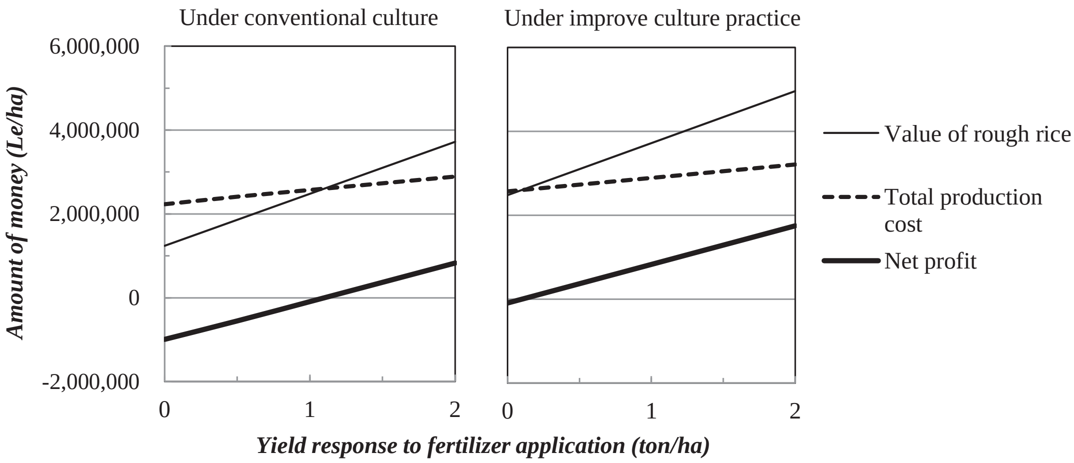



Fig. 8-2. Sensitivity analysis of production cost and profit as a function of yield increment by fertilizer application under conventional and improved culture systems.

### 8-4-2. Sensitivity analysis on fertilizer cost and rice price

Fertilizer cost and rice price are two dominant variables to control the profit. A sensitivity analysis was made to examine how those variables affect the profit (Fig. 8-3). In general, the recovery ratio or profitability is largely affected with fertilizer cost than with rice price, when the degree of variation is the same, as shown below.

Under the current economic condition where fertilizer cost is Le 4,000/kg and where rough rice price is Le 1,240/kg, yield response at 1 ton/ha is almost break even as described previously. When fertilizer cost is Le 3,000/kg (25% cheaper than the current price), yield response at 1 ton/ha makes the recovery ratio of about 1.5 and brings a good profit. In contrast, when fertilizer cost is Le 5,000/kg (25% higher than the current price), one surely loses their investment with the response at 1 ton/ha. When rough rice price is Le 1,550/kg (25% higher than the current price), the recovery ratio becomes about 1.4 and thus a certain profit can be expected.

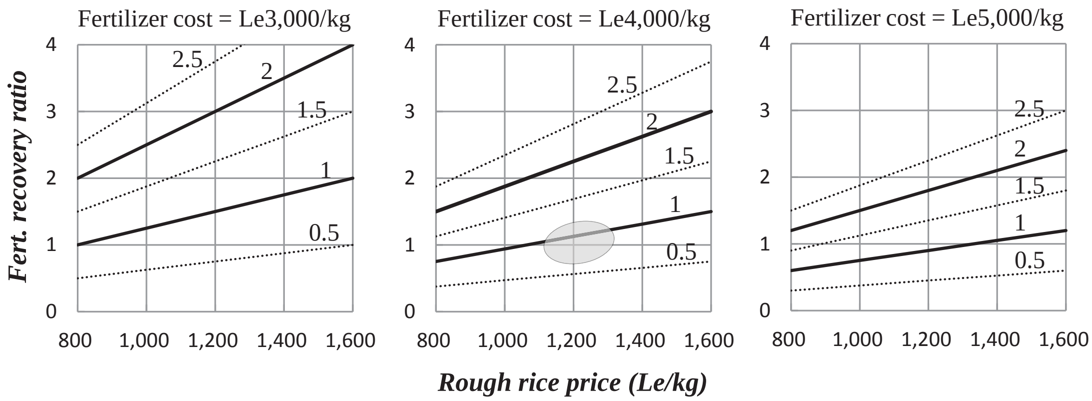



Fig. 8-3 Fertilizer recovery ratio affected with fertilizer cost and rough rice price. Isograms signify grain yield response to fertilizer application (ton/ha). The circle in the middle figure approximately shows current status.

# 9. Appendices

## A1. Useful information on plant, soil, climate, etc.

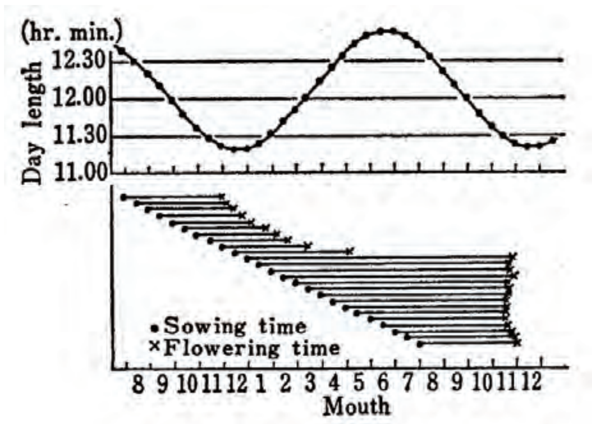
### A1.1. Plant physiology

A1.1-1. Essential elements of higher plants

| Group | Element |
|---|---|
| Macro-element | C, H, O<br>N, P, K, S, Ca, Mg |
| Micro-element | Fe, Mn, Zn, Cu, B, Mo, Cl, (Ni ?) |

*Benificial elements: Si, Na, Al, Co, Ni, Se*

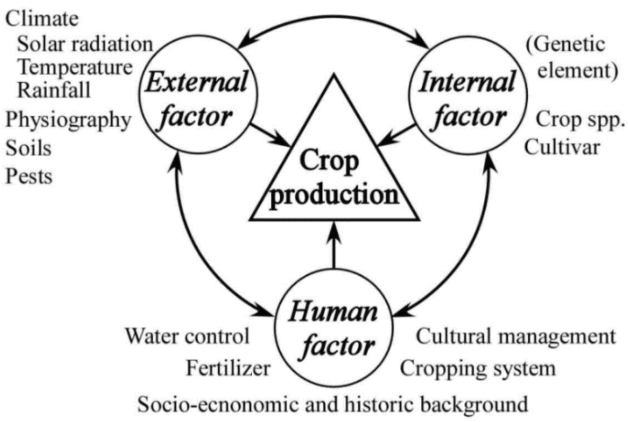
<Element essentiality signifies that plants does not survive without it.>



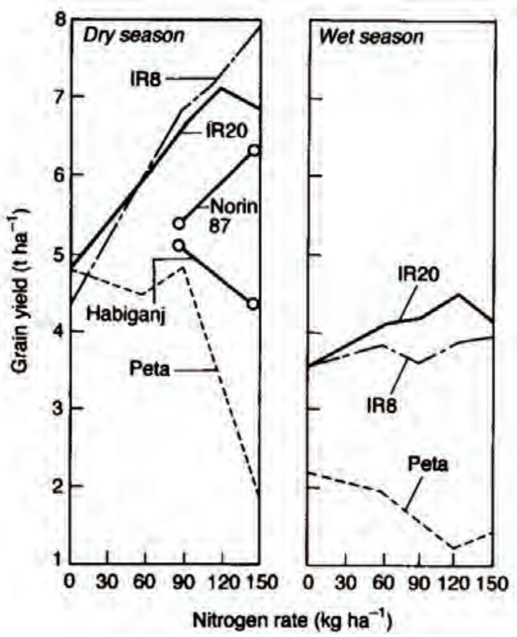

A1.1-2. Growth duration of photoperiod-sensitive cultivars (Neang Meas ) affected with day length at Battambang Neang Meas, Cambodia (Sato, 1960).

<Growing period of photoperiod-sensitive cultivars becomes short with short day length.>

### A1.2. Agronomy

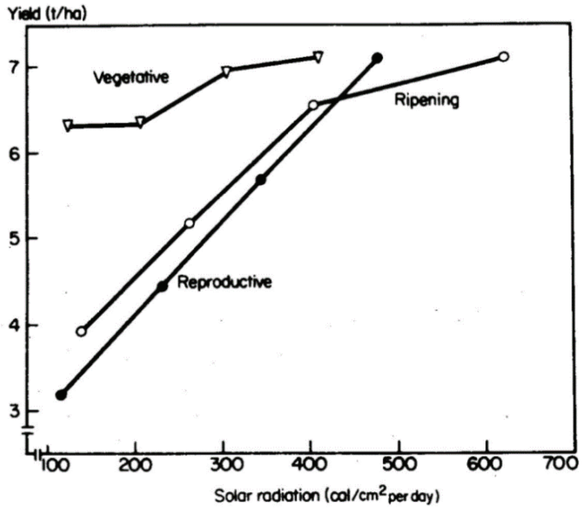



A1.2-1. Factors controlling crop production.

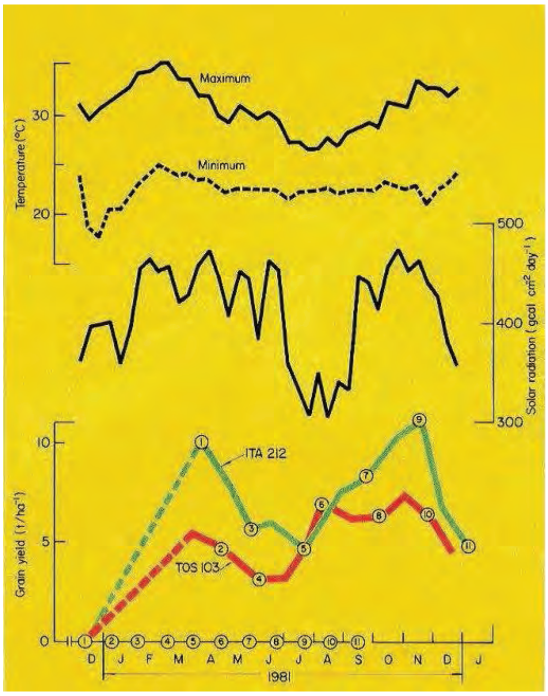



A1.2-2. Fertilizer response in dry and wet season at IRRI (Greenland, 1997).

<Grain yield is higher in dry season cropping than in the rainy season, due to larger solar radiation.>



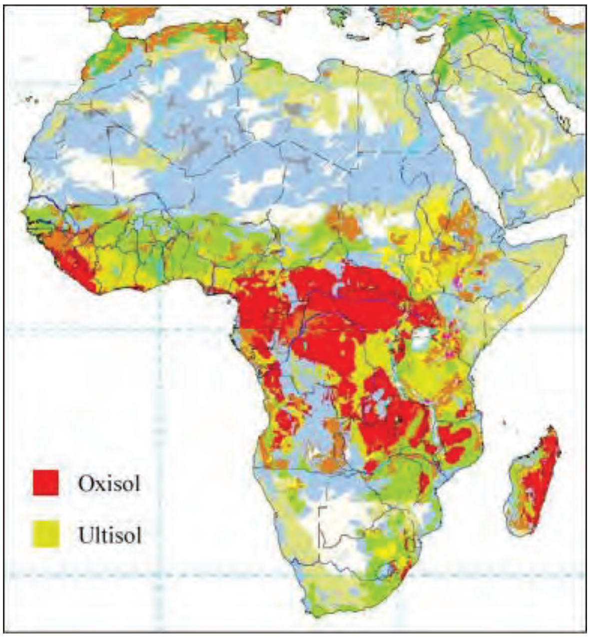

A1.2-3. Grain yield affected with solar radiation at different growth stages (Yoshida, 1981).



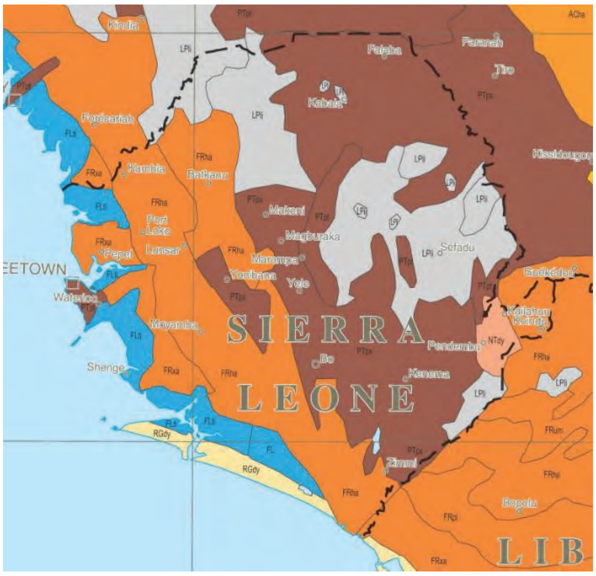

A1.2-4. Grain yield affected with solar radiation by monthly plantings of rice plants at IITA (Yamaguchi, 1981).

<Grain yield is higher when rice plants are grown under larger solar radiation condition.>

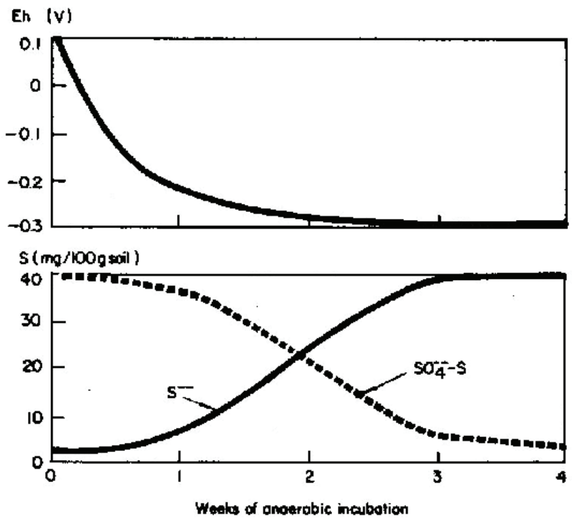
## A1.3. Soil Science




A1.3-1. Soil map of Africa (Soil taxonomy, 2005).



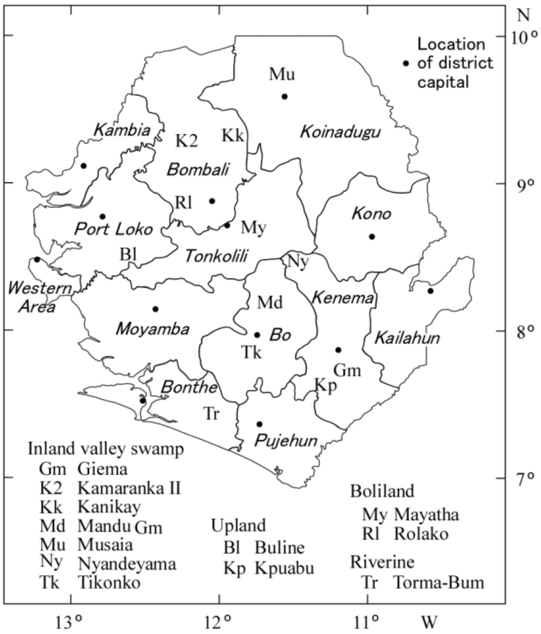

A1.3-2. Soil Map of Sierra Leone (EC, 2013).



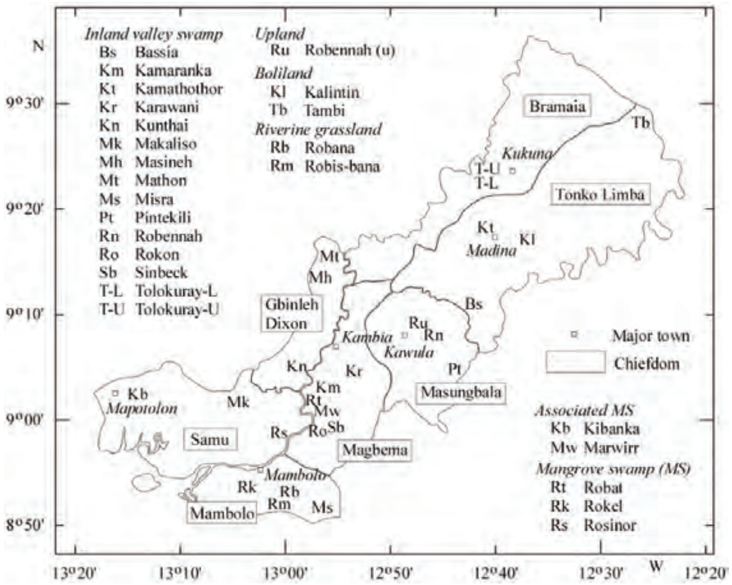

A1.3-3. Relationship between Eh and sulfate reduction under submergence (Yamane and Sato, 1961).

## A1.4. Fertilizer trials

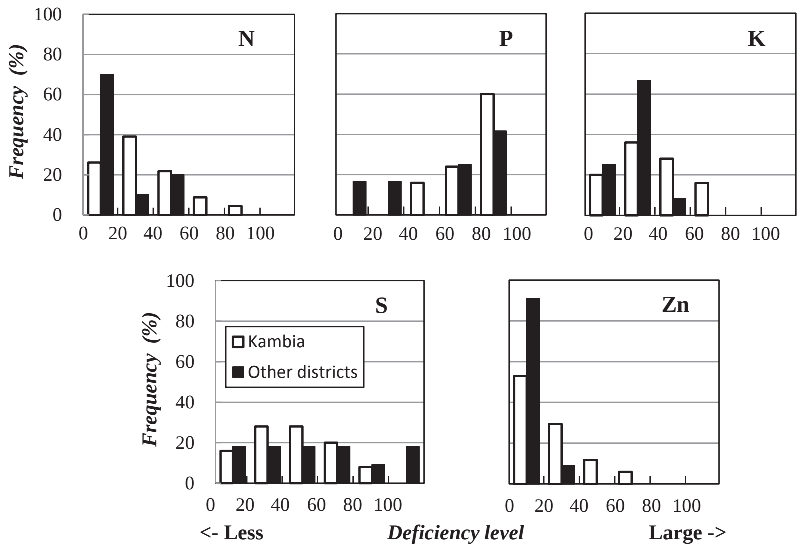
### A1.4 (1) Pot trials




A1.4-1. Soil collection sites in various districts other than Kambia.




A1.4 (1) -2. Soil collected in Kambia District.




A1.4 (1)-3. Frequency of nutrient deficiency levels in Kambia and other districts.

## A1.4 (2) Fertilizer trials in fields by SRDP

A1.4 (2)-1. Fertilizer trials at seven IVSs in Kambia district

| | Fertilizer treatment ($N-P_2O_5-K_2O-S$ kg/ha) |
|---|---|
| 1 | 0- 0- 0- 0 |
| 2 | 60- 40-40- 0 |
| 3 | 20- 40-40- 0 |
| 4 | 20- 40-40-10 |
| 5 | 20-100-40-10 |

| | Trial site (village) | Cropping season: Rainy 2013 | Dry 2013 -2014 |
|---|---|---|---|
| 1 | Fayale | * | |
| 2 | Laya | * | * |
| 3 | Masiaka | | * |
| 4 | Masineh | * | * |
| 5 | Rotifunk | | * |
| 6 | Tawuya Munu | | * |
| 7 | Tolokuray | * | |

A1.4 (2)-2. Total fertilizer applied, ingredient composition, mean grain yield and yield response to fertilizer application in fertilizer trials by ADPK and SRDP.

| Project | Agro-ecology | No. of sites | Year | Crop season | Total ingredient (kg/ha) | Ingredient proportion (N =100) | | | | Mean grain yield (ton/ha) (c) | | Mean response (ton/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | N | $P_2O_5$ | $K_2O$ | S | -F | +F | |
| ADPK | (a) | (a) | 2007 | Rainy | 91 | 100 | 25 | 25 | 0 | 0.9 | 1.3 | 0.4 |
| | | | 2008 | Rainy | 101 | 100 | 53 | 53 | 0 | 1.4 | 2.0 | 0.6 |
| SRDP | IVS | 4 | 2013 | Rainy | 130 b) | 100 | 242 | 167 | 25 | 1.9 | 2.8 | 1.0 |
| | | 5 | 2014 | Dry | 130 b) | 100 | 242 | 167 | 25 | 1.8 | 2.9 | 1.0 |

a) Number of sites in each ecology: 2 and 2 in upland, 3 and 2 in IVS, 1 and 1 in boliland and 2 and 3 in mangrove swamp respectively in 2007 and 2008.

b) Average of 60-40-40-0, 20- 40-40-0, 20-40-40-10, and 20-100-40-10 kg/ha of$N-P_2O_5-K_2O$ .

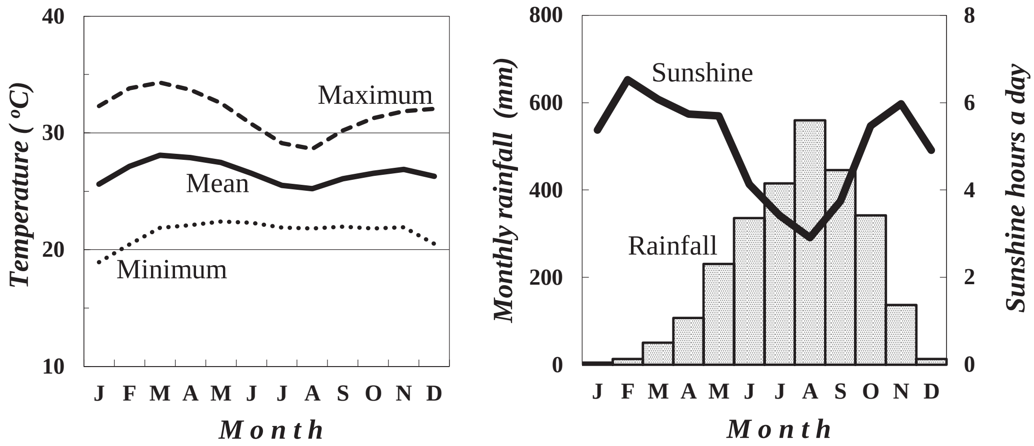
c) -F: without fertilizer, +F: with fertilizer.

## A1.4 (3) Experiment results reported by RRSR, IITA, FAO, etc. in Sierra Leone

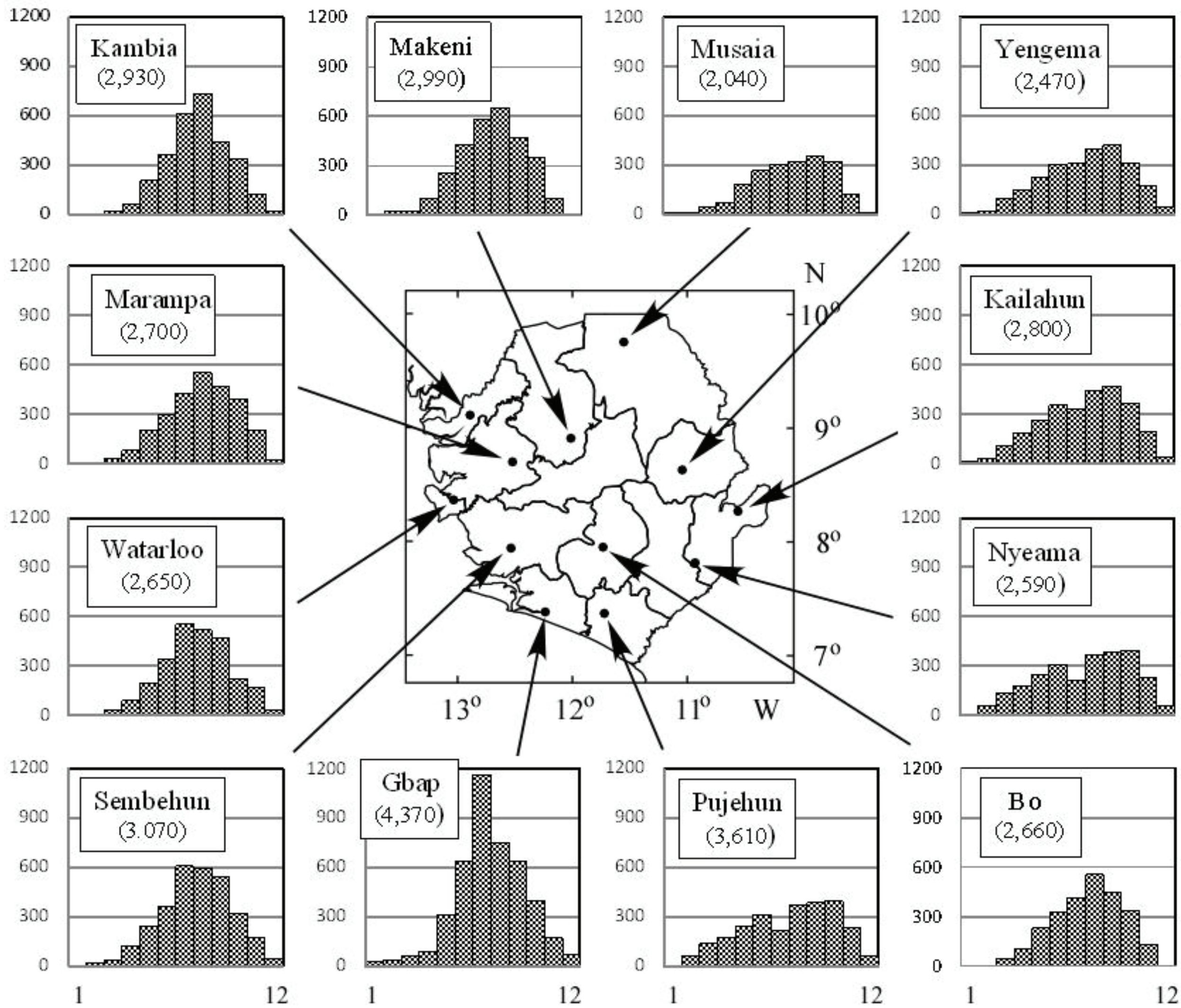
A1.4 (3)-1. References for compiling gain yield and the yield response to fertilizer application of rice plants in Sierra Leone

| RRSR Annual Report | | |
|---|---|---|
| 1972 | 1989 | RRSR, 1975 (workshop) |
| 1978 | 1990 | UNDP/FAO/IITA, 1984 |
| 1980 | 1991 | FAO/IITA, April 1976 (5) |
| 1983-1984 | 1992 | FAO/IITA, October 1976 (6) |
| 1984-1985 | 1993 | |
| 1985 | 1994 | IITA Ann. Rep., 1976 |
| 1986 | 1996-1999 | |
| 1988 | 2009-2010 | EEC/RRSR, 1994 |

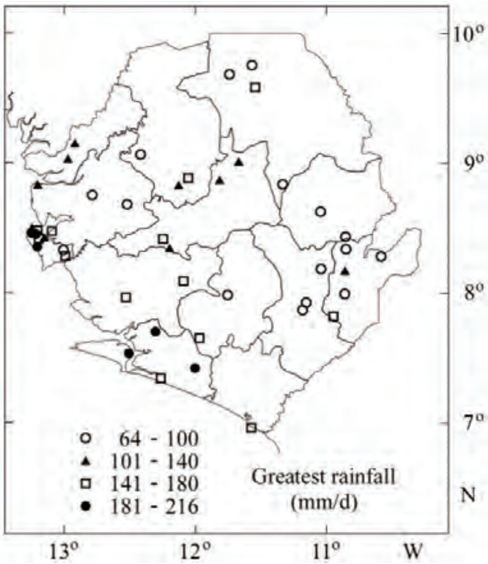
## A1.5. Climate




A1.5-1. Monthly changes of temperature, rainfall and sunshine hours at Bo (7°58' N, 11°45' W) (Meteorological Dept., 2014). Averaged over 1981-2007 with missing data differed in climatic elements.




A1.5-2. Monthly rainfall (mm) at the selected stations in Sierra Leone. Total rainfall in parentheses (Illustrated on the basis of British West African Meteorological Services, 1960 and Meteorological Dept., 2014).




A1.5-3. Greatest rainfall a day in 1960 (British West African Meteorological Services, Sierra Leone, 1960).

## A1.6. Statistics

A1.6-1. Current grain yield of rice culture in Sierra Leone

| Data source | Grain yield (ton/ha) |
|---|---|
| PEMSD (2013) | 1.2-1.96 |
| FAO (2013) | 1.8 |
| AHTS | 0.47 |
| Peters (GIZ, 2014) | 0.5-1.5 |
| SRDP (a) | 0.5-1.0 |

a) Estimation based on the baseline survey (ADPK), field trials at FBO sites, SRDP fertilizer trials and experiment results reported by RARC, etc. for the past 40 years.

## A2. Terminology

| | |
|---|---|
| brown spot | *Cochliobolus miyabeanus* (*Helminthosporium oryzae*) |
| bund | dike in the lowland rice fields |
| bush fowl | *Francolins bicolcoratus* |
| cultivar | variety and line |
| case-worm | *Nymphula depunctalis*, *Parapoynx stagnalis* |
| crawling grass | *Paspalum vaginatum*, indigenous species in the area. In the local language, *kireh-kireh* (or *kiri-kiri*). |
| cutting-grass | *Thyronomis swinderiannus*. In other regions of West Africa, it is called grass-cutter. |
| DMRT | Duncan's multiple range test |
| gall midge | *Orseolia oryzae* (*Pachydiplosis oryzae*) |
| leafhopper | *Nephotettix* spp. |
| leaf scald | *Metasphaeria albescens*, *Fusariumn ivale* & *Rhynchosporium oryzae* |
| oil palm | *Elaeis guineensis* |
| paddy | rough rice or unhulled rice |
| plant-hopper | *Nilaparvata* spp., *Sogatella* spp. |
| puddling | breaking up soil clods and flattening the surface of rice fields with water after plowing (digging); harrowing (tilling) rice fields underwater to prepare for transplanting. |
| rice blast | *Magnaporthe grisea* (*Pyricularia oryzae*) |
| rice bug | *Scotinophra* spp. |
| ripening | synonym of grain-filling |
| ripened grain rate | the ratio (percentage) of the number of filled grains to that of total spikelets. An antonym of sterile percentage (roughly). |
| stalked-eye fly | *Diopsis thoracica* |
| stem-borer | *Chilo* spp., *Maliarpha* spp., *Sesamia* spp. |
| water duck | *ealele* in Temne |
| weaver | *Ploceus cucullatus*, *Quelea quelea* |

## A3. Conversion table

| | |
|---|---|
| bag | 1) Fertilizer: Mostly 50 kg/bag and sometimes 25 kg or 40 kg/bag.<br>2) Milled rice: 24 dozens of cups/bag. |
| cup | The most common measurement unit (container) for milled rice. The unit weight is adopted as 250 g/cup by MAFFS, but it is 260-300 g/cup in commercial market. |
| bushel (bu) | 1) Rough rice (paddy): The official rate is 25 kg/bu. However, the local rate varies from 34 to 52 kg/bu among households, villages and chiefdoms in Kambia District, for example.<br>2) Cropped area: Field area of 1 bushel is assumed to be equal to 1 acre, sown with 1 bu (volume) of rice seeds. Measured area was 0.7 ± 0.3 (mean ± SD) ha/bu in Kambia District. |
| ha | 10,000 $m^2 \cong$ 2.47 acre (1 acre $\cong$ 4,047 $m^2$ ). |
| kerosene tin | 30 lbs (= 13.5 kg) at the official rate. Commonly used in the eastern region. Often simply called as tin. |
| kg | about 2.2 lbs |
| Le | Leone, currency unit in Sierra Leone. Le4,500≒US$1.00 (late 2013 to early 2014) |

| | |
|---|---|
| m | about 3.3 feet = 1.09 yard |
| MJ | 1 MJ $m^{-2}$ = 23.9 cal $cm^{-2}$ |
| Three pence pan | It is often called as TP. 3.5 lbs/TP = 1.6 kg/TP (rough rice) at the official rate. The unit varies 1.8 to 3.5 kg/TP among households, villages and chiefdoms in Kambia District. TP is used for measuring the field size too based on the quantity or rough rice volume. |

**A4. Abbreviations**

| | |
|---|---|
| ADPK | Agricultural Development Project in Kambia District, Sierra Leone |
| AHTS | Agricultural Household Tracking Survey |
| d | day |
| DAT | days after transplanting |
| DMP | dry matter production |
| EC | electrical conductivity |
| EC | European Commission |
| FAO | Food and Agriculture Organization of the United Nations |
| FBO | Farmer Based Organization |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| GoSL | Government of Sierra Leone |
| HH | household |
| IITA | International Institute of Tropical Agriculture |
| IRRI | International Rice Research Institute |
| IVS | inland valley swamp |
| JICA | Japan International Cooperation Agency |
| MAFFS | Ministry of Agriculture, Forestry and Food Security, Sierra Leone |
| NERICA | New Rice for Africa |
| PAC | phosphorus adsorption coefficient |
| PEMSD | Planning, Evaluation, Monitoring and Statistics Division |
| RARC | Rokupr Agricultural Research Centre |
| RRSR | Rice Research Station, Rokupr (presently RARC) |
| SLARI | Sierra Leone Agricultural Research Institute |
| SRDP | Sustainable Rice Development Project in Sierra Leone |
| TARC | Tropical Agricultural Research Center, Japan |
| TP | Three-pence pan |
| TP-R | Technical package on rice production |
| T/P | transplanting |
| UNDP | United Nations Development Programme |
| UNICEF | United Nations Children's Fund |
| USDA | US Department of Agriculture |
| WARDA | West Africa Rice Development Association (Presently Africa Rice) |
| WFP | United Nations World Food Programme |
| WHO | World Health Organization |
| y | year |

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